Tutorial on the application of systems approach to technology sustainability assessment (SATSA): the case of biodiesel production development

Musango JK; Brent AC; Pretorius L; Müller H
GCRO and Stellenbosch University. jkaviash@yahoo.com

Abstract
It has been observed that there are no formal technology assessment practices in African countries and many decision-makers face the challenge of selecting the appropriate or suitable renewable energy technologies to develop. This paper and tutorial provides a step-by-step procedure for assessing technology development for sustainability utilising a systems approach to technology sustainability assessment (SATSA). SATSA is a conceptual framework that provides a guiding framework for assessing renewable energy technology development for sustainability, particularly in the African context. The tutorial utilises an example of biodiesel production development in South Africa. However, SATSA can be applied to other energy technologies.

Keywords: Technology sustainability assessment; Renewable energy; System dynamics; Technology development; Sustainable development.

1. Introduction
While technology development has been a key driver of energy, securing sustainable energy provision is however a central challenge faced by decision- and policy-makers. Technology assessment is one of the technology management disciplines that has been utilised for energy technology development and has evolved from being an analytical tool to a strategic planning tool for policy-making.

Technology assessment for sustainability is characterized by: the need for change in the social and institutional dimensions such as the user practices, regulations and the industrial networks; multiple and competing goals from the different social dimensions; and corresponding differing perceptions about the technology that is being development. Although technology assessment has found value in many technology related problems, the need for developing more effective methods, particularly in Africa, was identified in Musango and Brent (2011a). This is because TA does not feature in many of the government policies and policy-makers find it challenging in making decision of the best or the appropriate technology to develop (Musango, 2012). It has been observed that there are no formal technology assessment practices in African countries and many decision-makers face the challenge of selecting the appropriate or suitable renewable energy technologies to develop (Musango and Brent, 2011a).

A systems approach to technology sustainability assessment (SATSA) was thus developed by Musango and Brent (2011b) due to the realisation of the lack of formal technology sustainability assessment practices in an African context. SATSA emphasises the importance of understanding the underlying elements of technology assessment for sustainability which are: technology development; sustainable development; and system dynamics approach (see Figure 1). The detail of the SATSA is found elsewhere (Musango, 2012; Musango and Brent, 2011b) and thus not discussed here.
This paper subsequently provides a step-by-step process into the application of the SATSA framework in energy technology development for sustainability. A practical case for its application in assessing biodiesel production development in the Eastern Cape Province of South Africa is used to demonstrate its application.

2. Methodological framework
In order to operationalize the application of the SATSA framework, a guiding process to energy technology assessment for sustainability was developed by Musango and Brent (2011b) as shown in Figure 2. This methodological framework, as applied to biodiesel technology development in a South African case study, is provided as an example in this tutorial. Further detail of this case study is found in Musango et al. (2011) and Musango et al. (2012).

Figure 1: Systems approach to technology sustainability assessment
Source: Musango and Brent (2011b).

Figure 2: Methodological process to the application of SATSA
Source: Musango and Brent Error! Reference source not found.
3. The case study of biodiesel production development

3.1 Sustainable technology development

This step entails assessing the existing features and situation of the technology that is to be investigated and this is divided into two activities.

3.1.1 Identifying the need for energy technology development

The need for the energy technology development can be identified from the policy documents, discussion and engagements with relevant the experts, decision-makers and the local communities in where the technology is to be developed. The identified needs for the biodiesel development case study in South Africa were: addressing rural poverty; rural development and black economic empowerment; and job creation particularly in the feedstock production.

3.1.2 Defining the sustainability goals for energy technology development

The sustainability indicators can be defined based on the literature review, survey, discussion with the policy- and decision-makers, communities and the technology developers. Some indicators are directly related to a specific technology under consideration while others are dependent on the economic, environmental, social and political context in which the technology is being implemented. This is because different stakeholders have differing and competing goals. In the biodiesel production case study, the identified sustainability indicators were three economic (biodiesel production; biodiesel profitability; Eastern Cape GDP), two social (community perception; employment) and five environmental (land use change; air emission; biodiesel by-product; water use; energy use).

3.2 System dynamics modelling

Having identified the needs and the sustainability indicators, the next step is the development of a system dynamics model to evaluate the effect of the specific energy technology development on the identified sustainability indicators. This step utilises systems-thinking (Flood and Jackson, 1991; O'Connor and McDermott, 1997; Maani and Cavana, 2007) and system dynamics theory (Forrester, 1994; Sterman, 2000). In addition, system dynamics software is used in the development of the model. Thus, the South African case study objective was to evaluate the effect of biodiesel production development on sustainability indicators (Musango et al., 2011). The VENSIM software was used. The main activities in this step are discussed in the sub-sections.

3.2.1 Model the domain of technology development

This step involves the problem definition, conceptualization and dynamic hypothesis. Effective models are those designed for a small problem or account for a part of the system rather than looking at the whole system itself. Identifying the purpose of the model based on the problem is fundamental in establishing the boundary of the model. For the case of the example of biodiesel development in South Africa, the key issue was the design of the model to explore policies to ensure sustainable transition in the biodiesel production in the Eastern Cape Province.

3.2.2 New energy technology assessment

This activity entails model formulation and testing. The model is formulated using system dynamics software. Model testing is an iterative process and begins from the moment the model building starts. These tests include the baseline simulations and the validation tests such as structural validity tests, behavioural validity tests and the use of the experts in assessing the usefulness of the model developed.

---

1 There are a number of system dynamics software which include: Vensim, Powersim, Stella, Simile, iThink
3.2.3 Technology accommodation in the energy sector domain
This is a critical stage and involves experimenting on the ways in which technology development could be accommodated to improve its effect on the selected sustainability indicators. It involves policy formulation and evaluation of the changes in policies and procedures that could help in improving the technology development impact on the sustainable development indicators.

4. Conclusion
SATSA was developed and applied in the biodiesel production development in South Africa. The framework can be extended and tested for other renewable energy technology development for sustainability. Although SATSA was developed in the context of energy technology development, it has potential for application in other technology development – water desalination is one example that is critical in the South African context.

Acknowledgements
This paper and tutorial is based on Josephine K. Musango PhD thesis on: “Technology assessment of renewable energy sustainability in South Africa”, with Stellenbosch University, South Africa (www.tsama.org.za). The research formed part of a larger project of the Council for Scientific and Industrial Research (www.csir.co.za) that has established a Bioenergy Systems Sustainability Assessment and Management (BIOSSAM) portal (www.biossam.org).
References


