Chapter

Hydropower and Sustainability

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Abstract

Renewable energy sources are gaining momentum in power sector mainly to address the impacts of climate change as well as the risks associated with usage of fossil fuels or nuclear energy sources. Hydropower is one of the most promising renewable energy source-based power plant that hold significant shares globally. But there are series of risks associated with hydropower project when we talk about sustainability and needs are felt to critically understand the pertaining risks as well as protocols or measures to quantify the risks. Such measure will prove to be crucial in underlining the strategic measures from planning, construction and operation phases of hydropower keeping on account of its sustainability.

Keywords: hydropower, renewable energy, sustainability, protocols, risks

1. Introduction

Power sectors today are facing stiff challenges in terms of its growing roles in contributions towards socioeconomic development. Electrical energy is one major components of the contributors that drives economic activities with stiff increases in its demand. On other hand there is pressure of climate friendly adoption through the adoption of the principles of green economy whereby the need for greenhouse gas emissions needs to be reduced [1].

But power sectors have been facing immense pressure of its dependency for fossil fuels usage for the electric power generations. With the threat of climate change and the commitment to combat climate change there is considerable move to harness electrical energy from renewable energy which is a clean source of energy. Amongst the renewable sources, hydropower holds considerable shares of electrical power generation due to its stable high power generation capabilities.

2. Renewable energy sources for electricity generation

The initiative for renewable energy sources has been considerably gaining momentum in recent decades. Prime reasons for this are due to its positive impacts of being environment friendly as well as its inexhaustible properties. Statistics maintained by IRENA shows that globally there was addition renewable energy capacity by 260 GW in 2020 despite a year hard hit by COVID-19 pandemic. Major reflection of this growth attributes due to fall in global fossil fuel additions [2].

The (**Figure 1**) below clearly highlighted the growth of renewable energy where major shares are of hydropower followed by wind, solar, bioenergy and geothermal. Just in 2019 there seems a considerable growth in solar power followed by wind, and other sources for electricity generations [3].

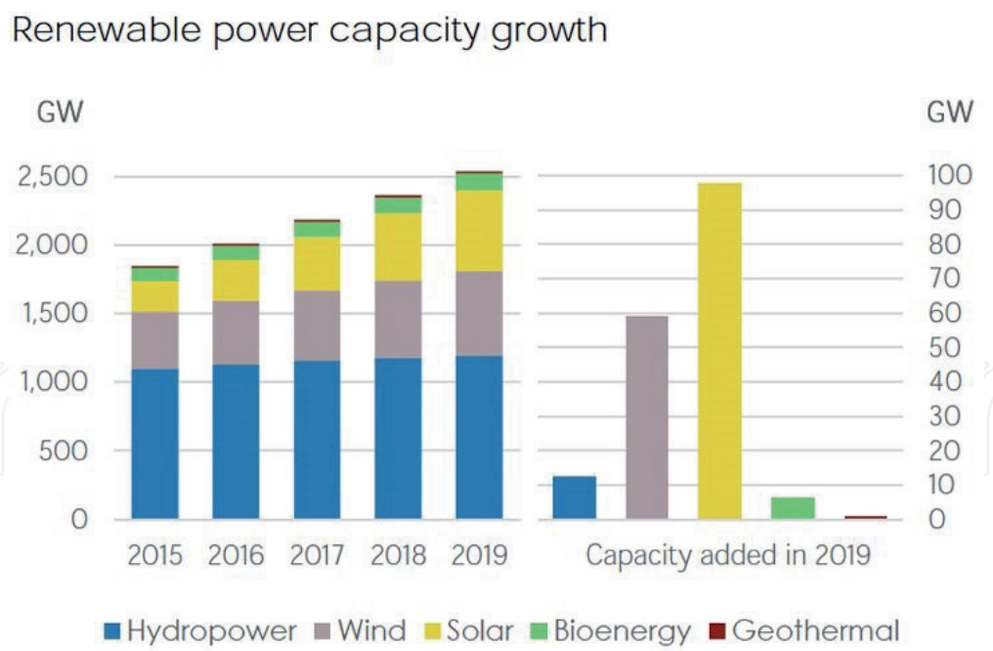

Figure 1.
Growth in renewable electric generation [2].

The share of installed capacity of hydropower in 2018 is at 1292 GW and there is a growth seen in the sectors of renewable energy (**Figure 2**). Such growth is due to be higher reliability of this source for renewable power generation along with its limited adverse impacts to the environment. As a result, there are indications that hydropower is gaining its potential across globe and the countries that can have feasibility of generating electric power from hydro. The trust based on its reliability assurance along with it being the source of renewable energy, penetration of hydropower in power sectors are substantial as well as growing.

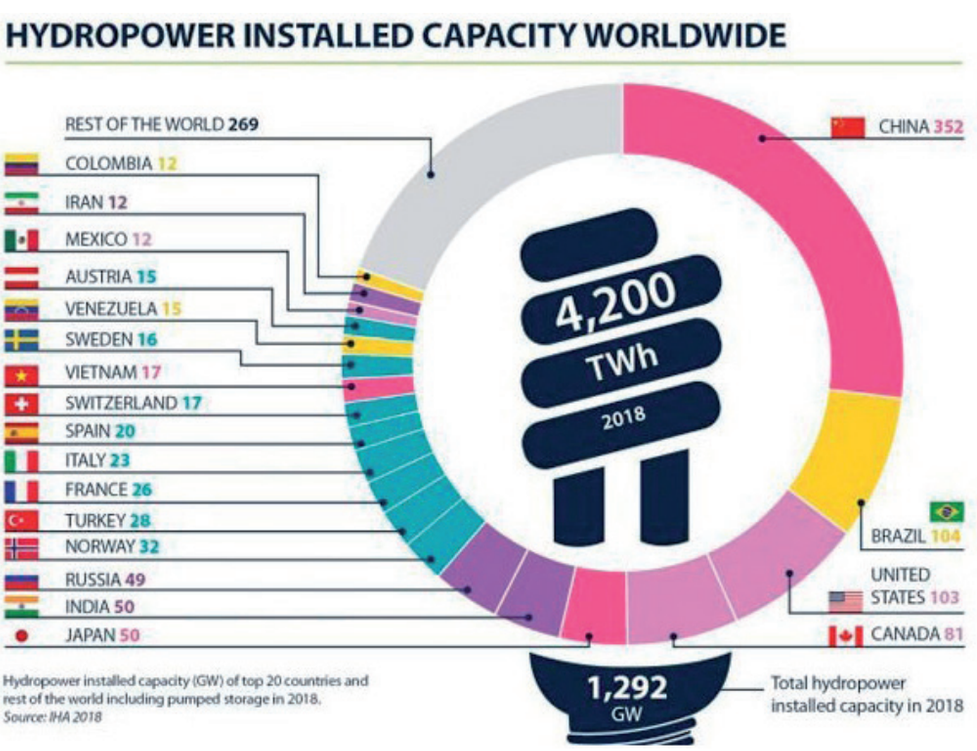

Figure 2.
The installed capacity of hydropower worldwide [4].

3. Hydropower as potential energy sources

Hydropower happens to be one of the major sources of electrical energy as it is clean, renewable and environment friendly as compared with fossil fuels or even the nuclear power [5]. Some of the major advantages of hydropower are:

1. Renewable source of energy with water as its primary source of energy (i.e. fuel),

2. Available capacity in abundance throughout globe with considerable potentials in developing countries,

3. Its potential avenue for flood control, contribution for networking to irrigation, aquatics farming and water parks,

4. Constant capacity and its enhancement during raining seasons.

World today hold considerable shares of electrical energy that are generated from renewable sources which is growing fast.

It is evident from the (**Figure 3**) below that hydropower hold 50% shares with 1,172 GW as compared with other renewable energy sources for electricity generation in 2018 where renewable energy accounts for the capacity of 2,351 GW. The share of hydropower in 2019 has increased to 1308 GW showing a significant increase in hydropower [6] despite the rising increases in solar and wind power generation capacities. Furthermore, IRENA statistic 2021 shows that of more than 80% install capacity which are from renewable energy in 2020 and the global renewable energy generation capacity reaches to 2799 GW in the end of same.

Though hydropower happens to be the major contributors for electricity generations, it has come into growing concern and threats. Water is the primary source of energy used which has been impacted due to climate changes. There are evidences of water bodies in rivers and streams drying up, prevailing situations of drought and glaciers meltdown. The actions to retain water bodies in this era of climate change needs to be device through collective initiatives ranging from policies, regulations, supports and mitigations measures.

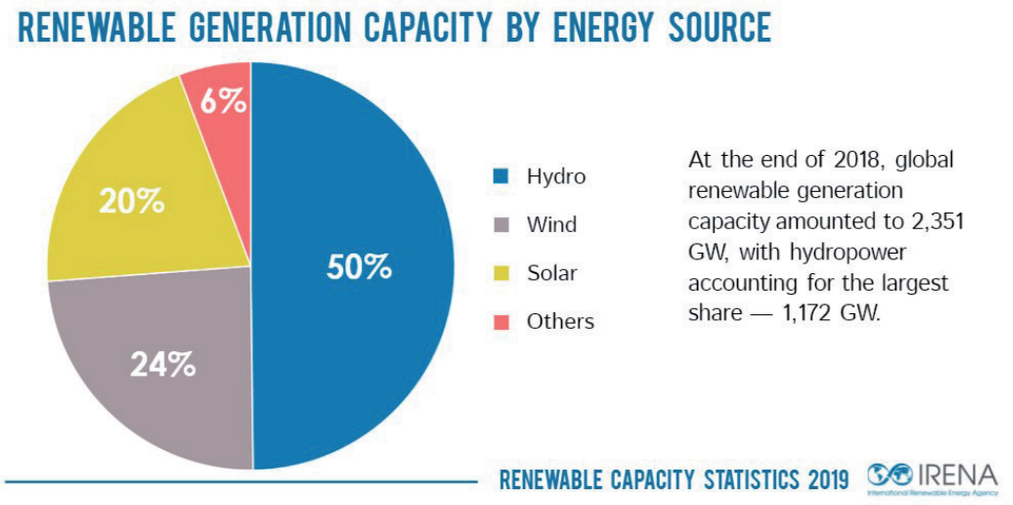

Figure 3.
The share of renewable energy generation sources [3].

4. Hydropower and sustainability

4.1 Understanding sustainable development

The concept of sustainable development has emerged in later parts of 1960s and in the earlier part of 1970s when the focuses on green movements was taking the momentum [7]. Environment concern has thus been the topic of discussion and that is to assure the sustainability (**Figure 4**).

There on the developmental activities are seen as an agent of environmental impacts and the focuses was shifted towards sustainable development. Sustainable development focuses more on the efficient measures of economic developmental activities that can be more in equitable manner and subsequently have limited impacts created to the environment (**Figure 5**).

Also, the dimensions of sustainability are well addressed in Sustainable Development Goals (SDGs) where the SDGs are measures devised to build the future that are sustainable, prosperous as well as equitable. The noble initiatives of SDGs are to provide a framework for addressing the needs of sustainable future through the initiatives and measures that works in broader aspects of activities that are planned for economic growth as well as living standards. This demand for strategic management which basically is 'understanding an organization's strategic position, making strategic decisions for the future, and managing [that] strategy in action' that can address the three phases of development as reflected below (**Figure 6**).

4.2 Understanding sustainable development of hydropower

Hydropower has to fit in the sustainability development models as discussed in earlier section where it needs to take account of economic, social and environment dimension starting from its planning phase till operations. Though these three factors are mostly in a nexus form when we are talking about sustainability.

The hydropower dams are main components of hydropower where it need to be constructed in water abundant regions. On the other hand, due to climate change the risk of drought and serviceability of the dams in meeting the needful impacts are in rise (**Figure 7**) [11].

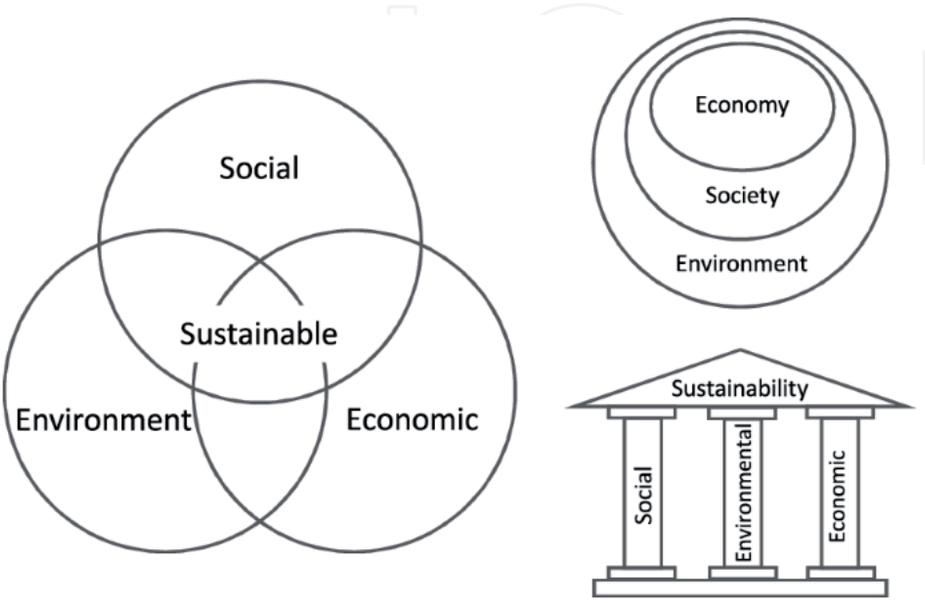

Figure 4.
Left, typical representation of sustainability as three intersecting circles. Right, alternative depictions: Literal 'pillars' and a concentric circles approach [8].

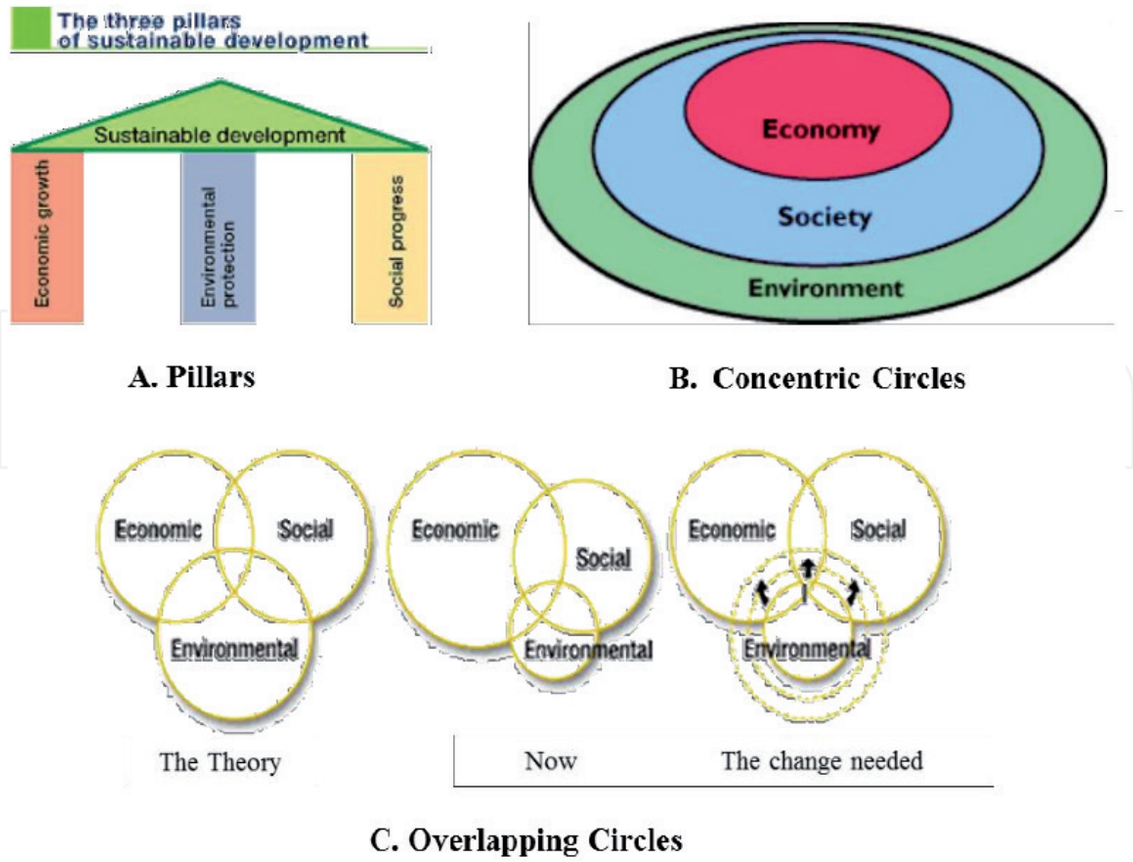

Figure 5.
Three visual representations of sustainable development: Pillars, circles, interlocking circles (IUCN, 2006) [9].

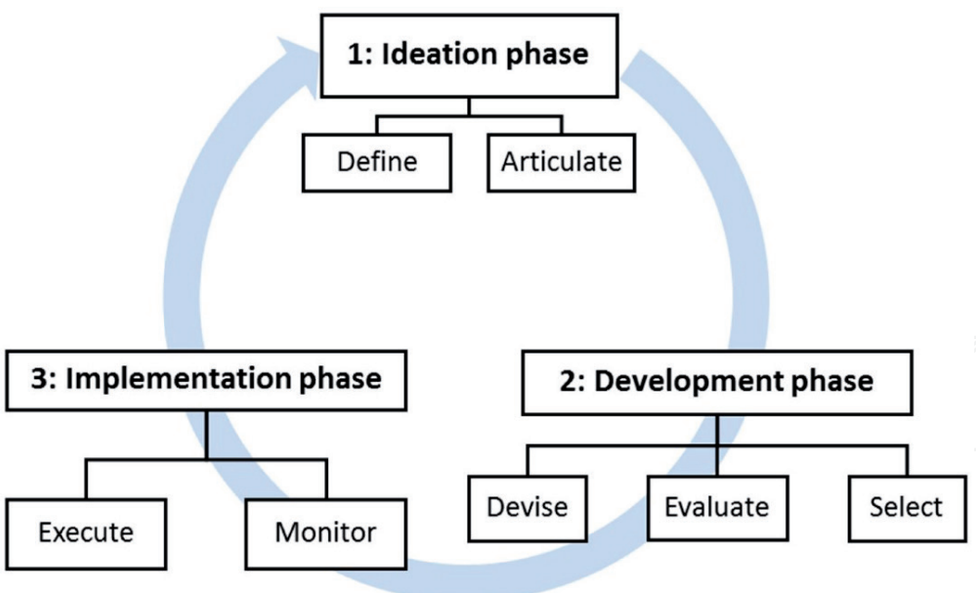

Figure 6.
A generalized strategic management process [10].

The (**Figure 7**) further clearly highlighted the rising risk of draught which also reported that around 31% of the dams that are 'planned/will be planned' will face the consequences of draught. Such threats will have serious implications on those countries which has major reliance in its power requirements from hydropower.

Other equal risk associated as a contribution of rising climate change are due to the floods that will be of risks to the dams associated with hydropower (**Figure 8**).

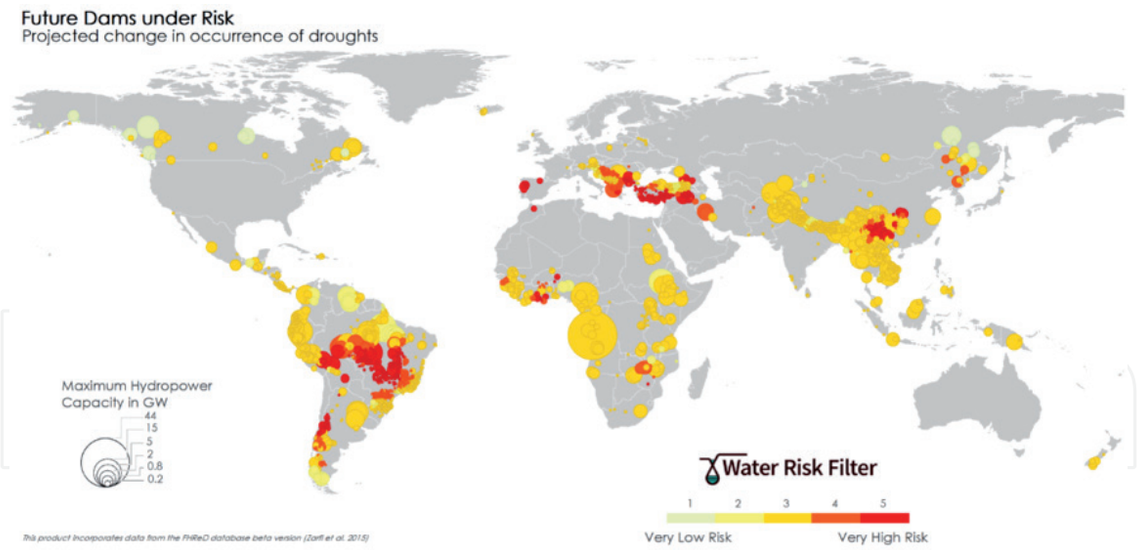

Figure 7.
The projected change in occurrence of draughts and risk to hydropower dams [11].

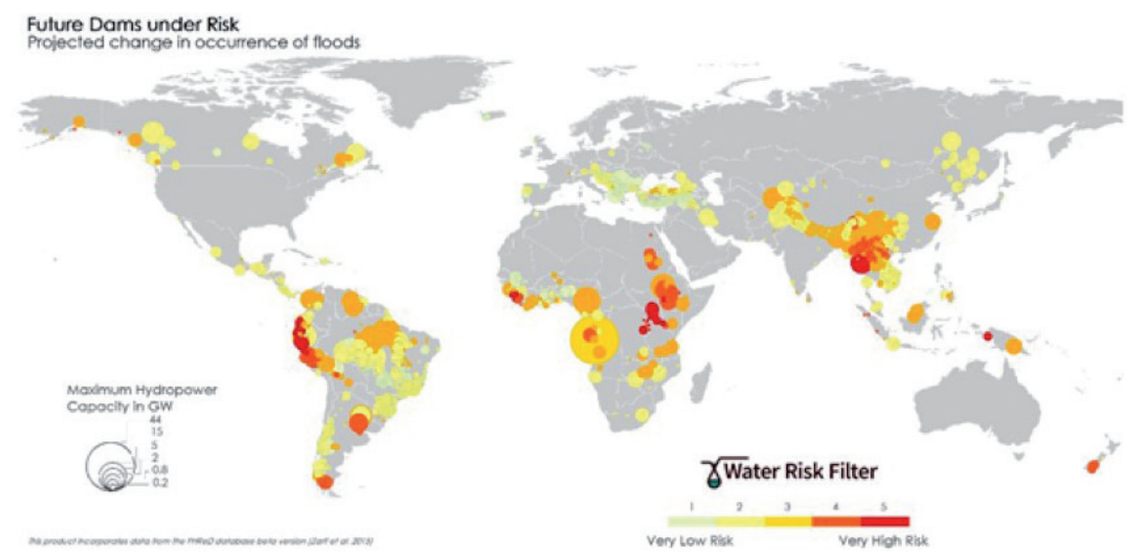

Figure 8.
The projected changes in occurrence of floods and risk to hydropower dams [11].

The figure and the resources clearly highlighted the growing risk that are poised to hydropower dams now and for future dams making it more venerable and may result into catastrophic consequences if the dams fail resulting in the devastating impacts. Though hydropower is clean source of energy, the functional loss of a hydropower reservoir's capabilities as a result of sedimentation or siltation could have both economic and environmental consequences [12].

Hydropower development is costly affairs and it can further be worsened with unforeseen complex challenges pertaining to geology as well as technical. Such situations can also stimulate the unexpected increases of the project duration in construction phase and subsequent threats during the operations demanding more attention [13].

Researchers has pointed out the needs for sustainability assessment tools. The integrated model of hydropower sustainability assessment has been also proposed where 'conceptual framework', and appropriate 'indicators selection' has been identified where the former is quite simple and practical tool and later is more of selecting indicators taking stock of environment, economic as well as social aspects into consideration. The model proposed are as shown in **Figure 9** [14]:

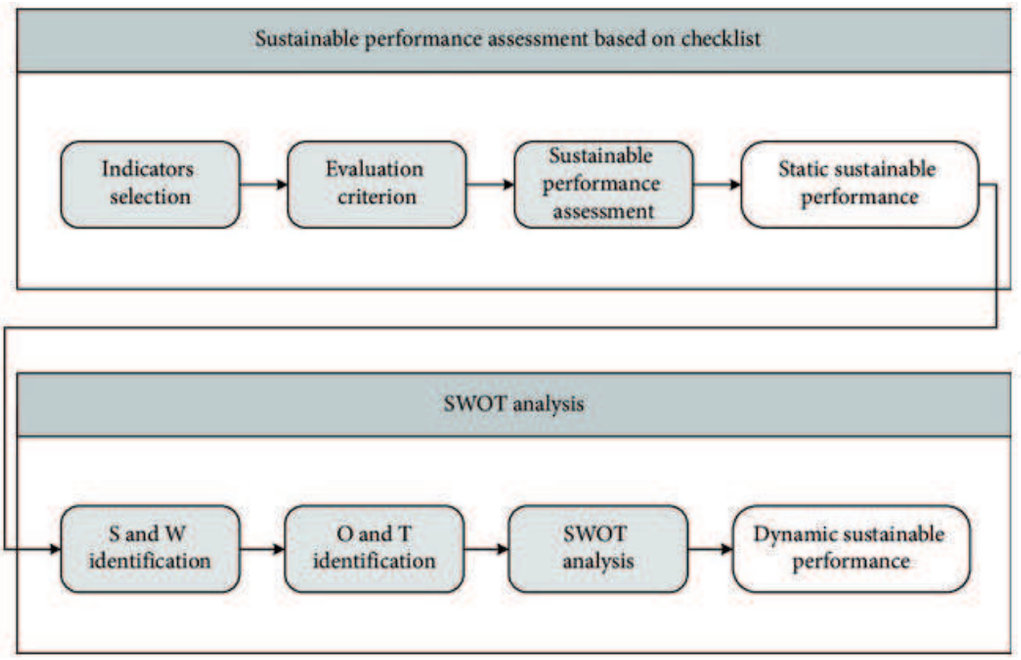

Figure 9.
Conceptual framework of the integrated hydropower sustainability assessment [14].

The above study further concluded that especially while considering the impacts associated with sustainability in case of integrated framework need to consider threats like very tight fiscal allocations and economic downturns that could further reduce sustainability.

Furthermore, there are series of risks as well as uncertainty associated with hydropower project. Some pertaining risks includes environmental, social, economic, policies and regulations, technological and financial, natural and many more which needs to be managed else threatening the availability along with sustainability of hydropower. This calls for effective risk managements in hydropower for ascertaining the sustainability [15]. On top of this one should clearly understand the internal and external risks which has direct impacts on hydropower sustainability. Internal risks are more associated with planning, accusation and execution measures including cost whereas the external factors mostly would be associated with weather, natural calamities and political measures.

Using expert judgment and a multi-criteria scoring technique, assess the potential risks of a hydro energy project. This risk assessment tool examines technical, economic, environmental, social, and regulatory threats. Researchers has presented some of the pertaining risks, its impacts and the mitigation measures as proposed are as shown in **Figure 10**.

The same figure also has shown how risks, impacts and mitigation can be looked in case of hydropower that need to be looked from the view of achieving the sustainability as well as ensuring the safe operation. Impacts level needs to be critically viewed and measures that need to be devised. Such risks, impacts and mitigation will be varied based on the location and capacity of the hydropower along with prevailing geographical as well as political issues.

This study found out that site geology and environmental issues are two external risks for hydropower projects. Hence risk assessment tools will prove handier in cost cutting as well as enhance deeper understanding of risks associated (**Figure 11**).

The appropriate planning and implementation are crucial as this will identify the actual size of hydro power plant, exact location of dam and other

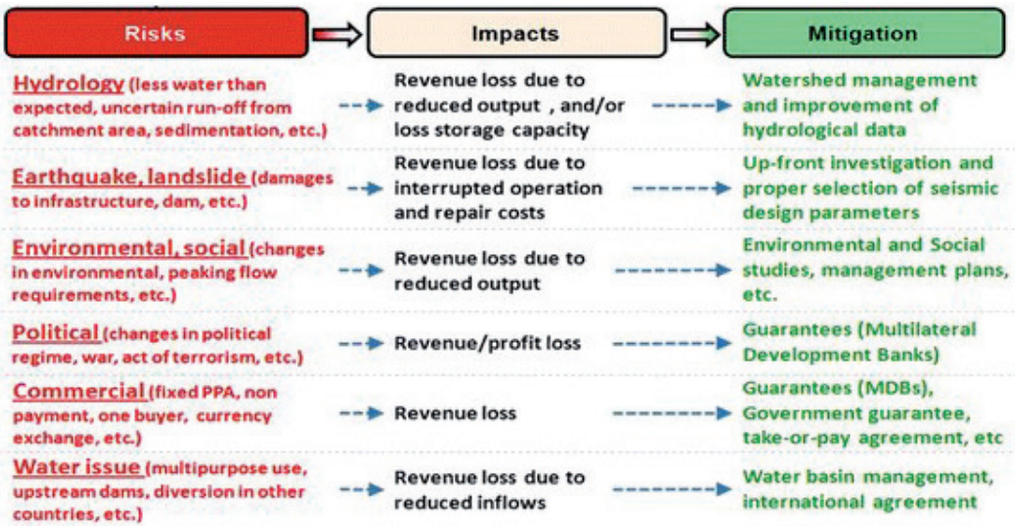

Figure 10.
The risks, impacts and mitigation approaches [16].

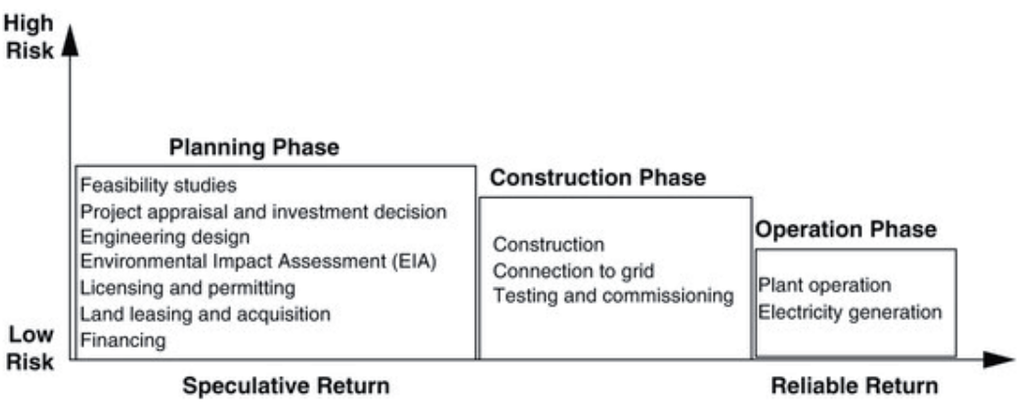

Figure 11.
*The phase wise risk assessment (**Figure 11**) [16].*

infrastructures, the right size and type of dam, right rating of turbine its capacity and types. Such system level approaches need to be materialized through proper research and evidences during the design phase whereas proper executions for quality assurance during the construction phases. Furthermore, the conditional aspects during its operation will hold equal importance in assurance sustainability issues pertaining to hydropower plant as well as power system networks as a whole.

The Low Impact Certification for the certification of hydropower with major focuses on ecological impacts by the Low Impact Hydropower Institute (LIHI) was initiated in 2000. Subsequent to it the Green Hydro Power certification was initiated by the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) which is more to safeguard the ecological integrity of river system. The inconsistency in sustainability assessment of hydropower have been highlighted by researchers and the development of hydropower sustainability assessment protocol (HSAP) by International Hydropower Association (IHA) which was launched in 2008 which aims in providing the more enhanced assessment tool for hydropower sustainability. This HSPA protocol has been extensively used for the development of multiple hydropower of large-scales including the 'Three Gorges Hydropower' in China. This protocol was endorsed by World Bank in 2014 recognizing it as a tool for developing hydropower [17].

Researchers pointed out that more of methodologies and models were incorporated for sustainable hydropower development but those were more of theoretical frameworks and there is a need for quantitively evaluate the sustainability aspects of the hydropower. One method to address this as proposed by researchers are information entropy and dissipative structure theory which are combined together so as to provide an appropriate method for evaluation research in terms of sustainable hydropower development capacity [18].

There is need to understand the environmental as well as social effects of the hydropower as these two factors are most significant indicators which are highlighted in case of sustainable hydropower. Hence the use of 'Environmental and Social Impact Assessment (ESIA) and 'Strategic Environmental Assessment (SEA) are implemented too. These ESIA and SEA are two tools that are used for addressing the impacts from various sectors (i.e. infrastructure, energy and mining as major sectors and processing and manufacturing sectors as minor sources). ESIA and SEA are internationally practiced, often legally enshrined, tools for assessing the consequences of policies, plans, programs, and projects from an integrated SDG perspective [19].

The innovative solutions in context of hydropower development especially the dams and other major infrastructures needs to be explored so as to achieve hydropower sustainability as there is tremendous potentials and benefits from hydropower. In the meantime, to address sustainability the incorporation of climate change needs to be incorporated especially in building the dams associated with large scales hydropower [20].

5. Conclusions

This chapter highlighted the need of hydropower thinking from the perspective of sustainability. As hydropower projects happen to be one of the main contributors in power sector and that too a promising renewable source, there are serious questions in relation to sustainability. As the sustainability aspects of hydropower has to be address from planning, construction as well as operation stages of hydropower, it requires validated tools and protocols that have been tested and verified. This is essential so address the risk associated with hydropower from internal (those that are pertaining due to types, capacities, expected working environments etc. for hydropower which need to be taken care during planning and design stage) as well as the external factors. Usually, the external risks are major sources of impacts to sustainability of hydropower a clear insight and needful intervention where possible is needed in timely manner. The two vital external risks of concern covering major impacts are ecological and social risks factors which has to be quantitively analyzed and address so as to ascertain the sustainability of the hydropower project and making it as a promising investment option for meeting growing demand of electric power from renewable energy sources.

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