AN OVERVIEW OF HYDROPOWER

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(**Executive Summary, “Hydropower”, Chapter 5, “IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation”, 2011** [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA)

Hydropower offers significant potential for carbon emissions reductions. The installed capacity of hydropower by the end of 2008 contributed 16% of worldwide electricity supply, and hydropower remains the largest source of renewable energy in the electricity sector. On a global basis, the technical potential for hydropower is unlikely to constrain further deployment in the near to medium term. Hydropower is technically mature, is often economically competitive with cur-rent market energy prices and is already being deployed at a rapid pace. Situated at the crossroads of two major issues for development, water and energy, hydro reservoirs can often deliver services beyond electricity supply. The significant increase in hydropower capacity over the last 10 years is anticipated in many scenarios to continue in the near term (2020) and medium term (2030), with various environmental and social concerns representing perhaps the largest challenges to continued deployment if not carefully managed.

Hydropower is a renewable energy source where power is derived from the energy of water moving from higher to lower elevations. It is a proven, mature, predictable and typically price-competitive technology. Hydropower has among the best conversion efficiencies of all known energy sources (about 90% efficiency, water to wire). It requires relatively high initial investment, but has a long lifespan with very low operation and maintenance costs. The levelized cost of electricity for hydropower projects spans a wide range but, under good conditions, can be as low as 3 to 5 US cents$_{2005}$ per kWh. A broad range of hydropower systems, classified by project type, system, head or purpose, can be designed to suit particular needs and site-specific conditions. The major hydropower project types are: run-of-river, storage- (reservoir) based, pumped storage and in-stream technologies. There is no worldwide consensus on classification by project size (installed capacity, MW) due to varying development policies in different countries. Classification according to size, while both common and administratively simple, is—to a degree—arbitrary: concepts like ‘small’ or ‘large hydro’ are not technically or scientifically rigorous indicators of impacts, economics or character-istics. Hydropower projects cover a continuum in scale and it may ultimately be more useful to evaluate hydropower projects based on their sustainability or economic performance, thus setting out more realistic indicators.

The total worldwide technical potential for hydropower generation is 14,576 TWh/yr (52.47 EJ/yr) with a corresponding installed capacity of 3,721 GW, roughly four times the current installed capacity. Worldwide total installed hydropower capacity in 2009 was 926 GW, producing annual generation of 3,551 TWh/y (12.8 EJ/y), and representing a global average capacity factor of 44%. Of the total technical potential for hydropower, undeveloped capacity ranges from about 47% in Europe and North America to 92% in Africa, which indicates large opportunities for continued hydropower development worldwide, with the largest growth potential in Africa, Asia and Latin America. Additionally, possible renovation, modernization and upgrading of old power stations are often less costly than developing a new power plant, have relatively smaller environment and social impacts, and require less time for implementation. Significant potential also exists to rework existing infrastructure that currently lacks generating units (e.g., existing barrages, weirs, dams, canal fall structures, water supply schemes) by adding new hydropower facilities. Only 25% of the existing 45,000 large dams are used for hydropower, while the other 75% are used exclusively for other purposes (e.g., irrigation, flood control, navigation and urban water supply schemes). Climate change is expected to increase overall average precipitation and runoff, but regional patterns will vary: the impacts on hydropower generation are likely to be small on a global basis, but significant regional changes in river flow volumes and timing may pose challenges for planning.

In the past, hydropower has acted as a catalyst for economic and social development by providing both energy and water management services, and it can continue to do so in the future. Hydro storage capacity can mitigate freshwater scarcity by providing security during lean flows and drought for drinking water supply, irrigation, flood-control and navigation services. Multipurpose hydropower projects may have an enabling role beyond the electricity sector as a financing instrument for reservoirs that help to secure freshwater availability. According to the World Bank, large hydropower projects can have important multiplier effects, creating an additional USD_{2005} 0.4 to 1.0 of indirect benefits for every dollar of value generated. Hydropower can serve both in large, centralized and small, isolated grids, and small-scale hydropower is an option for rural electrification.

Environmental and social issues will continue to affect hydropower deployment opportunities. The local social and environmental impacts of hydropower projects vary depending on the project's type, size and local conditions and are often controversial. Some of the more prominent impacts include changes in flow regimes and water quality, barriers to fish migration, loss of biological diversity, and population displacement. Impoundments and reservoirs stand out as the source of the most severe concerns but can also provide multiple beneficial services beyond energy supply. While lifecycle assessments indicate very low carbon emissions, there is currently no consensus on the issue of land use change-related net emissions from reservoirs. Experience gained during past decades in combination with continually advancing sustainability guidelines and criteria, innovative planning based on stakeholder consultations and scientific know-how can support high sustainability performance in future projects. Trans-boundary water management, including the management of hydropower projects, establishes an arena for international cooperation that may contribute to promoting sustainable economic growth and water security.

Technological innovation and material research can further improve environmental performance and reduce operational costs. Though hydropower technologies are mature, ongoing research into variable-speed generation technology, efficient tunnelling techniques, integrated river basin management, hydrokinetics, silt erosion resistive materials and environmental issues (e.g., fish-friendly turbines) may ensure continuous improvement of future projects.

Hydropower can provide important services to electric power systems. Storage hydropower plants can often be operated flexibly, and therefore are valuable to electric power systems. Specifically, with its rapid response load-following and balancing capabilities, peaking capacity and power quality attributes, hydropower can play an important role in ensuring reliable electricity service. In an integrated system, reservoir and pumped storage hydropower can be used to reduce the frequency of start-ups and shutdowns of thermal plants; to maintain a balance between supply and demand under changing demand or supply patterns and thereby reduce the load-following burden of thermal plants; and to increase the amount of time that thermal units are operated at their maximum thermal efficiency, thereby reducing carbon emissions. In addition, storage and pumped storage hydropower can help reduce the challenges of integrating variable renewable resources such as wind, solar photo-voltaics, and wave power.

Hydropower offers significant potential for carbon emissions reductions. Baseline projections of the global supply of hydropower rise from 12.8 EJ in 2009 to 13 EJ in 2020, 15 EJ in 2030 and 18 EJ in 2050 in the median case. Steady growth in the supply of hydropower is therefore projected to occur even in the absence of greenhouse gas (GHG) mitigation policies, though demand growth is anticipated to be even higher, resulting in a shrinking percentage share of hydropower in global electricity supply. Evidence suggests that relatively high levels of deployment over the next 20 years are feasible, and hydropower should remain an attractive renewable energy source within the context of global GHG mitigation scenarios. That hydropower can provide energy and water management services and also help to manage variable renewable energy supply may further support its continued deployment, but environmental and social impacts will need to be carefully managed.