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Hydro Power and its Role in Mitigating Climate Change

- A short perspective -

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Transitioning towards a carbon-neutral and, ultimately, carbon-negative future is urgent in light of ever-intensifying anthropogenic global warming and associated climate. The adoption of sustainable energy sources prompts an overwhelming shift in priorities in line with the objectives of the Paris Agreement.

Hydropower, governed by the kinetic energy of flowing water, is imperative in realising this renewable transition. This article explores the multidimensional landscape of hydropower, evaluating its positive, negative, and more enduring aspects and considering the relevant legal background, contractual obligations, and financial concerns.

I. Introduction

The 2015 Paris Agreement[1], the first universal and legally binding climate accord, assures that global average atmospheric temperatures do not rise 1.5 °C above pre-industrial levels. Aiming to help alleviate the augmenting effects of climatic change – owing to increasing anthropogenic greenhouse gas emissions, the Agreement's 195 signatories reconvene every five years within a progressively ambitious review cycle to limit the rise to "well below" 2° C.

The potential for renewable energy sources such as hydropower to deliver the demands of the Paris Agreement is profound, relieving society's hitherto heavy reliance on oil, natural gas, and coal. Nevertheless, despite

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[1] Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), dated 12 December 2015.

the clear reduction in emissions offered by hydropower, the industry is not free from trial. Indeed, an increasingly complex web of legislation governs hydropower's legal landscape. Understanding this setting is central for companies involved in hydropower developments, especially regarding contract and project consulting, dispute resolution, and regulatory and corporate compliance.

II. Types of Hydropower Facilities

Hydropower infrastructure varies by facility type:

Diversion facilities divert water from a river through channels or pipes that lead to turbines. Water flows through the turbines, driving an electrical generator to produce electricity.

Impoundment facilities use water stored in a reservoir, releasing it as needed to generate additional energy. The released water, propelled by gravity, turns turbines connected to electrical generators.

Pumped-storage facilities store energy from solar, wind, or nuclear sources for later use by pumping water from a lower-elevation reservoir to a higher one. The water released during peak electricity demand, propelled by gravity, turns turbines connected to electrical generators.

III. Benefits

1. *Clean* Renewable Energy Commitments

Hydropower is a clean energy source operating independently of solar and wind conditions and the exploitive and often controversial mining of rare materials (indeed, some renewable energy sources open a complex discussion surrounding human rights and (deep-sea) ecological concerns). The Intergovernmental Panel on Climate Change (I.P.C.C.) has anticipated hydropower to possess a median life-long emission intensity of 24 gCO_2-eq/kWh, as compared to the 490 gCO_2-eq/kWh attributed to natural gas (Ubierna et al., 2022). Furthermore, the associated emissions attributed to hydropower impoundment and pumped-storage facilities may be amortised over longer relative timeframes, becoming progressively negligible (see IV.5) (Kampa, 2022).

Frequent revisions to the European Union's (E.U.'s) Renewable Energy Directive (RED III)[2] call for increasing the renewable energy share in electricity generation to 42.5% by 2030 (Article 3). The RED III aligns with the objectives of the European Climate Law[3] and European Green Deal to reduce emissions by at least 55 percent by 2030, as compared to 1990 levels (as part of the 'Fit for 55' Initiative), and achieve climate neutrality by 2050. In addition to mandating compliance with rigorous sustainability criteria, the RED III incentivises hydropower integration into the grid, supporting national energy policies.

In Germany, as part of the broader 2050 Climate Action Plan administered by the Federal Climate Change Act the Federal Government has proposed a minimum 65% reduction in emissions, as compared to 1990.

[2] Directive (EU) 2023/2413 dated 18 October 2023, amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652
[3] Regulation (EU) 2021/1119 dated 30 June 2021, establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')

Ahead of the E.U. obligations, Germany strives to be climate-neutral by 2045 (G.F.M.E.A.C., 2024).

2. Grid Stability

Hydropower offers a consistent supply of electricity and the incorporation of other renewable energy sources, such as wind and solar, into the grid. It additionally reduces a nation's reliance on energy imports[4].

3. Long-Term Cost Benefits

Hydropower facilities often yield lower operating costs and extended operational lifespans relative to alternative sustainable energy sources, making them economically viable over the long term despite the initially substantial capital investment.

4. Regulatory Incentives and Guarantees

Many nations extend regulatory incentives to promote hydropower development. These mechanisms provide financial stability and underpin the legal agendas required for these developments.

The E.U.'s RED III encourages Member States to adopt measures facilitating long-term renewable energy purchase agreements. The Internal Market for Electricity Regulation[4] further promotes renewable energy through market incentives, including feed-in tariffs and premiums guaranteeing stable income, carbon pricing, and green certificates. Hydropower developments also benefit from tax support and subsidies to integrate with the electricity grid.

5. Water Infrastructure Synergies

Integrated hydropower developments serve manifold environmental roles, encompassing flood and drought management, irrigation, and water supply. This multidimensional functionality maximises the utility of such single developments to advance thorough water resource management.

IV. **Challenges and Risks**

1. Effects on local ecosystems and communities

Deforestation, habitat destruction, cultural disturbance, and community displacement are potential negative consequences caused, particularly by large-scale developments. Finding a balance between electricity generation, social and ecological connectivity, and preservation demands adherence to rigid environmental regulations and active stakeholder engagement.

The E.U. Water Framework Directive (W.F.D.)[5] requires all water bodies to achieve "good ecological status" by 2027. In this respect, Article 4 mandates the prevention of any deterioration, demanding water body enhancement and restoration where necessary. The W.D.F. accentuates the importance of complying with site-specific measures which address the unique challenges posed by each development case. Developments, furthermore, must obtain rigorous approval under the Environmental Impact Assessment (E.I.A.) Directive[6]. The E.I.A. ensures that changes to water flow, sediment transport, and habitat connectivity do not harm the ecological integrity of water bodies. Among various mandates, operators must provide detailed information

[4] A key example is the E.U.'s reduced dependence on Russian oil and natural gas imports due to hydropower developments following the global energy market disruption credited to Russia's ongoing invasion of Ukraine.

[5] Directive (EU) 2000/60/EC dated 23 October 2000, establishing a framework for Community action in the field of water policy.

[6] Directive 2011/92/EU, dated 13 December 2011, amended by Directive 2014/52/EU, dated 16 April 2014, on the assessment of the effects of certain public and private projects on the environment.

regarding the proposal to all stakeholders (Article 5). Authorities may request further data (Article 6), with derogations allowed only under strict conditions (Article 4).

Given their scale and impact, hydropower developments require meticulously drafted contracts to safeguard all stakeholder interests. During the development phase, customer and EPC-contractors must observe a comprehensive legislative and regulatory framework within the E.U.

2. Geopolitical Considerations and Inter-State Cooperation

Transboundary rivers often characterise hydropower developments. For cross-border projects, navigating complicated transboundary water resources can be arduous[7]. Navigating geopolitical complexities and aligning diverse national interests require strong diplomatic and legal efforts. In addition to the aforementioned influence of the W.F.D. and E.I.A., the U.N.E.C.E. Convention on the Protection and Use of Transboundary Watercourses and International Lakes[8] governs the management of transboundary water resources in Europe, providing a framework for arbitration and mediation in disputes over shared water resources. The Espoo Convention on Environmental Impact Assessment in a Transboundary Context[9] specifically addresses the environmental impacts of cross-border hydropower developments in Europe.

3. Climate Volatility

Climate change-induced variations in precipitation patterns can challenge the reliability of hydropower facilities; hydropower holds a double relationship with climate change. Unprecedented droughts reduce water pressure in hydropower facilities, which can result in higher water consumption tariffs (IEA, 2023). In other cases, reservoir sedimentation, amplified by heightened water levels, endangers the sustainable capacity of reservoirs. One percent of global reservoir storage capacities are proposedly lost each year. Indeed, based on observed filling rates in Asia, 85 percent of existing reservoirs will be filled by 2035. The cost of maintenance and reduced capacity (and thus energy loss), among other services, are high due to sedimentation and prolonged droughts (Opperman, 2022; Perera et al., 2022).

4. Operational Risks

Notwithstanding the sophisticated infrastructural structures of hydropower developments, nature can always intervene. Extreme flood events, landslides, slope instabilities, glacial lake outburst floods, and other natural hazards such as earthquakes pose a great risk. Climate change increases the danger of such disasters occurring. Hydropower facilities may also be a misfortunate target during military conflicts.[10]

Adaptive infrastructure design and effective risk management strategies are essential for mitigating such uncertainties. Contracts should include provisions for dealing with delays, cost overruns, accidents, and force majeure events, which can upend progress.

[7] The Grand Ethiopian Renaissance Dam (GERD) has triggered tensions with neighbouring Egypt and Sudan due to the unilateral reservoir construction on the Blue Nile. Delivering 85 per cent of the Nile's water flow, the unilateral reservoir construction disregards the interests and rights of downstream water security. A consensus on water management has yet to be reached (B.B.C., 2023).

[8] Convention on the Protection and Use of Transboundary Watercourses and International Lakes, dated 17 March 1992.

[9] Espoo Convention on Environmental Impact Assessment in a Transboundary Context, dated 25 February 1991.

[10] This was the case of Ukraine by Russia on 23 March 2024.

5. Ongoing Emissions

The undefined emissions of hydropower have been subject to intense scrutiny within scientific and policy spheres. Emissions are released during construction and operation, varying with reservoir type, size, and location.[11]

V. Enduring Aspects of Hydro Power Stations

1. Social and Economic Development

As assured by the Paris Agreement, hydropower developments catalyse regional development and social upliftment[12], particularly in underdeveloped areas.

2. International Investment Opportunities

Hydropower developments attract international investments and financing, inviting global partnerships and technology transfer[13], in line with the 2030 Sustainable Development Goals (U.N., 2024). RED III's policies create a favourable investment environment, attracting international funding. The E.U.'s Trans-European Networks for Energy (TEN-E) Regulation[14] promotes cross-border energy infrastructure projects, including hydropower, reforming permitting processes and providing financial support for Projects of Common Interest (PCIs), aligning with energy targets and climate neutrality goals. These projects further enhance energy security, system integration, and competition.

3. Technology Advancements and Innovation

The pursuit of hydropower solutions has spurred advancements in renewable energy technologies. Enhanced turbine designs, reservoir management systems, and transmission infrastructure have not only improved the operational efficiency of hydropower facilities but also contributed to broader progress in renewable energy research and development.

The Net-Zero Industry Act (N.Z.I.A.)[15] determines a framework to boost the EU's net-zero technology manufacturing capacity, reducing reliance on third-country imports. The Act promotes investment, innovation, and clean energy transition while ensuring judicial and legislative precedence. The regulation aims for 40 percent of net-zero technology deployment to be met domestically by 2030, with simplified permits for strategic projects crucial to energy and climate goals. By 2040, it targets 15 percent of global net-zero technology production.

VI. Conclusion

Hydropower has emerged as a linchpin in the global effort to combat climate change.

[11] Once filled, a reservoir's shape and depth, exposure to the sun, and wind speed influence the biogeochemical decompositional microbial processes by which the greenhouse gases carbon dioxide, CO_2, and methane, CH_4, are produced and released. In rare cases, reservoirs produce considerably higher emissions, while others display close to zero and can even form carbon sinks (I.H.A., 2021).

[12] The Regional Rusumo Falls Hydroelectric Project (R.R.F.P.) is a hydropower project under joint development by the Tripartite Agreement unifying the Governments of the Republic of Burundi, the Republic of Rwanda and the United Republic of Tanzania through a commonly owned Rusumo Power Company (R.P.C.L.), enhancing regional economic and social development in the project area.

[13] Itaipu Binacional, on the Paraná River between Brazil and Paraguay, is a strong example of joint efforts between two nations to enhance cooperation, capacities, and dialogues.

[14] Regulation (EU) 2022/869, dated 30 May 2022, on guidelines for trans-European energy infrastructure, amending Regulations (EC) No 715/2009, (EU) 2019/942 and (EU) 2019/943 and Directives 2009/73/EC and (EU) 2019/944, and repealing Regulation (EU) No 347/2013.

[15] Regulation (EU) 2024/1735 dated 13 June 2024, on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724.

Integrating the legal, contractual, and financial dimensions into the analysis emphasises the need for a comprehensive approach to harnessing hydropower's potential. Upon careful consideration of hydropower's undesirable outcomes, the hydropower industry has the power to revitalise contemporary energy infrastructure to achieve the goals of the Paris Agreement, working towards a carbon-neutral, and ultimately, carbon-negative world.

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