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Scope, Relevance and Sustainability of Decentralized Renewable Energy Systems in Developing Economies: Imperatives from Indian Case Studies

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***Abstract*—**'Energy for all', is a global issue of concern for the past many years. Despite the number of technological advancements and innovations, significant numbers of people are living without access to electricity around the world. India, an emerging economy, tops the list of nations having the maximum number of residents living off the grid, thus raising global attention in past few years to provide clean and sustainable energy access solutions to all of its residents. It is evident from developed economies that centralized planning and electrification alone is not sufficient for meeting energy security. Implementation of off-grid and consumer-driven energy models like Decentralized Renewable Energy (DRE) systems have played a significant role in meeting the national energy demand in developed nations. Cases of DRE systems have been reported in developing countries like India for the past few years. This paper attempts to profile the status of DRE projects in the Indian context with their scope and relevance to ensure universal electrification. Diversified cases of DRE projects, particularly solar, biomass and micro hydro are identified in different Indian states. Critical factors affecting the sustainability of DRE projects are extracted with their interlinkages in the context of developers, beneficiaries and promoters involved in such projects. Socio-techno-economic indicators are identified through similar cases in the context of DRE projects. Exploratory factor analysis is performed to evaluate the critical sustainability factors followed by regression analysis to establish the relationship between the dependent and independent factors. The generated EFA-Regression model provides a basis to develop the sustainability and replicability framework for broader coverage of DRE projects in developing nations in order to attain the goal of universal electrification with least carbon emissions.

***Keywords*—**Climate change, decentralized generation, electricity access, renewable energy.

I. Introduction

ACCESS to electricity has been a global critical problem over the decades. Despite the evolution of the number of technological innovations and breakthroughs in recent years, there has only been a 50% reduction in the number of people living without access to electricity worldwide since 1990 [1]. Still, globally over one billion people are living without access to electricity, where Africa shares 55%, and developing Asia shares 41% of the energy deprived population (Fig. 1) [2]. In terms of countries, India consists of the maximum population living with zero access to electricity accommodating 23% of the energy deprived population globally. It amounts to almost 18% of India's population living in dark [3]. Poor electricity access is one of the prime causes of socio-economic backwardness in developing countries. However technologically enabled developing countries like China, Japan and Mexico are struggling to reduce their carbon footprint due to the global commitment made at the United Nations convention on climate change. Specifically, developing Asia is responsible for almost 50% of the global CO_2 emissions (Fig. 2), where three-fourths of the emissions are generated through energy production from fossil fuels [4]. As per the Sustainable Development Goal, SDG-7, affordable, clean and reliable access to energy needs to be ensured everywhere by 2030. Thus developing economies like India, Indonesia and Africa are readily deploying renewable energy systems to provide electricity access to their energy deprived population. However, it is observed that maximum projects are installed in grid connected mode, while very less attention has been paid on decentralized mode of power generation [5]–[7].

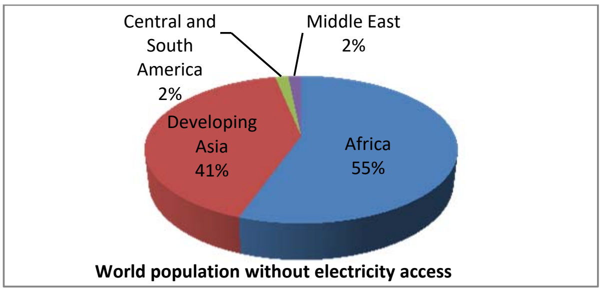

Fig. 1 Global electricity access

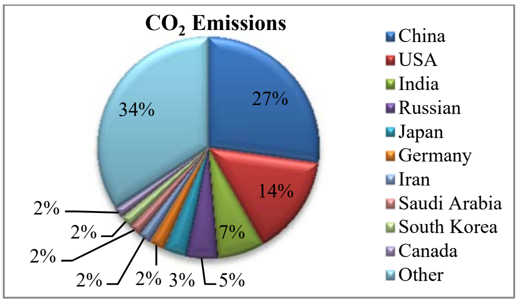

Fig. 2 CO_2 emissions over the globe

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It is evident from countries like Thailand, China and Mexico who achieved universal electrification recently, that DRE systems played a significant role to electrify the left-over communities [8], [9]. In addition to de-carbonization, DRE systems are proved to be effective in providing last mile energy access to remote and off-grid communities. Furthermore, such localized power generation initiatives are observed to be superior to the centralized electrification approach in terms of continuity of power supply and also responsible for strengthening the local economy [10]–[12]. Such types of DRE projects are reported in different regions of India as well for the past few years; however, the rates of growth of such types of off-grid systems are not sufficient to meet with the set target. Still, there exists a number of challenges in the deployment of such projects and their adaptability by beneficiaries [13]. This paper attempts to explore the critical factors associated with the deployment and operation of a typical DRE project by analyzing the selected Indian case studies involving solar, biomass and micro hydro as the source of power generation. Thereby, exploratory factor analysis is performed to narrow down the identified indicators and to evaluate the significant factors deciding the scope and relevance of such systems in developing economies. The evolved model would finally provide implications and policy recommendations to utilities for designing a sustainable electricity access framework for energy deprived communities.

II. Case Study Analysis

In this section, three case studies of typical DRE systems are discussed in detail in order to explore the critical success factors associated in the deployment of these projects. Here, the case studies are selected on the basis of the communalities shared by the factors which include source of power generation, location of project, technology used and project capacity, commencement and present status of project, developers involved and beneficiaries affected. One case study belonging to each of the three sources viz. solar, biomass and micro hydro is discussed based on the information available through project reports, corporate disclosures, and semi-structured interviews with project stakeholders. Other sources of renewable energy are not considered in this study as most of the DRE systems in India typically include solar, biomass and micro hydro as sources of power generation.

A. Case: Village Rampura

Rampura, a small hamlet in Bundhelkhand region of Jhansi district in Uttar Pradesh (U.P.) remained un-electrified until 2008. Villagers were using kerosene as a primary source of lighting with an annual demand of 2400 liters. In 2008, Development Alternatives (DA, a not-for-profit organization) took the initiative to establish a Community Solar Power Plant (CSPP) in Rampura along with the partnership of Scatec Solar (a solar power company). As of January 2009, CSPP operated with a capacity of 8.7 kWp to cater for the basic power requirements of 70 households and a battery bank sufficient to secure three days of autonomy (days with no sun). Power is distributed through a single phase mini-grid of 220 Volt A.C. to households, shops and community facilities. The approach adopted in setting up the plant was BOOT (Built-Own-Operate-Transfer), and thus, the ultimate stakeholder of plant will be the village community. The total cost incurred in setting up the pilot plant was INR 29.5 lakh. In order to make the project financially sustainable, the ‘pay-for-energy’ concept was introduced. Consumers are charged with an electricity tariff based on their load. There are three slabs of tariff ranging from 5 kWh to 10 kWh as shown in Table I. Financial analysis in Table II of the plant reveals that after deducting all the possible expenditures from collected revenue, the plant makes annual savings of INR 9,362, making it financially viable [14].

TABLE I
TARIFF STRUCTURE [14]

	Slab-I	Slab-II	Slab-III
Types	0-5 kWh	5-10 kWh	10 kWh
Domestic			
Fixed Cost (INR)	20	90	160
Variable Cost (INR)	4.50 / kWh	5.5 / kWh	6.50 / kWh
Enterprise			
Fixed Cost (INR)		200	
Variable Cost (INR)		6.5 / kWh	

TABLE II
FINANCIAL ANALYSIS [14]

Revenue	
Annual revenue from domestic load	INR 40,843 (including Rs. 4800 from street lights)
Annual revenue from commercial load	INR 4,819
Total annual revenue	INR 45,662
Expenditure	
Annual operator salary	INR 14,400
Annual salary of security guard	INR 14,400
Estimated annual expense on maintenance	INR 4,000
Annual insurance premium	INR 3,500
Total annual expense	INR 36,300
Annual savings	
INR 9,362	

1. Impact Assessment

The CSPP at Rampura brought a dramatic change to the lifestyles of the people living in the hamlet. There seemed to be a revolutionary improvement in the socio-economic status of the residents after receiving access to electricity. Children were able to spend 1.5-2 hours more on their studies, and some even had the opportunity to learn basic computer knowledge. Women had more flexibility to engage themselves in other activities, apart from cooking, like sewing, stitching, rope-making and sweater-weaving for generating income. Some of the electricity driven enterprises were also set up, thereby generating additional livelihood opportunities. Apart from household lighting, residents started buying other necessary electric appliances like TV sets, coolers, fans and a refrigerator to improve their living standards and quality of life. The community perception changed and they became more aware for making energy-efficient investments as well. The replacement of kerosene lamps with electric lights not only reduced CO_2 emissions, but also improved the health condition of households.

In order to make community participation active, a Village Energy Committee (VEC) comprising of selected villagers was formed to administer load management, revenue recovery and operation-maintenance of the plant. VEC gained autonomy for the plant after receiving training in accounting and management for eight months. This resulted in a successful revenue model entirely managed by the local community through their active participation achieved by capacity building of grass-root stakeholders. Thus, assured access to electricity had a spillover effect on the development of the village in different aspects of well-being by bringing the excluded section of the population in the mainstream.

2. Critical Success Factors Associated with Rampura DRE Project

Private-Public-Community (P-P-C) Partnership

The DRE project installed at Rampura is a result of the joint initiative of Development Alternatives (NGO), Scatec Solar (private company) and the local community. The P-P-C partnership model adopted for the Rampura project proved to be effective in the successful installation and operation of CSPP plant.

BOOT Model

The Built-Own-Operate-Transfer (BOOT) model introduced by project developers at Rampura facilitates the local community to understand the intricacies involved in the installation and operation of the project which eventually helped in the successful transfer of the project to the operation of the Village Energy Community (VEC).

Pay-For-Energy

Pay for energy scheme introduced by Development Alternatives helped the VEC in collection of sufficient revenue to make the project financially viable.

Effective Tariff Structure

The consumption based tariff structure introduced in Rampura helped VEC to manage the load effectively even in limited generation facility.

Livelihood Creation

Availability of power for commercial enterprises at Rampura helped villagers to utilize energy coming from solar power plant in earning their livelihood which acts as a catalyst in adoption of technology by the society.

B. *Case: Village Udmaroo*

Udmaroo is a small village comprising of about 90 households located on the bank of river Shyok in Nubra valley of Leh district. Until 2005, Udmaroo remained unconnected from the national grid because of its remote geographical location and villagers there were dependent on smoky kerosene lamps and diesel generator sets. In 2005, people of Udmaroo approached LEDeG (Ladakh Ecological Development Group) for a safe and reliable source of power. LEDeG, along with some funding agencies, took the initiative for village electrification and installed a 32 kVA micro hydropower system in the village by year 2008 powering Udmaroo for nine months of the year. Establishment of a micro hydro system at Udmaroo was a tough job. Initially, only 15 households showed interest to contribute in terms of money and labor, while others were not convinced about the feasibility of the project. Slowly, interested villagers persuaded the others, and finally, each house contributed Rs 1000 and possible labor for setting up the project. In total, the project cost around Rs 22,00,000, in which 48% of the cost was covered by villagers in terms of money and labor, while the remaining expenditure was met by LEDeG which arranged funds through European funding agencies.

A miniature grid was extended to supply power to each of the 90 houses in the village. In spite of operating the system at its full capacity for supplying power all the day, the residents of Udmaroo decided to keep some reserve capacity and agreed to transmit power for domestic use in houses in the evening from 6 pm to midnight. The tariff decided for each house is fixed at Rs 90 per month for a fixed load of five CFLs, but practically there was no restriction in terms of power consumption and appliances used because of the reserve capacity. Moreover, average power consumption of Udmaroo had a range of 20-25 kVA with reserve capacity of 7-12 kVA. Apart from domestic electrification, the micro hydro system at Udmaroo brought some employment opportunities for the villagers. With the availability of enough power in the day time, some of the village women formed a small group and set up an oil extraction plant by installing a 7.5 kW oil extracting machine drawing power directly from the power house. The oil extraction plant was operated to extract oil from mustard seeds and apricot kernels brought by the residents of Udmaroo and nearby villages. The plant received power at the rate of Rs 15 per hour and charged Rs 80 per hour for its services. Excess oil was filled in old rum bottles and sold to the army for Rs 300 each. Income generated from these services was deposited into a common bank account and utilized in various constructive ways such as providing quality education for the village children, visits to other places away from Ladakh and the overall improvement of living conditions.

In order to operate and govern the system, an Electricity Management Committee (EMC) was formed in which each customer was a member. All sorts of technical and social issues are managed by an elected body of six members. Revenue collected from the residents covered the operational costs of the system which include the salary of operator worth Rs 3000. After deducting operational expenses, the committee managed to save around Rs 5000 per month as emergency fund. As the micro hydro system in Udmaroo remained inoperative during the winter months of December to March, the EMC installed a small diesel generator set to supply power during these months; however, the tariff charged for this service is as high as Rs 600 as compared to Rs 90 in the case of the micro hydro system [15].

1. Impact Assessment

The micro hydro system installed in Udmaroo significantly reduced the drudgery of villagers by providing clean energy access through naturally available resources. Before electrification, the villagers needed to travel to nearby electrified villages or towns for services that require power like oil extraction and fruit processing. The micro hydro power system has allowed the village to become self-reliant and create income generating activities as many power-driven enterprises were set up to facilitate the frequent requirements of residents. Apart from the oil extracting plant, some of the men purchased a carpentry machine to carve windows and doors in the village, while a women's group installed a pulping machine producing apricot jam packed in bottles for sale in Udmaroo and nearby regions.

In addition to lighting, the micro hydro system enabled the residents to use additional electric appliances like radios, tape recorders and television sets providing them with the opportunity to connect with rest of the world and a source of entertainment. Households use mixers, irons and electric butter churners for their day-to-day necessities. The micro hydro system allowed villagers to save around Rs 120,000 as compared to diesel generators for producing equal amount of power for nine months of the year. Also, it helped to mitigate the pollution caused by running diesel generator sets. The community has adapted well to governing their own electricity system. This type of community energy system built such strong faith in people of Udmaroo that they showed no interest in the government's plan to connect the village with the grid. As well, they would need to pay more for a grid connection, while losing control and autonomy on the supply system. So, they continued to retain and maintain their own micro hydro unit.

2. Critical Success Factors Associated with Udmaroo Micro Hydro Power Project

Financial and Manpower Contribution

Participation received from the community in terms of funds and manpower played a significant role in the realization of the Udmaroo micro hydro power project where community contribution accounts for nearly half of the installation cost.

Maintaining Reserve Capacity

Preventing the complete exhaustion by making a reserve capacity of the plant is one of the pro-active measures adopted by the EMC of Udmaroo that helped to operate the plant safely in conditions of overload. Such measures adopted by the EMC have a strong impact in long term sustainability of plant.

Back-Up Power Source

Since power generation at Udmaroo micro hydro project is based on the natural stream of water, the plant remains inoperative in winter, thus EMC at Udmaroo installed a diesel gen-set as a back-up power source. This helps the villagers to receive an un-interrupted supply of power throughout the year.

Livelihood Creation

As the EMC at Udmaroo set the provision for reserve capacity by limiting the hours of domestic usage, the left over capacity is utilized for supplying power to commercial establishments which ultimately helps in livelihood creation.

C. Case: Village Garkha

Garkha is a densely populated village in the Saran district of Bihar State. The village was suffering from poor access to electricity for years and the villagers were forced to use diesel operated gen-sets to fulfill their domestic energy demand. In order to provide reliable energy access to the villagers of Garkha, a native entrepreneur from Saran established a firm known as Saran Renewable Energy (SRE) which aimed to set up biomass gasifier plants in the energy deprived villages of Saran. Under such an initiative, a 128 kW biomass gasifier plant was installed at Garkha in 2006. The gasifier is used to provide reliable access to electricity to nearly 1000 households, commercial establishments, a school and medical clinics. The gasifier installed at Garkha utilizes 'dhaincha' as biomass fuel. Dhaincha is a locally available plantation that used to grow on un-cultivated and water-logged tracts of low lying lands between 'Ganga' and 'Gandhak' rivers. Using dhaincha as fuel for gasifier, SRE, not only provides reliable electricity but also utilizes wastelands and provides employment opportunities to villagers. They cultivate dhaincha in wastelands and earn income supplying it as fuel for the gasifier. The gasifier operates 10 hours a day supplying electricity at Rs. 7.50/unit. The total cost of the plant was estimated to be around 85 lakhs, out of which, 20 lakhs was financed through ICICI bank and 18 lakhs was promised by the state government in the form of a grant [16].

1. Impact Assessment

The biomass gasifier at Garkha brought significant socio-economic transformations to the lives of the villagers. Farmers with marshy and un-cultivable land now earn Rs. 7500-10000 per year by supplying nearly 5 tonnes of dhaincha as the main fuel for the gasifier. Along with domestic lighting, farmers were able to operate irrigation pumps with affordable electricity supply from the gasifier. Commercial establishments like grain and oil mills used to operate through electricity received from gasifier. Electricity generated by the biomass gasifier plant is saving around 77,000 liters of diesel and 206 tonnes of CO_2 emissions per year.

2. Critical Success Factors Associated with Garkha Biomass Gasifier Project

Loan and Funding

A loan provided by the ICICI bank and funding ensured by the state government facilitated SRE to realize their plan of setting up a biomass gasifier at Garkha.

Availability of Dhaincha

Abundance of locally available plantation, 'dhaincha' proved to be a catalyst in the successful operation of the plant over the years. As continuous availability of fuel is a major concern in biomass-based DRE projects, availability of dhaincha in the region facilitates successful continued operation of the plant.

Utilization of Wastelands

Cultivation of dhaincha in water-logged wastelands of Saran brought additional income for farmers who are possessing marshy pieces of un-cultivable land.

Livelihood Creation

Supplying electricity from the gasifier to irrigation pumps saves expenditure of operating costly diesel operated water pumps. Also, availability of electricity at commercial establishments facilitated villagers to earn their livelihood in a sustainable way.

III. Identification of Indicators Associated with Sustainability of the DRE Systems

On the basis of the DRE case studies discussed in Section II and similar cases reported in the Indian the sub-continent, the following indicators (Table III) are identified as impacting the sustainability of DRE projects in India. In this study, 29 indicators (I1-I29) are identified in the context of the installation and operation of DRE projects.

TABLE III
Indicators Associated with DRE Systems

Label	Indicators
I1	Autonomy of DRE systems
I2	Improper forecasting of demand and supply
I3	Reliability of DRE systems
I4	Technology complexity
I5	Lack of indigenous manufacturing facility
I6	Role of local community in DRE systems
I7	Lack of short-term courses and skill development program aimed for promotion of DRE systems
I8	Role of DRE systems in providing energy access
I9	Continuous availability of renewable energy source in the localized region
I10	Promotion for renewable energy systems
I11	Lack of knowledge about installation and operation
I12	Improper estimation of cost
I13	Inefficacies in centralized grid extension
I14	Lack of information about subsidies
I15	Lack of private sector participation in DRE systems
I16	Potential assessment of localized resources
I17	Current schemes and policies for DRE systems
I18	Awareness for DRE systems
I19	Lack of information about credit schemes and loans
I20	Non-payment of tariffs
I21	Perceived uncertainty and risk about new technology and systems
I22	Prejudiced and biased perspective of beneficiaries
I23	Inappropriate government policies
I24	Lack of cooperation among the development agencies
I25	Political instability
I26	Power tariffs in DRE systems
I27	Price determination
I28	Lack of skilled manpower in DRE systems
I29	Doubts about financial viability of the system

IV. Methodology

In order to evaluate the scope and relevance of DRE systems in developing economies, three dependent factors are identified impacting the sustainability of DRE projects. It includes, long term economic benefits (O1), climate change (O2), and universal electrification (O3). As DRE projects are aimed to satisfy the requirement of a localized group of beneficiaries, key factors deciding the sustainability of DRE projects gets converged to O1, O2, and O3 broadly. Based on these, Exploratory Factor Analysis (EFA) is performed by collecting 105 responses for the indicators (I1-I29) on a five-point Likert-type scale representing the measure of dependence of each indicator towards the sustainability of a DRE project. Responses are coded on a (1-9) scale, where '1' denotes a strong impact of the respective indicator on the sustainability of the DRE project while '9' denotes negligible impact. Respondents in this survey include DRE project developers, beneficiaries, academicians, and policy makers. Exploratory factor analysis is performed in IBM-SPSS to analyze the data collected through respondents. Principal Component Analysis is carried out to extract the independent principal components from the original set of indicators. After performing factor reduction through EFA, linear regression analysis is performed to derive the relationship between the dependent factors (O1-O3) and principal components (F1-F8).

V. Results and Discussions

Results derived from exploratory factor analysis reveals, eight principal components are extracted out of the 29 indicators. The EFA results are shown in Table IV where factors, F1-F8 are listed out with respect to their relationships with associated indicators. F1 possesses a high degree of correlation with indicators representing current policies and schemes for DRE systems, non-cooperation among DRE developers and political instability. On the basis of communalities shared with these indicators, F1 can be termed as 'Governance' factor influencing O1, O2, and O3. Moreover, F2 is associated with assessment of localized resources, non-payment of tariffs and broadly classified as a 'Community' factor. Similarly, F3 is closely related with a lack of awareness about the installation of DRE projects, credit schemes and incentives, and falls under the dimension of the 'Education' factor. However, F4 is associated with technology complexity, lack of manufacturing facilities and skill development programs and is classified as a 'Technology' factor. Likewise, F5 is associated closely with improper estimation of cost and price forecasting and can be termed as a 'Funding' factor. F6 is closely coupled with improper forecasting of demand and supply, lack of community autonomy of DRE systems and can be termed as an 'Infrastructure' factor. F7 is associated with perceived uncertainty, prejudiced community outlook for DRE systems and can be classified as a 'Cultural' factor. Similarly, F8 is associated with continuous availability of renewable power source and can be termed as an 'Environment' factor.

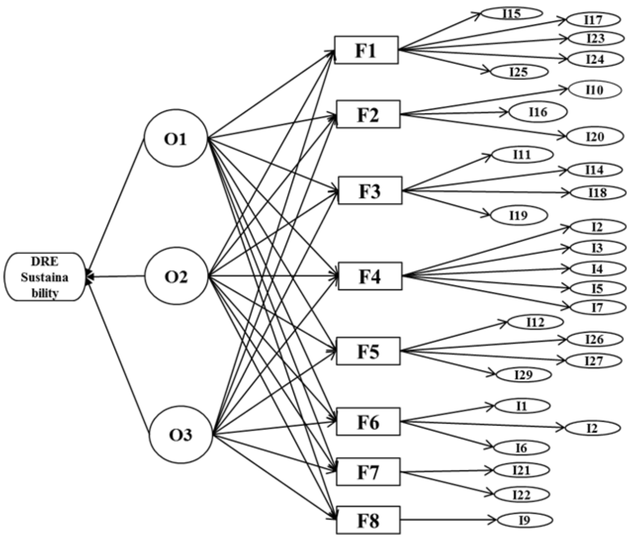

Fig. 3 EFA-Regression Model for DRE sustainability

TABLE IV
ROTATED COMPONENT MATRIX[A]

	Component							
	F1	F2	F3	F4	F5	F6	F7	F8
I1						0.745		
I2				0.483		0.549		
I3				0.519				
I4				0.535				
I5				0.757				
I6						0.701		
I7				0.751				
I9								0.872
I10		0.756						
I11			0.549					
I12					0.548			
I14			0.822					
I15	0.614							
I16		0.758						
I17	0.499							
I18			0.504					
I19			0.576					
I20		0.729						
I21							0.870	
I22							0.790	
I23	0.776							
I24	0.746							
I25	0.587							
I26					0.616			
I27					0.571			
I29					0.759			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.a
a. Rotation converged in nine iterations.

The factors extracted through EFA found their relevance in the successful operation of the case studies discussed. It is evident through critical success factors associated with case study, 'Rampura', factors like community-participation and funding played a major role in the financial sustainability of a DRE project. Likewise, in the case study, 'Garkha', environmental endowments and the availability of natural resources are the factors responsible for the long-term sustainability of the project. Moreover, in the case study of Udmaroo, effective governance and local infrastructural support are proved to be the factors of importance for successful project installation and operation. Furthermore, in order to validate the relationship between the dependent factors (O1, O2, and O3) and extracted factors (F1-F8), linear regression analysis is performed. It is clear from R^2 and F-value (Table V) that there exists a significant relationship among the dependent variables (O1, O2, and O3) and set of factors (F1-F8). The inter-relationship between the dependent, extracted and original indicators is represented in the EFA model shown in Fig. 3.

Regression Equations showing relationships between dependent and independent variables

$$O1 = 2.724 + 0.146\ F1 - 0.185\ F2 + 0.368\ F3 + 0.282\ F4 - 0.105\ F5 + 0.130\ F6 + 1.584\ F7 + 0.342\ F8 \quad (1)$$

$$O2 = 1.967 + 0.371\ F1 + 0.400\ F2 - 0.269\ F3 + 0.221\ F4 + 0.351\ F5 - 0.091\ F6 + 0.556\ F7 + 0.071\ F8 \quad (2)$$

$$O3 = 2.989 + 0.160\ F1 - 0.283\ F2 + 0.185\ F3 + 0.725\ F4 - 0.064\ F5 + 0.119\ F6 + 1.300\ F7 - 0.073\ F8 \quad (3)$$

TABLE V
REGRESSION ANALYSIS

Dependent variable	Independent variable	Coefficient	F- Value	VIF	R^2
O1	F1	0.146	0.79	1.00	69.83%
	F2	-0.185	1.28	1.01	
	F3	0.368	4.90	1.02	
	F4	0.282	2.56	1.02	
	F5	-0.105	0.43	1.00	
	F6	0.130	0.59	1.02	
	F7	1.584	91.27	1.00	
	F8	0.342	4.43	1.00	
O2	F1	0.371	9.57	1.01	59.42%
	F2	0.400	9.55	1.01	
	F3	-0.269	5.34	1.01	
	F4	0.221	3.55	1.01	
	F5	0.351	8.52	1.00	
	F6	-0.091	0.62	1.00	
	F7	0.556	23.35	1.00	
	F8	0.071	0.36	1.01	
O3	F1	0.160	0.79	1.03	61.81%
	F2	-0.283	1.97	1.10	
	F3	0.185	0.92	1.09	
	F4	0.725	16.26	1.05	
	F5	-0.064	0.14	1.03	
	F6	0.119	0.46	1.01	
	F7	1.300	51.75	1.06	
	F8	-0.073	0.14	1.12	

VI. CONCLUSION

Case study analysis of diversified DRE projects in India derives project specific critical factors responsible for the success or failure of a DRE system; however, factor analysis performed on DRE indicators provides generic factors responsible for the long-term sustainability of DRE systems. The factors extracted through EFA derive eight broad dimensions to assess the sustainability of DRE systems. The relevance of the extracted factors and their relationship holds true in the case of other developing nations as well. The developed EFA-regression model for DRE indicators describes the significance of real-time project parameters and their relationship in the successful installation and operation of the plant. At present, DRE systems are predicted to be the single solution with multiple problems pertaining to climate change, reliable power supply and universal electrification. This study provides implications for appropriate energy policy formulation in those countries suffering with energy poverty and high levels of carbon emissions.

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