Abstract

The diffusion of renewable energy technologies (RETs) has been progressing very slowly in global scope, particularly in developing countries where the diffusion challenges for renewable are greater. Among potential actors in the promotion and diffusion of rural-based renewable energy innovations, NGOs and NPOs have been mentioned as promising actors. However, empirical studies that show the role of the actors and the way they can be system builders by diffusing existing technologies have been very rare. This paper discusses the practices of an NGO in Ethiopia (Solar Energy Foundation) and an NPO in Bangladesh (Grameen Shakti) and shows how local technological innovation systems can be built by key actors in the context of developing countries. The study sheds light on the process of system building for accelerated diffusion of RETs in the context of developing countries. Using a theoretical framework, we compared the approach, technology adoption trend (solar home systems diffusion), and common challenges facing both actors in their respective countries. The two empirical cases which are in different geographical contexts provided lessons on the similarities and differences of system building practices and emerging innovation systems for diffusion of RETs in developing countries.

Keywords: Bangladesh; Ethiopia; diffusion; innovation system; renewable energy; solar

1. Introduction

The diffusion of renewable energy technologies (RETs) has been progressing very slowly in global scope, particularly in developing countries, where the diffusion challenges for renewable are greater. They act as
constraints prevail on both the supply and the demand sides [1, 2]. Unless such technologies diffuse to the community, their economic and social impacts would be minimal [3, 4]. Among potential actors in the promotion and diffusion of rural-based RETs, non-governmental organizations (NGOs) and not-for-profit organizations (NPOs) have been mentioned as active actors, and it is also claimed that they can complement or substitute the functions of national level systems of innovation in some cases [5]. However, empirical studies that show the role of such organizations and the way they can be system builders in developing countries have been rare [5-7].

So far, technology-based innovation system studies have been mainly limited to the context of developed countries [5-7]. Furthermore, there is lack of empirical studies in showing the process of innovation systems building [5-7]. In this study, we present two cases of technological innovation systems (TIS) building practices of an NGO called Solar Energy Foundation (SEF) in Ethiopia and an NPO called Grameen Shakti (GS) in Bangladesh. Using a theoretical framework, the study compares and analyzes the system building practices of these two organizations. The study is aimed at showing how local TIS for accelerated diffusion of RETs (particularly solar energy technology) can be built from ‘scratch’ by key actors in developing countries. Using the two cases in Ethiopia and Bangladesh, the study particularly demonstrates how TIS can be built by NGOs (NPOs) in less developed countries where actors are poorly linked and systems of innovations are in their embryonic forms. These two actors were selected as they have been ‘the exemplary’ in their respective countries. They did it by building local innovation systems in diffusion and solar energy innovations demanded in their respective local settings. The discussion will be about the approach they followed (system building process), the volume of technology disseminated by these actors, and the challenges they faced.

2. Study Framework

The goal of any systems of innovation has been to generate (develop), diffuse, and utilize new technology and technological knowledge [8-10]. While there are different levels of innovation systems (IS) such as national innovation systems [8, 11], regional innovations systems, [12] and sectoral innovation systems [13], we focus on a technology-specific IS (TIS) [14-16]. The scope of this study is how TIS can be built by key actors in developing countries for successful diffusion and further development of the technology.

Musiolik et al. [7] defined system building as ‘the deliberate creation or modification of broader institutional or organisational structures (system resources) in a technological innovation system carried out by innovating actors. It includes ‘the creation or re-configuration of value chains’ [7, p.1035]. System builders can be defined as actors “who are technically, financially, and/or politically powerful and commit themselves to initiate (or contribute) to innovation system building’ [10, p.630]. Hughes [17] in his seminal work on ‘system evolution’ showed that a system has phases along with corresponding actors and networks that preside over the system growth. Hence, a system builder may not preside over the life span of the system [17].

In the emerging literature of TIS, there has been a trend of emphasizing functional dynamics (in the TIS studies mostly in the context of developed countries) rather than on the structural dynamics (constructivist approach). However, the structural system building has to precede the functional system dynamics at the formative stage of IS building in developing countries [c.f. 15, 16, 18]. Previous studies focused on the emergence of TIS in developed countries where structural components are assumed to be ‘somewhere out there’ [7], which is not the case in developing countries. So that it is obvious to infer that without the presence of a system (system components), functional growth cannot be realized.

In a previous work on TIS building for accelerated diffusion of RETs in developing countries [19, 20], we identified that learning from experimenting (pilot projects), creating or attracting actors, building networks, and influencing institutions are essential steps [10, 20-22]. We then follow the argument that IS building in developing countries needs to start firstly at ‘constructing the system’, bringing system components together [23, 24]. System builders in developing countries first introduce innovations (which may not be new to the world, but new to the recipient society) as pilot projects and then aim for scale up and wider diffusion of the innovations. Through learning by doing, using and interacting (DUI forms of learning) [11], and ‘attracting through success’, new entrants (actors) may join the scale up effort. In the case of failure to attract other actors (for instance, financial institutions for the development and diffusion of a new energy technology), creating actors may be the other option for the system builder. Potential (essential) actors may not be there at all, as it is often a prevalent situation in developing
countries; for instance, there may not be trained engineers and technicians for technical system installations. Actor creation refers to the establishment of complementary (affiliate) actors required in the system building process [17, 20]. Moreover, a system building requires building networks through formal and informal linkages. Such networks play critical roles in the IS building process, for instance, through influencing the political agenda and expectations of the future [7]. Furthermore, institutions set the ‘rules of the game’ and influence the development and diffusion of a technology [25]; hence, system building requires influencing and aligning institutions for the goals of the system [7, 26].

Using a proposed framework of TIS building (Fig.1), we compared and discussed the system building practices of SEF and GS in Ethiopia and Bangladesh respectively. Though it may not be a linear process in all system building cases, a ‘deliberate system building’ [7] can take this form. The two illustrative cases served as both refining and validating cases of the proposed system building framework.

![Technological innovation system building framework](image)

3. Methodology

Case study has been selected as appropriate methodology for it is a pertinent method to study “how and why research questions” [27, p.8]. Our study discusses the practices of the two organizations, SEF and GS, and show how local TIS can be built for the diffusion of RETs from 'scratch' by such key actors in the context of developing countries. As part of an ongoing and larger research project, we have conducted intensive study on the practice of SEF-Ethiopia through multiple field visits between 2012 and 2014. Semi-structured interviews, questionnaire-based surveys, and focused group discussions were used in addition to the review of publications on the works of SEF. The data about GS were also collected both from primary and secondary sources including peer-reviewed publications, reports and homepages of the GS and the Grameen family. Three experts and officers we have known and worked with GS were interviewed in person and through email exchanges. Comparative analysis was carried out to derive the common lessons, and further explanations are included based on theoretical background from TIS studies.
4. Overview of Cases

4.1. Solar Energy Foundation (Ethiopia)

SEF-Stiftung Solarnergie, first established in Germany in 2004, is currently operated in Ethiopia, Philippines, and Kenya with the aim of “alleviating poverty in developing countries by promoting the use of renewable sources of energy, mainly solar power” [28, p.50]. SEF started its pioneer Ethiopian project in the now called ‘solar village’, Rema, and a nearby village called Kechemober, about 250 km away to the north of Addis Ababa, capital of Ethiopia. It was in Rema, a remote village of about 6,000 households who were dependent on kerosene and fire woods for lighting and cooking, that SEF installed 1,100 solar home systems in 2006. It later expanded its solar centers and addressed the other parts of the country. SEF, so far, has introduced solar systems and solar lanterns not only for individual users, but also for institutions such as rural primary schools and clinics. In addition to solar home systems (SHS), solar street lights, solar water pumps, and solar TVs are also other solar-based technologies that SEF has been providing to the rural users [28].

In Ethiopia, the main sources of light in homes and small businesses mainly in the rural community are kerosene lamps and candles, which emit fumes that cause health problems for the users. The first solar photovoltaics (PV) systems were introduced in the mid-1980s and were installed for rural homes and primary school lighting [29]. While still having un-electrified critical mass of population and relying on biomass for both cooking and lighting, the country is naturally endowed with an average annual solar radiation energy density of unit area amounting 1,992.2 KW·h/(m2·a) and annual total solar energy reserve of 2,199,000 TW·h/a [30]. Nevertheless, the diffusion of both solar PV systems and solar thermal technologies in the country, mainly to the rural community amounting more than 75% of the population has been so minimal. Looking for the right actors and ways for sustainable diffusion and further development of such rural innovations has been an on-going task.

SEF has been a pioneer in rural SHS installations in Ethiopia and considers its approach as “holistic” and “an approach that is binding social and financial sustainability together” [28, p.46], as shown in Fig.2. The governing approach of SEF, according to the founder, is “the profit-oriented affiliated enterprises led by the non-profit foundation and not vice versa” [28, p.15].

![Fig. 2. Approach of SEF (Adapted from: [28, p. 46]).](image)

4.2. Grameen Shakti (Bangladesh)

GS is an NPO established in 1996 with the goal of promoting environmentally friendly and affordable energy technologies focusing on the rural community without energy access in Bangladesh [31].

Bangladesh gets an average daily solar radiation of 4–6.5 kWh/m2 and it has been one of the pioneering countries in utilizing Solar PV for providing electricity to households and small businesses in rural areas [31, 32]. Fire wood,
twigs, agricultural residues, and other forms of biomass have been for long main sources of energy in the country [31].

GS, known as ‘a spillover from the success of Grameen Banks’, is a pioneer in Bangladesh on the use of micro-credit financial system and technical assistance to promote SHS [31-33]. It also promotes the use of small scale biogas plants and improved cooking stoves. It is also one of the fastest growing micro-finance based disseminator of solar home systems [31].

GS, though it is claimed that it does not receive direct fund from Grameen banks, has potentially used the legitimacy and ‘brand name’ of the Grameen bank. It used it as a family of the bank and to access loan and grant from different sources through bilateral and multilateral development partnerships. It has benefited from global partners including USAID, GEF, IFC, SIDA, etc. [31-33]. Despite such start-up funds from donors, GS claims that it has turned into a ‘self-sustainable non-profit company’ since 2003 and since then, it has derived more than 90 percent of its revenue from its sales [31, 33]. It has managed to cover 75% of all SHS sales in 2005 and 2006 and about 60% in 2010 throughout the country [31, 33].

5. Learning from the Practices of SEF and GS

Here, the common features of SEF and GS are categorized and discussed as approach (system building), technology diffusion trend, and common challenges.

5.1. System building practice

Following the theoretical framework presented in the previous section, the system building efforts of both organizations in the diffusion of solar energy technology is discussed. Both SEF and GS started with pilot projects in which they introduced solar systems to the rural communities in their respective countries.

• Learning from pilot projects (Experimentation)

SEF started its pioneer pilot projects in the now called ‘solar village’, Rema, and Kechemober, about 250 km away to the north of Addis Ababa, capital of Ethiopia. SEF started by installing 30 solar home light systems to the small village of Kechemober in 2005. The pilot projects in Kechemober, Rema, and its surrounding helped SEF to test the acceptance of the technology by the rural users. It also tested the learning curve growing in two to three years of pilot projects for further diffusion of solar home systems in Ethiopia. With good acceptance and feedback from the early adopters, further requests were placed by the nearby villagers [28, 34, 35]. Such early pilot projects provided SEF a learning experience for its later engagement in Ethiopia.

Following the success of Grameen bank, GS has been noted globally for its micro-credit based delivery of solar home systems to the rural areas of Bangladesh [31, 32]. GS started its engagement with pilot villages for the dissemination of SHS and through years, it even expanded to promoting and developing other energy technologies including biogas plants and cooking stoves [33]. Through learning from its year to year expanding program, it is now one of the “the largest and the fastest growing micro-generation renewable energy programs in the world” [31, p.5064].

• Creating affiliate actors

SEF during its pilot project in Rema and Kechemober learned that there was an acute lack of skilled manpower in solar technology in Ethiopia as it was forced to employ German engineer to install the first solar home systems. There were hardly any solar technicians in the country before 2005 [36]. SEF then launched a training school, later termed as International Solar Energy Institute (ISEI) in 2007 that could train both local and international solar technicians. The trainees follow a 3 months course work on solar technology and application and solar business management along with a following 3 months practical training in installing home systems in rural villages. SEF claims that until 2011, 65 solar technicians are graduated and some of the graduates became solar entrepreneurs and
employees of SEF (solar technicians). The first author managed to meet at least six of them during field visits. As an NGO, SEF started by donating the first solar systems and it later built a revolving fund and a micro-finance unit to provide loan to the rural users. The fund was available to those who could not afford to pay the upfront cost for the system so that they would pay the acquisition cost on installment basis. As to the director of SEF, this move of establishing own micro finance institute was due the reluctance of exiting microfinance institutions to provide loans to rural solar users.

SEF also got its own daughter-company called Sun Transfer which produces (assembles) solar system components. It has got a spacious compound (15,000sqm) from Ethiopian government for further building of solar PV industry locally. SEF introduced a service network of solar centres that are basically established by its graduates from ISEI and form a group of four and five to sell, install, promote, and provide maintenance services in the rural areas of Ethiopia. Although SEF had a plan to establish 50 solar centres by 2012, it only achieved 14, as the peer interview with the director. In general, SEF has established its affiliate actors- training school, micro-finance institute, technology source (assembly company), and solar centres.

As some call it a “global pioneer” [33, p. 4445], GS has also started its first solar installations with 20 systems and moved to the next 100 systems and more supported by international donors [36]. Learning from the success of those early experiments, it now claims installing its millionth installation recently. GS focused more on training of women technicians through its Grameen Technology Centres (GTCs) to decentralize its production, marketing, and maintenance services. As summarized by [31], the salient features of GS in its practice included: the use of micro-credit finance; its wide operational network; its local manufacturing and assembling facilities-(for instance, it locally develops a number of helping components including charge controllers, lights and mobile chargers.); and establishment of technology centres. The technology centres are established for educating the public about technologies, improving the distribution network and providing after –sales maintenance services [31]. GS also conducts R&D on solar devices and even managed to have their own design and patent original low-cost charge controllers and other components that are less costly than those available in the local market [31, 33].

One of the key drivers behind the success of GS is its supportive financial model. The vast majority of its targeted customers-base – households and businesses in rural areas – cannot afford to purchase a SHS or biogas system at their own. Through its micro-credit program, GS offers a range of financial and technical support packages to make these renewable technologies affordable for its customers [31].

**Network building**

Both SEF and GS have put enormous effort in expanding their network both locally and internationally. Moreover, in the case of SEF, its “hybrid” nature, being backed by a network of organizations and companies in Europe, Africa, and Asia contributed to its relative success in Ethiopia (REF). Both organizations also benefited from global funding organizations and other network partners. To make a strong and well-functioning IS, building networks with users, academic and research institutes, policy makers, etc. is essential.

While it is difficult to form a strong network during TIS building, putting own -actors (affiliate actors) in place at the ‘formative phase’ has been a means to a wider end as experienced by SEF and GS. However, the lack of integration between NGOs, companies and governmental organization has been prevalent particularly in Ethiopia [38]. To make a strong and well-functioning IS, building networks with users, academic and research institutes, policy makers, etc. is essential.

Both SEF and GS have put enormous effort in expanding their network both locally and internationally. Both organizations benefited from global funding organizations and other network partners. However, there still the remaining of an arduous task for both organizations in further networking with private sector, government organizations, and scaling up their efforts to a higher and sustainable level. In this regard, SEF claims that they are expanding and ‘taking lessons’ from Ethiopia to other part of the developing world. A noticeable difference we observed in future plan of the two organizations is that SEF plans to expand its network through its ‘for-profit’ hands such as Sun Transfer whereas GS seems to remain an NPO.

**Influencing institutions**

While building networks and creating affiliate actors may solve part of the problem in IS building, institutional
support from other relevant and mainly political actors including the government is critical. Placing own arms in place at the “formative phase” of IS building makes the system building less challenging. When institutional set up is weak, system builders face myriad challenges.

Both SEF and GS have contributed to the national level policy formulation and agenda setting for the promotion and dissemination of SHS. However, both actors faced challenges in this regard. For instance, SEF through building networks with other actors, such as through the establishment of Solar Energy Development Society of Ethiopia, tried to introduce a change and influence the taxation and import regulations of solar technologies in the country. In both countries, it is reported that lack of ‘integrated approach’ by the involved stakeholders made the national level of system building demanding need more effort. On the other hand, Bangladesh is taken as a ‘success story’ globally in rural off-grid electrification [38].

Further efforts, historical developments, and achievements of SEF and GS in their respective context are compared and compiled in Table 1.

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5.2. Technology diffusion trend

A well-established IS enhances the success of a technology to be developed. Diffused and the diffusion of the technology under study is taken as an indicator for the overall performance of a technological system where the system is well established [20]. Nevertheless, when it is in its ‘formative phase’, the rate of diffusion of an innovation is not a proper measurement performance; rather, how well the system is being formed is an indicator of performance [21, 39].

Eventhough the success of such embryonic IS may not be measured through the diffusion of the technology, SEF managed to grow its solar systems diffusion in Ethiopia as shown in Fig.3 (a). It makes it a pioneer in the country in diffusing solar innovations. A comparatively high success and faster diffusion rate of SHS, earned by GS is also

1 A typical SHS consists of components including a solar panel, an inverter, a charge controller, a battery, and fluorescent lamps [33]. Systems ranging from a capacity of 10Wattspeak (Wp) to 130 Wp are available in GS projects and, SEF provides even smaller systems such as a 2Wp solar lantern.
shown in Fig. 3 (b). Both organizations have managed to take the higher share of SHS diffusion in their respective countries.

Fig. 3. (a) Cumulative SHS installations by SEF (Source: SEF); (b) Cumulative SHS installations of GS (Source: GS).

5.3. Common challenges

Both SEF and GS operate in less developed countries where the institutional set ups, including economic, political, and social environments are not welcoming to the faster diffusion of RETs [1, 34]. Hence, there have been hurdles in engaging in the solar technology diffusion in both contexts particularly during the early experimentation periods. Officers of both organizations mentioned the early challenges in their solar PV projects including lack of awareness among the rural people, lack of rural network, and limited trained manpower. High upfront costs of the systems and lack of source of funds were also among the early challenges.

More challenges still abound even after some ‘success stories’ of both organizations as they have been seen as “competitors” by both governmental organizations and the private sector. Such competitions were manifested in terms of lack of commitment in capitalizing the system building practices of the organizations and running similar programs by government organizations in same areas where SEF and GS are active [14, 22]. As a system builder, such actors need to win the heart of policy makers and to sustain their effort towards a growing market and sustainable development of the society. In addition, a common criticism by private companies on the intervention of NGOs (NPOs) in the market of renewable is the ‘distortion of markets’. Such concerns can be addressed by strategic action of system builders through creation of (affiliate) entrepreneurs as argued in literature, following the “action-based model of organizational evolution” and building on the “entrepreneurial actions” [40, p.99]. Moreover, the private sector is expected to benefit from the emerging market of renewable. Hence, the early formation of market for new technologies may not be as attractive as the established market for companies in the developing world. In Ethiopia, for instance, solar market is taken as a 'side business' for most of the private companies [38].

6. Concluding remarks

It has remained an obvious fact that the diffusion of RETs in developing countries has been sluggish and prompted the joint effort of several actors. We followed the argument that there is a need to build functioning TIS for successful diffusion and further development of RETs. Since the context of developing countries is characterized by poor linkages and dis-integrated efforts, the need for system building is quite noticeable. Among the potential
actors in building systems and addressing particularly the rural energy market, ‘well-intentioned’ NGOs (NPOs) are main candidates as discussed in this paper. A caution remark here is that there is no intention in concluding that NGOs and NPOs are the only system builders in developing economies. It rather concludes that, as argued in previous literature, such actors are in a better position to kick off the system building process so that other actors (including other system builders and established interest groups) may follow or take over.

The two cases situated in different contexts help to identify similarities and differences of system building practices and emerging innovation systems in developing countries for diffusion of RETs. Such ‘exemplary’ cases in developing countries may serve as a ground for proper policy making and capitalizing on the practices to other levels of systems of innovations such as the sectoral and the national level systems of innovation. In analyzing the practices of the two cases using our theoretical framework, we revealed that they followed similar system building approach. Moreover, the technology diffusion trend served us an early indicator of their performance.

Further empirical investigation is needed to enrich the idea of innovation system building and the role of system builders for accelerated diffusion of RETs in developing countries. More importantly, further study on how to identify system builders and system building practices for successful diffusion and further development of innovations is our recommendation.

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References


