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An Approach of the Hydropower: Advantages and Impacts. A Review

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Authors' contributions

Both authors develop the document, and all authors read and approved the final manuscript.

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ABSTRACT

The present review shows a perspective of hydropower development, a renewable source that has a global installed capacity of 1308 GW with 9000 stations around the world. The document showed the advantages and the impacts around the different author's perspectives. The review method consisted of defining a criterial find of articles, thesis and scientific material to consolidate the knowledge and give a viewpoint of this renewable source. The results show extensible affectations from hydropower expansion and this renewable energy source that requires analysis and study to delineate development sustainable with multidisciplinary areas of reflection. Moreover, the investigated results worldwide show that hydropower is not a pollution source; however, it has environmental impacts, social and cultural; such facilities may affect land, homes, and natural habitats. It concludes that the development of hydroelectric projects brings benefits but entails unavoidable impacts; therefore, it recommends that these affections must evaluate with detailed studies based on sustainability criteria.

Keywords: Energy; hydropower; impacts; renewable; water.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

Abbreviations	
IHA	International Hydropower Association
IRENA	International Renewable Energy Agency
IPCC	Intergovernmental Panel on Climate Change
GHG	Greenhouse gases
kWh	Kilowatt-hour
USD	United states dollars
TWh	Terawatt-hours
GW	Gigawatts
MW	Megawatts

1. INTRODUCTION

In a world of sustainable awareness, the development of renewable technologies is constantly growing in the energy mix, by the fact of three-quarters of global greenhouse gas emissions come from the burning of fossil fuels for energy, such as shown the Climate Watch Institution in the following graphic based on 2020 data [1].

Moreover, dealing with the necessity of extensible energy production, society requirements to transition away from fossil fuels and decarbonize our energy systems. Thus, the development of renewables emerges. Nowadays, the principal renewable energies are hydropower, wind, and solar; next presents the
Fig. **2** with renewable development and production of the last 55 years.

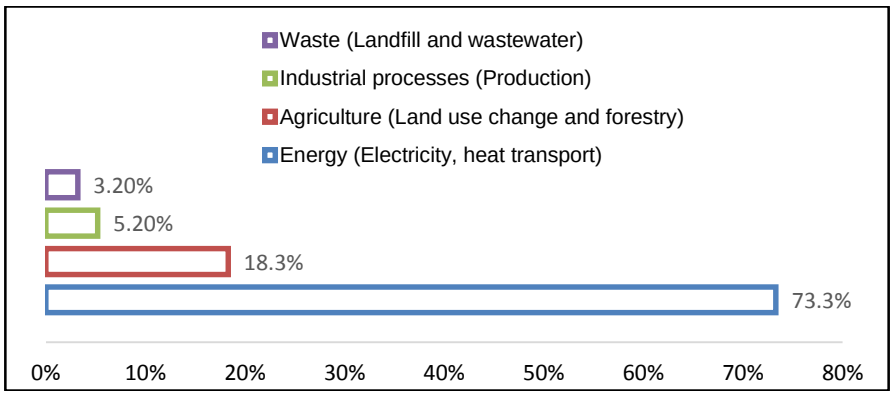

Fig. 1. Global greenhouse gas emissions by sector [1]

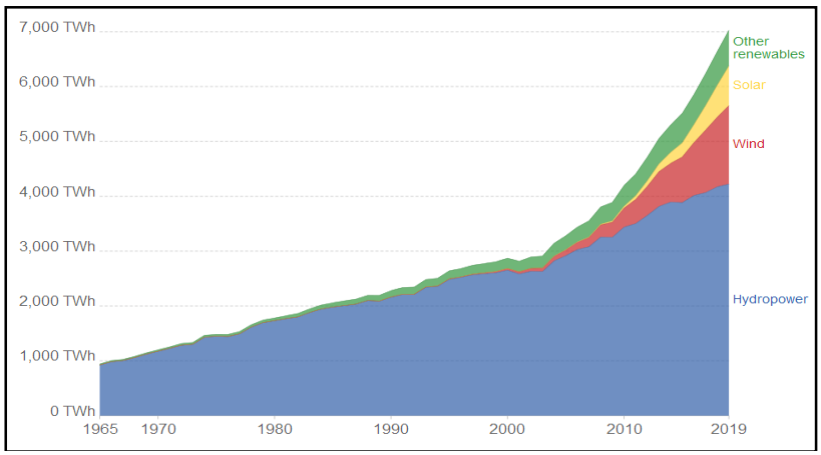

Fig. 2. World renewable generation [2]

Fig. **2** shows the breakdown of renewable technologies by their components where hydropower is the principal renewable source worldwide by a distant portion such as a mature renewable [3]. The development of renewables do the hydropower can expand around the continents and countries by the influence of the low-carbon energy technology for more than half a century [4].

Hydropower resource utilization holds a high position in the global electric power balance. In the 70-80s, the volume of hydropower amounted to about 26% of the generated electric power globally and reached its absolute value. After the Second World War, electric power production by hydroelectric generating stations of the world rapidly increased from 200 billion kWh in 1946 to 860 billion kWh in 1965 and 975 billion kWh in 1978 [5]**.** Next, British Petroleum, since their Statistical Review of World Energy in
Fig. **3** shows the renewable energy production to the period of 1985 – 2020 presenting energy capacity across the world.

The Statistical Review of World Energy mentions that hydroelectric consumption rose by 0.8%, below the 10-year average of 1.9%, and the growth was led by China (0.6EJ), Turkey (0.3EJ), and India (0.2EJ) [6]. Moreover, in 2016, more than 1 billion people covered their demand with hydroelectricity in 159 countries that reported benefiting [3].

The International Commission on Large Dams mentions that by 2020, around 9,000 hydropower projects are in operation due to the competitive cost of generating a similar cost such as thermal energy such as coal [7].

On the other hand, according to the International Hydroelectric Association (IHA) there are 1308 GW of total hydropower capacity;
Fig. **4** represent the global installed capacity on to the year 2019 about the main actors.

Instead, according to data on the distribution and consumption of hydropower energy in
Fig. **5**, the world use by region can be observed that the Asia-Pacific region consumes the most significant amount of electricity generated by hydropower, a trend that has accelerated since 2003, while markets in Europe, the Commonwealth of Independent States (CIS) and North America remained the whole stable. South America steadily increase its consumption, while the Middle East and Africa show slow growth due to lack of water, effective demand and capital, respectively [9].

Nowadays, 4000 billion kWh of hydropower per year is generated globally, and accelerated development of hydropower engineering in many countries of the world is explained by the perspective increase of fuel and energy.

Given this introduction, the study aims to analyze the approach of hydropower, showing the advantages and impacts of development throughout the world to investigate the results of scientific researchers in the face of sustainable hydroelectric development.

As shown by the trends and data of the various agencies and associations, there has been an accelerated development of hydroelectricity in recent years, and several questions arise. However, the problem is near the benefits versus impacts not studied or socialized when developing this so-called sustainable source, clean and renewable.

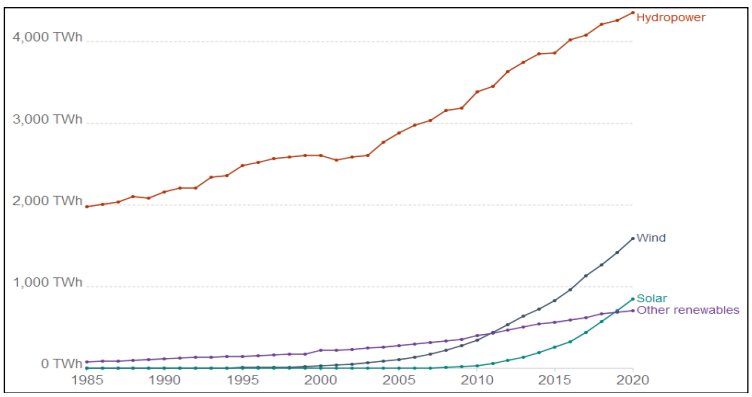

Fig. 3. Modern renewable energy generation by source [6]

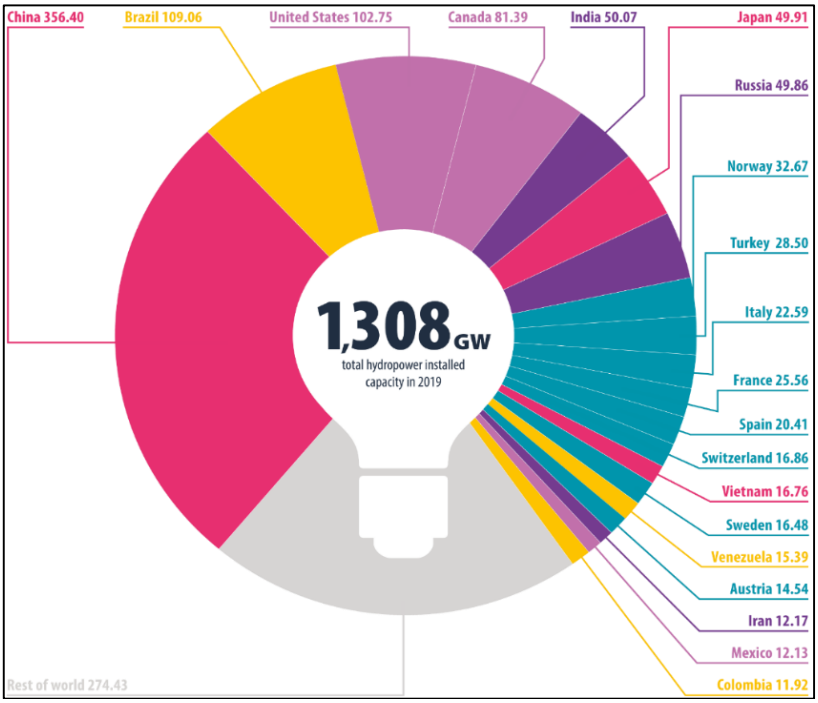

Fig. 4. Hydroelectric capacity installed in the world [8]

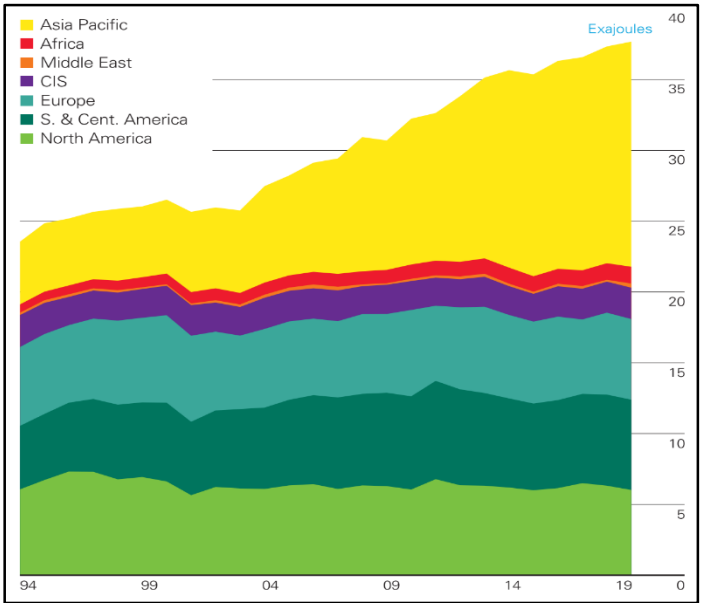

Fig. 5. Hydroelectricity consumption by region in exajoules units [6]

Finally, with this study, we intend to expand the knowledge determining above all the impacts and disadvantages of building large hydroelectric plants, and this analytical detail will serve engineers, builders and different Nations interested in the development of new hydroelectric projects to make decisions based on in mitigating the social, cultural and environmental impacts that will show.

2. METHODS AND METHODOLOGY

The methodology consists of finding the previous investigations around the hydropower and consolidated concepts, conducting a documentary and bibliographic review of scientific articles published from January 2013 to May 2021. The databases consulted were Science Direct, Taylor&Francis and Springer.

To find the relevant concepts and conclusions, we structure search parameters on the behaviour of hydroelectricity with keywords such as hydroelectric forecasts, advantages and disadvantages of hydropower, and pros and cons of hydroelectric development.

Several documents were found between articles, thesis, and studies that guide the advantages, impacts, and hydroelectricity development to specify this document with the finding criteria. On the results, we divide at fifteen parameters to establish the advantages or positives remark and their respective impact or disadvantage.

3. RESULTS AND DISCUSSION

Natural resources such as water in energy production require climate analysis, the introduction of energy balances, and water footprint studies as options for approaching changes for the desired sustainability. It is expected that the growing human demand would require natural resources at a global level, facing challenges in the coming decades [10].

Zhang, Xiao mentions that hydroelectricity *"generates considerable impacts that must be taken into account during the planning and management of hydroelectric projects to minimize adverse effects ..."* [11].

The different studies researched present hydroelectric energy as a source of clean energy and one of the leading renewables globally; however, social, environmental, and economic effects are associated with its use [12]. Therefore, hydroelectricity findings establish in Table 1 with the relationship of positive and negative variables.

It is remarkable to observe that the world's economic growth depends on energy and water resources, and the two demands have an overall accelerated increase [34]. Therefore, when analyzing global resources, hydroelectric production is essential in developing studies for low carbon emissions and because it is the primary renewable energy in the global deployment.

Nevertheless, since the impacts recollected in Table 1, there are technical, ecological, territorial, and cultural transformations at different levels and spaces of society where hydroelectric projects exist and often involve conflicts, new knowledge regimes and different local practices [30]. The infrastructure for hydroelectric production implies a high degree of affectation from the movement of populations to the change of life of the neighbouring town that is seldom considered and part of the relevant affectations [35].

Michelle Van Vliet projects declines in global average hydropower usable capacity from 0.4% to 6.1% on the Representative Concentration Pathways (RCP2.6 and RCP8.5) for the 2080s relative to 1971-2000. The analysis concludes that water reductions in the United States, Europe, East Asia, South America, South Africa and Australia by solid increases in temperature are programmed combined with reductions in the average annual water flow [37].

Nynke Hofstra presents a global assessment of the world's hydroelectric and thermoelectric production vulnerability due to climate change; options for sustainable adaptation of water and energy tested through coupled hydrological modelling. The study shows a reduction in usable capacity in hydroelectric and thermoelectric plants between 61% - 74% for the time scenario 2040–2069 [38].

Luis Berga presents an investigation on the hydroelectric role in Europe by mitigating and adapting climate change, knowing that hydroelectric projects have an enabling role as a financing instrument for multipurpose reservoirs acting as buffers against water changes such as floods. However, hydropower alters aquifer systems in their flow and free movement. From the analysis, it is concluded that because the impacts of climate change are variable and locally different, depending on the flow of rivers, it is estimated that the hydroelectric potential for all of Europe will decrease by 6% by the year 2070, and, it is expected, a decrease from 20% to 50% throughout the Mediterranean [39].

Moreover, the investigated results worldwide show that hydropower is not a pollution source; however, it has environmental impacts, social and cultural; such facilities may affect land, homes, and natural habitats. In addition, policies limited, disputes within governments, and lack of international cooperation generate the adequate analytical deficit before an investment in developing hydropower projects [40].

Table 1. Observations, conclusions, and studies of advantages and disadvantages of hydropower

No.	Parameter	Advantages	Impacts/ Disadvantages
1	Infrastructure	It provides facilities for flood control, which usually causes the desired effect when a multipurpose dam is built to the conservation of water during dry seasons in a controlled manner area [13].	The dam controls the river flow where it is located but alters and unbalances the aquatic life before and after the reservoir. In addition, the hydropower infrastructure fragment and transform the world's rivers, destroying ecosystems and dramatically reducing fishery resources [14].
2	Emissions	The potential for reducing carbon emissions in the electricity system is the low greenhouse gas (GHG) emissions generated concerning fossil sources such as coal [15]. The Special Report on Emissions Scenarios of the Intergovernmental Panel on Climate Change of the year 2011 shows that the estimated cycle of GHG hydropower is 4 and 14g of [CO2.eq /kWh] [5]	There is a negative impact due to the erosion produced by the downstream flows in a variable way depending on electricity generation at some hours of the day [16]. There are greenhouse gases in hydroelectric dams by the reduced oxygen in the obstructed water [17].
3	Polyfunctionality and protection	The storage infrastructure provided by a hydroelectric reservoir mitigates the risks posed by climate change, including extreme weather events such as floods and droughts [18].	It divides the river into two or three sections, removing flow and natural irrigation; this causes the plant's division upstream and downstream. It is avoided using fish ramps, kind of elevators so that the fish go upstream in the spawning season; however, the death of many animals is not prevented, unbalancing ecosystems [19].
4	Cost	Energy capacity with a low generation cost compared to other renewable and thermal energy sources. Hydroelectric power generation has a weighted average of 0.05 [USD/kWh] for new projects [20].	The hydroelectric projects require a high budget for construction and electrical equipment and the laying of transmission lines from remote locations to central cities [21].
5	Energy	It brings energy to people and drives industries, cities, and societies. There are currently around 9,000 active projects, and in 2016, 159 countries in the world reported benefiting from hydroelectricity [3 ,7].	The hydropower estimates globally cumulatively a trillion dollars compensation for deterioration caused in the last 18 years of hydroelectric generation associated with climate change [22].
6	Source	Hydropower does not require fossil fuel because it uses a renewable resource, providing a constant response from nature free.	Hydroelectricity accelerates the destruction of the environment due to the excessive use of water and global warming, mainly because it is located in tropical areas where rapid growth processes, soil decomposition, and forest deforestation occur [23].
7	Investment	Investment in renewable energy creates new jobs and	Generation of impacts on worker's health and nearby communities,

No.	Parameter	Advantages	Impacts/ Disadvantages
		generates an economic circle of products and services performing hydroelectric projects [24].	such as respiratory and eye problems by the dust produced during the construction of hydroelectric plants due to the demanding movement of the earth [16].
8	Efficiency	Hydroelectric plants have a high-efficiency coefficient from 55% to 92%, compared to approximately 33% nuclear and thermal power plants [25].	To maintain this high efficiency, hydroelectric plants must be located in scenarios without seasonality where the flow is constant without high climatic variations or changing seasons pronounced [26].
9	Construction and maintenance	Cost comparatively low preventive maintenance and low-cost primary energy electrical generated, 2-4 times lower than in nuclear power plants [27].	Hydropower plants take a long time to build, 10-20 years, compared to 3-4 years for nuclear power plants and thermal power plants [25].
10	Personnel and employment	A small number of workers operate a hydroelectric plant, so 0.25 people are 1 megawatt of energy; for a thermal power plant, there are 1.26 people; for a nuclear power plant, this number is 1.05 people [28]. Hydropower employs 1.8 million workers worldwide and has connected supply chains [29]	Hydroelectric dams are one of the largest energy infrastructures in the world, requiring complex adjustments and localized modifications [30]. There are data of the displacement of eighty million people worldwide by hydroelectric plants by the massive immigration of workers from other regions in the construction phase, causing widespread deforestation and loss of biodiversity in the areas due to commercial, industrial and residential development to support these newcomers and their respective means of subsistence [31].
11	Multifunction for other renewables	Hydropower supports the growth of variable renewables, such as wind and solar, and meets demand when these sources are unavailable [27].	The hydroelectric operation of dam projects damages fauna and flora when dam gates are aggressively opened as a flood control measure because it disturbs ecosystems by eliminating wildlife and aquatic life [32]. There are solar generation projects associated with hydro dams but presenting environmental impacts by installing solar panels in the surface water of the dam eliminated the passage of light [33].
12	Manage freshwater responsibly	Hydropower provides a vital means of managing freshwater safely, providing water supply for homes, businesses, and agriculture.	Hydroelectricity depends on hydrology, and this natural system depends on precipitation levels, which can fluctuate from one year to another or modified by externalities such as climate change, causing instability [34].
13	Strengthening cooperation between countries	Long-distance electricity transmission across national borders promotes strong intergovernmental cooperation [27].	Hydroelectricity can cause changes in the reservoir's water quality and the stream of neighbouring countries when there are border projects. In addition, the operation of a hydroelectric plant can alter the temperature of the water associated with climate change [9].

No.	Parameter	Advantages	Impacts/ Disadvantages
14	Communities and rural areas	Hydropower development can drive investment in local communities, including education, healthcare, and other services.	Reservoirs can cover people's homes, important natural areas, agricultural lands, and archaeological sites. Infrastructure for hydroelectric production required in several countries are in rural areas inhabited by peasant, indigenous and small farmers populations are generally economically vulnerable, where the degree of social marginalization and economic are marked [35].
15	Recreational activities and tourism	Hydroelectric reservoirs can offer regional development by creating tourism, recreational activities, and fisheries [36].	Creation of an artificial lake or reservoir, generating a change in the environment in a physical, chemical, and biological way.

Does the review open the discussion, ¿Is hydropower sustainable due to global climatic changes, extensible use of water resources, population movement, and other contrasting data?

Although renewable energies are a priority topic for global action and there is ample hydroelectric potential, it is necessary to diversify wind and solar energy to avoid changes with the construction of dams and gigantic hydroelectric infrastructure that affects the flow of rivers [41,42].

4. CONCLUSIONS

Hydropower is a renewable energy technology that can provide benefits, such as water supply to communities, flood control, and reduce the greenhouse gases; notwithstanding, at large scale infrastructure with dams produces changes in the water quality, death of wildlife and social problems and movements.

The future of hydroelectricity presents a challenging way for the projects in execution throughout the world through external variations such as climate change. However, a profound social, environmental and cultural analysis is recommended to develop the new projects and mitigate the disadvantages and impacts based on technical studies.

Hydropower generation is a renewable energy source that requires analysis and study to delineate development sustainable with multidisciplinary areas of total reflection.

The development of hydroelectric projects brings benefits but entails unavoidable impacts; therefore, it recommends that these affections must evaluate with detailed studies based on sustainability criteria.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is no absolutely conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but to advance knowledge. In addition, the producing company founded by the author's efforts and did not fund the research.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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