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Stakeholder signalling and strategic niche management: the case of aviation biokerosene

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Abstract

This paper explores a case of reputation and stakeholder management in sustainability transitions. We use the case of aviation biofuel (biokerosene) to explore the complications around signalling in strategic niche management processes. Biokerosene is currently supplied at several Scandinavian airports in a low percentage blend, either as standard or upon request, although trials suggest that modern jet engines can reliably handle much higher percentage blends. Airlines, airports and biokerosene suppliers cooperate in a process of mutual strategic positioning that supports confidence-building and market development, while at the same time being intended to encourage positive stakeholder perceptions. A key challenge for the sector, however, is that signalling biokerosene as a response to aviation-related climate emissions is complicated by mixed societal perceptions of biofuel sustainability; and the policy and material conditions for affordable, sustainable, large scale supply of biofuel are lacking. Thus while parts of the sector would like to more clearly signal the value of existing and greater biokerosene use, interrelationships between reputational risks, supply constraints and economics limit this. By bringing stakeholder management theory to strategic niche management, we present a view of the latter as in part reputationally driven, in response to the uncertain legitimacy of a technology at an early stage in its market development.

Highlights

- A relational view of the firm implies a role for stakeholders in strategic niche management
- Limited biokerosene use is examined from a strategic signalling perspective
- Non-technical uncertainties around biokerosene are constraining the extent of this signalling
- Biokerosene is an example of uncertain societal legitimacy limiting the diffusion of a niche technology

Keywords

Biokerosene, aviation biofuel, strategic niche management, signalling

1 Introduction

Stakeholder theory posits and emphasizes that firms operate in socio-political environments that have a significant bearing on market success (Freeman, 1984). Indeed stakeholder-related conflicts and incidents are among the most significant unforeseen risks in projects implemented in challenging environments (Aaltonen and Sivonen, 2009). Yet, while the project management literature provides numerous examples of stakeholder pressures and organisational responses, limited attention has been given to the way in which those responses reflect different strategies in different firms (ibid). Moreover, studies to date have primarily focused on the external, outward-facing aspects of the practice of public and stakeholder engagement, with internal considerations more difficult for researchers to access.

This paper analyses the reputational and stakeholder management aspects of aviation biofuels, characterizing their use by airports and airlines as a form of stakeholder signalling that is complicated by societal norms relating to biofuel sustainability being uncertain. The aviation biofuel industry represents an institutional and economic environment that is subject to several simultaneous selection pressures (Oliver, 1997; Scott et al., 2000). In such contexts, particular transition trajectories are the outcomes of interactions between multiple actors (Elzen et al., 2011), particularly given that firms-in-industries are embedded horizontally in two external environments and are shaped vertically by industry regimes Geels (2014). In other words, firms operate in bi-directional interactions between firms-in-industries and their environments Geels (2014). At a technology level, the wider diffusion of niche-innovations is also dependent on internal dynamics and on windows of opportunity at the regime level (Elzen et al., 2011). However, whereas the sociotechnical transition literature typically treats niche-level firms as agents that seek to challenge the status quo, the internal dynamics of firms are often under-emphasised (Koistinen et al., 2018). To understand more explicitly the impact of internal processes on niche development within single firms or within firms-in-industries, it is necessary to also understand the stakeholder, or agentic, relationships within an industry sector.

With the above in mind, our purpose here is to shed light on the interaction of normative uncertainty in wider society and corporate response, within strategic niche management processes. Now that biokerosene-based flight trials have proven technically successful, the technology has been expected to herald the development of a significant market for biofuel in coming years (Chiaramonti et al., 2014; Gutiérrez-Antonio et al., 2017). More recently, however, there has been corporate push-back against aviation biofuel targets[1], in which the main question regarding larger-scale use of biofuels (at least nominally) appears to concern the possible overestimation of the environmental benefits of the feedstocks aviation biofuels that are currently available. Our contention here is that the airlines and airports currently involved in low percentage blend use of biokerosene are not simply seeking to reduce the climate warming emissions of flying, but are also engaged in a reputational risk-management, corporate responsibility-related signalling process with stakeholders. However by maintaining a low scale of use, they do this without incurring significant financial cost or reputational risk. In these respects, uncertain societal norms are acting as a brake on technological diffusion: from this perspective, while cost is clearly an issue in limiting use, it is not the only issue.

Our key objective is therefore to make the above case, to which end our key research questions relate to how airports and airlines involved in aviation biofuel use have positioned themselves on this topic

[1]Please see the current development in the aviation industry:
https://www.transportenvironment.org/press/countries-reject-plan-aviation-biofuels-targets

and how they justify those positions. In the terms of the structure of the paper, we begin with an overview of the evolving use of aviation biofuels internationally. We then use both strategic niche management (SNM) and stakeholder signalling perspectives on corporate social responsibility-related activity, showing how the two perspectives share a common premise of technology diffusion needing to take into account stakeholder legitimacy and societal acceptability. After describing the analytic methodology of the study, which consists of a mix of interviews and document analysis, we show how airport and airline positions on – and justifications of - aviation biofuel use can be explained in part as cautious stakeholder signalling, allied to strategic niche management that is operating in a holding or maintenance pattern, rather than with the ambition of scale up through learning. Finally we conclude and make suggestions for further work.

1.1. Aviation biofuel technology and its potential

While air travel opens up new opportunities, the aviation industry also heavily contributes to climate change (Baumeister and Onkila, 2017). Aviation biofuels can be described as one solution within a large set of more sustainable solutions in energy transitions when replacing fossil fuels (Darda et al., 2019). The prospect of aviation biofuels lies specifically in their potential to reduce CO_2 emissions in the aviation industry (Filimonau et al., 2018). In this paper, the terms "*aviation biofuel*" and "*biokerosene*" are used interchangeably to describe renewable jet fuel that is produced from biomass.

1.1.1 Aviation biofuels production

Aviation biofuels have the potential for significant emission reductions compared to conventional jet fuel, but this depends on the feedstock type, the cultivation method and also the conversion process (ICAO, 2015). Biofuel production can provide positive ecological, social and economic opportunities for many agricultural regions (Darda et al., 2019) and pathway-specific calculations suggest emission reduction potentials of up to 80% compared to jet fuel of fossil origin (Kousoulidou and Lonza, 2016). At the same time, there are GHG emissions associated with biofuels arising from the cultivation, harvesting and transport of biomass, as well as its conversion to biofuel (Kousoulidou and Lonza, 2016).

Over the past two decades, several countries, various airlines and aircraft manufacturers have attempted to achieve a more sustainable aviation industry in part through the development of biofuels. For example, USA and the EU have engaged in actions that promote alternative fuels for aviation (Zhang et al., 2016). China launched its own alternative jet fuel initiative in 2012 (Zhang et al., 2016). As a large biofuel producer, Brazil has also initiated cooperation with Boeing, Embraer and local universities to build suitable supply chains for sustainable aviation biofuel (Kousoulidou and Lonza, 2016). Lufthansa, KLM, Finnair, Iberia, Thomson Airways, Air France, Norwegian, SAS, Alaska Airline and Gol Airlines are some of the airline companies that have performed commercial flights with biofuels (Kousoulidou and Lonza, 2016).

There are several pathways that have been defined to produce alternative jet fuels from bio-based and waste materials, with several options for conversion technologies (Kousoulidou and Lonza, 2016). In terms of feedstock, bio-jetfuel production processes include the transformation of oily biomass to triglycerides; but also use of lignocellulosic biomass, sugar and starchy feedstock (Gutiérrez-Antonio et al., 2017). In terms of conversion processes, there currently exist two main routes to alternative fuels in aviation, which are through: (1) synthetic Fischer-Tropsch (FT) process of natural gas or coal (synthetic jet fuels); and (2) hydro treating process of lipids (bio-jetfuels). The Fischer-Tropsch and hydroprocessing of triglyceride and the thermochemical conversion of biomass by gasification are the only two routes certified by ASTM (American Society for Testing and Material) for the production of bio-jetfuel for commercial use (Gutiérrez-Antonio et al., 2017). Sugar and starchy feedstock can be processed into alcohols through fermentation, and then transformed via dehydration, oligomerization and hydrogenation into bio-jetfuel (Gutiérrez-Antonio et al., 2016; Gutiérrez-Antonio et al., 2017). This alcohol to jet pathway is not yet certified (Gutiérrez-Antonio et al., 2017).

Synthetic Fischer–Tropsch fuels, also known as BtL fuels (biomass-to-liquids), are produced by a two-step process in which biomass is converted to a syngas rich in hydrogen and carbon monoxide (Kousoulidou and Lonza, 2016). After cleaning, the syngas is catalytically converted through Fischer–

Tropsch process into a wide range of hydrocarbon liquids, including a clean-burning bio jet fuel (Kousoulidou and Lonza, 2016; Zhang et al., 2016).

Despite the potential of FT/BtL routes, currently, most bio-jet fuels are produced from plant oils (e.g. algae, camelina, jatropha) and animal fats (e.g. beef or tallow) through hydroprocessing (Kousoulidou and Lonza, 2016), a process that removes the chemically-bound oxygen and produces proper molecular weight components for jet fuels (Zhang et al., 2016). Thus, these fuels are often termed as hydro-processed renewable jet (HRJ) or hydro processed esters and fatty acids (HEFA) fuels (Gutiérrez-Antonio et al., 2017; Kousoulidou and Lonza, 2016). HEFA production processes using plant oils such as palm oil have encountered criticism for being unsustainable (Kousoulidou and Lonza, 2016). Large crop-based biofuels production has been associated with risks and concerns relating to biodiversity, deforestation, increased demand for agricultural land and water scarcity (Zabaniotou, 2018; Castanheira and Freire, 2017).

In contrast, Kousoulidou and Lonza (2016) argue that HEFA processes can be sustainable, but that clear sustainability criteria are needed as a prerequisite. In general these processes share the potential sustainability impact characteristics of biodiesel, which is generally viewed as a renewable substitute for fossil fuels (Silva Filho et al., 2018; Miranda et al., 2018), which, as said, can be made from a wide variety of feedstocks (Jambulingam et al., 2019; Miranda et al., 2018; Uusitalo et al., 2014; Silva Filho et al., 2018), but for which sustainability performance depends very much on the specifics involved. In addition, currently various microorganisms such as microalgae, filamentous fungi, yeast and bacteria are being actively investigated for biodiesel production (Jambulingam et al., 2019), and hence with further potential for biokerosene production.

In short, bio-jet fuels (HRJ or HEFA) have been widely considered by the aviation industry to be one of the primary means to reduce its carbon footprint (Zhang et al., 2016). Lu (2018) argues that those biofuels are drop-in compatible with traditional kerosene have had the most rapid uptake, with many currently certified to ASTM D1655 equivalent for blending up to 50% with conventional jet fuel.

Moreover, it is expected that the use of bio-jet fuel in the aviation sector will enable, at least, partial fuel independence (Gutiérrez-Antonio et al., 2017).

1.2 Policy context

Airlines have a 'natural' incentive to reduce fuel use and hence per passenger CO_2 emissions, but the industry has resisted policy initiatives that would constrain growth in passenger kilometres. This is despite fossil-fuelled aviation emissions having the potential to consume a large fraction of the long term GHG emission budgets available to developed countries under stringent climate targets (Bows et al., 2009). Potentially, biokerosene offers a technical fix to the ongoing increase in aircraft-induced radiative forcing, itself a function of the constant growth in passenger kilometres over the last three decades, spurred by low-cost airlines and growth in emerging markets (Gössling and Upham, 2009). The aviation sector has argued that new fuels, notably biofuels, have an important role to play in climate mitigation, given that globally around 80% of carbon dioxide emissions are emitted from flights that are over 1500km in length, for which practical, alternative transport modes are limited (IATA, 2016). Domestic flights are included in CO_2 emission calculations of the Kyoto Protocol, but international flights are not – the International Civil Aviation Organization (ICAO) is supposed to regulate these but has not yet done so. The EU has attempted to extend emissions trading to international flights arriving in the EU, but has experienced strong opposition from the US and China. The International Air Transport Association (IATA) has committed to carbon neutral growth by 2020 and to reducing carbon emissions by 50% by 2050 (IATA, 2009), reductions will be sought mainly through the use of alternative fuels (e.g., Blakey et al., 2011; Stratton et al., 2011) and through emissions reductions credits purchased from outside of EU ETS.

While emissions reduction credits as a policy option suffer from uncertain additionality, the challenge of biofuels and bioenergy is that while at some forms and scales they offer promise, they also have the potential to incur direct and indirect socio-ecological consequences that can be adverse and difficult to anticipate (Upham et al., 2015). Governments have been slow to respond to this, despite biofuel policy involving multiple objectives and motives over time (Boucher, 2012). Besides providing a means for acting on climate change and providing renewable energy resources, European policy has sought to develop a cost-competitive biofuel industry (EBTP, 2014). Priority has been given to producing drop-in fuel substitutes with minimal disturbance to existing economic, transport and social systems (Boucher, 2012), in the hope that technical advances in terms of second and third generation fuels can help to resolve or reduce the burden on agricultural land (Levidow and Papaioannou, 2013).

One consequence of this is normative uncertainty: in terms of social norms, European-wide surveys of bioenergy/biofuel opinion have shown that publics have mixed and geographically differentiated mixed opinions regarding the appropriate balance for the use of forests for timber and for fuel (e.g. Ecorys, 2009). In general, use of biofuels is supported by publics, but knowledge of how this support varies for different types of biofuels and of which beliefs support these attitudes is little more plentiful now than the knowledge deficit observed by (Delshad et al., 2010) several years ago. This even more so with respect to biokerosene specifically (Filimonau et al., 2018).

Moreover, those trialing biokerosene also lack political, policy and market certainties. Biofuel policy for surface vehicle transport has been subject to on-going change, resistance to change and NGO (non-governmental organisation) campaigns and it is uncertain how these will play out in future for aviation. In 2003 the European parliament and the council approved the promotion of the use of biofuels or other renewable fuels for transport in EC Directive 2003/30/EC (European Commission, 2003). By October 2012, however, the Commission openly acknowledged serious problems with its biofuels policy, via COM (2012) 595. Biofuel technology has become heavily contested (IPCC, 2011) and IPCC Working Group III are cautious about the benefits of high end scenarios of bioenergy feedstock supply, both in terms of scientific consensus and evidence base (IPCC Working Group III, 2014, p.74). Yet it is difficult to imagine biokerosene making a substantial impact on the radiative forcing associated with aviation without a large scale supply. This supply would have to be found in addition to the many other uses to which biomass is put globally, particularly in the context of ongoing aviation growth. It is not surprising that the International Civil Aviation Organisation recently decided against volume-based biofuel targets[2].

Here we show how the complications of securing large scale, affordable and sustainable supply of biokerosene also limit the effectiveness of corporate social responsibility-related signalling (e.g., Heinberg et al., 2018), specifically in relation to the technology. Hence while those involved in the use of biokerosene are in favour of scale-up and moving the technology from niche use, the internal and external communication that might assist this is arguably being held back. Moreover use of the technology is – as an active choice - kept at a low level, until such time as policy, legitimacy and market uncertainties reduce, opening the way for production scale-up that can in turn reduce costs. In this way, the case of biokerosene illustrates some of the connections between stakeholder management theory and strategic niche management, and more specifically the way in which the latter can be both reputationally driven and reputationally constrained.

2. Material and methods

The material for the study consists of the positions and behaviour of exemplar stakeholders involved in aviation biofuel supply, positions that we argue imply that airports and airlines are engaged in stakeholder signalling processes. The primary data sources were semi-structured interviews with actors within the emerging organizational field of aviation biofuels. The interviewees were from three different continents: Europe, North America and South America. Semi-structured interviews supported the elicitation of both retrospective and real-time implications as understood by actors experiencing the phenomenon of interest (Zhang and Wildemuth, 2009). These actors are largely incumbents in the aviation regime, involved in the utilization of aviation biofuels or with the potential to do so. The interview questions probed issues relating to the way in which organizational positions and views are influenced by stakeholders' views of biofuels, stakeholders largely being other actors in

[2]Please see: https://www.transportenvironment.org/press/countries-reject-plan-aviation-biofuels-targets

the regime, but also NGOs as well as publics as citizens and/or consumers. Interviewees were asked to reply as organizational actors.

In addition, we analysed secondary data from several sources, i.e. from news articles, websites and from airline sustainability reports, in order to further understand actor views of other actors and their strategic positions, all in relation to aviation biofuel. Document analysis provides a systematic procedure for reviewing or evaluating documents, providing background information as well as historical insight (Bowen, 2009). Document selection criteria focused on obtaining an understanding of the evolution of biofuels use in civil aviation during the period 2007-17. In particular, we used this process the firstly identify and select stakeholders for interview and then to identify their roles and form of involvement in biokerosene supply and use, as well as their organizational position on the subject. In total we undertook 12 stakeholder interviews, all conducted via skype or telephone during summer 2017. Our interviewees are categorized as stakeholder groups in Table 1. The stakeholder groups that include more than one interviewee (e.g. airlines) in Table 1 represent different organizations under the same group, for example, three different airlines were interviewed for the paper. Interviews were recorded, transcribed and analysed with Nvivo qualitative data analysis software. We continued with data reduction and thematic analysis, abductively working towards stakeholder signalling as an account that helps to explain the existence and limited extent of biokerosene use. To this end we draw, as said, on those of the signalling constructs identified by Connelly et al. (2011) that are found in this context.

Table 1. Interviewee affiliation by category

Stakeholder categorization	**Number of interviewees**	**Number of different organizations**
Producers	1	1
Suppliers	1	1

Airlines	3	3
Airports	2	2
Umbrella organizations	1	1
NGOs	1	1
Certification bodies	1	1
Academics	2	2
Sum	**12**	**12**

3 Theory

3.1 Strategic Niche Management

Aviation biofuel being an emerging technology, we can analyse its situation and support options from the perspective of strategic niche management (SNM). In a sustainability context, SNM is advocated as a means of supporting innovations that are supposedly socially and environmentally desirable and that consist of path-breaking novelties incompatible with existing infrastructures, user practices and so on and that hence require protected space and support. The creation and management of such protected spaces may allow nurturing and experimentation with the coevolution of technology, user practices and regulatory structures (Kemp et al., 1998; Schot and Geels, 2008). The SNM approach was first formally presented as a policy tool by Kemp et al. (1998) who defined it as the following process:

> "The creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology." (p. 186)

Niches are spaces that offer temporary protection for configuration and development of path-breaking innovations (Kemp et al., 1998; Schot et al., 1994). Protection in the early stages is needed because path-breaking innovations cannot compete within selection environments in the existing socio-technical regime. Examples of such protection include Research & Development (R&D) support, subsidies, tax or tariff incentives, relaxed regulations and quotas, public awareness campaigns, planning and procurement rules, and other demand-side incentives. With such protection, the innovations are expected to develop and enter broader and more diverse markets; the need for protection gradually drops as the innovations become competitive and start to contribute to regime shifts towards a new state (Smith and Raven, 2012).

Smith and Raven (2012, pp. 1026-1031) ascribe three functional properties to niches (i.e. protected spaces), of which *empowering* is most relevant here. This deals with how the shielded and nurtured niche innovations escape the niche and enter the wider regime. There are two ways innovations might do this: *fit and conform* empowerment and *stretch and transform* empowerment. *Fit and conform* empowerment suggests that niche innovations be nurtured into forms which are able to compete in the conventional selection environments, such that they no longer need protective shields. In this empowerment model, innovations are, in fact, aligned with the existing industrial norms or structures, thus making it an incremental innovation to the incumbent regime. *Stretch and Transform* empowerment, on the other hand, empowers niche innovations by institutionalizing some of the niche practices in the wider regime. In other words, such empowerment restructures the mainstream selection environment in way that is favourable to the niche. In this respect, the niche is empowered because the wider regime is adjusted to the norms and routines of the niche. In the case of aviation biokerosene, arguably 'fit and conform' applies most directly, with aircraft engine technology and operating parameters being inflexible over short to medium timescales, obliging that biofuels fit the existing regime rather than vice versa.

3.2 Stakeholder signalling theory

Stakeholder management theories seek to explain and classify the strategic responses of companies or organisations when faced with external pressures from external constituents. For example, Oliver (1991) offers a classificatory scale from passivity to increasingly active resistance to such pressures: from acquiescence, to compromise, avoidance, defiance and ultimately manipulation, in which the power balance between those involved shifts significantly (Aaltonen and Sivonen, 2009). In the latter framework, acquiescence is the most passive strategy since, in applying it, an organization agrees to institutional pressure, while the most active strategy is active manipulation.

In addition to such frameworks, stakeholder theory also includes process-level accounts, such as signalling theory, which is widely applied in corporation communications research and which we apply here. Porter (1980) defines signals in this context as actions that express intentions, motives or goals directly or indirectly. The core focus of signalling theory concerns the different types of signals that a signaller sends to a receiver, as well as the interpretation and use of such signals (Ching and Gerab, 2017; Connelly et al., 2011). Stakeholders are key recipients of corporate signals and signalling theory is often applied in the study of corporate social responsibility (CSR) (Hetze, 2016), due to the reputational objectives of companies. Hence from this perspective, CSR is understood as having multiple, instrumental purposes, some of which are the signalling of social responsiveness to stakeholders and the activation of goodwill (Galbreath, 2010; Shapira, 2012).

Zerbini (2017) builds on the business case for CSR (e.g. as set out by Carroll and Shabana, 2010), using the case of CSR as signalling: "signaling theory maintains the assumption of economic rationality, and conceptualizes CSR initiatives as cueing tools that enhance the efficiency of the market and the performance of the firm (Rao and Monroe, 1989)." (Zerbini, 2017, p.3). Here we suggest that both companies and a niche technology itself may benefit from corporate signalling. Signalling may thus be a part of – indeed a method of – SNM and an enactment of niche protection. Through such signalling, corporate actors aim to communicate and shape the expectations of stakeholders as regards niche development processes.

This is particularly relevant in contexts of relative uncertainty. Stakeholder theory highlights the need to create value for all stakeholders. When a business case includes sustainability, then the corporate response needs to be perceived as creating value for stakeholders by solving or addressing relevant sustainability problems (Schaltegger et al., 2017). More generally, the premise of stakeholder theory is that business does not operate in isolation - instead firms always have stakeholders and need to proactively pay attention to them (Freeman, 1984). The approach suggests that a firm's success is dependent on its ability to manage relationships with its stakeholders (Marshall et al., 2010). Hence Freeman et al. (2010) observe how a good reputation is ultimately a requirement for long-term, successful business.

From the perspective of stakeholder theory, businesses are understood as a set of relationships among groups of actors or agents who have a stake in the activities that constitute the business (Wahid et al., 2017). Thus business activity is seen as inherently focused on the matter of how stakeholders - typically understood to include at least customers, suppliers, employees, financiers communities and managers - interact and create value; and hence in order to understand business activity, these relationships need to be understood (Wahid et al., 2017). Whereas stakeholder theory is widely applied, the perspective of firms-in-industry relationships is arguably underrepresented and knowledge of how internal corporate processes influence strategic niche management lacking (Koistinen et al., 2018).

Here, we treat aviation biofuel stakeholders who are internal to the production and use system as representatives of firms-in-an-industry who participate in mutual interactions that influence niche development: i.e. we take a relational view of firms (Dyer and Singh, 1998). With the firm considered as a relational entity, stakeholder perceptions have a strong bearing on what governance processes are deemed legitimate, something that is known to vary by technology context (Geels and Raven, 2006). As the signalling theory literature is diffuse, here we draw on selected key concepts from the literature identified by (Connelly et al., 2011), namely (i) signalling as a response to perceived opportunity and threat; (ii) the need to keep the cost of signalling affordable; and (iii) the need for signalling consistency, which we interpret in terms of a mandate for industry-wide, common signalling. Here we particularly connect to the question of *signal fit*, posed by Connelly et al. 2011 (p. 59f.): whether biokerosene, due to its contested nature, currently functions as a suitable signal for a more sustainable aviation industry.

4 Results

Analysis of interviews and background material enabled the identification of three themes relating to stakeholder positioning and signalling regarding biokerosene, as well as a timeline relating to the technology's supply and use. In this section we address those themes, namely issues of signalling as a response to perceived opportunities and threats, reducing the cost of signalling; and an emerging common vision for the future. We begin with a chronology of the recent development of aviation biofuel use.

4.1 The emergence of aviation biofuels

To provide a more detailed overview of the context in which the emergence of niche development happens, we provide a timeline regarding the development of aviation biofuels within the past decades in Table 2. The sources for this are our stakeholder interviews and analysis of secondary (e.g. news articles or media announcements) material.

Table 2. Timeline of the recent use of aviation biofuels

Time	Events related to aviation biofuels
At the turn of the millennium	-Interest from pioneer firms, particularly producers; university-based research; army and air forces. A framework for the use of biofuels is begun by ICAO.
2007	-Biokerosene refiners are now operating, mainly on palm oil.
2008	-Virgin Atlantic becomes the first airline to fly a test flight (not in commercial use) between London and Amsterdam with a blend of coconut and babassu (Wired, 2008).
2011	-In 2011 biokerosene gets the ASTM (American Society for Testing and Material) standard for commercial use. A 50% blend fuel is permitted (ASTM, 2011). -Producers are able to provide samples for commercial flights. -Commercial test flights on biofuel blends are conducted. The first airlines are KLM, Lufthansa and Finnair. In June 29th in 2011 KLM operated the first scheduled

	biofuel flight powered by biokerosene derived from cooking oil between Amsterdam and Paris. The fuel was provided by SkyNRG (FlightGlobal, 2011; KLM, 2016). In July 15th in 2011 Lufthansa becomes the first airline worldwide to operate regular scheduled flights with a biokerosene mix between Hamburg and Frankfurt. Biofuel was derived from pure biomass (BtL - Biomass to Liquids), consisting of Jatropha, Camelina and animal fats (The Guardian, 2011). In July 20th in 2011 Finnair flies its first commercial biofuel flight from Amsterdam to Helsinki by fuel derived from used cooking oil. The fuel was provided by SkyNRG (FlightGlobal, 2011).
2012	-ITAKA (Initiative Towards sustAinable Kerosene for Aviation) project starts in November 2012 and continues until October 2016. ITAKA is a collaborative project framed in the implementation of the European Union (EU) policies. In particular, it supports the implementation of the European Industrial Bioenergy Initiative (EIBI) of the European Strategic Energy Technology Plan (SET-Plan). It specifically aims to contribute to the fulfilment of some of the short-term objectives (2015) of the EU Advanced Biofuels Flight Path initiative, the goal of which is to reach a target of 2 million tons of biofuels used in European civil aviation by 2020. -As the first-of-its-kind project in the European Union, ITAKA will link supply and demand by establishing commercial relationships under guaranteed conditions among feedstock growers, biofuel producers, distributors and end-users (CORDIS, 2012).
2013	-In October 2013 the development of CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) starts, the mission is to keep the global net CO_2 emissions from international aviation from 2020 at the same level, which is so-called "carbon neutral growth from 2020"(ICAO, 2013).

	-Discussions relating to biokerosene rise up airport agenda. Before this point knowledge was often limited.
2016	-CORSIA is agreed. In October 2016 Government, industry and civil society representatives have agreed on a new global market-based measure (GMBM) to control CO_2 emissions from international aviation. The target is reduction in net aviation CO_2 emissions of 50% by 2050, relative to 2005 levels. Implementation of the CORSIA will begin with a pilot phase from 2021 through 2023, followed by a first phase, from 2024 through 2026 (ICAO, 2013; ICAO, 2016a).
2016 - 2017	-Pioneer airports are integrating biokerosene into their operations. Oslo, Los Angeles and Gothenburg airports supply biokerosene. -Further developments: The development in Oslo airport is ITAKA funded and the suppliers and supplyees are Avinor, Neste, SkyNRG, Lufhansa, KLM and SAS. The camelina supply is RSB certified. The first flights with biofuel were conducted in 2014 (ICAO, 2016b).
2017	-There are now c.5 different ways to produce ASTM certified biofuel -Military interest continues -Producers now have at least 10 different feedstocks for biokerosene. However, only the HEFA (Hydrotreated Esters and Fatty Acid) conversion pathway is used an industrial scale (Kousoulidou and Lonza, 2016) -ICAO is preparing a standard related to international emission trading and also to sustainability criteria for biofuels. Debate continues around: - which biofuels would be compensated (Biofuels International, 2017); - the role of the price of carbon vis a vis providing sufficient incentive for biofuel use;

	- a possible hierarchy between different transport systems (mainly road and aviation); - a possible mandate for biokerosene producers, to match supply and demand so there would be a guarantee for production and demand. -Approval for biokerosene production from the same production line as biodiesel is being sought, to help scale production and lower the price gap between fossil and bio fuel. -However, the volume based targets for alternative fuel use for 2025, 2040 and 2050 were rejected (ICAO, 2017; ICSA, 2017).

4.2 Signalling in response to perceived opportunities and threats

The first type of signalling that we argue can be seen as part of strategic niche management of aviation biofuels is signalling in response to perceived opportunities and threats. Table 3 illustrates how firms are responding to perceived possibilities or opportunities and threats originating from within or beyond the industry.

Table 3. Signalling as a response to perceived opportunity and threat

	Representative quotation
Response to future opportunities	"Those forerunner airlines and all of the pioneers of aviation biofuels, they will get a remarkable competitive advantage and a lot of positive visibility." (Airline representative 1)
Response to threat originating within the industry	"But there are still a lot of misunderstandings about what different things effect on everything and who are the different actors of aviation sector like, for example, ICAO, so what sort of possibilities or limitations they set. We need a lot of information still to get the

	conversation on right level, at least here in Sweden." (Airport representative 1)
Response to threat originating beyond the industry	"The development has been enormous. When the first plant started to operate, it was using mainly palm oil. At the time, it was the thing what was best known and it was thought that palm oil is a sustainable feed stock. I guess we communicated this issue bit poorly. But afterwards we have made huge amount of research and development in order to make everything according to the principles of sustainable development." (Producer representative)

In general, interviewees expect that pioneer users of biokerosene will create a strong position through being able to signal their early engagement, with biokerosene lending itself to strong communication via the use of multiple forms of media. Moreover, it was believed that the aviation sector has an educative role to play in relation to biofuels and their environmental benefits. At the same time, it appeared that signalling to date has not been fully effective. Concerns were expressed relating to misconceptions and limited public knowledge of biokerosene. One such concern was that while the news media have a tendency to frame biokerosene as novel and attention-worthy, the technology is at the same time adequately proven to be capable of meeting safety requirements.

4.3 Keeping the cost of signalling affordable

A second emergent theme in the view of the commercial interviewees is the perceived need for reducing the cost of signalling, be this through mandating or otherwise incentivizing biofuel use. It can be noted that the governmental view is more conditional (Table 4).

Table 4. Keeping the cost of signalling affordable

	Representative quotation

Commercial view	“Surely everything would be solved with a mandate. So, there should be an obligation for the producers to produce certain amount of renewable fuel. That would certainly create a market and it would give a possibility for the producers to invest in the renewable production. Then again, this is linked to the global nature of the business. In addition, who knows how long this takes. Probably at some point this kind of obligation will come, but there is still a long way to that.” (Producer representative)
Policy view	“Before there is a very precise sustainability criteria, we are not supporting any straight mandates or incentives on aviation biofuels. We believe that leveling up the sustainable aviation biofuels <needs to> make them more attractive than conventional kerosene. This includes that aviation biofuels should be opened up for same incentives that are used for road biofuels. Part of that is also to level a taxation for aviation sector. The current, basically zero taxation is also a barrier for aviation biofuels.” (Umbrella organization representative)

The business actors favour incentives or mandates for production that would be globally applicable, to avoid unduly impacting the nascent biokerosene supply industry. There are also industry concerns regarding any move to tax fossil kerosene. In addition, there is a concern that political discussion is currently relying too strongly on the notion of reducing flying rather than creating possibilities for technological development.

The policy view was elicited from actors who participated in the political discussion regarding biokerosene. These actors appear to seem extent conflicted. They emphasize the need for effective sustainability criteria for aviation biofuels and are reluctant to act ahead of the details of effective policy and practice being in place, something that is perceived as time-consuming to achieve. They are concerned that the large-scale use of biofuels will increase palm oil farming and deforestation. At the same time, they agree that biofuels are required for aviation and there is a commitment to advance policy in this direction. Based on the interviews, there is the expectation that political work will develop through particular pioneer countries or set of countries, such as the EU, who may act independently and lead to pressure for global-level negotiations and agreements.

4.4 A common vision for the future?

Based on the stakeholder interviews, the industry interviewees believe that there is a common sectoral vision relating to biokerosene and hence a mandate for a common approach to the technology in terms of emissions accounting (Table 5).

Table 5. Seeking a mandate for industry-wide, common signalling

	Representative quotation
Mandate for an industry-wide, common signal (1)	"Without these renewable aviation biofuels it is extremely hard for the airlines to meet the commitments that they have set for themselves. They will use every possible mean to enhance their operations, like improving aircraft, optimizing flight routes and so on. I mean, they have done this very well. However, there is a limit how much one can enhance the operations. Aviation biofuels are playing a key role in achieving the next leap in these emission reductions. The whole industry is quite unanimous in this issue." (Airport representative 2)
Mandate for an industry-wide, common signal (2)	"I see the future very promising since there is this strong common will within the industry. We do not have a standard yet, so we should get that. What is now worked through related to the emission compensations in ICAO, so there should be also some kind of common

	acceptability and there are NGOs and others also in the process and so on." (NGO representative)

Interviewees repeatedly referred to the way in which the aviation industry cooperates internally and externally, with this cooperation being further driven as common climate targets were adopted for the sector. The industry has agreed that from the year 2020 the growth of aviation should be carbon neutral (not allowed to increase from the level of 2020); and that by the year 2050, climate emissions should be halved from the level of 2005. Aviation biofuels are perceived as crucial for achieving this target. These targets are themselves intended as signals to policymakers that the sector is taking action. Yet although interviewees referred to cooperation with NGOs, in general it would be fair to say that environmental NGOs do not find these signals credible.

Despite the above, the interviewees noted that biokerosene is acknowledged as raising a wide array of issues and problems that complicate and confound simple, clear messaging. The interviewees referred repeatedly to competition inside and outside of the aviation industry. Table 6 illustrates some of the factors that confound simple messaging – again, both internally and externally.

Table 6. Issues that confound clear internal and external messaging

	Representative quotation
Competition within the industry	"There are many options for the feedstock, of course there are these oils. Then there are also different kind of sugars, which our competitors are using. One really interesting option would be a forest-based feedstock. For now, it seems that the feedstock type [vegetable oil] that we are using would be the most reasonable option also in the near future. If we produce currently 2.6 million tons of renewable product, and there is feedstock, residue feedstock, and leftover

	feedstock equivalent for 20 million tons. But of course, if you think about the massive volumes, of hundred million tons, of aviation, it isn't that much. But it is a good start and new technologies will emerge within upcoming years. In 50 years there might be also electric aircrafts. The transition is only slower." (Producer representative)
Competition beyond the industry	"There is not enough feedstock for a long time still. There is a big question about how to utilize microbes or halloysite <a catalyst> in the future. Or, then there is this algae. But in this algae there is the thing that it would be needed, was it the size of Belgium, in order to cover the flights of Great-Britain. I think these kinds of stuff would be needed in the future. What I think it is really interesting, but at the moment too expensive, but there are those test facilities, to make fuel out of wastes. But it will take time. But it will come surely and side by side solar power, hydrogen and something else will develop. In my opinion the road transport should be electrified first, since there is the possibility. The thing that we would get something with batteries to aircraft will take a long time." (Airline representative 3)

As Table 6 indicates, not only is there competition between different feedstock uses, but also potentially between biofuels and other technologies, be this hydrogen or batteries. The interviewees perceived that the competition with biofuel feedstock for surface transport is a driving pressure for a certification standard that will enable aviation-quality fuel to be produced from biodiesel production lines. This would mean that there would be no need to produce biokerosene separately, reducing costs. There is also a prevalent view that in future road transport should be electrified and biofuels should be allocated to aviation and shipping, although this would not resolve the problems of producing biokerosene on a large scale.

5. Discussion

Stakeholder communication on aviation biofuels is challenging. Interviewees often referred to mediating - and in their view often misleading – role of the informal and formal news media. This raises a more important dilemma that further illustrates the value of signalling as an investigative and explanatory frame: communicating on climate mitigation options, particularly with the political sphere, risks – indeed requires - drawing attention to the scale of actual and projected climate emissions from aviation. Communicators thus risk their messaging – in this case on biofuels - being obscured by the larger picture, as a result of their signalling. Again dilemmas abound.

As stated, a second and related concern of the commercial interviewees is the need for reducing the cost of signalling (Bird and Smith, 2005; Connelly et al., 2011). Note that this refers not to the cost of communicating about biofuels, althoughs this has a cost, but refers to the cost of using biofuels per se as a means of communication – as a symbolic practice. We infer that the commercial actors in the aviation sector fear loss of control of the signals being propagated and of the signalling environment generally. Together these risks arguably again incline the sector towards moderate, limited use of the technology, even if in principle there are perceived or possible benefits to scaling up. Our findings imply that the attempts to create positive reputations (Freeman et al., 2010) and to signal the possible positive opportunities beyond the industry are held back by doubts about the sector's capacity to get the intended message through and the economic risks of failing.

As an approach to stakeholder theory, signalling theory has much to offer in terms of helping to explain why firms act as they do (Connelly et al., 2011), including in relation to CSR (Hetze, 2016). Our purpose here has been to explore connections between such signalling and strategic niche management, in particular to examine the complex role of signalling in shifting a technology from niche to regime or mainstream use. The case of aviation biofuels illustrates the complications that can arise in such contexts. The aviation sector – and individual actors within the sector - see reputational value in biokerosene, as well as environmental benefits if particular sustainability conditions can be met. Yet industry actors face challenges to clear signalling both within and beyond the sector. It is far from clear that large scale, sustainable production of biokerosene is achievable and this limits what messages can be claimed, advocated and promoted. The poor signalling environment simultaneously compounds and reflects supply constraints and the sector itself is conflicted about scaling up biokerosene through mandated, volume-based targets. The situation is further complicated by competitive demand for feedstock inside and outside of the aviation industry. In sociotechnical terms, aviation biofuels involve multiple 'regimes' that include energy production, agriculture and transport. This multi-regime interaction, which is increasingly recognized as an important feature that sociotechnical transitions analysis needs to attend to (Gorissen et al., 2018), requires that stakeholders find ways of positioning themselves both internally and externally.

We do not view the above situation as a case of what management theorists describe as 'inferior signalling' in the sense of intention to deceive (Viljugrein, 1997), whereby message and reality are deliberately decoupled (Westphal and Zajac, 2001; Connelly et al., 2011). Rather, aviation biofuels or biokerosene involves a complex set of conditions in which multiple objectives are being sought, multiple interactions of different types exist and strongly differing societal views are held. That said, this inherently difficult signalling environment is in some respects not so different for other technologies advocated for sustainability objectives. For example, electric vehicles require consideration of issues of adequate fiscal subsidy and business/leasing models; national and international networks of charging points; impacts on power grids from multiple co-located electric vehicles; lithium sourcing and sustainability; development of production and maintenance supply chains; recycling; consumer perceptions and more (Doyle and Muneer, 2017). These entail many different types, scales and purposes of communication, all of which can falter at any stage. Nonetheless, large scale, planned system change is possible, even if uncommon – an example being the UK's shift from 'town gas' manufactured from coal, to natural gas from the North Sea, this shift requiring modifications to gas appliances in millions of homes (Dodds and McDowall, 2013).

Use of biokerosene is not a state- or civil society- led process, but a commercial response to managing societal pressures relating to climate change. We have characterised the currently limited use of biokerosene in civil aviation as a form of strategic niche management because of its relatively early, tentative nature and limited scale. To move beyond this, the set of industries involved will need to send convincing signals to wider society - and government policymakers specifically - that scale-up will be environmentally positive. That this has been a difficult case to make partly explains why the policy environment is not (yet) conducive to such scale-up. The industry knows that choice of feedstocks will be critical to producing sustainable biokerosene. It remains to be seen on what scale such feedstocks can be produced, given demand for biofuel in surface transport, further potential demand by shipping and also the option of fuel production from direct air capture of carbon (Lackner et al., 2012) combined with renewable hydrogen. Given the limited progress on reducing climate emissions from transport and increasing passenger kilometres globally, targeted policy support for the 'right' forms of technological change is increasingly urgent.

6. Conclusions

We have used the case of aviation biofuels to explore the complications around stakeholder signalling in strategic niche management processes. Our thesis is that airports and airlines are constrained in exploiting the signalling value of aviation biofuels, not simply by cost considerations, but also because policymakers and indeed wider societal stakeholders are conflicted as to how best to act, complicating the signalling environment. No form of industrial-scale renewable energy comes without some form of environmental impact and biofuels are no exception.

In terms of theoretical development, we have argued that stakeholder signalling can be viewed as a specific tool or form of strategic niche management. From this perspective, use of aviation biofuels per se can be viewed as a symbolic, reputational act. However the aviation biofuel case illustrates how signalling through practice can be as complicated for firms as signalling through other media. In so far as SNM is undertaken with sustainability objectives, the case in turn illustrates the complex role of stakeholder signalling therein. To our knowledge, this role of stakeholder signalling is under-explored in the sociotechnical sustainability transitions literature, but offers potential for further research as a form of agency that connects corporate and other stakeholders.

While signalling theory as a perspective on CSR is still rather small research field (Zerbini, 2017), here we add both theoretical propositions and new empirics, with the aim of improving understanding of the signalling hypothesis (Zerbini, 2017, p. 2). We do this particularly in relation to the question of signal fit Connelly et al. 2011 (p. 59f.), but also by examining this in the light of strategic niche management, given that the form of the signal is the use of a niche technology. Regarding the latter, the case serves as an example of uncertain societal perceptions – and genuine complexities regarding the sustainability of biofuels, which are highly differentiated - holding back the policy support necessary for scale up (in this case, larger scale biofuel production specifically for aviation). Hence the form of strategic niche management that is currently on-going with respect to biokerosene is more a holding operation than technical learning, given that certified products already exist and technical trials have proved safe and effective.

In terms of further research more generally, we would echo Connelly et al. (2011, p. 60), who advocate further study of how (e.g. CSR-related) signals impact on additional stakeholders such as host communities, employees and customers, as all become increasingly concerned about sustainability. Questions of how false signalling can be avoided and also how can firms leverage signal costs and penalty costs to differentiate themselves from less sustainably-minded firms. Similarly, there are questions around how firms adjust their sustainability signalling activity in response to feedback from different and possibly competing stakeholders.

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