ACHIEVING SUSTAINABLE DEVELOPMENT THROUGH HYDROPOWER– A WORLDWIDE APPROACH

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Abstract

Hydropower is a renewable energy source that is expected to ensure the transition to a cleaner and unpolluted world, together with the natural gas. Even if is one of the renewable energy sources that can be affected by persistent climate change in many regions of the world, it is still one of the most used by people in the last 2000 years. This study aims to give an overview of the present situation of hydropower and its future social, economic and innovation perspectives and challenges. In order to achieve the main purpose of the research, we used a quantitative analysis to reveal useful insights concerning the status of the current situation of hydropower sector. Also, we conducted a detailed qualitative analysis regarding the impact of economic, social and technological trends of hydropower to contribute to the enrichment of the research field. It can be concluded that hydropower is a sector on an ascending trend with major social, economic and technological implications. Despite slower capacity growth, hydropower will remain the largest source of renewable electricity generation. Its positive impact for all dimensions is beyond climate risk of the hydropower industry. There are voices which suggest that hydropower may be excluded from some "green" investment mechanisms due to its perceived carbon footprint. It will be very hard for governments and other authorities to deny the impact of hydropower sector on the road to achieve sustainable development.

Keywords: *hydropower, sustainable development, economic impact, social impact*

JEL codes: *M20, Q40*

1. Introduction

Energy is central to eradicate poverty, to improving human welfare and raising living standards as well as to supply power and heat to production systems [4], and, in the same time, is an essential factor in overall efforts to achieve sustainable development. Along with fossil fuels and nuclear resources, renewable energy becomes a more and more important source of energy nowadays [4]. Moreover, renewable energy sources have a potential to play an essential role in the world's future [6], because they can provide energy free of air pollutants and greenhouse gasses by emitting zero or nearly zero percent of these gasses. Many countries have already adopted the goal of enhancing the role of renewable sources in their energy supplies [9].
Among the renewable energy types, the oldest exploited is hydropower which was the first renewable energy source used by people, more than 2000 years ago. In the same time, it played an important role in the development of electric power industry or even economies, such as: China [11], Norway [13], Brazil [3] [16] or Canada [15].

2. Hydropower overview

About 85% of global renewable electricity is hydropower contribution to the energy total production [7] [10]. Hydropower is the major renewable electricity generation technology worldwide and will remain so for a long time. Since 2005, new capacity additions in hydropower have generated more electricity than all other renewables combined [7]. In South America, it is the main source of renewable energy, followed by biofuels [12]. There are many countries worldwide which produce more than 50% of their energy from hydro sources (table no. 1).

Table 1. Countries with more than half of their electricity generation from hydropower in 2010

Country	Electricity production from hydroelectric sources (% of total)
Albania, Paraguay, Congo, Dem. Rep., Nepal, Namibia	99% - 100%
Zambia, Tajikistan, Norway, Ethiopia, Kyrgyz Republic, Mozambique, Togo, Georgia	80% - 98.99%
Sudan, Uruguay, Cameroon, Korea, Dem. People's Rep., Colombia, Iceland	70% - 79.99%
Venezuela, Croatia, Austria, Costa Rica, Ghana, Brazil, Myanmar, Suriname, Cambodia	60% - 69.99%
Canada, New Zealand, Montenegro, Congo, Rep., Switzerland, Panama, Zimbabwe, Angola	50% - 59.99%

Source: own representation based on [7]

It is important to underline the performance of Albania which produces 100% of its energy from hydropower. Also, there are countries like Paraguay (99.98%) or Congo, R.D. (99.87%) which almost ensure electricity production based on hydropower sources.

The recent development of large hydropower plants, in countries like China and Brazil, has also stimulated debate about the economic [1], social [14], and environmental [5] effects of hydropower. Hydropower has developed as a safe, reliable and inexpensive source of power and energy services. Hydropower is a fully mature technology in use in more than 159 countries. In 2012, the sector provides 16.3% of the world's electricity, more than nuclear power (12.8%), 2 much more than wind, solar, geothermal and other sources combined (3.6%), but much less than fossil fuel plants (67.2%).

The aim of this research to give an overview of the present situation of hydropower and its future social, economic and innovation perspectives and challenges. The paper adds value to the body of knowledge by enabling the understanding of how the hydropower sector has evolved in the last decades. Also, the study provides an overview of the hydropower sector worldwide and identifies the future trends of this sector.

In this paper we analyzed hydropower from multiple perspectives and in terms of socio economic impact for sustainable development. When we speak about hydropower, we speak about 6 major aspects that we can correlate with hydropower (figure no. 1).

Each of the major aspects has a significant contribution to the development of hydropower worldwide and a direct impact to a sustainable development. Evaluating the main trends of these aspects could highlight the actual and future perspectives of the sector. Electricity generation and consumption are two indicators that are strongly correlated with the economic growth. The main social impact of hydropower is determinate by the number of jobs created by sector and the welfare generated. Either aspects as technology and innovation evolution in the field or the positive influence of hydropower in climate change should not be neglected.

Besides these major aspects, Dascalescu and Kleps [2] underlined others advantages that hydropower adds to a country, such as: floods mitigation in reservoirs, sources of drinkable, industrial and irrigation water or tourism and fish farming development.

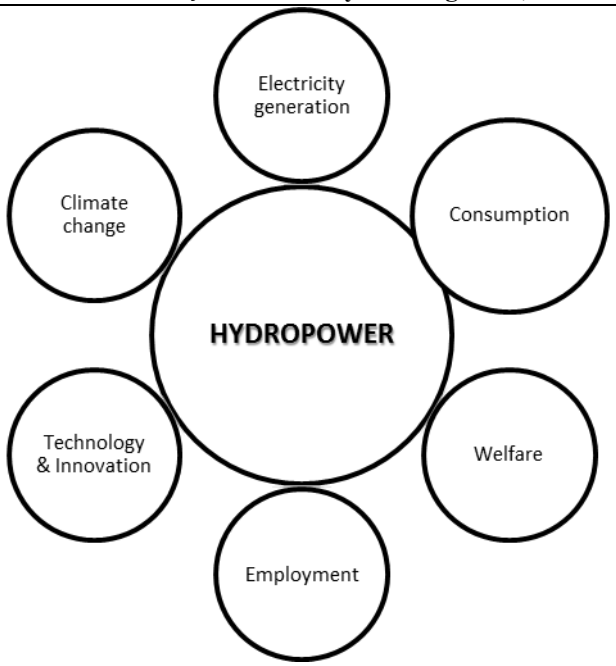

Figure no. 1**.** Hydropower socio-economic impact areas
Source: Own representation

Using quantitative analysis, the paper provides useful insights concerning first of all the status of the current overview of hydropower sector. Also, a detailed qualitative analysis on the impact of economic, social and technological trends of hydropower is conducted in order to contribute to the enrichment of the research field.

3. Research findings

HYDROPOWER - major source of electricity generation

Current energy structure which generates a lot of pollution and environmental negative impact should be gradually replaced by a clean and renewable energy. In 2015, energy produced from all sources was 24.660 TWh. In many countries as China or Germany, coal is the dominant source of energy, but its supply is declining annually and being replaced with renewable energy sources. Compared with 1990 when share of renewable electricity output in total energy output was 19.3%, in 2015 this share reached 22.8% worldwide. It is expected that share of renewables in electricity to be 30% in 2022.

With 3899 TWh produced, hydropower accounted 16% share in electricity generation from all sources. In the same time, it recorded 70.4 % share in renewable electricity generation in 2015.

In Europe, hydropower is a major source of energy in many countries. Albania is the only country on the continent whose energy production is ensured 100% from hydropower. A reference country in the field is Norway, which ensures 97% of his energy from hydro sources.

In terms of installed capacity, hydropower accounts, in 2016, 54% share in total of capacity. As presented in Figure no. 2, the first country ranked is China, followed by USA and Brazil. China holds 29.62% of total installed capacity in hydropower sector. Almost 47% of installed capacity in hydropower is owned by these three countries.

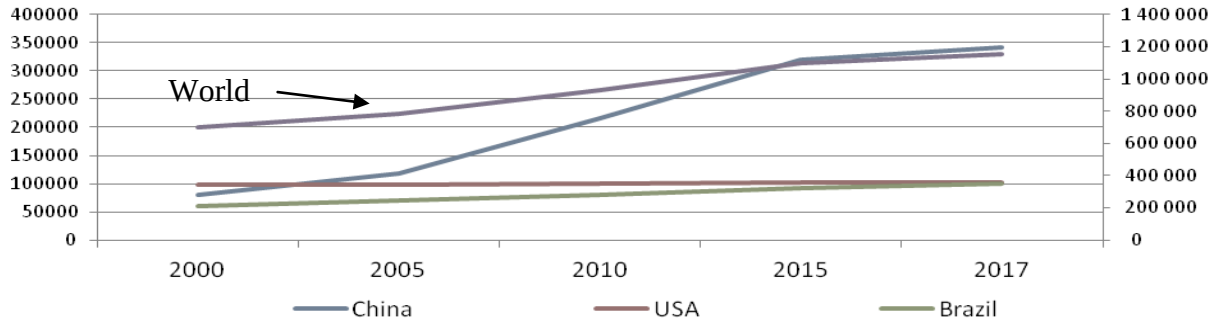

Figure no. 2. Installed capacity in hydropower
Source: own representation based on [8]

In 2015, hydropower development continued its strong growth trend. Globally, the drivers for this include a general increase in demand not just for electricity, but also for particular qualities such as reliable, clean and affordable power.
Analyzing the hydropower potential, it can be observed that the biggest undeveloped resources are in Russia (1502300 GWh/year). In Africa, only about 7% of the economic potential for new hydro projects has been developed. Countries like Congo or Angola exploits only 2% of their potential.
In Europe, leading country in hydropower, Norway has still 55% unexploited potential (165,296 GWh/year). A lower utilization rate (27%) can be remarked in Turkey, which holds yet 157,757 GWh/year undeveloped potential. A 10% increase in hydropower generation in Europe means:

- + 60 TWh renewable electricity;
- + 9-11 billion euro increase in GDP;
- + 27.000-36.000 new jobs.

HYDROPOWER - dominant form of modern renewables consumption
Hydropower remains dominant, accounting for approximately one-quarter of renewable consumption. In the existing literature is remarked that rapid economic growth determines greater energy consumption. Starting with year 2000, it can be remarked a continuously increase of hydropower consumption based on the rising of growth rate in many regions.
Hydroelectricity consumption increased by 4.8% in 2013, led by China, which became the leading producer of hydroelectricity in 2005. It has consolidated its position by commissioning the world's largest dam, Three Gorges on the Yangtze River. The second-largest consumer of hydropower is Brazil, which used 415 TWh in 2013.
BP Statistical Review emphasizes the growing trend in hydropower consumption. Hydropower share in modern renewable energy consumption is constantly increasing. In context of sustainable development main objectives, it seemed desirable that energy consumption be directly reduced, even if many countries record economic growth.

Contribution to welfare
Economic welfare is the level of prosperity and quality of living standards in an economy. In China, many researchers' results indicate that a 1% increase in renewable energy consumption increases real GDP by 0.120%, GDP per capita by 0.162%, per capita annual income of rural households by 0.444%, and per capita annual income of urban households by 0.368% respectively.
Renewable energy consumption, in general, and hydropower, in subsidiary, indirectly affects economic growth through its positive impact on real gross fixed capital formation. In the same time, the expansion of hydropower and renewable energy will also reduce dependence on foreign energy sources, volatile oil and natural gas prices on international markets. Meanwhile, it can

contribute to the reduction of long-run environmental degradation associated with greenhouse gases emissions.

Hydropower's contribution to European welfare is significant. Overall value creation of hydropower generation and equipment manufacturing amounts to approx. 0.3% of European GDP, which is comparable to the GDP of Slovenia. Therewith, it contributes to public sector revenues by taxes, levies and other charges. Since 2010, in Europe, more than 25bn € were invested by European hydropower companies into new and existing capacity. Worldwide, there are about 1200 large dams under construction in 49 countries around the world.

High-value employment

Compared with fossil fuel technologies, which are typically mechanized and capital intensive, the renewable energy industry is more labor intensive. This means that, on average, more jobs are created for each unit of electricity generated from renewable sources than from fossil fuels.

In Table no. 2, the evolution of jobs in the sector between 2012 and 2016 can be observed. The biggest increase of employment was in small hydropower. Even if the total number of jobs in hydropower as share in all renewables is slightly decreasing, from 21.4% in 2012 to 17.6% in 2016, large hydropower recorded +7.5% increase in the total number of jobs. The hydroelectric power industry employed approximately 66,000 people in 2017. In current economy, $1 million shifted from brown to green energy will create a net increase of 5 jobs.

Table no. 2. Jobs evolution in hydropower

No. of jobs	***2012***	***2013***	***2014***	***2015***	***2016***	***Increase***
All renewables	*7.100.000*	*8.200.000*	*9.300.000*	*9.700.000*	*9.810.000*	***38,17%***
Hydropower	*1.522.000*	*1.900.000*	*1.865.000*	*1.838.000*	*1.731.000*	***13,73%***
Large	*1.413.000*	*1.744.000*	*1.656.000*	*1.634.000*	*1.519.000*	***7,50%***
Small	*109.000*	*156.000*	*209.000*	*204.000*	*212.000*	***94,50%***
% share in total renewables	***21,44%***	***23,17%***	***20,05%***	***18,95%***	***17,65%***	

Source: own representation based on [8]

63% of jobs from large hydropower are in operation and maintenance. Key job markets were China, India and Brazil, followed by the Russian Federation, Pakistan and Indonesia.

In terms of investments, $1 million spending in renewables energy generates 7.7 full-time equivalent jobs (FTE), while the same expenditure in fossil fuels generates only 2.6 FTE jobs.

Technology & innovation

Technological innovation is fundamental for rendering the energy economy cleaner and more efficient with concurrent economical, developmental and environmental benefits. Understanding the factors that influence energy-efficient innovations is important for environmental policy.

In order to evaluate the evolution of technology and innovation in hydropower sector, we take into account the progress of patents in the field. In 2000, total number of patents in hydropower was only 918, while in 2016 it reached 36.331 patents. This represents a 3957% of patents in the field, in accordance with the trend in renewables which registered 5278% increase (Figure no. 3).

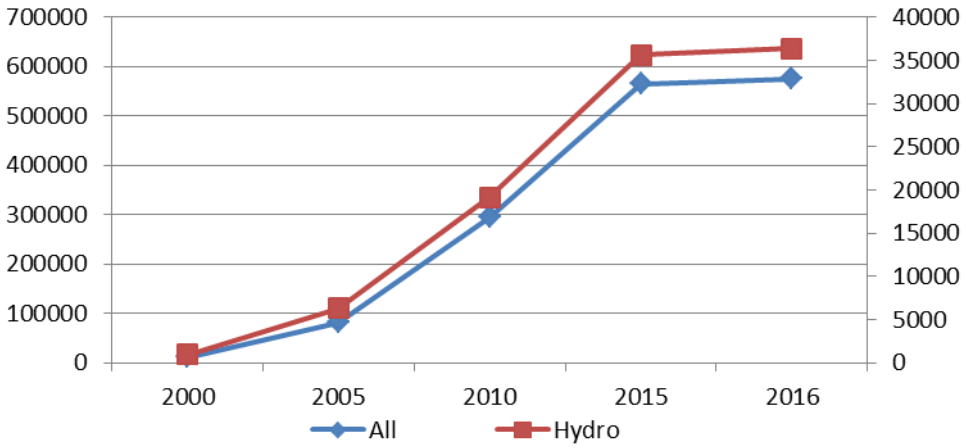

Figure no. 3. Hydropower patents evolution
Source: own representation based on [8]

Annual net additions have an ascending trend between 2006 and 2012, with an average of 2936 patents/year. In 2013 the technology and innovation segment recorded a slight decrease of patents from 3853 patents in 2012 to 3255 patents in 2013.
Energy sector innovation is particularly important in China, which has grown at an official annual average of 9.4 percent from 1978-2002. China added 1143 new patents in 2013 from 766 in 2009. Overall, innovation in China's energy sector seems to be influenced by the pre-reform institutional legacy, degree of market competition, relative technology costs, global energy prices, and government interventions in the form of incentives or regulations.
Secondly ranked in technology and innovation is USA. Favorable economics and technological innovations are yielding enormous opportunities to transition America to a clean, affordable, and reliable electricity grid. In hydropower, USA holds, in 2013, 2931 patents from a total of 30086 patents worldwide.

Climate change
Mitigating climate change is one of the most important goals for strategic sustainable development. The reduction of greenhouse gas (GHG) emissions is the focus of a number of international targets and agreements such as the recently ratified Paris Agreement, which seeks significant emissions reductions in order to limit global average temperature increases to well below 2 °C.
The Hydropower Sustainability Assessment Protocol has become broadly recognized as the primary tool for evaluating sustainability performance, having been implemented worldwide. The protocol provides a definition of sustainable hydropower, and includes some guidelines, it is presented as a methodology for assessment and scoring, and the guidance it contains is for completing an assessment.
Climate change is expected to have wide-ranging impacts on precipitation levels and regional hydrology. While these impacts will vary by location, generally speaking there is an expectation of increased precipitation and more extreme weather events, including both flood and drought periods. In some regions, climate change will affect water and energy availability as well as electricity demand, which would place a higher premium on water storage; this currently is not always adequately recognized. However, in other regions, climate change will result in increased water flows, such as regions that rely on glacial runoff.
Some organizations within the hydropower sector have recognized the potential impacts of climate change and are developing robust adaptation strategies and building climate resilience into their long range plans. For example, Hydro-Quebec in Canada has partnered with Ouranos, a research consortium with expertise in regional climate models and simulations.

Hydropower operational costs are relatively low, and hydropower generates little to no greenhouse gas emissions. The main environmental impact is that a dam to create a reservoir or divert water to a hydropower plant changes the ecosystem and physical characteristic of the river.

4. Conclusion

The research outlines the impact of hydropower in terms of increasing sustainable development from the perspective of socio-economic impact in the field. It contributes to the enrichment of the existing literature with implications in policy making or financial incentives.

The value added by hydropower has a significant contribution to the development of renewable energy sector and to the transition to a clean and affordable energy as sustainable development goals aims.

The potential for additional hydropower remains considerable, especially in Africa, Asia and Latin America. The estimations foresee, by 2050, a doubling of global capacity up to almost 2,000 GW and of global electricity generation over 7,000 TWh. There are many opportunities for hydropower development throughout the world and although there is no clear consensus, estimates indicate the availability of approximately 10,000 TWh/year of unutilized hydropower potential worldwide.

It can be observed that hydropower is a sector on an ascending trend with major social, economic and technological implications. Despite slower capacity growth, hydropower will remain the largest source of renewable electricity generation. Its positive impact for all dimensions is beyond climate risk of the hydropower industry. There are voices which suggest that hydropower may be excluded from some "green" investment mechanisms due to its perceived carbon footprint.

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