International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Life Cycle Assessment of Small Hydro Power Plants in Uttarakhand

Ruby Pant†*, Saurabh Aggarwal‡ and Kalpit joshi†

†Uttaranchal University Dehradun, India
‡Uttaranchal University Dehradun, India
†Tulas College of Engineering, Dehradun, India

Accepted 10 Feb 2016, Available online 20 Feb2016, **Vol.6, No.1 (Feb 2016)**

Abstract

In the past decades, the fossil fuels are being used for the generation of electricity. Due to this the gases emitted from combustion process affect our environment, economic and social conditions of human being and also the human health. In the recent times the new technologies are being introduced in the field of generation of electricity to reduce or mitigate the bad effects. Now a day's renewable energy resources are also being used for generation of electricity. In India energy needs will correspondingly increase in the future. The challenge is to produce required power in a sustainable manner and at realistic cost. Small hydropower has the potential of about 15000MW in India and is considered to be a sustainable source of electricity generation. Energy generation is a major source of GHG elements such as CO2, SOX, NOX and suspended particles. It also produces large quantity of solid waste, and also contributes to water pollution. Hydro power is a renewable energy source where power is derived from the energy of moving water from higher to lower elevation. Hydropower requires relatively high initial investment but has the advantage of very low operational cost and cleaner energy. In the present work three small hydro power plants are selected for the study. The capacity of these power plants is: 30MW, 33.33 MW and 51MW respectively. The objective of the present work is to do the life cycle assessment of hydro power plants and comparison of hydro power plant with coal based power plant on the basis of break-even analysis and to calculate the GHG emission of three small hydro power. A detailed LCA methodology is therefore presented. The results obtained from the work shows that GHG emission increase with decrease the capacity of the power plant and GHG emission increase with increasing the head of the power plants. The small hydro power plants have many environmental and social impacts. Small hydro power plant projects have much small environmental footprint compared to traditional reservoir storage hydro power projects. Small hydro power plants are more environmental friendly than other type of power plants (large dam, nuclear, natural gas fired plant and coal). The use of renewable energy has low visual impact, have minimum impact on vegetation and bird or wild life. GHG emissions of hydropower plant are mainly from construction, operation, maintenance and dismantling

***Keywords**: LCA, Hydro power plant, emission*

1. Introduction

The net greenhouse gas emission burden will reduce by using a low carbon alternative for generation of power. However, many renewable energy sources are not amenable to the provision of high temperature heat, for example wind, tidal, hydro and wave resources are more amenable to direct conversion to electricity, yet it is key for process plant operations that the fuel is fixed carbon, storable and available continuously (Whitaker *et al*. 2010). Renewable energy is to acquire through various sources such as: Geothermal, Coal, Wind, Solar, and Hydro Power. These all are being used in many manners to produce energy. Most of the energy is used by the electric power sector (EIA 2008). Renewable sources are essentially limited in how they can be used and their availability in certain areas at particular time. The 15% to 20% of world's total energy demand is currently supplied by renewable energy sources. Large hydropower plants contribute with 20% of global electricity supply.

About 2% contribution of total energy demand comes through new renewable energy resources (solar, wind, modern bio energy, geothermal, small hydro etc.)(Antonia V). in the present research work life cycle assessment of small hydro power plants situated in the state of Uttarakhand has been performed.

First life cycle assessment was carried out by coca cola in 1969. ISO produced a series of standards regarding LCA in 1997/98 which were recently revised in 2006. (First edition EUR 24708 2010) ISO14040 2006 outlining LCA principles and framework. (EuROFER, Methodology Report: March 2011,

*Corresponding author: **Ruby Pant**

Table 1.1 Fundamental characteristics of renewable energy sources (renewable energy resource assessment report 1995)

Resources	Energy type	Intermittence	Spatial variability
Solar	Thermal/Radiative	Yes	Low
Wind	Kinetic	Yes	High
Biomass	Chemical	No	Very high
Water	Kinetic/ Thermal	Some	Extreme
Geothermal	Thermal	No	High

International Standards Organization (ISO).ISO 14041 1998).ISO 14044 2006 for requirements and guidelines. (Rebitzer G *et al* 2004, JobienLaurijssen*et al* 2009).

LCA (life cycle assessment) is a method for measuring and controlling the environmental impact which is related to the life cycle process of the product (Seigl. S *et al* 2011). LCA method make informed about the environmental consequences of a particular process, product or service that is used by various government and non-governmental agencies for future planning. LCA database is used for the various products such as plastics, metals, various wood products, primary energy resources and energy carriers, sometimes LCA can be used for the rubber products, agriculture products and non-metallic production (Seigl, S 2011). Figure 1.1 shows the difference phases of LCA which may be used. Life cycle assessment is a systematic method or a technique to identify or mitigate the various environmental impact throughout a process, product development, solid waste, toxic substances, raw materials, transportation, land use etc. and common air pollution (SampoSoimakallio*et al* 2011).

Mainly life cycle assessment is a study or approach which covers the life cycle of the process from Cradle to Grave, but this life cycle of a product or process is limited to a confident and assured part of this life and mainly for the product information that is in the use phase (ISO 14040 1997).The life cycle assessment may be modelled by using system boundary. System boundary is nothing but It is the interface between the environment and the product system and also it is the interface between one product systems to the other products system. Under the system boundary the life cycle of the products includes raw materials, transportation, depreciation etc. Mass and energy flow remains in boundary product flow, intermediate product flow, and elementary flow. Elementary flow connects the system of the product to the environment not in case of only input and output (ISO 14041 1998). Boundary products contained a two product systems whereas intermediate products include one product system (Finnveden G *et al* 2009). LCA may be explained as a cyclic process as shown in fig.1.2. Each and every life cycle consists of one or more than one unit processes which are the smallest portion of a product system for which data is/or are collected ISO, (1997).

2. Hydro Power Plants in Uttarakhand

The current scenario at Uttarakhand remains largely rural with 69.45% of this population living in villages and 58.39% population is engaged in agricultural. But the agricultural land in state has decreased from7.91 lacshacter in 2009-10 to7.41 lacshacter in 2011-12, as revealed by Mr. Om Parkas principal secretary (agricultural), of Uttarakhand. 558 dams and HEPS (Hydroelectric powers station) have been either constructed or are in plan, and due to this, many more peoples will lose their live hood. The scenario shows that, the total power demand in Uttarakhand is calculated at 2,400 MW but the electricity production is just around 1,300MW. The HEPS in the Uttarakhand state are working for below their capacity. The estimate shortfall of electricity in Uttarakhand is between 700MW and 800MW a day.

In Uttarakhand there are 558 dams and hydroelectricity projects have been planned. These dams and hydroelectricity projects will converts 1,152km of river length into ground cannels. State government's nodal agency UJVNL (UttarakhandJalVidyut Nigam Limited) construct run and operate HEPS in the state. The on-going projects and under construction projects in Uttarakhand is only 290 and these included small, medium and large categories.

Small power plant – less than 55MW
Medium power plant- between 55 to 100MW
Large power plant- above 100MW

Small Hydropower (SHP) is one of the earliest known renewable energy sources. The technology was initially used in Himalayan villages in the form of water wheels to provide motive power to run devices like grinders. Hydropower plants generate anywhere from a few kW, enough for a single residence, to several thousands of MW, power enough to supply a large city and region. Each hydropower plants were much highly dependable then the fossil fuel fired power plants of the day. This resulted hydropower stations distributed wherever there was an adequate supply of moving water and a need for electricity. SHP technology was introduced in India shortly after the commissioning of the world's first hydro power plant at Appleton USA in 1882.In the year of 1897, 130 kW power plant at Darjeeling was the first Small Hydro Plant in the country. There are some other power houses are belonging to that period such as Shivasundaram in Mysore (2 MW, 1902), Galogi in Mussoorie (3 MW, 1907), Chaba (1.75 MW, 1914) and Jubbal (50 kW, 1930) near Shimla are still working properly. There is no international consensus on the definition of SHP. The general practice all over the world is to define SHP by power output. Different countries follow different norms keeping the upper limit ranging from 5 to 50 MW. In India, SHP schemes are classified by Central Electricity Authority (CEA) (Finnveden G *et al* 2009).

3. According to Small hydro power plants, Life cycle assessment of small hydro power plants is divided into four stages

1) Civil works
2) Electro-mechanical equipment (E&M)
3) Operation and Maintenance (O&M)
4) Decommissioning

In research work, the three small hydro power plants in Uttarakhand, which are located in the downstream of dakpatharbarrage. The small power plants which are located at the downstream of dakpathar barrage are

1) Dhakrani power plant.
2) Dhalipur power plant.
3) Kulhal power plant.

Dhakrani power station comprises of three units of 11.25MW and thus the total capacity of the power station is 33.75MW and Net head is 19.8m. Dhalipur power station comprises of three units of 17MW and thus the total capacity of the power station is 51MW and Net head is 30.5m.Kulhal power station has three units of 10MW capacities each and thus the total capacity of the power station is 30MW and head is 18m.

4. Methodology

4.1 Environmental impacts

All freshwater system, whether they are natural or manmade, emit greenhouse gas due to decomposing organic material. This means that lakes, rivers, wetlands, seasonal floodedzones and reservoir emit GHG (Finnveden G *et al* 2009).In addition, domestic sewage, industrial waste and agricultural pollution will also enter these systems and produce greenhouse gas emissions. The main GHG emission produced in fresh water system are CO_2 and methane. The nitrous oxide could be also an issue in some cases and more particularly in tropical regions. Greenhouse gas emissions from hydroelectric power plant are consisting from (SampoSoimakallio 2011).

Table 4.1 Summary of Environment Issue and pollutant involved

Issue	Type of Impact	Pollutant	Main Source
Acid Rain Formation of sulfuric and nitric acid	Regional impact on lakes, forest and material	SO_2 NO_x	Smelters ,Extraction of gas and transportation
Particulate Matter Very small particles have a direct effect on human lungs	Significant effect on human health particularly on asthmatics	PM 10	Diesel and wood
Greenhouse Gases	Climate change affecting agricultural and forest productivity and increasing the drought	CO_2 CH_4	Destruction of forest and transportation and distribution of natural gas

Construction: In this phase, GHG is from the production and transportation of construction materials (e.g. concrete, steel, etc.) and the use of civil work equipment's.

Operation and maintenance: Additional GHG emissions can be generated by operation and maintenance activities (building heating/cooling system, auxiliary diesel generating units, staff transportation, etc.).

Dismantling: Dams can be decommissioned for economic, safety or environmental reasons. Up to now, only few small-size dams have been removed, mainly in the USA. During this phase GHG emissions are emitted due to transportation/recycling of material etc. Hydro power and the Environment: Present context and Guidelines for the future action reports present a summary of life cycle impacts in which they conclude run of river power plants emits GHG emission, NO_x emission, SO_x emission , Particulate emission and the range of these emissions are (AntoninoMarvuglia*et al* 2013).

No_x emission (t NO_x/ TWH) 1 to 68
So_xemission (t So_x/ TWH) 1 to 25
Particulate emission (t/ TWH) 1 to 5
GHG emission (CO_2/ TWH) 1 to 18

The Main atmospheric Issue covered by Life Cycle Assessment is described as below table 4.1.

4.2 Social Impacts

The most sensitive social economic issue surrounding hydropower development revolves around involuntary displacement, which consists of two closely related yet distinct processes.

(i) Displacing and resettling people and
(ii) Restoring their livelihoods through the rebuilding or rehabilitation of their communities.
(iii) The third main issue of run of river power plant is to affect the human health is breach of dams.

GHG emission causes various health hazards for humans like respiratory problems, asthmatics. These are summarily described in the following table 4.2.

Table 4.2 Chain of Effects between Each Pollution and Human Health (Helene Lavray*et al* 2010)

First level Pollution	Second level pollution	Third level pollution	Final impact on human health
SO_2NOx	Formation of acid H_2SO_4 and HNO_3	Washout of toxic metals (Al) from soils to river	Impact on Respiratory health and Absorption of these metals by humans (through the food chain)
GHG :CO_2, CH_4	Climate change	Droughts	Direct impact on the health of affected populations
Particulate matter			Direct impact on respiratory health

4.3 Improvements

From the impacts, it is clear that run of river hydro power plant has both environmental and social impacts. The emissions come from run of river power plants i.e. GHG, NO_x,So_x, Particulate matter directly affect the human health (E. Santoyo-Castelazo*et al* 2011). For reducing these affects we control the emissions, which come from the power plant. That can improve the life cycle of the power plant.

5. Result and discussion

5.1.1ForDhakrani Power Station

H= 19.8 meter, Capacity= 33.75 MW (33750 kW)

Table: 5.1 GHG emissions (g-CO_2/ kWh) V_S Capacity(kW) for Dhakrani Power Station

S.No.	Capacity (kW)	GHG emission(g-CO_2/ kWh)
1.	15,000	18.3267
2.	20,000	17.195
3.	25,000	16.366
4.	30,000	15.718
5.	35,000	15.190
6.	40,000	14.74

Table: 5.2 GHG emission (g-CO_2/ kWh) V_S Head (meter) for Dhakrani Power Station

S.No.	Head(meter)	GHG emission(g-CO_2/ kWh)
1.	5	13.36
2.	10	14.31
3.	15	14.89
4.	20	15.32

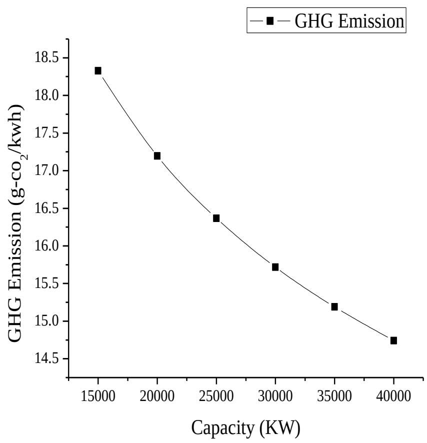

Figure 5.1 GHG emission (g-CO_2/ kWh) V_S Capacity (kW) for Dhakrani Power Station

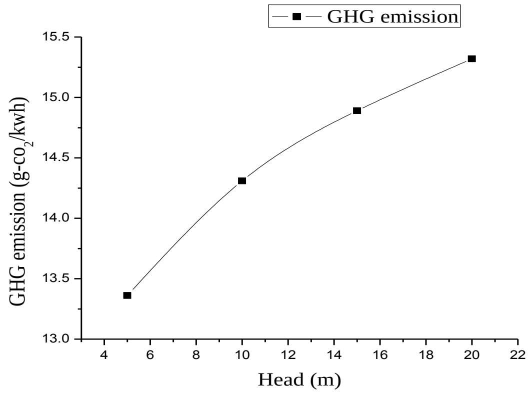

Figure 5.2 GHG emission (g-CO_2/ kWh) V_S Head (meter) for Dhakrani Power Station

5.1.2 ForDhalipur Power Station

Head= 30.5 meter, Capacity= 51MW (51000 kW)

Table 5.3 GHG emission (g-CO_2/kWh) V_S Capacity (kW) for Dhalipur Power Station

S.No.	Capacity(kW)	GHG emission(g-CO_2/kWh)
1.	15,000	19.12
2.	20,000	17.94
3.	25,000	17.07
4.	30,000	16.403
5.	35,000	15.85
6.	40,000	15.39
7.	45,000	14.99
8.	50,000	14.64
9.	55,000	14.34

Table 5.4 GHG emission (g-CO_2/kWh) V_S Head (meter) for Dhalipur Power Station

S.No.	Head(meter)	GHG emission(g-CO_2/kWh)
1.	5	12.19
2.	10	13.06
3.	15	13.59
4.	20	13.98
5.	25	14.30
6.	30	14.56
7.	35	14.78

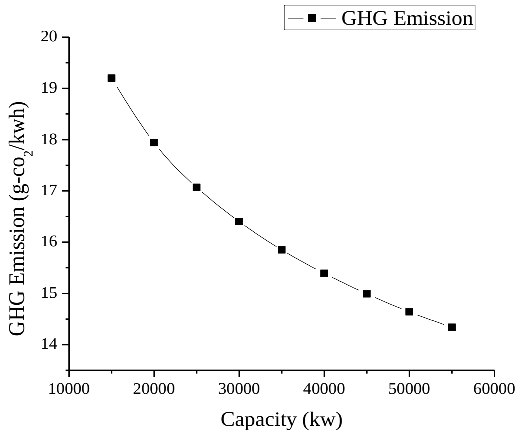

Figure 5.3 GHG emission (g-Co$_2$/kWh) V$_S$ Capacity (kW) for Dhalipur Power Station

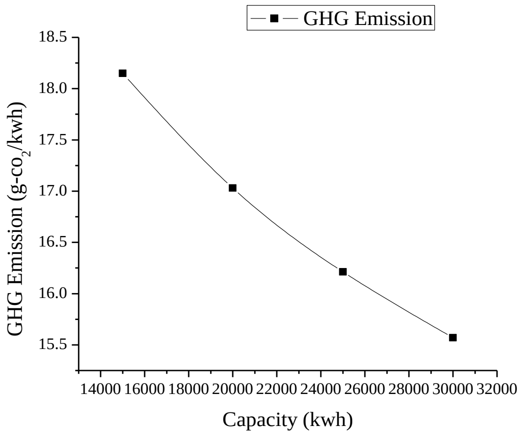

Figure 5.5 GHG emission (g-CO$_2$/kWh) V$_S$ Capacity (kW) for Kulhal Power Station

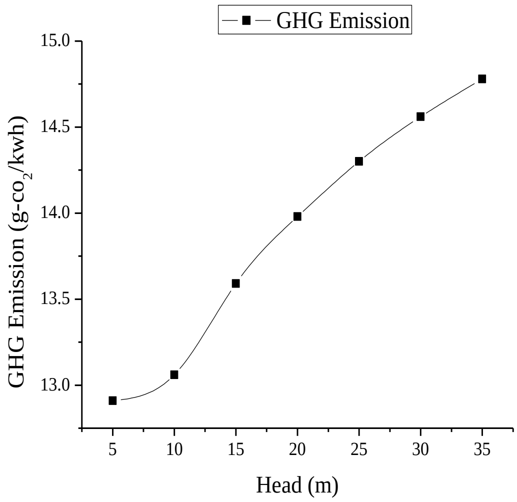

Figure 5.4 GHG emission (g-CO$_2$/kWh) V$_S$ Head (meter) for Dhalipur Power Station

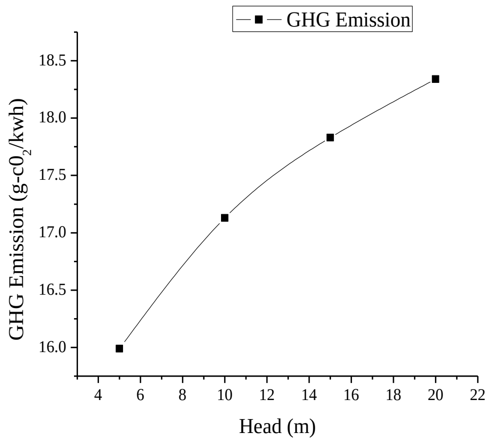

Figure 5.6 GHG emission (g-CO$_2$/kWh) V$_S$ Head (meter) for Kulhal Power Station

5.1.3 ForKulhal Power Station

Head= 18 meter, Capacity= 30 MW (30,000kW)

Table 5.5 GHG emission (g-CO$_2$/kWh) V$_S$ Capacity (kW) for Kulhal Power Station

S.No.	Capacity(kW)	GHG emission(g-CO$_2$/kWh)
1.	15,000	18.15
2.	20,000	17.03
3.	25,000	16.212
4.	30,000	15.57

Table 5.6 GHG emission (g-CO$_2$/kWh) V$_S$ Head (meter) for Kulhal Power Station

S.No.	Head(meter)	GHG emission(g-CO$_2$/kWh)
1.	5	15.99
2.	10	17.13
3.	15	17.83
4.	20	18.34

Conclusion

By the graph and the correlation, which is shown above it is clear that the GHG emission increase with increasing the head of the power plant and decrease with increasing the capacity of the power plant. The entire resource requirement for the generation of 1 kWh of electricity is low in big capacity small hydropower plant. It is similar to the generation cost of 1 kWh of electricity that is more in small capacity plants as compared with big capacity plants. However, GHG emissions increases or decreases with head depending upon the type of SHP scheme. For run-of-river GHG emissions increase with increase the head. This is due to the fact that with the increase in head, the civil work component increases; and civil work components (penstock, construction etc.) being highly energy intensive cause an increase in GHG emissions/. During the construction phase, the hydropower plants emit various emissions (i.e NO_X, SO_X, particulate matter).To mitigate these environment effect LCA technique is used to obtain better results.

The GHG vs. Capacity graph shows that as the capacity of power plant increases, the relative GHG emission decreases.

The GHG emission vs. head graph shows that as the head of power plant increases, there is an increase in GHG emissions.

References

Whitaker, J.Ludley, K.E.Rowe, R.Taylor, G.Howard (2010), D.C. Sources of variability in greenhouse gas and energy balances for biofuel production: a systematic review. GCB Bioenerg. 2 (3), 99e112,.

EIA (2008), Renewable Energy Consumption and Electricity Preliminary 2007 Statistics

Source, virtues energy research associates, Texas July (1995). renewable energy resource assessment report for the taxes sustainable energy development council,

Antonia V.H Herzog, Timothy E. Lipman, and Daniel M.Kammun, Renewable energy sources

First edition EUR 24708 EN 8, March (2010).. Luxembourg. Publications Office of the European Union.

EuROFER, Methodology Report: March (2011). Life Cycle Inventory on Stainless Steel Production in the EU, PE International

International Standards Organization (ISO). ISO 14041 (1998): Environmental Management - Life Cycle Assessment - Goal and Scope Definition and Inventory Analysi

Rebitzer G, Ekvall T, Frischknecht R, HunkelerD,Norris G, Rydberg T (2004); Life cycle assessment Part 1.framework, Goal and scope definition, inventory analysis and applications, Environment International. 701-20;

JobienLaurijssen. Andre P.C. Faaij (2009); Trading biomass GHG emission credits. 94; 287-317;

Seigl, S, Laaber, M, Holubar, P Val (2011); Green electricity from biomass part1: environmental impact of direct life cycle emission, waste biomass. 2,267-28

Seigl, S, Laaber, M, Holubar, P Val (2011); Green electricity from biomass part1: environmental impact of direct life cycle emission, waste biomass .2,267-284.

SampoSoimakallio, JuhaKiviluoma, Laura Saikku (2011); The complexity and challenges of determining GHG emission from grid electricity consumption and conservation in LCA- A methodological review

International Standards Organization (ISO) ISO 14040 (1997): Environmental Management - Life Cycle Assessment - Principles and Framewor

International Standards Organization (ISO) ISO 14041 (1998): Environmental Management - Life Cycle Assessment - Goal and Scope Definition and Inventory Analysis

Finnveden G, Hauschild MZ, Ekvall T, Guinee J, Heijungs R, Hellweg S, *et al* (2009). Recent developments in Life cycle assessment.,Journal of environment management 1:1-2

SampoSoimakallio, JuhaKiviluoma, Laura Saikku (2011);The complexity and challenges of determining GHG emission from grid electricity consumption and conservation in LCA- A methodological review.

AntoninoMarvuglia, Enrico Benetto, Sameer Rege, Colin Jury (2013), Modelling Approach for C-LCA of bioenergy, Critical review and proposed framework for biogas production

Helene Lavray*et al* (2010); life cycle assessment of electricity generatio

E. Santoyo-Castelazo, H. Gujba, A. Azapagic (2011); Life Cycle Assessment study of electricity generation in Mexico; 1488-1499,