Technological Forecasting & Social Change 92 (2015) 53–68

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Transitions in biofuel technologies: An appraisal of the social impacts of cellulosic ethanol using the Delphi method

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ARTICLE INFO

Article history:
Received 15 April 2014
Received in revised form 25 September 2014
Accepted 7 November 2014
Available online xxxx

Keywords:
Biofuels
Ethanol
Delphi
Social impacts

ABSTRACT

The sustainability of biofuels produced from food crops has become a focus of public and scientific scrutiny in the past few years. In the case of ethanol production, advanced technologies aim at avoiding controversy by using instead cellulosic biomass contained in wastes, residues and dedicated energy crops. However, despite the positive expectations that drive the development of the so-called "cellulosic" ethanol, sustainability challenges remain to be elucidated. Expecting to contribute to closing the gap in the field of the social assessment of biofuels, this paper reports and analyses the results of a Delphi survey that explored the perception of biofuel experts from different countries on potential social impacts of cellulosic ethanol. The complexity of appraising impacts emerges as one important conclusion of the study along with the realisation that these will be context-specific. Except for the case of municipal solid waste used as feedstock, such a technological transition might not be able to ameliorate the issues already faced by conventional ethanol, especially when production is based in poorer countries. This is because impacts of cellulosic ethanol depend upon both the technical dimension of its production and the socio-political context of locations where production might take place.

1. Introduction

Alongside the development of a promising international market, in the last decade liquid biofuels have been promoted as strong candidates in the search for alternatives to the use of fossil fuels in the transportation sector. However, the brisk development of a global commodity chain of liquid biofuels (Raikes et al., 2000) did not come without its share of controversy, as it has been facing great challenges regarding the governance of its impacts. In the development of biofuels, two antagonistic narratives have prevailed. On the one hand biofuels have been framed as an important, strategic solution to reduce greenhouse gas (GHG) emissions while increasing the energy security of countries that are dependent on oil imports. On the other hand however, some biofuel production chains have been coupled to both direct and indirect land-use changes, leading to increasing GHG emissions and putting pressure on food security. Because of the high levels of uncertainty regarding its potential impacts and already proven detrimental effects on the environment and society, large-scale production of liquid biofuels has become a focus of public and scientific scrutiny (see, for example, Doornbosch and Steenblik, 2007; Scharlemann and Laurance, 2008; Ajanovic, 2011; Selfa et al., 2011; Wright and Reid, 2011). As a response to the latter, the European Union and governments around the world have been supporting innovations in biofuel technologies, such as the ones involved in the conversion of non-edible biomass into liquid biofuels (EC, 2013). These particularly aim at addressing issues of technical efficiency and the environmental and social sustainability of biofuels by

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http://dx.doi.org/10.1016/j.techfore.2014.11.006
0040-1625/

achieving greater reductions in GHG emissions while avoiding negative impacts on food security along their lifecycle.

Ethanol is the world's most produced type of liquid biofuel. The United States and Brazil dominate production, but use in Europe is also increasing (RFA, 2012). Technological innovations in ethanol production are focused on bringing "second-generation" biofuels to market. These 'advanced biofuels'[1] commonly make use of the cellulosic components of biomass, which may be obtained from forestry and agricultural residues, municipal solid waste (MSW) and dedicated energy crops, such as grasses and short rotation coppice (SRC). The so-called cellulosic ethanol is commonly considered to offer advantages in comparison to conventional, "first-generation" ethanol made from edible crops rich in sugar or starch. These advantages include further reductions in GHG emissions and reduced competition with food production (Farrell et al., 2006; Hahn-Hägerdal et al., 2006; Solomon et al., 2007; González-García et al., 2010; Viikari et al., 2012; Mabee et al., 2011; Borrion et al., 2012). Based on these benefits, several countries have been encouraging the development and economical scale-up of cellulosic ethanol.[2] Presently, this is generally limited to production at experimental and demonstration scales because of economic and technical barriers (Limayen and Ricke, 2012).

Despite the positive expectations that drive the development of cellulosic ethanol, a number of important sustainability challenges have also been highlighted. Many of these derive from consideration of the impacts of conventional ethanol (Mohr and Raman, 2013). Moreover, previous research has demonstrated that the social dimensions of ethanol impacts are largely overlooked in the scientific literature; a transition from conventional to cellulosic ethanol may entail negative social impacts, and there is a lack of research dedicated to the appraisal of potential social trade-offs of such a transition (Ribeiro, 2012, 2013a).

Following up on previous work and expecting to contribute to closing the gap in the field of the social appraisal of advanced biofuels, this paper reports and analyses the main results of a Delphi survey that explored the perception of twenty-four biofuel experts from seven countries[3] on potential social impacts of cellulosic ethanol. Impacts were assessed against different hypothetical scenarios. These were based on the type and source of raw material for the production of cellulosic ethanol in different regions from the global North and South. Experts appraised impacts with regard to their probability of occurrence and two additional criteria that are less explored in the analysis of the impacts of technological change: reversibility and monitorability. Since ethanol production may take place in different locations across the world, the main objective of the survey was to stimulate reflection around the social sustainability of ethanol under different contexts. We focus the analysis in terms of 'best' and 'worst-case scenarios' that stem from quantitative and qualitative data obtained in the mixed methods survey (Bryman, 2012). The combination of these different data sets was helpful in unveiling interesting aspects of the variables assessed and supporting the findings of each approach.

The challenge of such an appraisal emerges as one important conclusion of the study along with the realisation that the potential social benefits and drawbacks of cellulosic ethanol will be highly context-specific and complex. In addition to highlighting the difficulty of analysing complex problems, participants revealed the dual, sometimes ambiguous, technical and social nature of their 'solutions' (Quintanilla, 1993). Main findings indicate that experts are sceptical if a transition to advanced biofuel production will be able to ameliorate the issues faced by the production of conventional ethanol, especially when production is based in poorer countries of the global South. Production from MSW may however be the exception to this rule.

This paper is divided into 6 sections. It starts with an introduction to the Delphi method (Section 2), followed by a description of the survey process (Section 3). It then presents a summary of the results (Section 4) and a discussion on the limitations and strengths of the study (Section 5). Finally, it offers key considerations on the development of cellulosic ethanol (Section 6) followed by some concluding remarks (Section 7).

2. The Delphi method: some applications and critiques

The Delphi method is a forecasting technique which elicits expert knowledge from a variety of participants (Scapolo and Miles, 2006). The makeup of this expertise is determined by the design of the exercise. Developed in the 1950s in the United States as an experiment aimed at estimating bombing requirements (Dalkey and Helmer, 1963), a Delphi traditionally involves an anonymous survey using questionnaires with controlled feedback to allow iteration within a panel of experts (Linstone and Turoff, 2011). A key feature of the Delphi technique is its potential to disclose subjective value judgements of a group of individuals assessing complex problems that are characterised by varying levels of uncertainty (Linstone and Turoff, 2002). It is also understood as a tool for reaching expert consensus through scientific discourse and helping to solve complex situations in which, while scientific knowledge elements are relatively certain, the relations between variables are very complex (Bijker et al., 2009).

The Delphi method has been employed in social impact assessment (SIA) to gather public opinion through community engagement in SIA studies (Burdge and Robertson, 1990); in environmental impact assessment (EIA) to assist in the estimation of impacts (e.g. Green et al., 1990; Vizayakumar and Mohapatra, 1992) and as an instrument for the evaluation of available tools for other types of assessment (e.g. Buytaert et al., 2011). The Delphi technique has also been used as an analytical tool for structured interaction in technology assessment (TA) between experts and other relevant actors (van den Ende et al., 1998). Among other methodologies for foresight and forecasting, such as lifecycle assessment and future-oriented bibliometrics, Delphi studies can serve as tools for decision-making in the context of the development of emerging

[1] The term 'advanced' in this work refers to a type of biofuel that is obtained from processes that involve technological innovations in comparison to conventional ones.

[2] In the United States and European Union this support is formulated in the Energy Independence and Security Act of 2007 and in Directive 2009/28/EC, respectively.

[3] Brazil, Canada, India, Spain, Sweden, UK and the US.