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Lessons from first generation biofuels and implications for the sustainability appraisal of second generation biofuels ☆

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HIGHLIGHTS

- Controversy surrounding 1G biofuels is relevant to sustainability appraisal of 2G.
- Challenges for policy in managing the transition to 2G biofuels are highlighted.
- A key lesson is that sustainability challenges are complexly interconnected.

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ABSTRACT

Aims: The emergence of second generation (2G) biofuels is widely seen as a sustainable response to the increasing controversy surrounding the first generation (1G). Yet, sustainability credentials of 2G biofuels are also being questioned. Drawing on work in Science and Technology Studies, we argue that controversies help focus attention on key, often value-related questions that need to be posed to address broader societal concerns. This paper examines lessons drawn from the 1G controversy to assess implications for the sustainability appraisal of 2G biofuels.

Scope: We present an overview of key 1G sustainability challenges, assess their relevance for 2G, and highlight the challenges for policy in managing the transition. We address limitations of existing sustainability assessments by exploring where challenges might emerge across the whole system of bioenergy and the wider context of the social system in which bioenergy research and policy are done.

Conclusions: Key lessons arising from 1G are potentially relevant to the sustainability appraisal of 2G biofuels depending on the particular circumstances or conditions under which 2G is introduced. We conclude that sustainability challenges commonly categorised as either economic, environmental or social are, in reality, more complexly interconnected (so that an artificial separation of these categories is problematic).

1. Introduction

The story of biofuels has been described as one of 'riches to rags' (Sengers et al., 2010). Initially cornucopian views of the potential of biofuels have been challenged under the weight of increasing speculation that their pace of development was racing ahead of understanding of the range of direct and indirect sustainability impacts of this technology. UK and EU targets for renewable fuels in the transport sector have further compounded perceptions of an unfettered dash for biofuels. Media headlines linking the rise of vast biofuel plantations in various parts of the world with rising food prices provoked a rapid shift in thinking about this technology in the second half of the 2000s. No longer is it possible to encounter the term 'energy crops' without some awareness of the potential conflict with the use of agricultural land for food encapsulated by the term 'food vs. fuel'. Other social, environmental, economic and ethical challenges are emerging especially with respect to so-called 'first generation' biofuels produced from food crops.

Biofuels have been roughly classified to distinguish between first generation (1G) biofuels produced primarily from foods crops such as grains, sugar cane and vegetable oils and second generation (2G) biofuels produced from cellulosic energy crops such as miscanthus and SRC willow, agricultural forestry residues or co-products such as wheat straw and woody biomass. Opposition to 1G biofuels is generally assumed to be about conflict with food security. Second generation biofuels are widely seen as a sustainable response to the

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increasing controversy surrounding 1G, and thus distinct from it. Indeed, it has been suggested that 2G biofuels raise few ethical or sustainability issues (e.g., Charles et al., 2007; Nuffield Council on Bioethics, 2011). But will the emergence of 2G biofuels dispel claims of 'food vs. fuel' conflicts and what new challenges might they raise? As the world's first commercial-scale cellulosic ethanol plant in Crescentino, Italy began operating at the end of 2012, this question is particularly timely.

2. Aims and methods

Examining the lessons arising from the controversy surrounding 1G biofuels, this paper assesses their relevance for perceptions of sustainability of 2G biofuels and considers the policy challenges for managing the transition to a sustainable UK bioenergy system, with particular emphasis on lignocellulosic options for biofuels. In doing so, we build on work suggesting that the ubiquitous reference to 'food vs. fuel' conflicts does not adequately capture the challenges posed by 1G biofuels (Raman and Mohr, in press). If this is the case, the case for 2G biofuels likewise needs to address a wider range of issues than conflict with food security alone. We draw on our experience as social scientists embedded in a major UK scientific programme on 2G biofuels where a key aspect of our work is to explore different stakeholder assessments of the sustainability of biofuels in the UK, in the context of a global bioenergy system.

Our map of sustainability issues arising from biofuels relies on the qualitative social research method of documents as a source of data and analysis (Bryman, 2012). We conducted a survey of articles in the field of energy research since the late 1970s, focusing on this flagship journal, supplemented by other key academic articles and reports produced by policy, professional and non-governmental organisations and the media. Treating these documents as a historical record of how debates about the sustainability of biofuels have evolved over time, we distilled the main themes, gaps or limitations and cross-cutting issues arising specifically around 1G biofuels. By comparison, there is less attention paid to 2G biofuel challenges in the documentary record, but we drew out the main themes where 2G was discussed.

We then tested and elaborated this map of challenges through semi-structured, in-depth interviews with 45 stakeholders from across the UK bioenergy 'system' (comprising science, industry, government and civil society, whilst recognising that some stakeholders may span more than one of these domains) to explore the state-of-the-art and future development of liquid transport biofuels in a global bioenergy system; and from a 2012 UK workshop involving 20 stakeholders that examined uncertainties inherent in life cycle assessment (LCA) of bioenergy and in estimations of the role of bioenergy in modelling the future UK energy mix (henceforth referenced as 'Modelling Uncertainties Workshop'). For the interviews, the established qualitative research approach of purposive sampling was used to sample stakeholders in a strategic yet sequential way, whereby an initial sample of stakeholders was selected by virtue of their relevance to the research questions posed, and the sample gradually added to as the investigation evolved (Bryman, 2012). This allowed a variety of stakeholder assessments from across the spectrum of the UK bioenergy system to be captured.

While our analysis focuses mainly on the UK context, since national and EU biofuel targets rely, implicitly or explicitly, on imports of biomass or biofuel rather than domestic supply, we refer to global issues where appropriate. Accordingly, the key challenges for policy that we pose are UK-focused, but may have broader relevance.

Our analysis draws on work in Science and Technology Studies (STS) (Rip, 1986; Cambrosio and Limoges, 1991; Romijn and Caniëls, 2011) that argues that controversies fulfil an important technology assessment function in that they help articulate potential issues and problems that need to be considered in implementing new technologies. Irrespective of the validity of specific claims, controversies focus attention on key, often value-related, questions that were previously unrecognised and that need to be posed to address broader societal concerns. In line with Romijn and Caniëls (2011) who consider contestation and conflict as constitutive rather than constrictive of innovation systems, we suggest that controversies help to open up and expose the different elements of the socio-technical system or network which constitute a specific technology. Thus the controversy surrounding the development of particularly 1G biofuels has focused attention on the critical relationship between biofuels and sustainability that is shaping the limits of social acceptability of 2G biofuels.

The need for biofuel sustainability assessments to take into account the 'whole system' in an integrated manner is now generally recognised in numerous articles published in this journal and others such as *Energy*, and *Renewable and Sustainable Energy Reviews*. However, only a few of these focus specifically on lignocellulosic options for biofuels (e.g., Black et al., 2011; Haughton et al., 2009; Singh et al., 2010). The state-of-the-art of whole system assessment of biofuels is also limited in a number of significant ways.

First, the social dimension is weakly integrated (if it is considered at all) into sustainability assessments which typically focus on LCA. Yet, from an overarching whole system perspective, there is a need to put these technical assessments in the broader context of social judgments that shape views on what is considered important and why. While some key publications do consider the social dimension, they also leave some gaps. Thornley et al. (2009) focus on constraints on UK biomass supply for bioenergy, whereas a whole system analysis needs to consider the role of imports in UK bioenergy policy and sustainability issues related to biomass conversion. The sustainability framework of Elghali et al. (2007) aims to take account of different stakeholder judgments but, as they observe, the method of ranking and weighing these through multi-criteria decision analysis (MCDA) is contested. Haughton et al. (2009) incorporate stakeholder views in their sustainability assessment framework; however, theirs is a case study of the biodiversity impacts of perennial crops in two specific regions in the UK while our assessment aims to examine a range of sustainability challenges for 2G biofuels (as a whole system from field to fuel) by drawing attention to the interface between the social dimension and the mainly environmental challenges of 1G and the potential implications for 2G.

Second, most sustainability assessments used in government policy (e.g., the 2012 UK Bioenergy Strategy) and in wider debate around biofuels focus on biomass supply to the relative exclusion of issues arising from the rest of the bioenergy chain (biomass pre-treatment and conversion through to bioenergy distribution and end-use). Consequently, although issues such as energy balance across the chain are usually considered in LCA, they are not widely discussed. In this respect, the whole system of bioenergy is not really considered, nor is the wider context of the social and policy system in which bioenergy research and policy are done. Our paper fills a gap in terms of bringing the sustainability of the bioenergy whole chain to bear on social judgments around biofuels.

Opening up the black-box of controversy surrounding 1G biofuels enables us to highlight a range of emerging challenges – encompassing the social, economic, ethical, ecological and political – that threaten to compromise perceptions of sustainability of 2G biofuels. The following section draws out and critically examines the key lessons that can be drawn from the controversy surrounding 1G biofuels, assesses their relevance for 2G, and highlights the key policy challenges in managing the transition to a sustainable UK bioenergy system. The key lessons arise from the most prominent themes that emerged from the documentary and stakeholder data and focus attention on the underexplored social dimensions in these areas.