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Use of Clean Energy in On-Farm Livelihood Security

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Authors' contributions

This work was carried out in collaboration among all authors. Author SSD designed the study, and wrote the first draft of the manuscript, wrote the protocol. Authors DDB and SPM managed the literature searches, performed the statistical analysis, analyses of the study and managed the field works. All authors read and approved the final manuscript.

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ABSTRACT

Livelihood security in rural areas can be broadly divided into three categories based on land use as primary criterion. Livelihood such as agricultural production depends on land. All such predominantly land dependent activities are covered under on-farm livelihood options. These include cultivation of paddy, wheat, vegetables, etc. Those livelihood activities that do not require cultivation but are of manufacturing or service category are called non-farm activities. These include input and output services for agriculture, agro-processing, transport, education, health, warehousing, retailing, etc. There are some activities which do not require large amount of land ownership are covered under off-farm category. These include goatery, poultry, fishery, dairy, etc. They may require access to pasture for grazing, which can be part of community or forest land. On the basis of livelihood activities practiced by households in rural areas the clean energy requirement will vary. Current study emphasizes on successful development of solar operative irrigation appliances mounted over bi-cycle. On farm use of one such case study has been deliberated from rural areas of South Odisha where the diffusion of clean energy products has taken place.

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Keywords: Clean energy; on-farm livelihood; solar power; CSP's; factors and actors; capacity building.

1. INTRODUCTION

Clean energy know how and commercial models enhance and empower the agro-yields by dropping the post-harvest losses, boost farmer's economy, income generation opportunities, ecofriendly, enhancing energy efficiency and lowering carbon growth during 21st century emerging countries like India. Little field data are open on energy demands for a specific value chain of agricultural yields which does not allow planning and designing a reassured outline for a dynamic value chain for agro-products specifically for rural zones, Chel et al. [1], Wang, L. [2], Sims, et al. [3], Xue, [4], Das et al. [5]. Development, transfer and capacity building of technology through appropriate framework of zero carbon solutions by 2030 was the target of the Paris agreement 2018 and India as a member has accepted the call, UNFCC –[6], Das et al. [7].

India is energy deficient as coal and fossil fuel supply is inadequate to meet the demand and imposition of taxes from the local government. Odisha a small coastal state ranking 8th position and population wise 11th position in India has stressed upon green energy. The state has present clean energy plant of 474MW and targeted for generation of 1500MW by 2022 to meet the RPO, (renewable power obligations) through OREDA (Odisha Renewable Energy Development Agency), and GEDCOL (the Green Energy Development Corp.). GEDCOL has projected roof top installation for 19MW and ground based plant for generating 8MW (Agri Odisha activity report [8], Economic Times, 7th July [9]). The renewable energy sources can be utilized to improve irrigation sustainability by strategic crop management through precision agriculture, crop coverage, crop drying, soil conservation, integrated nutrition and paste management, agro-forestry and water quality sustainability, Purohit et al. [10], Meath et al. [11], Chel at al. [1]. Present research explores the leading role of renewable energy in clean energy farming and on-farms agriculture, pumps, crop dryers and features associated with agronomy by maintaining sustainable ecology, the GHG based environment, economy and societal modification Al-Saidi et al. [12], Imad, [13].

2. ON-FARM CLEAN ENERGY APPLICATIONS IN LIVELIHOOD SECURITY

South Odisha geology and topography are basically comprises of hills, and rocks of Eastern Ghats belts (EGB) with scanty and uneven rainfall, Agri- Odisha Report, [14], Das et al. [15]. The rain fed areas are absence of irrigation, and the agricultural farmers face huddles of poor yield during both Khariff and Rabi season. In the view of providing round the year irrigation facility to the people, facilitating institution, financing institution, manufacturer, and agency for implementation have joined their hands to design and develop low cost, solar operative irrigation gadgets mounted over bi-cycle for easy use by the rural farmers. The case has been discussed and actors and factors have been identified in the subsequent sections.

Fig. 1. The study area (south Odisha) where solar on farm activities targeted

This study was undertaken for the member farmers of a cooperative called Pataneswari Agricultural Cooperative Society" (PACS) in South Odisha. The member farmers of the cooperative societies are the major bucolic consumers. The"Pataneswari Agricultural Cooperative Society" (PACS) is principally working being headquarters at Kundra and Jeypore blocks of Koraput district of South Odisha primarily trading agro forestry products.

The member farmers of PACS were encountering water scarcities for irrigating their rain fed agricultural fields as the region was arid and deprived of irrigation and dependable electricity for their bore wells. To mitigate the huddles of the study area, it was desired for solar operative cycle mounted irrigation architecture was planned, designed, and developed to support the affiliate farmers and imparting them livelihood security. The arrangements have attached a Pentair submersible pump (DC operative) of 0.25HP (Horse Power), for a maximum head of ≈70m, with a probable discharge of 310lph. The submersible pump had been contributed by the Tata Trusts to the Harsha Trust to facilitate and strengthen institutional activities. Harsha Trust; a professional NGO (non-government organization) was working in the study area of South Odisha with objectives of development at grass-root level for sustenance of natural resources, entrepreneurs uplift through livelihood up gradation, and providing improved health care services in the rural expanses in South Odisha (Fig. 2).

The cycle mounted solar operated irrigation system employs two solar photo-voltaic (SPV) panels that produces 175Wat about 4.1A current. The arrangement was attached to an open dug well, with a tank above the ground for storing water. The SPV panels were based tightly on the carrier of the bicycle for informal movement within various fields intended for irrigation. The arrangement is best suited for irrigating small segment of horticulture land, for the member farmers of PACS. The cost of such an irrigation architecture costs only 25000INR per one unit (Fig. 3).

Fig. 2. A meeting of the Harsha trusts in their meeting hall at Jeypore

Fig. 3. Solar Energy operated DC Pump for irrigation adopted by Harsha trust

The member farmers find difficulties in accumulating the required capital at the initial stage to purchase their irrigation supply unit. To ameliorate the this problem of achieving the ground capital, the member farmers were provided with easy financing options like Equated Monthly Installment (EMI) basis or providing subsidy with financing, or at low cost with marginal payment. After implementation the member farmers opted for the lucrative irrigation system and rented it for use by the co-farmers during their need. Hiring process shall assist the member farmers in accumulating funds for payment of installments conveniently. The economic initiative helped to revive the defunct bore wells gradually in the area and went for round the year vegetable production. Considering the initiatives surged within the farmer members, the cooperative units have started taking loan from State Bank of India (SBI) of an allotted amount of 200000INR to expedite and promote the cycle mounted solar operated irrigation system among the farmers. Community service providers (CSPs) of the cooperative were trained on technical and managerial aspects by the facilitating institution.

Further, the CSPs of the cooperative went on providing training to member farmers on installation of the system. Application of the architecture has been considered prospective for the rural farmers with limited financial resources. The water scarcity, irrigation deprivation on account of inoperative lift points, farmers, had to face crops failure for years. The present solar pumps are ray of hopes which can provide at least two-season crops assured in their field. After studying the case, a framework has been devised, presented in Fig. 1. Various factors and actors have been identified and linkages have been established given in Table 1, Table 2 and Table 3.

Tata Trusts act as a technology provider by donating the Pentair DC operated submersible pump and its spares, to Harsha Trust. Tata Trust is among the India's oldest, non-sectarian philanthropic organizations which supports and drives innovation in the areas of energy, education, rural livelihoods, healthcare, water and sanitation, etc.

Harsha Trust acts as a facilitating institution. It supported the implementing agency (i.e. PACS) in guiding, mentoring and providing handholding support through giving training to its CSPs. Harsha Trust provided the DC operated submersible pump to the implementing agency and guided in designing and developing the system.

Harsha Trust helped the implementing agency in linking to the financing institution. It helped in preparation of the Detail Project Report (DPR) for applying loan to the financing institution. Harsha Trust intention was not to earn profit but rather to promote clean energy usage. The reason for supporting the implementing agency was, although the member farmers of the implementing agency were getting enough profit from agro-forestry activities, but still they did not have access to clean energy which was important for improving quality of life.

State Bank of India acts as a financing institution. It provided the loan with payable interest to the implementing agency, to enable the upgrading of solar operated cycle mounted irrigation system among the member farmers.

Pataneswari Agricultural Cooperative Society acts as an implementing agency. It developed a common thinking in identifying the problem of irrigation among its member farmers. It approached the facilitating institution, Harsha Trust and sought guidance and mentoring. It designed and developed the cycle mounted solar operated irrigation system. It approached the bank to provide loan for carrying out promotional activities, ultimately leading to diffusion of the system. PACS provided the system in easy financing options by making the payment for the system on EMI basis. It developed a monitoring mechanism, a solar energy program card to keep track of the payments being made by the member farmers. PACS implemented an Information Technology (IT) enabled system. A designated toll-free number was placed for receiving complains on malfunction of the system from the member farmers, which would help the CSPs, reach the member farmers and provide service, repair and maintenance.

Process implementation focuses on the process of diffusion. Frequent interactions were held with the CSPs and member farmers by the implementing agency and facilitating institution. They were explained on the socio-economic benefits of using cycle mounted solar operated irrigation system. Live demonstration of the system was conducted in the field of a member farmer in order to create a sense of urge and motivating other member farmers to own it. More emphasis was given on how the use of the system would help in providing round the year irrigation, reducing drudgery, enhancing income and easy installments available for the system.

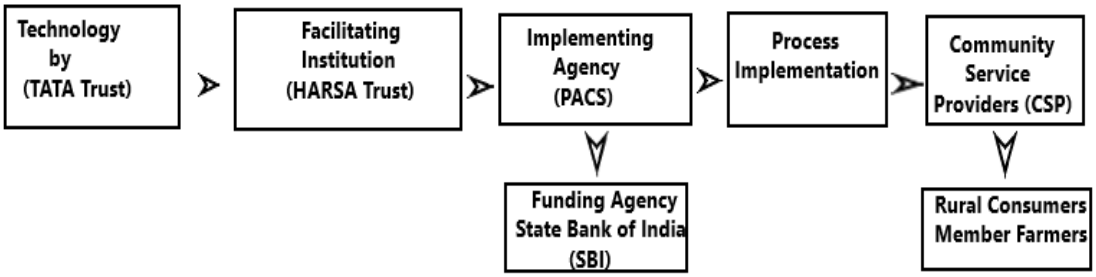

Fig. 4. Framework for the clean energy use of rural livelihood system

Community service providers were working in PACS in the field of agro-forestry, agriculture and livestock and were paid by PACS. They were given training by the facilitating institution on installation, repair and maintenance of the system. They focused on providing maintenance and service of the system when required and demanded by the member farmers.

Member farmers were the ultimate rural consumers for using the system. They took the system and used it in their fields. They were given training on installation of the system by the CSPs. They provided the system as rent to other farmers, which helped them in improving of their income and paying the installment without any obstacle. From the case study, major actors and factors have been identified which are presented in the Table 1 and linkages have been established.

2.1 Various Linkages

The various linkage that can be established by adaptation of clean energy based cycle portable irrigation system are finance based, capacity building related, technology associated and infrastructure correlated**.** They are:

2.1.1 Finance related

(a) *Member Farmers Linkage*

The initial cost of cycle mounted solar operated irrigation system was high and the member farmers were weak in financial capability. Affordability without financial intermediation was low for the member farmers. Hence, there was a need for financial intermediation. As a result, the system was provided through easy financing options, by making the payment for the system on EMI basis. Member farmers rent the system to other farmers which helped them in increase of their income and pay the EMI easily.

(b) *Implementing Agency Linkage*

The implementing agency developed an easy financing option. Implementing agency provided the system on EMI basis to its member farmers. They approached the bank in getting loan for undertaking promotional activity among the farmers in the region.

(c) *Facilitating Institution Linkage*

The facilitating institution helped in linking the implementing agency with the bank. It guided the implementing agency in preparation of the detail project report for applying loan to the bank.

(d) *Technology Provider Linkage*

Tata Trusts act as a technology provider by donating the pentair DC operated submersible pump to develop cycle mounted solar operated irrigation system. Tata Trusts under its philanthropic initiative donated the pump to the facilitating institution. From the present case, no such link could be established between the finance and technology provider.

(e) *Financing Institution Linkage*

SBI acts as a financing institution. It provided the loan with payable interest to the implementing agency, to facilitate the promotion of cycle mounted solar operated irrigation system among the farmers.

2.1.2 Capacity building related

(a) *Member Farmers Linkage*

Member farmers were given training by the CSPs which helped them in gaining knowledge on technical aspects related to operation of the system.

Table 1. Actors and factors linkages for clean energy Use in on-farm livelihood security

Factors and actors	(i) Finance related	(ii) Capacity building related	(iii) Technology related	(iv) Infrastructure related
(a) Member Farmers	Own the system in easy EMI Renting the system to other farmers	Gained knowledge on technical aspects through attending training programs CSPs provided training to the member famers	Requirement of reliable, economic, efficient and affordable solution	Creation of asset for the farmer
(b) Implementing Agency (PACS)	Developed the mechanism for easy payment of the system Approach bank for loan	Identify problem through discussions and conducted meetings with member farmers and CSPs	Design and developed the system Portable, easy to use, require less maintenance and technical knowledge	Developed a monitoring mechanism to keep track of the payments being made by the member farmers Toll free number for quick service delivery by CSPs
(c) Facilitating Institution (Harsha Trust)	Preparation of DPR Linking the implementing agency with Bank	Provided training to the CSPs Held discussions with the implementing agency	Donated the DC operated sub-mersible pump Studied the technical features of the pump Provided technical guidance in design and development of the system	Presence of Harsha Trust regional office Provided warehousing facility for keeping and storing of product and spare parts
(d) Technology Provider (Tata Trust)	No Linkage	No Linkage	No Linkage	Robust supply chain was established by the implementing agency, CSPs and facilitating institution
(e)Financing Institution (SBI)	Provided loan to the implementing agency	No Linkage	No Linkage	No Linkage

(b) *Implementing Agency Linkage*

The implementing agency conducted group discussion, meetings with the member farmers and CSPs. It identified the problems being faced by the member farmers. They tried to find out possible solutions. They sought for help from the facilitating institution.

(c) *Facilitating Institution Linkage*

The facilitating institution started providing training to the community service providers on different aspects. It ranged from technical to managerial aspects. They provided training on service, maintenance and repair of the system. In addition, the facilitating institution conducted several meetings and provided handholding support to the implementing agency.

(d) *Technology Provider Linkage*

The objective of Tata Trusts is to undertake development programs at grassroots level in association with the government bodies, international agencies and private organisations. They undertake various capacity building programs for NGOs, cooperatives, schools, etc. From the present case, no such link could be established between capacity building and technology provider, as the Tata Trusts donated the pentair DC operated submersible pump to the facilitating institution.

(e) *Capacity Building Related- Financing Institution Linkage*

Financing institutions conduct various awareness and sensitization programs for the rural consumers to adopt clean energy products. They provide loans and other financial products to the rural consumers. From the present case, no such link could be established between capacity building and financing institution.

2.1.3 Technology related

(a) *Member Farmers Linkage*

Member farmers were facing the problem of water crises which led to dying of crops. They wanted a reliable, economic, efficient and affordable solution which would help them in providing round the year irrigation facility.

(b) *Implementing Agency Linkage*

The implementing agency bought the Pentair DC operated submersible pump from the facilitating institution and started designing and developing the system. The DC operated submersible pump was placed in a bicycle and solar panels were placed on the bicycle carrier. They sought for technical help from the facilitating institution. The system was portable, required less maintenance and was convenient to use. It did not require much technical knowledge to operate it.

(c) *Facilitating Institution Linkage*

The Pentair DC operated submersible pump was donated by the Tata Trusts. The facilitating institution undertook a thorough study on the technical features of the pump and its operating conditions. The pump was provided to the implementing agency. It provided technical guidance and mentored the implementing agency for designing and development of the system.

(d) *Technology Provider Linkage*

Tata Trusts undertake various initiatives to solve social problems by supporting innovators in technological sector. It works with some leading organizations to find and build innovative projects and support them in funding. From the present case, no such link could be established between technology and technology provider as Tata Trusts donated the pump to facilitating institution.

(e) *Financing Institution Linkage*

Financing institutions like government, bank, donors, funding agencies, etc. provide financial support for setting up testing centers, laboratories, etc. which helps in design and development of clean energy product prototypes. From the present case, no such link could be established between technology and financing institution, as SBI only provided loan to the implementing agency for undertaking promotion for clean energy product among the farmers.

2.2 Infrastructure Related

(a) *Member Farmers Linkage*

Cycle mounted solar operated irrigation system became an asset for the member farmers. As the system was placed on a bicycle carrier it became convenient to transfer from one field to another field for irrigation purpose.

(b) *Implementing Agency Linkage*

The implementing agency developed a solar energy program card, which acts as a monitoring

mechanism to keep track of the EMIs being paid by the member farmers. Both the CSPs and the member farmers kept the solar energy program card to know the due date for payment of the EMI. In addition, the implementing agency also used an IT enabled system; a toll-free number was in place for quick service delivery by the CSPs.

(c) *Facilitating Institution Linkage*

The presence of regional office of the facilitating institution acts as a hub for discussions with the implementing agency and others. It provided a warehousing facility for storing and keeping the spare parts of the system for easy accessibility by the CSPs.

(d) *Technology Provider Linkage*

For any technology provider, having a robust supply chain is a crucial requirement for growth, and reaching to its consumers. It will result in improvement of ease of doing business and helps in creating a larger consumer base. From the present case, the supply chain was established by a collaborative approach between the implementing agency, CSPs and the facilitating institution.

(e) *Financing Institution Linkage*

Financing institutions like government, banks, donors, funding agencies, etc. undertake efforts in building physical infrastructure such as availability of reliable electricity, rural transportation services, proper sanitation, etc. and for people's development, availability of health centers, educational institutions, housing facility, etc. in rural areas. From the present case, no such link could be established between infrastructure and financing institution, as SBI only provided loan to the implementing agency for undertaking promotion for clean energy product among the farmers. After understanding the linkages between actors and factors, table 1.2 focuses on the linkages between each actor (Table 2).

2.2.1 Links narrated between actors and actors

(ia) Member Farmers- Member Farmers Linkage: No link can be established between member farmers and member farmers.

(ib) Member Farmers- Implementing Agency Linkage: The same link is established between implementing agency and member farmers.

(ic) Member Farmers- Facilitating Institution Linkage: The same link is established between facilitating institution and member farmers.

(id) Member Farmers- Technology provider Linkage: The same link is established between technology provider and member farmers.

(ie) Member Farmers- Financing Institutions Linkage: The same link is established between financing institution and member farmers.

(iia) Implementing Agency - Member Farmers Linkage: Member farmers of the implementing agency were facing the problem of water crises for irrigating their fields due to scanty rainfall and unavailability of reliable electricity. Member farmers discussed their problem with the implementing agency. The implementing agency identified the problem of irrigation among its member farmers and tried to find out a reliable, economic, efficient and affordable solution.

(iib) Implementing Agency-Implementing Agency Linkage: There is no link can be established between implementing agency and implementing agency

(iic) Implementing Agency- Facilitating Institution Linkage: The same link is established between facilitating institution and implementing agency.

(iid) Implementing Agency- Technology Provider Linkage: The same link is established between technology provider and implementing agency.

(iie) Implementing Agency- Financing Institution Linkage: The same link is established between financing institution and implementing agency

(iiia) Facilitating Institution-Member Farmers Linkage: Harsha Trust acts as a facilitating institution. The facilitating institution wanted the members of the implementing agency to have access to clean energy which was important for improving quality of life.

(iiib) Facilitating Institution-Implementing Agency Linkage: The facilitating institution supported the implementing agency. The facilitating institution guided, mentored and provided handholding support to the implementing agency in promoting clean

energy usage. It provided the pump to the implementing agency and guided in designing and developing the system. It helped the implementing agency in linking to the financing institution. It helped in preparation of the detail project report for applying loan to the financing institution.

(iiic) Facilitating Institution- Facilitating Institution Linkage: No link can be established between facilitating institution and facilitating institution as prototype.

(iiid) Facilitating Institution- Technology Provider Linkage: The same link is established between technology provider and facilitating institution.

(iiie) Facilitating Institution- Financing Institution Linkage: The same link is established between financing institution and facilitating institution.

(iva) Technology Provider- Member Farmers Linkage: Member farmers wanted a reliable, economic, efficient and affordable solution which would help them in providing round the year irrigation facility. Member farmers used the system in their fields. They were explained on the socio-economic benefits of using the system. From the present case, no such link could be established between the technology provider and member farmers as Tata Trusts only provided the pump to the facilitating institution.

(ivb) Technology Provider- Implementing Agency Linkage: Here the facilitating institution provided the DC operated submersible pump and its spare parts to the implementing agency. Implementing agency bought the submersible pump system from the facilitating institution and started designing and developing the system. From the present case, no such link could be established between the technology provider and implementing agency.

(ivc) Technology Provider- Facilitating Institution Linkage: Tata Trusts act as a technology provider. It donated the Pentair DC operated submersible pump and its spare parts to the facilitating institution.

(ivd) Technology Provider- Technology Provider Linkage: No link can be established between technology provider and technology provider.

(ive) Technology Provider- Financing Institution Linkage: The same link is established between financing institution and technology provider.

(va) Financing Institution - Member FarmersLinkage: Here State Bank of India is acting as a financing institution. From the present case, no such link could be established between financing institution and member farmers.

(vb) Financing Institution - Implementing Agency Linkage: Here State Bank of India is acting as a financing institution. It provided the loan with payable interest to the implementing agency, to facilitate the promotion of cycle mounted solar operated irrigation system among the farmers.

(vc) Financing Institution- Facilitating Institution Linkage : Facilitating institution helped the implementing agency in linking to the financing institution. It helped the implementing agency in preparation of the detail project report for applying loan to the financing institution. From the present case no such link could be established between financing institution and facilitating institution.

(vd) Financing Institution- Technology Provider Linkage: Tata Trusts act as a technology provider and State Bank of India acts as a financing institution. From the present case, no such link could be established between financing institution and technology provider.

(ve) Financing Institution - Financing Institution Linkage: No link can be established between financing institution and financing institution.

After understanding the linkages between each actors, Table 3 focuses on the linkages between each factors.

2.2.2 Links related between factors and factors

(ia) Finance Related- Finance Related Linkage: No link can be established between finance and finance.

(ib) Finance Related- Capacity Building Related Linkage: The same link is established between capacity building and finance.

(ic) Finance Related- Technology Related Linkage : The same link is established between technology and finance.

(id) Finance Related- Infrastructure Related Linkage: The same link is established between infrastructure and finance.

(iia) Capacity Building Related- Finance Related Linkage: Member farmers gained

Table 2. Actors and actors linkages for clean energy use in on-farm livelihood security

Actors and actors	(i)Member farmers	(ii)Implement agency (PACS)	(iii)Facilitating institution (Harsha Trust)	(iv)Technology provider (Tata Trust)	(v)Financing institution (SBI)
(a) Member Farmers	No Linkage	Identify the problem of irrigation	Have access to clean energy	No Linkage	No linkage
(b) Implementing Agency (PACS)	Same as (iia)	No Linkage	Guided, mentored and provided handholding support Provided the DC operated submersible pump and its spares Provided technical guidance in design and development of the system Preparation of DPR Linking the implementing agency with financing institution	No linkage	State Bank of India (SBI) acts as a financing institution. Provided the loan with payable interest to the implementing agency
(c) Facilitating Institution (Harsha Trust)	Same as (iiia)	Same as (iiib)	No Linkage	Donated the pentair DC operated submersible pump and its spares	No Linkage
(d)Technology Provider (Tata Trust)	Same as (iva)	Same as (ivb)	Same as (ivc)	No Linkage	No linkage
(e)Financing Institution (SBI)	Same as (va)	Same as (vb)	Same as (vc)	Same as (vd)	No Linkage

Table 3. Factors and factors linkages for clean energy use in on-farm livelihood security

Factors and factors	(i) Finance related	(ii) Capacity building related	(iii) Technology related	(iv) Infrastructure related
(a) Finance Related	No Linkage	• Gaining knowledge on financial aspect • Ability to identify problem • Provision of training • Knowledge on techno-managerial aspect	• Product given in easy financing option • Renting the system for EMI payment	• Asset creation through easy financing options • Monitoring mechanism for tracking payment
(b) Capacity Building Related	Same as (iia)	No Linkage	• Training on installation of the system • Understanding the technical features through demonstration	• Availability of physical space for discussion
(c)Technology Related	Same as (iiia)	Same as (iiib)	No Linkage	• Facility of warehousing and storing spare parts of the pump • IT enabled system, a toll-free number
(d)Infrastructure Related	Same as (iva)	Same as (ivb)	Same as (ivc)	No Linkage

knowledge on financial products, schemes, subsidy available, etc. which would help in diffusion of clean energy products in rural areas. Through discussions and meetings, they were able to identify the problems being faced for irrigation. They were provided training on techno-managerial aspects related to operation and management of the system.

(iib) Capacity Building Related- Capacity Building Related Linkage: No link can be established between capacity building and capacity building.

(iic) Capacity Building Related- Technology Related Linkage: The same link is established between technology and capacity building.

(iid) Capacity Building Related- Infrastructure Related Linkage: The same link is established between infrastructure and capacity building.

(iiia) Technology Related- Finance Related Linkage: The system was provided through easy financing options, by making the payment for the system on EMI basis. Member farmers rent the system to other farmers which helped them in increase of their income and pay the EMI easily.

(iii b) Technology Related- Capacity Building Related Linkage: Member farmers were given training on techno-managerial aspects. Through discussions and demonstration of the system they understood operation of the system.

(iiic) Technology Related- Technology Related Linkage: No link can be established between technology and technology.

(iiid) Technology Related- Infrastructure Related Linkage: The same link is established between infrastructure and technology.

(iva) Infrastructure Related- Finance Related Linkage: The system became an asset for the member farmers. The member farmers acquired the system though EMI, which helped the member farmers in providing round the year irrigation. It helped in reducing drudgery and enhancing their income. A solar energy program card was used as a monitoring mechanism which helped the member farmers in tracking their payments.

(ivb) Infrastructure Related- Capacity Building Related Linkage: Availability of physical space for discussion with member farmers and other actors helped in understanding the problems and come out with reliable, economic, efficient and affordable solution.

(ivc) Infrastructure Related- Technology Related Linkage: Availability of warehouse facility for storing and keeping the spare part of the system helped in easy accessibility to the community service providers to provide quick service. An IT enabled system, a toll-free number was in place for quick service delivery.

(iv d) Infrastructure Related- Infrastructure Related Linkage: No link can be established between infrastructure and infrastructure.

3. DISCUSSION

From the case study, major role was played by the implementing agency, facilitating institution and member farmers. Factors such as cost of the product, payment through EMI, portability of the product, renting the product, easy to operate, demonstration of the product, repair and maintenance by CSP and system as an asset for the member farmers were some of the factors which helped for the diffusion of cycle mounted solar operated irrigation system.

There was a need for which was fulfilled by the facilitating institution, implementing agency and the CSPs. Presence of a warehouse facility with availability of system and spare parts of cycle mounted solar operated irrigation system, provision of training to CSPs on service, repair and maintenance and a designated toll-free number for quick service delivery were also put in place. With the introduction of EMI scheme and the use solar energy program card, it was easier for the member farmers to pay for the system and track their payment easily. It acts as an effective monitoring mechanism. Involvement of various actors and factors helped in the diffusion to take place. The cycle mounted solar operated irrigation was used by 6 member farmers of “Pataneswari Agricultural Cooperative Society” working in Jeypure and Kundra blocks of Koraput district of South Odisha.

4. CONCLUSION

From the case, major actors and factors were identified and linkages were established which helped in the diffusion of clean energy products in rural areas. From the analysis it is inferred that a strong and determined technical service partners to last mile connectivity is essential. The sanction of loans and record of EMI payments

must be monitored by the intermediary agency. Involvement of many factors and actors should not make the process complex rather search for a simplified mechanism is to be searched.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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