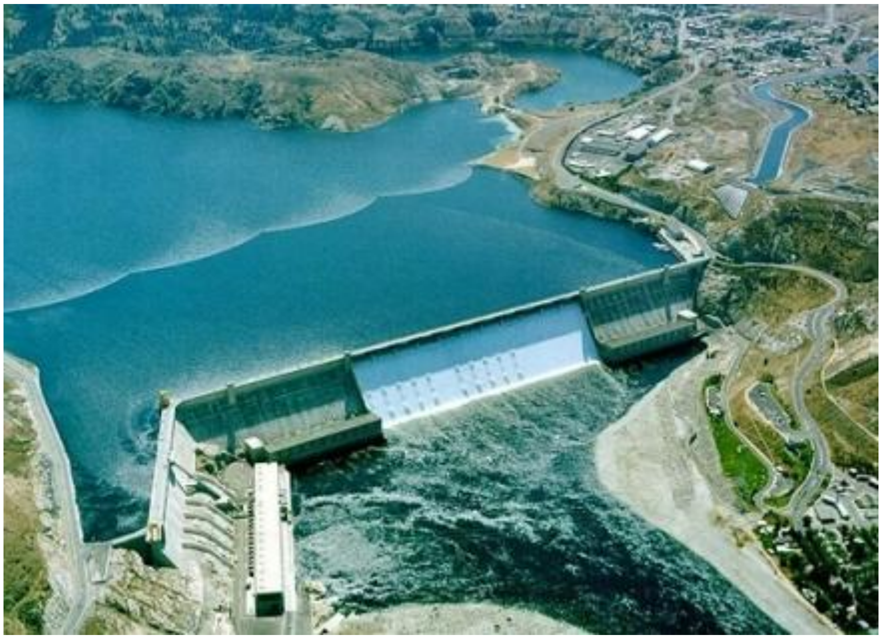
Hydroelectricity



Grand Coulee Dam, Columbia River, the largest hydroelectric unit in the USA. Source: U.S.Bureau of Reclamation

Three Gorges Dam, Yangtze River, China. Source: C.Michael Hogan

Hydroelectricity is electricity generated by converting the kinetic energy of falling or flowing water. It is considered the most widely installed form of renewable energy, although most large dams have a finite lifetime unless dredging of silt is periodically conducted. Hydroelectricity has and has a considerably lower output level of the greenhouse gas carbon dioxide than fossil fuel powered energy plants, and less life cycle greenhouse gas impact than solar power. Furthermore, the ecological impacts of**hydropower** is arguably greater than any form of energy production, due to the large footprint of biological impact of reservoirs and other needed developed areas. Worldwide, an installed capacity of 777 Gigawatts was catalogued in the year 2006, sufficient to supply one fifth of the world power supply. Since most of the prime locations for hydroelectric power have been tapped, the promise for new installed capacity is limited.

Basic theory

Ffestiniog pumped storage facility, Wales. Source: Adrian Pingstone

Hydroelectric power can be viewed as the conversion of potential energy of water situated at a higher elevation engaging in fall to yield kinetic energy that drives a water turbine, which in turn produces electricity by a generator. Thus the energy extracted from the falling water depends on the water volume and on the difference in height between the elevated source and the position of the turbine. This height difference is called the hydraulic head, the potential energy being proportional to the head. To deliver water to a turbine a large pipe called a penstock is often employed.

The power produced by a hydroelectric facility can be calculated as:

$P = f * h * g * d * e$

where d is the density of water; h is the height of the water head, f is the flow rate; g is the acceleration of gravity; and e is an efficiency coefficient varying between ranging from 0 to 1. Efficiency is typically the highest for installations having large and modern turbines.
A fundamental drawback of hydroelectricity is the variation of water flow, even when a large reservoir is present to moderate some flow. Typical temporal variation in river flow may span a factor of ten over an annual cycle. This varation places an inherent mismatch in supplying power to a grid. One method of mitigation is to have consecutive reservoirs, which can allow use of surplus electricity to pump water to the higher elevation source, when there are peak water flows. This technique evens out the power generation, but at the expense of considerable wasted power.

Facility life

Aswan High Dam viewed from space. Source: NASA

The useful life of a hydroelectric project can be measured by its engireered elements or by its rate of sedimentation. Efficiencies and improvements in design of the power plant and hydraulic elements can almost indefinitely expand the useful engineering life of the equipment; however, sedimentation is an inherent limiting factor of the hydroelectric facility. Moreover, dredging or weir construction can add to the useful life of a project, even though the energy and environmental consequences of dredging may outweigh the benefits of such an undertaking. The fundamental rate of sedimentation of dams varies widely, but useful lives of twenty to 100 years represent the majority of plant expectations.[1] Correspondingly many of the world's major hydro plants are well along in their life cycle.

Risks and adverse impacts

There are a number of significant adverse consequences of hydroelectric facilities. Chief catastrophic risks include dam failure and ensuing loss of life. There are also considerable environmental and human impacts in the course of constructing these facilities, chiefly involving inundation of natural areas. Such actions are responsible for large amounts of habitat destruction in loss of valley and riverine ecosystems; the resulting lake or slow moving river is typically a totally different habitat, which typically supports little of the native biota. In addition to ecological loss, there is often considerable displacement of human settlements and frequently loss of archaeological resources.

Dam failures have led to some of the largest man-made catastrophes in history. Failure of the Banqiao dam in southern China directly caused the deaths of more than 26,000, and produced a further 145,000 human casualties resulting from epidemics related to the dam failure; additional millions of Chinese were left homeless. In China alone there have been 322 dam failures in the last half century.[2] Lack of adequate geological studies for the Vajont dam in Italy led to a disaster in which almost 2000 people were killed.

Probably the largest ecological destruction occasioned by any hydroelectric project is that induced by construction of the Three Gorges Dam on China's Yangtze River.[3] Over 50,000 acres of relatively pristine habitat was destroyed upriver of the dam, also inducing habitat fragmentation, especially in the narrow gorged tributaries.[4]

Loss of archaeological resources through dam construction is a widespread phenomenon around the globe. The Three Gorges Dam annililated hundreds of archaeological sites; the Iranian government is planning to inundate dozens of key archaeological resources in the Fars Province, including the legendary Tomb of Cyrus.[5]

Comparison with other power sources

With regard to greenhouse gas generation, hydroelectric and nuclear power have the lowest production of such gas emissions in their life cyle analysis. Solar power ranks slightly below both of these two mehods of energy generation with regard to life cycle greenhouse gases, chiefly due to intensive manufacturing processes for solar energy. The impacts of air pollution have an identical ranking for these three methods of power supply. When compared to fossil fuel plants all of the three sources (hydroelectric, nuclear and solar) have reduced impacts with respect to both greenhouse gases and air pollutant production.

With regard to catastrophic deaths from facility failure, hydroelectric ranks as the highest risk to human life, followed by fossil fuel plants. Solar energy ranks as the most favorable, with nuclear energy following closely behind, based upon historical track record. With regard to total deaths (catastrophe plus air pollution) hydroelectric power and fossil fuel power plants both rank very high in numbers of deaths. Solar power ranks as the safest with nuclear power second safest. Note that direct comparison of a coal fired power plant can be expected to produce 50 deaths per annum, while nuclear power can be expected to produce .01 deaths per annum.[6]

References

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