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Social, economical and environmental impacts of renewable energy systems

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ABSTRACT

Conventional energy sources based on oil, coal, and natural gas have proven to be highly effective drivers of economic progress, but at the same time damaging to the environment and to human health. Keeping in mind, the social, economical and environmental effects of renewable energy system have been discussed in this paper. The uses of renewable energy system, instead of, conventional energy system, to control the social, economical and environmental problems have been discussed. The results show that the trends of total emission reduction in different years, which is exponentially increasing after the installation of renewable energy system in remote areas.

1. Introduction

Conventional energy sources based on oil, coal, and natural gas are damaging economic progress, environment and human life. These traditional fossil fuel-based energy sources are facing increasing pressure on a host of environmental fronts, with perhaps the most serious challenge confronting the future use of coal being the Kyoto Protocol greenhouse gas reduction targets. Renewable energy sources currently supply somewhere between 15 percent and 20 percent of world's total energy demand. The supply is dominated by traditional biomass, mostly fuel wood used for cooking and heating, especially in developing countries in Africa, Asia and Latin America. New renewable energy sources (solar energy, wind energy, modern bio-energy, geothermal energy, and small hydropower) are currently contributing about two percent. A number of scenario studies have investigated the potential contribution of renewables to global energy supplies, indicating that in the second half of the 21st century their contribution might range from the present figure of nearly 20% to more than 50% with the right policies in place [1].

The potential of renewable energy sources is enormous as they can in principle meet many times the world's energy demand. Renewable energy sources such as small hydropower, wind, solar, biomass, and geothermal can provide sustainable energy services, based on the use of routinely available, indigenous resources. A transition to renewable-based energy systems is looking increasingly likely as the costs of solar and wind power systems have dropped substantially in the past 30 years, and continue to decline, while the price of oil and gas continue to fluctuate. In fact, fossil fuel and renewable energy prices, social and environmental costs are heading in opposite directions. Furthermore, the economic and policy mechanisms needed to support the widespread dissemination and sustainable markets for renewable energy systems have also rapidly evolved. It is becoming clear that future growth in the energy sector is primarily in the new regime of renewable, and to some extent natural gas-based systems, and not in conventional oil and coal sources. Financial markets are awakening to the future growth potential of renewable and other new energy technologies, and this is a likely harbinger of the economic reality of truly competitive renewable energy systems.

These systems can have dramatically reduced as well as widely dispersed environmental impacts, rather than larger, more centralized impacts that in some cases are serious contributors to ambient air pollution, acid rain, and global climate change. Keeping in mind, the social, economical and environmental effects of renewable energy system have been discussed in this paper.

2. Aspects of renewable energy systems

The social aspects of human needs have been subjected to considerable debate as the term 'basic', which is understood within different contexts for improving the economy of the developing countries. It is also necessary to list different social aspects such as: (i) the disparity in income, (ii) the disparity in raw material and energy resources and sources, the technical progress favoured by the standard of living, the educational level, the climatic conditions, (iii) the demography, and (iv) the difference between an urbanized industrialized society, where the agricultural sectors represents

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only a small percentage of the working population, and a society with an important (often relatively inefficient) rural sector together with an uncontrolled increase of some urban areas due to social constraints. The following social benefits are (i) improved health, (ii) consumer choice, (iii) greater self-reliance, (iv) work opportunities and (v) technological advances.

Environmental aspects and quality of life indicate that environmental pollution (of air, water, etc.) is largely linked to the increasing use of energy, presently the climate changes due to heavy use of fossil fuel with emissions of sulphur dioxide, nitrogen oxide and carbon dioxide become more and more a planetary problem and will influence in the future. Air pollution is one of the aspects of the environmental problems. The following pollution agents are sulphur dioxide, nitrogen oxides, ozone, dust and aerosols, carbon dioxide, chlorofluorocarbons, steam-laden emissions and meterological inversion. Air pollution is not the only aspect of the environmental problems created by the energy sectors. Water pollution is another aspect of environmental problem. Water pollution includes any detrimental alteration of surface waters, under ground waters or the marine environment with a thermal or material pollution. Water polluting agents can be solid, liquid, or gaseous that detrimentally alters the natural conditions of waters. Water pollution occurs primarily from: (i) effluents such as water discharges from households, industries, trade or polluted rain, (ii) discharge of used oils, (iii) discharge of liquid substances containing poisonous chemicals including heavy metals (mercury, lead, etc.), also products like arsenic, zinc, copper nickel, cadmium, etc., and (iv) pollution by acid rain precipitation. The following environmental benefits are (i) reduced air pollution, (ii) lower greenhouse gas emissions, (iii) lower impacts on watersheds, (iv) reduced transportation of energy resource and (v) maintaining natural resources for the long term.

Using renewable energy generates a wide variety of economic benefits, many of which are described below:

Job creation is a key part of economic development activity and healthy economies. When more people are working, the benefits extend beyond the income earned from those jobs. Benefits occur when workers spend part of their income in the local economy, generating spin-off benefits known as the "multiplier effect." This increased spending creates economic activity (jobs and revenues) in other sectors such as retail, restaurant, leisure and entertainment. Renewable energy systems can create more jobs per Rupees invested than conventional energy-supply projects. The number of jobs also depends on how many stages of production are carried out in the region, as more jobs will be created if the materials and technologies are processed and manufactured locally.

Many of the renewable energy applications in the study area could be cost-effective applications, meaning that investors in new technologies will save more money from reduced fuel use or power bills than they originally invested in plant capital. The technology descriptions in these days include an assessment of the approximate generating cost of electricity technologies and the approximate financial savings for heating technologies. These should be compared with typical energy production costs and consumer prices in the study area.

The study area is continually seeking to diversify its economy. More varied economic activity in different sectors strengthens the overall economy because there are more ways to generate revenues. Investing in renewable energy can help diversify the economy. Instead of one or two main sources of energy supply (such as oil or coal), there can be numerous sources spread across a range of technologies, depending on what resources are available in any particular location (wind, solar, biomass, etc.).

The renewable energy industry, and the sustainable energy sector in particular, have grown rapidly in recent years. Another economic opportunity is providing renewable energy development and maintenance services in circumpolar jurisdictions.

3. Clean development mechanism

The clean development mechanism (CDM) is one of the "flexible mechanisms" under the Kyoto Protocol. It provides for industrialized countries to invest in emission-reducing plants in developing countries and to use the resulting "certified emissions reductions (CER)" towards their own compliance with the emission limitation targets set by the Kyoto Protocol. The certified emissions reductions (CERs) would then be calculated as the difference in emissions between the baseline (thermal or gas-fired power plant) and the plants (MHP, SPV, and wind-based electricity).

This CDM enables develop countries to meet their emission reduction commitments in a flexible and cost-effective manner, and assists developing countries in meeting their sustainable development objectives. These are also involved in investors to benefit by obtaining certificates of emissions reductions programme. Brazil is the only one country in the world acting for country benefit in the form of investment, access to better technology and local sustainable development and also enhances viability of low/zero carbon technologies [2].

CDM is eligible for power plant and depends upon following points: (i) renewable energy, (ii) fuel switching, (iii) end-use energy efficiency improvements, (iv) supply-side energy efficiency improvement, (v) agriculture (reduction of CH_4 and NO_2 emissions), (vi) industrial processes (CO_2 from cement) and (vii) sink projects.

The following risks are in CDM financing: (i) renewable energy plants are connected risk by financing institutions, (ii) multitude of risks could reduce the value of the plant to zero and (iii) measures are needed to mitigate risks at different stages of the plant.

Impact of carbon finance on plant financial Rate of Return (IRR) is indicated [2] by Table 1 for different renewable energy sources.

Further more, the Kyoto Protocol of 1997 was crucial step in the implementation of the UN Framework Convention on Climate change (UN FCCC) as it sets legally binding emission targets for a basket of six greenhouse gases (GHGs). These targets apply to most countries with economics in transition and relate to the period 2008–2012. To reach the targets, Kyoto Protocol allowed three flexibility mechanisms: (i) joint implementation, (ii) clean development mechanism and (iii) international emissions trading.

Among these three mechanisms, CDM plants would achieve their sustainable development objectives. Such plants would also lead to indirect benefits in the developing country like income generation, employment generation, improvement in local air quality, and enhancement of quality of life. One of the most crucial issues in this respect is the calculation of the GHG emission reductions/sequestration achieved via CDM plant. For this a reference scenario has to be determined of what the emissions would have amounted to if the plant had not taken place. This scenario is called a baseline.

However, the development of simple and standardized baselines for renewable energy plants will help developing countries like India maximize the potential opportunities available through the CDM by encouraging priority plants that meet

Table 1
Impact rate of return

Technology	ΔIRR
Small hydro, wind, geothermal	0.8–2.6
Biomass (crop/forest residues)	3–7
Municipal solid waste (MSW)	5–10+

Source: [2].

national environmental and developmental goals, and technology needs.

3.1. Baseline determination for renewable energy CDM plants in India

It is evident for the above discussion in the previous sections that the baseline is dependent on the "application" or "end use" rather than on the "technology" employed in the plant. The CDM has opened up new opportunities for clean energy technologies. Tata Energy Research Institute (TERI), with support from Ministry of Non-conventional Energy Sources (MNES) developed baselines for the following renewable energy technologies [3]: (i) wind power, (ii) small hydro, (iii) biomass, (iv) bagasse cogeneration, (v) solar photovoltaic and (vi) waste to energy.

The renewable energy technologies in wind, solar, biomass, waste to energy, small hydro/micro-hydro and can be divided in to three broad categories depending on the application: (i) grid connected renewable energy systems, (ii) off-grid power generating renewable energy systems and (iii) renewable energy systems for thermal energy and mechanical use.

The baseline methodologies in these three sectors can be developed for the four or five mini or local grids based on emissions from operating plants. The baseline methodology has been explained with case studies for different applications because of the diversity involved.

3.2. Overview of baseline methodologies

Among all the renewable energy technologies local (mini) grid connected renewables, producing power and feeding it to the existing local grid, provide most attractive option as CDM plants. The perceived ease in monitoring and verification and relatively good data availability for determination of baseline can be cited as major advantages making the local grid connected renewable energy based plants attractive under CDM. Both of these reasons are related with baseline determination.

There are number of possible methodologies to estimate what will a renewable energy system in a local grid connected mode will displace. The main methodologies are as follows: (i) system average, (ii) build margin, (iii) operating margin and (iv) combined margin.

3.3. System average

This approach is based on the assumption that the renewable energy system is displacing the average electricity mix in the local grid. Thus in this method, baseline emissions are estimated from the mix of different fuels that are used to generate power. The baseline is weighted average of emissions from all the currently operating power plants. The system average is to be estimated for most recent year for which comprehensive data is available.

3.4. Build margin

The approach followed for estimation of baseline is to estimate average emissions from the recently added and/or planned power generation facilities. The build margin is the weighted average emissions (unit: kg CO_2/kWh) of recent capacity addition to the system, defined as the lower of most recent 20% of plants built or five most recent plants.

3.5. Operating margin

The baseline is established based on emissions from a power plant, which would be operating at highest cost and hence would be shut down as a result of power generation from CDM plant or as a result of reduction in demand or due to availability of an alternative cheaper source of supply. This approach usually involves complex analysis of operating costs of power plants, demand forecasting, seasonal analysis involving effect of hydro-electricity, etc. The system average method explained above is a simplified case of operating margin.

The average of the "approximate operating margin" and the "build margin", where the approximate operating margin is the weighted average emissions (Unit: kg CO_2/kWh) of all generating sources serving the systems such as microhydro, solar, wind and biomass.

Table 2
Life cycle emissions from various energy sources

Energy Sources	Green-house gas emission		
	CO_2	SO_2	NO_x
	g/kWh	g/kWh	g/kWh
Coal (best practice)	955	11.8	4.3
Coal (NO_x) and FGD	987	1.5	2.9
Oil (best practice)	818	14.2	4.0
Natural gas (CCGT)	430	–	0.5
Diesel	772	1.6	12.3
Small hydro	9	0.03	0.07
Large hydro	3.6–11.6	0.009–0.024	0.003–0.006
Wind	7–9	0.02–0.09	0.02–0.06
Solar photovoltaic	98–167	0.2–0.34	0.18–0.30
Solar thermal electric	26–38	0.13–0.27	0.06–0.13
Energy crops – current practice	17–27	0.07–0.16	1.1–2.5
(likely to improve to)	(15–18)	(0.06–0.08)	(0.35–0.51)
Geothermal	7–9	0.02	0.28

Source: [6].

3.6. Combined margin

The methodologies used for operating margin and build margin are used and the baseline is combination of these results.

The different methodologies discussed above have different levels of accuracy, complexities in baseline estimation, data requirements and hence cost associated. Further these methodologies have different degrees of applicability in different countries or energy systems. Appropriateness and applicability of these methodologies and selection of method for this study is discussed in the subsequent section on selection of baseline estimation methodology.

The following steps are involved in the development of baseline as:

Step 1 *Determine expected annual electricity production of plant*: determination of expected annual electricity production, found by multiplying the installed capacity by plant capacity factor by 8760 (number of hours in one year) is

$$\text{Annual Plant Capacity or annual electricity generation (kWh/year)} = \text{Plant Capacity (kW)} \times \text{Plant Capacity Factor} \times 8760\ \text{(hrs)} \quad (1)$$

Table 3
Increasing order CO_2 emissions

Energy sources	Unit: g CO_2/kWh	Unit: kg CO_2/TJ
Large hydro	3.6–11.6	999.94–3222.02
Wind	7–9	1944.32–2499.84
Geothermal	7–9	1944.32–2499.84
Small hydro	9	2499.84
Biomass	17–27	4722–7499.52
Solar thermal electric	26–38	7221.76–10554.88
Solar photovoltaic	98–167	27220.48–46385.92

Step 2 *Determine expected plant emissions*: annual emissions of carbon dioxide are calculated by multiplying electricity generation by corresponding emission factors.

$$\begin{aligned}\text{Annual } CO_2 \text{ Emissions (Tonnes } CO_2) \\ = \text{Power Generation (kWh/year)} \\ \times \text{Emission Factor (Tonnes } CO_2/\text{kWh)}\end{aligned} \quad (2)$$

Step 3 Determine baseline emissions: total emission (E) is given as:

$$E \text{ (Tonnes } CO_2/\text{year)} = \sum_j E_j \text{ (Tonnes } CO_2/\text{year)} \quad (3)$$

where $E_j = CO_2$ emissions per year of the generation mode j, calculated as:

$$E_j \text{ (Tonnes } CO_2/\text{year)} = \frac{FC_j \times CV_j \times EF_j \times CF}{10^9} \quad (4)$$

where FC_j is the annual fuel consumption of power plant j (1000 $m^3$of biogas or producer gas from biomass energy

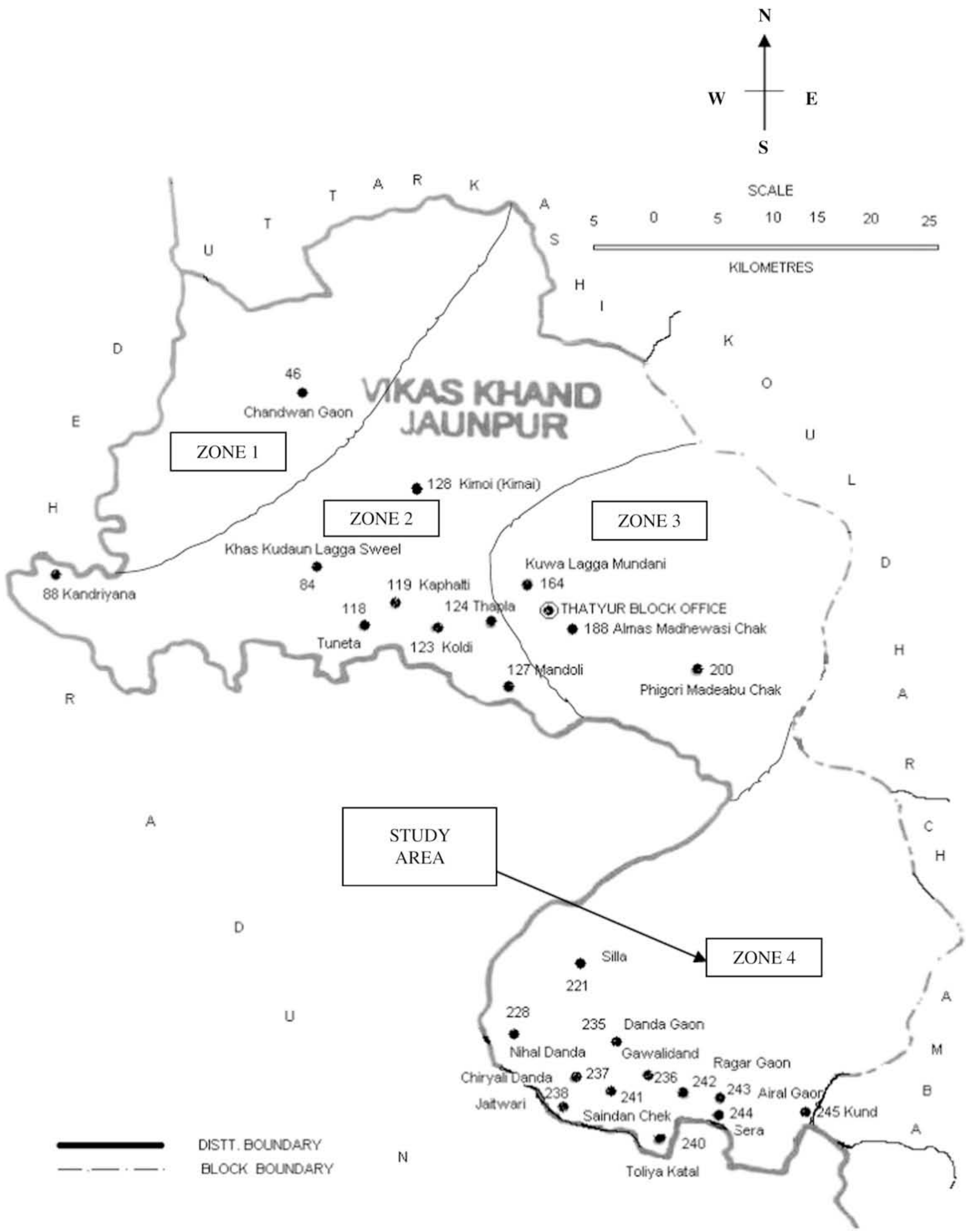

Fig. 1. Map of un-electrified villages (Uttaranchal state, district-Tehri garhwal, Jaunpur block).

system); CV_j, calorific value of source j (kcal/m^3 or kcal/l), EF_j, emission factor of the fuel used in power plant j (Tonne CO_2/TJ), and CF, unit conversion factor = 4186 J/cal and 10^9.
Further, weighted average emission intensity ($E_{wt.ave}$), is given by:

$$E(\text{kg CO}_2/\text{kWh}) = \frac{E\ (\text{Tonnes CO}_2/\text{year})}{\text{PG}\ (\text{MWh/year})} \tag{5}$$

where PG is the power generation and PG (MWh/year) = $\sum_j PG_j$ (MWh/year) and E (Tonne CO_2/year) is given by Eq. (3).

Eq. (5) is applicable to both the operating margin and the build margin cases. The only difference lies on the set of power plants considered in each case. Thus, the emission intensity coefficient, $E_{baseline}$, is obtained as:

$$E_{\text{baseline}}\ (\text{kgCO2/kWh}) = \frac{\{E_{\text{operating}}\ \ m \arg in + E_{\text{build}}\ \ m \arg in\}}{2} \tag{6}$$

Finally, baseline emissions, $E_{baseline}$, are given by:

$$E_{\text{baseline}}\ (\text{kg CO}_2/\text{year}) = \frac{\{E_{\text{baseline}}\ (\text{kg CO}_2/\text{kWh}) \times \text{CG}\ (\text{kWh/year})\}}{1000\ (\text{kg/Tonne})} \tag{7}$$

where CG stands for study area's (Zone 4 of Jaunpur Block) electricity generation given in Eq. (1).

Step 4 Determine annual emission reduction: description of the formula used to estimate anthropogenic emissions by source of greenhouse gases in the baseline using the baseline methodology for applicable plant for the small-scale CDM plant activities.

$$E_{\text{reduction}} = E_{\text{baseline}} - E_{\text{plant}} \tag{8}$$

4. GHG emissions from various energy sources

The greenhouse gases (GHG) emitted by various energy sources are shown in Table 2. As we have seen from Table 2, the renewable energy sources have very little contribution to the anthropogenic carbon dioxide emissions. These resources are stated in increasing order of their contribution to CO_2 emissions shown in Table 3 [4].

Biomass absorbs carbon dioxide (CO_2) from the atmosphere for its growth and stores in the plant itself. When the biomass is burnt, carbon dioxide is released. If biomass is used for producing heat in a power plant, the amount of CO_2 released to the atmosphere during combustion is almost same as captured during the growth of the plant.

Electricity thus produced from biomass fuels is carbon cycle neutral. In addition, empirical research conducted by the University of Florida concludes that for every 100 green tonnes of tree energy crop fuel used, 58 tonnes of CO_2 emission reduction occurs due to agriculture source carbon sequestration in the roots below ground. This fact naturally points at increased use of biomass as a source for meeting future energy needs which is not only renewable but also does not contribute to increase in carbon dioxide content in the atmosphere and consequently global warming. Further, since biomass fuels contain almost no sulphur or mercury, the contribution of biomass combustion to acid rain (SO_2) and mercury contamination in water is almost nil and comparable to zero pollutant emission technologies such as micro-hydro, wind and solar. Thus, use of biomass as a renewable energy source cannot meet the energy needs but will help in restoring balance in the environment and generate much needed employment in rural areas.

Table 4
Operating margin estimation for biogas

Items	Values	Unit	Sources
Energy generation	66.1874	MWh/year	Primary data
Biogas fuel consumption	45.5155	Thousand m^3/year	Primary data
Colorific value (biogas)	4780 [7]	Kcal/m^3	Reference value
Conversion factor	4.186 [2]		Reference value
CO_2 emission factor for biogas	7499.52 [4]	kg CO_2/TJ	Reference value
Emission factor for Biogas	0.1032	kg CO_2/kWh	Calculated value

Note: Assume CO_2 emission factor for biogas is equal to CO_2 emission for solid biomass (i.e. producer gas).

5. A case study

Renewable energy plants are going to be installed in Zone 4 of Jaunpur block. The map of the study area is shown in Fig. 1.

5.1. Description of the plants activity

The objective of the plant activity is to generate clean electricity using micro-hydro power plants, solar, wind and biomass energy systems and supply to the end-users i.e. villages of 12-unelectrified of Zone 4 of Jaunpur block. The plants are expected to have an installed capacity, i.e. MHP-19.26 kW, SPV-2 kW, WES-3 kW and BES (biogas)-25 kW and BES (producer gas)-70 W and total is 119.26 kW (i.e., 0.11926 MW). These power plants delivered renewable energy about 773091.024 kWh/year (i.e. 773.091 MWh/year) by using Eq. (1) (i.e. $119.26 \times 0.74 \times 8760$), where 0.74 is plant capacity factor and generation for 8760 h in a year. As we know that

$$\text{Plant Capacity Factor} = \frac{\text{Average Demand}}{\text{Installed Capacity}}$$

5.2. Technical description of the plant activity

Location of the plant activity is 12-unelectrified villages of Zone 4 of Jaunpur Block, district: Tehri Garhwal, state: Uttaranchal, country: India. The plants are located in the region of hilly, remote and far flung area at latitude: $30^\circ 04'$–$30\ 34'$ and longitude: $78^\circ 03'$–$78^\circ\ 14'$.

Table 5
Operating margin estimation for producer gas (solid biomass)

Items	Values	Unit	Sources
Energy generation	575.198	MWh/year	Primary data
Firewood (solid biomass) fuel consumption	575.198	Thousand kg/year	Primary data
Colorific value (solid biomass)	4000 [7]	Kcal/kg	Reference value
Conversion Factor	4.186 [2]		Reference value
CO_2 emission factor for solid biomass (fire wood)	7499.52 [4]	kg CO_2/TJ	Reference value
Emission factor solid biomass	0.1256	kg CO_2/kWh	Calculated value

Table 6
Biomass energy generation and their percentage

System	Energy generation (MWh/year)	% Energy generation
Biogas	66.1874	10.32
Solid biomass (producer gas)	575.198	89.68
Total	641.3854	100

5.3. Calculation of emission estimation

The calculation of operating margin estimation for biogas is shown in Table 4, using Eqs. (4) and (5), we have obtained

$$E_{\text{operating margin}} = \frac{\text{FC} \times \text{CV} \times \text{EF} \times \text{CF}}{\text{PG (MWh/year)} \times 10^9} \text{ kg CO}_2/\text{kWh for biogas}$$

$$E_{\text{operating margin}} = \frac{45.5155 \times 4780 \times 7499.52 \times 4.186}{66.1874 \times 10^9} = 0.1032 \text{ kg CO}_2/\text{kWh}$$

Similarly, the calculation of operating margin estimation for solid biomass (producer gas) is shown in Table 5, using Eqs. (4) and (5), we have obtained

$$E_{\text{operating margin}} = \frac{\text{FC} \times \text{CV} \times \text{EF} \times \text{CF}}{\text{PG (MWh/year)} \times 10^9} \text{ kg CO}_2/\text{kWh}$$

for producer gas (solid biomass)

$$E_{\text{operating margin}} = \frac{575.198 \times 4000 \times 7499.52 \times 4.186}{575.19 \times 10^9} = 0.1256 \text{ kg CO}_2/\text{kWh}$$

According to Table 6, we have seen that percentage energy generation through biogas and producer gas (solid biomass) system is 10.32% and 89.68%, respectively. Therefore, 10.32% of biogas emission factor is equal to 0.1032 × 0.1032 (i.e. 0.01065) and 89.68% of producer gas (sold biomass) emission factor is equal to 0.1256 × 0.8968 (i.e. 0.11264). Thus total emission factor or weighted emission factor is 0.1233.

Finally, $E_{\text{operating margin}} = 0.1233$ kg CO_2/kWh.

The calculation of build margin estimation is shown in Table 7. According to Table 7, the percentage energy generation by MHP, SPV and wind energy system is 64.89%, 0.944% and 0.6443%, respectively, and 33.51% energy generation through biogas system so far. As we have calculated biogas emission factor is equal to 0.1032 kg CO_2/kWh and as we know MHP, SPV and WE system emission factor is zero, because no any type of pollution occurs due to very remote rural area. Therefore, 33.51% of biogas emission factor is equal to 0.138 kg CO_2/kWh (i.e. 0.1032 × 0.3351 = 0.03458). This 0.03458 kg CO_2/kWh emission factor of biogas is actually weighted emission factor.

Finally,

$$E_{\text{build margin}} = (0.03458 + 0) \text{ kg CO}_2/\text{kWh}$$

Table 7
Generation from biogas, MHP, SPV, and WES

System	Energy generation (MWh/year)	% Energy generation
Biogas	66.1874	33.51
MHP	128.1662	64.898
SPV	1.863604	0.944
WES	1.27239	0.6443
Total	197.4896	100

Table 8
Total emission reduction

Years	Annual emission reduction (Tonnes CO_2)
1 Year	101.17
5 Years	505.85
7 Years	708.19
10 Years	1011.7
15 Years	1517.55
20 Years	2023.4
30 Years	3035.1

$$E_{\text{build margin}} = 0.03458 \text{ kg CO}_2/\text{kWh}$$

Using Eq. (6), we have obtained

$$E_{\text{base}} = (E_{\text{operating}} + E_{\text{build}})/2$$
$$E_{\text{base}} = (0.1233 + 0.03458)/2$$

$$E_{\text{base}} = 0.1579 \text{ kg CO}_2/\text{kWh}$$

In this case study, we have used four renewable energy systems such as micro-hydro, solar photovoltaic, wind and biomass among these system only biomass system, which is basically related to biogas and solid biomass or fire wood (producer gas) systems. The total installed capacity from these two biomass systems is equal to 95 kW. Therefore biomass system delivered energy about 640794 kWh/year (i.e. 95 × 0.77 × 8760) and 640.794 MWh/year.

Finally, Using Eq. (7), we get

$$E_{\text{baseline}} = \frac{0.1579 \times 640,794}{1000} = 101.17 \text{ Tonnes CO}_2/\text{year}$$

Step 4 indicates the calculation of annual emission reduction and using Eq. (8), we obtained the total emission reduction in one year and then corresponding years as:

$$E_{\text{reduction}} = E_{\text{base}} - E_{\text{plant}} = 101.17 \text{ Tonnes CO}_2$$

Therefore, total emission reduction in corresponding year is shown in Table 8, which shows that the trends of total emission reduction in different years, which is exponentially increasing after the installation of renewable energy system in remote areas.

6. Conclusions

The following conclusions are obtained:

(i) Emissions resulting from the plant should be lower than what would have occurred had the prevalent technology been used.
(ii) Emission reductions are expected to be real, measurable and long term.
(iii) Establishment of emissions additionality (reduction in emissions) is a prerequisite under the CDM.
(iv) Baselines can be plant-specific or standardized.
(v) The CDM has to contribute to sustainable development in India and developing countries.
(vi) On a global scale the plant brings "clean" electricity to end-user, thus reducing even neglecting fossil fuel import dependence if any. As the study area plants are located at the end-user, another important function would be to improve the quality of power supply in the villages of remote area, through improvement in voltage, reduction in system losses and a reduction in the interruption of power supply.
(vii) Micro-hydro, SPV and wind are a clean form of generation. Moreover, since study area is run-of-river hydro power plant,

with no dam and flooding area, there is virtually no environmental impact caused by the plant. There is, however, a visual impact. In addition to CO_2 emissions reductions, the plant would also mitigate other pollutants, such as SO_2, NO_x and particulates associated with power generation from fossil fuels.

(viii) The study area is located in villages of remote area. The plant will have associated benefits such as job creation and increase the revenue of the villager's. The plant has the ability to distribute some of its electricity to local inhabitants, improving their quality of life.

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References

[1] <http://socrates.berkeley.edu/~rael>.
[2] Sharma MP, Kumar A. International course on small hydro power development (sponsored by MNES, Govt. of India and organized by AHEC, IIT, Roorkee); 2004. pp. 284–330.
[3] <http://www.teriin.org/reports/rep160/rep160.htm>.
[4] Das DD. Kyoto Protocol and renewable energy development. In: First international conference on renewable energy, New Delhi; 6–8 October 2004, p. 193–203.
[6] International Energy Agency. Benign energy? The environmental implications of renewables. Paris: OECD; 1998. p. 15, 45.
[7] Rai GD. Non-conventional energy sources. 2B, Nath market, Nai sarak, Delhi: Khanna Publishers; 1996. 904–905.