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Article

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Abstract: This paper analyzes the socio-cultural dimensions of obstacles facing solar photovoltaic projects in two villages in rural Nepal. The study was conducted in Humla District, Nepal, one of the most remote and impoverished regions of the country. There are no roads in the district, homes lack running water and villagers' health suffers from high levels of indoor air pollution from open cooking/heating fires and the smoky torches traditionally burned for light. The introduction of solar energy is important to these villagers, as it removes one major source of indoor air pollution from homes and provides brighter light than the traditional torches. Solar energy is preferable in many villages in the region due to the lack of suitable streams or rivers for micro-hydroelectric projects. In the villages under study in this paper, in-home solar electricity is a novel and recent innovation, and was installed within the last three years in two different geo-spatial styles, depending upon the configuration of homes in the village. In some villages, houses are grouped together, while in others households are widely dispersed. In the former, solar photovoltaic systems were installed in a "cluster" fashion with multiple homes utilizing power from a central battery store under the control of the householder storing the battery bank. In villages with widely spaced households, a single home system was used so that each home had a separate solar photovoltaic array, wiring system and battery bank. It became clear that the cluster system was the sensible choice due to the geographic layout of certain villages, but this put people into management groups that did not always work well due to caste or other differences. This paper describes the two systems and their management and usage costs and benefits from the perspective of the villagers themselves.

Keywords: solar photovoltaic systems; village end-user; Nepal

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1. Introduction

This paper considers the socio-cultural costs and benefits associated with two different types of solar photovoltaic systems presently in use in Humla District of Northwestern Nepal. With a *per capita* GDP of $72, Humla ranks among the poorest regions of the country. Approximately 80% of the Nepalese population lives in rural areas and many of those areas do not have access to the national energy grid. Humla is one such area. The district experiences chronic food shortages and 65% of children under five years of age are malnourished [1]. Infant and maternal mortality are even higher than the alarming national averages [1,2], and Humlis live in homes without running water, access to latrines, or regular medical care. Under circumstances such as these, it is critical that development be both holistic and sustainable, and should be conceptualized and implemented in long-term holistic community development projects that take a multi-pronged approach to health, food security, drinking water, indoor air pollution and education. In this paper, I consider the socio-cultural dimensions of one component of a local non-government organization's holistic community development project, namely the solar photovoltaic component. The non-government organization offers the solar photovoltaic project in combination with clean drinking water, pit latrines, smokeless stoves, greenhousing, solar dryers, non-formal education, and nutrition monitoring and intervention in dire cases. In a previous paper, the technical parameters of the solar photovoltaic projects described herein are described [1-3]. Here, I report the results of a series of interviews conducted in October, 2009, with the-end users of two types of solar energy system projects commonly installed in this region.

Because Nepal has no fossil fuel resources but is rich in renewable energy resources, it is important that its government and populace take advantage of the renewable energy resources available in the area. Hydro power plants provide 98–99% of Nepal's grid electricity, which enables roughly 25% of the population, mainly in urban areas, to access electricity [1,2]. But because approximately 80% of Nepal's inhabitants live in areas not reached by the grid, solar photovoltaic and other renewable energy systems are key, and the social and cultural impediments to accessing and fully benefitting from them are important to understand.

2. Research Site and Methods

Humla is in the remote northwestern corner of Nepal. Straddling 30° N latitude and lying between 81° and 82° longitude, Humla is one of Nepal's "High Himalayan" districts. It is one of the most isolated regions in Nepal, reachable only by foot or on the small planes that land irregularly in the district capital, Simikot. The district lacks roads altogether and indicators of development are correspondingly low. There are no hospitals in the district (though an under-equipped health post exists in Simikot, the District capital) and literacy rates are among the lowest in the country: 20% for males and 11% for females [4]. Population density is also very low, with fewer than ten persons per square kilometer [5]. This is due partly to the fact that along with the other northwestern districts of Nepal (Manang, Mustang, Dolpo, and Mugu), Humla has relatively low total fertility rates. The total fertility rate (total births per woman) for the district was estimated at 4.5 in both 1986 and 1991, while the rest of Nepal was 6 in 1985 and 5.6 in 1990 [6]. The relatively low total fertility rates in the northwestern regions may reflect the proportion of their populations that is composed of polyandrous Tibetans.

Polyandry is a marriage system practiced by many ethnic Tibetans in this area, and allows a single woman to have multiple husbands simultaneously. The common practice is for a woman to marry a man and all of his brothers, and to have sexual relationships with each of them. Unmarried women do not typically have children in this system and are thus excluded from the pool of reproductive women. At an aggregate level, this practice depresses the fertility rate [7-11].

The ethnic composition of Humla is complex but not unique, as a similar mix characterizes most of the districts in the High Himalayan zone. Nepal is divided from north to south into five regions: the High Himalaya, the High Mountain, the Middle Mountain, the Siwalik, and in the furthest southern areas, the Tarai [12]. Glaciers cover parts of the High Himalaya. The majority of villages in northern Humla are populated by Hindus, mainly Chettris, Thakuris and occupational castes, particularly in the southern part of the district. However, like most of the other mountainous districts, part of Humla's population is ethnically Tibetan (roughly 16% according to the 1991 Census of Nepal). This is not because Tibetans moved into the region after their exodus from Tibet in the 1950s, but because the region was part of various Tibetan kingdoms for many centuries. Some of the population of those former kingdoms fell to the south of the northern Nepalese border when it was finally drawn after the 1793 political unification of Nepal.

In October 2009, I conducted focus group discussions and individual interviews with approximately 50 householders in three villages in which the two types of solar photovoltaic systems had been placed. Interviews were conducted in Nepali and were drawn from a questionnaire that had been approved by the University of Montana's Institutional Review Board for compliance with human subjects protections guidelines. Both men and women were interviewed, and members of all ethnic groups and castes were present at the group discussions. Some people wandered in and out of the group discussions as they progressed, and for this reason my sample size is only approximate. I recorded notes of all conversations as they unfolded, and later, discussed my notes and any translation issues with a Nepalese colleague with whom I was traveling. He was also a participant in each village discussion. Because it was important to me at the time to dispel any notion that resources might be withheld from villagers based on honest descriptions of negative experiences with the systems, I did not record the names of interviewees, nor did I code my notes to distinguish exactly who said what. My intention was to elicit a general, frank, and open discussion of the pros and cons of each of the two systems, rather than to collect data for statistical analysis.

Living conditions in all of the villages in the study area are extremely difficult. Houses are small, poorly ventilated, and, until recently, unlit. Most are built in three stories, with domestic stock kept in rooms on the lowest level, the main room (for cooking, sleeping and eating) and storage rooms on the middle level, and storage rooms (for some valuables, equipment and hay, or to house guests) above. The third level of the house is mostly open—comprised of the roof of the second level, at the back of which (against the hillside) are the storage or guest rooms. When the weather is nice the rooftops are sunny and pleasant and are the primary site of public meetings (including ours), domestic chores such as threshing, children's play, and lice picking (an important form of personal interaction among villagers, especially women and children). The main room may have a wood floor, but is usually hardened mud (re-plastered regularly with a cow-dung and water mixture), and is centered on the cooking fire. There may be one small window in this room, but most light comes from the fire and a ventilation hole in the flat roof above it. The hole is partially shaded to keep out rain and snow, and is to let light in and smoke out. Generally, this room is extremely smoky, and when the fire is burning it is impossible to stand without significant eye and lung discomfort.

Figure 1. Interview with a group of villagers in Humla, about a cluster photovoltaic system.

Space, like the community in this caste-bound society, is stratified in a hierarchy that defines its layers in terms of purity and pollution. More ritually pure areas are at the top story of the house, which is where you are likely to find valuable ceremonial items, religious icons, or quarters for distinguished guests. The lowest level of the home, where the animals are stabled, is the more ritually and literally polluted area. This is also the place where women give birth, since childbirth is considered to be a polluting event in the life-course of a woman. Women are secluded from men during menstruation and childbirth as a regular reminder of notions of purity and pollution, and menstruating women are expected to refrain from visiting tap stands where men drink. Similarly, villages and caste groupings themselves are spatially separated, with clear boundaries between castes and behavioral limitations determined by the caste hierarchy. One constant and obvious reminder of this is the reality that lower caste individuals, like menstruating women, do not draw water from the same tap as the higher castes.

Prior to the installation of the solar PV systems, none of the houses in the study area had electricity. Still, none of the homes have running water. In most villages, centralized taps have been built by non-government development organizations or sometimes by the government itself (two or three taps per village of 300 individuals is standard). These taps work sporadically and provide unfiltered water (as they draw off of streams uphill from the villages they are contaminated by domestic stock in the pastures above).

As shown in Figure 2, villages are very crowded, with houses built on top of each other on hillsides, and little space in between. In some villages, it is possible to walk from one end to the other without leaving the flat rooftops. Trails in between houses are often deep in mud and always littered with garbage and human excrement. Although there has been some progress on introducing latrines in the area, there are persistent land availability problems and user problems associated with not wanting to visit places that are considered to be polluted, as a latrine, being a receptacle for human waste, would be. Fields are considered sacred and off-limits as latrine locations, and villagers claim that there is no available space within the village itself.

Figure 2. Humli village conditions—settlements are densely packed and built into hillsides.

As described above, home interiors were traditionally extremely smoky and villagers are well aware of the impact of the indoor air pollution on their respiratory and eye health. A major contributor to the particulate matter indoors is the tradition of burning *jharro*, a resin rich pine wood (chir pine, *Pinus roxburghii*), for light. This wood burns brightly and minimally lights the home, but it produces a great deal of soot, contributing significantly to the indoor air pollution in homes. It is also extremely inconvenient to collect this type of wood, as this type of tree is uncommon in the area (in part because of depletion of the resource due to constant harvesting over many years). Of all of the project components introduced in this holistic community development project, the solar photovoltaic lighting systems are by far the most popular. This is very interesting considering that other project components also have the ability to significantly benefit villagers: the smokeless stoves use less wood than the open cooking fires, the pit latrines help keep the village clean, greenhousing and solar dryers help with food security and nutritional status, and so on. But none of these other project components is as positively regarded and sought after as the solar photovoltaic component. Indoor lighting is widely considered to be very beneficial, in terms of its ability to improve health and the all-around quality of life. In light of all of the other extreme challenges to life in this area, this is a very interesting fact. It underscores the importance of having a convenient and clean method of lighting one's home. For these reasons it is very important to understand why one of the two system types considered in this paper often functions poorly.

3. Solar Photovoltaic Systems in Humla

In the living conditions described above, the availability of solar photovoltaic systems has been critical to villagers. Measurements of indoor air pollution by the organization that installed the solar photovoltaic systems in combination with smokeless metal stoves (which replaced the traditional open fire cooking method) have shown a massive reduction in PM_{10} and $PM_{2.5}$ in homes with a solar lighting and a smokeless stove, in comparison with homes heated and lit by fire. Villagers uniformly praised this outcome of switching to the new systems of heating and lighting homes. Additionally, the solar lighting is significantly brighter than *jharro* is, and villagers talked about how this allows children to read and look at books at night and for everyone to simply see what they are doing in their homes after dark, without relying upon flashlights or carrying around a lit stick of *jharro*, which is inconvenient for obvious reasons as well as unsafe for small children.

Employees of the non-government organization that installed the solar photovoltaic systems were interested in testing two different approaches to providing indoor lighting via solar energy. The two systems are the cluster and single home systems, and as I have suggested, each one has its costs and benefits. I explore these below.

3.1. The Cluster Solar Photovoltaic System

The cluster system was considered to be desirable in villages where homes had been built in distinct groupings, each distinguishable from the other. In a village such as this, the cluster photovoltaic system approach appeared to provide the best solution from both technical and economic standpoints (Figures 3 and 4).

Figure 3. A village in which a cluster system was used. Note that the households are clustered, with some well below and others well above the main village, rather than uniformly distributed.

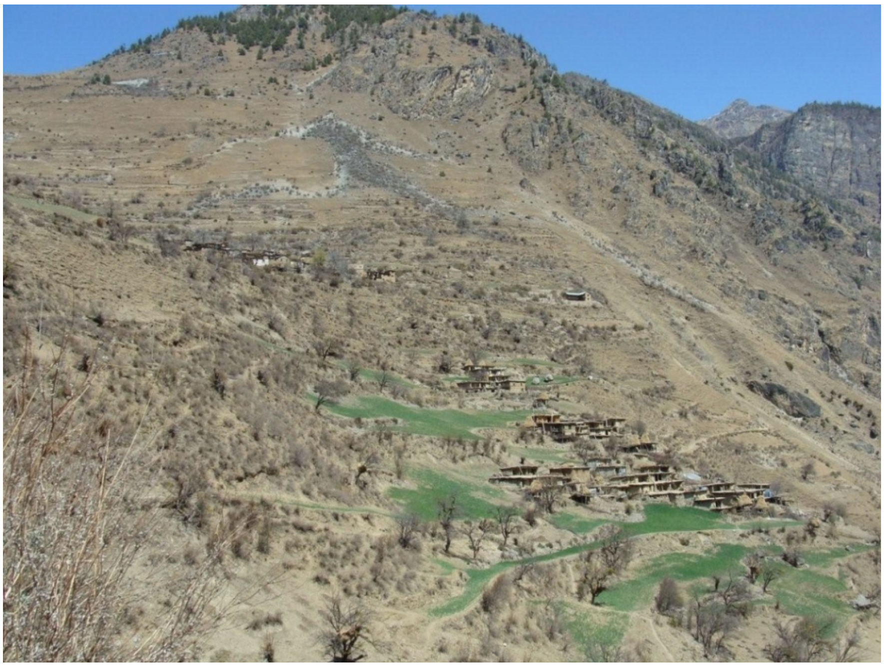


Figure 4. Typical Cluster System. Note the photovoltaic panel in the top center. It is connected to a battery bank servicing six households in this section of the village.

As explained in previous publication [1], a cluster typically consists of six to twelve homes. These homes share one solar PV module (usually 75 W_R), mounted on a 1-axis adjustable aluminium frame. They also share a battery bank. Each home in the cluster connects to the battery bank via armoured underground cables, and the system powers three 1 watt WLED lamps per home for roughly seven hours per day.

There are many important technical benefits to this system, and the cost of equipment and installation is often significantly less than in a typical single home photovoltaic system [1]. There is only one battery bank to maintain, and fewer end-users will need training on how to look after the battery bank, and monitor the proper functioning of the system. However, it became clear in my interviews with villagers that there were some fairly significant issues relating to the maintenance and usage of the system. Many villagers had even begun to look more favorably upon micro or pico hydro solutions to their energy needs than they had previously.

One common complaint about the solar photovoltaic systems in general related to disposal of non-functional batteries, and it is important to point out that this complaint was voiced by end-users of both types of systems. By the time this study was conducted, villagers had seen the results when batteries had been tossed onto the ground after they are no longer useful, and the acid had spilled out and contaminated the downhill soil. As subsistence farmers, villagers were understandably alarmed to see the impact on the arability of the soil downhill from the dump site. If solar photovoltaic systems continue to be installed in the region, it will be important to pay careful attention to battery bank maintenance, to extend the lifetime of the battery for as long as technically possible. Then, when the lifetime of the battery has ended, it is critical that villagers are given disposal options that are safe for human and environmental health.

Beyond this issue, several interesting themes emerged from the discussions with villagers. Most important from both a theoretical and practical perspective is the collective action problem associated with multiple common resource users. In this case, the resource is the energy available in the battery bank. The collective action issue is proper and fair usage of the available energy and sticking to the agreed usage pattern. That is, during the installation phase, all members of the cluster agree to use the available energy only to power the white LEDs that light each home. But, because the cost of other uses of the system is borne by all members of the cluster, the temptation to use energy provided by the system to power other devices appears to be irresistible. Most commonly, end-users will splice devices into the wiring, typically radios or cell phone chargers. As in other collective action situations, these "free riders" pose additional strains on the system at little cost to themselves while imposing a relatively large cost on others (users get light *and* radio, for instance, while others only get reduced power to their lights).

There is also a significant second order collective action problem in these villages, which has to do with policing the system and punishing people who use the available energy for non-lighting purposes. No one is really empowered to, nor, typically, wants to be in a position of policing their neighbors. When the person splicing additional devices into the system is (as is often the case) the owner of the home that houses that battery bank, the problem takes on a particularly intransigent form. This is because the policing problem is now exacerbated by the fact that the person empowered to house the battery bank and subsequently maintain it, is usually a more educated individual, and along with higher educational attainment, as in other developing societies, comes a higher degree of social capital and, usually social and personal power. Additionally, if the cluster includes households of more than one caste, additional uses of the system by members of both high and low caste positions can be rationalized in terms of caste. A higher caste individual may convince himself that the lower caste members of the cluster don't really deserve energy as much as he does, due to the unfortunate but evidently unavoidable fate of being born into a low caste position. Meanwhile, lower caste individuals can see the opportunity to load the system with other devices as a rare opportunity to assert some power over a cultural and social situation that generally leaves them feeling powerless. In any case, when end-users are disgruntled with the behavior of such an individual but their behavior toward that person is for example constrained by a sense of inferiority, publicly identifying the behavior, not to mention punishing it, can appear impossible. A common solution to both first and second order collective action problems is to increase the frequency of contact and transparency within the system, but, due to the nature of the configuration of homes and the wiring system within home interiors and the fact that misuse can be easily hidden or secretive, this may be hard to engineer in this particular social situation.

Another problem described by end-users is that the owner of the home with the battery bank has too much control over the system, and, if he/she is gone and the system breaks down, other cluster system users cannot enter the battery bank room in order to address the problem. Some users described battery bank "owners" as having actually removed parts or all of the battery bank to take to another location. Since these villagers are transhumance pastoralists who move a significant proportion of their population from the main village to other homes in spring, summer, and fall grazing areas for their livestock, this is a serious issue. Meanwhile, back in the main village, the rest of the cluster may go for months without light.

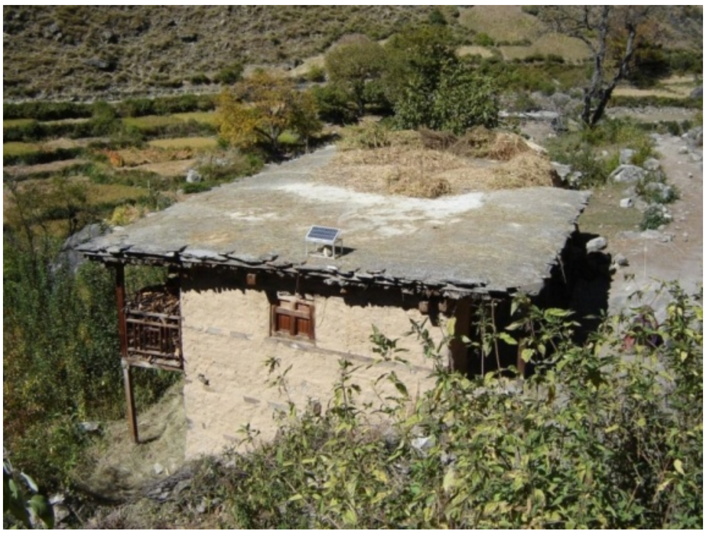
Another problem that came to the surface during the group interviews related to the fact that the cluster system frankly forces people to cooperate with one another, that is to say, people who otherwise would not cooperate. This has included, sometimes, people who have long-standing disputes with one another. Those disputes were either hidden or minimized during the installation and cluster identification phase, perhaps optimistically, or maybe because villagers were worried that if they didn't appear agreeable and cooperative they would not receive any solar energy system from the non-government organization. In actual operation, these underlying disputes have caused many serious issues from an end-user standpoint. Indeed, the need for cooperation among some of the households within a cluster appears to have actually exacerbated existing, in some cases generations-old tension between and among families. In one case, villagers described the actual sabotage of the system by a disgruntled cluster member, due to a dispute between the families that went back several generations. This kind of issue proves to be a drain on everyone's time, energy and resources, since disputes need mitigating and systems need repair.

One way to address the conflict situations described above is to study and then integrate common solutions to collective action problems. For instance, analyzing and then restructuring incentives and enhancing opportunities for and processes of negotiating cooperation could be very useful to villagers who feel trapped into the roles in which they find themselves. For instance, it may be possible to devise a culturally appropriate change in the incentive structure associated with cooperation, in order in order to make cooperation more likely. Or, end-users could be encouraged to increase the frequency with which rules are jointly revisited, revised and understood in order to give each member of the cluster the sense that they are part of the management team. This would also provide a venue in which to publicly broadcast and reinforce the notion that individual actions affect other households in a way that can negatively affect the quality of life of children, for instance, or the infirm, or other less powerful members of households. Alternatively, a single home system may be chosen.

3.2. Single Home Solar Photovoltaic System

To the non-government organization in charge of the project, a single home system promised to be appropriate when the village's houses are uniformly distributed across the village landscape, or when villages have many stand-alone homes, as can be seen in Figure 5.

Figure 5. Where a single home system was used. Stand alone homes or villages where homes are widely spaced may lend themselves to this approach.



Due to the topography of this particular valley, the further north the village is, the more likely it is that one will find villages with many stand alone homes. This is because the valley broadens and flattens significantly as one approaches the Tibetan border, only two days walk north of the villages described herein.

In the single home system installed in this region, each house has one solar photovoltaic module mounted on an aluminium frame, a battery bank, and three white LED lamps. Each home's battery bank provides enough energy for up to five days of usage without sunshine. In this system, a different set of challenges can arise. First, though no one admitted doing so him or herself, it was evident that in the single home system the temptation to sell system components was both strong and ungoverned by community approbation, as would have been the case in a cluster system. Also, the cost to both end-users and the organization installing the single home system is higher than in the cluster system. Additionally, the training and maintenance demands are higher. One or two members of every household have to be trained how to properly use and maintain the system, and more batteries enter the region, increasing the need for proper disposal and storage of old batteries.

However, these costs may be worthwhile. It neatly does away with the collective action issues described above. Villagers described many benefits of this approach. One of the other beauties of the single home system is that every household includes members who have been empowered with a new body of knowledge and level of technical expertise. This can be incredibly uplifting to entire communities. It can open new vistas for both men and women, particularly in societies such as in Humla, where people have relatively little exposure to formal education and modern technology. Also, because every household has the same technology and know-how, the single home system can level the playing field, whereas the cluster system can actually introduce disparity into a community. The single home system is predicated on the notion that each household owner can and will take responsibility for his or her own system. When some households are female headed, as is inevitable in human societies, the example set by women who successfully maintain and operate their systems can send a message about the ability of women that can be powerful to the age-mates of those women and to their sons and daughters. In a society such as Humla's, where the convention is to keep girls home from school, the impact and importance of such a message on a community is difficult to overstate. It is also common for a healthy competition to arise among households, due to each owner's pride in his or her system. That increases the likelihood that more care and maintenance takes place, increasing the system's reliability and life expectancy [1].

4. Conclusions

While it is easy to understand the technical and financial reasons supporting the installation of a cluster solar photovoltaic system, the experiences of the end-users in a region with both cluster and single home systems seems to support the choice of single home systems when possible. When cluster systems are the absolute clear choice of the project funder, or when cost, technical, or other issues require that a cluster system be chosen, the experience of the villagers in this region suggests that both primary and secondary collective action problems can be expected. These problems may be surmounted with close and careful attention to solutions such as increased focus on training, regular cluster meetings about problems, and other devices as socially appropriate.

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