



Solar Energy Programs for Rural Electrification: Experiences and Lessons from South Asian countries

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ABSTRACT

South Asia represents 37 percent of the total population without access to power. Such a circumstance keeps on existing regardless of a few activities and strategies to help country jolt endeavours by the particular nation governments including utilization of sustainable power source innovations. While traditional matrix expansion has been the transcendent method of zap in the area, the nations have additionally broadly utilized sun oriented photovoltaic (PV) innovation for vitality get to. Be that as it may, there has been execution challenges including specialized, money related, institutional, also, administration hindrances. This paper, in view of broad writing audit and overview of chose programs, shares the experience and lessons of sun powered PV programs for country jolt in South Asia – both at the provincial and nation levels - and furthermore introduces a near examination to misuse the cross learning potential. The paper proposes that yield centred methodologies, budgetary developments, packaging of ventures for concentrating vitality loads, receiving standard procedures and measurements, creating vital foundation, and building neighbourhood specialized limit are vital to upgrading the adequacy of the sun powered PV programs upgrading the adequacy of the sun powered PV programs.

Keywords: SHS, Rural electrification, of grid, developing

I. Introduction

Home to one-fifth of the worldwide population in only 4% of the world land mass, the South Asian region is thickly populated. With a substantial rustic populace and minimal in excess of 60 percent provincial power entrance rate, two out of each five individuals in the country regions live without access to power (IEA, 2012). While the figure fills in as a shared factor to the issue, there exists wide uniqueness in rustic jolt in South Asia. Sri Lanka has a provincial jolt rate higher than the worldwide normal while just 22 percent of the rustic populace in Afghanistan approaches power. While the concentrated lattice based zap has been the most widely recognized approach, decentralized sustainable power source choices particularly, sun powered PV(photovoltaic) frameworks has likewise been received, particularly for zones where it is techno-financially not plausible to expand the power network. These off-matrix groups are for the most part little, comprising of low-wage family units – with attributes that may have been monetarily ugly to power appropriation organizations to broaden the framework. In any case, a generous segment of such recipients of sunlight based PV frameworks is additionally found in standard rustic and peri-urban regions, officially associated with the lattice, where the issue is by all accounts less of chance to get associated with network, yet a greater amount of failure of family units to take matrix power association because of their money related requirements or the observation that power

administrations (amount and quality) will be insufficient. With vast populace in the locale proceeding to be without power get to and the colossal measure of subsidizing bolster required for expansion of network based jolt to cover such remote zones, combined with insufficient supply and unwavering quality in existing matrix associated regions, give a window of chance to off-framework sunlight based arrangements.

II. Solar based rural electrification

The significance and effect of improving vitality access through sun oriented PV based decentralized mediations in realizing social and financial advantages for groups in South Asia, going from incremental employments to better office for wellbeing and instruction has been all around archived in writing (Gunaratne, 1994; Chakrabarti and Chakrabarti, 2002; Wijayatunga and Attalage, 2005; Urme and Harries, 2009; Palit and Singh, 2011; Laufer and Schafer, 2011; Mondal and Klein, 2011, Sovacool and Drupady, 2011). In the meantime writing likewise shares that critical part of sun based PV projects and activities in the district have met with restricted achievement (Martinot et al., 2001; Palit and Shukla, 2003; Kumar et al., 2009; Wong, 2010). This paper inspects the present patterns of sun oriented PV for provincial zap at the territorial level and in the meantime endeavors to exhaustively catch the advancement in India, Bangladesh, Nepal and Sri Lanka, where sunlight based PV based country charge has been generally critical. The investigation depends on an audit of late associate looked into writing and in addition reports from different ventures executed in the area complimented by visits to a portion of the tasks in the nations under survey for connection with the actualizing offices, the framework administrators, end clients and other key partners. In light of the audit, a near examination was done to misuse the cross learning potential, both at the nation and district levels. Area 2 of this paper endeavors to catch the present patterns of sun powered PV based charge in four nations, specifically India, Bangladesh, Nepal and Sri Lanka, where sun based PV based zap has been huge when contrasted with different nations in

the locale. Segment 3 examines the dispersal of sun oriented PV frameworks in the four nations in light of different parameters, for example, specialized plans, conveyance models, cost, approach and administrative r engineering and so on. As information accessibility on off-lattice jolt is frequently restricted, the survey is particular.

III. Current trends in solar energy-based rural electrification in South Asia

Solar PV technological know-how has been of the forefront because of off-grid area electrification within India, Bangladesh, Nepal and Sri Lanka. However, the development over such programs has proven a blended trend. The near common solar PV services carried out between the location encompass both decentralized - photo voltaic domestic systems² (SHS) or solar lanterns (SL) yet centralized options such as like solar PV mini-grids⁴ (SMG), photo voltaic DC micro-grids⁵ (SDCMG) then photo voltaic charging stations⁶ (SCS). While the advantages on SMGs above SHS within terms on more advantageous electric performance then reduction about storage wishes are properly documented (Aulich et al., 1998; Chaurey and Kandpal, 2010), between phrases regarding numbers disseminated all through the five years period beyond 2006 until 2011, SHS is discovered after stay the just favoured among whole the international locations strong (Figure 1). The lower increase on SHS dissemination into Sri Lanka may lie attributed after greater growth among grid based electrification into the country, as Bangladesh data a excessive boom due in conformity with community's stress in imitation of shift after cleaner lighting fixtures among absence about grid electricity attaining them yet incursive advertising and marketing efforts by means of the challenge proponents. While most over it projects/programs bear and proceed according to keep by using offers yet donor driven in just countries, a mixture on arbitrary want and provide based totally mannequin bear additionally been effectively tested then wight scaled-up within Bangladesh, Sri Lanka or India, showcasing innovations within rule design or monetary or institutional mechanisms (Palit or Chaurey, 2011).

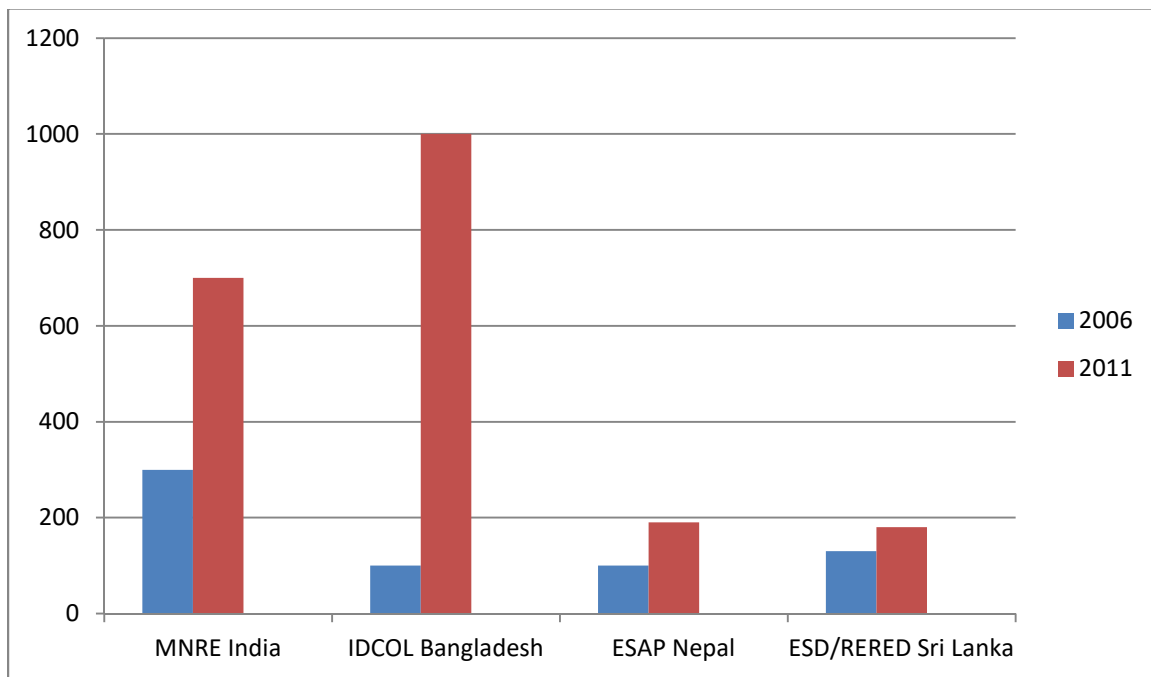


Figure 1: Growth in SHS dissemination in South Asia

2.1 India

Measurements from the Indian Service of New and Sustainable power source (MNRE) show arrangement of around 733,245 SHS and 831,604 SL (as of January 31, 2012) for furnishing lighting to rustic families with aggregate limit of roughly 40 MW. Aside from these, sunlight based PV ventures (>1 kWp limit), incorporating SMGs with limit running from 1 - 500 kWp, have likewise been introduced with an aggregate limit of 96.61 MWp (as of August 31, 2012). Further, lion's share of the 12,369 towns and villas (as of December 31 2011), taken up for jolt under Remote Town Zap program of MNRE were given SHS. The fundamental states where the RVE has more noteworthy significance because of essence of difficult to reach regions are Jammu and Kashmir, Madhya Pradesh, Orissa, Chhattisgarh, Jharkhand and the North Eastern states. The SMGs, then again, have been actualized in few select states dominantly in Chhattisgarh, West Bengal and Lakshadweep Islands. CREDA (Chhattisgarh Sustainable power source Improvement Organization) have zapped around 35,000 family units spread crosswise over around 1000 towns and villages with little matrices. WBREDA (West Bengal Sustainable power source Advancement Office), then again, has in excess of 15 practical sun powered power plants with total limit of in excess of 1 MWp limit, providing steady and solid power to around 10,000 family units. The non-legislative associations and little sunlight based organizations have likewise been complimenting

government endeavors to increase vitality access with sun powered PV. TERI, a non-administrative association in India, has been executing the "Lighting a Billion Lives" (LaBL) program since 2008 and has secured in excess of 1900 towns over 22 states in India (as of December 2012), profiting around 450,000 individuals, and has likewise taken its impressions to a few nations in East and West Africa. LaBL works on expense for-benefit demonstrate where SCS or SDCMG are set-up in towns to give lighting administrations. Figure 2 delineates the photo of a run of the mill sunlight based accusing station of reviving office for 50 lamps. SELCO India, a social venture working since 1995, has introduced in excess of 0.1 million SHS for the most part in the province of Karnataka. Moreover, seventeen provincial banks have additionally been financing SHS under the sponsorship cum-renegotiate plan of MNRE actualized through National Bank for Farming and Country Improvement, particularly in lattice associated territories with poor power supply. The vast majority of these establishments are in the conditions of Uttar Pradesh, Haryana, Madhya Pradesh, Karnataka and Gujarat.

2.2 Bangladesh

In spite of the fact that the rustic family jolt level is low, the nation recorded an amazing SHS program for off-framework territories, executed by IDCOL (Foundation Advancement Organization Restricted), a state-possessed money related establishment. IDCOL

executes the SHS program through its 30 accomplice associations (POs) whose primary part is to choose the task territories and potential clients, offer miniaturized scale loaning, introduce the frameworks, give after deals upkeep support, and preparing to clients and nearby specialist so as to make neighborhood ability and possession on the framework. A portion of the main POs with noteworthy accomplishments are Grameen Shakti, BRAC and Rustic Administrations Establishment. IDCOL has over-accomplished its objectives more than once: for instance, it financed 50,000 SHSs by 2003 against an objective for 2008; it accomplished 200,000 SHS target seven months in front of calendar in May 2009; and against an objective to fund 1 million SHSs before the finish of year 2012, IDCOL accomplished financing of 1,429,440 frameworks (as on April 30, 2012) with rough total limit of 75 MWp (IDCOL, 2012). Very nearly 55% of the aggregate SHS introduced in the nation is by Grameen Shakti alone taken after by Rustic Administrations Establishment (15%) and BRAC (5%) While the execution indicate relatively comparable pattern in the whole nation, the Dhaka Division represent just about a fourth of the establishment took after by Barishal in the south and Chhittagong in southeastern district of Bangladesh with 19% each.

2.3 Nepal

In Nepal, the ESAP (Vitality Division Help program) has been instrumental in advancing SHS in the nation. The stage 1 (1999 to 2004) of ESAP introduced a sum of 69,411 SHS, over-accomplishing the program focus of 40,000 (EASP, 2010). Aside from ESAP, SHS have likewise been introduced secretly and by various NGO run programs. The combined establishments of SHS and little SHS under ESAP stage 1 and stage 2 (2007 to 2012) is 314,633 and 24,646 individually (AEPC, 2012). Further, an aggregate of 138 institutional frameworks including water pumping frameworks have likewise been introduced with the aggregate introduced limit at 1.29 MWp. The aggregate combined limit of sun based PV establishment in the nation is accounted for to be around 7.6 MWp (AEPC, 2012). Bhandari and Stadler (2009) take note of that right around 83 percent of the introduced SHS have board estimate under 40Wp, showing that these are chiefly utilized for lighting. Measurements from AEPC (2012) demonstrate that right around 33% of the sun oriented home

frameworks have been spread in the mid-western locale took after by western (18%) and eastern area (17%). ESAP likewise set up a legitimate framework for directing the sunlight based vitality appropriations and a quality confirmation and checking frameworks for sun based PV ventures, which additionally added to their accomplishments. Two sorts of value affirmation steps are taken before the establishment of SHS. Right off the bat, AEPC permits establishment of SHS just by pre-qualified organizations and also testing and accreditation of segments of SHS is performed by Nepal Photovoltaic Quality Affirmation rules.

2.4 Sri Lanka

The nation has a standout amongst the most noteworthy market-based sunlight based PV program, advanced through imaginative financing plans under the ESD (Vitality Administrations Conveyance) and RERED (Sustainable power source for Provincial Monetary Improvement) program. The ESD venture, which was in task amid 1997-2002, catalyzed the sunlight based market by introducing 20,953 SHS with an aggregate limit of 985 kWp, against an objective of 15,000 frameworks (RERED, 2011).

After the fruitful usage of the ESD venture, the Legislature of Sri Lanka built up the RERED Task in relationship with the World Bank and the Worldwide Condition Office (GEF). This undertaking, enduring from 2003 till 2011, has furnished SHS to 110,575 country family units with a combined limit of around 4.81 MWp. The south focal region of Sabaragamuwa has the most noteworthy infiltration of SHS representing around 20% the aggregate SHS establishment in the nation, took after northwestern region (18%) and Uva area (16%) in the southeastern piece of the nation.

IV. Analysis of the solar PV programme

While traditional network augmentation has been the dominating method of zap in the area, as specified in Segment 1, the nations have additionally widely utilized sun powered PV innovation for improving vitality get to. This area examines the dispersal of sun powered PV, which has been principally spread for provincial vitality access, in the four nations of Bangladesh, India, Nepal and Sri Lanka. The examination has been done regarding specialized outline and estimating, benefit conveyance models, framework cost, access to fund, arrangement and

administrative engineering, and observing and support.

4.1 Technical design and sizing

As talked about in Segment 2, Sun oriented PV applications in the locale incorporate SHS and in addition SMGs, SCS and SDCMGs. A run of the mill SHS incorporates a 20 to 100 Wp PV exhibit, a rechargeable battery for vitality stockpiling, at least one high proficiency lights (either reduced fluorescent or Drove) and a port for a compact highly contrasting TV or other low power devouring machines. The SMGs are normally of considerably bigger limit and give air conditioning power. Then again, SDCMG are secluded with limit extending from 75 Wp for interfacing 10 families, utilizing a DC (coordinate current) circulation network, to around 1 kWp for associating say around 200 family units and normally give just lighting administrations through LEDs and offices for charging mobiles, not at all like the SMGs which appropriates power. All the nations investigated have utilized SHS as a methods for stretching out lighting to regions that couldn't be come to with lattice power. Most SHS spread in the locale are in the limit scope of 37-75Wp (Urme and Harries, 2009), the most widely recognized being 50Wp frameworks. Komatsu et al. (2011) watch that family unit pay and lamp oil utilization to be the fundamental factors behind the determination of specific SHS limit by families in Bangladesh. Then again, an intriguing element in Nepal is expansive scale utilization of littler limit SHS (privately called sun based tuki) with limit in the vicinity of 2.5Wp and 10Wp.

India, then again, has actualized both SHS and SMGs to cover un-energized territories. While the SHS actualized are primarily of 37Wp/40Wp limit, SMGs executed in Sunderban locale by WBREDA are in the scope of 25kWp and 150 kWp, and those in Chhattisgarh state are of much lower limit (<7 kWp). Both CREDA and WBREDA introduced SMGs in towns with concentrated populaces, while towns with scattered settlement have gotten SHS. These small scale frameworks utilize best in class inverters and capacity frameworks of an opportunity to guarantee long life and solid field execution. Contingent upon the limit, they give matrix quality energy to household applications, business exercises (e.g. shops, video focuses, correspondence booths, and little processors) and group prerequisites, for example, drinking water supply, road lighting, antibody refrigeration and

schools. Pico PV has additionally risen as another watchword in country zap with the presentation of exceedingly productive Drove globules for sunlight based lights.

Further, advancements in SMG configuration were additionally acquired India relying upon innovative improvement and groups' need with change of time. Till 2000, Sun based PV smaller than expected frameworks in the limit scope of 25kWp - 26kWp were actualized by WBREDA (Ulsrud et al., 2011). In spite of the fact that heap evaluation was done at the arranging stage keeping future request into thought, bigger limit plans were not authorized as the acknowledgment of idea and innovation was not yet demonstrated. Notwithstanding, watching the solid development in intrigue and request, WBREDA began to manufacture the power plants with bigger limit (>100 kWp) and in a few spots introduced extra age units, for example, little breeze generators and little limit biomass gasifiers to give the incremental power (Palit and Sarangi, 2011). Chaurey and Kandpal (2010) watch that incorporated and professionalized support in the SMG demonstrate liberates the individual client from such duties aside from repair and substitution of machines utilized inside the house/premises, which may have additionally contributed for their fruitful spread.

As far as framework usefulness, the sun powered PV program seems to have better achievement rate in Bangladesh and India, where quality models have been guaranteed for PV boards, batteries and different parts as affirmed by the specialized measures advisory groups. Then again, an investigation of batteries show that the SHS configuration adjusted in Sri Lanka depended on a given value constrain controlled by the political and budgetary courses of action (Laufer and Schafer, 2011). This influenced the task defenders to utilize car batteries and not profound cycle batteries for the SHS. These batteries could store power for just around 4 hours per day and have a normal life expectancy of just 2.5 years. Laufer and Schäfer (2011) additionally watch that because of the poor battery exhibitions which much of the time don't work until the finish of the advance length of 3 years, there has been default in credit reimbursement by the clients. Then again, SELCO India (through Vitality Administration Focuses) and Grameen Shakti (through Grameen Innovation Focuses) and different POs in Bangladesh, dispersing SHS through small scale loaning, have taken due care on the quality

affirmation and post establishment support administration of the frameworks at the neighborhood level, guaranteeing specialized maintainability in this way accomplishing low default in advance reimbursement in their regions.

Off-late, more current battery innovation is additionally being put into utilization. For example, Ni-MH and Li particle batteries have not just enhanced their volumetric vitality densities and their helpful life, the expenses have likewise descended significantly finished the previous couple of years making them an appealing alternative for the versatile sun powered lamps and undertaking lights in perspective of offering longer working hours (Chaurey and Kandpal 2009). The new battery advancements are additionally being guided because of the poor administration, regarding valuable life and profound release condition, gave by the regular fixed support free lead corrosive batteries. Since Li-particle and Ni-MH batteries are routinely utilized as a part of items, for example, convenient PCs, cordless apparatuses, media transmission and therapeutic gear, the results of innovative progressions and cost decreases will likewise profit the sun powered lighting segment. Nonetheless, neighborhood producing limits must be created in the area for these more up to date battery advances for their simple accessibility and lessened cost and exploit their adaptable utilize and higher life.

4.2 Service delivery models

Diverse administration conveyance models have additionally been received in various nations for sun based PV based provincial zap. If there should be an occurrence of individual SHS, charge for-benefit, renting and purchaser financing have been endeavored. Sri Lanka and Bangladesh took after the shopper financing model including banks and MFIs (small scale financing organizations) for substantial scale dispersal of SHS.

In Bangladesh, the SHS demonstrate is executed by IDCOL through its POs. The PO goes about as the money related middle person in the model. IDCOL is in charge of giving stipends and renegotiating the frameworks, setting the specialized details for the sun oriented hardware, creating reputation materials, giving preparing to PO limit building and observing PO execution. Two diverse sort of allow bolster – institutional advancement give and framework purchase down give is given by IDCOL to its POs.

The institutional advancement allow has been instrumental in making the fundamental country foundation for benefit conveyance both as far as scattering and in addition post establishment support of the frameworks by the POs. The institutional advancement concede likewise empowered the POs to assemble their ability by enlisting staff, and preparing representatives in microfinance and credit checking. Both these gifts are likewise proposed to empower POs to buy the innovation beneath advertise rates and give advances to clients, generally bringing down the cost of SHS and expanding the institutional quality for last mile circulation and support. Be that as it may, to advance rivalry, such gives are diminished in sum after some time as more SHS limit is introduced, a component called "a staged decrease of awards" (Sovacool and Drupady, 2011). For instance, the aggregate give which is \$90 for usage of the initial 20,000 SHS is lessened to around \$48 after the PO has accomplished execution of around 150,000 frameworks.

Then again, the Rustic Jolt Board (REB) in Bangladesh have developed an alternate model in scattering SHS. REB introduces the SHS in the client's home and the family unit pays a month to month charge for power utilization however never claims the genuine sun powered board. Grameen Shakti has likewise been utilizing a sunlight based DC miniaturized scale utility model on a little scale under the aegis of the IDCOL sun oriented program. For this situation, a provincial business person secures the sun oriented board, say of 50Wp limit, alongside Drove lights on a portion premise (around 10% is paid as up front installment) and interfaces 4-5 neighboring families to furnish every family with one Drove light. The business visionary makes an employment however the expense (around 6 US pennies/night/light point) charged from every family. Sun based air conditioning smaller than expected network display is likewise observed to rise in Bangladesh with their Service of Energy wanting to extend the model under the as of late propelled Remote Territory Power Supply Framework (RAPSS) conspire. Thirty remote Upazillas (sub-locale) have been distinguished for execution where the SMGs will be controlled by private RAPSS administrators. It is accounted for that these administrators will be chosen through an aggressive offering process for an agreement time of 15-20 years. The framework cost will be met through half give from Service of Energy, 30% low intrigue credit from IDCOL and 20% value from the

administrator (Anam, 2012). IDCOL will channelize the give and credit support and REB will give the required supervision and if required, feasibility hole financing, through a duty appropriation. While tax sponsorship will be given by REB through cross-endowment, the test will be to create enough financing for the give from Service of Energy to cover the towns. Sri Lanka has seen a quick development in the SHS showcase which is predominantly determined by the private part, and is bolstered by the World Bank (Worldwide Improvement Affiliation), GEF and nearby money related establishments. This private area drove activity is a piece of RERED and its ancestor ESD project⁹ whose point was to supplement network based augmentation by the Ceylon Power Board, the nation's vertically-incorporated national utility. The task's middle piece was a market-based credit program accessible to the Taking an interest Credit Foundations (PCIs) –, for example, business banks, microfinance establishments, and renting organizations that meet the qualification criteria of the program (Govindarajulu et al., 2008). These PCIs renegotiate upto 80 percent of their credit distributions. They get to credit at the normal weighted store rate¹⁰, repayable in 15 years with a greatest 5-year beauty period. PCIs utilized their standard techniques to assess the undertakings, set up financial soundness and arrange loaning terms with their clients. They likewise expected full credit hazard on sub-advances dispensed and need to reimburse them as indicated by a conceded to amortization plan, paying little respect to whether their borrowers reimburse.

The financing model took after for SHS is purchaser credit, through the MFIs who work intimately with sun oriented organizations. The sun oriented organizations, through their merchant systems, offer SHSs and offer task and support administrations. Since poor administration by the sunlight based organization can prompt disappointment in client and a breakdown in advance reimbursement, the PCIs who give smaller scale credit likewise go into a reminder of comprehension with the sun based organizations, ordinarily covering viewpoints, for example, least administration levels, repossession of the sun based board on dispossession and buyback in case of a matrix development. This prompts a tripartite game plan including the PCI, sunlight based organization and the end client. This prompted the buyers profit the fund from the PCIs and obtaining the frameworks

from sun oriented firms, subsequently dealing with two unique organizations.

In India, private organizations like SELCO¹¹ and rustic banks, (for example, Aryabrat Grameen Bank and Prathama Grameen Bank in Uttar Pradesh, Gurgaon Grameen Bank in Haryana, SEWA Bank in Gujarat and Syndicate Bank in Karnataka) have been utilizing purchaser financing model (around 10% loan fee for residency of 3-5 years) to scatter SHS (Palit and Chaurey, 2011). Then again, the SMGs in India are worked by neighborhood helpful social orders or VEC (Town Vitality Boards of trustees) shaped by the recipients and are in charge of determination of purchasers, getting ready for the dispersion systems, tax setting and income accumulation. While the group display for sun powered PV ventures have been generally effective not at all like different advances, for example, biomass gasifiers primarily because of lesser specialized intercession required for the sun powered innovation (Palit and Chaurey, 2011), there has additionally been negative aftermath making it all the more trying for supportability. Shrank (2008) watches, in light of a contextual analysis of sun based power plants in the Sunderbans, that the group administration framework did not make motivating forces for amplifying benefit at each power plant, consequently making issues for the scope of expenses of the power supply. CREDA, be that as it may, have been more fruitful in its approach. They developed their own particular administration conveyance show and straightforwardly deal with the activity and support through a three-level arrangement of maintenancel² to guarantee inconvenience free working of the smaller than expected lattice frameworks.

Then again, TERI has been broadening clean lighting under its LaBL activity utilizing the adaptable expense for-benefit model¹³, through receiving both the SCS and also SDCMG display. TERI's model is additionally nearer to the 5P (star poor open private association) model¹⁴, which off-late is getting to be prevalent to upgrade vitality access for the base of pyramid populace (Chaurey et. al, 2012). Then again, Mera Gao Smaller scale Lattice Power (MGP), Naturetech Infra and Minda Nextgen Advancements are new companies in India, who are additionally assembling a few pilot SDCMGs in towns/villas in Uttar Pradesh and Bihar following a more business type of the charge for-benefit display. Their model spotlights on actualizing the full vitality framework –

age, stockpiling, DC dispersion lines and Drove lights – with clients paying administration charges for benefiting the lighting. Their center advancement is benefitting from the ease control conveyance of Drove lights and charging of mobiles (both DC applications) without arrangement for fueling some other apparatuses. While this paper focusses on near examination of the common sunlight based PV programs in the district, it will be beneficial to complete a money related investigation of the different administration conveyance models to see whether there is a particular example rising in benefit models relying upon the innovation being utilized by the specialist organization and what are the essential necessities for such exercises to be feasible with respect to benefit organizations.

4.3 Cost of systems

The unit cost of the sun oriented PV frameworks offered in various nations differs altogether, with programs in India and Bangladesh offering the most reduced normal introduced framework cost (US\$ 6.5-7.5/Wp). A regular 40 Wp SHS in India costs US\$ 300, yet the cost to clients is bring down because of appropriation gave by MNRE to provincial regions. The normal announced cost of 50 Wp framework in Sri Lanka is US \$480 (Urmee and Harries, 2009), though the normal zap cost in Nepal is US\$ 432 for each family utilizing sunlight based PV (Mainali and Silveira, 2011). The national appropriation per sold SHS in Sri Lanka and Bangladesh is paid straightforwardly to the sunlight based firm, and the agreement of offer is joined with a guarantee offer. The cost shifts between different projects/extends in these nations and is dictated by elements, for example, remoteness, number of framework program clients and most critical dependence on imported gear (Table

2). For instance, in Nepal, the appropriation by AEPC is given in light of the remoteness of the town improvement committee¹⁵. The lower framework cost in India what's more, Bangladesh is predominantly a result of indigenous assembling of some segment or the total SHS (Figure 2). A checking review of the Bangladeshi sun powered market by the creator uncovers that the nearby get together of charge controllers has decreased their expenses from around US \$18 to US\$10 for a few wholesalers. If there should arise an occurrence of SMG, the cost per Wp is around US\$7-10 in India. An investigation of the SMG frameworks actualized by CREDA shows that the cost of setting up SMG (control framework in addition to transmission links) is US\$500 per family while the same for SHS is US\$ 280 (Malviya, 2011). Despite the fact that the cost per family unit if there should arise an occurrence of SMG is higher, CREDA watches that SMGs gives power benefits in contrast with just lighting administration by SHS and furthermore are from time to time inclined to burglary and require negligible support. Consequently, the capital assets contributed are ensured. TERI's involvement in executing SDCMGs show their run of the mill cost is around US\$ 60-64 for every family to provide just lighting administrations (2-3 Drove focuses/family) to the clients. Experience from the Lighting a Billion Lives program by TERI demonstrates that the cost for setting up sun oriented charging stations in India is around US\$ 2000 for every office (counting expense of sun based boards, lamps and intersection boxes and their establishment) for energizing 50 lights.

Country	Technologies implemented	Business models	SHS pricing \$/Wp
India	SHS,SMG SL	Consumer financing, l easing, VEC, fee-for-service	7.5
Bangladesh	SHS	Consumer financing	6.5
Nepal	SHS, SSHS	Consumer financing/credit sales	7.8
Sri Lanka	SHS	Consumer financing	9.6

Figure 2: Solar technologies, business models and pricing in four South Asian countries

4.4 Access to Finance

The kinds of financing instruments utilized as a part of the different projects incorporate smaller scale credits plans, loan cost purchase downs and charge for benefit system, all with or with no sponsorships. A study of sun oriented PV programs in South Asia (Urmee and Harries, 2009) demonstrates that greater part of the clients have profited miniaturized scale credit or buyer credit, a quarter utilized state or giver subsidized appropriations and charge for-benefit and just 5% utilized money buy for acquiring sun powered PV frameworks. Among the fruitful SHS projects, IDCOL and ESD/REREDP offer renegotiating through advances (6% interest¹⁶ with 10 years development and 2 years elegance period) to their middle people, (for example, POs and PCIs) and furthermore channel stipends (for instance around US\$25 per 50Wp framework is given as framework buydown concede to POs by IDCOL) to lessen the cost of SHS. The mediator gives credit to clients, who pay 10-20% of the aggregate cost as up front installment and the exceptional in regularly scheduled payments, which likewise covers the interest¹⁷ and the upkeep cost. Mainali and Silveira (2011) share that in Nepal advances secured 55% of the capital cost of SHS, trailed by endowment (27%) and proprietor's value (18%). The middle bit of these plans was long haul credit bundles from contributors to the national government which made it feasible for government to 'on loan' assets to nearby banks for demonstrating credit to clients.

In India, JNNSM (Jawaharlal Nehru National Sun powered Mission) gives capital appropriation on off-network sun based items (INR 90/Wp) and delicate advance at 5% for each annum. Further, to take care of neglected group demand for power or in un-zapped country territories, independent sun based power plants with smaller than normal network, capital appropriation is given at INR150/Wp and delicate credit at 5%. Be that as it may, inspite of having the accessible financing window, the measure of dispensing is accounted for to be poor under JNNSM. In view of communication with provincial banks and shoppers, it is watched that getting to the back from country banks is tedious with long endorsement process presented by the actualizing associations in accordance with government necessities in this way making a barricade to the whole procedure. Further, it is likewise watched that business fund for sun oriented PV off-matrix zap ventures has been

exceptionally negligible. Jaisinghani (2011) watches that most organizations dynamic in off-lattice appropriation are not ready to get to adequate funding to grow. He additionally contends that off-network jolt is likewise prevented by non-uniform specialized methodologies, undeveloped non-specialized procedures, (for example, levy accumulation, and reaction to framework mishandle) which are likewise thwarting access to fund at the early undertaking stage.

This examination additionally watches that the decision of financing system utilized was likewise identified with the association write. Most government associations utilized the charge for-benefit instrument and these projects gave all hardware and upkeep costs, and the clients pay an administration expense as it were. Private associations or NGOs tend to utilize shopper credit, smaller scale credit or money deal system. An issue worth featuring is that absence of reasonable financing system was respected in a study (Urmee and Harries, 2009) as most huge boundary to the take-up of SHS, and was thought to be of more significance than the specialized and approach issues. For instance, in the event of Bangladesh, a TERI overview watches that regardless of an amazing scattering figure of SHS, it is trusted that advantages of sun based innovation have not completely entered into the most reduced strata of the general public, which think that its hard to acquire the SHS on the right now accessible financing choices. This is likewise authenticated by another investigation (Sovacool and Drupady, 2011), which watches that Grammen Shakti programs in Bangladesh require a considerable initial installment for their items that is still past the methods for the poorest individuals from numerous groups. Another imperative finding was that while low wages were viewed as obstructions, it was not apparent to be the essential, or even a noteworthy boundary to the take-up of SHS.

4.5 Monitoring and maintenance

While most actualizing organizations esteemed the significance of support and observing and set up into a normal upkeep framework, this likewise is by all accounts a standout amongst the most basic determinants of restricted accomplishment of numerous projects in the area. In Sri Lanka, buyers benefit the fund from the PCIs and get the frameworks from sun based firms, consequently

dealing with two distinct organizations. As the sun based firms were not dependable to get the reimbursement of the credits benefited, they appear to give less significance to the after-deals benefits as installment default is specifically not affecting them. PCIs endure the worst part of the poor administration as deferral or disappointment in giving the administration straightforwardly impacts the credit reimbursement.

The "single window" show is more suitable to deliver clients' needs and to guarantee usefulness of the specialized framework amid the time of credit reimbursement as saw from Bangladesh. The POs give the smaller scale fund to the customers, encourage deal and establishment of the SHS and furthermore deal with the after-deals benefit. TERI's involvement in executing LaBL likewise certifies the requirement for single window benefit for specialized supportability of frameworks. Amid the underlying stage, the accomplice NGOs of the LaBL program were not getting the required post establishment administrations from the providers of the lamps, as TERI was obtaining the lights (following a standard quality confirmation) and sending them to different towns. With the SCS administrators or clients having not acquired the sun oriented lamps straightforwardly from the providers, the framework providers were not tending to the deformities happening after establishment available to come back to work by the administrators or clients. The issue is presently tended to through setting up of Innovation Asset Focuses or Vitality Endeavors, kept an eye on by neighborhood young people prepared by TERI, covering groups of SCS. The providers of the frameworks now likewise include the vitality undertakings amid establishment of the frameworks and enable them to repair the frameworks amid the guarantee time frame and in addition past, in this way guaranteeing a responsive post establishment upkeep administrations made and oversaw at the nearby level. Both CREDA and TERI have widely utilized the bunching way to deal with give a responsive after deals administration of the establishment in this way guaranteeing their maintainability.

It is likewise watched that fitting preparing and limit building has additionally assumed a key part to ensure viable support and checking of frameworks and in this manner their supportability. One of the key empowering factors for wide scope of families by CREDA utilizing the SMG and SHS frameworks is

because of the provisioning of fitting subsidizing for normal upkeep preparing for experts. It is accounted for that in excess of 1,400 prepared administrators keep up PV frameworks at various areas and a further 75 experts and nearly 60 bosses, prepared by CREDA, repair inverters and other electronic machines in the state. The serious preparing made a pool of specialized labor, who are giving administrations to the SMGs actualized by CREDA, as well as occupied with advancement of decentralized sun oriented applications in the state. The LaBL activity is additionally giving part of significance to refinement and preparing of each partner at various phases of undertaking execution for guaranteeing supportability (Chaurey et al. 2012). This incorporates group refinement and engagement preceding the commencement of the venture at any site to evaluate the need and guarantee worthiness of the task by the group. It is trailed via preparing of the business visionary when establishments, concentrating on the specialized and entrepreneurial perspectives, aside from upkeep and support of the charging station. Second level client preparing is led promptly after establishment to guarantee that the clients are made mindful about appropriate utilization as well as prepared on the institutional example to empower them to look for legitimate after-deals, as and when required. Each accomplice, especially those engaged with coordinate usage is given comprehensive and propelled preparing on the vision of the program, innovation, execution show and their part in maintaining the activity.

In Bangladesh, while there has been no immediate spending plan for preparing, institutional improvement concede and long haul renegotiating are diverted to the executing organizations for limit building. What's more month to month gatherings of POs and IDCOL operational and specialized advisory groups are assembled at IDCOL to examine any field related specialized and operational issues to discover its answer. Aside from these, joint preparing, advertising and limited time exercises are likewise persistently attempted by the POs to build mindfulness among potential clients. IDCOL additionally gives a specialized help allow once a specific measure of limit has been achieved, which can be used by POs for cutting edge preparing and special battles (Sovacool and Drupady, 2011).

4.6 Policy and regulatory architecture

The nations checked on here have built up their own particular arrangement structures and imagine bringing more regions under sun based PV based provincial charge. In India, the JNNSM, propelled in 2009 as a feature of the Indian National Activity Anticipate Environmental Change (NAPCC), however has not been set up to cultivate country jolt fundamentally, it mentions the utilization of sun based vitality as a methods for zap and visualizes that before the finish of 2022, the JNNSM ought to have prompted the setting up of total limit of 2000 MW of off-framework control (MNRE 2010). The Mission additionally imagines that before the finish of the thirteenth Five-Year Design, in 2022, around 20 million decentralized sunlight based lighting frameworks will get introduced in the rustic zones.

Nepal and Bangladesh saw a noteworthy development in SHS establishment in the vicinity of 1998 and 2002. The development in Nepal can be related with the usage of various strategies (endowment approach 2000 with its conveyance system, VAT exclusion and import charge exception) and bolster programs i.e. Country Vitality Advancement Program (1996) and ESAP (1998). Nepal has now set a spread target 600,000 sunlight based home frameworks and 1550 institutional Sun oriented PV Frameworks and Sun oriented PV directing frameworks amid the period 2012 to 2017 under their as of late propelled National Rustic and Sustainable power source Program (AEPC, 2012). In Bangladesh, IDCOL planned the sun powered vitality program in 2002, upheld by the Legislature, and started its task in January 2003 with a fittingly outlined money related model of give and small scale loaning including the POs.

It is likewise seen from the sun oriented PV programs in the locale that there is a part of endowment in every one of the nations. The IDCOL show in Bangladesh and ESD demonstrate in Sri Lanka, be that as it may, is likewise in light of market based conveyance, aside from the little endowment part, with a reasonably outlined financing model. In any case, the dispersal in numerous nations experiences vulnerability in the political structure conditions with governments and legislators regularly choosing precipitously to interface country locales to the national framework. For instance, connection with enter sun based specialists in Sri Lanka and overview by the creator in un-jolted towns in India indicate numerous sun

oriented PV framework clients in Sri Lanka cease the reimbursement against the SHS acquired once network achieves such zones or numerous towns in India demonstrate their hesitance to have sun powered ventures reckoning expansion of lattice in not so distant future. Another reality worth featuring is that while SHS are not considered in the national rustic jolt figures in India and Bangladesh as they cook just to lighting needs, Nepal and Sri Lanka considers SHS additionally as a methods for charge (Palit and Chaurey, 2011).

It is likewise watched that projects, for example, IDCOL or smaller than expected frameworks in Sunderban area and Chhattisgarh in India have been more effective when contrasted with different projects in these nations fundamentally because of their usage through an appropriate institutional courses of action following a standard arrangement of rules (Palit and Chaurey, 2011; Ulsrud et al., 2011). This unmistakably substantiates the requirement for a strong institutional structure alongside fitting arrangement empowering agents for accomplishment of any sun based projects.

V. CONCLUSIONS

The success belief in the broadcasting of solar PV technologies in Bangladesh, Sri Lanka, Nepal and India authenticate that bigger admission to capital, development of able after-sales service, chump centric bazaar development and approved stakeholder captivation assisted in scale-up. Further, achievement focused admission in Bangladesh and Sri Lanka offered the clandestine companies and MFIs/NGOs incentives to admission new markets and bear pre-defined products, while grants added artefact affordability and covered a allocation of the incremental costs of introducing apple-pie activity products. Whereas the subsidy apparatus in case of India and Nepal did advice admission the assimilation of decentralized solar applications, the academy development admission in Bangladesh (instead of a absolute subsidy) helped in sales advance as able-bodied creating able afterwards sales account network. A case in point actuality is from Chhattisgarh state, area INR 25 (US\$ 0.5) per domiciliary per month, provided by the government, was affiliated by CREDA to actualize able basement accessories for accouterment the appropriate aliment of the SHS and SMGs.

It also highlights banking addition and clandestine area captivations are the two capital factors that assisted in college assimilation of solar PV technology to enhance rural electricity access. However, micro-credit getting provided absolute of assets level, banking abetment from the government programs seems to accept either not penetrated into the lower assets households or the accepted banking mechanisms are not in band with their assets level. Further, banking casework accept yet to ability everywhere in the region, and even admitting they abide in abounding areas, the almost top absorption ante and claim of a down transaction still anticipate economically challenged households to annex solar lighting solutions on the accessible costs options. The key affair which calls for actual absorption is acumen of the absorption amount for micro-lending to awning poor households and added advantage through bargain transaction cost. For example, India Post can channelize micro-lending in rural India through its all-encompassing arrangement of branches and accommodate a advanced ambit of small-scale accounts that banks commonly are afraid to do or adaptable cyberbanking can be abundantly acclimated to abate the transaction bulk and thereby the absorption bulk for micro financing. Instead of absolute subsidy by the government, adjustable banking instruments, such as absorption bulk buy down, activity gap funding, achievement based aid, for both the end-users and/or activity account entrepreneurs and adapted accident acknowledgment measures for the rural lending breadth will be added able in ensuring not alone broadcasting of solar articles but aswell their sustainability. There is as well charge for creating apparatus for simple admission to acclaim and financing, both for solar articles as able-bodied as for creating all-important aliment infrastructure, through simpler processes and bigger accountability mechanisms.

As the off-grid projects are consistently abate in capacity, apperception activity endless in a accustomed breadth or bundling projects can abetment in accretion the bazaar size. Off-grid solar projects could be articular in clusters, to ensure economies of calibration and scope, which would advice to administer them sustainably. For example, CREDA has been auspiciously active the projects in limited and densely forested areas, mainly because of the array admission followed for operation and maintenance. Banking institutions/banks would aswell be absorbed as activity accomplishing and acclaim

risks would be less. Bundling aswell can be accessible in minimising the transaction costs associated to get carbon benefits.

Also with added and added areas getting affiliated through filigree electrification, the bazaar for solar PV systems in case of un-electrified areas is getting pushed to added and added limited areas. The acceptable bazaar admission getting followed in a lot of cases or the accessible costs options may not be acceptable to awning such areas with low disposable income. Such areas could be covered through the 5P model. Each of the stakeholders in the 5P archetypal can play a altered role with the accepted ambition of announcement access: clandestine breadth participants can accommodated their accumulated amusing albatross obligations, utilities and activity companies can fulfil their obligation to bear buoy activity services, communities and associates of civilian association can aggrandize admission to basal services.

Also, the fee-for-service archetypal for renting of lantern from a SCS or accouterment alone lighting account from SDCMG may be afterpiece to the charge of poor sections of population. Wong's (2010) analysis aswell corroborates the actuality that after the abutment of any micro-credit systems and area poor humans are accepted to pay for the account by their own means, they adopt to pay for the 'service', rather than own the solar lighting systems back this exerts beneath banking burden on the poor households. Simultaneously, it aswell fosters a faculty of buying that is capital for co-financing the technology. However, the bulk appropriate in setting up SCS or SDCMG filigree is top as compared to agnate amount of alone lanterns/lamps with baby panels. This is because of poor ability of absolute solar installers to limited rural areas and un-availability of able abstruse accommodation to install such systems in such areas, thereby accretion the amount of installation. These calls for bigger architecture efficiency, abridgement of calibration and development of bounded operations to advance a ample basin of aptitude in limited areas for all-embracing amount reduction.

Added to this, developing all-important basement and abstruse accommodation at the bounded akin for developing the endure mile administration approach and accouterment after-sales casework is aswell critical. In abounding cases villagers accept had an acquaintance with poor-quality products, or bare

after-sales which is bringing bad acceptability to the solar solutions. There is appropriately charge for austere adherence to superior affirmation and superior ascendancy of systems. This can be best accomplished by the solar industry itself who charge to basin their aggregate ability in and advance the cipher of practice/standard operating practises for accession of off- filigree systems as able-bodied as standards and superior ambit for the products. Added to this, abstruse acknowledgment on artefact achievement has to be consistently calm and accomplishment should be fabricated to advance customized apartment of articles best ill-fitted for rural areas.

Lastly, for the solar area to ability a cogent scale, companies charge to abolish barriers to supply, appeal and scalability and at the aforementioned time accept accepted action and metrics, which will as well advice them to allure the all-important akin of investment from banking institutions and adventure capitalists acknowledging 'green' programs. The deepening of the financing, administration and after-sales account alternation by facilitating the development of bounded capabilities to micro-finance, assemble, accumulation and account the systems will not alone facilitate action development on the accumulation side, it could potentially enhance alimentation activities that can be affiliated to the accoutrement of electricity services. The opportunities accept to be apparent not alone from the rural electrification opportunities but in the beyond ambience of acceptable activity aegis of the region.

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