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Research article

Replication and scaling-up of isolated mini-grid type of off-grid interventions in India

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Abstract: Providing basic minimum energy services has become a real challenge for developing countries of the world. India encounters the problem of provisioning basic minimum electricity services to a section of her population. Renewable energy-based decentralised systems have emerged as a viable electrification option for many developing countries of the world, particularly for rural and remote areas of the country. This study explores the replication and scaling-up of potential of such mini-grids in the least electrified states of India by considering a set of evaluation criteria i.e. grid-extension option, renewable energy resource potential, electrification rate, organisational strength, presence or absence of technical support system, and ease of access to banking services. Overall rankings suggest that top 20% districts offer good business potential for private investors to venture into the mini-grid market. However, the concern lies with the districts placed at the bottom, which require specific government interventions through appropriate policy, regulatory and financial support.

Keywords: Isolated mini-grids; India; scaling-up; off-grid energy

1. Introduction

Electricity is one of the fundamental inputs for the development of any country, and it is one of the crucial parameters of socio-economic development of any nation. There are nearly 1.2 billion people (17% of world's population) who are deprived of the basic minimum electricity supply. South

Asia, being one of the least electrified regions of the world, shares about 35% of the total global population who do not have access to electricity. Within South Asia, 306 million people only in India lack access to electricity [1]. Providing basic minimum energy services has become a real challenge for countries like India [2].

Renewable energy has emerged as an effective alternative route to provide electricity to all [1]. UN's SE4ALL is a clear manifestation of the recent thrust on renewable energy as a viable alternative to the grid-based centralised electricity supply system, with its specific emphasis on renewable energy-based decentralised energy options. There exist several technological delivery models to provide electricity access through decentralised modes. Amongst them, mini-grids have emerged as cost effective, technologically suitable, and more sustainable option to provide electricity access to remote areas of a country [3]. One of the greatest challenges for the sector is to scale-up these initiatives as an alternative to the prevailing grid-based system. Given the diverse socio-economic profiles and varying resource endowment characteristics of the country, it is difficult to assume on priori that mini-grid type of interventions are feasible in all regions of the country. Exploring the feasibility of mini-grid type of interventions is a valuable exercise to ascertain as to what extent these interventions could serve as a viable alternative to the prevailing centralised electricity supply system. It is crucial to design and select certain criteria in a scientific manner in order to assess the feasibility of mini-grids in India.

In this back drop, the paper aims at assessing the feasibility of scaling up of mini-grids as an effective off-grid alternative option to the grid based systems. The feasibility assessment is carried out in an objective manner by applying a select set of criteria. Rest of the paper is organised as follows. Section II discusses the insights from the review of select literature in the domain. Section III explains the methodology and indicators used for the analysis of this study. Section IV maps the detailed estimation approaches for each of the indicators. Section V presents the key results derived from the study and the final section concludes the paper.

2. Insights from literature

Providing electricity to all regions through the national grid in India is quite a challenging task due to difficult geographical contours, existing dispersed population in remote locations, and lack of infrastructure services [4]. Many scholars argue that renewable energy-based off-grid systems could be considered as suitable electrification options for rural and remote areas. Studies point that renewable energy-based off-grid systems possess numerous advantages. These systems generate clean and sustainable energy, provide income generation opportunities to the local people, and these systems are also highly reliable due to proper designing of the system [5,6]. The use of locally available resources for electrification not only provides the basic minimum energy required for the sustenance of life, but also helps in promoting economic development of the area by generating productive employments. These systems operate at small-scale capacities, usually designed to meet local community needs and requirements. Overall, these systems are highly reliable, affordable, and environmentally sustainable [7-9]. However, there is not enough scientific evidence as to how to scale up these off-grid systems as means of electrification, particularly as a business venture. Though, scholarly efforts have been made to identify a set of parameters for effective designing of individual projects, it has really not gone beyond that. For example, Kumar et al. [10] emphasize on a standard procedure for deployment of mini-grid type of interventions in India. The paper suggests a decision making tool which can be useful for the project planning and project formulation and largely limited to address management issues associated with a single project. Similarly, Mishra and Sarangi [11] propose a sustainability framework based on a decision hierarchy. The study identifies a set of key determinants of successful decentralised interventions. However, the approach again limits to deal with issues arising at the project- level interventions. GSEP [12] in similar vein uses several criteria such as grid-electrification plans, customers/users, topography, and resource availability/potential for the assessment of renewable energy-based mini-grid for community rural electrification in South Africa. As mentioned above, in most of the scholarly efforts, feasibility mapping of off-grid interventions is limited to the assessment at the project level. However, a recent study by Sanyal [13] proposes a methodology to assess the feasibility of off-grid energy products and services beyond project level by considering administrative boundary of district as the unit of analysis. The target districts are selected on the basis of a set of criteria such as high non-electrification rate, high percentage of rural households having bank accounts, strong growth in percentage of rural households owing assets between 2001 and 2011, and slow decrease in non-electrification or sluggish activity between 2001 and 2011. Building on Sanyal's study [13], the present study attempts to assess the feasibility of mini-grids in India in a holistic fashion by considering a set of criteria. The next section elaborates in detail the methodology adopted for the study.

3. Study design

The present study takes into account a set of criteria to assess the feasibility of scaling-up of mini-grids at the district-level in India. As emerged from the studies mentioned in the previous section, a set of criteria is crucial for assessing the feasibility of mini-grid type of interventions and is largely drawn from literature as well as selected expert consultations. The set of criteria considered for the study are levelised unit delivered cost of electricity, percentage of household electrification, percentage of households availing bank accounts, organisational strength, presence/ absence of technology support systems and renewable energy resource potential. Levelised unit delivered cost of electricity (LUCE) for grid electricity has been identified as an important criterion to assess the feasibility of decentralised energy intervention by other scholars too [14]. Similarly percentage of household electrification and percentage of households availing bank accounts as important criteria for assessing the feasibility of decentralised electrification systems have also been considered crucial for scaling up of mini-grids [13]. In addition, several other scholars in the field [8,15] also have suggested renewable energy resource potential as one of the important criteria [8,15]. While we draw insights and evidences from earlier scholarly efforts in this domain, at the same time, we also conducted a series of expert consultations working in this area, in order to identify additional criteria, particularly relevant in the context of India. Our interviews with experts led us to incorporate two more additional criteria; 1) organisational strengths and; 2) presence/absence of technology support systems. One of the major constraints we encountered while operationalizing these criteria was the lack of required data to measure the set of select criteria. This constraint arose, as we focus our analysis at the district level in India. Given the data availability related challenges, we were compelled to employ some proxy set of indicators as representative indicator for the chosen set of criteria. The detail set of indicators chosen for the study are presented below.

1. Levelised unit delivered cost of electricity (LUCE)
2. % of rural household electrification

3. % of rural households availing bank accounts
4. Presence/absence of NGOs as a proxy indicator for organisational strength
5. Solar resource potential and biomass resource potential of the region as proxy for renewable energy resources
6. Presence of Akshay Urja shops as proxy indicator for technology support system

The first and foremost criterion is to find the financial viability of mini-grid systems vis-à-vis grid electricity in the district. We employ the methodology adopted by Nouni et al. [14] to estimate the delivered cost of unit electricity from centralised supply system. The second step is to identify the least electrified districts. This can be elicited from the information on percentage of rural household electrification rate. This criterion helps to identify gap in the electrification of that particular district. Lower the household electrification rates higher the chances of deploying mini-grids and vice versa. Third crucial criterion is about ease of access to banking services. It is mapped on the basis of the data on percentage of households having bank accounts. A fourth, important criterion is to assess the organisational strength. We propose a simple measure of mapping of presence of NGOs in a district with specific focus on NGOs working in the larger domain of energy and environmental arena as a proxy for organisational strength. Higher the numbers of NGOs in a district indicates better the organisational strength and consequently better the chances of scaling up of mini-grid systems and vice versa. Fifth most important criterion is the renewable energy resource potential of the district. Building on the data on various forms of renewable energy resource mapping, we could make a distinction of districts and their suitability for resource specific technology interventions such as solar, and biomass. However, for the present purpose, we limit our study to two different varieties of resources i.e. solar and biomass. Last important criterion is the presence of technology support systems. We propose to capture this by mapping the presence or absence of Akshya Urja shops[1] in a district. This criterion intends to measure the strength of technical support system available in a district. Figure 1 shows the schematic indicating the methodological framework.

While attempt has been made to be holistic in measuring the criteria which will have significant bearings on scaling up of mini-grid type of interventions, a caveat is in order regarding the select set of criteria. The nature and characteristics of the select set of criteria differ across the criteria. For instance, while some indicators estimate the quantitative values (e.g. levelised costs), some others cannot be changes easily (e.g. available renewable energy resources), still some others can easily be changed (e.g. no. of Akhaya Urja outlets). Therefore, it is indeed essential to know the chosen set of criteria is neither sacrosanct nor complete, rather offer some indicative guidance for project selection. Household's affordability has been suggested by scholars as one of the important criteria for feasibility assessment, which requires data on household income and expenditure. However, data constraints act as barrier to incorporate this in the chosen set. However, the criteria 'households availing bank accounts' to some extent is indicative of the households state of affordability.

[1] Akshay Urja shops are retail outlets, promoted by the Ministry of New and Renewable Energy (MNRE), Government of India for sale and service of renewable energy products. MNRE is considering the district level as the basic administrative unit for the promotion of renewable energy products by introducing at least one Akshay Urja shop at every district, and planning to establish those shops in all the districts of the country in the near future.

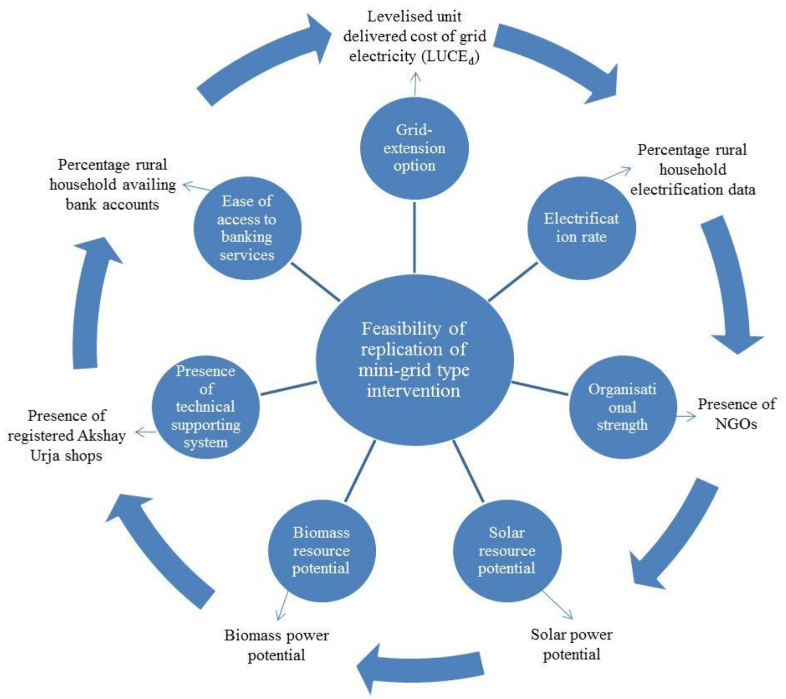

Figure 1. Schematic indicating the methodological framework.

3.1. Scale and scope of the study

One of the key challenges for us was to decide the scale of analysis. Since feasibility of mini-grids is contingent upon multiple factors placed at different scales, it is really difficult to select the appropriate scale for analysing the feasibility of such interventions. Scale of analysis differs for different type of decentralised energy interventions; there have been various models operating at cluster-levels, project-levels, and district levels. While, most of the studies concentrate on village/project level as unit of analysis, a few have indicated higher level of administrative units as the basic unit of analysis (e.g. district level analysis [13]. We highlight certain examples, where scale of analysis differs for different type of decentralised energy interventions. MNRE is considering district level as the basic administrative unit for the promotion of renewable energy products by introducing at least one Akshay Urja shop at every district, and planning to establish those shops in all the districts of the country. Similarly, existing mini-grid models in the country such as Husk power systems (HPS), Mera Gao power (MGP), Chhattisgarh solar mini-grid models, Sunderban solar mini-grid models operating in West Bengal consider cluster based approach for O & M of these systems. These cluster based approaches consider either a cluster of several villages or a cluster of households as the scale for O & M of the projects. However, there is no consensus on what constitutes a cluster. While each cluster in Chhattisgarh solar mini-grid models comprises of between 10 and 15 villages, in case of HPS, a cluster constitutes 2 to 4 villages with a capacity between 50 and 400 households. On the other hand, in Sunderban, a cluster consists of 50 to 250 households [16-18]. Given the criteria spelt out above, associated with the difficulty in defining the scale of analysis, we propose district as the basic administrative unit for our analysis.

Next important methodological issue is the scope of the study. There are about 168 million rural households in India. The average rural household non-electrification rate of India is about 44.7% [29]. However, the rural household non-electrification rates vary among states ranging between 0.24% to almost 90%. Several states such as Assam, Bihar, Jharkhand, Meghalaya, Odisha, Uttar Pradesh, and West Bengal, are having higher non-electrification rates compared to the national average rate. Figure 2 highlights the rural household non-electrification rates across states in India. The present study focuses on those states which have higher national average rural household non-electrification rates such as Assam, Bihar, Jharkhand, Meghalaya, Odisha, Uttar Pradesh, and West Bengal. However, given the small size of Meghalaya, we have excluded it from our analysis. In addition, Meghalaya is the only state, which does not have a single Akshay Urja shop [220].

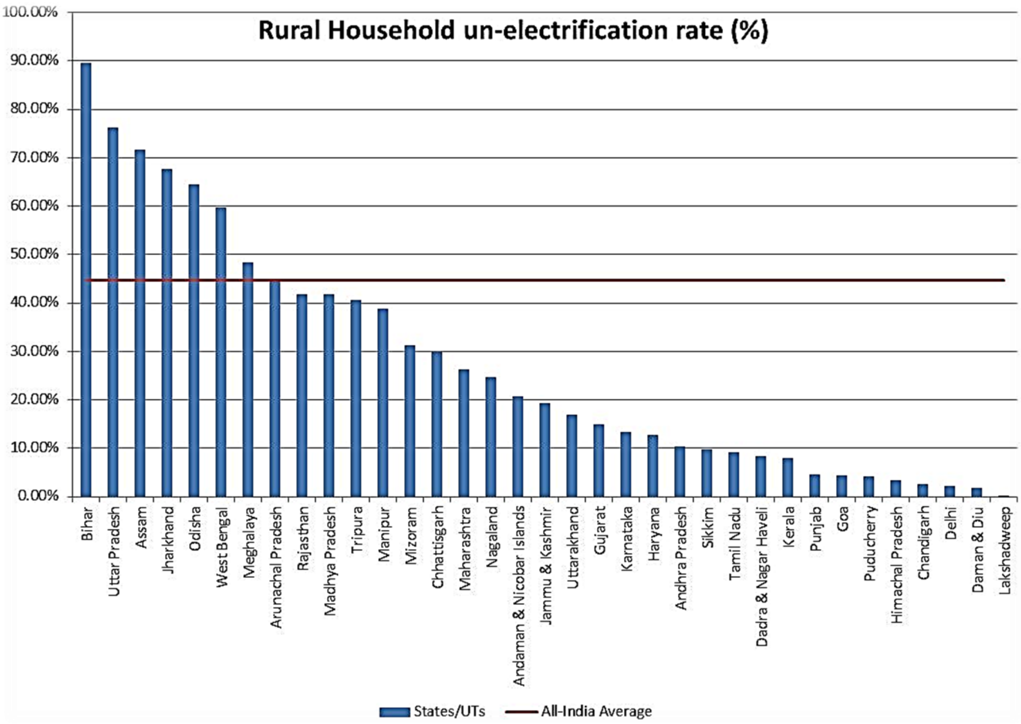

Figure 2. Rural household un-electrification rate in India (Source: Census, 2011).

The next section presents in detail the estimation approaches for the chosen set of indicators.

4. Estimation approaches for the individual indicators

4.1. Levelised unit delivered cost of grid electricity

Levelised unit delivered cost of grid electricity (LUCE) comprises of three sequential costs such as levelised unit cost of electricity generation ($LUCE_g$), levelised unit transmission cost of electricity ($LUCE_t$) from the generation station to the end-users, and levelised unit distribution cost of grid electricity ($LUCE_d$) through the distribution network lines. Levelised unit cost of electricity generation varies according to the source of the power generation such as thermal coal, oil, large hydro, nuclear, and renewables. Levelised unit cost of electricity transmission is the wheeling charge decided by the state electricity regulatory commissions (SERCs). Levelised unit cost of distribution of grid electricity varies for different locations due to the capital cost of the transformer, cost of distribution networks with respect to the distance to be installed, geographical locations, peak load of the village/community, and load factor. Due to the constraints in finding the capital cost of transformer, and the costs required for laying down the distribution network for each location/district, we have taken two boundaries depending on whether the region is a plain region or a hilly region. In order to differentiate the cost of distribution of electricity for each geographical location, we have categorised the districts into two different groups such as plain districts and hilly districts. Annexure 1 gives the list of districts and its geographical status of all states. The $LUCE_d$ for the hilly districts differs from the $LUCE_d$ derived for the plain districts due to the difficulty in deploying the distribution networks in the hilly regions compared to the plain regions.

4.1.1. Levelised unit cost of electricity generation ($LUCE_g$)

More than 80% of electricity for the centralised grid in India comes from thermal power plants using coal and natural gas, while about 15% comes from hydropower stations and the rest from nuclear and renewable energy sources. At present, the installed capacity of coal-based thermal power plants in India is about 153.5 GW, which is about 60% in total installed capacity of the country. Coal-based thermal plants constitute major source of electricity generation for almost all the study states except Assam[2]. The other resources such gas, diesel, and nuclear are not much available in these states. Given the importance of thermal energy in these states, we limit our analysis only to coal based electricity generation for LUCE calculation. The $LUCE_g$ is the ratio between the annualised capital costs of the power plant to the electricity output of the plant [14]. The total annualised cost of the coal thermal power plant is

$$\text{Total annualised cost of coal thermal power plant} \\ = \left[\left(C_o \times CRF\right) + 8760 \times PLF \times P\left(c_{scc} \times p_c + o_{soc} \times p_o\right) + \left(m \times C_o\right)\right]$$

$$\text{Electricity output of coal thermal power plant}\left(E_o\right) = \left[8760 \times (1-a) \times PLF \times P\right]$$

Where the C_O is the capital cost of the power plant, CRF is the capital recovery factor, p_c and p_o is the average unit cost of coal and oil respectively, c_{scc} and o_{soc} is the specific coal consumption and specific fuel oil consumption respectively, m is the fraction of operation and maintenance (O & M) costs to its capital cost, PLF is the plant load factor of the power plant to its rated capacity (P). Table 1 shows the parameters taken for the estimation of levelised unit cost of electricity generation. The levelised unit cost of generation of electricity from coal based thermal power plants for the study states is estimated to be Rs. 1.02 per kWh.

[2] For instance, coal based power plants contribute about 89% of electricity generation in Bihar, almost close to 90% in Jharkhand, 73% in Odisha, 75% in Uttar Pradesh, and 83% in West Bengal. (Figure 3)

Table 1. Parameters and value for estimation of levelised unit cost of electricity generation Source: [14,22-24].

Parameter	Value
Size of the plant (kW)	1000
Capital cost of the plant (Rs.)	40000000
Average heat rate of the plant (kilojoules/kWh)	10892
Specific fuel oil consumption (ml/kWh)	1.83
Average calorific value of fuel oil (kilojoules /litre)	42340
Average calorific value of coal (kilojoules /kg)	17497
Auxiliary power consumption (% of total generation)	8.44
Plant load factor (%)	73.32
Average unit cost of coal (Rs./tonnes)	1000
Average unit cost of oil (Rs./kl)	10000
Fraction O &M cost to its capital cost of the power plant	0.04
Useful life of the plant (years)	25
Interest rate (%)	10.00

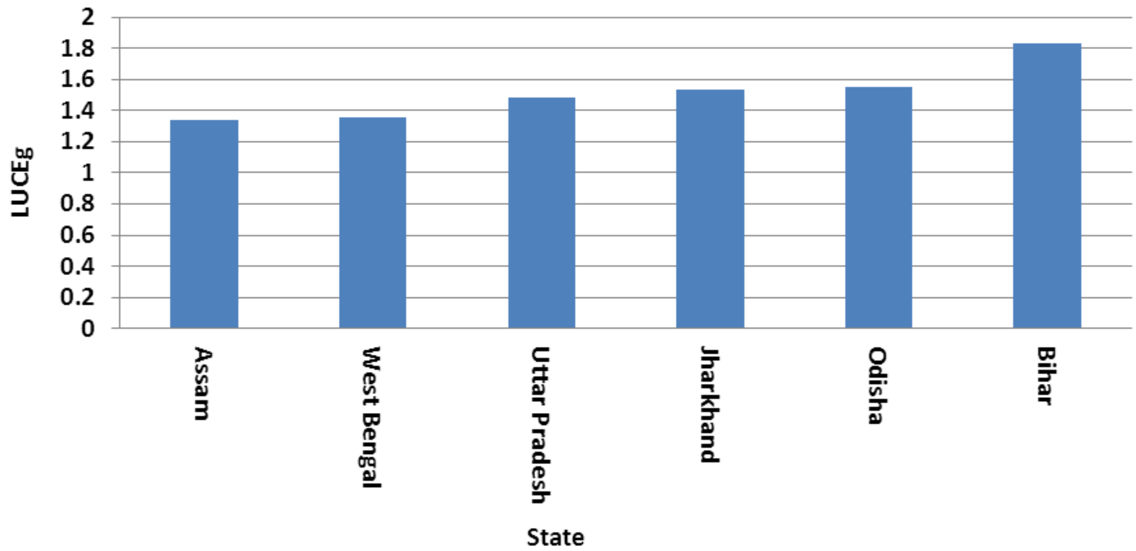

Figure 3. The levelised unit cost of generation for coal based thermal power generation units.

4.1.2. Levelised unit cost of transmission of electricity (LUCE$_t$)

Levelised unit cost of transmission is the cost required for the transmission network for the transmission of electricity from the generation to the distribution network. The transmission cost for per unit of electricity is different for each state. For 2012–2013, the transmission cost of per unit electricity is Rs. 0.70 for Assam, Rs. 0.37 for Bihar, Rs. 0.70 for Jharkhand, Rs. 0.25 for Odisha, Rs. 0.62 for Uttar Pradesh, and Rs. 0.50 for West Bengal [24-28].

4.1.3. Levelised unit cost of distribution of electricity ($LUCE_d$)

The cost of distribution of electricity depends on various components of distribution network such as the capital cost of step down transformer, and cost of installation of LT (low-tension) distribution network lines to carrying electricity to the end-use. These component costs vary across different geographical locations such as plain terrain and hilly terrain. The levelised cost of distribution of electricity ($LUCE_d$) is estimated by using the following expression,

$$(LUCEd) = \frac{[C_T + (0.5 \times x \times C_{11}) + 0.25 \times x \times (C_{4W} + C_{2W})] \times [CRF + m]}{[8760 \times P_{PL} \times LF]}$$

Where C_T is the capital cost of the step down transformer (11 kV/433 kV), C_{11}, C_{4W}, and C_{2W} are the unit costs of 11 kV distribution line, unit cost of three-phase four wire distribution line, and unit cost of single-phase two wire distribution line respectively, x is the length of the distribution line is to be extended, m is the fraction of O&M of distribution network towards the total capital cost of distribution system, P_{PL} is the peak load in the village, and LF is load factor in the village where the electricity is to be served. Drawing from other studies [32,33], it is assumed that the peak loads[3] in rural areas in India varies with the geographical distribution of the village and ranges between 5 kW and 100 kW with the load factor of 0.2 to 0.8. We also assume that the distance of LT distribution network line ranges between a minimum of 5 km to a maximum of 25 km.

4.1.4. Levelised unit delivered cost of grid electricity

Figure 4 presents the two extreme cases where LUCE is estimated for each state for two different categories of region i.e. plain and hilly. It is evident from the figure that LUCE for hilly regions are higher compared to plain regions due to high transmission and distribution cost of electricity to those regions.

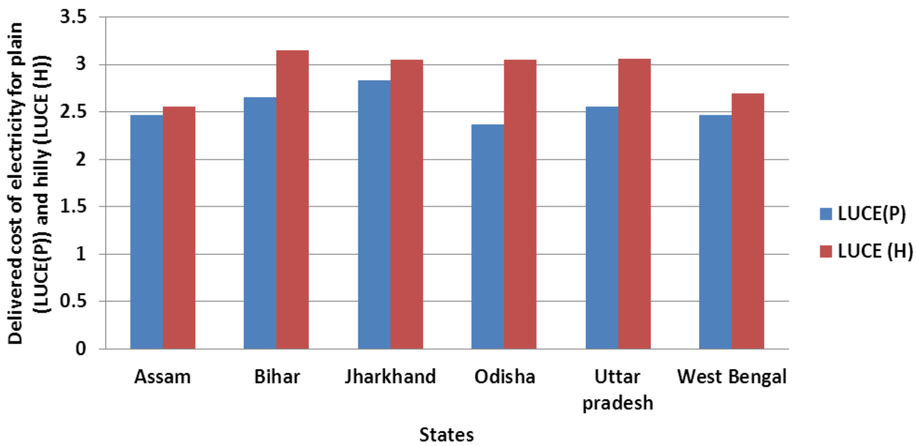

Figure 4. Levilised unit cost of electricity (LUCE) for plain and hilly districts.

[3] The peak load of a typical village in India includes household lighting, community/commercial loads, water (irrigation) pumping, entertainment loads such as television, radio, and small-scale industrial loads. The average peak load for rural households in India is 0.335 kW[3] [34].

4.2. Electrification rate

The second most important indicator is the finding the electrification rate for the individual districts of the state. This is very straight forward. This can be elicited from the information on percentage of rural household electrification rate for each district from Census data. The main source of lighting in India is from electricity, kerosene, solar energy, and other sources such as oil and biomass [19]. The rate of non-electrified rural household excludes the household connected to grid electricity for their lighting source. The average rural household un-electrification rate of India is about 45% [19]. The average rates of non-electrified rural households for the study states are as follows. For Bihar, it is 89.6 %; for Uttar Pradesh, it is 76.2 %; for Assam, it is 71.4 %; for Jharkhand, it is 67.6 %; for Odisha, it is 64.4 %; and for West Bengal; it is 59.7 %.

4.3. Organisational strength

As we mentioned above, presence of NGOs in a district with specific focus on NGOs working on energy and environmental domain is taken as a proxy to measure the organisational strength. The number of NGOs in India is estimated to be around 2 million working in multiple sectors such as culture, health and family welfare, social justice and empowerment, child and women development, education, rural development and livelihoods, and energy and environment. We confine our analysis by only considering NGOs working on energy and environmental domains. The main data for this indicator is taken from NGOs and/or Voluntary Organisations (VOs) registered with the Planning Commission of India under the NGO Partnership System [35]. There are around 6753 NGOs working on energy and environmental issues registered under the NGO partnership system. It is assumed that higher the number of NGOs present in a district indicates better the organisational capability of that district to manage decentralised mini-grid type of projects.

4.4. Renewable energy potential

Assessing the feasibility of mini-grids requires assessment of resource potential of that district. Renewable energy resources such as solar PV, biomass gasification, and small hydro based mini-grids systems are best possible options for South Asia [36]. For the present study, only biomass and solar energy resources are considered for analysis. Solar PV and modern biomass gasifier are also identified as most suitable resources for electrifying rural areas through mini-grids [37]. The annual resource potential for biomass and solar is calculated from the Biomass Atlas of India published by Indian Institute of Science (IISc) and NREL solar radiation data respectively [38,39]. The resources are calculated on the basis of their total annual possible power generation capacity in a district. The total annual biomass power generation indicates the total biomass resource availability including agro residue, forest, and wasteland residues in a district. The total annual available solar power capacity of the district is estimated by using certain parameters[4] such as solar radiation (kWh/m^2/day) [39], total wasteland available [40], and total sunny days [41].

4.5. Presence of technical supporting system

As mentioned above, presence of Akshay Urja shops in a district is taken as a proxy indicator for the status of the technical support system. As mentioned elsewhere in the paper, we understand the limitation of this indicator as a proxy indicator for technical support system. However, due to data related constraints we were unable to consider any other indicator for this. The presence of Akshay Urja shops is assumed to provide technical support to the decentralised mini-grid systems. Akshay Urja shops are set up by the MNRE in order to mainstream the renewable energy products in a district. There are about 326 Akshay Urja shops in the country as of 31 January 2013 [20].

4.6. Ease of access to banking services

This criterion will help to identify the rural socio-economic profile of the district. We capture this by taking the data on percentage of households that have bank accounts. Higher the percentage of rural household bank accounts indicates better socio-economic status and vice-versa. This indicator is measured by using the Census data on rural households availing bank accounts. The average rural households availing bank accounts in India is about 55%. However, it varies from state to state ranging between 23% at the lowest to 90% at the highest. States chosen for the present study have less than the national average figure as far as this particular indicator is concerned [19].

5. Results and discussion

While the above section elaborates the individual indicators and ways of measuring them, the real challenge is to aggregate them in a scientific way in order to rank districts based on the combined performance of all the indicators and to draw some meaningful insights. Aggregation requires some sort of normalisation. Since the indicators are measured in different units; we have adopted simple normalisation method[5] to make these individual indicators unit free. This is followed by aggregating individual indicators for every district of all the study states. This ultimately helps us in ranking districts on the basis of their feasibility for mini-grid type of intervention. For analysis of individual states, we present the ranking of districts for individual states separately. We also identified top 10% and bottom 10% districts for each of the study states on their basis of their ranks in order to identify most feasible and least feasible districts for each state under consideration. We present ranking of districts for each state separately. We start with Assam.

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[4] In the present case, we have assumed total sunny days of about 275 days in a year and efficiency of the solar systems of about 15% [41] and land-use factor[4] is taken as 0.4 (from the existing project by L&T). As per MNRE, 3% of wasteland in the region is used for solar power projects [42]. So, the solar resource potential also takes into account the 3% available total waste land of the district.

[5] $\text{Value} = \frac{X - \text{Min}}{\text{Max} - \text{Min}}$, where X is the actual value of that particular district, Max and Min are the maximum value and minimum value of the combined districts.

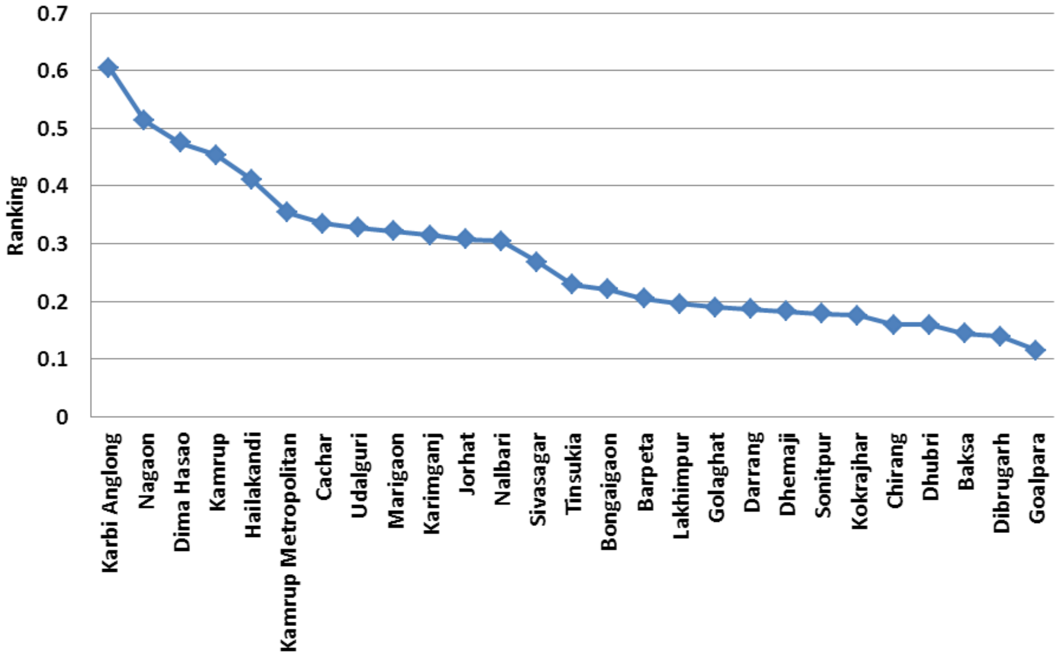

Figure 5. Districts in Assam ranked on the basis of their feasibility for mini-grid intervention.

For the state Assam, Karbi Anglong, Nagaon, and Dima Hasao (North Cachar Hills) are the most feasible districts for mini-grid type of intervention. A cursory look at the individual indicators reveals that these are districts which have not performed well even in individual dimensions. For example, Karbi Anglong is the district having high rural household non-electrification rate of about 77.4%, which is higher than the average household non-electrification rate of Assam. Along with this, Karbi Anglong has also good renewable energy resource potential. However, absence of Akhay Urja shops representing the proxy for technical support system is making this indicator weak, therefore may act as a hindrance for project developers. On the other hand, Goalpara, Dibrugarh, and Baksa are the least potential districts for mini-grid type of intervention in Assam. This is primarily because of absence of MNRE designated Akshay Urja shops, combined with absence of registered NGOs working in the domain of energy and environment. In addition, these districts have very poor biomass and solar energy resource potential. Further, out of these three districts, Goalpara and Dibrugarh districts have lower non-electrification rate of 64.2% and 60.2% respectively, which are better when compared to the other districts in the state. Figure 5 shows the ranking of districts for the feasibility of replication of mini-grids in Assam.

In case of Bihar, most of the districts are potential districts for mini-grids, primarily because of high non-electrification rates (e.g. out of 38 around 34 districts have more than 80% of rural household non-electrification rate). In addition, it is estimated that for extending 5 km of distribution network in the hilly districts, the delivered cost of electricity is as high as Rs. 351/kWh, indicating greater possibility of mini-grid type of intervention. Gaya, Rohtas, Katihar, and Nalanda are the most potential districts for the mini-grid type of intervention in Bihar. The presence of Akshay Urja shops in all the four districts indicates the better organisational strength present in these districts. Figure 6 shows the ranking of districts on the basis of their feasibility for mini-grids in Bihar. Darbhangra is the least potential district in Bihar, the district has better presence of NGOs and better biomass resource power potential, but it has low socio-economic profile and poor solar energy potential. Similarly, poor renewable energy resource potential and absence of technical support system are key reasons behind the low performance of districts such as Lakhisarai and Monghyr in Bihar. In case of Khagaria, though non-electrification rate is high among the least performing districts but the socio-economic profile of the district and weak presence of NGOs make the district as one of the low performing districts in Bihar for mini-grid type of intervention. In these districts, it is essential to promote government led or government supported electrification interventions.

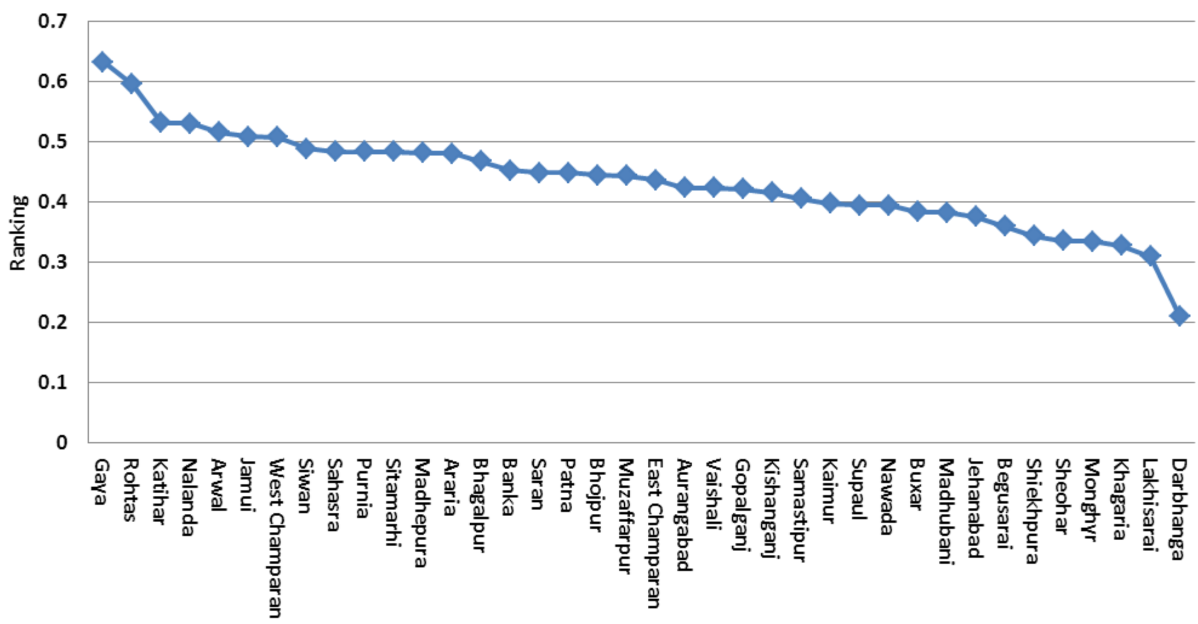

Figure 6. Districts in Bihar ranked on the basis of their feasibility for mini-grid intervention.

In case of Jharkhand, Ranchi, Hazaribagh, and Palamu are the most potential districts for mini-grids. In case of Ranchi, even though it has a rural household non-electrification rate of 56.8%, lower than many other districts in Jharkhand, the district has very good socio-economic profile and has very good solar and biomass energy resource potential. Organisation strength represented through presence of NGOs is also relatively better in Ranchi. There are about 34 NGOs in Ranchi out of 104 present in the state. Therefore, Ranchi emerges as the most potential district for scaling-up of mini-grids. Hazaribagh is the second best suited district; it has very good socio-economic profile compared to Ranchi and has a better organisational strength and has better renewable energy resource potential. Figure 7 shows the ranking of districts on the basis of their feasibility of replication of mini-grids in Jharkhand. Ramgarh district ranks as the least performing district for mini-grid intervention in the state. The district has very low rural un-electrification rate of around 22.8%, and also has weak organisational strength. Simdega and Pakur districts are ranked next to Ramgarh, both the districts have high non-electrification rates, but absence of NGOs and weak socio-economic profile make the districts un-attractive for private investors to support mini-grids in these districts for mini-grid type of intervention. Therefore, some form of government support is required to electrify these districts.

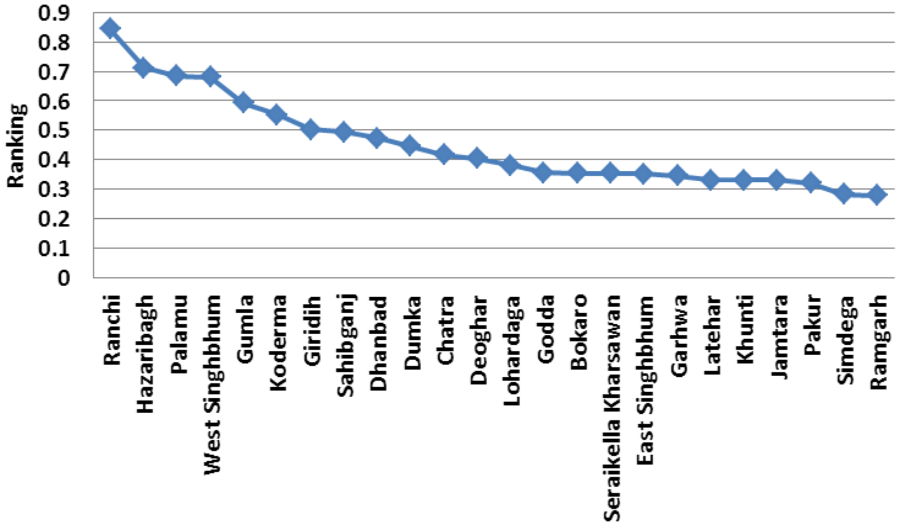

Figure 7. Districts in Jharkhand ranked on the basis of their feasibility for mini-grid intervention.

In case of Odisha, Koraput, Sundargarh, and Kandhamal districts are ranked most potential districts for mini-grid type of intervention. These are the districts with high un-electrification rates in the state i.e. about 75%, and possess good organisational strength as measured through presence of NGOs. The high solar and biomass energy potential put Koraput ahead of Sundargarh and Kandhamal. Sundargarh ranked second due to its better socio-economic profile than Kandhamal. The final ranking of districts in Odisha for feasibility of mini-grid type of intervention is shown in Figure 8. Bhadrak, Jajpur, and Balasore (Baleswar) are bottom ranked districts in Odisha for feasibility of replication of mini-grids. These districts have rural household un-electrification rates ranging between 47 to 55%. Even though the district Bhadrak has better socio-economic profile, but it has very poor solar and biomass energy potential, and has weak organisational strength (as only one NGO is present in the district) and almost half of the rural households in the districts has been already electrified. Similarly, Jajpur has rural non-electrification rate of about 55% which is lower than the state average un-electrification rate. Nabarangur district in Odisha needs a special attention from the both Government and private investors; the district is the least electrified in Odisha with 91% non-electrification rate combined with and poor socio-economic profile with 21% of households availing bank accounts. Due to its poor renewable energy potential and poor presence of NGOs, it is ranked as one of the bottom performing districts in Odisha. Interestingly, out of 326 Akshay Urja shops spread out in the country, only a meagre 2 such outlets are present in Odisha, which indicates the lack of focus of MNRE in promoting decentralised energy systems in Odisha.

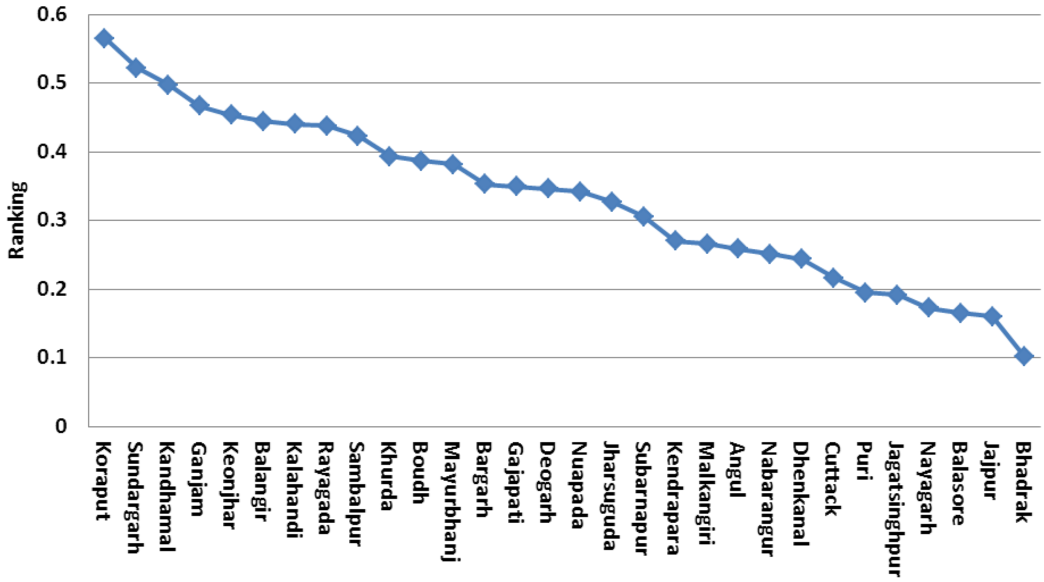

Figure 8. Districts in Odisha ranked on the basis of their feasibility for mini-grid intervention.

Uttar Pradesh is the largest state in India of having 71 districts and is one of least electrified states in India with more than 75% of the rural households are not-electrified. There are 60 Akshay Urja shops present in 60 Districts in Uttar Pradesh. Jhansi is ranked as the most potential district for feasibility of mini-grid intervention in Uttar Pradesh. The district has very good socio-economic profile. The district also has good solar and biomass energy potential. The capital district Lucknow is ranked next to Jhansi. Lucknow is having a very good organisational strength compared to other districts in the state, and also it has high rural household non-electrification rate (which is about 70%). The district has around 111 NGOs working in the domain of energy and environment. All these indicators put the district as one of the most potential districts for the feasibility of mini-grids. Hathras (Mahamaya Nagar), Sant Ravidas Nagar, Aligarh, and Kaushambi are the least performing districts in Uttar Pradesh. Hathras has weak organisational strength as only one NGO is present in the district and also has low renewable energy resource potential. Also, the district has low non-electrification rate of about 57%. Out of 70 districts in Uttar Pradesh, Hardoi, even though has the maximum non-electrification rate, (i.e. about 93%) and has very good solar and biomass energy potential, better presence of NGOs, better technical support system too, and about 68% of rural households availing bank accounts) it is not coming in the top 10% of the potential districts largely because of some individual indicators compared to most potential districts. However, this could be one of the most potential districts in the state. Figure 9 shows the ranking of districts for the feasibility of replication of mini-grids in Uttar Pradesh.

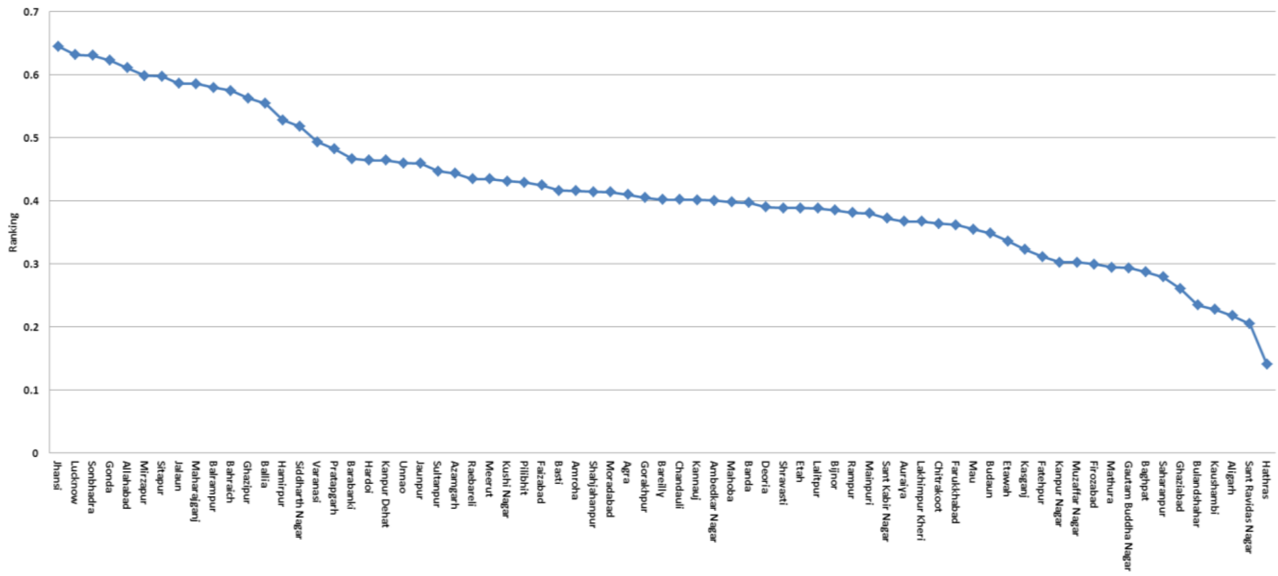

Figure 9. Districts in Uttar Pradesh ranked on the basis of their feasibility for mini-grid intervention.

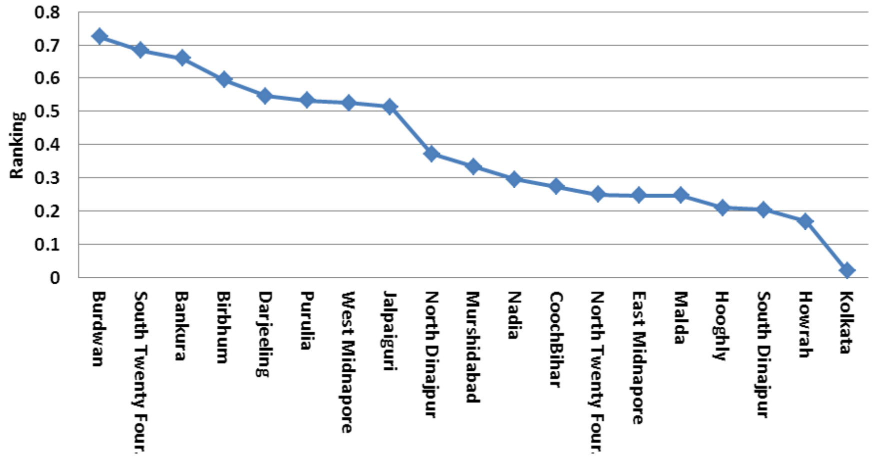

Figure 10. Districts in West Bengal ranked on the basis of their feasibility for mini-grid intervention.

In the state of West Bengal, 15 out of 19 districts have non-electrification rates more than 50%. We have not considered Kolkata district as it does not have any rural population. Bardhaman comes out to be the most potential district even though the un-electrification rate of the district i.e. 51% is less than the mean un-electrification rate of the state. But, the district performs better in other indicators. All this makes the district a better place for the development of mini-grid type of intervention. South Twenty Four Parganas is ranked next to Bardhaman, due to high rural household un-electrification rate and better solar and biomass energy resource potential. The district also has better the presence of technical support system and has a strong supporting system (About 50% of NGOs out of total NGOs present in West Bengal are present in this district). Howrah is the bottom performing district for mini-grid intervention in West Bengal. This is one of the high electrified districts in the state of having 37.98% of rural un-electrification rate and has very less wasteland available for deploying renewable energy projects. Figure 10 shows the ranking of districts for the feasibility of replication of mini-grids in West Bengal.

While the above paragraphs highlight in detail the state wise picture, we here present (Table 2) the top 20 most and bottom 20 least potential districts (10% of the total districts for all the study states) drawing from our analysis. Normalised values for all the districts across the study states are given in Annexure 2.

Table 2. Top and bottom 20 performing districts for scaling-up of mini-grid intervention.

Top 20 districts	Bottom 20 districts
Ranchi	Lakhimpur
Bardhaman (Burdwan)	Puri
Hazaribagh	Jagatsinghpur
Palamu	Golaghat
South Twenty Four Parganas	Darrang
Pashchimi Singhbhum (West Singhbhum)	Dhemaji
Bankura	Sonitpur
Jhansi	Kokrajhar
Gaya	Nayagarh
Lucknow	Howrah
Sonbhadra	Balasore (Baleswar)
Gonda	Jajpur
Allahabad	Dhubri
Karbi Anglong	Chirang
Mirzapur	Baksa
Sitapur	Hathras (Mahamaya Nagar)
Rohtas	Dibrugarh
Birbhum	Goalpara
Gumla	Bhadrak
Jalaun	Kolkata

The top 20% of districts are the most potential districts for renewable energy-based mini-grid type of interventions based on the set of criteria chosen for the study. It also implies that these are the districts where private investors will prefer to venture in. However, concern lies with the districts placed at the bottom. Most of these districts have weak institutional arrangements, poor socio-economic profiles, and poor renewable energy resource potentials. These districts need special attention from the government through appropriate policy and regulatory support as well as financial support. These are districts, where provisioning of electricity should be made as a merit good.

6. Conclusion

Among the several technological options for energy access, mini-grid is argued to be one of the best suited options for electrification in remote and rural areas in the country. Scaling-up of mini-grids for electrification as a substitution for conventional grid system is a real challenge for India. The aim of the paper is to assess the feasibility of scaling-up of mini-grids in India based on a set of criteria such as grid-extension option, electrification rate, organisational strength, resource potential, ease of access to banking services, and presence of technical supporting system. The proposed framework helps to rank the districts for the feasibility of replication of mini-grid type of intervention in India. The study reveals that the delivered cost of electricity in many rural and remote villages in India is high due to the poor load factor, small number of households, and remoteness of the village. So providing electricity to these villages is economically not viable. The framework primarily will aid the project investors and developers to choose districts potential for mini-grid type of interventions. The rural household non-electrification rate, presence of Akshay Urja shops, rural household availing bank accounts will helps to identify the remoteness of the area and development required for energy access.

Overall ranking analysis suggests that the top 20% of districts indicate that these districts are the most potential districts for renewable energy-based mini-grid type of interventions based on the set of criteria chosen for the study. It also implies that these are the districts where private investors will prefer to venture in. However, concern lies with the districts placed at the bottom. Most of these districts have weak institutional arrangements, poor socio-economic profiles, and poor renewable energy potentials. These districts need special attention from the government through appropriate policy and regulatory support as well as financial support.

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Conflict of interest

The views expressed in this report are those of the authors and do not necessarily represent the views of the institutions they are affiliated to or the funding agencies.

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Annexure 1. Districts and its geographical status.

Assam	Bihar	Jharkhand	Odisha	Uttar Pradesh	West Bengal
Plain districts					
Baksa	Aurangabad	Bokaro	Angul	Aligarh	CoochBihar
Barpeta	Begusarai	Chatra	Balasore	Ambedkar Nagar	Dakshin Dinajpur
Bongaigaon	Bhojpur	Deoghar	(Baleswar)	Amroha (Jyotiba Phule Nagar)	(South Dinajpur)
Chirang	Buxar	Dumka	Bhadrak	Auraiya	Hooghly
Darrang	Darbhanga	Garhwa	Cuttack	Azamgarh	Howrah
Dhemaji	East Champaran	Giridih	Dhenkanal	Baghpat	Kolkata
Dhubri	Gopalganj	Godda	Gajapati	Barabanki	Malda
Dibrugarh	Jamui	Gumla	Ganjam	Bareilly	Murshidabad
Goalpara	Jehanabad	Jamtara	Jagatsinghpur	Basti	Nadia
Golaghat	Kaimur	Khunti	Jajpur	Bijnor	North Twenty Four
Jorhat	Lakhisarai	Latehar	Kendrapara	Budaun	Parganas
Kamrup	Monghyr	Lohardaga	Keonjhar	Bulandshahar	Purba Medinipur
Kamrup Metropolitan	Muzaffarpur	Pakur	(Kendujhar)	Chandauli	(East Midnapore)
Kokrajhar	Nawada	Purbi Singhbhum	Khurda	Chitrakoot	Uttar Dinajpur
Lakhimpur	Patna	(East Singhbhum)	Malkangiri	Deoria	(North Dinajpur)
Nalbari	Samastipur	Ramgarh	Mayurbhanj	Etah	
Sivasagar	Saran	Seraikella Kharsawan	Nabarangur	Etawah	
Sonitpur	Sheohar	Simdega	Nayagarh	Faizabad	
Tinsukia	Siwan		Puri	Farukkhabad	
Udalguri	Supaul		Rayagada	Fatehpur	
	Vaishali			Firozabad	
	West Champaran			Gautam Buddha Nagar	
				Ghaziabad	
				Gorakhpur	
				Hardoi	

	Hathras (Mahamaya Nagar)
	Kannauj
	Kanpur Dehat
	Kanpur Nagar
	Kasganj (Kanshiram Nagar)
	Kaushambi
	Kushi Nagar (Padrauna)
	Lakhimpur Kheri
	Lalitpur
	Mahoba
	Mainpuri
	Mathura
	Mau
	Moradabad
	Muzaffar Nagar
	Pratapgarh
	Raebareli
	Rampur
	Saharanpur
	Sant Kabir Nagar
	Sant Ravidas Nagar
	Shahjahanpur
	Shravasti
	Sonbhadra
	Sultanpur
	Unnao

Hilly districts

Cachar	Araria	Dhanbad	Balangir	Agra	Bankura
Dima Hasao (North Cachar Hills)	Arwal	Hazaribagh	Bargarh	Allahabad	Bardhaman (Burdwan)
Hailakandi	Banka	Koderma	Boudh	Bahraich	Birbhum
Karbi Anglong	Bhagalpur	Palamu	Deogarh (Debagarh)	Ballia	Darjeeling
Karimganj	Gaya	Pashchimi Singhbhum (West Singhbhum)	Jharsuguda	Balrampur	Jalpaiguri
Marigaon	Katihar	Ranchi	Kalahandi	Banda	Paschim Medinipur (West Midnapore)
Nagaon	Khagaria	Sahibganj	Kandhamal	Ghazipur	Purulia
	Kishanganj		Koraput	Gonda	South Twenty Four Parganas
	Madhepura		Nuapada	Hamirpur	
	Madhubani		Sambalpur	Jalaun	
	Nalanda		Subarnapur	Jaunpur	
	Purnia		Sundargarh	Jhansi	
	Rohtas			Lucknow	
	Sahasra			Maharajganj	
	Shiekhpura			Meerut	
	Sitamarhi			Mirzapur	
				Pilibhit	
				Shravasti	
				Siddharth Nagar	
				Sitapur	
				Varanasi	

Annexure 2. Normalised value of each parameter.

a. Assam

Name of the district	Cost of electricity delivered to the grid	Un-electrification rate	Total No. of NGOs	Total solar power potential available	Total biomass power potential available	Rural HHs availing banking services	Total No. of Akshay Urja shops	Total average normalised value`
Baksa	0	0.7271	0.0000	0.0093	0.0000	0.2767	0	0.1447
Barpeta	0	0.8087	0.1842	0.0197	0.1383	0.2792	0	0.2043
Bongaigaon	0	0.7084	0.0263	0.0288	0.0896	0.6938	0	0.2210
Cachar	1	0.5854	0.1579	0.0042	0.2852	0.3122	0	0.3350
Chirang	0	0.8067	0.0000	0.0045	0.0000	0.3064	0	0.1597
Darrang	0	0.7920	0.0526	0.0317	0.1258	0.3019	0	0.1863
Dhemaji	0	0.8653	0.0526	0.0341	0.0566	0.2661	0	0.1821
Dhubri	0	1.0000	0.0000	0.0063	0.1119	0.0000	0	0.1597
Dibrugarh	0	0.3117	0.0000	0.0005	0.1271	0.5334	0	0.1390
Dima Hasao (North Cachar Hills)	1	0.6832	0.1053	0.6609	0.5228	0.3543	0	0.4752
Goalpara	0	0.4138	0.0789	0.0197	0.0784	0.2111	0	0.1146
Golaghat	0	0.5301	0.1053	0.0396	0.1006	0.5538	0	0.1899
Hailakandi	1	0.6350	0.1316	0.0023	0.1126	1.0000	0	0.4116
Jorhat	0	0.2416	0.1842	0.0000	0.1174	0.6069	1	0.3072
Kamrup	0	0.4133	1.0000	0.0183	0.2749	0.4690	1	0.4536
Kamrup Metropolitan	0	0.0197	0.5789	0.1034	0.0000	0.7765	1	0.3541
Karbi Anglong	1	0.7305	0.1579	1.0000	1.0000	0.3452	0	0.6048
Karimganj	1	0.7107	0.1053	0.0027	0.1050	0.2818	0	0.3151
Kokrajhar	0	0.8284	0.0789	0.0269	0.0725	0.2197	0	0.1752

Lakhimpur	0	0.7027	0.0526	0.0111	0.1153	0.4883	0	0.1957
Marigaon	1	0.7052	0.0263	0.0054	0.0604	0.4516	0	0.3213
Nagaon	1	0.6092	0.4211	0.0222	0.2838	0.2580	1	0.5135
Nalbari	0	0.3180	0.0263	0.0154	0.0972	0.6731	1	0.3043
Sivasagar	0	0.1791	0.0000	0.0053	0.1215	0.5698	1	0.2680
Sonitpur	0	0.5917	0.1579	0.0034	0.1588	0.3368	0	0.1784
Tinsukia	0	0.0000	0.0000	0.0155	0.1471	0.4418	1	0.2292
Udalguri	0	0.5708	0.1316	0.2768	0.0000	0.3175	1	0.3281

b. Bihar

Name of the district	Cost of electricity delivered to the grid	Un-electrification rate	Total No. of NGOs	Total solar power potential available	Total biomass power potential available	Rural HHs availing banking services	Total No. of Akshay Urja shops	Total average normalised value
Araria	1	0.8880	0.1148	0.0565	0.2839	0.0242	1	0.4811
Arwal	1	1.0000	0.0000	0.0000	0.0000	0.6126	1	0.5161
Aurangabad	0	0.8104	0.0000	0.1121	0.4831	0.5636	1	0.4242
Banka	1	0.5419	0.0164	0.9171	0.3619	0.3386	0	0.4537
Begusarai	0	0.6295	0.0984	0.0491	0.3206	0.4245	1	0.3603
Bhagalpur	1	0.3099	0.0656	0.1131	0.3461	0.4419	1	0.4681
Bhojpur	0	0.8198	0.0492	0.0419	0.4329	0.7752	1	0.4456
Buxar	0	0.6484	0.0000	0.0268	0.3420	0.6749	1	0.3846
Darbhanga	0	0.6829	0.1639	0.0147	0.2891	0.3273	0	0.2111
East Champaran	0	0.8779	0.0164	0.1658	0.6130	0.3889	1	0.4374
Gaya	1	0.8171	0.0656	0.3239	0.7588	0.4647	1	0.6329
Gopalganj	0	0.5701	0.0328	0.1049	0.3940	0.8520	1	0.4220
Jamui	0	0.8143	0.0000	1.0000	0.4222	0.3320	1	0.5098

Jehanabad	0	0.7790	0.0164	0.0159	0.2907	0.5342	1	0.3766
Kaimur	0	0.4140	0.0164	0.1327	0.7704	0.4529	1	0.3981
Katihar	1	0.8874	0.0656	0.2279	0.4103	0.1323	1	0.5319
Khagaria	1	0.7057	0.0164	0.0294	0.3014	0.2432	0	0.3280
Kishanganj	1	0.5863	0.0164	0.0793	0.2335	0.0000	1	0.4165
Lakhisarai	0	0.3640	0.0328	0.0548	0.1718	0.5502	1	0.3105
Madhepura	1	0.9120	0.0000	0.0383	0.2157	0.2093	1	0.4822
Madhubani	1	0.6752	0.1639	0.0375	0.4535	0.3522	0	0.3832
Monghyr	0	0.3361	0.0328	0.1768	0.1630	0.6401	1	0.3356
Muzaffarpur	0	0.6097	0.3443	0.1358	0.5270	0.4905	1	0.4439
Nalanda	1	0.6530	0.1148	0.0008	0.4428	0.5108	1	0.5317
Nawada	0	0.9108	0.0492	0.1193	0.4319	0.2535	1	0.3950
Patna	0	0.0000	1.0000	0.0741	0.4650	0.6064	1	0.4494
Purnia	1	0.7788	0.0820	0.0868	0.3549	0.0907	1	0.4847
Rohtas	1	0.4490	0.0164	0.1289	0.8658	0.7161	1	0.5966
Sahasra	1	0.8195	0.0164	0.0491	0.2183	0.2905	1	0.4848
Samastipur	0	0.7618	0.1148	0.1153	0.3949	0.4599	1	0.4067
Saran	0	0.6970	0.1311	0.1554	0.4027	0.7609	1	0.4496
Sheohar	0	0.8535	0.0164	0.0128	0.0943	0.3802	1	0.3367
Shiekhpura	1	0.6708	0.0000	0.0024	0.0918	0.6423	0	0.3439
Sitamarhi	1	0.8158	0.0328	0.0316	0.2630	0.2460	1	0.4842
Siwan	0	0.8141	0.0328	0.0858	0.4938	1.0000	1	0.4895
Supaul	0	0.7280	0.0000	0.3693	0.2527	0.4188	1	0.3955
Vaishali	0	0.7629	0.1639	0.0372	0.3757	0.6287	1	0.4241
West Cham paran	0	0.9084	0.0328	0.2819	1.0000	0.3341	1	0.5082

c. Jharkhand

Name of the district	Cost of electricity delivered to the grid	Un-electrification rate	Total No. of NGOs	Total solar power potential available	Total biomass power potential available	Rural HHs availing banking services	Total No. of Akshay Urja shops	Total average normalised value
Bokaro	0	0.3379	0.1176	0.2024	0.2370	0.5813	1	0.3537
Chatra	0	0.9599	0.0294	0.1270	0.3202	0.4816	1	0.4169
Deoghar	0	0.5150	0.2353	0.5517	0.1146	0.4122	1	0.4041
Dhanbad	1	0.0434	0.0882	0.3014	0.1119	0.7664	1	0.4730
Dumka	0	0.8498	0.0882	0.4348	0.3916	0.3601	1	0.4464
Garhwa	0	0.9973	0.0588	0.4279	0.6935	0.2439	0	0.3459
Giridih	0	0.7324	0.2353	0.4733	0.3638	0.7071	1	0.5017
Godda	0	0.9159	0.0294	0.1977	0.1265	0.2266	1	0.3566
Gumla	0	0.9410	0.0588	0.7677	0.7744	0.6082	1	0.5929
Hazaribagh	1	0.3604	0.3824	0.6050	0.6286	1.0000	1	0.7109
Jamtara	0	0.7234	0.0588	0.1498	0.0000	0.3831	1	0.3307
Khunti	0	0.7810	0.0000	0.2052	0.0000	0.3337	1	0.3314
Koderma	1	0.4471	0.0294	0.3308	0.1758	0.8902	1	0.5533
Latehar	0	0.7516	0.0588	0.3294	0.0000	0.1865	1	0.3323
Lohardaga	0	0.7614	0.0294	0.0000	0.1482	0.7280	1	0.3810
Pakur	0	0.9289	0.0294	0.1378	0.1340	0.0121	1	0.3203
Palamu	1	0.9346	0.2059	0.3161	0.7921	0.5379	1	0.6838
Pashchimi Singhbhum (West Singhbhum)	1	0.6257	0.0294	0.9551	1.0000	0.1580	1	0.6812
Purbi Singhbhum (East Singhbhum)	0	0.1323	0.1176	0.4078	0.2269	0.5765	1	0.3516
Ramgarh	0	0.0000	0.0000	0.1866	0.0000	0.7723	1	0.2798

Ranchi	1	0.4953	1.0000	1.0000	0.6806	0.7213	1	0.8424
Sahibganj	1	1.0000	0.1471	0.1119	0.2011	0.0000	1	0.4943
Seraikella Kharsawan	0	0.3133	0.0294	0.3442	0.0000	0.7886	1	0.3536
Simdega	0	0.9698	0.0000	0.6591	0.0000	0.3613	0	0.2843

d. Odisha

Name of the district	Cost of electricity delivered to the grid	Un-electrification rate	Total No. of NGOs	Total solar power potential available	Total biomass power potential available	Rural HHs availing banking services	Total No. of Akshay Urja shops	Total average normalised value
Angul	0	0.3953	0.0769	0.2681	0.5000	0.5687	0	0.2584
Balangir	1	0.7085	0.2500	0.4805	0.5061	0.1648	0	0.4443
Balasore (Baleswar)	0	0.0941	0.1154	0.0450	0.2764	0.6267	0	0.1654
Bargarh	1	0.3475	0.1346	0.1468	0.5031	0.3358	0	0.3525
Bhadrak	0	0.1416	0.0192	0.0000	0.0000	0.5561	0	0.1024
Boudh	1	0.8596	0.0192	0.1506	0.1844	0.4908	0	0.3864
Cuttack	0	0.1140	0.4231	0.1071	0.1864	0.6827	0	0.2162
Deogarh (Debagarh)	1	0.6365	0.0000	0.1412	0.1526	0.4931	0	0.3462
Dhenkanal	0	0.3853	0.2500	0.3525	0.3269	0.3887	0	0.2433
Gajapati	0	0.2571	0.0000	0.7669	0.5819	0.8385	0	0.3492
Ganjam	0	0.2269	0.1346	0.4539	0.8819	0.5716	1	0.4670
Jagatsinghpur	0	0.1239	0.1731	0.0159	0.0886	0.9392	0	0.1915
Jajpur	0	0.2576	0.1154	0.0773	0.1703	0.5013	0	0.1603
Jharsuguda	1	0.2646	0.0000	0.1580	0.1192	0.7485	0	0.3272
Kalahandi	1	0.7926	0.0769	0.4651	0.6568	0.0893	0	0.4401

Kandhamal	1	0.9496	0.1731	0.4501	0.1110	0.7982	0	0.4974
Kendrapara	0	0.1221	0.2115	0.0107	0.5469	1.0000	0	0.2702
Keonjhar (Kendujhar)	0	0.7022	0.1346	0.6580	0.9969	0.6801	0	0.4531
Khurda	0	0.0000	1.0000	0.2250	0.1905	0.3340	1	0.3928
Koraput	1	0.8678	0.0962	1.0000	0.7678	0.2224	0	0.5649
Malkangiri	0	0.8986	0.0000	0.3764	0.4379	0.1475	0	0.2658
Mayurbhanj	0	0.7712	0.1731	0.2183	0.7892	0.7210	0	0.3818
Nabarangur	0	1.0000	0.0769	0.3023	0.3768	0.0000	0	0.2509
Nayagarh	0	0.1057	0.1154	0.3519	0.3890	0.2472	0	0.1727
Nuapada	1	0.6632	0.0192	0.1912	0.3401	0.1799	0	0.3420
Puri	0	0.1697	0.4038	0.0372	0.1670	0.5862	0	0.1949
Rayagada	0	0.8146	0.0769	0.8669	0.7851	0.5190	0	0.4375
Sambalpur	1	0.4410	0.0577	0.2541	0.6110	0.5959	0	0.4228
Subarnapur	1	0.5685	0.0192	0.0943	0.1559	0.2997	0	0.3054
Sundargarh	1	0.6490	0.1154	0.1895	1.0000	0.7021	0	0.5223

e. Uttar Pradesh

Name of the district	Cost of electricity delivered to the grid	Un-electrification rate	Total No. of NGOs	Total solar power potential available	Total biomass power potential available	Rural HHs availing banking services	Total No. of Akshay Urja shops	Total average normalised value
Agra	1	0.0000	0.0811	0.1683	0.2141	0.4062	1	0.4100
Aligarh	0	0.6737	0.0360	0.0308	0.3010	0.4836	0	0.2179
Allahabad	1	0.6102	0.3604	0.4479	0.2629	0.5957	1	0.6110
Ambedkar Nagar	0	0.7366	0.0901	0.0800	0.1165	0.7805	1	0.4005
Amroha	0	0.8977	0.0270	0.0385	0.1513	0.7958	1	0.4158

(Jyotiba Phule Nagar)								
Auraiya	0	0.8212	0.0180	0.2143	0.1332	0.3848	1	0.3674
Azamgarh	0	0.7141	0.0901	0.2479	0.2189	0.8350	1	0.4437
Baghpat	0	0.2752	0.0090	0.0000	0.0953	0.6323	1	0.2874
Bahraich	1	0.9465	0.0270	0.2497	0.3336	0.4681	1	0.5750
Ballia	1	0.7655	0.0901	0.1238	0.1702	0.7323	1	0.5546
Balrampur	1	0.8920	0.0090	0.0496	0.2471	0.8614	1	0.5799
Banda	1	0.8751	0.0090	0.3589	0.1489	0.3877	0	0.3971
Barabanki	0	0.8717	0.1532	0.2840	0.2275	0.7341	1	0.4672
Bareilly	0	0.8718	0.0721	0.0379	0.2900	0.5438	1	0.4022
Basti	0	0.6931	0.0541	0.0702	0.0978	1.0000	1	0.4165
Bijnor	0	0.5743	0.0360	0.0142	0.3249	0.7464	1	0.3851
Budaun	0	0.9574	0.0450	0.1193	0.3207	0.0000	1	0.3489
Bulandshahar	0	0.6862	0.0721	0.0198	0.4233	0.4430	0	0.2349
Chandauli	0	0.6547	0.0180	0.2150	0.2265	0.6998	1	0.4020
Chitrakoot	0	0.7856	0.0090	0.0996	0.1277	0.5259	1	0.3640
Deoria	0	0.6536	0.0270	0.0506	0.1412	0.8605	1	0.3904
Etah	0	0.8782	0.0450	0.0916	0.3238	0.3827	1	0.3888
Etawah	0	0.6297	0.0180	0.2203	0.1579	0.3300	1	0.3365
Faizabad	0	0.7341	0.0450	0.1519	0.1756	0.8663	1	0.4247
Farukkhabad	0	0.8505	0.0541	0.0674	0.1494	0.4134	1	0.3621
Fatehpur	0	0.9549	0.0541	0.4231	0.2354	0.5154	0	0.3118
Firozabad	0	0.6294	0.0541	0.1396	0.1507	0.1254	1	0.2999
Gautam Buddha Nagar	0	0.1764	0.1171	0.0076	0.0993	0.6574	1	0.2940
Ghaziabad	0	0.0556	0.1081	0.0042	0.1422	0.5128	1	0.2604
Ghazipur	1	0.8459	0.1171	0.0440	0.1950	0.7404	1	0.5632

Gonda	1	0.8609	0.2432	0.1328	0.3255	0.7995	1	0.6231
Gorakhpur	0	0.5881	0.2342	0.0979	0.1415	0.7755	1	0.4053
Hamirpur	1	0.8108	0.0180	0.0337	0.1750	0.6617	1	0.5285
Hardoi	0	1.0000	0.0541	0.3043	0.3660	0.5281	1	0.4646
Hathras (Mahamaya Nagar)	0	0.4038	0.0090	0.0272	0.0931	0.4526	0	0.1408
Jalaun	1	0.6818	0.0000	0.5070	0.1990	0.7179	1	0.5865
Jaunpur	1	0.7355	0.0450	0.3097	0.2539	0.8722	0	0.4595
Jhansi	1	0.6163	0.0721	1.0000	0.2176	0.6091	1	0.6450
Kannauj	0	0.8755	0.0450	0.1923	0.1654	0.5329	1	0.4016
Kanpur Dehat	0	0.9324	0.0270	0.6084	0.1860	0.4986	1	0.4646
Kanpur Nagar	0	0.8507	0.1802	0.2281	0.1743	0.6858	0	0.3027
Kasganj (Kanshiram Nagar)	0	0.9266	0.0090	0.0643	0.0000	0.2615	1	0.3231
Kaushambi	0	0.9021	0.0180	0.1212	0.0690	0.4840	0	0.2278
Kushi Nagar (Padrauna)	0	0.7694	0.0450	0.0285	0.2456	0.9325	1	0.4316
Lakhimpur Kheri	0	0.9189	0.0180	0.1744	0.6287	0.8309	0	0.3673
Lalitpur	0	0.6530	0.0270	0.3571	0.1359	0.5447	1	0.3883
Lucknow	1	0.6143	1.0000	0.2061	0.0879	0.5156	1	0.6320
Maharajganj	1	0.7906	0.0090	0.0208	0.4139	0.8679	1	0.5860
Mahoba	0	0.8168	0.0000	0.2082	0.0988	0.6635	1	0.3982
Mainpuri	0	0.8390	0.0090	0.1489	0.1951	0.4694	1	0.3802
Mathura	0	0.1521	0.0631	0.0202	0.2338	0.5923	1	0.2945
Mau	0	0.4956	0.0360	0.0407	0.0847	0.8299	1	0.3553

Meerut	1	0.1794	0.0721	0.0137	0.1818	0.5949	1	0.4346
Mirzapur	1	0.6059	0.0360	0.5279	0.3212	0.6983	1	0.5985
Moradabad	0	0.8728	0.1261	0.0067	0.3387	0.5523	1	0.4138
Muzaffar Nagar	0	0.4076	0.0180	0.0139	0.1871	0.4909	1	0.3025
Pilibhit	1	0.8781	0.0000	0.0632	0.3850	0.6796	0	0.4294
Pratapgarh	0	0.7225	0.0541	0.5538	0.1853	0.8626	1	0.4826
Raebareli	0	0.5023	0.0360	0.4193	0.3322	0.7552	1	0.4350
Rampur	0	0.8182	0.0270	0.0041	0.2345	0.5855	1	0.3813
Saharanpur	0	0.1475	0.0450	0.0047	0.2848	0.4733	1	0.2793
Sant Kabir Nagar	0	0.6507	0.0270	0.0200	0.0706	0.8395	1	0.3725
Sant Ravidas Nagar	0	0.5827	0.0360	0.0703	0.0534	0.6932	0	0.2051
Shahjahanpur	0	0.9165	0.0090	0.0493	0.3873	0.5395	1	0.4145
Shravasti	0	0.9518	0.0090	0.0341	0.1064	0.6209	1	0.3889
Siddharth Nagar	1	0.7447	0.0631	0.0482	0.0032	0.7660	1	0.5179
Sitapur	1	0.9904	0.0180	0.1534	0.2066	0.8150	1	0.5976
Sonbhadra	0	0.8266	0.0180	0.7225	1.0000	0.8487	1	0.6308
Sultanpur	0	0.5418	0.0901	0.4104	0.3137	0.7751	1	0.4473
Unnao	0	0.9692	0.0270	0.5036	0.1817	0.5383	1	0.4600
Varanasi	1	0.4600	0.1532	0.0497	0.0616	0.7311	1	0.4937

f. West Bengal

Name of the district	Cost of electricity delivered to the grid	Un-electrification rate	Total No. of NGOs	Total solar power potential available	Total biomass power potential available	Rural HHs availing banking services	Total No. of Akshay Urja shops	Total average normalised value
Bankura	1	0.7496	0.0821	0.5567	0.3437	0.8805	1	0.6589
Bardhaman (Burdwan)	1	0.6505	0.0560	0.3686	1.0000	1.0000	1	0.7250
Birbhum	1	0.8059	0.0597	0.2075	0.3541	0.7345	1	0.5945
CoochBihar	0	1.0000	0.0149	0.1020	0.1960	0.6038	0	0.2738
Dakshin Dinajpur (South Dinajpur)	0	0.8158	0.0000	0.0000	0.1365	0.4718	0	0.2034
Darjeeling	1	0.3875	0.0075	0.0709	0.6048	0.7544	1	0.5464
Hooghly	0	0.4215	0.0336	0.0015	0.1808	0.8260	0	0.2090
Howrah	0	0.4829	0.0597	0.0000	0.0481	0.5871	0	0.1683
Jalpaiguri	1	0.8541	0.0224	0.2293	0.8782	0.6101	0	0.5134
Kolkata	0	0.0000	0.1306	0.0000	0.0000	0.0000	0	0.0187
Malda	0	0.8913	0.0373	0.0183	0.3431	0.4365	0	0.2466
Murshidabad	0	0.8996	0.0336	0.0152	0.8454	0.5394	0	0.3333
Nadia	0	0.7770	0.0522	0.0087	0.6829	0.5437	0	0.2949
North Twenty Four Parganas	0	0.7168	0.1567	0.0010	0.1887	0.6834	0	0.2495
Paschim Medinipur (West Midnapore)	1	0.6496	0.0261	0.7668	0.4445	0.7902	0	0.5253
Purba Medinipur (East Midnapore)	0	0.7016	0.0784	0.0117	0.2964	0.6387	0	0.2467

Purulia	1	0.9106	0.0224	1.0000	0.1215	0.6718	0	0.5323
South Twenty Four Parganas	1	0.8269	1.0000	0.0057	0.4173	0.5337	1	0.6834
Uttar Dinajpur (North Dinajpur)	0	0.9161	0.0037	0.0070	0.3075	0.3722	1	0.3724