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Hydropower for Sustainable Energy Development

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Abstract —*Hydropower creates fewer pollution and climate problems than fossil fuel power, as they create reservoirs of clean water, which to some are both pleasing to the eye and a place for tranquil recreation. They promise control of flooding, provide a steady supply of water for irrigation and, with time, a source of fresh fish. Hydroelectric power is a source of green energy because it makes use of water - a free abundant and inherently benign medium. It takes advantage of gravity, transforming energy from flowing water into electricity in a process that is at once clean and carbon free. Hydroelectric projects are the energy source with lowest greenhouse gas (GHG) emissions compared to Thermal Coal, Thermal Natural gas, solar, wind & nuclear. Hydropower is also worldwide recognized as the renewable energy source*

Keywords*-Hydropower, electricity, sustainability, economy, development.*

I. INTRODUCTION

The term “hydro” is a latin term for water, so hydroelectric power is generated using the flow of water in the river. The hydrologic cycle is a continuous process of flow/movement of water all around the earth without really having a starting point. The four main sub stages of this hydrologic cycle are evaporation, condensation, precipitation and runoff. In passing through these sub-stages, water transforms into different phases of solid, liquid & gas. Sun is the global force for the transportation of water all around the earth by furnishing the energy required for evaporation. While evaporating from sea into the atmosphere, the mass of water gains potential energy, a portion of which is used in the process of precipitation from the clouds while the remainder is dissipated in the course of flow in streams and rivers. The water particle which starts from the hill and runs towards the sea possesses more or less kinetic energy depending upon the changes in the velocity of flow stream. However the amount of kinetic energy is insignificant as compared to the dissipating potential energy; the change in kinetic energy is negligible. Thus the dissipation of potential energy of run-off waters in mountainous and hilly regions, regardless of small and negligible quantities, does not mean gain in kinetic energy. The potential energy of run-off is dissipated to overcome the internal friction of the turbulent water, to supply energy to spiral flows, whirls and eddies, to scour the river bed and to transport bed load. By erecting dams and weirs, a considerable portion of potential energy in any steam or in a river is utilized. This energy is utilized to generate hydroelectric power.

Power Development in Jammu and Kashmir has a long and distinguished history. 9MW Mohra Hydro-electric Plant, among the first of its kind in the subcontinent, was developed as early as 1905. Out of the identified potential, only 3263.46 MW i.e. 19.80 % (of identified potential) has been exploited so far, consisting of 1211.96 MW in State Sector from 21 power projects, 2009 MW in Central Sector from 7 projects and 42.5 MW in private sector from 4 projects.

These projects are techno-economically viable, besides being eco-friendly and socially beneficial. In order to harness this potential in a sustained manner, the Government of J&K established the Jammu & Kashmir State Power Development Corporation Limited (JKSPDCL) which has been incorporated as Private limited company on 16th February 1995. The Corporation was incorporated to takeover, execute, complete, operate and maintain all power stations and power projects of the State.

According to the annexure of Government order No.205-PDD of 2011 dated 07.07.2011, The installed capacity of 21 operational powerhouses of JKSPDCL is 929.70 MW comprising of 754.70 MW of Hydel Stations with the largest being 450 MW Baglihar HEP Stage I and 175 MW of Gas turbines. In addition, installed capacity of the projects under operation with NHPC is 1680 MW from which free power to the extent of 12 % of the installed capacity is available to the State. Currently the state is able to harness only about 15 per cent of this potential with a total installed capacity of around 2438.70MW, out of which more than 1500MW are under central ownership and control, leaving only about 5 percent, that is 758.70 MW with the state.

One of the major constraints in tapping hydro-power in the state besides shortage of resources is the ―Indus Water Treaty, to which both India and Pakistan are signatories. The Treaty prohibits reservoir storage of water on major rivers of J&K restricting the scope of generating electricity from hydro power to generation from only run off the river projects. The treaty which was carried out in the best interest of both nations has, however, deprived the Jammu and Kashmir state to use its own water resources and thereby severely affected the developmental process of the state. Conforming to the treaty criteria, State cannot fully exploit the water potentialities of the Indus, Jhelum and Chenab rivers.

In this way the J&K state has been converted into serious energy deficient economy with repercussions on various sectors, especially industrial sector, of the economy

II. PURPOSE OF STUDY

With most of the world's hydropower potential available for near future development, it is finally the local interests and sovereign states that decide how to manage their water resource base. Hydropower projects require extended planning and construction time period. During that time span, Governments change, electricity needs shift and increase but the basic physical conditions tend to carry on their physical characteristics for a predictable time span. Given the enhanced environmental awareness, why and how do hydropower systems continue to find social and political acceptance in diverse social systems? How sustainable and environment friendly are the projects of hydropower? How does hydropower project planning address issues beyond electricity generation? How does hydropower generate the economy and contribute to the wealth of a nation or state? How compatible is hydropower with the changing energy matrix? What are the risks involved with the changing weather & climate data.

III. CLIMATE RESILIENCE

Climate resilience refers to the capacity of a system to adjust or withstand the possible impacts of Climate change. One of the concerns in Hydro-power is the repercussions due to the change in climate. Although hydro-power facilities provide adaptive capacity against flood and drought regulation and rapid response to the variation of load. The changes in the climatic conditions have a perceptible effect on the hydro-power sector and probably these effects will become more articulate in the near future. Developers, designers & operators may essentially have to make changes in the schemes & systems of design and operation to improve resilience or adapt to new conditions. The climate change may also result in bringing new opportunities for the hydro power sector which may include higher hydro-power potential due to increase in precipitation as well as the roles & responsibilities which storage projects can play in helping societies adapt to climate change. According to the 2016 hydro-power status report published by International hydro-power association (IHA), IHA survey was the first to examine the hydro-power sector's views on climate resilience from the perspective of industry. Further research in this direction is required to examine how governments view this risk and how are they preparing themselves to manage this risk. IHA undertook the survey of more than 50 companies active in the hydro-power sector to determine how they view climate risks and what actions they are or are not taking to address those risks. The results of that survey is tabulated below.

Table 1 IHA SURVEY OUTLOOK

No. of Companies participated in survey.	50
% of companies which felt that main impacts of climate change felt in their organization.	63
% of companies which took steps to increase climate change resilience	22
% of companies which felt that climate change may bring potential opportunities for their business	70

IHA, in concurrence with partner organizations, continue to examine climate resilience in the hydro-power sector and is engaging with international organization such as the World Bank Group, the European Bank for Reconstruction and Development and others who are active in this space.

IV. SUSTAINABLE HYDROPOWER PROJECT

The International Hydropower Association (IHA) released the Sustainability Guidelines for hydropower projects in 2004 & revised in 2010. This guideline and the subsequent sustainability assessment protocol have defined the criteria of sustainability assessment of hydropower developments (see Table below). Table III indicates the hydropower development needs to pay attention to all three dimensions of sustainability but clearly there are more criteria for environmental and social sustainability compared to economical sustainability.

The Hydropower Sustainability Assessment Protocol, launched in 2011, is a framework for assessing project sustainability across a range of social, environmental, technical and economic considerations. It was developed by a multi-stakeholder community of governments, commercial and development banks, social and environmental NGOs, and industry. The principles underlying this Hydropower Sustainability Assessment Protocol, combined with results of a Protocol assessment, provide an important framework for considering questions about the sustainability of any particular hydropower project. There is a common view across a diversity of sectors (e.g. governments, NGO's, civil society, industry, banks) on the important sustainability considerations that need to be taken into account to form a view on hydropower project sustainability.

The Protocol captures these considerations in a structured framework, and provides a platform from which to produce a sustainability profile for a project. All countries and organizations adopting and supporting this Protocol respect the need for institutions to have their own policies and positions on acceptable performance for a hydropower project. All organizations expressing support for the Protocol recognize that a Protocol assessment can make a substantial contribution towards understanding and achieving sustainable projects. In producing a sustainability profile, the Protocol can help inform decisions on what is a sustainable project; decision-making on projects is left to individual countries, institutions and organizations.

Table 2 CRITERIA FOR SUSTAINABILITY ASSESSMENT OF HYDROPOWER PROJECT

Environmental	Social	Economical
Air and water quality	Reduce poverty and enhance the quality of life	Capital cost and recurrent cost
Waste management	Equitable distribution of the benefits of the project	Savings on GHG emissions
Sediment transport and erosion	Effectiveness and ongoing compensatory and benefits	improved air quality
Downstream hydrology and environmental flows	Public health	Payback period
Rare endangered species	The impacts of displacement on individuals and communities	
Passage of fish species	Community acceptance	

Sustainable energy refers to the energy provided and used in ways that support sustainable development in all its economic, social and environmental dimensions. It does not mean simply expanded supply of energy but a progressive shift to energy resources and technologies that support human well-being and ecological stability over the long term. Sustainability has become the focal point of nearly every single development. A number of studies offer definitions of sustainability and sustainable development with some slight variations. In essence, sustainability means that what we are doing is not at the expense of the future generation. It is well recognized that sustainability is multi-facet concept. As a result, the triple bottom line approach has been commonly adopted to emphasize that developments need to be sustainable not only economically, but also socially and environmentally.
Much of economical development throughout then world has been hopped-up by hydropower, whether it came off the waterwheel or from the hydropower plant. Hydropower finds worldwide general acceptance as a domestically available energy source. With the future increase in electricity demand and rising electricity costs point to the shrinking decision making options to policy makers on how to balance environmental conservation and electricity demand. Hydropower experts are turning progressively environment sensitive and hydropower projects are designed to lessen the environmental stress. In the near future Hydropower cannot be expected to meet the world's electricity needs, however it serves as the ‘‘energy bridge’’ to a technology manipulating world. It contributes to infrastructure formation, transmission systems, transformers, and influences electricity pricing.

V. HYDROPOWER AS A SUSTAINABLE AND RENEWABLE ENERGY SOURCE

The primary Reasons to Include Hydropower in All Renewable Energy Initiatives are presented below. In the last decade, representatives from more than 170 countries have reached to an agreement by asserting that hydropower is renewable and worthy of international support, Initially at the world summit on sustainable development in Johannesburg (2002), and then again at the 3rd world water forum in Kyoto (2003). Some of the supporting grounds of information for this is summarized below.

1. Hydropower is a renewable energy source due to the fact that it uses the energy of flowing water, without consuming it, to generate electricity; therefore, all hydropower projects – small or large, run-of-river or storage – meet the explanation of being renewable.
2. Hydropower assists the development of other renewables: hydropower facilities having reservoirs offer unparalleled operational flexibility in that they can respond immediately to fluctuating demand for electricity. Hydropower's flexibility and storage capacity make it the most efficient and cost-effective way to support the deployment of intermittent renewables such as wind or solar power.
3. Hydropower promotes energy security and price stability: river water is a domestic resource and, unlike fuel or natural gas, it is not subject to market fluctuations; moreover, hydropower is the only major renewable source of electricity, and its flexibility, cost effectiveness, efficiency, and reliability help optimize the use of thermal plants.
4. Hydropower contributes to fresh water storage: hydropower reservoirs collect rainwater, which can then be used for drinking or irrigation. By storing water, they protect aquifers from depletion and reduce our vulnerability to floods and droughts.

5. Hydropower improves electric grid stability and reliability: the management of electricity grids depends upon fast, flexible generation sources to meet peak power demands, maintain level system voltages and quickly restore service after a blackout.
6. Electricity generated from hydropower can be placed on the grid faster than any other energy source. Hydropower's ability to go from zero power to maximum output rapidly and predictably makes it exceptionally good at meeting changing loads and providing ancillary electrical services that maintain the balance between electricity supply and demand [9, 10].
7. Hydropower helps fight climate change: the life-cycle of hydro- power produces very small amounts of greenhouse gases (GHGs). By offsetting GHG emissions from gas, coal and oil fired power plants, hydropower can help slow global warming.
8. Although only 33% of potential hydro resources have been developed, hydropower currently avoids burning 4.4 million barrels of oil equivalent daily, worldwide.
9. Hydropower improves the air we breathe: hydropower plants produce no air pollutants. Very often, they replace fossil-fired generation, thereby reducing acid rain and smog. Moreover, hydropower projects do not generate any toxic by-products.
10. Hydropower makes a significant contribution to development: hydropower facilities bring electricity, roads, industry and commerce to communities, thereby developing the economy, improving access to health and education, and enhancing the quality of life. Hydropower is a technology that has been known and proven for over a century. Its impacts are well understood and manageable through mitigation and enhancement measures. It offers vast potential and is available where development is most needed.
11. Hydropower means clean, affordable power for today and tomorrow: with an average life span of 50–100 years, hydro-power projects are long-term investments that can benefit several generations. They can easily be upgraded to incorporate the latest technologies and have very low operation and maintenance costs.

Hydropower is a key tool for sustainable development: hydropower projects that are developed and operated in an economically viable, environmentally sound and socially responsible manner represent sustainable development at its best, i.e. ‘‘development that meets the needs of the people today without compromising the ability of future generations to meet their own needs.’’ (World Commission on Environment and Development, 1987)

VI. ENERGY ECONOMICS

As economies develop and become more complex, energy needs increase greatly. Historically, as supplies of firewood and other biomass energy proved insufficient to support growing economies in Europe and the United States, people turned to hydropower (also a form of stored solar energy), then to coal during the nineteenth century, and then to oil and natural gas during the twentieth century. In the 1950s nuclear power was introduced into the energy mix. Society will eventually adopt renewable energy, since fossil fuels are limited in supply and only created over geologic time. Thus the question is not whether society will shift to renewable energy, but when. The current state of global energy consumption is given below in the figure 1.

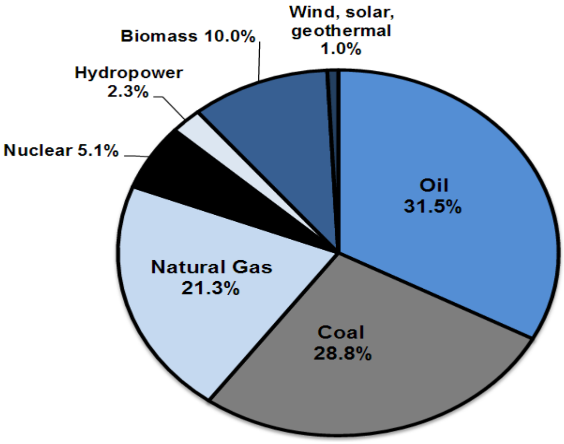

Figure 1: Global Energy Consumption by source.
Source: International Energy Agency (IEA 2013)

Since much of the capital stock and infrastructure of modern economic systems are based on fossil-fuel energy use, any transition away from fossil-fuel dependence will involve massive restructuring and new investment. While private markets will play a critical role in this process, major changes in government policies are necessary to foster the transition. The considerable economic implications of this justify a special focus on renewable energy use as a central economic and environmental issue. In one sense, renewable energy is unlimited, as supplies are continually

replenished through natural processes. The daily supply of solar energy is theoretically sufficient to meet all human energy needs for an entire year. Most renewable energy is ultimately solar energy.
The sun's energy can be used directly for heat or electricity. Hydropower comes from falling water, which occurs because solar energy evaporates water at low elevations that later rains on high elevations. The sun also creates wind through differential heating of the earth's surface. Biomass energy comes from plant matter, produced in photosynthesis driven by the sun. Thus biomass, wind, and hydropower are just secondary sources of solar energy. Non-solar renewable energy sources include geothermal energy, which comes from the earth's core, in some combination of energy left from the origin and continued decay of nuclear materials. Tidal energy is another non-solar renewable energy source, being driven by the moon. The International Energy Agency (IEA) estimates that that in 2008, world hydropower production was 3,288 TWh, (TWh = Terawatt-hours, or trillion watt-hours, or billion kilowatt- hours), or about 2-3% of total global energy use in 2008, while technical potential is about five times greater at 16,400 TWh, equivalent to about 11% of 2008 global energy use.
Extent of hydropower development varies greatly by country. For example, Switzerland has developed 88% of its estimated technical potential, Mexico has developed 80%, and Norway has developed 70%. China is estimated to have developed just 24% of its technical potential, and the United States 16% (IEA 2010).

IHA compiled a list of countries having highest installed capacities till the year 2016. The list is briefly tabulated below

Table 3 GLOBAL HYDROPOWER SCENARIO

Continent/Region	**Country with highest installed capacity**	**Installed hydropower Capacity (MW)**
North and Central America	United States	101755
South America	Brazil	91650
Africa	Egypt	2800
Europe	Norway	30566
South & Central Asia	India	51494
East Asia & Pacific	China	319370

The world has about 45,000 dams over 15m in height and 22,000 or almost half of these are in China (compared to just 6,390 dams of this size in the United States), so China was the world's largest dam-building country even before Three Gorges (Wu et al. 2004)
Each method of generating electricity has advantages and disadvantages, as well as significantly different effects on the environment. The chart below helps illustrate the differences between the various energy sources used to generate electricity.

Table 4. EVALUATING ENVIRONMENTAL IMPACT

Fuel Type	**CO2 Emissions**	**Power availability**	**Environmental Impacts**
Coal	About 200 pounds	365 days per year	Strip mining & ground water contamination,
Natural Gas	About 130 pounds	365 days per year	Non-renewable fuel source.
Nuclear	Zero	365 days per year	Extremely dangerous toxic waste
Wind	Zero	Varies with wind speed	Potential bird kill, noise issues
Solar	Zero	Daytime only	Toxic silicon tetrachloride waste, high energy used in manufacture.
Water (Reservoir Hyderpower)	Zero	24x7, affected by seasonal precipitation	Flooding behind dam, impacts on fish migration.
Water (Reservoir Hyderpower)	Zero	24x7, affected by seasonal precipitation	Reduction in stream water flow.

VII. GREENHOUSE EMISSIONS

Thanks to our enhanced understanding of environmental awareness, the emission of GHGs and their implications have sparked global interest. As per the data provided by Intergovernmental panel on climate change (IPCC), electrical production emits 10 Gigatonnes (37%) out of the 27 gigatonnes of CO_2 worldwide. Lifecycle GHG emissions for the different electricity generation methods are provided in Table V and shown graphically in the Figure 2

Table 5 EVALUATING ENVIRONMENTAL IMPACT

Technology	**Mean**	**Low**	**High**
	Tonnes CO2 e/GWh		
Lignite	1054	790	1372
Coal	888	756	1310
Oil	733	547	935
Natural Gas	499	362	891
Solar	85	13	731
Biomass	45	10	101
Nuclear	29	2	130
Hydroelectric	26	2	237
Wind	26	6	124

Coal fired power plants have the highest GHG emission intensities on a lifecycle basis. Although natural gas, and to some degree oil, had noticeably lower GHG emissions, biomass, nuclear, hydroelectric, wind, and solar photovoltaic all had lifecycle GHG emission intensities that are significantly lower than fossil fuel based generation.

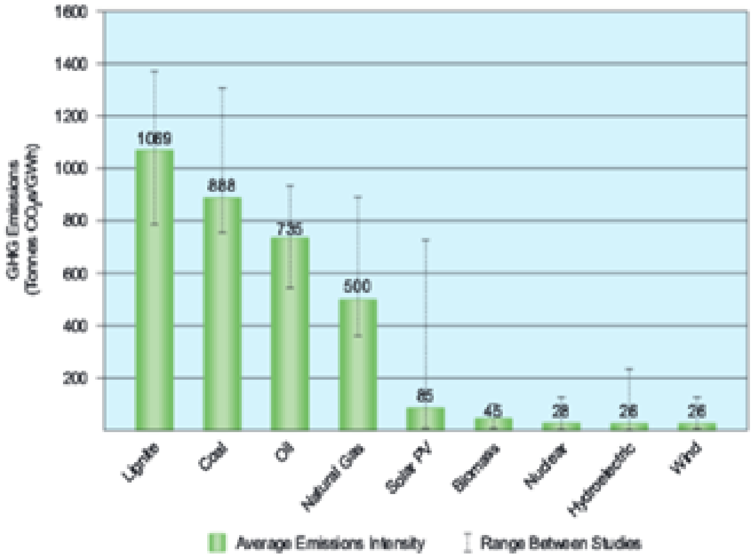

Figure 2: Summary of Lifecycle GHG Emissions Intensity.
Source: World Nuclear Association (Jul 2011)

Based on the studies reviewed, the following observations can be made:

- Greenhouse gas emissions of hydro power plants are among the lowest of any electricity generation method and on a lifecycle basis are comparable to wind and nuclear.
- Lifecycle emissions of natural gas generation are 19 times greater than hydropower.
- Lifecycle emissions of coal generation are 34 times greater than hydropower.
- There is strong agreement in the published studies on life cycle GHG intensities for each generation method. However, the data demonstrates the sensitivity of lifecycle analysis to assumptions for each electricity generation source.
- The range of results is influenced by the primary assumptions made in the lifecycle analysis. For instance, assuming either gaseous diffusion or gas centrifuge enrichment has a bearing on the life cycle results for hydropower

VIII. CONCLUSION

Water is a vital resource that supports all forms of life on earth. As hydropower does not consume or pollute the water it uses to generate power, it leaves this vital resource available for other uses. At the same time, the revenues generated through electricity sales can finance other infrastructure essential for human welfare. This can include drinking water supply systems, irrigation schemes for food production, infrastructures enhancing navigation, recreational facilities and ecotourism. Throughout history, dams and reservoirs have been used successfully in collecting, storing and managing water needed to sustain civilization. Hydropower often supports other essential water services such as irrigation, flood control and drinking water supplies. It facilitates the equitable sharing of a common vital resource

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