Journal of Environmental Management 126 (2013) 122–131

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Feasibility assessment tool for urban anaerobic digestion in developing countries☆

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ARTICLE INFO

Article history:
Received 3 January 2013
Received in revised form
2 April 2013
Accepted 6 April 2013
Available online 28 May 2013

Keywords:
Anaerobic digestion
Decision support
Developing countries
Feasibility assessment
Integrated sustainable waste management
Organic waste

ABSTRACT

This paper describes a method developed to support feasibility assessments of urban anaerobic digestion (AD). The method not only uses technical assessment criteria but takes a broader sustainability perspective and integrates technical-operational, environmental, financial-economic, socio-cultural, institutional, policy and legal criteria into the assessment tool developed. Use of the tool can support decision-makers with selecting the most suitable set-up for the given context. The tool consists of a comprehensive set of questions, structured along four distinct yet interrelated dimensions of sustainability factors, which all influence the success of any urban AD project. Each dimension answers a specific question: I) *WHY*? What are the driving forces and motivations behind the initiation of the AD project? II) *WHO*? Who are the stakeholders and what are their roles, power, interests and means of intervention? III) *WHAT*? What are the physical components of the proposed AD chain and the respective mass and resource flows? IV) *HOW*? What are the key features of the enabling or disabling environment (sustainability aspects) affecting the proposed AD system? Disruptive conditions within these four dimensions are detected. Multi Criteria Decision Analysis is used to guide the process of translating the answers from six sustainability categories into *scores*, combining them with the relative importance (*weights*) attributed by the stakeholders. Risk assessment further evaluates the probability that certain aspects develop differently than originally planned and assesses the data reliability (*uncertainty factors*). The use of the tool is demonstrated with its application in a case study for Bahir Dar in Ethiopia.

1. Introduction

In most cities of low- and middle-income countries municipal solid waste consists mainly of biodegradable matter (Troschinetz and Mihelcic, 2008; Wilson et al., 2012). This fraction, if not properly managed and treated, poses considerable health and environmental risks (Scheinberg et al., 2010). In addition, recovery of resources from this fraction is not yet common. Anaerobic digestion (AD) of organic waste is an effective treatment option that significantly reduces the amount of waste destined for disposal, and generates products of value, such as energy in the form of biogas and nutrient-rich digestate (Mata-Alvarez, 2003; Hartmann and Ahring, 2006; Deublein and Steinhauser, 2011). Given the fairly simple process and its suitability for warm climates it is generally considered appropriate for developing country conditions (ISAT/GTZ, 1999; Foresti, 2001; Parawira, 2009; Mshandete and Parawira, 2009).

Yet experience shows that urban AD projects in developing countries either face severe operational problems or have failed. Inappropriate technologies, lack of ownership and responsibility of operators, lack of markets for biogas and digestate, and weak business models are some of the reasons for failure. In addition, the absence of professional and academic networks, hindering legislation, lack of institutional support, and underdeveloped commercial system in the country may constitute barriers to success (Parawira, 2009; Bond and Templeton, 2011). Design and scale that do not match availability of feedstock, lack of local skills for operation, and the absence of maintenance and service support have resulted in technical failures (Bensah and Brew-Hammond, 2010). A sophisticated large-scale project in Africa stopped operation due to a lack of technical know-how, spare parts and funds to maintain the facility (Parawira, 2009). Such examples illustrate that AD projects,

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http://dx.doi.org/10.1016/j.jenvman.2013.04.028

although technically feasible, are bound to fail without proper understanding of the local needs, problems, capacities and priorities.

Past feasibility assessments are typically limited to an analysis of technical and financial criteria. The authors of this paper postulate that omitting the non-technical factors in feasibility assessments is one of the main reasons for the discrepancy between theoretical suitability and the observed low success rate of AD projects for organic waste treatment in developing countries. Drivers and motivations, the level of cooperation between the main stakeholders, and the institutional and legislative frameworks are considered crucial factors influencing success or failure of AD projects. An AD project is considered to be feasible if it can be sustained locally and is suitable from technical, economic, social, environmental, institutional and legislative perspectives.

This paper describes the development of a tool which

- specifies key criteria for successful AD projects, including sustainability
- allows screening and comparison of AD systems and their respective suitability in a given context
- reveals differences in stakeholders' views, and provides a basis for discussion and negotiation
- quantifies feasibility

The tool thus assists in conducting a comprehensive, participatory feasibility assessment of AD technologies for organic waste in developing countries. It examines the technologies, their material chains, stakeholder motivation, interest and influence, and systematically examines the enabling environment in which the project will be embedded. The tool was then applied to the city of Bahir Dar in Ethiopia (Lohri, 2012).

2. Methodology

2.1. Approach and research methods

In the first research phase theoretical considerations, literature and document analysis, field visits and interviews led to the development of a draft of the feasibility assessment tool. Literature research comprised topics of anaerobic digestion (technologies and case studies), Integrated Sustainable Waste Management (ISWM) and Multi-Criteria Decision Analysis (MCDA). In the second phase of research the draft version of the tool was applied to the city of Bahir Dar, Ethiopia. Specific research methods included document analysis, observations, stakeholder analysis (Grimble and Wellard, 1997), semi-structured interviews with stakeholders and a multi-stakeholder workshop using both qualitative and quantitative techniques to solicit participants' opinions in order to refine and adapt the tool and thereby ensure its practical usefulness.

The ISWM framework (Van de Klundert and Anschütz, 2001) was adopted to guide the semi-structured interviews and organise checklists for visits to AD projects in Ethiopia (Bahir Dar and Addis Ababa), which both helped identify relevant issues of the AD project for the assessment.

Stakeholder analysis is incorporated in the tool and was applied in Bahir Dar to determine stakeholders' power (the extent to which their decision, influence or persuasion can achieve a relevant course of action) and interest (the extent to which the issue is a priority for them) (Grimble and Wellard, 1997). The resulting power-interest matrix helps identify relevant stakeholders for the AD project and the MCDA process.

The strong focus on (interaction among) stakeholders derives from the concept of reflexive engineering. Robbins (2007) describes it as a more integrated ethical and system-based approach to development, which values communities and the environment in which they are sited as well as the technology. In other words, while 'traditional engineers' search for technological solutions in a state of 'partial ignorance' about the physical and social environment, 'reflexive engineers' work with this environment in a joint effort.

2.2. Dimensions of the feasibility assessment tool

The Integrated Sustainable Waste Management (ISWM) was used as a framework of analysis. ISWM proposes a structure along three distinct dimensions: (i) stakeholders, (ii) physical system components and (iii) the enabling environment/sustainability aspects (Van de Klundert and Anschütz, 2001). Analysis of these dimensions enables a comprehensive view of the SWM system to identify options for minimizing negative impacts on public health and the environment while maximizing economic and social benefits (Zurbrügg et al., 2011).

For completeness of analysis, a dimension of development drivers was added to the ISWM framework, as proposed by Wilson (2007) and applied by Scheinberg et al. (2010). This dimension looks at mechanisms or factors that have driven development of waste management system in the past and at present. Such information is crucial to understand the prevailing concerns and determine how best to move forward in developing sustainable waste management.

Each of the four dimensions answers specific questions and together they build the structure of the feasibility assessment tool (Fig. 1).

I. WHY? (Development drivers related roughly to the three main physical components)
   a. Public health as driver for effective waste collection
   b. Environment as driver for sound (treatment and) disposal of the waste
   c. Resource management as driver for high rates of resource recovery, reuse and recycling (valorisation of recyclables and organic materials)

II. WHO? (Stakeholders)

Identification of the main stakeholders and their roles in the SWM system.

III. WHAT? (Physical system components)

Technical components of a waste management system, starting from waste generation, and including collection, resource recovery and disposal.

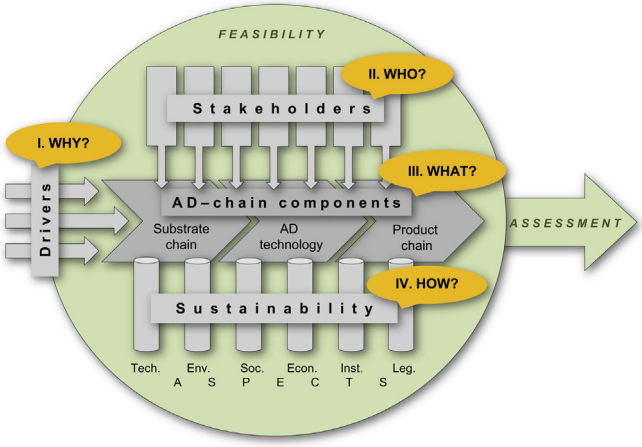

Fig. 1. Scheme of feasibility assessment tool for urban AD in developing countries.