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A model to evaluate the success of Solar Home Systems

Hans Holtorf*, Tania Urmee, Martina Calais, Trevor Pryor,
School of Engineering and Information Technology, Murdoch University,
WA 6150, Australia

* Corresponding author. Murdoch University, School of Engineering and Information Technology, Murdoch, WA, 6150, Australia, Ph: +61 8 9360 1316, Fax: +618 9360 6332,
E-mail:  h.holtorf@murdoch.edu.au

Abstract
Around twenty per cent of the world’s population currently do not have access to electricity while the importance of electricity services for society continues to increase. Solar Home Systems (SHS) are a competitive option for supplying basic electrification under meteorological conditions in Sunbelt countries. However, many of the SHS electrification programmes have failed in the past. Furthermore, their evaluation is often still based on one individual indicator such as the number of disseminated systems. This research explores how to measure success of SHSs in a comprehensive manner. Success can be defined as the achievement of self-set goals. From this statement a model of success was developed which incorporates all key-stakeholders and their multiple self-set goals. The model of success combines the individual level of success with the SHS implementation’s overall success. A hypothetical example is used to demonstrate the application of the model. The challenges relating to the measurement of success are also illustrated. The resulting methodology combines general success factor research, diffusion of innovation research, and lessons learned from SHS projects. The drawbacks of the current approaches to SHS implementation, and their characteristic of still being an innovation, were also determined. The proposed model of success can be applied to pre-evaluate SHS programmes, to evaluate existing SHS projects, and to observe and evaluate the development of SHS implementation over time.

Keywords: Success, Solar Home System, Diffusion of Innovation
1. Introduction

Electricity is a driving force in the development of societies and in the achievement of the Millennium Development Goals (MDGs) [1, 2]. Currently, approximately one fifth of the world’s population lack access to electricity. The electrification rates for the twenty least-developed countries range between 9% and 47.3% [3]. Interestingly, a much higher percentage of inhabitants of these countries are telephone (cell phone) subscribers. With the exception of Eritrea (4.6%) and Ethiopia (9.4%) the figures lie between 14.1% and 77.6% [3]. This shows that there is a need for meeting the very basic electricity needs for appliances such as cell phones, which can be met with a minimum basic electricity supply.

Electrification by grid extension is a very expensive option for dispersed rural households [4, 5]. The ratio of the costs of grid extension to the income that would be earned from the amount of electricity consumed, means that this is not an economically feasible option for utilities. Solar Home Systems have been promoted as a viable solution and, indeed, the best
option for off-grid electricity supply [4, 6-8]. So far, many SHS programmes have been implemented in developing countries, but only a few appear to be successful [9-13].

The reason for the lack of success is still a vital research question. Not many researchers have addressed the question, ‘Why are some programmes more successful than others?’ Most of the previous studies attempting to answer this question were not based on a comprehensive understanding of these programmes, for example how the programmes are planned, designed, and implemented. There was no exact definition or set of criteria for successful programmes. Some studies define the SHSs’ success and related indicators based on successful and failed programmes [14]. But no model was yet proposed to define the success of SHSs incorporating all key players and their requirements. Therefore, a model to determine the success of Solar Home Systems is required which incorporates further indicators of success along with the indicators developed by Urmee and Harries (2009) [15].

This research aims to develop a model to evaluate the success of SHS implementation. The guiding questions of this research are:

i. What are the elements that need to be incorporated in measuring the success of SHSs?

ii. How are these elements linked with each other?

iii. How should these elements be assessed to determine the success of a SHS implementation?

This paper addresses the first two questions by proposing a model of success incorporating the viewpoints of all players. The concept of Freeman (1984) on stakeholders is applied for grouping the respective players in the environment of SHSs [16].

The paper defines Solar Home Systems as small systems, based on a PV generator, with a nominal power between 50 Wp and 150 Wp.

The term “successful” is used to describe a situation where all of the goals of involved stakeholders are achieved.

The considerations of success are applicable for any approach to the dissemination of SHSs, be it a donor, governmental, or any other institutional driven programme, as well as the dissemination of SHSs by the private sector. Therefore, the term “implementation of SHSs” is
used in this paper. The terms “project” and “programme” are exclusively used when the implementation is conducted within a planned course of action.

2. Approaches to Determining Success of Solar Home Systems
The success factors of SHSs reported by many researchers are based on specific projects. Asif (2012) and others report that Bangladesh’s SHS regime is the most successful at present [17]. Grameen Shakti (2009) summarizes the success factors for the Bangladesh SHSs as [18]:

- no provision of direct subsidies in the programme;
- innovative financing is available for the consumers;
- a supply of locally developed and manufactured SHS components;
- a good supply chain network;
- training of local technicians and Users is built in within the implementation programme;
- highly motivated staff; and
- the coupling of income to the SHS.

According to other researchers, successful SHS projects are those which address certain factors such as the affordability, cultural views, income generation by the systems, the Users’ familiarity with the technology, and which have a clear view on specific engagement of stakeholders beyond the donor/government funding [19-22].

2.1. Success Factor Research
Many research projects have been conducted to answer the question, ‘What are the criteria for measuring the success of a business?’ Early research in this field included the PIMS study (Profit Impact of Market Strategies) by General Electric which started in the 1960s. This study was further developed by the SPI (Strategic Planning Institute) [23]. A major finding of the PIMS study was the high importance of the quality of products and services. This lesson can be transferred to the SHS business.

Welge and Al-Laham (2008) point out that the Return on Investment (ROI) dealt with in the PIMS study is an insufficient indicator for success of a business when contemplated in isolation [24]. This implies that the research on the success of SHSs needs to consider
benchmarks beyond the ROI and should incorporate multiple indicators to measure that success.

Bullen and Rockart (1981) propose that success is based solely on a few Critical Success Factors (CSFs) [25]. But, in referring to this source, these CSFs depend on multiple influences: industry type and position, environmental factors such as the current economic situation of the industry’s sector, national policies, temporal factors (an internal or external short term impact), and, last but not the least, the contemplator’s point of view. These views can be applied to SHS implementation as they also feature Critical Success Factors. But these also differ for the different stakeholders involved in the SHS environment. For example, international manufacturers of SHS components will deal with other CSFs than those of local entrepreneurs selling and installing SHSs in the implementation area. Also, the employees’ views on the success of the SHSs of specific stakeholders will depend on their position in the hierarchy and their division in the company. A sales manager of a component manufacturer has a different view on success than a member of the production division in the same association.

Welge and Al-Laham (2008) suggest that the Critical Success Factors can be classified into endogenous and exogenous success factors. Endogenous success factors are related to an actor. These success factors can be influenced by the corresponding actors. Exogenous success factors cannot be influenced by the actor [24]. A local entrepreneur’s endogenous success factor is the quality of the SHS installation. The impact on the prices of components by taxes is an example of the entrepreneur’s exogenous success factor.

The investigation of the success of SHSs needs to consider the endogenous and exogenous nature of different success factors in the SHS setting when seeking to improve the implementation success.

Some success factors are shared by multiple players, but again the distinction between the exogenous and endogenous nature of these factors is necessary. For example, the quality of products is a success factor shared by international component manufacturers and rural installers. But in this case it is an endogenous success factor for the manufacturers while it is an exogenous success factor for the installer.
There are challenges for the research on success. Weindlmaier, Schmalen et al. (2006) underline the necessity of a set of measurable quantities with which to consider the impact of success factors [26]. They add that the indicators for success may be of quantitative or qualitative nature. Furthermore, they discuss the number of measured variables. Lower numbers of measurable variables increase the lucidity. But a low number of variables also leads to loss of informative content.

This lesson can be transferred to the gauging scale applied later on. A wide scale allows a high resolution but may not be workable. Therefore, it will be important to carefully determine the measurement scale for this investigation.

Woywode (2002) summarizes the difficulties of obtaining the qualitative information from key informants which may bias the evaluation of the SHS success in the following ways: key informant bias, endogeneity, simultaneity, unobserved heterogeneity, regression-to-the-mean-problem, and survival bias [27].

Below are some SHS related examples of these difficulties, taken from the literature:

**Key informant bias:** Key informants may fail to provide information on past dependencies compared to their situation today [28]. SHS Users may fail to remember living conditions before the implementation of their SHS. Therefore, the evaluation of the SHS services may be biased.

**Endogeneity:** Independent variables are influenced by variables which have not readily been accessible [29]. At first sight, the price of SHS components seems to be an independent variable. But the price may be influenced by difficulties and hidden costs of importation. Information on these influences is often difficult to access.

**Simultaneity:** Previous success or failure has an influence on applied measures. Hence, the influence of a measure is highly dependent on the situation in which it was applied [30]. Advertising road-shows may be applied in a region where SHSs are unknown and other sales activities have failed. But the impact of road-shows decreases when awareness of SHSs has been created. Subsequently, road-shows may not be a success factor. By contrast, advertisement concepts which previously have failed may turn out to be more effective now.

**Unobserved heterogeneity:** Enterprises may differ in their long term success potential. This again influences success independently of certain measures [30]. Projects of NGOs, governments, or donors may differ in their project success, despite the fact that they use identical implementation strategies. The individual implementer’s difference in success may
be based on other factors than the implementation strategy—e.g. the User’s trust in the implementing agency.

Regression-to-the-mean problem: Failures may occur randomly during several periods and measures taken may randomly lead to success. But it is not clearly distinguishable that the success is connected to these measures [31]. An increase in sales numbers may be assigned to a governmental awareness campaign. However, the motivation of buyers to purchase SHSs actually may be an improved income situation, e.g. in the harvesting season.

Survival bias: Research taken in retrospective mode may only consider enterprises which have survived [27]. For example it will be difficult to find a trader who has failed in the SHS business, and consequently some possibly important failure factors will stay undisclosed. Even in the case where former traders are detected, there would be a high risk of key informant bias in their interrogation.

In order to learn about SHS success, a list of these pitfalls needs to be considered when approaching research participants.

2.2. Diffusion of Innovation Research

Rogers (2003) postulates that the typical rate of adoption of an innovation displays an ‘S-shape’ curve in terms of the % of adoption versus time [32]. According to Rogers, the diffusion of an innovation starts off at a low rate with innovators and early adopters, followed by the early majority and an accompanying increasing in slope of the uptake curve. Next, the late majority engages in the innovation and the slope of the uptake curve starts to flatten out. When the laggards who decide to adopt an innovation at a considerably later point in time get active, the slope of the uptake curve flattens out and asymptotically approaches a horizontal saturation line.

Figure 1 depicts the development of SHSs installed in Bangladesh up to now and the predicted number according to the logistic function (S-shape). The total number of SHSs was 2.7M in 2013. Assuming that there are 96 M non-electrified inhabitants in Bangladesh [33], that 50% of these could be electrified by SHSs with other options of electrification being applicable for the rest, and that an average of 5 persons share one SHS, the potential number of SHSs in Bangladesh is 9.6M:
The plotted number of SHSs in Bangladesh over time indicates that in one of the most successful countries for SHS dissemination the stage of early adoption is close to achievement. From this graph the authors conclude that SHSs still constitute an innovation in this market. Furthermore, the diffusion of this innovation requires a large amount of time.

Figure 1a: Up to date SHS installations in Bangladesh.
Figure 1b: Cumulated installed and forecasted systems.
Data Source: [34].

Therefore, fundamentals on the diffusion of innovation are necessary to help with understanding the success or failure of SHSs in a region. Rogers describes four main elements involved in the diffusion of innovation [32]. Given below are examples of these elements which are specifically related to the SHS context:

i. The innovation itself and its six attributes:

- The relative advantage: Electric light supplied by a SHS has a higher quality. This is a generally accepted statement.
- The compatibility: Financing of SHSs should be compatible with the financing schemes of previous energy services—small amounts of money to be paid on a regular basis rather than remitting a large sum of cash up front. Therefore, over a long period of time, multiple authors have recommended financing schemes for SHSs [15, 35, 36].
- The complexity: For Users matching the load to the energy which the solar system may supply under fluctuating solar radiation is a challenge on multiple levels. A long learning period should be allowed in order to optimize the operation of their systems. Users’ training is called for in literature on SHSs, e.g. Urmee (2009) [15].
- The trialability: Wimmer (2012) reports on the SHS implementation in the early times in Bangladesh. Systems were supplied to Users just for testing, which was a very successful approach [37].
- The observability: Wimmer describes the importance of demonstration systems which can be observed by the public [37]. Users need to see what a SHS looks like and how it works in practice to understand the technology.
• The re-inventability: According to Rogers (2003), new technology is successful when it can be modified [32]. The desire to re-invent the innovation SHS is reflected in the numerous reports of Users bypassing the charge controllers in these systems.

ii. The communication of the innovation by mass media, interpersonal and interactive channels:

The IEA (2003) reports on case studies of SHS deployment where mass media have played a major role in advertising for SHSs. Additionally, the professional salesperson’s face-to-face interaction has led to SHS dissemination success in these case studies [38]. This is supported by Acker and Kammen (1996) [4]. Interactive channels, mainly internet-based information, education, and sizing sites are not considered important for SHS implementation at present. Potential Users of SHSs have restricted access to the internet due to the predominant lack of electricity and the cost of internet access in internet cafés.

iii. The amount of time required for the innovation diffusion process to be established demands consideration:

Time is needed for the decision in favour of SHSs: for getting to know this innovation, to develop an attitude towards SHSs, for a decision in favour or against the investment in a SHS, for the implementation process, and for the final confirmation of the usefulness or uselessness of the innovation [32]. In the implementation process the authors include the time to get acquainted with the SHS and to learn how to best operate the SHS. A challenge for SHS Users is to not make the final decision on the usefulness/uselessness of the SHS before the operation has been understood and optimized. The challenge for the SHS implementer may be to train the User quickly and to demonstrate maintenance before a precipitous decision on the usefulness of SHSs is taken. Friebe, Flotow et al. (2013) confirm the latter by one of their two key elements for the successful implementation of SHSs: Professional system maintenance is obligatory for more than one year after the installation [35]. User training and system maintenance could go hand-in-hand on the one occasion.

iv. The elements of the social system and the associated impact factors:

These are the social structure, the system norms, the opinion leaders, and the change agents [32]. Urmee (2014) relates the success of SHS projects to formal
structures such as the existing policy framework, and informal structures, those which can be found on the local level. Furthermore, Urmee postulates that social acceptance is indispensable for the success of SHSs [39].

Innovation has both desirable and undesirable consequences, direct and indirect consequences, and anticipated as well as unanticipated consequences. These types of consequences and their specific forms will impact on the success of SHSs. They may be measurable and they can be expressed in numbers, but they may be qualitative and their grading can be subjective. In the measurement of success, the qualitative indicators need to be assessed very carefully.

Rogers’ general conclusions on the diffusion of innovation and the SHS examples stated above indicate that SHSs still constitute an innovation. Research on the success of SHSs needs to consider this background. Success factors are closely linked to the characteristic features of diffusing innovation. Furthermore the assessment of success is likely to be time dependent. This depends in part, on which stage of the diffusion of innovation cycle is occurring: the innovators’, early adopters’, early majorities’, late majorities’, or laggards’ level. This again refers to some of the challenges listed in the previous subsection.

2.3. Solar Home Systems Successes and Failures

Despite their long history, barriers exist to the implementation of SHSs. These barriers can be categorised into five areas [40-42]:

- implementation,
- financial,
- technical,
- policy, and
- social.

Figure 2 summarizes the barriers and provides further details on the five categories of barriers to success.
The 21 subordinates of the five areas of success barriers from “Lack of Technical Knowledge” through to “No Link to Existing Social Structures & Values” lead to the Critical Success Factors (CSFs) applied in this research. The statements presented in Figure 2 are another indicator that SHSs are still an innovation. Furthermore, the listed success-barriers are a starting point for the evaluation of success of SHS implementation.

2.4. Further Issues
It has been indicated above that views on success depend on the stakeholder. Therefore, it is obligatory to determine the most important stakeholders in order to assess the success, or otherwise, of a SHS implementation. Brugha (2000) proposes how to extract key-stakeholders [43], whereas Friebel, Flotow et al. (2013), and Hellpap (2011) propose the key-stakeholders within the SHS environment [35, 44] to be:

- Users: those who electrify their homestead with a SHS;
- Representatives of the supply chain: all business-related institutions involved in distributing the SHS components from the manufacturer down to the Users; and
- Manufacturers: companies that manufacture the components of SHSs such as solar modules, charge controllers, batteries or balance of system components.

This choice of key-stakeholders is applied in the coming sections.

3. A Model of Success
From the above discussion a model of success for Solar Home Systems is proposed in this paper. The model is based on the following assumptions:

i. The driving force for a stakeholder’s engagement in the field of SHSs are self-set goals and their attainment.
ii. Success is the achievement of self-set goals. Thereby the level of success is the level of achievement of self-set goals.
iii. The level of achievement of self-set goals is influenced by endogenous and exogenous success factors.

iv. All stakeholders are treated equally in this model when gauging success.

v. Success of a SHS implementation is gauged by considering the level of self-set goal achievement of all key-stakeholders involved in the implementation process.

The model of success was developed in two steps: First, the success of an individual stakeholder is described (refer to Figure 3), then, the model of success for the overall SHS implementation is established by combining the sub-models for the different stakeholders involved (refer to Figure 4).

3.1. Individual Stakeholder’s Level of Success
A stakeholder has 1–j self-set goals (SSGs) when engaging in SHSs. Self-set goals have different importance and they are weighted accordingly by the stakeholder (ISSG).

The level of achievement for the stakeholder’s self-set goals (LoASSG) needs to be determined by the affected stakeholder. Endogenous and exogenous success factors and their impact need to be analysed carefully in order to identify factors that could improve the level of success over time.

The weighted arithmetic mean of the importance of an individual stakeholder’s self-set goals and the levels of achievement determine the stakeholder’s overall success, as summarised in Figure 3.

Figure 3: Sub-model of success for an individual stakeholder.

3.2. SHS Implementation’s Success
The overall model of success for a SHS implementation is developed by combining sub-models for all of the key-stakeholders involved. The final model of success is described in Figure 4.
The model considers all the key-stakeholders (1 to m) that exist in the environment of SHS implementation. All stakeholders have self-set goals motivating their engagement. In total, there will be 1 to n self-set goals. Some of the self-set goals are shared by multiple stakeholders; some are individual self-set goals. However, all stakeholders assign individual importance $I_{SSG}$ to the self-set goals. Therefore, the number of importance of SSG values $I_{SSG}$ (1 to o) is larger than the number of SSGs. Critical Success Factors impact on the achievement of these self-set goals. The CSFs may be either endogenous or exogenous in nature. Distinct success factors impact on multiple self-set goals. At a given time, the importance of the self-set goals and the level of achievement of the self-set goals may be ascertained. Based on the result of this analysis the overall success of a particular SHS implementation can be determined.

Figure 4: The model of success for Solar Home Systems’ implementation.

The concept shown in Figure 4 allows gauging the success of individual stakeholders in SHSs in a certain region and the overall success of SHSs in that region. The precondition for measuring the success is the determination of implementation stakeholder’s self-set goals, including their importance as well as the levels of achievement. The first measurement (as described in Figure 3) serves to compare the level of success of different stakeholders at a site. The second result (as described in Figure 4) allows the comparison of different SHS implementations.

4. Application of the Model of Success

In this section, the model of success is applied to a hypothetical case to demonstrate the applicability of the model. The overall success of SHSs for this case will be derived. Furthermore, the respective success of the involved stakeholders will be compared. To complete the picture, the methodology will be applied as a pre-evaluation procedure for coming projects.
Before applying the model, the key-stakeholders are selected as the Users, representatives of the supply chain, and the manufacturers of SHSs.

4.1. Application of the Model of Success to a Hypothetical SHS Implementation

First, a consistent scale is required for grading some of the elements in the model of success. The width of the scale’s range determines the resolution of the result. However, in the application of the model of success the grading can only be given in rough estimations [45]. Therefore, a scale of zero to five, from failure to excellent, is proposed. For the elements importance of self-set goal as well as impact of Critical Success Factor “zero” is not applied (not appl.): Self-set goals and CSF are not listed by stakeholders when they have zero importance. The level of achievement as well as the overall success of SHSs can be zero in the case of a complete failure of a self-set goal or an implementation. Table 1 translates the scaling for different elements.

Table 1: Grading of components in the model of success for SHSs.

Table 2 gives an example of determining the success of a SHS implementation. A set of common self-set goals found in literature (onsite energy service, local ecological improvement, profit and regional market share) is assigned to the key-stakeholders: Users, supply chain representatives, and manufacturers. The self-set goals’ importance and levels of achievement are assigned by the authors to the self-set goals in this hypothetical example as shown in Table 2. These figures are based on the authors’ personal experience and on published literature. Some of the self-set goals may not be applicable to certain stakeholders. This is indicated by ‘NA’ in lines A, B, and C. For example, Users are motivated to invest in SHSs to have energy services supplied while members of the supply chain and manufacturers deal with SHSs to make profit or to increase their market share. Distinct self-set goals are shared by all stakeholders such as the wish to contribute to the onsite ecological improvement. However, the importance of shared self-set goals may differ from stakeholder to stakeholder.

The importance of self-set goals is given in lines A1, B1, and C1. They vary from 1 to 5–refer to Table 1 for the translation of this grading.
The level of achievement for self-set goals is indicated in lines A2, B2, and C2 of Table 2. Here, the range may vary from 0 to 5.

In the right column of Table 2 the overall success is supplied for the individual stakeholders. I.e. \[ \sum_{i=1}^{j} I_{SSG_i} \cdot LoA_{SSG_i} / \sum_{i=1}^{j} I_{SSG_i} \] where \( j \) stands for the number of self-set goals of one individual stakeholder (refer to Figure 3).

Lines A3, B3, and C3 indicate the contribution of the self-set goals to the stakeholders’ overall success by dividing the multiplication of the importance of the self-set goals, and their level of achievement by the sum of the stakeholders’ complete SSGs’ importance \[ I_{SSG} \cdot LoA_{SSG} / \sum_{i=1}^{j} I_{SSG_i} \].

There are qualitative and quantitative indicators for the measurement of the level of achievement of self-set goals. The particular characteristic is displayed in lines A4, B4, and C4.

Table 2: A hypothetical example to determine the success of SHSs.

<table>
<thead>
<tr>
<th>SSG</th>
<th>LoA</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onsite Energy Services</td>
<td>5</td>
<td>2.50</td>
</tr>
<tr>
<td>Local Ecological Improvement</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Supply Chain</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

In this example, the Users are the most successful stakeholder. Their score of success is 3.25 out of 5. It can be seen that the onsite energy services self-set goal contributes the largest contribution to the success of the User (2.50) due to its high importance (5) and its high level of achievement (4) while the local ecological improvement plays a minor role (0.75). The supply chain scores 3.0 and the manufacturer’s success renders 2.0. The overall level of success of SHSs in this hypothetical example is 2.81 out of 5. This translates to between sufficient and satisfactory according to Table 1. The individual stakeholder’s success does not differ fundamentally from the average score of success.

It is important to emphasize the time dependency of this evaluation. All the parameters and their values in Table 2 may alter with time. Therefore, this model can be applied to observe
the development of an implementation’s success by carrying out the investigation at different times.

An overall success score of 0 reflects full failure of SHSs. In that case, none of the self-set goals is achieved. A score of five reflects maximum possible success—self-set goals of all stakeholders are fully achieved.

4.2. Stakeholders’ and Overall Implementation’s Success Potential

As explained in section 2.1, only a few Critical Success Factors exist [25]. In order to evaluate the potential of success of stakeholders or implementations these factors need to be determined. Furthermore, the CSFs’ impact on a self-set goal as well as the stakeholders’ capability to address these success factors needs careful assessment. In the following discussion the process is shown by an example.

Table 3 merges information from Figure 2 and Table 2. It adds the impact of success factors and the stakeholders’ capacity to influence these success factors. Additional information is given on the origin (exogenous or endogenous) of the success from the individual stakeholder’s perspective. Based on this collection of data the evaluation of the stakeholder’s success potential is proposed.

The self-set goals (onsite energy service, local ecological improvement, profit, regional market share) and the key-stakeholders (Users, supply chain representatives, manufacturers) are selected from Table 2. Some success barriers are selected from Figure 2. However, here they are applied as success factors: technical knowledge, availability of capital, maintenance, policy, perception on technology. The success factors’ significance (S) on the achievement of self-set goals and the stakeholders’ power (P) to manage these success factors are hypothetical values in this example. They are set by the authors.

Referring to Table 3 the significance of the success factor technical knowledge on the Users’ self-set goal onsite energy service is assumed to have a maximum value of five, while the Users’ power in this field is assumed to be high (four out of five). Technical knowledge is an endogenous success factor from the point of view of the User as well as maintenance and perception on the technology. The User can address these factors. By contrast, the availability
of capital and policy are exogenous success factors. The User has little power to influence these success factors which is reflected by a 2 (low) and a 1 (very low) in Table 3. The stakeholders’ power to cope with success factors is the same for all self-set goals. In other words, the Users’ capability for the success factor maintenance is the same independently of whether it is applied to the self-set goal onsite energy services or local ecological improvement in the homestead. The Users’ success potential is given by \( \sum_{i=1}^{j} S_i \cdot P_i / \sum_{i=1}^{j} I_i \) and is calculated as 3.03 in this example. The same procedure is applied to the supply chain and manufacturer stakeholders, producing a success potential of 2.72 and 2.10 respectively.

The potential of success of stakeholders (3.03, 2.72, & 2.10) and the potential of success of the entire implementation (2.60) given in Table 3, differ from the success of the stakeholders (3.25, 3.00, & 2.00) and the success of the implementation (2.81) given in Table 2. The discrepancy in figures highlights that the described process can give only an indication of the potential success of stakeholders in the regime of SHSs. It is highly dependent on the assessment of success factors, their impact on the achievement of self-set goals, and the stakeholders’ power to contribute to success. However, this evaluation can also enable the improvement in the potential for success of the SHS implementation at a certain site by analysing strengths of success factors and weaknesses of stakeholders.

Table 3: Implementation’s success potential.

5. Implementation, Operationalization and Application of the Model of Success

This model of success can be applied to different approaches for implementing SHSs in order to compare the levels of success achieved. Likewise, it can be used to observe the change in level of success of a SHS implementation by applying it at different times. The potential success of a SHS implementation can also be gauged by the considerations given in section 4.2.

An independent board needs to be engaged to evaluate the success of SHS implementation with this methodology.
Figure 5 depicts two stages for the implementation and the application of this model. In the current stage 1 of this research the model should be tested for modification and adaptation. Common elements of the model need to be determined as a starting point for future application. This should be done by qualitative methods such as semi-structured interviews, group discussions, or participatory observation. In a subsequent stage 2 the model of success can be applied to pre-evaluate the potential of a SHS implementation to be successful, to compare the success of different implementations, or to evaluate the change in level of success of a particular implementation over time. Quantitative methodologies can be applied here which would involve processes such as questionnaire surveys.

In both stages, the methodologies of data collection applied need careful consideration. According to Laatz (1993, page 57) it is necessary to adapt these methodologies to the participants within the evaluation [46]. Institutional participants can deal with graphs and they are familiar with quantifying statements. Users may not be in the position to deal with such concepts.

6. Challenges for Success Measurement

As for most of the renewable energy programmes, there are many factors where the level of achievement can only be benchmarked by qualitative indicators. This is the difficult part of the success-measuring process. For example, the User’s goal is to achieve onsite energy services. In this example, the importance of the goal may be five out of five. But the level of achievement could be graded four out of five. This value may be related to the ratio of energy services achieved over energy services the system should be able to supply. The ranking can be determined based on the components’ rated capacities and the solar radiation. In this case, the grading is based on a quantitative approach. However, four out of five may reflect the User’s expectations towards his system. This is a qualitative approach. The mark can be influenced by multiple factors, e.g. the User’s technical understanding or the supplier’s level of consultancy. Therefore, both classifications (qualitative and quantitative) are given in Table 2.
Another challenge may result from stakeholders influencing the overall success by exaggerating the importance of self-set goals which have been well achieved and by low grading self-set goals which have been poorly achieved and vice versa. The outcome of an evaluation of success for a project needs validation. One approach is to set the stated parameters against generally reported values. Another possibility is to compare the individual success of stakeholders with the implementation’s overall success. Extreme deviations should be carefully reviewed.

7. Conclusion and Outlook
Measuring the success of SHSs by incorporating all key players and their requirements has not been done before. The paper proposes a preliminary model of success of SHS programmes. The paper discusses the complexity of appraising the success of a SHS implementation while seeking indicators beyond the simple number of installed systems.

The proposed model of success for SHSs incorporates multiple stakeholders engaged in SHSs and has developed various indicators of success. The linkages between the elements in the model of success have also been shown. This model of success may help to pre-evaluate the potential for success of a SHS implementation. It allows the measurement and comparison of the success of different SHS implementations on a level beyond the number of disseminated systems. Furthermore, the model can be applied to compare the success of SHSs for individual stakeholders within a project. The model of success is likewise applicable for PV systems from pico to kWp range.

The proposed model of success is currently based on information from literature and the personal experiences of the authors. To successfully apply the model, the key-stakeholders, the importance of self-set goals and their level of achievement, as well as the Critical Success Factors, need to be determined and quantified.

The next stage of this research is to survey participants (both institutional stakeholders and Users) operating in the area of SHS implementation to get feedback on the proposed model and, in particular:

1. to determine a set of standard key-stakeholders involved in SHSs;
2. to determine the main self-set goals and the importance of these self-set goals for the key-stakeholders; and
3. to determine how easy it is to measure the level of achievement of self-set goals. The results of this survey will be used to further refine the model and identify any issues in using the model.

Several issues are likely to arise in this phase of the investigation such as how to measure the level of achievement of self-set goals. A second issue is the time-dependence of any assessment of success of a particular SHS implementation. The self-set goals and their level of achievement, their importance, the success factors as well as the measurement of the level of achievement may well change during the course of a project. Additionally, Solar Home Systems and the appliances driven by these are also subject to a dynamic technological development. Such developments will impact on the model’s parameters and their significance. Therefore, any evaluation of the success of SHS implementation using this model will only relate to that point in time. A third issue is that the results of the model could be affected by bias on the part of those providing values for the model, and so these values reported for the parameters in the model will need to be carefully reviewed in order to minimize such bias in the measurement of success.

Once the revised model of success has been developed, the final step will be to apply the model of success to an actual situation in the field and to evaluate its effectiveness.

Acknowledgements

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Literature


Figure 1a: Up to date SHS installations in Bangladesh.
Figure 1b: Cumulated installed and forecasted systems.
Data Source: [34].
Figure 2: Reported barriers for Solar Home Systems.
Adopted from Sources: Wamukonya (2007), Urmee, Harries et al. (2009), and Sovacool, D’Agostino et al. (2011) [40-42].
Stakeholder’s success in SHSs

\[
Success_{SH} = \frac{\sum_{i=1}^{I} I_{SSG_i} \cdot LoA_{SSG_i}}{\sum_{i=1}^{I} I_{SSG_i}}
\]

Figure 3: Sub-model of success for an individual stakeholder.
Overall success of SHSs’ implementation considering 1 to o Self-Set Goals’ importance & Levels of Achievements

\[
\text{Success}_{\text{impl.}} = \frac{\sum_{i=1}^{o} I_{SSG_i} \cdot LoA_{SSG_i}}{\sum_{i=1}^{o} I_{SSG_i}}
\]

Measurement of 1 to o Levels of Achievement (LoA_{SSG})

Critical Success Factors (CSF)

Endogenous and exogenous CSFs impact on the achievement of Self-Set Goals
Distinct CSFs impact on multiple Self-Set Goals

1 to n Self-Set Goals (SSG) and their 1 to o Importance (I_{SSG})

1 to m Key-Stakeholders

Figure 4: The model of success for Solar Home Systems’ implementation.
Figure 5: Stages of the model of success.
Table 1: Grading of components in the model of success for SHSs.

<table>
<thead>
<tr>
<th>Grading</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of Self-Set Goal</td>
<td>not applicable</td>
<td>very low</td>
<td>low</td>
<td>considerable</td>
<td>high</td>
<td>maximum</td>
</tr>
<tr>
<td>Level of Achievement</td>
<td>not achieved</td>
<td>very low</td>
<td>sufficient</td>
<td>satisfactory</td>
<td>good</td>
<td>fully achieved</td>
</tr>
<tr>
<td>Successfulness of SHSs’ Project</td>
<td>failure</td>
<td>very low</td>
<td>sufficient</td>
<td>satisfactory</td>
<td>good</td>
<td>excellent</td>
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</table>
Table 2: A hypothetical example to determine the success of SHSs.
SSG = Self-Set Goal, LoA = Level of Achievement.

<table>
<thead>
<tr>
<th>Pos</th>
<th>Key-Stakeholder / indicators / classification of indicator</th>
<th>Onsite energy service</th>
<th>Local ecological improvement</th>
<th>Profit</th>
<th>Regional market share</th>
<th>Success of stakeholder</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>User</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Importance of SSG</td>
<td>5</td>
<td>3</td>
<td></td>
<td>applicable</td>
<td>not applicable</td>
</tr>
<tr>
<td>A2</td>
<td>LoA of SSG</td>
<td>4</td>
<td>2</td>
<td></td>
<td>applicable</td>
<td>applicable</td>
</tr>
<tr>
<td>A3</td>
<td>Contribution to success</td>
<td>2.50</td>
<td>0.75</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Characteristic of LoA</td>
<td>quant./qual.</td>
<td>qual.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Supply Chain</td>
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<td>2</td>
<td>5</td>
<td>4</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Importance of SSG</td>
<td>applicable</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>B3</td>
<td>Contribution to success</td>
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<td>0.18</td>
<td>1.36</td>
<td>1.45</td>
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<tr>
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<td>quant.</td>
<td>quant.</td>
<td>quant.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Manufacturer</td>
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<td>1</td>
<td>5</td>
<td>1</td>
<td>2.00</td>
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<tr>
<td></td>
<td>Importance of SSG</td>
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<td>5</td>
<td>1</td>
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<tr>
<td></td>
<td>LoA of SSG</td>
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<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Contribution to success</td>
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<td>1.43</td>
<td>0.14</td>
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<tr>
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<td>Characteristic of LoA</td>
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<td>quant.</td>
<td>quant.</td>
<td>quant.</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Overall success of the implementation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.81</td>
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Table 3: Implementation’s success potential.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Onsite Energy Service</th>
<th>Local Ecological Improvement</th>
<th>Profit</th>
<th>Regional Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signific. 5</td>
<td>3 3 2 2 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power 4</td>
<td>2 4 1 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ex/en</td>
<td>en ex en ex en</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Chain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signific. 3</td>
<td>3 3 2 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power 4</td>
<td>3 2 1 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ex/en</td>
<td>en ex en ex en</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Signific. 2</td>
<td>2 2 2 2 1</td>
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<td></td>
</tr>
<tr>
<td>Power 5</td>
<td>2 0 1 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ex/en</td>
<td>en ex ex ex ex</td>
<td></td>
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<td></td>
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Project’s overall Potential of Success 2.60