Science of the Total Environment 481 (2014) 638–643

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

A critical view on the eco-friendliness of small hydroelectric installations

M. Premalatha, Tabassum-Abbasi, Tasneem Abbasi *,[1], S.A. Abbasi

Centre for Pollution Control & Environmental Engineering, Pondicherry University, Chinnakalapet, Puducherry 605 014, India

HIGHLIGHTS

- It is believed that a complete shift to renewables will mitigate global warming.
- We show how that belief is questionable, with the example of hydropower.
- Large hydropower, once considered totally clean, is now known not to be so.
- The paper brings out that small hydro, too, is no more clean/green than large hydro.
- There is no basis in the belief of eco-friendliness of small hydro.

ARTICLE INFO

Article history:
Received 26 September 2012
Received in revised form 5 November 2013
Accepted 8 November 2013
Available online 14 December 2013

Keywords:
Renewable energy
Large hydro
Small hydro
Global warming
Methane mining
Environmental impacts

ABSTRACT

Renewable energy sources are widely perceived as 'clean', 'green', and 'inexhaustible'. In recent years the spectre of global warming and ocean acidification, which has been primarily attributed to fossil fuel burning, has brought renewable energy at the forefront of most climate change mitigation strategies. There is strong advocacy for large-scale substitution of conventional energy sources with the renewables on the premise that such a move would substantially reduce environmental degradation and global warming. These sentiments are being echoed by scientists and policy makers as well as environmental activists all over the world.

'Small hydro', which generally represents hydroelectric power projects of capacities 25 MW or lower, is one of the renewable energy options which is believed to be clean and sustainable even as its bigger version, large hydro, is known to cause several strongly adverse environmental impacts.

This paper brings out that the prevailing perception of 'eco-friendliness' of small hydro is mainly due to the fact that it has only been used to a very small extent so far. But once it is deployed at a scale comparable to fossil fuel use, the resulting impacts would be quite substantially adverse.

The purpose is not to denegrade small hydro, less so to advocate use of fossil fuels. It, rather, is to bring home the point that a much more realistic and elaborate assessment of the *likely* direct as well as indirect impacts of *extensive* utilization of this energy source than has been done hitherto is necessary.

1. Introduction

All hydroelectric power projects are sources of renewable energy but the larger versions of such projects are not counted among renewable energy sources because, in the general perception, large hydropower projects (LHPs) are not 'clean' while other renewables are. Small hydropower projects (SHPs), which include minihydel, microhydel and picahydel units, are considered sources of renewable energy because they are perceived as the 'clean' and 'green' alternatives to LHPs. Driven by this perception, governments of several countries provide subsidies and other incentives for the promotion of small hydro, even as large hydro is denied that kind of patronage and is subjected to much more intense pre-licence scrutiny.

1.1. LHPs used to be regarded as the most clean, dependable and versatile of all energy sources

Interestingly, till as recently as in mid 20th century, LHPs had a much more favourable image than is commanded by SHPs at present. LHPs had appeared to be the cleanest of all energy sources, as 'totally clean' as the sunlight is when it is used directly for obtaining heat or light. Hydropower appeared even more *virtuous* than sunlight for the crucial reason that whereas sunlight is intermittent, hydropower is continuous. Hydropower had yet another distinguishing feature: its use seemed to provide numerous benefits over and above energy production. The very long roaster of the virtues – of cleanliness, dependability, and versatility of hydropower as were perceived then – included the following:

* Corresponding author.
E-mail address: tasneem.abbasi@gmail.com (T. Abbasi).
[1] Concurrently Visiting Associate Professor, Department of Fire Protection Engineering, Worcester Polytechnic Institute, Worcester, MA 01609, USA.

0048-9697/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scitotenv.2013.11.047

1. It revolves round the use of one of the world's most benign, inexpensive, and abundant fluids: water.
2. It utilizes water in a totally non-destructive fashion. After hydropower generation, the water remains intact and reutilizable with hardly any deterioration in its quantity or quality.
3. It utilizes two basic forms of energy – solar heat and force of gravity – which both are 'carbon free', perpetual, and inexhaustible (in foreseeable geological time).
4. It transforms these carbon-free forms of energy to electricity which, again, is carbon free and 'clean' in that sense.
5. It is linked to creation of reservoirs by damming rivers at suitable sites. At one time, the reservoirs themselves had appeared to be a great boon. They promised to utilize the river flow to the maximum. They stored water when it was available in excess, for use in times when the flow in the stream was too lean or totally stopped. Additionally, reservoirs promised to control floods, promote fisheries, facilitate irrigation, recharge underground aquifers, and ensure uninterrupted public water supply.
6. Unlike thermal power plants no gaseous or flyash emissions were seen coming out during the production of hydropower. And, unlike nuclear power plants, there were no radioactive wastes to contend with.
7. The reservoirs had an additional virtue no other type of power plants possessed: they made an aesthetically pleasing sight. Wast spans of clean water always have great recreational value: reservoirs provided it. Indeed very many large reservoirs continue to be highly sought-after tourist spots.

During the middle of the 20th century, when only a few LHPs existed in the world outside North America and a few West European countries (WCD, 2000), and before anything was known about their downside, LHPs appeared paragons of virtue; the ultimate gift of technology. Everything about LHPs appeared unquestionably good, and more, while nothing negative came to mind. There was such a euphoria about LHPs that Jawaharlal Nehru, the then Prime Minister of India and a major global personality associated with the *Non Aligned Movement*, was moved deeply enough by the sheer appeal then felt of LHPs to call them the 'temples of modern India' (Chari et al., 2005a,b; Abbasi and Abbasi, 2012).

Riding on such faith and euphoria, developing courtiers committed large chunks of precious public money in LHPs in particular and dams in general. There was such a spurt in dam building that by the end of the 20th century the world had over 45,000 large dams, recording an staggering 9-fold increase over the figure that had existed in 1949 (WCD, 2000). The world did not just build more and more dams, it built bigger and bigger dams, too.

1.2. The changing perception

As the number and the size of LHPs increased, there was also an increase in the reports of their adverse impacts. By the late 1970s LHPs had begun to lose their pre-1949 sheen, a process which became quicker with each passing year as public opposition to new LHPs became more and more strident. All over the world more and more environmental activists began going up in arms whenever a hydroelectric power project was planned. In India, several persons even offered to lay down their lives through the Gandhian means of fast-unto-death in protest against hydel projects (Chari et al., 2005a). By now the tide has turned so completely that efforts are on to even dismantle some of the existing hydroelectric dams, especially in the USA (Huesemann, 2006; Hoffert-Hay, 2008) where there is little dam-building since 1976 after an exponential growth in this sector between 1916 and 1976 (Kosnik, 2008).

2. Environmental impact of LHPs

LHPs have now become the most closely scrutinized and extensively studied of power generation options vis a vis environmental impacts, alongside thermal power plants (Abbasi and Abbasi, 2000, 2012; Chari et al., 2005a,b; Nilsson et al., 2005; Poff et al., 2007; WCD, 2000). There is general agreement that large hydroelectric projects cause major adverse environmental impacts (IEA, 1998, 2000; WCD, 2000; Ronayne, 2005; Fearnside, 2012), and there have even been suggestions (Harte and Jassby, 1978) that LHPs may well be the most ecologically damaging of all power generation alternatives. With the increasing evidence gathered in recent years on the release of methane from hydel projects (Duchemin et al., 2000; Fearnside, 2011), another blot has come to be associated with this – once perceived as squeaky clean – source of renewable energy. Methane is 25 times more powerful than CO_2 in its global warming potential (Forster et al., 2007); 34 times by a more recent estimate (Shindell et al., 2009), and it is believed that the contribution of LHPs to overall global warming may be as high as 4% (Lima et al., 2008; Melack et al., 2004). In two of the nine Brazilian reservoirs studied by Santos et al. (2006), the net GHG emissions were higher than of coal-fired power plants of equivalent capacity. It is even being proposed that tropical reservoirs can be used to mine methane (Bambace et al., 2007; Ramos et al., 2009). As detailed elsewhere (Tauseef et al., 2013), major gaps often occur between the promise and the performance of methane capture initiatives, hence how well methane capture may work for tropical reservoirs remains to be seen. No system is in place as yet (Fearnside, 2011).

It is also feared that hydel projects may also be releasing significant quantities of another powerful greenhouse gas – nitrous oxide – which is formed during the course of microorganism-mediated nitrification (Guérin et al., 2008). Each molecule of N_2O is equivalent to 300 molecules of CO_2 in its global warming potential.

Innumerable studies across the world have now established that major ecological impacts are caused by large hydropower projects in all the four habitats associated with the projects — the reservoir catchment, the artificially created lake, the downstream reaches of the dammed river, and the estuary into which the river flows (IEA, 1998, 2000; WCD, 2000; Lessard and Hayes, 2003; Harrison et al., 2007; Qiu, 2012).

The environmental stresses are caused by the altered timing of the river flow, increased evapotranspiration and seepage water losses, barriers to aquatic organism movement, thermal stratification, changes in sediment loading and nutrient levels, and loss of terrestrial habitat to artificial lake habitat (IEA, 1998; WCD, 2000; Jansson et al, 2000). There is an enhanced tendency towards eutrophication of the impounded lake and downstream sections of the river. The hypolimnic water that is normally used for power generation and then discharged into the river downstream is much cooler than the river water. This generates temperature shocks which stress the river biota (Chari et al., 2005a). Estuarine organisms are effected due to disruption of the natural mix of salt water and inflowing freshwater (Restrepo and Cantera, 2013). The nesting, mating, and other behaviours of riparian organisms are affected as a result of altered river flow and barriers to movement (Harrison et al., 2007; Qiu, 2012; Ziv et al., 2012). Impounding, and increased human activity in the reservoir catchment, leads to deforestation and loss of wildlife (Chari et al., 2005a; Kingsford and Thomas, 2004). There is often an increase in the incidence of waterborne diseases (Chari et al., 2005b). Above all, the damming is associated with great trauma for those who are forced to leave their habitat (Ortolano and Cushing, 2010); the number of people adversely affected in this manner runs into several millions in large countries like China, Brazil and India (Fearnside, 2012; Sukumaran, 2012; Qiu, 2012). There is similarly massive disturbance caused to other fauna and flora (Grumbine and Pandit, 2013).

A very serious concern also, as mentioned earlier, is the release of greenhouse gases, especially methane, from man-made reservoirs created for hydropower generation (Giles, 2006). Some authors have gone to the extent of suggesting that, per unit of electrical energy produced, greenhouse gas emissions from at least some hydroelectric reservoirs may be comparable to, or greater than, the emissions from