Examining the potential for developing women-led solar PV enterprises in rural Myanmar

Andrew Pascale[a], Tania Urmee[b], Jonathan Whale[b], S. Kumar[c]

[a]UQ Energy Initiative, School of Chemical Engineering, The University of Queensland, Australia

[b]Energy Studies, Department of Electrical Engineering, Energy and Physics, School of Engineering and Information Technology, Murdoch University, Western Australia, Australia

[c]Energy Field of Study, Asian Institute of Technology, Pathumthani, Thailan

Abstract

Access to electricity is limited in rural areas of Myanmar, where the majority of the population live. Myanmar′s rich solar resource and the recent price drop in solar PV modules indicate initial suitability for rural solar electrification systems to meet the electricity demand. In many parts of Myanmar, women are responsible for supporting the family financially. The ability of rural women in Myanmar to take advantage of solar PV powered services to improve their lives depends on concurrent progress towards addressing the many dimensions of gender equality – empowerment, health, education, opportunity, voice, representation, and livelihood-in rural locations. This paper examines the barriers of solar PV applications and the potential for women led solar PV enterprise development in rural Myanmar. Although the entrepreneurial process is the same for men and women in theory, in practice different factors e.g. social/cultural, religion, economic and educational ultimately result in the disadvantaged status of women-led enterprises. Therefore, widespread and long-term eventuation of this potential in Myanmar depends on a government committed to renewable energy resources for

rural electrification and to diligently and holistically addressing geographical, political, educational, financial, ethnic and technical barriers to the empowerment of a rural, female population.

Keywords: Myanmar; Solar PV; Women; Enterprises

1. Introduction

Myanmar′s first national population and housing census in thirty years conducted in 2014 shows that 73%[1] of Myanmar′s population of 51.5 million live in rural locations [1]. Rural Myanmar is marked by ethnic diversity[2][2], abundant natural resources [3] and impoverished populations [4]. When grouped by gender and urban/rural location, rural women head 22% of conventional counted households, have a 50% workforce participation rate and number 18.9 million forming Myanmar′s single largest population group [1]. Although living in a country ranked 83rd out of 152 countries on gender equality and 120th of 175 countries listing per capita gross national income for women [5], Myanmar′s rural women are, like women in other poor rural economies [6], the central providers of goods and services meeting the rural population′s basic human needs.

As the rural population in Myanmar lacks widespread access to electricity and modern cooking options [1,7] negative health, education and time impacts accrue on those tasked with the collection and use of solid fuel resources needed to meet basic human needs. Around 43% of total population have access to electricity, of which, only 18% is in rural areas [7].

Poor lighting sources are linked to marginalization in education, personal safety (especially for women), productive time [8] and life [9]. Time spent collecting fuels and cooking is time lost towards education, social and economic activities [10]. Health issues arise from the inhalation of pollution from solid fuels and kerosene used in households for cooking, heating and lighting [11]. Due to the traditional roles of women in Myanmar, women are more likely than men to be exposed to these negative impacts.

If leveraged to improve health, equality, educational, economic and empowerment outcomes in the lives of women [12], energy can be an important entry point for improving the lives of women in rural Myanmar. Changes to rural cooking systems that move users away from solid fuel use in inefficient and polluting cook stoves represent an energy intervention that faces large challenges [13] but also has great potential to improve the lives of rural women in Myanmar. Despite such potential and a range of community targeted cook stove programs in Myanmar [14,15], neither the government nor multilateral institutions supporting energy interventions in Myanmar appear to be targeting this Sustainable Energy for All goal [16] yet. However, the ongoing development of Myanmar government policy initiatives supporting universal electrification in rural areas [17] and gender equality across the country [18,19] suggest the widespread potential for the realization of positive synergies between rural electrification and women′s empowerment.[3]

A review of the literature shows that the cost of supplying electricity by extending the grid to rural areas is usually prohibitively high worldwide [20–23]. Therefore, supplying access to electricity to those in less densely populated rural areas by using stand-alone household or village-scale distributed generation systems (either fossil fuel or renewable energy based) is usually the only practical or realistic option. Renewable energy systems have several important advantages over fossil fuel generators. They avoid the risks of high and increasing fuel and transport costs, and reduce the risk of environmental pollution. For these and other reasons, small stand-alone household systems, including solar home systems (SHS) or village-scale solar photovoltaic (VSSPV) systems, have emerged as one of the preferred electricity options in rural areas of developing countries [24,25].

Myanmar′s rich solar resource available across most of its territory [26,27], is an initial indicator of feasibility for rural solar electrification systems. In addition, solar PV prices have dropped [28], solar PV powered services in Myanmar are increasingly affordable [14,29–31] and a range of solar PV projects have already been proposed in Myanmar [14,32–34]. However, there are currently a host of barriers facing the diffusion and adoption of functionally sustainable solar PV systems in rural Myanmar [14,17,26,30,35–39]. These include lack of financing, lack of standards, bureaucratic

complexity, reliance on equipment subject to import taxes and poverty levels that still make the upfront costs of the more affordable solar PV services unreachable for the rural communities.

This paper examines the status of both solar PV and women in rural Myanmar. The paper reviews and reports on academic literature, institutional literature, magazine articles, and newspaper and organizational reports sourced using library databases and online search engines. Due to a paucity of both relevant and recent academic literature on Myanmar, this study largely relies on the mass of institutional literature arising from the 2012 international finance institution reengagement with the country [40]. The contribution of this study is to compile, review and reorganize surveyed literature in order to identify and classify the key issues that need to be addressed in order to create a solar PV empowered female population in rural Myanmar.

2. Demographic background of Myanmar

Burma′s transition to the globally courted state of Myanmar is ongoing and far from over. Myanmar plans to hold its first general election following military rule in November 2015, although only 75% of parliamentary seats are publically contestable and Nobel peace prize laureate Daw Aung San Suu Kyi is barred from contesting the presidency [41]. One of 10 Association of Southeast Asian Nations (ASEAN) nations, Myanmar held the rotating chairmanship of the group in 2014 – a first in its seventeen year membership [42]. Once known as Asia′s rice bowl [43], the UNDP [4] found that in 2010, 24% of the Myanmar population was landless and 25% of the population lived in poverty. The 2014 Human Development Index (HDI) ranked Myanmar 150th out of 187 countries [5], a ranking that has not changed since 2008. Despite over fifty years of governance struggles and declining economic prospects [44], Myanmar remains a country filled with natural beauty, abundant natural resources [3], and prospects for positive change [45].

2.1. Women in rural Myanmar

Despite a 52% population share [1] and the presence of Nobel peace prize laureate Daw Aung San Suu Kyi in Parliament, women held less than 5% of parliamentary seats following the 2010 election

[18]. Additionally, although the government is a signatory to the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) and other global gender action agreements, the UN recognizes an unmistakable need in Myanmar for gender equality, economic opportunities for women and political representation in government. UN listed barriers facing gender-related change and empowerment include a “shortage of gender statistics and research, a lack of awareness, and limited institutional capacity” [46].

Rural women comprise 36% of Myanmar′s counted population and this share of Myanmar′s population would increase if census rural/urban breakdowns extended to the non-enumerated population living in-country [1] and refugees living on its borders [47]. Rural women head 22% of conventional counted rural households and have a working age labor force participation rate of 50% [1]. Organizations representing women in Myanmar include the Myanmar Women′s Affairs Federation [48] and the Women′s League of Burma, which is comprised of thirteen ethnic women′s organizations [49]. On a distributed scale, women have also been organizing to represent their own interests (“increased economic well being, increased social development and social security, greater communal harmony and augmented individual capacity”) in limited areas of the country since 1997 through UNDP supported Self Reliance Groups [50].

However, an ADB scoping report covering rural portions of two of Myanmar′s 21 administrative divisions found that women earned, on a normal day, a lower rate of pay for labor than men and traditionally spent four to six hours a day preparing meals [35]. In addition, the UNDP′s *Human Development Report 2014* estimated that in 2013 women had a Gross National Income (GNI) that was 72% of men′s GNI in Myanmar [5]. Although microfinance is available to both men and women in some areas of Myanmar [50,51], women were reported to represent 83% of 13,282 borrowers in the only scheme providing a gender breakdown in a 2013 International Finance Corporation assessment [51]. Another scheme self-reported that 99% of over 500,000 borrowers in 2012 were women [52].

3. Energy use in rural Myanmar

Energy consumption data from Myanmar shows that although 85% of the country′s total final energy consumption comes from renewable energy sources, modern biomass and hydropower only account for a combined 5.4%, while traditional biomass accounts for the remaining 79.5% [7].

3.1. Modern energy access

Despite an abundance of coal, gas, petroleum, hydropower and solar resources, Myanmar′s population centrally relies on forest products for household energy provision [53]. In fact, in 2010 only 28% of the rural population had access to electricity and only 5% had access to non-solid fuels. Comparatively, 92% of the urban population had access to electricity[4] and 17% had access to non-solid fuels [7].Fig. 1 shows the electrification status of Myanmar villages.

Reflecting this situation, Myanmar ranks 10th on the International Energy Agency′s (IEA) 2010 index of least energy developed nations [54]. In addition, the World Bank/ESMAP and IEA [16] number Myanmar in the top 20 nations with the largest populations lacking access to non-solid cooking fuels (11th, 44 million people) and electricity (10th, 24.6 million people). A 2015 Ministry of Livestock, Fisheries and Rural Development (MOLFRD) presentation reports that out of 64,917 rural villages in Myanmar, 6914 villages are powered by the national grid, 13,088 villages by generator, 2426 by mini-hydropower, 2693 by solar power, and 1232 by biomass or gas. 38,560 villages remain unelectrified [55]. Recent census results report that over 25% of conventional counted rural households still use candles as their main source of lighting [1].

The Myanmar government, in collaboration with international finance institutions is working on a national electrification plan (NEP) that aims for universal access by 2030 [56] as well as laws to enable better rural energy service provision. These include a 2014 draft electricity law allowing small power enterprises with a generating capacity of up to 10 MW and a renewable energy law [17]. Policy suggestions for promoting renewable-powered rural electrification in Myanmar can be found in a recent UNDP [14] report and include: credit support, human capacity building, innovative loan reforms supporting solar and renewable energy; solar and renewable energy technology subsidies and

import tax breaks; and national renewable energy technology standards. Specifically with respect to government SHS, a World Bank consultant recently identified the lack of quality control on government SHS and the need for SHS equipment quality standards [39].

3.2. Energy and gender in rural Myanmar

Allendorf and Allendorf [57] suggest that although household patterns vary by area, men are the primary fuel wood collectors in the four rural areas in northern Myanmar covered by their study. However a Mercy Corps [58] survey of the Ayeyarwady Delta reported that females assist in firewood collection in 64% of surveyed rural households. The UNDP [14] more broadly states that women spend valuable time collecting fuel wood for cooking and heating and usually cook the meals. Both Mercy Corps and UNDP studies note that a local NGO carried out a 1997–2001 fuel-efficient stove project in part to address the impacts of solid fuel collection and use on rural women.

Electricity also has a gender dimension in parts of rural Myanmar. In a study of six rural villages in Myanmar′s central dry zone, Dolly Kyaw et al. [59] found that female-headed households are less likely to have access to electricity – sourced at a high price from private diesel generators – than male-headed households. Using policy simulations around electricity and other significant determinants, the study found that increasing access to electricity aided in alleviating poverty in all households but particularly had the largest poverty alleviation impact on rural female-headed households.[5] A UNDP reading of this same study found that in Myanmar the “poorest households are headed by women, with such households representing only 9% of the population but 46% of those in poverty” [14].

4. Solar PV in rural Myanmar

Most remote areas in Myanmar are not connected to the national grid system, which in 2011 had an installed capacity comprised of 76% hydropower generation, 21% gas generation, and 4% coal generation [53]. Even the government′s recent NEP which plans to reach over 90% of currently unpowered households with a national grid connection, will not cover many areas of rural Myanmar

in the next decade [60]. Decentralized renewable energy systems like solar are offered up by some as a promising way to light [31] and power [61,62] the rural countryside. Such analyses are supported by studies finding that nearly 90% of Myanmar receives an annual average of more than 4.7 kW h/m^2 of solar radiation per day [26],[6] which indicates that Myanmar has a relatively high solar energy potential that can be utilized for various solar energy applications.

Surveyed literature provides evidence of practical applications of solar PV′s use in Myanmar. Khaing [63] reports that in 2010, Myanmar generated 0.75 GW h of energy from solar power and describes a solar lighting and solar water pumping village restoration project in the Ayeyarwaddy Division that benefited 135 families, a health clinic, a primary school and a storm shelter. Yee et al. [36] note that in Myanmar, solar energy is used in irrigation, rural electrification, water pumping and health service provision. Kyaw et al. [37] discuss the use of solar power at rural government health centres and the potential of solar PV powered villages to improve socio-economic status in remote locations. The ADB [53] notes solar power′s use in rural Myanmar for irrigation and battery charging.[7] However, despite solar PV′s varied applications in Myanmar, a recent UNDP [14] document reports that only 176 kW of solar powered energy plant were installed and operating in Myanmar in 2009.[8] Furthermore, as shown in Fig. 2, in 2014 solar PV systems/energy were the fourth most common rural household lighting source after candles, batteries, and grid electricity.

According to Fig. 2, solar energy systems/energy represented the main source of lighting for over 900,000 rural households, or 12% of surveyed conventional houses in rural Myanmar in 2014. An ADB [35] study found similarly in a smaller survey of twenty villages that 11% of households – classified as having “very high” wealth-owned SHS with less than one percent of all households surveyed owning solar lanterns. Another scoping report authored by Bodenbender et al. [30] for the EU Energy Initiative (EUEI) observed the following evidence of solar power use and availability in Myanmar: a well-kept commercially purchased 50 Wp solar home system (SHS) next door to a less well kept but free donor-provided SHS; firsthand visits to two solar PV vendors focused on rural customers; and listings for roughly a dozen solar PV companies in the phone directory. A later UNDP

[14] report describes an similarly sparsely populated solar industry in Myanmar with four commercial providers selling foreign produced (China, Thailand, Japan and Singapore) equipment and one minor, government-operated thin film PV plant. In Greacen′s [39] assessment of government SHS, he reports meeting with six rural SHS installers and that China was the main SHS equipment provider for five of the six companies.

Humanitarian organizations report additional instances of solar PV usage in Myanmar. In 2012, Women′s Emergency Communication and Reliable Electricity (non-profit organizations) reported a maternal health solar power project in Myanmar [65] with at least five fielded solar suitcases providing lights for medical procedures [66]. Local Myanmar NGO ALARM reports that it is already promoting solar systems in five villages and will be reaching out to 20 more villages by the end of 2014 [67]. Ratterman et al. [68] describe the NGO provision of 13 solar power systems serving ethnic minority health clinics in conflict areas of Burma in 2005. The clinic solar electrification programme was later expanded to over 60 clinics [69] and Sovacool [61] notes that the success of this programme is partially due to the fact that end user consultation preceded design, system distribution to clinics bypassed government bureaucracy, and that two medics from every clinic were given hands on training on maintaining the solar systems.

Industry and media organizations also report instances of solar PV availability and deployment in Myanmar. The Earth Renewable Energy Co. Ltd. [70] details 13 different styles of available solar PV systems ranging from 45 Wp SHS′s to a 3780 Wp hospital supply system. Ferry [31] reports that a German NGO installed two solar pumping systems and two solar electricity systems in Myanmar and that a local NGO began offering solar lamps and village committee backed microcredit in 2012.[9] Oil giant TOTAL launched a pilot solar lighting project in mid-2013 that involves training local entrepreneurs to resell solar lighting systems. From an initial cohort of 14 that included six females, two of the pilot project′s top three resellers over a one year period starting August 2013 were female. TOTAL reports that it is in the process of transitioning to a national solar lamp pilot project [71].

Ongoing and future solar PV projects also appear in surveyed literature. A report by Greacen [17] notes that Myanmar′s Department of Rural Development (DRD) is planning to electrify over 170,000

households in 1491 villages with SHSs in the 2014–2015 fiscal year. In addition to government plans for solar PV in Myanmar, in August 2013, a US investor announced a $480m project covering two solar PV plants in the Mandalay region of Myanmar [33]. In January 2013, SPCG, a Thai company, announced plans to install two solar farms in rural Myanmar, starting construction in 2014 [32]. The UNDP [14] reports pursuing a rural LED solar lighting project in 30 villages in collaboration with the Renewable Energy Association of Myanmar. The ADB also plans to reach 25 villages in Myanmar with renewable energy systems (including solar PV systems) through an "Off-Grid Renewable Energy Demonstration Project" which was approved in May 2014 [34].

Despite evidence of a diversity of solar PV systems in use across rural Myanmar, the preceding section is challenged by a lack of solar project and system details (design, specifications, cost, financing, policy, regulation, functional sustainability). Even sources that do provide a thorough and detailed look at specific rural solar PV systems in selected areas of Myanmar, such as Greacen′s [39] report on DRD SHS in 10 villages in three states/regions of Myanmar, have limited transferability beyond their designated system focus, geographical, and temporal boundaries. Until a comprehensive field study is undertaken, solar PV system reporting standards improve and national policies, standards and regulations provide an enforced framework for solar PV implementation in Myanmar, a comprehensive study of the status of solar PV in the country will remain challenged.

5. Drivers and barriers facing solar PV in Myanmar

A recent UNDP [14] report recognizes the potential for solar lanterns and torches to meet basic lighting demands within rural household energy budgets as well as the potential to link solar and renewable energy technologies to women′s empowerment in Myanmar. However, the same report details the barriers facing these and other renewable energy efforts in the country, including a "labyrinthine policy landscape", the clash between market economy and subsistence needs, competing and conflicting priorities, and the inaccessibility of bank loans to poor people. An International

Finance Corporation [72] market analysis on the use of renewable energy for mobile phones found that the following factors hinder renewable energy – and especially solar PV in Myanmar:

•lack of a fully transparent institutional and legal framework to support exploration, development, and deployment;

•lack of policy guidelines with necessary support and incentives for the development of renewable energy in rural electrification;

•lack of finance to support research and development;

•lack of human resource capacity;

•lack of awareness on resources and technology.

The ADB [35] lists existing human capacity in rural areas as a potential driver for solar PV and renewable energy systems, but provide a longer list of barriers including high up-front costs, lack of access to financing and solar PV markets, knowledge gaps, and poor quality equipment. An EUEI sponsored report provides Strength, Weakness, Opportunity and Threat (SWOT) analysis for a range of solar powered systems in Myanmar, finding in general that, although Myanmar has a good solar resource countrywide, widespread solar PV system uptake at a household level is hampered by affordability and a range of other factors [30]. Table 1 lists recent UNDP, ADB and EUEI findings for drivers and barriers facing solar PV in rural Myanmar.

Drivers and barriers of a similar nature are mention variously in other literature [26,27,36–39,73]. For example, Aung [26] mentions limited funds, lack of proper financing mechanisms, lack of standards, and lack of capacity development as barriers to off-grid electrification in Myanmar. Swe [73] highlights the following as barriers facing solar enterprise development in Myanmar:

•access to finance (credit, loans),

•poor technical and management skills,

•low quality products,

•lack of networking,

•lack of government support for technology transfer, and

•bureaucracy.

A Mercy Corps [58] report, in which solar power (1%) ranked just above candles and well below grid electricity (55%) for preferred lighting energy source in a region of the Ayeyarwady Division, suggests a deficit of positive examples of solar PV lighting in the area [74].

6. Discussion

6.1. Prospects for solar PV in rural areas

Solar PV systems in rural areas allow people to work longer hours and increase income, as well as to manage household work better [75]. Analyses of energy challenges and synergies in Myanmar suggest that solar PV in particular offers environmental benefits in rural areas [61,74, 76] – areas with a good solar resource but where nearly three quarters of the population lacked access to electricity in 2010.

Due to the country′s rugged landscape, large area and reliable national solar resource, solar will certainly need to play a role in any plan that realistically aims for universal access to electricity in Myanmar by 2030. According to 2014 consultancy connected with the government′s NEP, solar does play a role in rural electrification-although mainly as a “pre-electrification” solution for areas expected to receive a grid connection near the end of the 2030 universal electrification target. Permanent off-grid and mini-grid solar PV electrification are expected to be entirely in rural locations but surprisingly will account for less than 0.3% of total national connections [60].

The actual progress towards stated government infrastructure intentions in rural areas remains to be seen. For rural communities facing a sizable wait before government facilitated electrification reaches them, the continuing need and opportunities for ‘self-help electrification’ using solar PV and other renewable energy technologies in rural areas of Myanmar should not be overlooked [77]. For those

communities, the ability to take advantage of needed solar PV-powered services depends not on eventualities and intentions but on the timely diffusion of affordable and high quality solar PV technologies.

A central driver for that diffusion is the growing affordability of solar PV-powered services [28] in Myanmar, which is evinced by sales [31,71], comparisons with household energy budgets [14,29,30] and studies by local NGOs.[10] Local knowledge and experience that supports solar PV service diffusion in rural areas represent another central driver. However, as Table 1 shows, barriers facing solar PV in rural areas far outnumber drivers.

Solar PV programs in rural Myanmar face barriers similar to those addressed by rural electrification and solar PV diffusion activities elsewhere in Asia. Sovacool [78] provides six model programs from Asia involving off-grid solar PV that variously address affordability, credit, technology development, market creation, finance and coordination barriers. Palit [79] provides examples of successful activities addressing financial, technical and social barriers to rural solar PV energy programs in South Asia. Greacen [39] and Haque [80] highlight aspects of the IDCOL SHS program in Bangladesh that address maintenance, equipment standard, sustainability, credit and affordability barriers. More generally, a study of regional rural electrification programs in South and Southeast Asia found that governments implementing reforms to address the affordability barrier increased both the energy access and consumption of the targeted poor population [81]. Lessons learned from past and current solar PV programs, initiatives, studies and projects represent a key resource for all supporters of solar PV in Myanmar to draw on.

Diffusion of solar PV to rural areas through efforts such as those of the UNDP and ADB will also increase the incidence of high quality fielded equipment and human capacity in rural areas. However, such efforts, on their own, will fall short of the necessary ecosystem[11] to ensure the functional sustainability of solar PV systems in rural areas. What are required are synergies between efforts addressing barriers, such as the one suggested by Greacen [39] between the government DRD SHS program and the government′s NEP in combination with legislation that supports equipment standards for solar PV systems.

6.2. Solar PV systems for the empowerment of women in rural areas

A broad study of gender and energy by Panjwani [82] concludes that “energy interventions can contribute to women′s empowerment and to achieving greater gender equality.” Examples of interventions combining women′s empowerment and solar PV include Sharma [83], which discusses the use of solar-charged rental batteries in India to generate income both for the woman renting out the batteries and the female vendors using batteries to extend sales hours. The Barefoot College in India represents another example and reports that as of November 2014, 740 women solar engineers empowered by the College′s efforts currently maintain lights for over 450,000 people in 64 countries, creating concrete positive environmental, educational and financial impacts in their communities [84]. According to the Barefoot College in India, although many of its trainees are illiterate or semi-literate, they are tough, exceedingly smart, and confident enough to learn new things that interest them [85]. Women friendly spaces and centres like the Barefoot College also allow women to network and make business contacts. Solar Sister provides a third example and reports over a thousand women entrepreneurs operating in three countries and providing solar-powered lighting for 180,000 people [86].

Each of the three examples given would have needed to address common problems women face in achieving their full potential as entrepreneurs. One problem is that although the entrepreneurial process is the same for men and women in theory, in practice different factors (e.g. psychological, social/cultural, religion, economic and educational factors) in the Asian region ultimately result in the disadvantaged status of women led enterprises [87]. A second identified issue comes from the same study points out that many women in developing countries are unaware of new technologies or not received proper training in their use. A third issue is identified by the United Nations Industrial Development Organization (UNIDO) which reports that women face more difficulties in obtaining credit, despite the fact that they can repay the loan [88].

Common additional barriers facing solar PV empowered women entrepreneurs in Myanmar and worldwide include:

•traditionally female responsibilities for children, home and other dependent family members that make it difficult for women to devote their time and energies to their business;

•village accessibility and social restrictions on the mobility of women impacting their ability to network with other villages;

•a lack of women representatives in shaping important gender and renewable energy policy;

•a lack of technical skills allowing women to design, repair, use, and care for solar PV systems in rural areas.

While there are studies on positive examples of solar PV microenterprise [89] in Ghana and solar PV micro utilities serving local entrepreneurs [90] in Bangladesh, neither focused on the interaction of women with solar PV systems and services. In addition, although the use of solar PV for rural electrification in Asia has been studied extensively [91–93], most existing studies have taken a technology approach to PV development [94,95] and none of the studies have analyzed the impact of gender on the promotion and use of solar PV in rural Myanmar. Examples such as the Barefoot College and Solar Sister show not only the relevance, but also the important role that solar PV systems and services can play in women′s empowerment. Ideally, the design and rollout of government partnerships and commitments towards improving national gender equality [19] will include core integration into the design and rollout of other National Action Plans focusing on rural development, poverty alleviation and universal electrification and inclusion of organizations representing ethnic communities [96] and ethnic women.

7. Conclusion

To address the low electrification rate in rural areas in Myanmar, a number of initiatives and programs have been undertaken by the government and non-government institutions to improve electricity access through solar PV. Myanmar′s rich solar resource across a majority of the country and the growing affordability of solar PV powered energy services due to price reductions in PV modules,

make solar PV a good fit for rural areas. Besides the reduction observed in solar PV prices in recent years, local village level conditions (financial, social) and national level policies are key drivers for the promotion of solar PV in rural Asia, including Myanmar. Lessons from past and current solar PV programs in Myanmar, as well as those from neighboring countries will be useful in this regard.

In addition to rural electrification, Myanmar has recognized the need for greater gender equality across the entire nation. There are many barriers facing gender related change and empowerment including lack of awareness and limited institutional capacity. Electricity also has a gender dimension in parts of rural Myanmar. Female-headed households are less likely to have access to electricity than male-headed households and even if they have, it is sourced at a high price from private diesel generators. There is potential for solar lanterns and torches to meet the basic lighting demands within rural household energy budgets as well as the potential to link solar and renewable energy technologies to women′s empowerment in Myanmar.

Rural, women-focused, solar PV initiatives represent either a yet untapped or yet unstudied opportunity to improve the lives of rural women in Myanmar while also meeting the need for rural women friendly spaces. There are barriers to implement solar PV for electricity access and also women led solar PV enterprise development. However, the ability of rural women in Myanmar to take advantage of solar PV powered services to improve their lives depends on concurrently addressing the barriers facing solar PV and gender equality in rural Myanmar.

Practical Action. Poor people′s energy outlook 2012: Energy for earning a living. UK: Practical Action Publishing Ltd.; 2012.

[1]This figure assumes that the Kachin, Kayin and Rakhine populations not enumerated in the census lived in rural locations. Although unlikely, if they all lived in urban locations, the percentage drops to 70%.

[2]Although the 2014 Myanmar census included 135 sub-ethnic groups, ethnicity was not included in the results [1].

[3]An ADB study of two successful rural electrification programmes in Bhutan observes not only improved household economic outcomes but that women in electrified households attended more school due to time savings from reduced fuel wood collection, had greater household decision making power, and knew more than their male equivalents about education and health [97].

[4]However, an urban grid connection does not preclude the need for reliable, affordable and high quality electrification. The UNDP [15], Bodenbender et al. [30] and ADB [35] all note that blackouts are common occurrences for the Myanmar power grid.

[5]Ramani [98] reports Myanmar′s inclusion in a 1996–1998 UNDP sponsored project aimed at pro-poor energy enabled rural enterprise in which 85% of participants from eight countries were women. Though reporting that five households in Myanmar operated solar PV powered community microenterprises allowing them to increase their income by 61%, the article does not shed any light on the involvement of women in Myanmar project households.

[6]Modeling by Janjai et al. [27] shows a 5.08 kW h/m^2 per day long-term annual average solar radiation for all of Myanmar.

[7]The report also notes that Mandalay Technological University had designed and constructed internationally compliant materials for their 3 kW solar training centre pilot projects, but gives no further details.

[8]A 2008 paper from Yee et al. [36] list over 500 kW of installed capacity in Myanmar with 250 kW of privately owned solar PV plant sourced from a 1998 Yangon Technical University document.

[9]And as of mid-2013 they had already sold 14,000 lanterns.

[10]ALARM shows that on the solar PV service supply side village service providers can earn USD300 per year [64].

[11]See discussions of energy access ecosystem′s starting in the 2012 edition of Practical Action′s Poor People′s energy outlook series [99].

Acknowledgment

This research is supported by the Grant from the School of Engineering and Information Technology at Murdoch University, Western Australia. It has also been supported by a Fellowship for the corresponding author Tania Urmee at the Hanse-Wissenschaftskolleg in Delmenhorst, Germany.

References

[1] Department of Population, The 2014 Myanmar Population and Housing Census, The Union Report, Census Report Volume 2, M.o.I.a. Population, editor, Republic of the Union of Myanmar: Nay Pyi Taw. Available from: ⟨http://countryoffice.unfpa.org/myanmar/2015/05/25/12157/myanmar_census_2014/⟩; 2015.

[2] Holliday I. Ethnicity and democratization in Myanmar. Asian J Polit Sci 2010;18(2):111–28.

[3] Larmer B. Land of shadows, in National Geographic. Available from: ⟨http://ngm.nationalgeographic.com/2011/08/burma/larmer-text⟩; 2011.

[4] IHLCA project technical unit, integrated household living conditions survey in Myanmar (2009–2010): Poverty Profile, UNDP: Myanmar. Available from: ⟨http://www.mm.undp.org/content/dam/myanmar/docs/FA1MMRPovertyProfile_Eng.pdf⟩; 2011.

[5] UNDP, Human Development Report 2014: sustaining human progress: reducing vulnerabilities and building resilience. NY, NY. Available from: ⟨http://hdr.undp.org/sites/default/files/hdr14-report-en-1.pdf⟩; 2014.

[6] Palmer I. Rural women and the basic-needs approach to development. Int'l Lab. Rev. 115;1977. p. 97.

[7] SE4All, Sustainable energy for all dataset, Bank W, editor. Available from: ⟨http://data.worldbank.org/data-catalog/sustainable-energy-for-all⟩; 2014.

[8] Practical Action, Poor people's energy outlook 2010. UK: Practical Action Publishing Ltd.; 2010.

[9] Practical Action, Poor people's energy outlook 2014: key messages on energy for poverty alleviation. UK: Practical Action Publishing Ltd. 2014.

[10] Cabraal RA, Barnes DF, Agarwal SG. Productive uses of energy for rural development. Annu Rev Environ Resour 2005;30(1):117–44.

[11] World Health Organization, The World Health Report 2002: reducing risks, promoting healthy life. Geneva, Switzerland; 2002.

[12] The World Bank Group, Voice and agency: empowering women and girls for shared prosperity. The World Bank Group; 2014.

[13] Vahlne N, Ahlgren EO. Policy implications for improved cook stove programs-a case study of the importance of village fuel use variations. Energy Policy 2014;66:484–95.

[14] UNDP, Accelerating Energy Access for all in Myanmar; 2013.

[15] Simon GL, et al. Current debates and future research needs in the clean cookstove sector. Energy Sustain Dev 2014;20(0):49–57.

[16] World Bank/ESMAP and International Energy Agency, global tracking framework-sustainable energy for All, in Working Paper 77889, Kennedy SB, editor. World Bank: Washington, DC. Available from: ⟨http://www.iea.org/publications/freepublications/publication/Global_Tracking_Framework.pdf⟩; 2013.

[17] Greacen C. SPP Regulatory Framework Options in Myanmar. IFC. Available from: ⟨https://palangthai.files.wordpress.com/2013/04/finalreport-myanmarsppregulatoryoptions.pdf⟩; 2014.

[18] The Government of the Republic of the Union of Myanmar and The United Nations Pupulation Fund, Country Programme Action Plan (2012–2015). Available from: ⟨https://data.unfpa.org/downloadDoc.unfpa?docId¼163⟩; 2011.

[19] Alex Nyi Nyi Aung, Myanmar's national strategic plan for women advancement released. UNDP: Nay Pyi Taw. Available from: ⟨http://www.mm.undp.org/content/myanmar/en/home/presscenter/pressreleases/2013/10/strategicplanwomen/⟩; 2013.

[20] ACE, Annual Report. Asean Center for Energy: Jakarta, Indonesia; 2003.

[21] Institution of Engineers Australia. Towards a sustainable energy future: setting the directions and framework for change: sustainable energy taskforce report, August 2001. [Barton, A.C.T.]: Institution of Engineers, Australia; 2001. 77 p.

[22] FAO. FAO and World Energy Council call for higher priority to energy problems in rural areas [cited 2006 October 15]. Available from: ⟨http://www.fao.org/waicent/ois/press_ne/presseng/2000/pren0001.htm⟩; 2000.

[23] Ibrahim M, et al. Demonstration of PV micro-utility system for rural electrification. Solar Energy 2002;72(6):521–30.

[24] Cabraal A and Martinot E. World Bank SolarHomeSystemProjects:experiences and lessons learned 1993–2000. In: Proceedings of world renewable energy congress VI. Brighton, UK: Elsevier Science, Oxford, UK; 2000.

[25] Williams N. Chasing the sun: solar adventures around the world. 1 ed.. Gabriola Island, Canada: New Society Publishers; 2005.

[26] Htun Naing Aung. Off grid solar pv status & its potential in Myanmar. in Off Grid Power Forum-Inter Solar Europe 2014. Munich, Germany; 2014.

[27] Janjai S, Masiri I, Laksanaboonsong J. Satellite-derived solar resource maps for Myanmar. Renew Energy 2013;53:132–40.

[28] Soe Sandar Oo. Solar power may offer alternative solutions to rural Myanmar, in Myammar Times. Available from: ⟨http://www.mmtimes.com/index.php/business/5178-solar-power-offers-alternative-solutions.html⟩; 2013.

[29] Fullbrook D. Power shift: emerging prospects for easing electricity poverty in Myanmar with distributed low-carbon generation. J Sustain Dev 2013;6(5):65.

[30] Bodenbender M, Messinger DC and Ritter R. Mission Report Energy Scoping Myanmar. EUEI; 2012.

[31] T. Ferry. Renewable energy in Myanmar: not just clean, it's necessary. Renewable Energy World; 2013.

[32] Darana C. SPCG to give Myanmar solar power, in McClatchy-Tribune Business News. Washington. Available from: ⟨http://www.bangkokpost.com/business/economics/330280/spcg-to-give-myanmar-solar-power⟩; 2013.

[33] Chan C. Myanmar's Solar Ambitions Kickstarted With $480 Million ACO Pact Bloomburg; 2014.

[34] DB. 47128-001: Off-Grid Renewable Energy Demonstration Project. [cited 2014 6 October]. Available from: ⟨http://www.adb.org/projects/47128-001/main⟩; 2014.

[35] ADB. Scoping off-grid renewable energy opportunities in Myanmar: Mandalay Region and Chin State. Asian Development Bank. Available from: ⟨http://www.scribd.com/doc/214577355/Scoping-Off-Grid-Renewable-Energy-Opportunities-in-Myanmar#download⟩; 2014.

[36] Yee Thet Thet Han, Win Su Su, So Nyein Nyein. Solar energy potential and applications in Myanmar. World Acad Sci Eng Technol 2008;2:376–9.

[37] Kyaw Wint Wint, et al. Energy utilization and the status of sustainable energy in Union of Myanmar. Energy Procedia 2011;9:351–8.

[38] Kyaw U Hla et al. Status and potential for the development of BIOFUELS and rural renewable energy: Myanmar. Asian Development Bank; 2009.

[39] Chris Greacen, DRD Solar Home Systems (SHS) in Myanmar: status and recommendations. Report to the World Bank. Available from: ⟨https://energypedia.info/wiki/File:Assessment_of_DRD_SHS_Myanmar25Jan15-Greacen.pdf⟩; 2015.

[40] World Bank. Myanmar overview: strategy. 14 February 2014 [cited 2014 6 October]; Available from: ⟨http://www.worldbank.org/en/country/myanmar/overview⟩; 2014.

[41] BBC News. Myanmar 2015 general elections explained. [cited 2015 26 August]. Available from: ⟨http://www.bbc.com/news/world-asia-33547036⟩; 2015.

[42] Asean Summit 2014. 2014 Chairmanship. [cited 2014 16 November]; Available from: ⟨http://asean2014.gov.mm/2014-chairmanship⟩; 2014.

[43] Mya Than, Agriculture in Myanmar: what has happened to Asia's rice bowl? Southeast Asian affairs. 17; 1990. p. 240–54.

[44] Turnell S. Burma's Economy 2010: a fresh look at some elemental issues; 2010.

[45] Special report: Myanmar, A Burmese spring, in The Economist. Available from: ⟨http://www.economist.com/news/special-report/21578168-after-50-yearsbrutal-military-rule-myanmars-democratic-opening-has-been-swift-and⟩; 2013.

[46] Executive Board of the United Nations Development Programme, United Nations Population Fund, and United Nations Office for Project Services United Nations Population Fund Myanmar Final country programme document for Myanmar. United Nations. Available from: ⟨https://data.unfpa.org/downloadDoc.unfpa?docId¼162⟩; 2012.

[47] TBC, Programme Report July–December 2014. The Border Consortium. Available from: ⟨http://www.theborderconsortium.org/media/57568/2014-6-MthRpt-Jul-Dec.pdf⟩; 2015.

[48] Myanmar Women Affairs Federation. [cited 2014 17 November]; Available from: ⟨http://www.mwaf.org.mm/⟩.

[49] Women's League of Burma. Members. 2014 [cited 2014 12 October]; Available from: ⟨http://womenofburma.org/wlbmembers/⟩.

[50] Lwin Lwin Aung, Self Reliance Group (SRG) Case studies. Policy Unit, UNDP: Yangon, Myanmar. Available from: ⟨http://www.mm.undp.org/content/dam/myanmar/docs/Publications/PovRedu/MMR_FA1_5_SRG_CaseStudies.pdf⟩; 2009.

[51] Duflos E et al. Microfinance in Myanmar Sector Assessment. International Finance Corporation. Available from: ⟨https://www.cgap.org/sites/default/files/Microfinance%20in%20Myanmar%20Sector%20Assessment.pdf⟩; 2013.

[52] PACT. Pact and LIFT partners lend to Myanmar poor [cited 2015 27 August]; Available from: ⟨http://www.pactworld.org/press-releases/pact-lift#sthash.l3ShcwqQ.dpuf⟩.

[53] ADB. Myanmar Energy Sector Initial Assessment. Philippines: Asian Development Bank; 2012.

[54] IEA. Energy Development Index database, in World Energy Outlook 2012. Available from: ⟨http://www.iea.org/medi/weowebsite/energydevelopment/2012updates/WEO2012EDIdatabase_WEB.xlsx⟩; 2012.

[55] U Khant Zaw. Rural Electricity Access by MOLFRD. in The NEP Workshop on Off-Grid Electrification in Myanmar. Nay Pyi Taw; 2015.

[56] World Bank, Myanmar – Development of a Myanmar national electrification plan towards universal access 2015–2030 (English). Available from: ⟨http://documents.worldbank.org/curated/en/2014/01/20187855/myanmar-development-myanmar-national-electrification-plan-towards-universal-access-2015-2030⟩; 2014.

[57] Allendorf TD, Allendorf K. Gender and attitudes toward protected areas in Myanmar. Soc Nat Resour 2013;26(8):962–76.

[58] Mercy Corps. Myanmar Energy Poverty Survey. MercyCorps, Mangrove Service Network, EcoDev with support by the European Union; 2011.

[59] Dolly Kyaw, Routray JK. Rural poverty assessment with gender dimension in Myanmar. Asia-Pac J Rural Dev 2006;16(2):1–30.

[60] Castalia Strategic Advisors. Myanmar National Electrification Program (NEP) roadmap and investment prospectus: draft final road map and investment prospectus. World Bank. Available from: ⟨https://energypedia.info/images/3/37/Myanmar_NEP_Roadmap_and_Prospectus_Draft_Final_14_08_28.pdf⟩; 2014

[61] Sovacool BK. Confronting energy poverty behind the bamboo curtain: A review of challenges and solutions for Myanmar (Burma). Energy Sustain Dev 2013;17(4):305–14.

[62] Greacen Chris. Technologies that empower distributed generation for rural electrification: options for Myanmar; 2013.

[63] Khaing U Win. Current policy and investment opportunities in Myanmar. In Renewable Energy Asia 2013-New Opportunities in the ASEAN Community; 2013.

[64] Republic of the Union of Myanmar. The 2014 Myanmar Population and Housing Census. 2015. Available from: ⟨http://www.themimu.info/censusdata⟩.

[65] Callister LC. Let there be light: we care solar. MCN. Am J Matern Child Nurs 2012;37(5):351 351.

[66] Stachel L. Solar Suitcases for Medics at the Thai-Burmese border. [cited 2014 16 November]; Available from: ⟨http://wecaresolar.org/solar-suitcases-formedics-at-the-thai-burmese-border/⟩; 2011.

[67] ALARM, Report. ALARM: Myanmar; 2014.

[68] Ratterman W, Garwood A. Solar power in the war zone: Burma clinics light up. Refocus 2005;6(1):46–8.

[69] Border Green Energy Team. Background. [cited 2014 27 September]; Available from: ⟨http://www.bget.org/about-the-team/background⟩.

[70] Earth Renewable Energy Co. Ltd., Off-grid rural electrification and solar home system in myanmar business models, key issues and challenges.

[71] Total, Tats Myanmar insights report: Transitioning from Pipeline Area Pilot to National Pilot; 2014.

[72] International Finance Corporation. Sizing the opportunity: green telecoms in Myanmar, in Green Power for Mobile: Market Analysis Myanmar.World Bank Group. Available from: ⟨http://www.gsma.com/mobilefordevelopment/wpcontent/uploads/2014/06/GPM-Market-Analysis-Myanmar-June-2014.pdf⟩; 2014.

[73] Myat Mon Swe. Entrepreneurship development in solar energy sector for rural area in Myanmar. in ARTES/SESAM Alumni Regional Level Workshop. Nepal; 2008

[74] Sovacool B. Environmental conservation problems and possible solutions in Myanmar. Contemp Southeast Asia: J Int Strateg Affairs 2012;34(2):217–48.

[75] Mondal AH, Klein D. Impacts of solar home systems on social development in rural Bangladesh. Energy Sustain Dev 2011;15(1):17–20.

[76] Htun Naing Zaw, Mizoue N, Yoshida S. Changes in determinants of deforestation and forest degradation in Popa Mountain Park, Central Myanmar. Environ Manag 2013;51(2):423–34.

[77] Myint U Aung. Role of existing self-help electrification in off grid areas of Myanmar. In: Proceedings of NEP workshop on off-grid electrification in Myanmar. Nay Pyi Taw: energypedia; 2015.

[78] Sovacool BK. Expanding renewable energy access with pro-poor public private partnerships in the developing world. Energy Strateg Rev 2013;1(3):181–92.

[79] Palit D. Solar energy programs for rural electrification: experiences and lessons from South Asia. Energy Sustain Dev 2013;17(3):270–9.

[80] Haque N. IDCOL Solar Home System Program. In: Proceedings of NEP workshop on off-grid electrification in Myanmar. Nay Pyi Taw: energypedia; 2015.

[81] Shrestha R et al. Institutional reforms and their impact in rural electrification: South and Southeast Asia. Sub regional technical report by Asian Institute of Technology, prepared for GNESD, Thailand; 2004.

[82] Panjwani A. Energy as a key variable in promoting gender equality and empowering women: a gender and energy perspective on MDG #3, in Discussion Paper; 2005.

[83] Sharma K. How to energize women: the Indian response. Bulletin of the Atomic Scientists. 70, 2; 2014. p. 13–16.

[84] Barefoot College. Our impact. [cited 2014 4 November]; Available from: ⟨http://www.barefootcollege.org/solutions/solar-solutions/impact/⟩; 2014.

[85] Barefoot College. Museum Pick: The Barefoot Approach. 2014 18 March [cited 2015 21 August]; Available from: ⟨http://www.barefootcollege.org/museumpick-the-barefoot-approach/⟩; 2014.

[86] Solar Sister. Impact by the numbers. [cited 2014 18 November] Available from: ⟨http://www.solarsister.org/how-it-works/the-numbers/⟩.

[87] Singh A, Raina M. Women entrepreneurs in micro, small and medium enterprises. Int J Manag Soc Sci Res 2013;2(8):4–8.

[88] UNIDO, Women, industry and technology. Available from: ⟨https://www.unido.org/fileadmin/user_media/Publications/Pub_free/Women_industry_and_technology.pdf⟩.

[89] Obeng G, Evers H-D. Impacts of public solar PV electrification on rural microenterprises: the case of Ghana. Energy Sustain Dev 2010;14(3):223–31.

[90] Ahammed F, Taufiq DA. Applications of solar PV on rural development in Bangladesh. Journal of Rural Community. Development 2008;3(1):93–103.

[91] Kumar S, Bhattacharya SC, Anisuzzaman M. Role of a regional programme for promotion of photovoltaic based rural electrification in Asia. Int J Global Energy Issues 2003;20(2):139 139.

[92] Mainali B, Silveira S. Renewable energy markets in rural electrification: country case Nepal. Energy Sustain Dev 2012;16(2):168–78.

[93] Sovacool BK, D'Agosti AL. A comparative analysis of solar home system programmes in China, Laos, Mongolia and Papua New Guinea. Prog Dev Stud 2012;12(4):315–35.

[94] Urmee T, Harries D. Determinants of the success and sustainability of Bangladesh's SHS program. Renew Energy 2011;36(11):2822–30.

[95] Urmee T, Harries D, Schlapfer A. Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific. Renew Energy 2009;34(2):354–7.

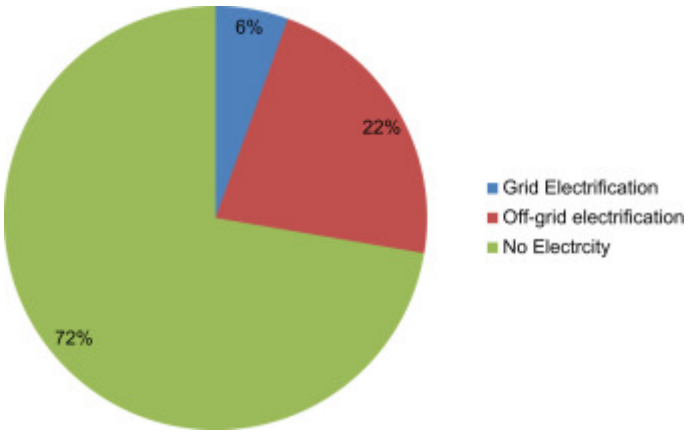
[96] Dadwal SR. Salience of energy sector in Myanmar's economic growth. Himal Cent Asian Stud 2014;18(1/2):35.

[97] ADB Independent Evaluation Department. Asian Development Bank assistance for rural electrification in Bhutan—does electrification improve the quality of rural life? evaluation study, Asian Development Bank; 2010.

[98] Ramani K. Energy as an instrument of women economic empowerment. Energia News 2002;5(1):8–10.

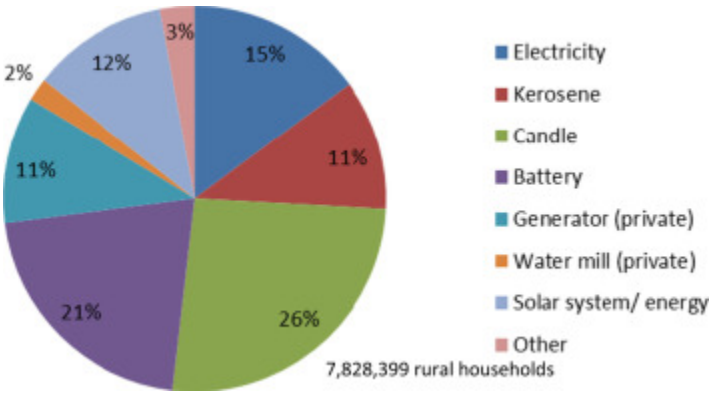
[99] Practical Action. Poor people's energy outlook 2012: Energy for earning a living. UK: Practical Action Publishing Ltd.; 2012.

Fig. 1. Status of electrification in Myanmar villages.



Data Source: [54].

Fig. 2. Census results for main source of lighting for surveyed conventional households in rural Myanmar.



Data Source: [64].

Table 1. Recent UNDP, ADB and EUEI findings for drivers and barriers facing solar PV in rural Myanmar.

Study and year	Sources of data	Drivers	Barriers
EUEI [30]	Government officials; domestic NGOs, CBOs and businesses; international NGOs and multilaterals; Shan state visit	Domestic energy market already exists, emerging global solar PV market, good solar resource, simplicity of PV systems, government expression of support for PV, existence of basic PV experienced networks, potential for economic and environmental benefits	Poverty, upfront costs, lack of financing, knowledge gap, human capacity gap, end user training gap, poor quality systems and poor track record, lack of coordination
UNDP [14]	Ministry of Energy, literature	Synergy between economic and environmental benefits of solar power, potential economic accessibility of small high quality systems, PV experienced local businesses and NGOs; potential for policy change and cross-subsidization of PV	Poverty, lack of accessible financing to end users, end user knowledge gap, taxes on imported solar equipment, bureaucratic complexity in implementation, lack of standards and quality enforcement, human capacity gap, policy fragmentation, conflicting government priorities
ADB [35]	Surveys in 18 villages Mandalay Division, 2 villages Naypyitaw Territory, 8 villages Chin State	Local organization and project management experience at a village level in many surveyed villages	High up-front costs of solar PV systems and lack of access to financing; lack of diffusion of solar PV markets; end user knowledge gap; lack of equipment standards and availability of poor quality equipment