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Economic impact of productive use of renewable energy: A case of a women-collective from rural Maharashtra (India)

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Abstract
Development activities and energy access are intertwined; however, they also contribute towards climate change. Therefore, climate friendly activities are needed to be promoted to ensure socio-economic development. Productive use of renewable energy for income generation is an emerging area of development in developing countries and is under-explored; therefore, there is a need to study the impact of such interventions on income generation. In this context, this paper attempts to estimate the impact of a renewable energy based, women managed collective from rural Maharashtra (India) on the income of beneficiaries using interview-based survey design. An analysis of the data indicates a significant change in beneficiaries' income with associated multiplier effect vis-à-vis non-beneficiaries', depicting such initiatives have potential to effect socio-economic development while being environment friendly. This is vital as India foresees an important role for renewable energy to address development issues, rural infrastructure gaps, and climate goals.

Keywords: Climate Change, Sustainable Development, Renewable Energy, Collective, Women Empowerment.

1. Introduction

Industrial development and economic growth have elevated standard of living of people; however, they have also led to climate change, which has implications for the sustainability of the planet (Smol 2012). Climate change is also interwoven with electrical energy as fossil resources contribute substantially towards electricity generation and greenhouse gas emissions. Electricity is a building block of a modern and prosperous society; however, provisioning of a reliable electricity is yet to be realised as close to a billion people have limited or no access to it (Bhandari et al. 2018; Bahaj et al. 2019; Ngowi et al. 2019; Dauenhauer et al. 2020; WinEED 2020). India has achieved close to 100 per cent electrification of her villages, yet poor reliability and quality of energy have compelled a significant number of households to use fossil fuel for illumination purpose. The rural micro-enterprises, in states like Uttar Pradesh and Bihar, have remained largely un-connected to the grid, affecting enterprising spirit of rural communities (Katre and Tozzi 2018; The Rockefeller Foundation et al. 2019). In this context, renewable energy has emerged as a development alternative especially for remote and rural locations (Terrapon-Pfaff et al. 2018; Bahaj et al. 2019; Ngowi et al. 2019). Renewable energy interventions provide end users with pollution free indoor environment, opportunities to undertake farm irrigation, and productive activities among other benefits (Lighting Global 2019; Ibrik

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2020).

Productive activities have potential to improve income levels and achieve human development goals (Ray 1998; Lighting Global 2019). Collective based productive activities draw upon talent, creativity, and knowledge of members, diffused in a synergic way to achieve the whole which is greater than individual contributions (Sudgen et al. 2021). However, in Indian context, the concept of collectives managed by underprivileged communities is in its nascent stage as is the concept of productive use of renewable energy (PURE) for income generation and socio-economic development.

India envisions a green economy and has committed to several climate related goals during COP26 such as 500 GW of non-fossil-based energy capacity, 50 per cent of energy from renewable sources, reduction in emission intensity by 45 per cent, and reduction in emissions by one billion tonnes (all by 2030) and to become a net zero emitter by 2070. In continuation of this policy framework, Government of India has promulgated *Framework for Promotion of Decentralised Renewable Energy (DRE) Livelihood Applications*, to harness DRE for livelihood creation and income generation purpose, targeting rural youth and women; thus, paving a way for climate friendly productive activities—with no negative externalities.

A review of literature indicates a few studies have been conducted in India for analysing socio-economic impact of off-grid based PURE interventions—renewable energy used as an input in a production process—as most studies focus on benefits of energy access to households for domestic use. Some studies, which discussed the impact of productive use, were opaque in methodology, lacked in-depth analysis and were conducted by the sponsors of the projects. Therefore, there is a need to analyse PURE interventions for their socio-economic impact, while ensuring transparency and avoiding conflict of interest.

With this background, the paper analyses the economic impact of a collective managed PURE intervention (located in Central India). It is a unique initiative in the country, which is promoted by the state and managed by marginalised women. The collective processes raw cotton into finished garments using renewable energy as one of the factors of production, thus, in the process, creating a socio-economic impact on the beneficiary members. This paper comprises five sections including introduction. Section two enumerates review of literature and conceptual framework to address the research objective. Section three provides a brief on geographic and socio-economic profile of the region, where the project is located. The fourth section discusses the initiative in terms of profile of the members, its formation process, and value chain among other things. It also discusses methodology and findings about the economic impact on beneficiaries. The fifth and the final section concludes the study.

2. Review of literature

In Indian context, not many studies have been conducted to analyse the impact of PURE initiatives as it is an emerging area of development. Brief analyses about small-scale commercial use are a part of studies related to domestic renewable energy access, therefore, studies which have relevance are discussed here. A study by Bhattacharyya and Palit (2014) on institutional and financial aspects of mini grid system for domestic energy access in eight villages of Chhattisgarh mentions about its impact on local community. The system is subsidised by the state for capital and operational expenses, while private sector

is responsible for installation, commissioning, and maintenance. The impact analysis was carried out through group discussions and interviews with the subject experts without field-based research which was the major shortcoming of the study. It mentions benefits such as improvement in commercial activity for small businesses (provisional stores, salons etc.) due to illumination, awareness due to access to TV/mobile devices, indoor health due to reduction in kerosene use, and study hours for children. As the mini grid system was for lighting purpose, its impact on productive activities could not be assessed separately, which was another shortcoming of the study.

An interesting field-based study was conducted by Aklin et al. (2017) to assess the impact of solar energy in non-electrified 81 neighbourhoods of Barabanki district in Uttar Pradesh. The impact was studied for control and treatment group for one year. The treatment group was provided with off-grid energy for lighting and mobile charging purpose for a limited number of hours a day. It was observed that there was a decrease in kerosene expenses, however, villagers continued to procure a smaller amount, depicting a restricted use of solar energy is not a perfect substitute for kerosene. On household front, no evidence was found to suggest its effect on income, lighting for study and women empowerment. This reiterates quality and quantity of energy are critical to derive a meaningful impact. As the study area neither had scope for productive activities nor sufficient quantum of energy to power the same, therefore, the research recommended a similar experimental analysis for a productive use.

A survey-based study for solar home system (SHS) conducted by GOGLA (2018) in five African countries—Kenya, Mozambique, Rwanda, Tanzania, and Uganda—presents a different picture when it comes to rise in income and quality of life. The study mentions SHS has enabled about 58 per cent of the consumers to increase their income by taking up illumination enabled job opportunities (salons, restaurants etc.) and to spend more time at work apart from reducing indoor pollution and increasing safety during night. The study also mentions a significant reduction in kerosene consumption which corroborates Chhattisgarh experience as discussed by Bhattacharyya and Palit (2014), where solar energy enabled lighting reduced consumption of kerosene and promoted small-scale commercial activities such as provisional stores, salons etc. Therefore, entrepreneurship and scope for business opportunities have significant bearing on the outcome of energy use. It is pertinent to note that most of the Sub-Saharan countries have low penetration of national grid, therefore, they are more conducive to such interventions. The study also recommends research on impact of PURE interventions and agriculture activities.

A project-sponsor driven study by Sambodhi and The Rockefeller Foundation (2019) suggests rural enterprises (rice hullers, water plants, printers etc.) in Jharkhand (India) have shown preference for off-grid solar power due to reliability and quality although the project area had grid energy, albeit of poor quality and irregular in supply. The study mentions improved socio-economic and environmental indices for users without providing details about methodology, sampling, data analysis etc. Moreover, the study was conducted by the sponsor of the intervention with a likelihood of biased observation. Another study in the African context, on a small hydropower based mini grid (in a small village in Tanzania), was conducted by Ngowi et al. (2019). The mini-grid was established by a local hospital for its own consumption and for providing energy access to households and small businesses—carpentry, welding, milling etc. in the adjacent village. The research mentions

improvement in socio-economic indices for the households and business activities for workshop owners without a detailed analysis, results, and discussions.
A control and treatment group-based study of solar energy enabled domestic energy access in Kenya (Bahaj et al. 2019) also depicts reduction in consumption of kerosene, increase in study hours for children, improvement in provisioning of healthcare and education facilities along-with proliferation of small businesses such as salons, fee-based TV viewing, printers/photocopiers etc. in treatment group vis-à-vis control group, however, no energy access was provided for productive use as the system had a small installed capacity. A study by Ibrik (2020) in two villages of West Bank, Palestine mentions positive impact of solar PV systems on agriculture through irrigation, health on account of access to potable water and indoor environment. It further states improvement in entrepreneurship in farmers, productivity, income, and food security as the farmers commenced to practice a multi-cropping system. The women could devote more time for other productive activities on account of improved indoor lighting. The solar PV system, however, was not utilised for agro-processing activities.
A study by 60 Decibels (2020) depicts a favourable impact of off-grid energy on households, income generation, reduction in kerosene consumption etc. It also prescribes financing options, subsidies, involvement of women in management etc. for the energy systems. The study was conducted through telephone interviews and the scope was limited to domestic energy access and irrigation pumps. Although, studies discussed here are not exhaustive in scope, however, they broadly cover recent body of work which majorly focusses on the impact of domestic energy access with associated small commercial use; there was no research on the impact of collective based productive activities, which could have wider impact on communities due to their larger membership. This research gap therefore provides a scope to study the socio-economic impact of a collective managed PURE intervention in the rural areas of Amravati district of Central India.

2.1 Conceptual framework

It is argued that productive activities have potential to increase income levels, provide access to conveniences and achieve human development goals (Ray 1998). Studies also indicate access to reliable electricity leads to opportunities for productive activities and consequent income generation among other benefits (Aklin et al. 2017; Lighting Global 2019). Therefore, importance of energy access cannot be overstated in poverty alleviation and achieving sustainable development goals (WinEED et al. 2020). For the proposed study, the conceptual framework (shown in Figure 1) is derived from a three-pillar based model of sustainable development (social, economic, and environment), considered as an ideal model for community-based development initiatives (Hardi and Industry Canada 1997). The framework also amalgamates the concept of theory of change in terms of input activities for the intervention (need assessment, capacity building, financial incentives, and commissioning of PURE initiative), output (availability of energy for productive use and production capacity) and long-term outcome/impact (socio-economic development) as it attempts to depict causality between the PURE intervention and impact (Terropon-Pfaff et al. 2018). The sustainable development paradigm and associated sustainable development goals (SDGs) provide conceptual underpinnings to

frame the impact indicators. Although, the SDGs are applicable at national/regional level and have broader appeal and lesser specificity; however, for this study, SDG indicators, measures, and relevant state surveys in Indian context are referred to provide guidelines to estimate the impact. In other words, they are used to operationalise and prepare questions to analyse the impact of the intervention. SDGs such as SDG 1 (no poverty), 2 (zero hunger), 3 (health), 4 (education), 5 (gender equality) and 8 (decent work/economic growth) provide a theoretical foundation for estimating impact on beneficiaries. It may be noted these SDGs are interrelated, interconnected, and have impact on each other. In the context of the study, SDG 7 (access to clean energy—energy which has no emissions) is used as a factor of production to drive a collective based production activity; in the process, it creates socio-economic impact on the people and addresses the other SDGs (WinEED et al. 2020).

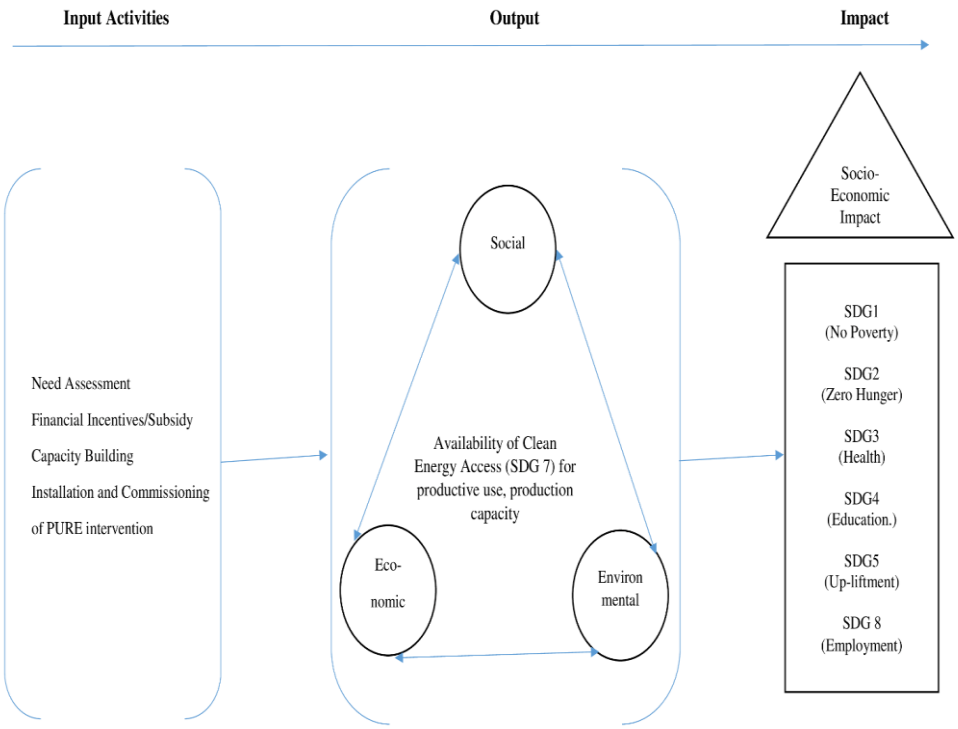

Figure 1. Conceptual framework
Source: Author

3. Geographic and socio-economic profile of Amravati district

Vidarbha is an eastern region of Maharashtra State (India) and occupies about 31 per cent area and has about 21 per cent population of the State of Maharashtra. Amravati district, located in Vidarbha region (as shown in Figure 2), has one of the highest proportions of scheduled castes (SCs) and scheduled tribes (STs) of its population (31.5 per cent)—SCs and STs are the disadvantaged socio-economic groups in India. As per 2011 census, the district had a population of 2,887,445 with a literacy rate of 87 per cent. The majority of population is rural (64 per cent) and is dependent on agriculture for livelihood (Govt. of Maharashtra 2019). Although, the state has taken initiatives to promote industrial development, however, the district, remains an agriculture-based economy. As per Directorate of Industrial Safety and Health, Amravati district had 219 industrial units with 11,442 workers, of which 907 were female workers—about 7.9 per cent vis-à-vis the State average of 12.4 per cent, depicting a lower participation of women in industrial activities in the district (Gupta and Sharma 2018; Govt. of Maharashtra 2020). As for collectives, the Agriculture Department Report (2018) mentions a presence of 64 farmer producer companies (FPCs) in the district, majorly dealing with farm input supply, capacity building, market linkages for produce, and farm mechanisation services. As with the industrial units, the FPCs were under-represented by women on their board (9.5 per cent), thus affecting social equity and economic wellbeing, especially of women from marginalised communities.

Figure 2. Amravati district
Source: Google map

4. Kasturba Solar Khadi Mahila Samiti

Maharashtra State Khadi and Village Industries Board (MSKVIB), a government department, operates in the realm of promotion of production of khadi—a cotton cloth, livelihood, and micro-industrial development in the state of Maharashtra. During the year 2014-2015, MSKVIB envisaged and commenced to set-up a solar charkha cluster in Amravati district to promote livelihood opportunities and participation of women from marginalised communities in industrial activities. Solar charkha is a solar energy based spinning wheel, which produces yarn from the cotton; the yarn thus produced could be subsequently processed to produce garments. MSKVIB had also established a special purpose vehicle, legally a Public Charitable Trust—Kasturba Solar Khadi Mahila Samiti (KSKMS), for managing the operations of the cluster in 2016. It is one of its kind, women managed, and functioning development project in the country. During its inception,

women from disadvantaged SC and ST communities, living below poverty line from 20 small villages (see Table 1), were encouraged to participate as communities of choice in cotton yarn production activity; thus, it was a novel concept and a non-traditional activity for the people of the region (Kumar and Aiken 2021). MSKVIB officials had participatory discussions with communities to assess their need, interest, and suggestions on the activity. Women, who had proclivity towards the intervention, were selected for capacity development. Simultaneously, their credit history was also verified through local banks for loan eligibility. A single unit of solar charkha was proposed to be funded through a loan of Indian Rupees (INR) 40,000 and a subsidy of INR 10,000 from the state government. Women with satisfactory credit history were selected and trained for solar charkha operations, minor maintenance, and management. Of the members, more than 50 per cent were landless labourers as landholding still indicates socio-economic status in rural India. For tribal members (ST)—more underprivileged of the two communities—the charkha units were grant funded to ensure social equity.

Table 1. Socio-economic characteristics of members of rural solar charkha centres.

Village/ Centre (Category of members)	Year of inception	No of members	Average age of members (years)	Average family size of members	Average landholding of members (acres)	Village population (2011)
Surali (SC)	2015	10	35.2	4.2	0.7	2,795
Nimbha (SC)	2015	11	33.3	5.7	1.3	1,009
Dighi Kolhe (SC)	2015	9	36.2	3.9	3.3	739
Kholapur (SC)	2015	9	35.3	4.6	Nil	11,643
Ramtirth (SC)	2016	8	45.2	4	Nil	2,431
Dabha (SC)	2016	10	42.9	4.1	0.2	3,179
Belora (SC)	2016	10	32.8	3.9	1.2	2,653
Shiwangaon (SC)	2016	10	36	3.8	1.4	DNA*
Belora Hirapur (SC)	2016	10	39.2	4.4	Nil	1,231
Vani Belkheda (SC)	2016	10	37.2	4.0	Nil	1,783
Ghodasgaon (SC)	2017	10	47.9	4.1	0.6	543

Nimkhed Bazar (SC)	2017	10	36.2	4.0	0.9	2,344
Koltek (ST)	2018	10	43.5	4.3	1.9	455
Toli (ST)	2018	11	26.4	4.4	1.4	667
Aki (ST)	2018	11	19.7	6.2	1.8	1,064
Dharakot (ST)	2018	19	24.9	4.7	1.5	464
Titamba (ST)	2018	15	26.8	4.5	2.4	2,650
Ghuti (ST)	2018	26	31.2	5.2	1.6	923
Mandu (ST)	2018	18	26.7	5.2	0.9	1,144
Bihali (ST)	2020	7	21.7	5.4	0.4	829
Total		234	33	4.6	1.2	

**Data not available*
Source: Author, Government of India

The cluster has 21 solar charkha centres, of which 20 are in villages and one in urban area at Amravati. The urban centre—also a central office—is primarily used for capacity building and training purpose. The membership of rural centres ranges from 8 to 26 with 234 members in aggregate. At the centres, the women are provided with cotton to produce yarn and receive compensation based on quantity and quality of the yarn produced on a weekly basis (see Figure 3). The solar charkha unit has several advantages over the hand-operated charkha unit as the former has better productivity, quality, lesser manual intervention, and negligible human drudgery vis-à-vis the latter, thus providing better working conditions for the operators.

Figure 3: A typical solar charkha centre and CFC
Source: KSKMS

The yarn is subsequently processed into garments and marketed by a common facility centre (CFC) located at Amravati. The CFC, also known as Greenfab Solar Khadi Processing Cluster (Greenfab), was registered as a not-for-profit company in 2017 and commissioned with the grant assistance from government in 2019. This in-house value addition was expected to improve productivity and profitability of KSKMS. The CFC is also powered with solar energy along with the grid on a net metering basis. It also uses organic dyes and effluent treatment unit, to improve its green footprints. The members of KSKMS are also the members of Greenfab similar to that of a producer company. The project currently provides livelihood to more than 300 women including spinners, weavers, packers, trainers, and administrative staff, thus, improving participation of marginalised women in industrial activities.

KSKMS sources raw cotton from local farmers to ensure regional economic development. For promoting green measures in backward linkages, it has encouraged farmers to grow organic cotton, which reduces soil, water, and air pollution, as the region reports fatalities due to pesticide inhalation. KSKMS has also executed an MoU with a local FPC for the supply of organic cotton, depicting a gradual development of an environment friendly, institution-based supply chain.

As for marketing, the organisation opened retail outlets Kutir at the district place and nearby urban centres. It also markets its products under the brand name Kasturba and Green Fab to institutional buyers such as government departments, corporates, and colleges. It has collaborated with a national marketing agency to ensure regular offtake of products and income. KSKMS is also going global as its product line has received an enquiry from a Japanese firm. Thus, marketing efforts have been gradually gaining grounds for the products of KSKMS.

The business model of KSKMS is a mix of co-operatives and private sector, where, sales revenue is used for procurement of raw material, compensation to members, and meeting operating and administrative expenses. KSKMS strives to provide maximum compensation to the members for their patronage. Besides, professionalism of a private sector is maintained by ensuring relentless marketing, efficient procurement, and capacity development among other practices. The state organ, MSKVIB, continues to provide guidance and assistance to KSKMS in facilitating financial assistance through government schemes and donors, for development of backward and forward linkages, and training among other things.

4.1 Methodology

After the review of literature, the research focused on preparation of an open and closed-ended questionnaire comprising questions related to income, food security/agriculture, health access, education, gender equality, and productive work. The author has visited KSKMS and rural centres several times to understand their operations in last seven years, which also assisted preparation of survey instrument.

Randomised controlled trials (RCTs) are considered as the gold standard for causal inference. However, conducting RCTs are expensive and time consuming. Alternatively, observational studies are used to establish a causal association between exposure and outcome as they are less resource intensive (Garcia-Huidobro and Oakes 2017). Therefore, for the study, an observational retrospective cohort study framework was proposed. The retrospective studies identify the cohort (groups having similar characteristics), exposure (access to intervention), and outcomes (impact) for exposed as well as non-exposed group to establish causal association between exposure and outcome (Wang and Kattan 2020). In the context of the study, we are interested in computing economic impact (outcome) in terms of income of the intervention (exposure) on the members vis-à-vis non-members (cohort).

For survey purpose, centres having an operational vintage of more than one year were considered to ensure meaningful impact. Of the 20 rural centres, 19 (Twelve SC and seven ST centres with 227 members), had a vintage of more than one year. Of these, two centres, Nimbha and Dharakot, representing SC and ST community respectively, were randomly selected for data collection purpose—to ensure equal representation for both communities as well as for compliance with COVID-19 guidelines as the survey was conducted in November 2021. The cohort had two groups—women with exposure to PURE intervention and women without exposure. The sample size was 10 for exposed as well as for non-exposed group from the same community of a village having similar economic characteristics to minimise confounding bias. In total, 40 samples from two villages were randomly selected (Twenty beneficiaries and 20 non-beneficiaries) with 100 per cent acceptance rate. The average land holding for beneficiaries was 0.95 acre and for non-beneficiaries 0.9 acre, depicting similar socio-economic characteristics. The unit of study was a woman member from a family.

For drawing conclusion about the impact of the intervention; mean value of outcome variable of exposed group needed to be compared with the mean value of non-exposed group. As income (annual) is one of the major enablers and has multiplier effect on

standard of living (Ray 1998), we have adopted it as an outcome variable and proposed following hypotheses:

Hypothesis 1:
Ho: There is no significant difference in the income of beneficiaries and non-beneficiaries
Ha: The income of beneficiaries is more than the income of non-beneficiaries

Further, to make it more conclusive that the intervention indeed had impact on the income of the beneficiaries, another hypothesis was proposed; where, total income of the beneficiaries did not include income from the intervention—the income from solar charkha unit was excluded from beneficiaries' annual income—and was compared with the income of non-beneficiaries.

Hypothesis 2:
Ho: There is no significant difference in the income of beneficiaries and non-beneficiaries
Ha: There is a significant difference in the income of beneficiaries and non-beneficiaries

4.2 Results

The hypotheses were tested using student's t-test (Independent samples) as the sample size was 20 per group. Results for hypothesis 1 in Table 2 indicate that we need to consider statistical values corresponding to Equal variances assumed as the significance value associated with Levene's Test is high. The *t*-test result indicates a two-tailed *p*-value as 0.002 for Equality of Means. The corresponding one-tailed *p*-value is obtained by dividing two-tailed value by two. Accordingly, the one-tailed *p*-value is 0.001, which is less than 0.01. Therefore, we reject the null hypothesis even at 1 per cent significance level and we conclude that income of beneficiaries is significantly greater than the income of non-beneficiaries.

Table 2. Results for Hypothesis 1.
T-Test

Group Statistics

	Exposure to intervention	N	Mean	Std. Deviation	Std. Error Mean
Income in INR	0	20	24950.00	10659.688	2383.579
	1	20	41150.00	19051.937	4260.143

Independent Samples Test

	Levene's Test for Equality of Variances	t-test for Equality of Means

		F	Sig.	T	Df
Income in INR	Equal variances assumed	1.045	.313	-3.319	38
	Equal variances not assumed			-3.319	29.834

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Income in INR	Equal variances assumed	.002	-16200.000	4881.625
	Equal variances not assumed	.002	-16200.000	4881.625

Source: Author

For Hypothesis 2, results in Table 3 indicate that we need to consider statistics corresponding to Equal variances assumed as Levene's Test significance value is high. Accordingly, we get a two-tailed *p*-value of 0.144 (this is a two tailed test), which is greater than 0.05, therefore, we do not reject the null hypothesis even at 5 per cent significance level. In other words, there is no significant difference between the income of beneficiaries and non-beneficiaries, if we exclude income from solar charkha unit.

Table 3. Results for Hypothesis 2.
T-Test

Group Statistics

	Exposure to intervention	N	Mean	Std. Deviation	Std. Error Mean
Income in INR	0	20	24950.00	10659.68	2383.579
	1	20	31725.00	17260.75	3859.621

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	Df
Income in INR	Equal variances assumed	.527	.472	-1.494	38
	Equal variances not assumed			-1.494	31.652

		t-test for Equality of Means

		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Income in INR	Equal variances assumed	.144	-6775.000	4536.312
	Equal variances not assumed	.145	-6775.000	4536.312

Source: Author

A multiple regression analysis (See Table 4) was performed to assess a relationship between an income (dependent variable) and exposure to intervention (dichotomous variable with 0 or 1 level), land holding, age, and education level (independent variables) as land holding still signifies economic status of an individual in India, whereas age and education level are expected to indicate maturity in active participation in the intervention. In the Model Summary (see Table 4), the Adjusted R Square value is 0.635, which indicates the independent variables account for 63.5 per cent variance in the dependent variable (Income), depicting it is a good model to predict the income. The Coefficients table shows independent variables Age and Education are not significant. In other words, we conclude that Income is positively related to Land holding and Exposure to the intervention.

Table 4. Multiple regression analysis.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.820[a]	.672	.635	10456.4047

a. Predictors: (Constant), Exposure, Land holding in Acres, Age, Education

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig.
1	(Constant)	-6298.573	13124.462		-.480	.634
	Age	569.303	297.459	.211	1.914	.064
	Education	953.108	890.537	.123	1.070	.292
	Land holding in Acres	6962.975	1490.096	.534	4.673	.000
	Exposure	13674.101	3552.304	.400	3.849	.000

Coefficients

Model		Collinearity Statistics Tolerance	VIF
1	(Constant)		
	Age	.769	1.301
	Education	.707	1.414
	Land holding in Acres	.716	1.397
	Exposure	.866	1.154

Source: Author

Subsequently, a Hierarchical regression (see Table 5) was conducted to understand the importance of Land holding and Exposure to intervention for Income generation. This would be additionally helpful to understand the importance of Income that gets accrued due to the Exposure to the intervention. We assessed the model with introduction of Landholding in the first stage and Exposure in the second to ascertain how Exposure has incrementally impacted the income. The Model Summary indicates different R values for both Models and Change Statistics. Under Change Statistics, the first column R Square Change provides change in the value of R Square between the models. The last column Sig. F Change tests whether there is a significant improvement in the models as we introduce additional independent variable. As can be seen, the R Square Change value in row two is 0.213. This suggests introduction of Exposure in the second stage helps in explaining an additional 21.3 per cent variance in the Income which is significant even at 1 per cent significance level. This indicates inclusion of Exposure significantly improves our model to predict Income. It is worthwhile to note that acquiring Land is more difficult than becoming a member of the initiative (subject to compliance with membership requirements) for raising the income. Tribal community members do not have financial resources to acquire even a solar charkha unit (Land acquisition would be almost impossible), which therefore underscores the importance of the intervention and grant funding to ensure economic development and social equity respectively.

Table 5. Hierarchical regression analysis.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change
1	.651[a]	.423	.408	13313.3428	.423	27.897
2	.798[b]	.637	.617	10711.9190	.213	21.698

Model Summary

Model	Change Statistics Df1	Df2	Sig. F Change
1	1	38	.000
2	1	37	.000

a. Predictors: (Constant), Land holding in Acres
b. Predictors: (Constant), Land holding in Acres, Exposure

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	25206.834	2576.086		9.785	.000
	Land holding in Acres	8479.099	1605.358	.651	5.282	.000
2	(Constant)	17422.073	2662.549		6.543	.000

Land holding in Acres	8364.364	1291.906	.642	6.474	.000
Exposure	15781.782	3388.022	.462	4.658	.000

Source: Author

4.3 Discussions

During discussions with the members, it was noted that members, who had farmland, used a part of solar charkha unit income as an income multiplier to procure better farm inputs (seeds and fertilisers) to increase production and improve food security depicting their enterprising nature in the context of rain-fed agriculture. The income from the intervention was also utilised towards medical expenses of the family and payment of school fees. This multiplier impact of productive use of renewable energy was also corroborated by the Rockefeller Foundation (2019) and Ibrik (2020) studies in India and Palestine respectively. The project offered safe working conditions to members and had a positive impact on empowerment indices related to social, familial, political, and economic dimension, which improved their agency especially in matters related to finance. The saved time in travelling to the work and freedom to schedule their work on charkha unit contributed towards better time management for other activities. This is an important finding as empowerment of women, renewable energy and productive activities nexus has not been studied widely and therefore, it was needed to be studied as suggested by Katre and Tozzi (2018). The beneficiaries also confirmed the project instilled a sense of ownership due to encouragement for their participation during need assessment and project commissioning stage. Although, the beneficiaries lack knowledge about climate change and green footprints of the intervention, however, capacity building of the members about positive externalities may assist them to appreciate the intervention. These findings therefore confirm climate friendly productive activities have potential to bring about socio-economic change without imposing negative externalities on environment.

KSKMS has been endeavouring to scale up its operations, however, it encounters a few impediments. After witnessing a positive change in the socio-economic profile of beneficiaries, non-beneficiaries from the region have developed proclivity towards the initiative. However, it has not been able to extend membership to them due to paucity of funds, affecting the scale and larger impact, therefore, state support in terms of grants or subsidies is critical for creating a wider development impact as depicted by the intervention in Chhattisgarh (India) (Bhattacharyya and Palit 2014). Further, to boost revenues, forward linkages need to be augmented as awareness about green fabric is still low among the people as revenues have cascading effect on raw material supply, earnings, and fulfilment of operational potential of members. An uninterrupted supply of raw material i.e., cotton also needs to be streamlined as a few members had reported issues in receiving the raw material. Securing working capital facilities from financial institutions is another important issue as it requires profitability of operations for several years, which is difficult to achieve as collectives generally attempt to provide better rates to the members, thus affecting profitability. In near future, KSKMS is expected to overcome these issues through improved marketing efforts, gradual rise in demand for products, maturity of operations, inhouse production, and conducive policy environment.

As mentioned, the Indian Government has proposed an overarching policy framework to promote PURE interventions to address rural livelihood, societal inequality, and inequity. Besides, abundance of natural resources, advancements in clean technologies, and inadequacy of post-harvest infrastructure provide opportunities to collectives like KSKMS. A few women operated collectives have been developing roots in parts of Maharashtra in sectors such as milk processing, fruits and vegetables drying among other activities, thus demonstrating opportunities for socially equitable, remunerative, and environment friendly development.

5. Conclusion

Vidarbha is an industrially underdeveloped region of Maharashtra with insignificant participation of women in productive activities. Productive use of renewable energy-based interventions—which attempt to address income generation, climate change, and social inclusiveness—are emerging as development alternatives in India. One such intervention in Amravati district has established its operations by engaging women from marginalised communities and demonstrated its ability to create socio-economic impact while being eco-friendly. However, for creating greater impact and scaling-up such operations need seamless value chain development, capital supply, and conducive policy environment among other things. Although, the study was carried out on a small sample size owing to the pandemic restrictions, which is also a limitation of the study; however, it provides an overview of a unique, collective based PURE intervention in India as such initiatives are in early stage of their development and are scarcely studied, therefore, future research focussing similar PURE activities could be conducted with a larger sample size covering wider geographical area for their long-term sustainability and broader impact. Socio-economic settings, agro-climatic conditions and enterprising spirit differ from region to region, therefore, a customised approach taking cognisance of the local context could help establish such interventions in collaboration with local communities and improve their socio-economic status, as India foresees a significant role for renewable energy to address sustainable development and climate change goals.

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