

## Recent Trends in Hydroelectric Power Technology

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**ABSTRACT:** *The needed for renewable energy sources is growing day by day because of the severe energy crisis in the world today. Several renewable energy sources like hydroelectric, wind, solar, and biomass can be used for generation of electricity and for meeting our daily energy demands. Hydroelectric energy is essential for a sustainable energy future, and it is a renewable energy source depending on the natural water. As a matter of fact, hydroelectric is a primary source of sustainable power supply. This paper traces an overview of the hydroelectric power and the history of hydroelectric power. Moreover, it will show the prospects the recent trends in hydroelectric power and how it works. Advances and future challenges are proposed. The hydroelectric power for a sustainable Europe will be illustrated.*

**Keywords:** *Hydroelectric Power, Sustainability, Small Hydropower, Power Generation, and Greenhouse Gas Emissions.*

### I. INTRODUCTION

The need for electricity is growing more and more in every aspects and field in our life. The world has an insufficient oil reserve, which will be dropped in the future. Indeed, the massive oil consumption and the increase of CO<sub>2</sub> Emission created a necessity to look for new alternatives such as hydropower, biomass, geothermal, solar and wind, which are the most important renewable sources. However, renewable energy accounts small portion from the world energy production and we still mainly depend on fossil fuel to generate power. Hydropower is a clear choice for the supplying of clean, reliable, and low-cost electricity [5]. Hydropower strategies have a substantial pliability in their design and could be designed to meet base load needs with relatively high capacity [3]. The world has been meeting a tremendous challenge to fulfill the energy requirements of a rising population and to reduce the greenhouse gas emissions while climate is changing. Hydropower provides 19% of global energy needs. However, there are enormous unexploited potentials especially in developing countries. Indeed, hydroelectricity is in the forefront of green energies because it plays an important role to reduce the greenhouse gas emissions. Since the past decades hydropower developments have been extremely questionable due to the society and the environment matters in spite of the strengths of hydroelectric power [13].

### II. HISTORY OF HYDROELECTRIC POWER

Hydropower technology has a long history. It has been used for centuries. The Greeks used water wheels in more than 2,000 years ago, to mill wheat. After that, the Americans realized the features of hydropower and utilized it widely for pumping and milling, which was in 1700's. As early as the 1800s, the European started to use the water wheel for powering machines. Hydropower generated about 75 percent of the electricity utilized in the West and Pacific Northwest, which was in 1940. The beginning of the American hydroelectric power generation produced is Niagra Falls and still working as a source of electricity today. In the following decades, a lot of hydroelectric plants were built. Hydropower contributed one of the best ways for quickly increasing the country's energy output [9]. By the end of the 1940s, big dams had been developed. After a while, people showed a keen interest in smaller hydroelectric plants. This technology has evolved towards getting higher efficiency, performances, and larger power output. The hydropower plants have the longest average lifespan by 80 years comparing with other power generation technologies [2]. Hydropower can be multi-used to generate electricity, power machinery, or both at the same time. The main elements of hydroelectric power plant are:

- Dam
- Intake
- Turbine
- Generators

- Reservoir
- Transmission lines
- Penstock

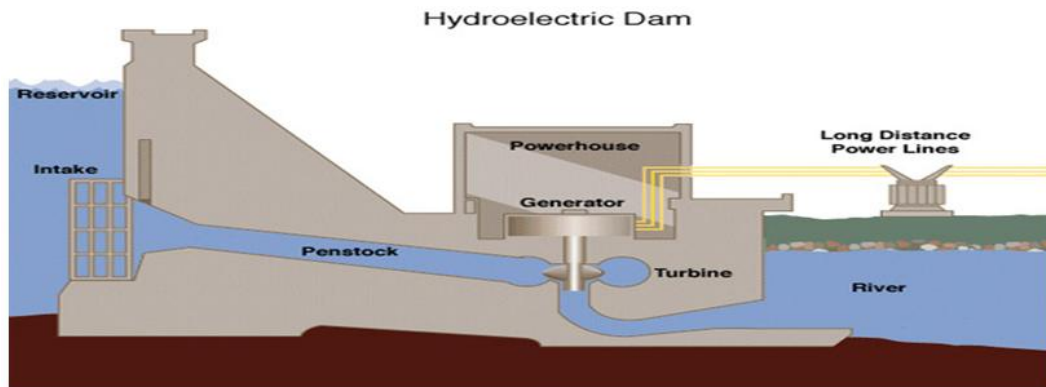


Figure 1: Typical Hydroelectric Power Plant. ([HTTP://WWW.ALTERNATIVE-ENERGY-NEWS.INFO/TECHNOLOGY/HYDRO/](http://www.alternative-energy-news.info/technology/hydro/))

### III. RECENT TRENDS IN HYDROELECTRIC POWER

Within many types of renewables technology nowadays, hydropower will undoubtedly play a vital role throughout the world. Hydropower provides around 16.3 % of the electricity throughout the world [16]. Indeed, it is the most important renewable energy source today. Currently, many countries in the world have been using hydropower for their electricity supply. Moreover, more than 150 countries are reliant on hydropower to produce their electricity. For instance, Canada, China, Brazil, and the United States are the countries which utilized hydropower generation in a wide range because they have the largest hydropower production capacity. From 1990 until today there is a big increased in hydropower generation by 50% and the highest increased was maintained in China. In 2014, hydropower development reached 39 GW as seen in Figure 1 due to the continued growth. Pure hydropower capacity placed into operation producing 1,055 GW1 of the total installed capacity in the world as seen in Figure 2. [11]. Recently, the investment is focusing on pumped storage projects, refurbishment, and modernization projects to boost the lifespan and the efficiency. Also, have been given attention to reducing greenhouse gas emissions and the environmental impacts as well.

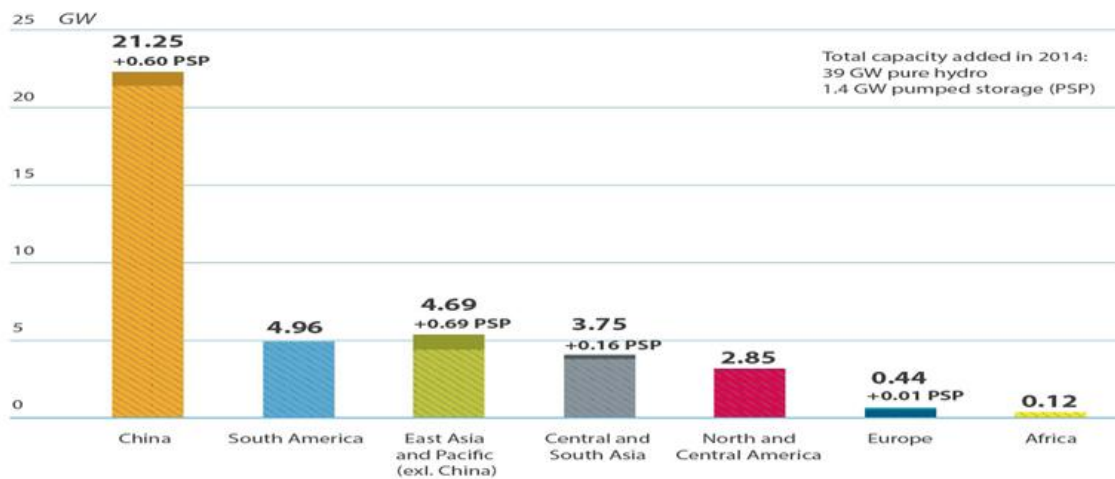
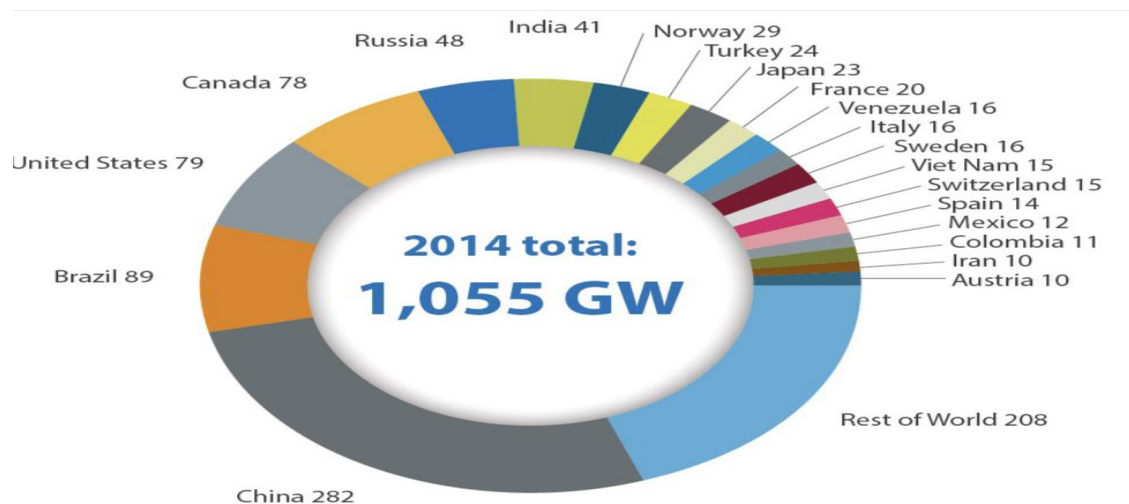


Figure 2. Distribution of new capacity added by region, including pure hydropower and pumped storage. Picture Adapted from 2016 Key Trends in Hydropower (<http://www.hydropower.org/2016-key-trends-in-hydropower>)



**Figure 3.** Global total of pure installed hydropower capacity (GW) by country in 2014. Picture Adapted from 2016 Key Trends in Hydropower (<http://www.hydropower.org/2016-key-trends-in-hydropower>)

#### IV. HYDROELECTRIC POWER FOR A SUSTAINABLE EUROPE

Hydropower plays a significant role in reaching Europe's climate and energy target. Notably, hydropower can accomplish the increased development of renewable technologies into the European power grid. The future energy systems in Europe of the wind and solar demands steady capacity and potentiality to stabilize unsteady generation over time varying from hours to sundry months. The only configuration of hydropower electricity storage that is convenient on a large scale is pumped storage. As a result, pumped storage hydropower provides additional Energy services. Therefore, the European markets start to require operators to enhance the increased penetration of variable renewables over the continent. A lot of projects of pumped storage under construction such as in Switzerland, more than 3,000 MW, 104 MW of new capacity was installed in Portugal and is expecting to build two pumped storage by the end of 2016. A 100 MW hydropower project takes place in Iceland is expected to complete in April 2018 [13].

Nowadays in Europe, there is roughly approximate of 218 GW of installed hydropower capacity. Scandinavia and the Alpine countries have the maximum of the installed hydropower capacity. However, the hydropower potential that is not exploited is located in Eastern Europe. In contrast, the strongly developed hydropower markets are located in western and northern Europe [13]. The most three important factories of hydroelectric power for a sustainable Europe are:

##### 1. Hydropower European Technology Leadership

European industry completely relies on hydropower technology. As a matter of fact, all the global heads equipment of hydropower technology are in Europe. The hydropower markets in Europe account for more than 50% of the whole world market. In addition, small hydropower plants play a role lead Europe industry to be more than two-thirds of the world market. The bright reason that makes Europe lead the world in hydropower technology is the research centers of this area locate in Europe. Furthermore, the universities with good education and focusing on the hydropower technology make Europe taking the leadership of the hydropower technology throughout the world. As a consequence, many qualified jobs are existing in Europe for millions of researchers [7]. Besides their concentrating on the development and research, they open a lot of centers for training and searching. Meanwhile, they have been trying to reduce the greenhouse gas emissions as well as to reduce the environmental impacts to make a clean environment. Even though there are a lot of the advantages of the hydropower technology, they are disadvantage such as migrating fish. Currently, the researchers have carried out solutions, which are including ladders, passes, and lifts, to improve the living for fish [12].

##### 2. The most efficient power generation

Hydropower presents the greatest energy payback ratio comparing to the others renewables technologies and traditional ones as well. The proportion of total energy generated during the lifetime of technology divided by the energy needed to build fuel preserve is the real meaning of the energy payback ratio. It is a paramount benchmark when taking the efficiency and sustainability of a power plant into account. Therefore, getting a better environmental performance requires higher payback ratio. Due to the lifetime of hydropower, the plant produces more than 200 times the energy that wanted for maintenance, operation, and building too. The extremely long lifetime of hydropower systems and the short energy conversion process are

the reason for getting high-energy payback ratio. For this reason, life cycle evaluation for hydropower supplies a splendid carbon footprint [8].

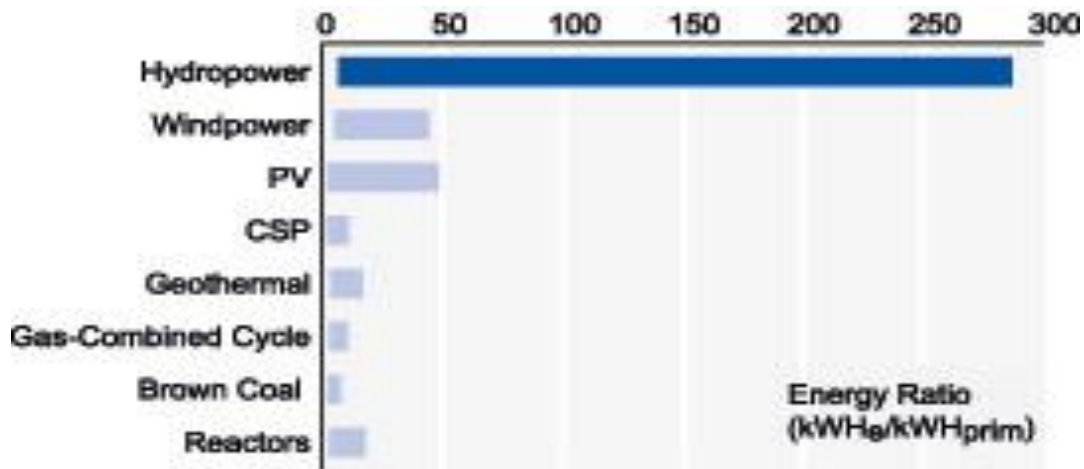
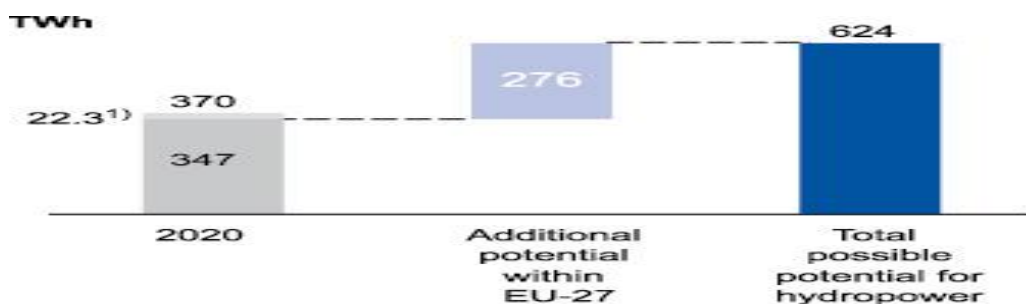


Figure 4. Energy Ratio of Hydropower comparing to the other renewable technologies [12].

As a consequence, hydropower can assist to come face to face with the increasing pressure on natural resources. Hydropower plants with reservoirs produce accessibility of water for an abundance of ideas and improve the observation of the resource. The rate of hydropower efficiency is varying between 85% and 95%. Indeed, it is extraordinarily comparing to other energy technologies [7].

**3. Sustainable solution for climate change**

From the past decades until today the temperatures are still keeping to rise. Scientists carried out that an increase in the average temperature of manufacturing level would have extreme consequences for the environment and the humans. A fossil fuel, which produces greenhouse gas emissions, such as CO<sub>2</sub> is the main reason of ongoing climate change. In order to avoid the growth of temperature, the world must give attention to the greenhouse gas emissions and reduce it to the half before 2050. Finding a substitute for fossil fuel with renewable energies is pivotal since the energy sector has observed for more than 50% of global emissions [10]. Hydropower is crucial in reducing climate change because of its low carbon footprint. It can produce remarkable volumes of renewable and low carbon electricity. Hydropower plants assist us to be away from flood disaster and supply water in wilted seasons. Europe can adapt to a changing climate by integrated water management [12]. Investigating the lifecycle greenhouse gas emissions for various electricity generation technologies demonstrates that hydropower plants have the lowest carbon footprint [12].



Hydropower’s potential in Europe [8].

16% of electricity in Europe produced by hydropower appearing for 67% of renewable energy. The hydropower industry is interested in reaching the goals of balancing the different economic, social, and environmental factors during the riskiness of climate change [14].

**V. ADVANTAGE AND DISADVANTAGE OF HYDROELECTRIC POWER**

Hydropower has several unique features that are essential to contribute to the national power because of the ability that makes it respond quickly to any changing in the loads, system distractions, and long life. Even though there are many advantages of hydroelectric power, there are negative environmental impacts especially large ones as shown in Table 1. The new hydropower plants that currently under construction threaten the

environment and society. As a matter of fact, the long history of hydropower will make challenges both environmental and social [5]- [4].

**Table 1:** Advantage and disadvantage of hydropower

Advantage	Disadvantage
<p><b>Economic aspects</b></p> <ol style="list-style-type: none"> <li>1. Has a low operating and maintenance cost.</li> <li>2. Provide reliable and affordable electricity supply.</li> <li>3. Provides long life span (50–100 years and even more).</li> <li>4. Includes proven technology.</li> <li>5. Reduce the dependence on energy imports and fossil fuels.</li> <li>6. Creates employment opportunities.</li> <li>7. Ensure sustainable growth.</li> </ol> <p><b>Social aspects</b></p> <ol style="list-style-type: none"> <li>1. Improves the living in this life.</li> <li>2. Regularly provide flood protection.</li> <li>3. Often intensify navigation conditions.</li> <li>4. Enhances recreation.</li> <li>5. Sustains livelihoods (fresh water, food and supply).</li> </ol> <p><b>Environmental aspects</b></p> <ol style="list-style-type: none"> <li>1. Produces only very few GHG emissions.</li> <li>2. No air pollution</li> <li>3. Respond quickly to changing system conditions.</li> <li>4. No waste is produced.</li> <li>5. Enhances air quality.</li> </ol>	<p><b>Economic aspects</b></p> <ol style="list-style-type: none"> <li>1. High capital cost.</li> <li>2. Requires several academic disciplines involvement.</li> <li>3. Precipitation.</li> <li>4. Long-term planning is required.</li> <li>5. Needed out sourcing of contractors and funding.</li> </ol> <p><b>Social aspects</b></p> <ol style="list-style-type: none"> <li>1. May lead to resettlement.</li> <li>2. May restrict navigation.</li> <li>3. Effecting outdoor recreation.</li> <li>4. The power lines can change the land scape.</li> <li>5. Management of competing water uses is needed.</li> </ol> <p><b>Environmental aspects</b></p> <ol style="list-style-type: none"> <li>1. Obstacles for fish migration.</li> <li>2. Involve modification of aquatic habitats.</li> <li>3. Requires management of water quality.</li> <li>4. The populations may need to be monitored.</li> </ol>

Source: [15]- [6]- [10].

## VI. FUTURE GLANCE AND NEW METHODS AND TECHNOLOGIES OF HYDROELECTRIC POWER

Generally, the water covers two-thirds of the earth; therefore, water demonstrates the largest source of energy. Hydropower is necessary, and it will unquestionably be at the heart of the renewable energy technology in the world [10]. The Department of Energy researchers are working to evolve new techniques to rise the generation of hydroelectric plants. Furthermore, they are leading research to harness undeveloped hydropower capacity without constructing new dams and consolidate hydropower with other renewable technologies [1].

## VII. CONCLUSION

Taking everything into consideration, water is the most reliable resource, and hydropower makes utilization of this renewable valuable. Hydropower is the lowest technology that producing greenhouse gas emissions, and produce electricity with minimum impacts on global climate change. Hydropower has the ability to increase or decrease the amount of power in a wide range. Additionally, it supplies to the system immediately to meet the power demand promptly. As a matter of fact, hydroelectric pumped storage facilities are the only substantial way yet available to store electricity. Hydropower technology is reliable and mature since it has a role in a sustainable energy future by combatting the challenge of global energy needed and reducing greenhouse gas emissions.

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