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ENERGY POLICY

Clean development mechanism and off-grid small-scale hydropower projects: Evaluation of additionality

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Abstract

The global climate change mitigation policies and their stress on sustainable development have made electrification of rural mountainous villages, using small hydro, an attractive destination for potential clean development mechanism (CDM) projects. This invariably involves judging the additionality of such projects. The paper suggests a new approach to judge the additionality of such stand-alone small hydropower projects. This has been done by breaking up additionality into two components: external and local. The external additionality is project developer dependent. For determining the local additionality, the paper takes into account the probability of a village getting electrified over a period of time, which is kept equal to the possible crediting period. This is done by defining an electrification factor (EF) whose value depends on the degree of isolation, financial constraints and institutional constraints encountered while electrifying a mountainous village. Using this EF, the additionality of a CDM project can be judged in a much easier and accurate way. The paper is based on the data and inputs gathered during site visits to many isolated villages located in the eastern Indian Himalayas.

Keywords: Small hydro; Rural electrification; Electrification factor

1. Introduction

After years of negotiation, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) has finally come into force in the year 2005. One hotly debated voluntary policy tool is the clean development mechanism (CDM) under Article 12 of the Kyoto Protocol. CDM is designed to entice developing countries to participate in global carbon emissions abatement by allowing them to sell their certified emission reductions (CERs) to industrialized countries that are abiding by the strict caps on emissions set forth in the Kyoto Protocol (Zhang et al., 2004). Numerous studies have indicated the practical challenges in identifying robust methods for implementing CDM (Meyers, 1999; IEA, 2000). Many of these studies have focused on one of the most important aspects of implementing CDMs: the issue of additionality. Additionality is a highly subjective criterion, which is often very difficult to define since it requires knowing the unobservable future dynamics of a complex system. How the judging of additionality could have profound implications for the global supply of carbon credits is also well known (Broekhoff and Trexler, 2003).

Under such circumstances, determination of additionality gains paramount importance in a CDM project. Various approaches have been suggested to check for the additionality of a CDM project. Financial test and environmental test (Baumert, 1999); regulatory or institutional screen, technological test and barrier test (Susel and Odom, 2002) are among the commonly discussed ones. Despite abundant methodological debates, until recently there have been very few independent, detailed empirical studies of additionality in the real settings where CDM projects may occur. Also most studies focus too much on the financial test for CDM projects (Langrock et al., 2000; Bode and Michaelowa, 2003).

The present study attempts to analyse the additionality criteria under real settings where CDM projects may occur. This has been carried out by studying the various issues affecting implementation of CDM in off-grid small-scale

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hydropower projects. The aim was to observe other parameters, besides the environmental and financial, which affect additionality in these projects and accordingly define the additionality.

2. Study overview and methodology

The study focused on the isolated mountain villages located in eastern part of the Indian Himalayas at altitudes between 1500 and 3000 m above sea level. Visits were conducted in 12 villages (all without electricity). This was performed to identify the reasons behind non-availability of electricity in the villages. It also helped in forming a broad picture of the whole situation. Each of the villages studied has between 40 and 70 households. A household may have between 4 and 10 members. The average per capita income of the villages is less than US\$1 day^{-1}. As many villages are not recognized by the government, it is difficult to obtain accurate records of any kind. For analysis, interviews were conducted from three villages. These three seemed to be most representative of the entire scenario. These three villages were Doko Puto (district: West Siang; state: Arunachal Pradesh), Karek (district: East Sikkim; state: Sikkim) and Zeema (district: North Sikkim; state: Sikkim). Out of the three, Doko Puto and Karek have micro-hydro installations in the process being set up. The interview results and inferences are discussed in Section 5.2.1.

3. Reasons for selecting small hydro projects

3.1. Suitability of small hydro in the study area

The quantity and quality of energy services required in the mountains is quite low due to the scattered settlement pattern and lack of infrastructure development and diversification of economies. At the same time, the extension of grid electricity in the mountain areas is not economically feasible. In neighbouring Nepal, with similar terrain, the cost of grid extension is US\$10,000–30,000 (HLF, 2000). In India, it is estimated that only another 8% of Indian villages can be electrified by extension of the grid (Srivastava et al., 1998). Where line extensions are installed in rural areas, those are characterized by poor reliability and high line losses. Line extensions are often awarded as political favours, leading to inefficient service area growth. Metering individual customers is prohibitively costly in rural areas, and customers are charged a flat rate (or not billed at all), leaving no incentive to conserve electricity. It is desirable to take into consideration of mountain specificities such as inaccessibility, fragility, marginality and diversity as it provides conditions for feasibility and suitability of certain types of energy technologies. These arguments, together with the fact that mountains are extremely scale sensitive due to their fragile nature, make small hydro and micro-hydropower as one of the suitable options among various options available for the provision of energy in rural mountain areas. Also, the small-scale interventions in mountain communities are also less risky compared to large-scale interventions, be they road or dam construction (Rijal, 2000).

Other common non-conventional sources of electricity generation like solar photovoltaic and wind are not significant in the study area. This is essentially due to the awareness, technological and financial constraints in their use. For rural electrification of the present study area of North East India, the Ministry of Non-conventional Energy Sources (MNES), Government of India spent almost 52% of its financial resources on the development of small hydro projects during the 9th plan period between 1997 and 2002. The expenditure on solar and wind during the same period was 9% and 0.5%, respectively (MNES, 2004). Hence, the present study focuses on small hydro. However, many methodologies discussed in the paper may very well apply to other renewable energy technologies also.

3.2. Small hydro and the Indian scenario

As per India's Central Electricity Authority and Bureau of Indian Standards, small hydropower stations are classified, as shown in Table 1.

In India, about 18,000 villages are to be electrified mainly through renewable energy sources (CII, 2000). Many of these villages have potential for setting up small, mini and micro-hydro projects. It presents a huge business potential for investors and equipment manufactures. Table 2 shows the small hydropower potential in India.

As mini hydro and micro-hydro projects are normally installed under river run-off scheme, they are located in hilly areas. Most of the micro-hydro projects are used for stand-alone power generation application to cater to domestic and commercial requirements, while power generated from mini hydro plants is normally exported to the grid (CII, 2004).

Table 1
Indian classification of small hydro (as per Bureau of Indian Standards)

Name	Unit size (kW)	Installation (kW)
Micro	Up to 100	100
Mini	101–1000	2000
Small	1001–6000	15,000

Table 2
Small hydro potential in India

Potential available	15,000 MW
Installed so far	1530 MW
Projects under implementation	610 MW

Source: CII (2004).

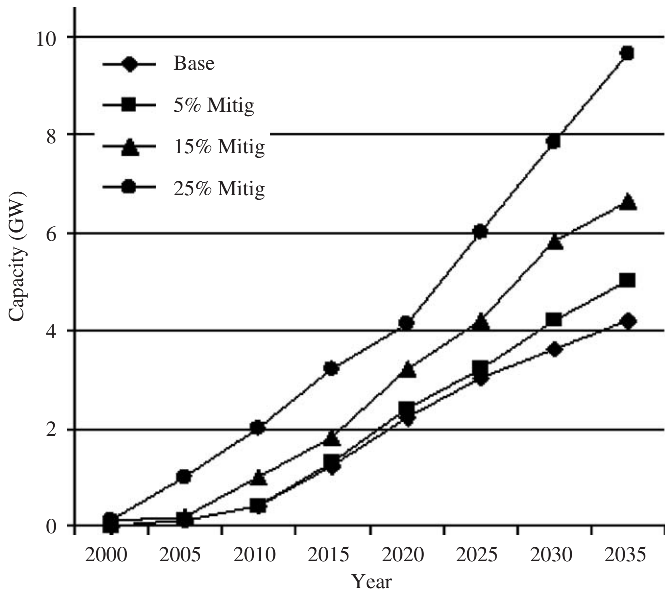

Fig. 1. Projections for small hydro capacities. *Source*: Adapted from Ghosh et al. (2002).

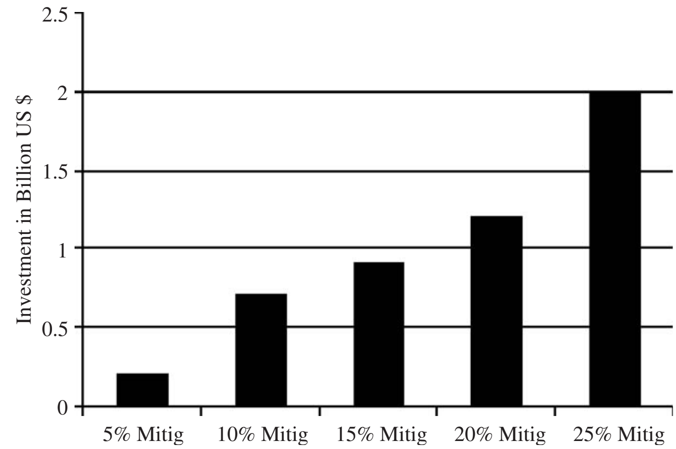

Fig. 2. CDM investment of small hydro. *Source*: Adapted from Ghosh et al. (2002).

The focus of the present study is on stand-alone power generation projects only. For CDM implementation, the UNFCCC categorizes such stand-alone small- and micro-scale power generation projects as "Type 1: Renewable Energy projects" (UNFCCC, 2004).

3.3. Small hydro and CDM potential

There are opportunities for renewable energy technologies (including small hydro) under the new climate change regime as they meet the two basic conditions to be eligible for assistance under UNFCCC mechanisms: they contribute to global sustainability through greenhouse gas (GHG) mitigation; and, they conform to national priorities by leading to development of local capacities and infrastructure (Ghosh et al., 2002). Fig. 1 shows capacity projections of renewable small hydro technologies under baseline and different mitigation scenarios in India.

Fig. 2 shows the CDM potential for small hydropower at different levels of mitigations.

4. Additionality in the isolated stand-alone rural electricity generation projects

As in the case of other CDM project activities, the issue of additionality has to be dealt in case of stand-alone electricity generation using small hydro in rural mountainous regions also. Attempts to judge whether a given project or investment is likely to take place without CDM is invariably subjective. For investments that are clearly not financially attractive, most observers might agree that those would be rather unlikely to occur, at least in the near future. But unless the potential value of the carbon credits is very high, who would want to make such an investment? The closer an investment is to being attractive without carbon credits, the more difficult it is to judge whether it would take place without CDM (Meyers, 1999).

Another reason for a small hydro project not being termed additional is that it may be the case that the electrification of the village, using small hydro was already planned by the local government (without taking into account the investment possible through the sale of CERs). There is a possibility that the government plans electrification of the village sometime in the near future. It may be the case that a project that is additional at present may not be so in the future.

5. A new approach to judge additionality

Mostly, the additionality of a CDM project has been analysed only from the host country and project developer point of view. For the villagers of the unelectrified village where the project ID being developed, any form of electricity is additional. From their point of view, off-grid electricity generation project is as good as a conventional grid-based power supply scheme. Electricity in any form and from any source is additional for them.

Taking the local people also into account, the additionality of a CDM project can be defined as

$$\text{project additionality} = \text{external additionality} + \text{local additionality},$$

where external additionality is the additionality as seen by CDM project developers and local additionality the additionality as seen by local people and host government.

5.1. External additionality

The additionality as seen by project developers is termed as external additionality. This should include the criteria of "environmental" additionality, i.e., the project brings down the amount of effective GHG emissions within the project boundary after the project implementation. Judging it can be fairly simple in the case of a small hydro-based

CDM project as it is a clean source of electricity generation.

5.2. Local additionality

Local additionality implies that the village is having electricity from the CDM project. Judging it is exceptionally difficult as it involves judging the unforeseen developments of the future, especially with relation to government's electrification policy. Government's electrification policy is further influenced by financial and political factors.

To help decide the local additionality, the chances of electrification of a village (by fossil fuel based or any other clean source based), now and in the future, must be found out. This will help in providing a definite answer, yes or no, to the additionality question.

5.2.1. Interviews to judge local additionality

The local additionality is dependent on the chances or probability of a village being electrified. In order to examine the local additionality of a project, the various factors affecting the electrification of a village must be identified. In the study area, interviews were carried out asking local villagers to identify the major factors that affect the chances of their village getting electrified. Before this was done, the authors themselves identified three factors that seemed to affect the probability of village electrification. These were the number of electrified villages surrounding the village under investigation, the degree of isolation and the financial and technological limitations a proposed project may encounter. The respondents were asked to comment on these three factors and list any other factor that they considered important. Based on discussions and interviews with 10 adults from each village, the following five most important factors were identified:

- perceived increase in household income after electrification,
- availability of grid electricity in the neighbouring villages,
- financial and technological limitations encountered during electrification,
- degree of isolation,
- Institutional factors.

Some of the above factors may be interdependent. This can be established by carrying out various tests of statistics. However, collection of reliable data to test these factors in these isolated areas is not only difficult but also not practical. The resources available to set up such small-scale electrification project are limited (the credits earned through CDM are small). Any extensive data collection methodologies and analysis will result in increased costs. Hence, instead of focusing on reliable data, the relatively quick and reliable subjective interviews with the local population should be used to judge local additionality. The present study, thus, does not follow the conventional methods of analysis, considering them to be impractical in actual conditions.

5.2.2. The electrification factor (EF)

The best way to judge local additionality is through defining a new parameter, the EF, which takes into account the effect of all the five factors mentioned in Section 5.2.1. This involves assigning equal weights to these five factors affecting electrification and then determining whether these are directly or indirectly proportional to the probability of electrification. Values are now assigned to these factors, on an ordinal scale of 1–10, from a predetermined table. The combination of these values gives us the value of the EF. Values of EF may be found for various years in the future. The changes in the values of EF are indicative of the probability of a village getting electrified. The higher the EF, the higher the probability of electrification. The EF values are plotted against time in years. This plot (which is exclusive for a geographical area and project type) is used to test local additionality. This exercise is explained in the later sections.

6. Probability of a village getting electrified without CDM consideration

By observing the past and present trends in the villages selected for the study, the various factors on which the electrification of an isolated village depends are found to be related as follows:

probability of village getting electrified at time

$$t \propto \left(\frac{PN}{F_{\text{off grid}}\, i}\right) I, \tag{1}$$

where P is the quantity whose value depends on the average per household income of the village under consideration at any given time t, N the quantity whose value depends on the number of villages with electricity in an area of 5 km radius around the village under consideration at any given time t, $F_{\text{off grid}}$ the quantity whose value depends on the financial and technological limitations likely to be encountered in setting up an off-grid power source in the village under consideration at any given time t, i the quantity measuring the degree of isolation of the village under consideration at any given time, I the quantity measuring the institutional factors associated with the village under consideration getting permission to be electrified and t the time in years starting from when Project Design Document is submitted and whose maximum value can vary from 10 to 14 years.

The quantity on the left-hand side of Eq. (1) is the EF.

6.1. Weights and choice of values for the factors contributing to EF

The choice of weights depends on the type of project and the geographical area in which the project is located. In other words, these may be assumed to be sector specific. These may be decided during the interviews and surveys done in the area. The various factors contributing to the EF have been assigned equal weights in Eq. (1). This has been done since the interviews were unable to identify any one factor more important than the other. Moreover, rather than assigning of weights, it is easier to assign values on the ordinal scale of 1–10. For initial projects, it is advisable to keep things simple. With experience, changes to the scale or any other appropriate modification may be made.

7. Various factors affecting the probability of village getting electrified and their relationship with CDM

7.1. The time factor t

Judging the additionality involves foreseeing the dynamics of the future. The criteria used for judging additionality may not hold true in the future (during the crediting period), although it might be applicable at the time of Project Design Document preparation. Considering the modalities of Annex II "Simplified modalities and procedures for small-scale clean development mechanism project activities" (UNFCCC, 2002), the time t in relationship (1) has been assumed to have a maximum value of 10 or 14 years: 10 years corresponding to a fixed crediting period without review; 14 years corresponding to 7 years crediting period renewed two consecutive times.

7.2. The per household income factor P

The per household income in the villages surveyed remains low at around $1 day^{-1} household^{-1}. The value varies greatly within the village. It is observed that the tendency to consume fuels such as kerosene above the village average increases with increasing per capita income. At the same time, the families with highest incomes are the ones that keep diesel-powered grinding machines. These machines also function as generators used for providing electricity primarily during the evening hours. Table 3 shows the per household income of families with diesel generators.

However, in actual practice, the perceived increase in income is the reason behind a household purchasing a diesel generator. The generators were not purchased to provide electricity. The aim was to set up small-scale commercial activities like grinding and cottage industry so that the family income could be increased. Subsequently, those were used for electrification of the household. These phenomena may be termed as "follow up electrification".

Table 3
Per household income of households with diesel generators

Name of village	Per household income of village (US$ month^{-1})	Per household income of households with diesel generator (US$ month^{-1})
Doko Puto	27.55	45.55
Karek	30.12	43.25
Zeema	26.00	35.34

Source: Collected field data in 2004.

Table 4
Values of P for different increases in per household income

Increase in monthly per household income of village by use of diesel generator (%)	Value of P
More than 100	10
Between 50 and 100	3–9
Up to 50	1–2

To take into account the effect of per household income on EF, the values of quantity P mentioned in Table 4 are adopted.

The increase in monthly per household income might take place in many ways. Electrification might lead to increase in volume of handicrafts produced, economically productive activity during night, rise in education levels, etc.

7.3. The number of villages nearby having electricity: the quantity N

The number of villages around the non-electrified village influence greatly the day-to-day life of the villagers. This is mainly in the form of trade and social contacts. For the purpose of electrification, following two cases may be considered:

(a) *If villages nearby are connected to grid*: This makes it easier for extending connection up to the village. However, in the present study, there was only one village that had electricity supply lines passing within an area of 5 km radius. The reasons for the grid not being extended to this village were more or less institutional.
(b) *If village(s) nearby have some off-grid electricity generation facility*: The level of motivation increases if the neighbouring village is successfully using diesel generator to produce electricity. Out of the 12 villages surveyed, five had diesel generator in their neighbouring village. It was observed out of these five villages, four themselves had diesel generators. Out of these four villages, three had purchased the generators after seeing it being used in their neighbouring villages. The

interviews with the generator owners revealed that their decision to purchase the diesel generators was greatly influenced by other generator owners of the neighbouring villages. Hence, with greater diesel-enabled electrification in the neighbourhood, the probability of purchasing diesel generator increases.

In case there exists a micro-hydropower facility in the adjacent village, the chances of electrification of the village under consideration increase again. However, as the village does not have the capacity (financial and technological) to initiate such a project by its own, they remain depended on the government. But the level of motivation and acceptance for such projects does increase.

For the purpose of assigning a value to N, Table 5 is used.

It may be noted that in Table 5 that when more than 50% villages around are considered to have electricity, then they are assumed to be connected to the grid.

7.4. Financial and technological limitations in setting up an off-grid power source in the village: the quantity $F_{off\ grid}$

The costs of setting up the micro-hydro projects in the two villages where the construction is going on are shown in Table 6 (APEDA, 2003; SREDA, 2004).

The interviews with the agency officials indicated that the cost were not prohibitive. But cost exceeding the ones in the table would have made the project almost impossible to implement. In fact, as per the preliminary project report for the Doko Puto project, US$96,591 was mentioned as the project cost. However, due to financial limitations the project capacity was reduced from 50 kW (2 × 25 kW with one unit of 25 kW as the stand by unit) to 20 kW (2 × 20 kW, no stand by unit). Some technological modifications were also made. The reevaluation process took one more year to complete. It was also observed that it was beyond the capacity of the government agencies to undertake more than one project at a time. Also the time duration between two consecutive projects was large due to the excessive time taken by various other departments to release the funds. Table 7 assigns values to the parameter $F_{\text{off grid}}$.

Another point to be noted is that with time, the costs of electrifying a village fully are bound to rise. As the village grows/expands, the cost of laying transmission lines will increase.

7.5. The isolation factor i

It was observed that the isolation of a village is governed by factors such as if or not the village is connected by road, distance of nearest highway from the village and number of people from the village making frequent visits outside the village for trade purposes. These are themselves most of the times a function of the geographical location of the village. To assign a value to the degree of isolation, Table 8 is used.

When two or more reasons occur together, the reason with higher value of i is considered.

7.6. The institutional factor I

It was observed in the study that the institutional factors influence greatly the electrification process for isolated villages. The influences can be positive as well as negative. Table 9 shows the results from the survey of the 12 villages.

Table 5
Value of N as per number of villages around having electricity

Percentage of villages around having electricity (%)	Value of N
100	10
Between 50 and 100	6–9
Less than 50 (using diesel generators)	3–5
Less than 50 (using micro-hydro)	2
Less than 50 (connected to grid)	3–4
None	1

Table 6
Cost of projects being implemented in the study area

Name of project village	Project capacity (kW)	Project cost (in US$)[a]
Doko Puto	20	63,637
Karek	10	38,762

Source: APEDA (2003) and SREDA (2004).
[a]Conversion rate used: 44 Indian rupees = 1 US$.

Table 7
Value of $F_{\text{off grid}}$

Factors affecting $F_{\text{off grid}}$	Value of $F_{\text{off grid}}$
Financial constraints	8–10
Awareness regarding the off-grid technology	5–10
Motivation to test new off-grid technology	5–10
Non-availability of off-grid technology locally	1–5

Table 8
Value of isolation factor i

Reasons behind isolation	Value of i
No major road within 5 km radius	7–10
Village not connected by road	5–7
Village inside dense forests with no approach road	9–10
Village cut off from nearby areas for greater than 4 months in a year	7–9
Takes more than 2 days to reach the village from nearest town	7–9

However, many times the institutional reasons also act as a strong force in favour of electrification. Many villages are electrified because of the various political gains which are made by doing so. Based on the above observations, Table 10 is prepared.

Table 9
Institutional reasons effecting the electrification process

Institutional reason	Number of villages observed	Number of villages that identified it to be the most prominent reason
Village not recognized by the government (the village came up after the last census/census did not record it)	3	3
Strategic reasons	2	2
Village not significant from political point of view	9	2
Cultural/ethnicity differences	4	2

Table 10
Value of institutional factor I

Institutional reason	Value of I
Political significant	8–10
Strategically important (acts in favour)	8–10
Politically not significant	1/1–1/2
Not recognized in census	1/5–1/8
Cultural/ethnicity differences	1/5–1/8
Strategically sensitive (acts against)	1/8–1/10

8. Calculation of EF in the study villages

Once the appropriate values for various parameters affecting the EF have been assigned, the value of EF can be found and the probability of electrification can be inferred using Eq. (1). Table 11 shows the values assigned to various parameters of Eq. (1) and the value of EF at different times during the probable crediting period.

9. Judging local additionality from probability of electrification

The plot between EF and time (various years of the possible crediting period) is shown in Fig. 3. The three curves represent the three different villages. It is seen that the value of EF changes with time, indicating a proportionate change in the probability of village electrification.

Low values of EF indicate low probability of electrification due to financial, technological, isolation and institutional reasons. It, thus, implies that any CDM project will

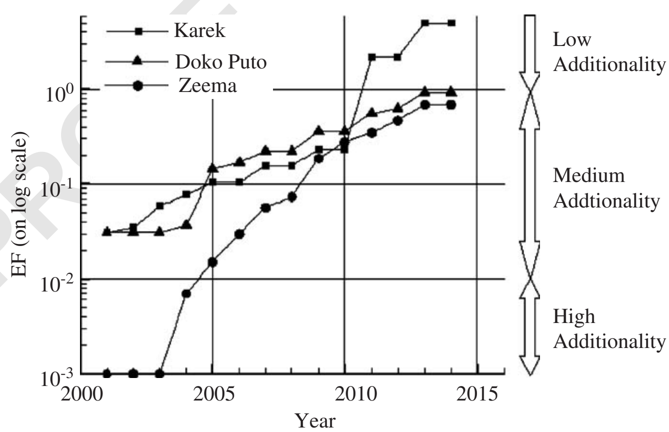

Fig. 3. Variation of electrification factor (EF) during the crediting period.

Table 11
Values for various parameters and the final value of electrification factor (EF) for the three villages: Karek (K), Doko Puto (DP) and Zeema (Z)

Year	P			N			$F_{off\ grid}$			i			I			EF		
	K	DP	Z	K	DP	Z	K	DP	Z	K	DP	Z	K	DP	Z	K	DP	Z
2001	2	5	1	10	1	1	10	9	10	8	9	9	1/8	1/2	1/8	0.031	0.031	0.001
2002	2	5	1	10	1	1	9	9	10	8	9	9	1/8	1/2	1/8	0.035	0.031	0.001
2003	3	5	1	10	1	1	8	9	10	8	9	9	1/8	1/2	1/8	0.059	0.031	0.001
2004	3	6	1	10	1	3	6	9	9	8	9	9	1/8	1/2	1/5	0.078	0.037	0.007
2005	4	6	2	10	3	3	6	7	9	8	9	9	1/8	1/2	1/5	0.104	0.143	0.015
2006	4	7	3	10	3	4	6	7	9	8	9	9	1/8	1/2	1/5	0.104	0.167	0.030
2007	5	7	3	10	4	5	5	7	6	8	9	9	1/8	1/2	1/5	0.156	0.222	0.056
2008	5	7	4	10	4	5	5	7	6	8	9	9	1/8	1/2	1/5	0.156	0.222	0.074
2009	6	8	4	10	4	5	4	5	6	8	9	9	1/8	1/2	1/2	0.234	0.356	0.185
2010	6	8	5	10	4	5	4	5	5	8	9	9	1/8	1/2	1/2	0.234	0.356	0.278
2011	7	8	5	10	5	5	4	4	4	8	9	9	1/1	1/2	1/2	2.188	0.556	0.347
2012	7	9	5	10	5	5	4	4	3	8	9	9	1/1	1/2	1/2	2.188	0.625	0.463
2013	8	10	5	10	5	5	2	3	2	8	9	9	1/1	1/2	1/2	5.000	0.926	0.694
2014	9	10	5	10	5	5	2	3	2	8	9	9	1/1	1/2	1/2	5.000	0.926	0.694

be highly additional under such low values of EF. Similarly, high values of EF indicate a lower level of additionality. In the present study, the values of EF between 0 and 0.01 indicate high additionality, between 0.01 and 1.0 level of additionality was medium and values greater than 1.0 were considered high.

Based on above discussion, the local additionality of the three projects was found to be satisfactory. Throughout the assumed crediting period, the additionality of two projects varies from high to a medium level. Only for one small hydro project (the Karek village project), the additionality was found to be low after the year 2011. But for most of the time, the project would be within the high-to-medium additionality range.

10. Procedure for judging additionality in a new project

Any proposed stand-alone electricity generation project can be deemed to be additional if it passes the test of both ‘‘external’’ as well as ‘‘local’’ additionality. Small hydropower projects that do not sell electricity to the grid are inherently environment friendly and hence can be said to be externally additional. In order to judge the local additionality, the various factors that affect electrification in the geographic region and project type under consideration are identified. The EF can then be computed after deciding a suitable scale for the various factors. Further, a plot between the proposed crediting period and EF can be made. It can be now seen for how much time the project is having adequate levels of additionality. The values demarcating high, medium and low levels of additionality are region specific and should be chosen after surveying at least 10 villages in the same region where small hydropower projects is proposed to be set up.

11. Conclusion

In order to award genuine CDM projects and keep out possible bogus projects, additionality criterion is the only test available. Because of its highly subjective nature, additionality is a difficult criterion to be employed in actual field conditions. The paper suggests a new approach to judge the additionality of CDM projects. The projects considered are off-grid small hydro projects located in Indian Himalayas. Considering the need for electrification and CDM potential of small hydro, there are good chances that in future a lot many small hydro projects would come up for discussion in front of the CDM executive board. The approach followed in the paper can be helpful in a quick and accurate judgement of the additionality of these projects.

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