CEDRO
Empowering Lebanon with Renewable Energy

November 2016
Exchange Issue 24

Off-Grid Solar Home Systems as Part of Rural Electrification in Lebanon

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1 General introduction on off-grid RE systems and rural electrification

1. UN Sustainable Energy for All initiative (SE4All - Sustainable Energy for All)

Launched by UN Secretary-General Ban Ki-moon in 2011, the SE4All initiative is looking forward to making energy more accessible, cleaner, more efficient and more affordable. It pursues three main goals: doubling the share of renewable energy in the global energy mix by 2030, providing access to modern energy services and doubling the global rate of improvement in energy efficiency. Thus, governments have been invited to take actions to transform their energy systems and foster investments towards the market changes that are needed to achieve these goals.

Since the 1970s, off-grid solar systems have already succeeded in providing energy to many African and South-East Asian rural areas - without or with poor access to the grid. Their expansion was made possible thanks to the advanced technology and higher efficiency of the system components: PV (Photovoltaic) modules, storage batteries, charge controllers and appliances (Phadke, et al., 2015). These recent technological developments and the reduction of costs[1] have favored the development of small off-grid renewable energy systems, especially in developing countries.

Therefore small off-grid renewable energy systems have proven to be key to provide households that are not connected to the grid with the basic energy services they need - in a reliable, cost-effective, clean and efficient way - thereby very effective in achieving SE4All's targets.

The Project is funded by the European Union

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2. SHS (Solar Home System) for rural electrification in developing countries

The IEA (International Energy Agency) estimates that about 1.5 billion people worldwide still lack access to electricity from the grid[2], mostly in rural areas of African and Asian countries in which grid extension isn't likely to grow sufficiently to cover the population growth. Thus, estimation by the IEA is that 950 million people will have gained access to the grid by 2040 while 530 million people will still be living off-grid[3]. For these households off-grid RE (Renewable Energy) technologies offer an interesting source of energy: IRENA estimates that 26 million households have an off-grid RE system and 20 million a solar home system[4]. Analysis from experts of Lighting Global, Bloomberg New Energy Finance and Global Off-Grid Lighting Association highlights that the market of SHS has attracted $511 million so far with 100 companies already offering SHS solutions and 89 million people from developing countries having a solar lighting product in their homes[5]. Furthermore it is estimated that, by 2020, 7 million off-grid households will be using solar-powered fans and 15 million solar-powered TVs.

3. SHS as a source of electricity

SHS benefits the end-users directly by providing them with a reliable and stable source of electricity, installed locally.

Lighting is the most basic electricity need covered by a SHS. Several options are available in terms of the type of light bulbs and luminosity. The direct benefits are extended hours of light for studying, working, cooking or as leisure time.

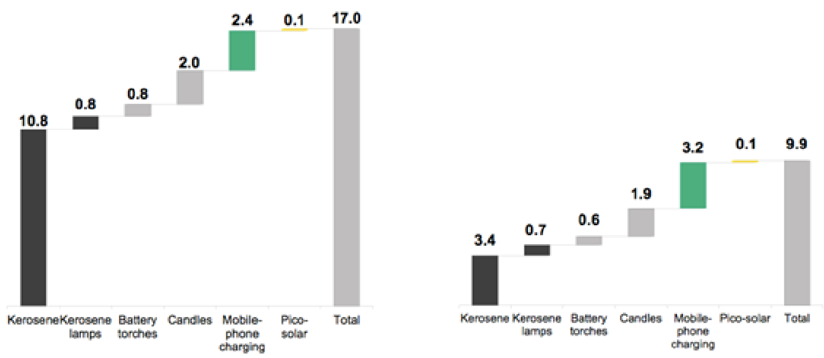
Mobile phone charging is the second most-used option of SHS. It is very useful, especially for rural households to secure their communication needs.

Furthermore SHS providers also offer upgraded versions with additional capacity ranging from 80 to 400 Wp to power small home appliances such as a radio, a fan, a TV set or a refrigerator.

4. Social, economic and environmental benefits of SHS

Apart from allowing the households to meet their basic electricity needs, SHS have a broader impact on social and economic activities. Lighting favors social interactions and gatherings between neighbors and it also allows longer working hours for small shops and businesses. Small communication devices such as mobile phone, radio and small TV can also be plugged to the SHS, enhancing connection between people within the same village and outside of it. Thus, providing the poorest households with SHS help reduce their vulnerability and improve their living standards.

For many households SHS replaces non-efficient and polluting lighting technologies: an average $27 billion is spent annually on kerosene lamps, candles, battery torches or other fossil-fuel powered technologies to fill the electricity gap of off-grid households[6].



Source: Bloomberg New Energy Finance, UNEP[10], GSMA, World Bank. Assumes phone charging costs of $0.20 for one-two weekly charges.

Figure 1: Analysis on annual spend on off-grid lighting and phone charging in Africa and Asia from Lighting Global, Bloomberg New Energy Finance and Global Off-Grid Lighting Association report

SHS are very profitable to off-grid households compared to existing lighting technologies: payback period of SHS is estimated three months in Kenya and a year in India - where kerosene lamps are less expensive because of government subsidies[7]. Additionally, in some countries off-grid households often have to travel far to reach a mobile phone charging point and pay $0.15 to $0.25 per charge, equivalent to $30-50 per kWh[8].

Recent research on the impacts of low-quality fuel-based lighting identifies health and security risks that include burns, indoor air pollution, poisoning due to accidental ingestion of kerosene fuel by children and maternal health issues[9].

Finally, SHS also have a positive impact on the environment: they usually replace oil lamps, eliminating the risk of fire hazards and cutting CO_2 emissions by 112 kg each year[10].

5. SHS solutions and associated services

Worldwide, many companies have specialized in SHS, offering a large panel of solutions from mere lighting to phone charging and powering of small equipments. The smallest systems range from 2 to 5 watts for 2 to 4 LED lights and a small radio, such M-Kopa or Bright Box in Kenya. Larger systems range from 80 to 200 Watt - Peaks and provide enough electricity for phone charging and powering a TV or a refrigerator, such as Leonics in Thailand and Barefoot Connect in Africa.

SHS companies differentiate themselves in the services they provide: from mere selling of product to a more complete solution including installation and maintenance. In Bangladesh, Grameen Shakti warranties the systems during three years and the solar panels during twenty years. In East Africa, Azuri insures SHS installation by locally trained technicians. Some SHS companies also offer remote payment technologies through scratch cards and mobile phones. Finally, some business models allow end-users to become owner of their SHS after a number of monthly payments (1.5 year in the case of Azuri and 3 years for Mobisol).

II. Assessment of Lebanon's energy situation and poverty in rural areas

1. The Syrian conflict and its impacts on Lebanon's energy crisis

As a direct consequence of the Syrian crisis, Lebanon is experiencing increasing stress on its already fragile economic and social structure. The World Bank and the UN conducted jointly an economic and social impact assessment, identifying particular areas that are considerably more affected than others. These include large pockets in South and North Lebanon, as well as the Bekaa Valley in the East that presently accommodate the bulk of the refugees. Due to geographic proximity to the conflicts in Syria, many areas carrying the greatest refugee burden also happen to be among the least developed and most chronically poor regions of Lebanon pre-crisis.

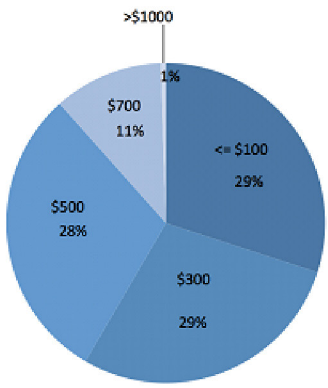
2. The energy situation in rural Lebanon

Lebanon has a high electrification rate (99.9%) however the grid lacks reliability and in some areas the service provided by EDL (Electricite du Liban) is unreliable: 98% of the households experience power cuts[11] and in rural areas this is even more significant with most households experiencing up to 12 and 18 hours of blackout per day.

As part of UNDP's (United Nations Development Program) initiative on sustainable energy for host communities in Lebanon, two hundred households[12] living in rural areas have been surveyed in early 2016.

The social characteristics of the surveyed households

In each household there are on average 6.5 persons with 56% composed of 6 to 9 persons. Their income is on average 342 USD per month and almost 30% of households have a monthly income equal or lower than 100 USD.



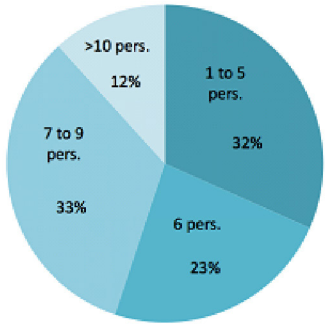


Figure 2: Households' income (left) Figure 3: Number of person per household (right)

Among the persons who were interviewed, only 14% have a full-time job and more than 90% have either attended primary school or have no education. The unemployment rate for people between 20 to 60 years old is high (57%) and unequal given the gender: 95% for women and 32% for men[13].

The energy situation of the surveyed households

To cover the blackouts 17% have a diesel generator while the remaining use either a rechargeable battery (32%), candles (23%), rechargeable lights (17%), borrow electricity from neighbors (4%) or use oil lamps (2%) (Fig.7). If households' main electricity need is for lighting (100%) a great majority also needs it to power their washing machine (98%), refrigerator (94%) and TV set (93%) (Fig.5).

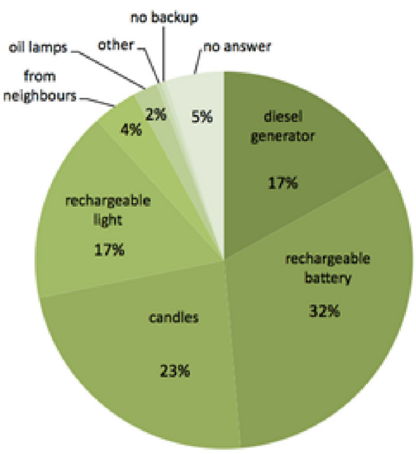


Figure 4: Backup solutions

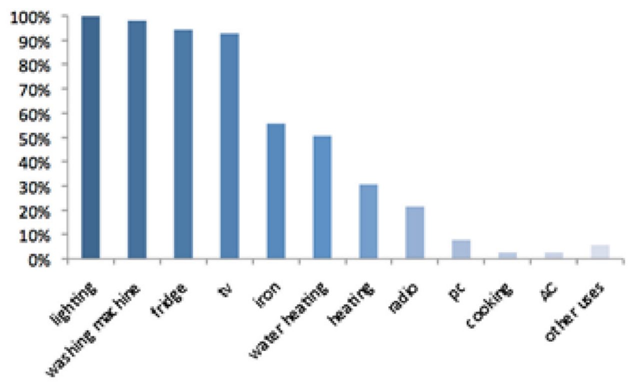


Figure 5: Priority electricity needs

Energy poverty of the surveyed households

The concept of energy poverty would require much attention and details, however a practical definition that can be taken on for this study is the share of monthly income dedicated to electricity expenditures. Among the surveyed households expenditures on electricity averages 26 USD per month, which represent 8% of the average income. However a focus on the 30% poorest households (with an income equal to or lower than 100 USD per month) shows that electricity expenditures weight on average 20% of their income. Exposed to high costs, combined with long and frequent blackouts, Lebanese rural households easily fall into the "energy poor" category and without any clear national policy to tackle the energy problems they are facing.

Sizing rural households' electricity demand

A study on photovoltaics in rural Lebanon[14] estimates that a typical rural household uses approximately 1,200 kWh per year. It estimates that their minimum and basic electricity needs correspond to 25% of their total consumption, thus an average of 300 kWh per year of basic electricity needs (Fig.6). To fulfill them, a SHS could be useful if it provides lighting but also includes the powering of a refrigerator and a TV set, run on DC.

Table 1: Survival Rural Lebanon off-grid usage

	CF Lights 2 /10W		Fridge DC/VC/60W		TV/DC 60W		
Month	Hours /day	Wh/ day	Hours /day	Wh/ day	Hours /day	Wh/ day	Daily (Wh)
Jan	6	120	5	300	5	300	720
Feb	6	120	5	300	5	300	720
Mar	5	100	6	360	5	300	760
Apr	4	80	8	540	4	240	860
May	4	80	10	700	4	240	1020
Jun	4	80	12	840	2	120	1040
Jul	3	60	12	840	0	0	900
Aug	3	60	12	840	0	0	900
Sept	4	80	10	700	4	240	1020
Oct	5	100	8	480	5	300	880
Nov	5	100	6	360	5	300	760
Dec	6	120	5	300	5	300	720
Yearly averaged daily energy consumption							858

Figure 6: Off-grid basic electricity needs in rural Lebanon in DC

III. SHS project as part of rural electrification for Lebanon

UNDP's mission for host communities targets the improvement of Lebanon's rural poorest households access to sustainable electricity. SHS, as a small-scale solar decentralized source of electricity, are most useful and cost-effective to provide the poorest households with the basic energy they need. More than one thousand households have been targeted as beneficiaries, in different regions of Lebanon. SHS are financed thanks to international grants and offered to the Lebanese households who thereby become owners of their SHS. The lifespan of the system is estimated to be approximately eight years, after which they can replace the battery and still benefit from it.

1. The selection of beneficiaries: identifying most vulnerable households

Households to benefit from SHS are targeted in coordination with the Lebanese Ministry of Social Affairs. All beneficiaries come from a poor or very poor background. They were selected based on socio-economic criteria such as the household's income and the employment situation. Another criterion is the number of persons living in the household and the presence of Syrian refugees welcomed in the home. Also, households in which the head of home is physically impaired or widowed or orphaned were targeted in priority, as well as those in which students from schools or universities need lighting for studying. The energy situation of the households was not known before the first visit – therefore it could not be used as a criterion for pre-selection – once the energy situation acknowledged, priority was given to households experiencing a poor energy situation with long blackouts hours and no diesel generator as backup system[15] .

2. SHS beneficiaries by region and by village

A total 1,380 rural Lebanese households benefited from SHS in 2014-2016. As of May 2016, 1,127 beneficiaries have already been selected and a remaining 253 households are still under the selection process by the project engineers. Three main Governorates of Lebanon have been targeted: the North, the Bekaa valley and the South (Fig.7). Most of the beneficiaries are from the North Governorate and from Akkar District (Fig.8).

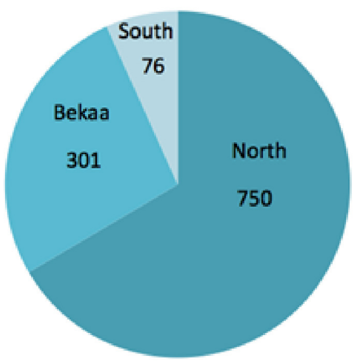


Figure 7: SHS beneficiaries in Lebanon, by Governorate

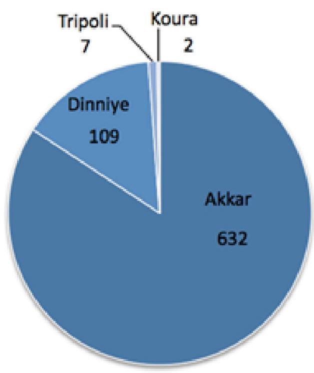


Figure 8: SHS beneficiaries in the North Governorate

3. Technical description of the SHS implemented by the UNDP

SHS are designed to provide lighting to three rooms and most households chose to light in priority: the living room, one bedroom and the kitchen. On-site engineers recommended not selecting the toilets as the SHS includes a torchlight that can easily be used as a complement.

End-users benefit from a kit composed of:

- Three PV panels
- Six fluorescent LED (Light Emitting Diode) lamps of 400 lumen and from 3 to 5 watts
- Three boxes containing each the charge controller and a lithium battery
- One phone charger
- One torchlight

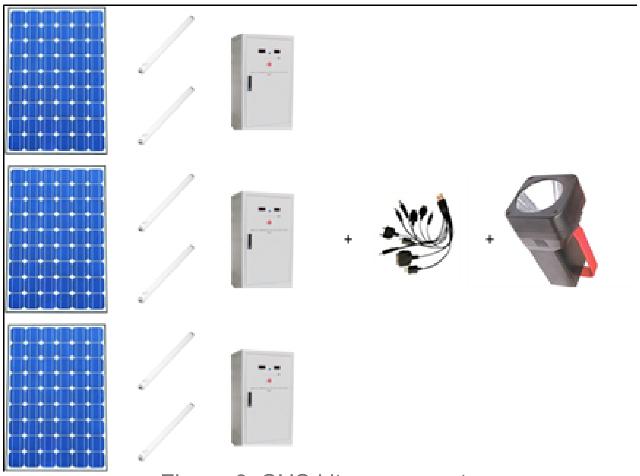


Figure 9: SHS kit components

The role of women in promoting SHS

In some households we have observed that women play a special role in giving information about the household's characteristics prior to implementation. During the first visit, in many cases, the head of home was not present and was represented by a woman in charge of the household – mostly the wife. Even when the head of the home was present during the visit, the wife would sometime answer herself or correct her husband to give more accurate details when answering questions on the living conditions, the energy situation and the electricity bill. During implementation, women have a particular role in defining where the SHS is most needed, recalling the importance of lighting in the kitchen and in the room where children are studying

General observations from UNDP engineers involved in SHS implementation

In most houses the phone charger and the torchlight are very much used, especially to help them light outside

SHS are particularly useful for two categories of households: the ones including elderly for whom the light is very useful to increase their security and the ones including students whom can benefit from extra studying hours after school or university

In very few cases SHS had technical malfunction and the beneficiaries would directly refer to their municipality and alert the installer to fix it

During implementation, the operation of the SHS is explained to the beneficiaries and most of them would easily understand it. Awareness is done to stress on the environmental benefits of the SHS and most people are considerate regarding this issue

IV. Recommendation/discussion on the success factors of SHS for rural electrification

For SHS to successfully bridge the electricity gap in rural areas, the program needs to meet the priorities of the different stakeholders: national officials, development agencies and end-users or their representative. For example, through a SHS program for rural areas national officials usually target poverty reduction and favor solutions with both long-term efficiency and direct immediate benefits.

Development agencies are concerned with meeting development objectives while providing the most suitable available technology at the lowest cost. As for end-users, they have concrete electricity needs and even if these might not be fully covered by the existing solution available in the market, they should be taken into account. For example, in Kenya's SHS program television was not considered a priority tool for development, while Kenyan households' demand for PV was in fact driven by the desire for television[16].

The design phase of a SHS program analyses the following four pillars (Fig.10):

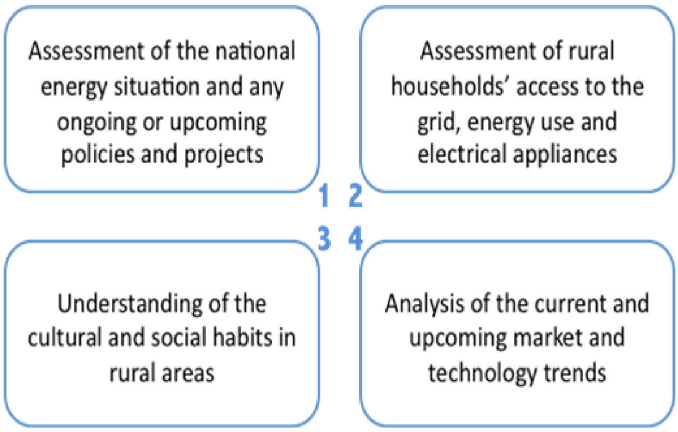


Figure 10: SHS program design phases

Once analyzed and in order to tackle all stakeholders' issues, long-term quantitative and qualitative objectives have to be defined clearly, as the electricity gap to be fulfilled and the total number of beneficiaries in the short, medium and long term. Only then can the business model and the market organization be defined to achieve these objectives.

1. Market organization, business models and financing mechanisms

If off-grid SHS benefited from tremendous technological breakthroughs, allowing most technical barriers to be overcome such as PV panel costs, battery storage and control systems; other non-technical challenges still need to be dealt with efficiently, such as market organization, business models and financing mechanisms.

An efficient market organization maximizes end-users' needs while providing the best available technology and improving global access to electricity in a financially viable framework for all economic actors (Fig.11).

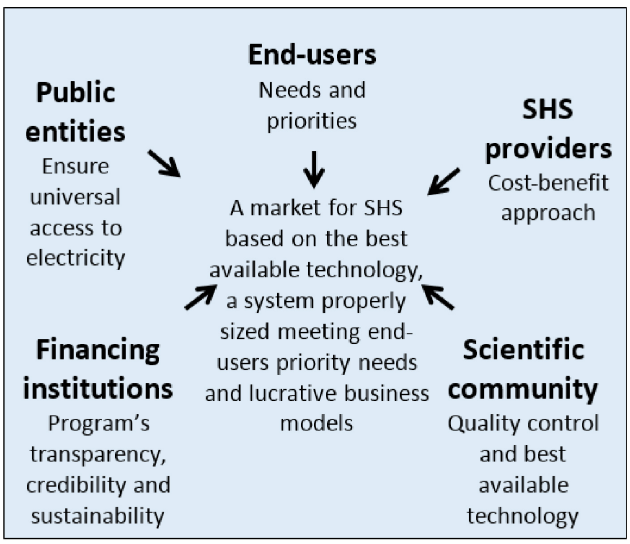


Figure 11: Actors involved in a SHS program

All actors share a common interest, which is to favor a sustainable and independent market for SHS. This can be achieved in many different ways, with more or less support from the government, from NGOs (Non Governmental Organizations) and from private donors.

Support from the State and the local authorities

Different state interventions are possible to favor the creation of a market for off-grid renewable energy systems, both at the national and local levels. Direct or indirect market incentives can be introduced such as facilitating entrance to the local market or removing subsidies on fossil fuels. Public authorities can also provide financing tools to increase and secure investments in off-grid RE as low interest rates, specific loans or the creation of a national fund for RE. Government support can also include awareness programs and technical trainings on off-grid RE technologies. Local public entities can help coordinate locally with providers of off-grid RE systems and end-users for awareness campaigns, access to financing, implementation, collection of fees and maintenance. This can be very helpful especially for providers to reach remote areas in which the cost of servicing can be very high.

The importance of low-cost financing

Most of the SHS installed in developed countries of Africa and Asia benefited from grants and donations from governments, NGOs or private donors. Even in these cases, financing instruments are introduced to foster the creation of a market for SHS.

Michael Eckhart presented an analysis of PV systems costs in Africa in the year 2004[17] showing that the monthly cost of a SHS can be reduced if the system's efficiency is increased, if the costs of components are reduced, or if the interest rate is low and available for a longer period of time (Fig.12).

	SHS cost per month	Interest loan	System efficiency	System costs
SHS of 50 Wp capacity	$16.40	18% for 7 years	10%	x
	$10.93	18% for 7 years	15%	x
	$8.20	18% for 7 years	10%	x/2
	$6.37	5% for 20 years	10%	x

Figure 12: SHS costs depend on system efficiency, technology and interest loans

Access to low-cost financing is decisive in making SHS more affordable. These financing tools need not only to reach individual end-users but all actors such as the provider of the system, any ESCO (Energy Service Company) involved and any association of end-users who wish to benefit from it.

Defining the business model

The business model defines the relationships between all actors and the set of rules in terms of ownership, payment and maintenance. Many different models of business can be designed in which ownership of the system and maintenance responsibility can vary. SHS can be paid for by the government, NGOs or ESCOs and either remain their property or become the property of end-users. SHS can either be given for free to end-users or paid for once or through monthly payments. The market for SHS has to tackle effectively the following issues:

1. Cover demand outside of dense areas
2. Ensure quality control through affordable battery replacement, quality spares and skilled technicians

Adequate incentives have to be set for all actors to deal with those two issues; mostly through financing schemes and control mechanisms (Fig.13).

Type of model	Owner	Provider	Intermediary	Type of payment	Maintenance	Issues
Commercially led model	end-user becomes owner	merchants that can be dealing with other commodities		cash sales	consumers responsible for maintenance or by the provider on a cost-recovery basis	pb of quality control
multi-stakeholder programmatic model	end-user becomes owner	chosen through procurement from project management	project management unit which selects the systems, reaches rural homes and extends consumer credit		consumers responsible for maintenance	pb of quality control and reaching only dense geographic markets
utility model	provider remains owner	chosen through procurement		fee-for-service as a monthly fee	provider responsible for maintenance	reaching only dense geographic markets
grant-based model		chosen through procurement at a national level	local authority	free	local authorities are responsible for maintenance	have enough financial resources for maintenance

Figure 13: Presentation of the different business models in Krause 2004[18] (see references)

Try to benefit from a business and/or social network that already exists

An interesting and useful way to successfully overcome these issues is to try and benefit from a national or regional business or social network that already exists. For instance, some African programs relied on oil lamps vendors or other commodity vendors to become in charge of SHS coordination and the collection of the monthly fees. They act as representatives at the local level and help reach remote areas in which the cost of servicing is too high for providers. In the particular case of oil lamps vendors, as SHS are to replace oil lamps, from a social and economic perspective helping them convert into SHS vendors is key to the long-term success of a SHS program in rural areas. Additionally, the SHS program can benefit from their client network and their knowledge on the targeted end-users.

Develop remote payment options

Another successful way of reducing additional costs to reach remote areas is to develop distance payments know as pay-as-you-go or PAYG. Most of them rely on mobile banking technologies whenever available, also depending on network coverage and mobile phone access[19]. A Cambridge University spin-off designed a PV including an additional electronic sensor that allows remote pre-payment: end-users have to buy a recharge card corresponding to the amount of credit (in kWh) they would like to benefit from or send the number by mobile phone. Other technological options include a meter that is installed in the house and allow remote pre-payment by a recharge card which code has to be entered on the meter to benefit from kWh.

Favor collective initiatives

Collective business models can also be effective to promote SHS. For example, a fund can be created in which all people who are part of the same village participate and get a loan which will allow them to afford SHS for one house in the village, then another one and another one, until all participants benefit from a SHS. Gathering and contracting collectively with the same provider will help reduce the costs of servicing. Moreover, anticipating the installation of SHS for all the houses from the same village will lower the risks of vandalizing or stealing and favor good practices, awareness and good maintenance.

The success story of carbon credits in Bangladesh

Clean Development Mechanisms (CDM)[20] allow climate change projects in developing countries to be financed by developed countries through certified emission reductions. Therefore, if eligible, RE projects such as SHS can benefit from carbon credits as an additional project financing opportunity. In Bangladesh, about 3.5 million SHS have been installed so far, through a World Bank program[21]. The microcredit scheme consists of a network of NGOs that provide end-users with SHS and an independent company that certifies the equipments and gathers the subsidies. End-users pay a first amount of 10% to the local NGO which itself apply for refinancing in order to collect money and fund other systems. The rest is paid by end-users during a three to five year period. Subsidies are fixed at $25 per system from CDM credits.

Create a national RE fund

To secure long-term financing and the sustainability of SHS as a reliable source of electricity for rural households, it is necessary to favor the creation of a national fund for RE. All actors can supply it: the State, SHS providers, donors, NGOs and end-users. Its objective would be to secure future investments for battery replacement, for the development of a market for SHS, for awareness and for training national experts and technicians[22].

Conclusion

A study on solar systems conducted by Bhattacharrya, et al., in 2013 stresses on the barriers to the development of off-grid solar systems, highlighting that “most rural households can only pay $2-$3 per month for electricity” (Cust, et al., 2007). Even in households which income is above the average lowest income, the willingness to pay (WTP) for off-grid SHS is very low. Many reasons account for this, among which the lack of awareness on energy and RE, the lack of government support and incentives, the lack of required skills and experts and the lack of financing solutions. For the latter, there is a key challenge to convince and support commercial banks in financing off-grid RE systems, especially that some of them still do not consider solar PV technologies as reliable (Cust, et al., 2007). Another reason why willingness to pay is very low is that SHS can be seen as a second-best option, helpful to meet some of the most basic electricity needs but undermining long-term government policies towards sustainable solutions such as extension of the grid, improvement of grid maintenance and additional energy services from the grid.

When surveyed, Lebanese rural households were also asked about their willingness to pay for a SHS and three types of systems were given as options:

1. The first type of SHS option provides lighting for three rooms and includes a phone charger (option 1)
2. The second type provides lighting for three rooms, includes a phone charger and can also power a small TV (option 2)
3. The third type provides lighting for three rooms, includes a phone charger, can power a small TV and a small refrigerator (option 3)

Although the survey would need to be extended to other rural areas in Lebanon and include a more robust methodology in order to improve the level of accuracy of the analysis, results showed that the majority of surveyed households were not willing to pay for any of the three options (86%). Only 10% would be willing to pay on average 9 USD per month for the 3rd option. Although surveys show that reluctance to pay for a SHS is mostly due to the households’ perception that they would not be able to afford it (67%), it is assumed that their reluctance to pay is more linked to their disappointment in the current lack of a reliable connection to the electricity grid, the cost of their backup generator when they rent one and their disappointment in PV SHS that are unable to cover their real electricity priorities.

2.2 Technical success factors

Reliability of the system is essential to ensure the sustainability of off-grid renewable energy systems as a tool for rural electrification. It depends both on the technological improvements and the setting of quality control procedures.

The price decrease of PV modules and of the systems' components[27], alongside with improvements in storage batteries, charge controller technologies and improved mechanical and electrical designs have favored the development of off-grid solar systems over the last decade. This expansion of solar PV technologies use contributed to increase labor skills and reduce the total cost of labor in systems' design, manufacturing, testing, installation and maintenance. Coupled with improvements of home appliances' energy efficiency and the development of LED lighting technologies, it became more and more interesting to offer SHS as a reliable solution for rural electrification.

Quality control procedures are very important to make sure that the systems entering the market are consistent with international standards. Therefore, an independent national agency is very useful to set the quality requirements, define the testing procedures and enhance products certification.

Other non-technological standards can also be defined, such as the quality of information provided to end-users through both advertising and users manual[23].

The technical quality of SHS is a minimum requirement and prerequisite for SHS programs to be launched; it is necessary and essential in contributing to SHS' acceptability by both governments and end-users as a sustainable solution for electrification.

V. Conclusion

A study conducted by UNDP DREG project[24] estimates that, on average, a total 817 kWp of off-grid solar capacity has been installed in Lebanon, so far. The main sector benefiting from off-grid solar systems is the Lebanese residential sector with a total capacity of 414 kWp (Fig. 14).

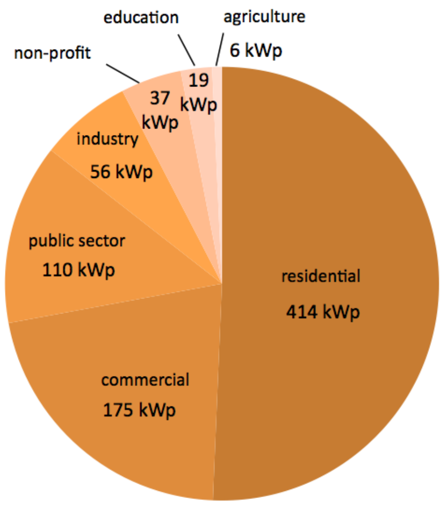


Figure 14: Total installed off-grid PV capacity in Lebanon, as of April 2016[25]

The UNDP's SHS program for rural Lebanon is contributing to an additional 83 kWp[26] of installed capacity.

Although solar energy is expanding in Lebanon, there is a significant challenge to make it more affordable for households, especially those that already suffer from vulnerable economic and social backgrounds. Access to financing is decisive for rural Lebanese to help them afford RE systems that can help them cover at least their basic electricity needs. Thus, the launching of a national financing mechanism in Lebanon under "National Energy Efficiency and Renewable Energy Action"[27] and supported by the Central Bank, is key. NEEREA facilitates access to subsidized loans for EE and RE projects – through Lebanese commercial banks. In the years 2012-2014, approved projects have been mostly in the residential sector (75%), followed by commercial (18%), industrial (5%) and non-profit (2%). The main technology implemented is PV (52%), followed by LED lighting (13%), Solar Water Heater (9%), Green Building (9%), Biomass boiler (9%), building envelope (2%) and others (6%) (Fig.15).

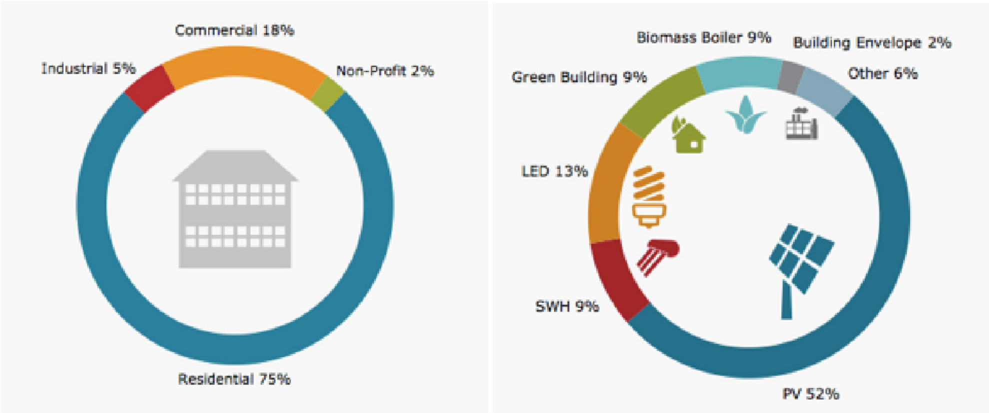


Figure 15: NEEREA approved projects by sector and by technology[28]

The mechanism does not limit PV projects in size – there is no minimum capacity requirement – however, low-income households interested in small PV systems face more difficulties to access a loan as they usually can't provide sufficient collateral to apply for a green loan at a commercial bank.

Micro-credit appears as a solution to bridge the financing gap for rural low-income households. In Lebanon, four institutions dominate the market: Al Qard al Hassan, Al Majmoua, Vitas and Emkan. They are mainly financed by donors, social and corporate investors. The central bank offers Lebanese commercial banks the right to use their statutory reserves to finance microcredit institutions, favoring their development. All Lebanese micro-credit institutions offer sustainable financing services both for business purposes and for social needs – including home improvement works. Lebanese Blom bank states that micro-credit reaches more than 150,000 borrowers and a total loan portfolio of $150 million[29]. The average loan amount is $2,000 and all loans range between $300 and up to $5,000 for a period of 6 months to 2 years. SHS fall into this category in terms of costs and the loan repayment period offers interesting perspectives in monthly installed payments.

Al Majmoua[30] states that only 6% of the borrowers are from North Lebanon, while this region concentrates 20.7% of Lebanon's population and 38% of the entire poor population[31] (Fig.16).

Governorate	Extremely Poor (1)	Moderately Poor (2)	Entire Poor Population (1+2)	Proportion of Total Population
Beirut	0.9	2.6	2.1	10.4
Mount Lebanon	18.9	30.5	27.3	39.9
North	46.0	34.9	38.0	20.7
Bekaa	17.2	11.4	13.0	12.7
South	15.4	15.6	15.6	10.5
Nabatieh	1.6	4.9	4.0	5.9
Total	100	100	100	100

Source: Authors' estimates based on CAS, UNDP and MoSA Living Conditions and Household Budget Survey (2004-5).

Figure 16: The poor population in Lebanon by region and by type (source: UNDP)

Al Majmoua's figures would need to be compared to that of other institutions, still it highlights that micro-credit yet doesn't reach Lebanon's poorest households. Thus, upcoming SHS programs aimed at the poorest would need to include their own financing schemes.

Alongside with fostering access to finance, another important matter to stimulate a market for SHS in rural Lebanon is the correct sizing of households' electricity needs. In Lebanese rural homes the electricity need for lighting can be efficiently covered by a SHS, especially when daylight is lacking in winter evenings and at night in all seasons. But as previously stated, most Lebanese rural households are already well equipped with basic home appliances such as washing machines, refrigerators and TV sets. Therefore, a SHS that improves their well-being and for which they would be willing to pay would have to include these electricity needs and power these appliances during blackout hours. Otherwise the use of diesel generators remains a second-best solution while waiting for constant and reliable access to the national grid.

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[11]: Report on Willingness to pay for RE by UNDP CEDRO, Oct. 2015
[12]:The panel includes precisely 200 households: 114 from the North, 58 from the South and 28 from Bekaa.
[13]: Some people were labeled unemployed as they do not have a full-time job but they still have irregular sources of income through help, commissions, daily salaries or self-employment.
[14]: Thermoelectrically-complemented photovoltaics in rural Lebanon, by Nuwayhid, AbouSaid and Taha, 2011
[15]: In the first phases of the program (2014-2015) 60% of the households in the North and 70% in the Bekaa did not have a backup generator to provide electricity during the blackout hours while all of them experience more than 12 hours of blackouts per day. More than 40% of the households who benefited from a SHS were using either candles and/or oil lamps as alternatives during blackouts, while some houses had no light at all.
[16]: Solar Photovoltaics in Africa by Krause and Nordström, 2004
[17]: Solar Photovoltaics in Africa by Krause and Nordström, 2004
[18]: As note #6
[19]: Pico solar PV systems for remote homes, IEA report, 2013 states that phone coverage is not always available in remote areas, beneficiaries do not have mobile phones or that mobile banking is not accepted as a cultural habit.
[20]: CDM is a project-based mechanism, which is designed to help developing countries to achieve a sustainable development.
[21]: For more information refer directly to World Bank project documents for rural electrification in Bangladesh.
[22]: In Zambia beneficiaries pay a monthly fee for battery replacement when needed (Bhattacharyya 2013 on Rural electrification through off-grid systems)
[23]: Giannakopoulo (2014) estimates that PV module price has decreased -85% over the last decade
[24]: WorldBank Lighting Africa defined quality standards such as "truth in advertising" manufacturer name, product name and model, light output, power consumption, run time and functionalities.
[25]: DREG is a UNDP project for Lebanon in small Decentralized Renewable Energy power Generation
[26]: Data collected from DREG in May 2016
[27]: 60 Wp per SHS and a total 1,380 SHS installed in 2014-2016

[28]: NEEREA is a national financing mechanism launched since 2012 by the Central Bank of Lebanon, the Ministry of Energy and Water, the Ministry of Finance, the EU and the Lebanese Center for Energy Conservation.
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Acknowledgment: This exchange was possible thanks to the EU funded UNDP CEDRO project team and the feedback they kindly shared after implementation of the first phases of the Solar Home System (SHS) program in rural Lebanon. It is also based on the results of a survey that was conducted in early 2016 with two hundred rural households in vulnerable Lebanese villages.

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