Chapter 9
Putting the End-User First: Towards Addressing Contesting Values in Renewable Energy Systems Deployment for Low-Income Households—A Case from Likoma Island, Malawi

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Abstract This paper focuses on barriers and opportunities for the adoption of modern renewable energy technologies by low-income households in the light of energy requirements for household well-being; household prioritization of energy services; household purchasing power for energy; and households' experiences with traditional and conventional energy sources. Approaches for addressing the identified barriers to the adoption of renewable energy solutions by low-income households are discussed as well. Our findings show that low-income households will continue to use traditional and conventional energy sources and technologies unless modern energy solutions come with integrated financing mechanisms that enable households to pay for good-quality systems capable of meeting their energy needs. The work is based on empirical evidence from Likoma Island in Malawi.

9.1 Background

The positive correlation between modern energy usage and living standards (Eggoh et al. 2011; Jumbe 2004) is compelling policymakers worldwide to promote the replacement of traditional energy sources such as kerosene and firewood, which are

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Table 9.1 Feed-in tariffs introduced by the Government of Malawi for renewable energy systems of 500 kW and more

Renewable energy source	Feed-in tariff for	
	Firm power[a] (US$/kWh)	Non-firm power[b] (US$/kWh)
Photovoltaic	0.20	0.10
Biogas/biomass	0.10	0.08
Wind	0.13	

[a]Firm power means that the producer can guarantee feeding non-intermittent power into the grid
[b]Non-firm power means that the producer cannot guarantee feeding non-intermittent power into the grid

still widely used in developing countries. This trend is further encouraged by global efforts to mitigate climate change. As a consequence, country governments are adopting a range of policies and planning measures to promote renewable energy technologies. But these efforts do not always bear fruit; in some cases, adoption of renewable energy systems does not take place at all, and in other cases, beneficiaries abandon these systems after a short time and revert to using traditional fuels. Successful adoption is underpinned by relative advantages of the available choices measured in economic terms, social prestige, convenience, and satisfaction, as well as the compatibility of available choices with existing values, past experiences, and potential adopters' needs (Rogers 1995, 2001).

In 2012, Malawi introduced feed-in tariffs as an incentive for independent power producers to invest in renewable power generation. Among other things, the government hoped that the feed-in tariffs would eventually lead to the replacement of existing diesel-fired electricity production on Likoma Island with renewable energy solutions (Malawi Energy Regulatory Authority 2012). The feed-in tariffs were set as shown in Table 9.1.[1]

Zalengera (2015) modelled a photovoltaic and wind-based energy system which could replace the existing diesel generators on Likoma Island. This model shows that the cost of producing photovoltaic and wind-based electricity could be between US$0.296 and US$0.626 per kWh, depending on the interest on capital finance, which is considerably less compared to US$0.888 per kWh for diesel-fired electricity. In 2014, the (subsidized) grid electricity tariff in Malawi averaged US$0.085 per kWh for all households, including low-income households. Thus, photovoltaic and wind systems could reduce the subsidy spent by the government on grid electricity on Likoma Island from US$0.803 per kWh to at least US$0.541 per kWh. The same study by Zalengera (2015) also showed that household-based photovoltaic and wind energy systems are more economically competitive than the existing diesel-fired electricity on Likoma Island.

The present paper examines factors affecting the deployment and diffusion of modern renewable energy technologies in low-income households, taking Likoma

[1]Geothermal and small hydropower plants are also eligible for feed-in tariffs, but are not included here because of the scope of this paper.

Island in Malawi as a paradigmatic example. In addressing this overall goal, the work focuses on:

- Assessing energy needs and requirements of households;
- Determining households' energy purchasing power;
- Determining priority energy services and household satisfaction with energy services from existing technologies; and
- Discussing potential barriers and opportunities for renewable energy adoption on Likoma Island.

9.2 Methodology

9.2.1 Study Site

The study was carried out on Likoma Island, which is located in Lake Malawi and has a land area of 18 km^2 (National Statistics Office 2008). The island is home to about 10,500 people living in 1500 households, which amounts to an average household size of seven people. The major sources of energy on the island are firewood for cooking, as well as kerosene and dry-cell-battery-powered torches for lighting. Electricity is supplied by diesel generators feeding a grid system that is independent of the mainland grid. Due to high operation costs, the generators are switched on only from 6 a.m. to 12 noon and from 2 to 10 p.m., that is, during 14 h each day.

9.2.2 Data Collection and Analysis

We did a survey in January 2013 using a semi-structured questionnaire (Laws et al. 2002; Mikkelsen 2005) administered to households in face-to-face interviews and for self-completion. The participating households were selected using proportionate stratified random sampling (Curwin and Slater 2004; Laws et al. 2002; Mikkelsen 2005; Scheyvens and Storey 2003) based on the population of each of the twelve villages on Likoma Island. Survey participants were selected from village registers in the presence of the respective village chiefs, who were then asked to comment on the representation of different social classes in the final sample. When necessary, participants were added until the desired social class was represented. The final retained sample size was 202 households.

The household energy requirement for good well-being (Dodge et al. 2012) was estimated based on households' energy needs, their current energy consumption, and the authors' assessment of what electrical appliances are required for comfortable living. Households were asked to name their energy needs by selecting appropriate entries from a list. The needs listed were lighting, cooking, water heating, radio, television (TV), telecommunication/phone charging, refrigeration, and space cooling/water heating. Respondents were also asked about the number of rooms in their property (to determine lighting energy demand[2]), as well as their daily hot water requirement, the daily amount of firewood used for cooking, electrical appliances owned, and electrical appliances they planned to purchase. In order to determine energy purchasing power, the questionnaire elicited quantitative data on households' total monthly expenditure on energy services (excluding for transport and mobility); how much they were willing to pay per month for all household energy services (willingness to pay for energy per month); and the maximum they could afford in terms of capital costs of an energy system (willingness to pay for one-time purchase of energy system).

In addition, households were asked to rank the importance of selected household energy services such as cooking, lighting, water heating, radio, TV, and phone charging on a scale of 1–10 (1 = most important). Lastly, respondents were asked to rank their satisfaction with the aforementioned energy services on a scale of 1–4 (1 = very dissatisfied, 2 = dissatisfied, 3 = satisfied, and 4 = very satisfied).

Data analyses consistent with the data types—nominal, ordinal, or scale (Curwin and Slater 2004; Leech et al. 2008; Morgan et al. 2004)—were carried out in SPSS and Microsoft Excel. The energy expenditures on individual energy services were summed up to determine the total energy expenditure for each respondent household. This was averaged within a confidence interval of 95 % for all respondent households. Likewise, households' monthly willingness to pay for energy services and the willingness to pay for the one-time purchase of an energy system were averaged within a confidence interval of 95 %.

Importance ranks of energy services were first reversed so that what had been ranked 1 (most important) was now assigned the highest rank 10; the importance rank of each service was then averaged within a confidence interval of 95 %. The ranks for satisfaction with energy services were also averaged within a confidence interval of 95 %. The ranks of importance of each energy service and the satisfaction scores of each energy service were then summed up for all respondents and normalized to their maximum expected sums determined by the number of valid responses and the possible maximum score. This normalization helped to validate the results obtained by averaging the ranks for the priority of services and satisfaction with the services.

[2]We assumed that one energy-efficient 15-W compact fluorescent light bulb is sufficient for a room; the Malawi government distributed energy-efficient bulbs to replace incandescent bulbs in all households with access to electricity. Two additional compact fluorescent lights are required for outdoor lighting from 6 p.m. to 6 a.m.; and the lighting for toilets and bathrooms was assumed to be equivalent to one 15-W bulb operating for one hour.

9.3 Findings

9.3.1 Household Energy Requirement

Artificial Lighting Households require artificial lighting from 6 p.m. to 10 p.m. daily. An average living property on Likoma Island has seven rooms (three bedrooms, living room, storeroom, corridor, and veranda; a kitchen is not usually part of the main property but is included in the energy requirement calculations). Two additional compact fluorescent lights are required for outdoor lighting from 6 p.m. to 6 a.m.; and the lighting for toilets and bathrooms was assumed to be equivalent to one 15-W bulb operating for one hour.

Electrical Appliances Households require the following electrical appliances (power ratings estimated by the authors): a refrigerator (225 W), a colour TV screen (70 W), a satellite decoder (30 W), a radio (30 W), and five cooling fans (45 W each). A hotplate (1,500 W) is required for cooking three times a day, for a total of six hours per day (5 to 6 a.m., 10 a.m. to 1 p.m., and 6 to 8 p.m.). Water can be heated using solar thermal energy.

TV Screens TVS are usually used with a decoder or a VCR or DVD player for eight hours per day (6 to 7 a.m., 12 to 3 p.m., and 6 to 10 p.m.). Indeed, during fieldwork, we observed in some households that TV screens were switched on soon after waking up in the morning, remaining on through breakfast time until the household members left to go about their daily livelihood activities. During lunchtime, the TV was again switched on, and after lunch, children would continue watching films on VCR/DVD depending on whether or not they had other activities to do; based on our observations, we set 3 p.m. as the cut-off time for children's daytime TV usage to take account of the time they spend doing household chores and participating in community social activities. After 6 p.m., when all household members were at home, the TV screen usually remained on until bedtime around 10 p.m.; during these hours, there was always at least one person in the living room (usually males). In addition to TV, a radio is used for 8 to 12 h daily when the TV is switched off, although sometimes we observed both appliances to be simultaneously on.

Cooling Fans Households need cooling fans because temperatures on Likoma are above comfort levels as defined for Malawi by Zingano (2001). Three cooling fans (one for each bedroom) need to be on overnight (one from 10 p.m. to 6 a.m., and two from 8 p.m. to 6 a.m. for those who go to bed earlier). Fans in the other rooms are required whenever someone is there, which, based on our observations, we assumed to be 6 to 7 a.m., 12 noon to 3 p.m., and 6 to 10 p.m. for the living room, totalling eight hours daily; as well as 11 a.m. to 12 noon and 6 to 8 p.m. for the kitchen, totalling three hours daily. Toilets and storerooms do not require cooling.

Daily Household Energy Requirement Fig. 9.1 shows the daily household energy requirement by energy needs. Cooking contributes the largest share, followed by refrigeration, space cooling, water heating, entertainment, and lighting.

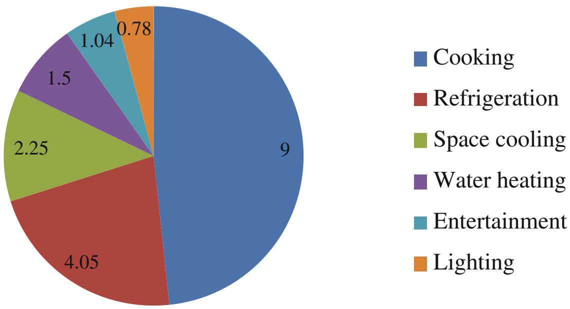

Fig. 9.1 Distribution of household energy requirements (in kWh) by energy needs. Entertainment includes radio, TV, and VCR/DVD player. The total energy requirements amount to about 19 kWh (sum of all numbers provided in the figure)

As can be seen from Fig. 9.1, the daily household energy requirement on Likoma Island is estimated at 19 kWh. This adds up to 6796 kWh annually, which is consistent with the minimum per capita energy consumption defined by Sanchez (2010), as cited by Practical Action (2010). According to these authors, in order to live above the energy poverty line: "*A person should have access to at least: (a) the equivalent of 35 kg LPG for cooking per capita per year from liquid and/or gas fuels or from improved supply of solid fuel sources and improved (efficient and clean) cook stoves*; *and (b) 120 kWh electricity per capita per year for lighting, access to most basic services (drinking water, communication, improved health services, improved education services and others) plus some added value to local production*". For a family of seven persons, this means a minimum cooking fuel requirement of 8.5 kWh daily, assuming 46 MJ/kg for liquefied petroleum gas (LPG) and an electricity requirement for lighting of 2.3 kWh daily.

9.3.2 Purchasing Power for Energy

Table 9.2 presents households' energy purchasing power. It appears that the total monthly energy expenditure is twice as high as the willingness to pay for energy during the same period. In addition, nearly 50 % of the respondent households indicated having experienced financial pressure due to energy bills.

9.3.2.1 Energy Service Prioritization

Table 9.3 presents households' prioritization of energy services. Lighting is perceived as the most important energy service, followed by cooking, TV, radio, telephone, and water heating.

Table 9.2 Energy purchasing power of households on Likoma Island (US$ 1 = 400 Malawi Kwacha)

	Total monthly expenditure on energy (US$)	Willingness to pay for energy per month (US$)	Willingness to pay for one-time purchase of energy system (US$)
Lower bound of mean	9.00	5.00	66.00
Upper bound of mean	12.00	6.00	93.00
Central mean	11.00	5.28	80.00
Median	8.50	4.00	56.00
Standard deviation of mean	8.70	5.00	78.00
Standard error	0.68	0.38	7.00
Skewedness of data	1.345	2.936	1.484
Kurtosis of data	1.796	11.895	2.236
Valid responses (from 202)	163	179	130

95 % confidence interval for mean

Table 9.3 Prioritization of energy services by households on Likoma Island. Importance values range from 1 (=most unimportant) to 10 (=most important)

How important is…	Mean	Median	Skewedness of data	Normalized sum of ranks	Valid responses
… cooking	8.50	9.00	−2.308	1029/1121 = 0.85	121
… lighting	8.93	10.00	−2.608	1098/1230 = 0.89	123
… water heating	7.15	8.00	−1.172	472/660 = 0.72	66
… radio	7.29	7.00	−0.869	634/870 = 0.73	87
… TV	7.56	8.00	−0.788	597/790 = 0.75	79
… telephone	7.17	7.00	−0.440	502/700 = 0.72	70

Mean and median values in the table are based on these values

9.3.2.2 Satisfaction with Energy Services

Table 9.4 presents households' satisfaction with current energy services. The mean satisfaction scores for all energy services are below 3, which clearly indicates that people are dissatisfied with the existing energy services.

9.4 Discussion

The following sections discuss barriers and opportunities for the adoption of renewable energy technologies on Likoma Island in the light of energy requirements, purchasing power, the importance attributed to different energy services, satisfaction with energy services, and the theory of diffusion of innovations.

Table 9.4 Satisfaction scores for household energy services on Likoma Island (4 = very satisfied; 3 = satisfied; 2 = dissatisfied; 1 = very dissatisfied)

Satisfaction with energy services for …	Mean	Median	Skewedness of data	Normalized sum of ranks	Valid responses
… cooking	2.38	2	0.165	331/556 = 0.595	139
… lighting	2.34	2	0.157	320/448 = 0.714	137
… water heating	2.33	2	0.159	207/356 = 0.581	89
… powering radio	2.27	2	0.28	207/364 = 0.568	91
… powering TV	2.33		0.332	135/232 = 0.581	58
… charging mobile phones	2.64	3	−0.071	156/236 = 0.661	59

9.4.1 Barriers to Renewable Energy Development on Likoma Island

9.4.1.1 Local Socioeconomic Barriers

At Malawi's current electricity tariff of US$0.085 per kWh, a household on Likoma Island that relies entirely on grid electricity for its energy requirement would spend about MWK 19,000.00 (US$47.48) on energy per month (not including water heating which can be achieved using solar thermal energy). This is four times the prevailing monthly average energy expenditure, which we estimated at US$11.00 based on our survey, and it is nine times the prevailing willingness to pay for energy, which we estimated at US$5.28 per month (Table 9.2). Thus, based on the prevailing willingness to pay for energy, households can afford only 11 % of their daily energy requirement from grid electricity. Thus, promoting grid electricity for meeting all household energy needs would put financial pressure on households or increase energy poverty. Since there is no evidence that electricity from renewable energy sources would reduce the electricity tariff (see Sect. 9.1), it is highly likely that a significant proportion of households would continue to use traditional energy technologies in order to keep their energy expenditure within their willingness to pay. Moreover, upfront investments for connection (US$70) and electrical wiring (about US$500) (Zalengera et al. 2014) exceed households' willingness to pay for the one-time purchase of an energy system.

9.4.1.2 National Institutional Barriers

The minimum size of systems eligible for feed-in tariffs, which was set at 500 kW, is the result of a technology-centred approach aimed at supporting affluent entrepreneurs without addressing the challenges faced by low-income households to access clean energy. Although electricity from renewable energy sources is cheaper to produce than the diesel-fired electricity, Malawi's feed-in tariffs are still relatively lower than the cost of generating renewable energy (see Sect. 9.1). This is unconducive for private-sector investment and thus contradicts the original intention behind the introduction of feed-in tariffs.

9.4.1.3 Market System Barriers

In our case study on Likoma Island, we noted that developers tend to respond to households' low purchasing power by marketing cheap technologies, for example, solar lanterns and 50–100-W solar home systems. Although it is arguably useful, these market-based solar lanterns and solar home systems are not only inadequate but also focus on energy needs that do not significantly contribute to household energy demand. In addition, due to the island's remoteness, compounded by households' low income, professional after-sales support for the installed systems is usually not available—which in turn has an adverse effect on their reliability.

9.4.2 Opportunities for Renewable Energy Development on Likoma Island

Considering our findings, the theory of diffusion of innovations (Rogers 1995, 2001), and the renewable energy system modelled by Zalengera (2015; see Sect. 9.1), there are a number of opportunities for renewable energy development on Likoma Island. They are outlined in the following sections.

9.4.2.1 Potential for User Satisfaction and Convenience

The results in Tables 9.3 and 9.4 show that the prevailing energy technologies do not satisfy households' needs. We noted during the survey on Likoma Island that poor satisfaction with energy services is linked to people's bad experiences with traditional and conventional technologies. Households without access to electricity expressed dissatisfaction due to indoor air pollution from solid and liquid fuels, which causes coughs; the need for continuous attention to ensure that firewood keeps burning; the time spent collecting firewood and preparing the fire; backaches due to drudgery associated with firewood; the non-durability of dry cell batteries; spillage of acidic gel from dry cell batteries; as well as bad odours and the risk of accidents from kerosene lamps. By contrast, households with access to grid electricity expressed poor satisfaction with energy services due to the intermittent operation of the diesel generators feeding the grid. Households' dissatisfaction with traditional and conventional energy solutions is an opportunity for introducing renewable energy technologies that address the dislikeable properties of traditional and conventional technologies and thereby provide a real alternative for local households. A better understanding of existing dissatisfaction could be useful in planning and designing adequate alternative systems.

9.4.2.2 National Economic Advantages

Renewable energy technologies have the potential to reduce the costs of electricity generation on Likoma Island—and hence government expenditure on tariff subsidy—by at least US$0.262 per kWh of electricity supplied to households. This is equivalent to a reduction of at least 33 % compared to the current subsidy. Furthermore, renewable energy technologies are compatible with international values and policies on reducing carbon emissions and could therefore attract financing from international multilateral organizations such as the United Nations Framework Convention on Climate Change (UNFCCC n.d.), through its Clean Development Mechanism (CDM), and the Global Environmental Facility (GEF 2013).

9.5 Conclusion and Way Forward

Given the findings and discussion presented in this paper, it is essential that energy practitioners developing technical solutions make use of the available knowledge about people's satisfaction with services, their priority energy services, and any dislikable or likeable properties of existing technologies. According to the theory of diffusion of innovations, households—including those with a low income—are more likely to pay for, and maintain, costly but reliable products if these technologies are aligned with social values and preferences, as adoption of such technologies can increase households' social prestige and is compatible with their values.

We propose a review of the Malawi feed-in tariffs that were introduced in 2012 and still present a significant barrier to low-income households on Likoma Island in accessing adequately sized sustainable renewable energy solutions. Given that household-based photovoltaic and wind systems are also potentially more economic than diesel-fired electricity, it might make sense to reduce the minimum size of renewable energy systems eligible for the feed-in tariff to the order of 1–5 kW and to introduce loans for covering capital costs which could be repaid within a period determined by the households' willingness to pay for capital costs as presented in Table 9.2. It should be noted that when households generate their own power, this is similar to feeding power into the grid; excess energy would indeed be fed into the grid. Accordingly, households could earn money from the feed-in tariff, which could contribute to repayment of capital costs and probably also address households' income poverty (Zalengera et al. 2014). In addition, since cooking is a major contributor of energy demand (see Fig. 9.1), the feed-in tariff (or equivalent incentives) and capital financing could be extended to other end-user renewable energy technologies that can be used directly for cooking, such as biogas or solar thermal cookers.

In view of market-based technologies, we agree with Lindner (2011) that a sustainable approach to disseminating renewable energy systems should not be based on attempts to increase affordability by developing cheaper products, but on fostering income-generating activities (and financing mechanisms) that enable people to pay for good-quality systems that are capable of meeting their energy needs.

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