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Future energy transitions for bagasse cogeneration: Lessons from multi-level and policy innovations in Mauritius

Long Seng To[a,b,*], Vikram Seebaluck[c], Matthew Leach[d]

[a] Department of Geography, Loughborough University, Epinal Way, Loughborough, Leicestershire LE11 3TU, United Kingdom
[b] Department of Science, Technology, Engineering & Public Policy, University College London, 2nd Floor, Boston House, 36-38 Fitzroy Square, London W1T 6EY, United Kingdom
[c] Department of Chemical & Environmental Engineering, Faculty of Engineering, University of Mauritius, Le Reduit, Mauritius
[d] Centre for Environment and Sustainability, Faculty of Engineering & Physical Sciences, University of Surrey, Guildford, GU2 7XH, United Kingdom

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ABSTRACT

Agro-industries have the potential to catalyse energy access and promote development. Mauritius is one of the most advanced countries in the use of waste from sugar processing (bagasse) to simultaneously generate heat and electricity (cogeneration) to feed into the grid, but developments have evolved over several decades with complex dynamics between different actors. A multi-level perspective is used in this paper to examine this process and to extract policy lessons for other countries. The analysis shows how policies influenced the development of the bagasse cogeneration niche and changes in the sugar and energy regimes over time. The formation of independent power producers, centralisation of sugar mills, the use of a complementary fuel (coal) in the off-crop season, and targeted financial incentives were important for the development of bagasse cogeneration in Mauritius. Mauritian sugar mills are at the forefront of niche technological and organisational innovations in response to recent reduction in sugar prices. The country has been able to respond to changes and manage niche innovations strategically due to the deployment of finance, technical expertise and strong governance structures which enabled the government to coordinate with industry. Therefore, local capacity and institutional context are important for managing transitions towards sustainable energy.

1. Introduction

Agriculture plays a central role in economic development in sub-Saharan Africa and accounts for up to 50% of the GDP in some of the countries in the region [1]. Agro-industries add value to these important crops by processing them into more refined products. Agro-industries already use energy for these processes and they have access to technical expertise and finance for new energy projects. Thus, agro-industries have the potential to serve as catalysts for greater energy access in rural areas by supplying energy to employees and surrounding communities. New investments into sustainable energy in sub-Saharan Africa are set to accelerate through the Africa Renewable Energy Initiative and the African Development Bank's New Deal on Energy. The agricultural industry has the potential to achieve rapid change in energy access, modernise the agricultural sector, improve environmental sustainability and contribute to rural development. However, the willingness of agro-industries to be involved in energy supply and the barriers to their active participation in the energy sector is not well understood [2].

One of the most economically viable options for agro-industries to participate in the energy sector is the use of fibrous waste (bagasse) from the processing of sugarcane into sugar to provide heat and electricity (via cogeneration) (see Fig. 1 for an example of bagasse). The global production of sugar currently yields an estimated 565 million tonnes of bagasse per year, which is used to meet the energy requirements of the sugar mills but in most cases with surplus resource which can be used to generate additional power for sale to the grid. Such projects boost the share of renewable energy in the national generation mix, contributes to energy access and security while equally supporting climate mitigation efforts as well as sustainable development goals. The significant availability of the resource, its generation at point of use, fully-matured conversion technologies and cost competitiveness with other energy sources are thus key factors driving development of bagasse cogeneration projects.

The largest sugarcane producers, namely Brazil and India, have well established commercial-scale bagasse cogeneration plants while many other cane producing countries such as Australia, Guatemala, Kenya, Uganda, Vietnam and the Philippines are also already producing

* Corresponding author at: Department of Geography, Loughborough University, Epinal Way, Loughborough, Leicestershire LE11 3TU, United Kingdom.
E-mail addresses: l.to@lboro.ac.uk (L.S. To), v.seebaluck@uom.ac.mu (V. Seebaluck), m.leach@surrey.ac.uk (M. Leach).

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Fig. 1. Bagasse storage facility in Mauritius.

bagasse electricity [3]. The potential for cogeneration from bagasse has been estimated at 135,029 GWh per year globally [4] and 3885 GWh per year in Eastern and Southern Africa [5]. An analysis of five selected countries in Eastern and Southern Africa showed that there was potential to double the contribution of electricity produced from bagasse cogeneration [1].

This paper aims to identify the technical and policy success factors for cogeneration from a case study of the sugarcane industry in Mauritius, and explores the implications for the future of energy and agro-industries in Africa. This case study offers many points of reflection in the cosmopolitan energy futures in this Special Issue on 'energy and the future' [6] and is an important case study for several reasons. Firstly, Mauritius has been developing sugar processing systems and associated cogeneration strategies for a long time, under changing global contexts and with various national policy imperatives. Thus the experience from this single country is wide and varied. Mauritius has been ambitious and very successful in deploying bagasse cogenerated electricity, such that it accounted for 17% of the national electricity generation share in 2015 [7] with continued growing future prospects. Therefore, whilst of a single country, the scale of this case study is large. Finally, lessons learnt in Mauritius are important for other African countries not only because Mauritius is a technology use leader, but also because Mauritius is actively bringing their expertise to bear on policy innovation across multiple levels in future sugar and power projects in Africa and elsewhere. Taken together with Schelhas et al. [8], this Special Issue offers alternatives for bioenergy pathways relevant to both developed and developing countries.

The Multi-Level Perspective and Strategic Niche Management frameworks are used to trace the historical development of the sector, and examines how bagasse cogeneration contributed to the response of Mauritian sugar mills to evolving domestic and global pressures. We discuss the political, economic and policy landscape; the sugar and energy regimes; and technological developments at the niche level. The analysis focuses on the role of policy in influencing changes at the regime and niche levels. The outline for the rest of the paper is as follows. Section 2 describes the research methods and the analytical framework adopted. Section 3 presents the case study and analysis results. Section 4 discusses the implications of the case on the future of energy in sub-Saharan Africa and the energy transitions literature.

2. Methods

2.1. Research methods

Empirical fieldwork was undertaken in Mauritius in July 2015. Data were collected using semi-structured interviews, field observations, photographs taken on site and document analysis. Site visits were made to all bagasse cogeneration plants in Mauritius and their associated sugar factories, as well as to one coal-fired power plant. Site visits were also made to field trials of new biomass varieties that were emphasized for energy production. In total, 27 interviews were conducted with a range of stakeholders, including policy-makers, sugar industry executives and engineers, project developers and researchers. The interview topics included the historical development of the sugar industry, technical details of the plants, business models, sugar industry outlook, energy policies and the experience of Mauritian sugar firms overseas. To protect the identity of participants, interviews are cited in this paper with the participant's role in generic terms and the date of the interview (e.g. Manager 1 2015, pers. Comm. 15 July).

2.2. Analytical framework

As Hanna et al. [9] demonstrate, there has been a flourishing series of literatures with different disciplinary perspective on innovation since the 1930s. Concepts of induced innovation, the evolutionary approach and path dependency were developed in the second half of the 20th century, all highlighting the significance of existing institutions and past decisions in shaping future options. Through the 1980s and 1990s more integrated theories of innovation were developed [10]. More recently, further theoretical attention to the complexity of innovation has led to structured approaches to technological innovation as a system (e.g. [11]). A parallel set of literature explores the nature of radical and often disruptive transitions in products and services. A key component of this emerging transitions theory is the multi-level perspective (MLP) [12]. Here, energy systems can be conceptualised as socio-technical systems with actors, institutions, material artefacts and knowledge that work together to provide energy services to society. Geels explores these at the three levels of 'micro' technological niches, 'meso' socio-technical regimes and 'macro' landscapes. A sustainable transition involves shifting the existing socio-technical regime towards a more sustainable form through long-term, multi-dimensional and fundamental transformation processes ([13], p. 958). The transitions approach is proving valuable in improving the understanding of long-term technological change and helping inform governance and management decisions on technological change ([14], p. 1436) and has been widely adopted for analysing sustainable energy transitions in developed countries (e.g. [15,16]) and increasingly in developing countries (e.g. [17]), including by authors in this Special Issue [18,19].

This paper adopts the MLP as the framework of analysis, which organises analysis into three levels in the socio-technical system: landscapes, regimes and niches [12,20]. Central to the MLP is the socio-technical regime which represents current practices and 'normal' development of them [21]. The regime includes technology; user practices and markets; symbolic and cultural meaning; infrastructure; industrial networks, sectoral policy and techno-scientific knowledge. Socio-technical regimes are relatively stable configurations; transitions from one