Sustainability As A Characteristic Of Renewable Energy Systems In Remote Himalayan Villages

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Abstract

This work investigates sustainability as a characteristic of renewable energy systems with the goal of improving the rigor of how it is applied. This work is based upon 20 years of developing and deploying sustainable solutions to villages in the Nepal Himalayas and particular to the village of Moharigaun (near Jumla) since 2002. Sustainability has been used in at least four different ways when applied to renewable energy systems which are described and contrasted. In addition, sustainability is analyzed using a systems engineering approach so they are recognized as non-functional properties impacting stakeholder value. Stakeholders of these systems include users, system developers, various relevant government entities and investors. A set of more rigorous definitions are then given along with suggestions on how the definitions can be applied. The work concludes with suggestions for additional work on sustainability.

Keywords: Renewable, Pico Hydro, Sustainability, Energy Systems

1. Introduction

As described in [1,2,3], the Rural Integrated Development Services (RIDS) has been developing methods to enhance the living conditions of remote mountain communities in Nepal since 1996. The approach taken by RIDS is holistic and contextualised to geographical region, local cultural values and belief systems, meteorology and governmental policies. This approach improves the long term success of the deployed systems. Those solutions include:

1) Pit Latrines: Used for individuals and communities to improve overall village hygiene and sanitation.

2) Smokeless Metal Stoves: They are used for cooking the local available dishes, room heating and heating of water for tea and personal hygiene (through a separate attached stainless steel water tank).

3) Basic Indoor Lighting: Local energy resources such as water, solar energy or wind are used for pico-hydro power plants, solar photovoltaic systems based on the local context and small scale wind turbines, to generate electricity for basic access to indoor lighting with low wattage while LED lights.

4) Clean and sufficient Village Drinking Water Supply: Water supplies from the communities' owned water sources are designed and built for safe and sufficient drinking water for all.

The development of these four solutions, called the "Family of 4" (http://www.rids-nepal.org/index.php/Family_of_4.html) has resulted in a new understanding of sustainability that has important, synergistic benefits. This is due in part to a recognition that the needs of all stakeholders, especially of the end-users' expressed verbally, must be taken into account when considering sustainability.

Prior workers have investigated sustainability. In [4], for instance, the authors provide several examples of how sustainability is applied such as economic, energy, agriculture and then attempt a common definition. However, their definition does not account for long term continuance of systems and neglects critical stakeholders such as investors. In [5], the authors take a systems approach and investigate sustainability across multiple levels of complex systems. While this is a valuable contribution, the authors emphasize environmental engineering and focus only on systems themselves. As a result, they don't account for stakeholder needs.

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This work is a unique contribution since it recognizes sustainability of renewable energy as a non-functional system property, often called “quality attributes” of a system, of particular importance to stakeholders. As a result the needs of the stakeholders are paramount. This approach is critical for deployment of renewable energy solutions to remote villages since it allows other stakeholders to listen to their self-identified needs, enabling a better understanding of the local stakeholder essential requirements through long term local engagement. This work also considers other stakeholders such as financial backers of renewable energy solutions. This group of stakeholders is a critical partner required for long term success. However, financial stakeholders often have a different perspective and motivations for requiring “sustainable” solutions, though based on current and “ear tickling” development theories rather than on detailed baseline surveys and long term understanding of the end users’ context and self-identified needs. In addition, this work proposes a sustainability measurement system so that it can be optimized. Emphasis upon sustainability as a non-functional system property and upon stakeholder needs is the focus of this work**.**

2. Sustainability as a Non-Functional Requirement

It is common in systems engineering to use ‘ilities’ to describe non-functional system properties. Examples are reliability, portability, quality, maintainability, and durability [6]. One benefit of using “ilities” is that they allow the system designer and user community to perform system architecting trade studies with a focus on a balanced solution with the potential to meet stakeholder needs [7]. From this perspective, sustainability is one of many different stakeholder needs that must be met to ensure value delivery over the life cycle of the system. Once a full set of “ilities” and their relative importance has been established, trade studies can be a useful tool for choosing the preferred system architecture as described in [8].

One trade study method is to use a quality function deployment matrix as described in [9]. This method uses criteria (ilities in this case) which are assigned a weighting, W_k. Each system architecture option is evaluated against the criteria (ilities) and assigned a value, V_k, which represents the capacity of the architecture to achieve the criteria. The score for each architecture option is then calculated using.

$$Score = \sum_{k=1}^{n} W_k V_k \tag{1}$$

The result of this approach is a system architecture baseline that can be further developed.

The importance of system architecting using “ilities” for this work is that shows that sustainability is one of many system level non-functional properties that must be considered when developing highly contextualized green energy solutions.

3. Four Uses of Sustainability In Highly Contextualized Renewable Energy Systems

There are at least four different uses of sustainability when applied to green electric power systems for remote villages. While each of the definitions may have common stakeholder interests as a concern, each of the definitions also address interest of specific stakeholders.

The first is Investor Centric Sustainability. The deployment of renewable energy solutions requires financial backing which is just as true for large multi-mega Watt solar power systems as it is for pico-hydro electric systems. Most financial backers want to supply a onetime investment (or investment over a fixed time frame) and after the investment period is over, they expect the system to continue without any further investment.

True enough that future expansion may require additional funding, but the goal of the financial backer is a system that continues to perform its function without additional investment. This is the case for investors in for-profit power generation ventures with an expectation of a return on their investment and it is true for financial backers in non-profit power generation systems. The investor in a non-profit power generation system expects their investment to continue to deliver value to the users after the investment period has ended.

Financial backers of non-profit power generation systems expect that the deployed system will continue well after they have invested. Moreover, non-profit power system investors will often expect the system the system to sustain expansion to new users without additional investment. This is due, in part, to the fact that some non-profit investors desire their investment to continue to deliver value as a personal legacy. Investor Centric

Sustainability is an important driver to proper system architecting since it can mean the difference between attracting and not attracting investment.

The second is Environmental Sustainability. This understanding is what most individuals think of when they hear the word sustainable. It means that the deployed system will deliver value to users with minimal or zero negative impact to the environment.

The third is Physical Sustainability. The concept is that the deploy system can be sustained and maintained by the resources gathered as revenue from the operation of the system. This requires a maintenance plan and financial plan (often user payment for energy services/units) which funds required maintenance as required.

The fourth is Growth Sustainability. This type of sustainability refers to the capacity of the system to sustain value delivery as the system itself grows and increases in scope. This requires a long term plan (≥20 years) for how the system will be expanded over time. Growth sustainability includes the idea that the solution can serve as an example for others to implement. In this case, the system is sustainable when its energy services can be delivered as the user community grows over the decades and when the system can be replicated by others.

4. Measurement of Sustainability

Sustainability can be measured. For instance, the long term financial sustainability of the system can be analyzed according to income sources once the system is deployed. Some percentage of the local population will be able to contribute to Maintenance Sustainability and some percentage of new residents will be able to contribute to Growth Sustainability. Contribution (financial, human resource, land, etc.) goals can be established and compared to actual levels to understand trends and lessons learned for future deployments.

5. Conclusions

Sustainability has been analyzed as a non-functional system property of rural green power systems. The method of using "ilities" to architect the solution was described. Four uses of sustainability were also described. Finally, a method for measurement of sustainability has been proposed.

6. References

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