LIFE CYCLE INVENTORY OF CONSTRUCTION OF HYDROELECTRIC DAM IN CHILE

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ABSTRACT

Currently, there are plans to build five hydroelectric dams in Southern Chile, amounting to 2,750 MW, with a total flooding area nearly 6,000 ha. Given the relatively pristine ecosystem in Chilean Patagonia, where these plants are to be located, potential environmental impacts associated with this project have led to considerable public concern. This paper presents results of the life cycle inventory related to the dam construction stage. Hydroelectric dams require significant amounts of energy and building materials during construction. Data was obtained from environmental impact assessment official documents mainly, and the system boundaries include cements, steel, and materials transport from production plants to building sites. Results show that the flooding area does not correlate with the installed power, and LCIs are highly dependent on topographic features, and transport distances.

INTRODUCTION

Currently, 33% of electricity generated in Chile comes from hydroelectric sources. All Chilean reservoir hydroelectric plants are located in the Andean zone, where rivers are mostly sourced by melting ice from high lands (CDEC-SIC, 2011). The LCI reported here is based on inventories from a big hydroelectric complex to be built in Southern Chile, involving 5 reservoir plants and one pass-through, with a total installed capacity around 2.75 GW. These plants will be sited in the Baker and Pascua river basins in the XI Region, between latitude 47° and 49°S (Patagonia), Chile.

GOAL AND SCOPE

As a first approximation, a cradle-to-gate approach has been followed here, including construction operations, building materials, machinery, electricity generators, transportation, and other upstream processes. Plant operation, maintenance, mechanical pieces replacement and end-of-life activities were not included here. Data was obtained from primary sources, and official environmental reports (Centrales Hidroelectricas Aysen, 2008).

RESULTS AND DISCUSSION

As shown in Table 1, the inventory data did not show a direct correlation between land transformation and installed power, due the singularity in the hydrographic basins. Indeed, steep terrain upstream the dam will lead to lower flooded surface area, than in the case of flatter lands.

Additionally, dam size (ie. length and height), is determined by the basin topographical features and, to a lesser extent, by the power capacity. Therefore, cement, steel and other building materials requirements are also dependent on such local topographical features, affecting directly the environmental burdens associated to materials transport.

In the case of GHG emissions, Baker 1 showed the highest level per MW installed, mainly due to emissions from materials transport. The energy sources used for this plant are dramatically higher than others plants, that which would determine the major magnitude in the others emissions of the inventory.

On the other hand the main source of GHG emissions in Pascua 2.1 comes from the use of machinery for construction, based on internal combustion of fossil energy sources, as was identified in other previous study (de Miranda, 2010).

These cases support the idea that every single dam has singular features, which determine the environmental burdens.

Table 1: Life cycle inventory for dam construction en Chile

	Baker 1	Baker 2	Pascua 1	Pascua 2.1	Pascua 2.2
Coal, in ground [kg/MW]	1,87 10^6	2,51 10^5	3,44 10^5	4,40 10^5	2,89 10^5
Gas, natural, in ground [m^3/MW]	1,04 10^6	7,64 10^4	7,49 10^4	1,10 10^5	4,95 10^4
Oil, crude, in ground [kg/MW]	9,42 10^6	6,55 10^5	6,20 10^5	1,21 10^6	3,79 10^5
Transformation to water bodies, artificial [m^2/MW]	1,47 10^4	1,01 10^5	1,15 10^4	1,33 10^4	2,57 10^3
GHG emissions to air [kg CO_{2eq}/MW]	3,09 10^7	2,30 10^6	2,45 10^6	4,58 10^6	1,67 10^6
Nitrogen oxides [kg/MW]	2,48 10^5	1,64 10^4	1,50 10^4	4,26 10^4	7,74 10^3
Sulfur dioxide [kg/MW]	3,38 10^4	3,49 10^3	5,13 10^3	8,56 10^3	4,16 10^3
BOD_5, water [kg/MW]	8,24 10^4	6,19 10^3	6,05 10^3	1,55 10^4	3,80 10^3
Sulfate [kg/MW]	1,69 10^4	2,70 10^3	1,89 10^3	2,27 10^3	1,42 10^3
Oils, to soil [kg/MW]	2,49 10^4	1,83 10^3	1,84 10^3	4,97 10^3	1,16 10^3

Unfortunately, methane emissions from hydroelectric reservoirs in the Southern hemisphere has not been studied in depth, and reported works are based on data from boreal zones (Huttunene, 2002), and mostly in tropical and Amazonian zone (Barros, 2011)(Bastviken, 2011)(Rosa, 2004) (Kemenes, 2011)(Kemenes, 2011) (Demarty, 2011). Moreover, reported data on methane emissions rates from hydroelectric plants vary over a wide range, and there is no agreement on recommended values (Rosa, 2006)(Fearnside, 2006).

It is important to mention that local considerations play a significant role in LCI inventory for hydroelectric plants. Indeed, additional to the basin topographical features mentioned above, consideration has to be made of the organic matter content in the water system. In this respect, it must be mentioned that cold high mountain Andean rivers feature negligible organic matter content. Thus, methane generation due to anaerobic digestion should be much less significant than reported values for tropical latitudes, where the high organic matter loads constitute a considerable carbon source for biological processes, as shown in the methane emissions reported in the literature. At present, no studies on methane evolution from pristine water ecosystems such as Baker river in Chilean Patagonia has been reported in the literature.

Others relevant factors such as dam age, characterization and impacts on biodiversity, sediment composition and deposition, social displacement or ecosystem modifications, and impacts from decommissioning, are not included in this assessment as presented or recommended elsewhere

CONCLUSIONS

This work presents LCI information associated to the construction of hydroelectric dams in Southern Chile. Results show that the flooding area does not correlate with the installed power. LCI are highly dependent on topographic features, and transport distances.

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