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## UK biofuel policy: envisaging sustainable biofuels, shaping institutions and futures

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**Abstract.** Technoscientific innovation has played a central role in UK biofuel policy. When the government was proposing mandatory targets in 2007–08, public controversy over ‘unsustainable biofuels’ was channelled into prospects for future biofuels to avoid environmental harm and land-use conflicts. This vision serves as an imaginary—a feasible, desirable future. Societal benefits have been envisaged according to specific models of economic competitiveness, valuable knowledge, and environmental sustainability—together comprising a prevalent imaginary of future ‘sustainable biofuels’. This has informed institutional change along two lines. First, targets are envisaged as a temporary transition until future ‘advanced biofuels’ make liquid fuel more sustainable. Second, UK research institutes realign their priorities towards seeking investment from foreign counterparts and global energy companies, in the name of making UK science and industry more competitive. Together these measures have been justified as necessary for a transition to advanced biofuels which would better contribute to a low-carbon economy. Although this imaginary may eventually be transformed into reality, initially realised has been institutional change that reinforces infrastructural dependence on liquid fuel for the internal combustion engine. As an imaginary, then, ‘sustainable biofuels’ can help explain how a policy agenda promotes one future, while marginalising alternatives.

**Keywords:** imaginaries, un/sustainable biofuels, low-carbon economy, innovation policy, technofix, waste hierarchy

### 1 Introduction

Like many EU member states, the UK had a high-profile controversy over biofuels in 2007–09. A 2003 EC Directive had set indicative targets for many aims, especially to reduce greenhouse gas (GHG) emissions. Under a 2008 proposal from the European Commission, moreover, member states would have mandatory targets: 5.75% of transport fuel by 2010, and 10% by 2020, must come from renewable sources—in practice, mainly meaning biofuels. Critics attacked biofuels as ‘unsustainable’ in several respects—eg, doubtful GHG savings, ‘food versus fuel’ conflicts over land use, harm to habitats and livelihoods in the Global South, and dispossession of rural communities there.

By 2009 the UK government had somewhat accommodated such criticisms through a new policy vision of future biofuels: targets would be linked with sustainability criteria to ensure environmental benefits and to incentivise efforts towards next-generation (or ‘advanced’) biofuels from nonfood biomass. The government also expanded R&D funds for future biofuels, as a further contribution to a low-carbon economy.

This paper analyses the role of technoscientific advance in UK biofuel policy by discussing four questions:

- (1) What have been the aims and drivers of UK biofuel promotion?
- (2) How does this promotion link ‘sustainable biofuels’ with technoscientific advance?
- (3) How do future visions inform biofuel policy?
- (4) What institutional changes accompany the search for future biofuels?

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In answering these questions, we argue that a specific future vision promotes currently available biofuels and wider institutional changes which effectively reinforce infrastructural dependence on liquid fuel for the internal combustion engine. The result delays or marginalises environmentally more sustainable alternatives such as hydrogen fuel cells.

The paper is structured as follows. Section 2 discusses our main analytical perspectives—on policy agendas for a ‘low-carbon economy’, as well as future visions as ‘imaginaries’. Section 3 explains the research methods used to collect and analyse empirical data. Section 4 focuses on biofuel promotion, the ensuing controversy and its translation into a technofix. Section 5 examines biofuel R&D priorities and visions, especially drawing on the case of a UK Research Council. In conclusion, section 6 summarises the argument about policy roles of technoscientific innovation.

## **2 Analytical concepts: protecting the climate, imagining futures**

The biofuel controversy relates to rival societal visions for addressing climate change. Technoscientific innovation has been promoted for decarbonisation methods which can thereby avoid the need for infrastructural and cultural changes. Consequent conflicts over societal futures can be analysed as rival imaginaries. These analytical insights and concepts are surveyed below.

### **2.1 Climate protection via economic growth?**

During the 2007–09 high-profile controversy over UK biofuel targets, they were promoted through a discourse of ecological modernisation, argues Palmer: through adequate management and technological development, such targets eventually could help address climate change and boost the British economy. Within this discursive frame, current patterns and levels of road transport use were immutable. Biofuels were “depicted as the only option for cleaning up the road transport sector, and as essential to the UK’s climate change mitigation efforts” (Palmer, 2010, page 1001). Alongside a wider research community of biotechnologists and environmental scientists, the biofuel industry foresaw UK targets as a pathway towards a “bioeconomy”, whereby “society would eventually depend for all of its energy, industrial, and food requirements upon land” (page 1000).

Such reconciliation between environmental aims and dominant economic interests more generally characterised the UK’s New Labour government. It positioned itself as proactive with regard to climate change, constantly engaging and building ‘partnerships’ with industrial and other nongovernmental actors, thus blurring responsibility for solutions (Carvalho, 2005, page 15). Various proindustry policies were addressing climate change, while also pursuing economic aims: “climate change was subsumed in wider agendas and was often used to justify externally-motivated measures” (pages 19–20). Climate protection has been the putative rationale for policies which prioritise other aims, especially economic growth via low-carbon industry.

A bioeconomy perspective seeks new conversion techniques for diverse nonfood biomass, as a means towards GHG savings and economic advantage: “The challenge of developing biomass energy systems to reduce carbon emissions is by definition a question of industrial ecology’ (van der Horst and Evans, 2010, page 180). Climate change has been globally framed as a problem of inadequate technology or inefficient resource usage; this problem diagnosis reinforces current infrastructures and consumer habits. In many such ways, climate protection has been discursively reconciled with economic growth, even when perpetuating fossil fuels:

“The global governmentality of climate protection is built on four discursive pillars—*globalism*, *scientism*, an ethics of *growth* and *efficiency*—that ... make it possible to integrate climate protection into the global hegemonic order without changing the basic

social structures of the world economy. In addition, they provide discursive strategies to make fossil-fuel-based growth and free trade appear as part of the solution” (Methmann, 2010, pages 348–49, italics in original).

Such reconciliation has high stakes especially in the transport sector, which is the second fastest-growing source of GHG emissions. In recent decades neoliberalism has globally generated sites of consumption excess, especially ‘high-carbon mobility systems’ proliferating demand for fossil fuel. New social practices “presuppose huge increases in the speed of travel (by humans) and in the distances covered (by both goods and humans), although not so much in the time actually spent travelling” (Urry, 2010, page 199).

From such reasons, climate change has been highlighted as an imperative for fundamental change in production and consumption patterns. Environmentalists have advocated a reduction in economic growth, especially its dependence on energy. Yet a business-as-usual approach has instead sought technofixes for energy consumption (Wynne, 2010, page 301; cf Palmer, 2010).

## 2.2 Future visions as imaginaries

Such rival visions can be analysed as imaginaries—feasible, desirable futures. They are “representations of how things might or could or should be”. They may be institutionalised and routinised as networks of practices (Fairclough, 2010, page 266). An imaginary pre-figures a possible and intended reality, by including an objective and a strategy to achieve it (page 480). This key concept has been theorised more specifically as economic and sociotechnical imaginaries.

Economic imaginaries simplify complex economic relations through abstract concepts: for example, the knowledge-based economy, defining epistemically the knowledge which is most relevant or valuable. Through such abstractions, an “imagined economic community” may become grounded both in an “imagined economic space” and an “imagined community of economic interest” among diverse social forces (Jessop, 2005, page 162). Economic imaginaries can play a role “in the restructuring of economic and political institutions, organisations, and activities and in the reorienting of the economic and social policies pursued by the state as a mechanism of translation and authorisation” (page 152).

By simplifying economic relationships, an economic imaginary can help to promote new institutional arrangements as a common interest or even as a societal imperative. Drawing on those concepts, a report critically analysed how EU research policy incorporates the “linear model”, whereby research leads to innovation and thus to European economic competitiveness.

“This is how universities, and academic institutions generally, in Europe are being exhorted to interact with industry, and to work towards valorisation of the knowledge they produce.

If the model is too simple (as we have argued), the diagnosis and policy measures linked to it will not be productive—but will still shape society (Felt et al, 2007, page 19).

By contrast to economic imaginaries, “sociotechnical imaginaries” have been defined as “collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects” (Jasanoff and Kim, 2009, page 120). Such imaginaries describe and/or prescribe futures that states ought to attain through science and technology policies. Although less instrumental than a policy agenda, a sociotechnical imaginary is “an important cultural resource that enables new forms of life by projecting positive goals and seeking to attain them”, especially by elaborating “what constitutes the public good” (page 122). Sociotechnical imaginaries “and the policies built upon them, have the power to influence technological design, channel public expenditures and justify the inclusion or exclusion of citizens with respect to the benefit of technological progress”. Thus the term ‘collectively imagined’ means actors speaking in the name of the public good, as a basis for promoting some potential futures rather than others.

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Economic and sociotechnical imaginaries can be mutually constituted as cultural resources for policy frameworks, creating expectations and mobilising resources for specific futures. This role has been analysed elsewhere through case studies extending ‘imaginaries’ to the EU policy context. Within the EU’s master narrative of societal progress, the knowledge-based bio-economy encompasses rival imaginaries, linking future technoscientific advance with an economic community in different ways (Birch et al, 2010; Levidow et al, 2012a). The EU’s economic and sociotechnical imaginaries are mutually reinforcing, potentially as self-fulfilling prophecies. As a cornucopian imaginary, ‘competitive sustainable biofuels’ discursively reconciles conflicting aims, while also naturalising the societal problems to be addressed through EU policy (Levidow et al, 2012b).

A similar analytical combination is extended here to UK biofuel policy, with some differences in context. EU biofuel targets undermined earlier UK policy on the most desirable future transport, amidst a high-profile UK public debate on environmental sustainability. All this generated overt conflicts among various policy aims and state bodies, as well as a mutual dependence between the state and a new biofuel industry. Here biofuel policy is analysed as a process involving tensions among key actors. Imaginaries provide a cultural resource for the policy framework to manage such tensions, as will be shown in subsequent sections.

### **3 Research methods and key actors**

The introduction above posed several questions relating to a wider research project that investigated UK R&D priorities for bioenergy (Levidow and Papaioannou, 2013; Levidow et al, 2013). From that wider study, this paper focuses on links between the government’s mandatory targets and R&D priorities for transport fuel. The study investigated numerous state bodies: the Department for Transport (DfT) has made long-term proposals for future fuels: for example, for electric vehicles. It sets mandatory targets for biofuels, while justifying these in relation to sustainability standards and future innovation for novel biofuels. The Department of the Environment, Farming and Rural Affairs (DEFRA) has played a role in sustainability issues of biomass uses and conversion methods. Since 2009 the new Department of Energy and Climate Change (DECC) has led bioenergy policy, shared with DEFRA and DfT, the latter especially for liquid biofuels.

Public sector funds for bioenergy R&D have two main sources. Near-market innovation has been funded mainly through government departments: for example, via specific project grants or subsidy for renewable energy. R&D funds have been allocated mainly through research councils. In particular, the Engineering and Physical Sciences Research Council (EPSRC) set up the Supergen Biomass and Bioenergy Consortium in 2003. The Biotechnology and Biological Sciences Research Council (BBSRC) set up the Sustainable Bioenergy Centre (BSBEC) in 2010.

Its establishment extended a long-term commitment to the life sciences, whose rationale is somewhat contradictory. On the one hand, a deep policy commitment assumes that the relevant UK science base powers industrial success and UK economic growth; indeed, such “policy objectives drive the search for and interpretation of evidence” (Nuffield Council on Bioethics, 2012, page 122). Yet R&D and industrial success have been increasingly globalised (pages 126–127). Indeed, a “diplomacy for science” seeks “to facilitate international cooperation, whether in pursuit of top-down strategic priorities for research or bottom-up collaboration between individual scientists and researchers” (Royal Society, 2010, page 9).

Over the past decade UK government rationales for research have shifted from technoscientific advance per se to ‘societal challenges’, such as greater pressure on natural resources and the global climate. As conduits for public sector funds, UK research councils have justified their research agendas as generating relevant knowledge to address those challenges. For example, the EPSRC proactively engages in debate on research policy, while also linking

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public sector and private sector institutions in research activities (Kearnes and Wienroth, 2011, pages 58–60). Even curiosity-driven ‘basic research’ is presented as a strategic response to current and future societal challenges; the energy area exemplifies such engagement with agenda setting for research policy (pages 46–47). In such ways, research bodies may play central roles in elaborating future visions of innovation pathways; such linkages can thereby gain greater plausibility, policy commitments, and financial resources.

To analyse such relationships, our study sought to identify semantic elements of policy processes (Fairclough, 2005). We used two main methods of data gathering: documents and interviews, as follows.

The study analysed documents from several bodies. As listed in the references, sources include: government departments [DECC (eg, 2009a; 2009b), DEFRA (eg, 2004a; 2004b) DfT], expert reports that they have cited and generally funded [eg, AEA, National Non-Food Crops Centre (NNFCC), European Recycling Platform, Low Carbon Innovation Co-ordination Group], research councils (eg, BBSRC/BSBEC, EPSRC), and other state bodies [Environmental Audit Committee, Renewable Fuels Agency, Committee on Climate Change (eg, CCC, 2011a; 2011b)] whose recommendations elicit government responses. In particular, parliamentary hearings provided primary source material from various stakeholders, especially industry and NGOs (EAC, 2008a; 2008b).

Using an Nvivo program, an initial search looked for various terms relevant to the three concepts above—economic competitiveness (eg, efficient, commercial), valuable knowledge (eg, genomics, biology, patents, intellectual property rights) and environmental sustainability (eg, renewable, GHG savings)—especially their discursive links with bioenergy. The search terms were varied according to the main theme of each document (eg, biomass, renewable energy, low-carbon economy). Initial results led to a more systematic search of documents over the past decade, in order to identify similar or different discursive links—among relevant bodies and over time. Several academic studies also suggested concepts and documents for elaborating our research questions.

The document analysis provided a sharper basis for interview questions, which investigated in depth the process of selecting priorities for bioenergy R&D. So far the face-to-face interviews have been carried out with fifteen individuals from the same bodies which originated the policy documents (listed above and in the references).

From the documentary sources, along with interview comments, we sought to identify similar or different models of the three concepts above, as well as continuities over the past decade. Similar statements have been analysed elsewhere as intertextuality: actors “draw on, anticipate and respond to other events and texts” (Keenoy and Oswick, 2004, page 141). Statements gain significance from wider chains of meaning across various sources (Fairclough, 2010, page 421). In our intertextual analysis, interview comments have informed the selection and interpretation of documentary quotes.

Drawing on the overall study of bioenergy, this paper focuses on liquid biofuels for transport. From actors’ statements, the analysis identifies underlying imaginaries—as a community of economic interest and/or the public good through future technoscientific advance—corresponding to our analytical frameworks.

#### **4 UK biofuels: promotion, controversy, and its displacement**

During 2007–09 biofuels became a contentious sector for several reasons. The 2003 EC Biofuel Directive had set an ambitious indicative target for 5.75% of transport fuel to come from biofuels by 2010 (EC, 2003). In 2008 the European Commission proposed a similar mandatory target for transport fuel to come from renewable energy (including biofuels), plus a 10% target by 2020. This proposal raised the stakes for claims about environmental benefits, especially in debates leading to the Renewable Energy Directive

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(RED) (EC, 2009). A Europe-wide public controversy raised doubts about GHG reductions, environmental sustainability, and development benefits in the Global South. These doubts were somewhat displaced onto a techno-optimistic anticipation of future novel biofuels (Levidow, 2013). A similar displacement is analysed here for UK policy.

#### 4.1 Displacing controversy via future visions

For at least the past decade, UK policy has emphasised the need to reduce GHG emissions from transport. The DfT made a commitment to promote electric vehicles, especially via development of hydrogen fuel cells (DfT, 2002), which would eventually overcome the need for liquid fuel. This aim was reiterated in *The UK Low Carbon Transition Plan*: “In the long term, reductions in emissions will require a radical transformation in the way vehicles are built and powered—whether hybrid, electric vehicles, biofuels or hydrogen fuel cell technology” (DECC, 2009b, page 140; cf DfT, 2002).

Government reports anticipated that “electric and plug-in hybrid cars would become increasingly common” from 2012 onwards, powered by alternatives to fossil fuels. “While electrically powered vehicles will increase demand for power, through smart management of our networks we can minimise the need for new power stations” (DfT et al, 2009, page 3).

Likewise over the past decade, biofuels have been compared unfavourably with alternative biomass uses for environmental benefits, even in official reports. As the 2007 *UK Biomass Strategy* acknowledged, the most cost-effective savings of GHG emissions come from converting biomass to heat, followed by combined-heat-and-power and cofiring in large fossil fuel plants; the least effective is conversion to liquid fuel (DEFRA and DTI, 2007, pages 7, 15). Nevertheless, government policy need not reflect that hierarchy because “it does not take into account the relative importance of biomass fuel sources in delivering climate change goals and targets”, especially the target for renewable energy in transport fuel (page 7). According to an academic analysis of the above tension, “Reconciliation was achieved by highlighting the paucity of alternatives for carbon saving in the transport sector and the ‘overly simplistic’ nature of the hierarchy” (Slade et al, 2009, page 687).

As another means to justify expansion of conventional biofuels, their sustainability problems were displaced onto future technoscientific solutions. Future biofuels were expected to need less land or less-fertile land, while also converting nonedible biomass:

“It is likely that by 2020 second generation biofuel technologies will be in place. This should make the production of biofuels from land much more efficient, with a reduced area needed to produce a given volume of biofuels” (DEFRA and DTI, 2007, page 22).

As a means to fulfil EU targets, in 2008 the UK government required suppliers to blend a minimum proportion of biofuels, thus mandating a market. Officially called the Renewable Transport Fuel Obligation (RTFO), this set criteria for environmental sustainability but did not make them mandatory. Consequently, the scheme provoked public controversy. NGOs criticised biofuel expansion and its harmful implications for land use. They also raised concerns about the effects on environment and on the human rights of people in countries where biofuel crops are grown: for example, sugar cane in Brazil and palm oil in Malaysia (Upham et al, 2011).

Endorsing such criticisms, the UK Parliament’s Environmental Audit Committee (EAC) advocated a moratorium on biofuel targets. Its report also counterposed other means to reduce GHG emissions from transport: for example, a shift towards electric vehicles and/or public transport (EAC, 2008a). At the same time, the committee’s consultation procedure became an arena for different standpoints on biofuel targets, markets, technoscientific advance, and their relationship (Berti and Levidow, 2014).

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In the consultation process, pro-RTFO submissions highlighted a mutual dependence of government and an incipient biofuel industry. The latter demanded long-term incentives for new infrastructural investment, in turn necessary for fulfilling the UK's EU obligations and eventually generating novel biofuels. Support for the RTFO brought together various industry and farmer groups linking biofuel targets with techno-optimistic visions of future biofuels. Their production would use various waste biomass, thus avoiding land-use conflicts and replacing much more oil.

As important actors in framing energy policy, industry lobby groups supported the government's RTFO proposal as a necessary transitional measure towards future biofuels. According to the Renewable Energy Association, mandatory targets were essential for stimulating investment towards more sustainable future fuels. For future biofuels to obtain a market, first "there will need to be a functioning market based on current technology":

"Once the market has been established on the basis of the new parameters of carbon saving and sustainability, and there is predictable consumer demand, it would be reasonable to suppose that the private sector will invest in technological innovation to move transport to low carbon usage at the lowest cost possible" (EAC, 2008b: Ev10 = Evidence section).

In supporting biofuel targets, the UK Petroleum Industry Association likewise noted the industry's efforts to develop new technology such as second-generation biofuels, which will further reduce GHG emissions (EAC, 2008b, Ev183). Also the Biofuels Trading Corporation stressed that biofuels must be put in place "now to reduce carbon emissions before advanced technologies such as hydrogen fuel cells are widely available" (Ev1). According to British Petroleum, transitional regulatory support is necessary for the development of advanced biofuel technologies, whose costs could eventually become competitive with fossil fuels (Ev195). Similarly the National Farmers Union argued that current biofuels were the only economically viable alternative to fossil fuels for transport. Countries such as the USA and Brazil have made efficiency gains in converting renewable feedstocks to biofuel, and future technology will take these gains further (Ev70).

Industry's arguments were echoed by the UK Transport Minister: second-generation biofuels would be a crucial pathway towards sustainable energy (Ev119). Moreover, "Encouraging greater use of biofuels is the most effective way of reducing greenhouse gas emissions from road transport currently available that does not rely on changing individual behaviour" (Ev1). Or more precisely, the government must make an "effort to change consumer behaviour" favourably towards available biofuels, argued the Renewable Energy Association (Ev11); lower fuel consumption was not mentioned.

By contrast to industry actors who enthusiastically advocated the RTFO, NGOs sought to reframe the issues to favour alternative trajectories. According to Greenpeace, for example, high targets would perpetuate conflicts between food and fuel, regardless of second-generation biofuels, which "do not conjure up new land" (Ev159). Friends of the Earth likewise criticised investment in such technology for "distracting funds and political attention away from readily available solutions" for climate change (Ev42). Thus NGOs reframed the debate around uncertainties over sustainable biomass sources, while also counterposing environmentally more sustainable uses of biomass (Palmer, 2010).

In its follow-up report, the UK Parliament's EAC raised doubts about the government's optimistic expectations: there may be a technological lock-in of current biofuels. It warned that "support for first-generation biofuels might not have the desired effect": that is, generating viable second-generation biofuels (EAC, 2008c, page 4). Presuming their environmental benefits, disagreements focused on whether conventional biofuels would stimulate or impede such advances.



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The public controversy was taken up by the government's Renewable Fuels Agency (RFA), resulting in the Gallagher report. This also criticised targets for transport fuels but emphasised solutions from second-generation biofuels, almost as if they already existed:

“Second generation or advanced biofuels (that do not use food crops to produce bioethanol through fermentation from starch or sugar crops; or biodiesel from oil crops) offer the prospect of enhanced greenhouse gas benefits from a wide variety of non-food feedstock” (RFA, 2008, page 41).

#### 4.2 Locking in conventional biofuels?

Despite NGOs' criticisms, the UK government accommodated industry proposals, maintaining its general support for the RTFO's rising targets on several grounds. As key assumptions, the UK had no other feasible means to accommodate EU requirements for transport fuel, and future sustainability criteria would ensure environmental benefits. Moreover, mandatory targets were a necessary transitional stage towards future biofuels. According to the government,

“In the longer term, second generation biofuel technologies have the potential to reduce pressure on land because they can use a wider range of feedstocks, including waste. However, the Government does not believe it is feasible to wait for technological improvements before utilising biofuels. It is through stimulating a market for biofuels that we will encourage investment and the development of advanced technology” (government reply in EAC, 2008b, Ev11).

This prospect resonated with a similar rationale for EU targets. Sustainability criteria define which biofuels qualify: GHG savings must rise from 35% to 50% in 2016 for existing production and to 60% for new installations after 2017, according to the RED (EC, 2009). At the time the RED was enacted, the future 60% criterion was fulfilled only by Brazilian bioethanol; fulfilment presumably would stimulate and depend upon next-generation biofuels.

As a minor concession to biofuel critics, the government slowed down its original plan that the RTFO mandatory target would rise to 5% by 2011; this target was deferred until 2014 (DfT, 2009). The DfT's public consultation solicited comments on the appropriate timetable. In their responses, environmental NGOs and biofuel suppliers took opposite sides on whether to maintain or slow down the rise in targets.

Biofuel critics also advocated fundamental changes beyond current infrastructure. For example: “The scope of the consultation was not wide enough. Transport will need to be decarbonised through a combination of biofuel use, other renewable energy (such as hydrogen and electricity), vehicle efficiency and reducing the need to travel” (quoted in DfT, 2011, page 64). More generally, environmental NGOs questioned the following:

“whether a large scale biofuels/bioenergy trade is necessary for climate change mitigation; necessary for UK energy security; poses a GHG emissions risk from land use change; poses a risk in terms of food poverty; whether reducing transport energy demand should be a higher priority than increasing biofuel supply; and whether use of land for bioenergy should prioritise power and heat as end uses, rather than biofuel for transport” (Upham and Tomei, 2010, page 5).

As a policy issue, however, biofuel targets were kept separate from unfavourable comparisons—regarding alternative uses of biomass (cf DEFRA and DTI, 2007) and alternative transport infrastructure (DfT, 2002; 2009). By narrowing the issue, the government could justify the rising targets and preempt other options (Palmer, 2010, page 1003).

Beyond the 5% target for 2014, any higher target would await “greater evidence ... regarding biofuel sustainability and deployment issues”, according to the government (DfT, 2011). As a related means to bypass or defer contentious issues, R&D investment was more

widely advocated as a route to sustainable biofuels. This deferral links future visions from otherwise divergent perspectives:

“[from ‘Energy supplier’] Government funding should provide research and development for sustainable aviation biofuel and government policy should mitigate the risks associated with start-up risks and should incentivise deployment.

[from ‘Energy interest groups’, e.g. NGOs] Policy makers should incentivise research and development of new biofuels technologies that need less land and other resources, avoid social and environmental harms, and reduce GHG emissions” (quoted in DfT, 2011, pages 62–64).

In the UK policy framework, biofuel targets and R&D priorities became mutually reinforcing, on the assumption that second-generation biofuels will eventually link environmental sustainability with competitive advantage. This linkage has been anticipated by several expert reports, especially by the NNFCC, a hybrid organisation combining expert advice to government with a private consultancy role. According to its 2009 report, advanced biofuels could even help to meet the 2020 RED biofuel target, while also offering economic benefits:

“Taking an early lead in developing these technologies would be of strategic benefit to the UK through developing new Intellectual Property and realising cost reductions that come with increased technical understanding to give the UK a competitive position in the international biofuels market place” (Evans and Natrass, 2009, pages 13–14).

The government likewise has emphasised “the potential for significant growth ... if advanced technologies using wastes and woody feedstocks are commercialised” (DECC et al, 2012, page 8). For a more sustainable use of biomass, it has envisaged “the production of biofuels through a variety of advanced conversion technology routes”, which could produce a range of coproducts in a “biorefinery”. Eventually hydrogen fuel cells could go beyond liquid fuels (pages 14, 36).

Given the tension between different potential futures, the beneficent vision of ‘sustainable biofuels’ has remained contentious, even within government and research circles. There have been doubts about the sustainability of any future liquid biofuels, especially compared with alternative transport infrastructure such as electric vehicles. Mandatory targets in transport fuel are foreseen as a poor route to GHG savings, even by some civil servants:

“The targets are not particularly well aligned from a greenhouse gas perspective when it comes to biofuels. The targets are for renewable energy, not for GHG savings. If you were using renewable energy to achieve GHG savings as your primary objective, then you wouldn’t necessarily have the targets in the way they are now framed and possibly not the transport subtarget, which gives relatively poor GHG savings from biofuels” (DEFRA interview, 3 November 2011).

As the EAC had warned the government in 2008, targets could lock in conventional biofuels through policy commitments as well as technological investment:

“Policy may lock in particular pathways—eg, through investment decisions and several thousand jobs—so that government would face political difficulties in shifting its support to a different pathway later. There is a risk of technological lock-in to specific infrastructures which may be seen later as less sustainable than they are now or as less sustainable than future alternatives. There may already be a lock-in of conventional biofuels” (DEFRA interview, 22 May 2012).

This risk was acknowledged for bioenergy overall:

“It is important that future policies and incentives are aligned to incentivise low risk areas that minimise technology and investment lock in to pathways that may become undesirable and minimise lock out of potential vital pathways” (DECC et al, 2012, page 57).

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Such a lock-out has become more plausible, given the distant prospects of advanced biofuels. Despite the earlier optimism, by 2020 nearly all the UK's 10% renewable energy contribution to transport fuel will come from conventional biofuels; a small amount will come from electric vehicles, but none from advanced biofuels—officially called “biofuels from wastes, residues, non-food cellulosic and lignocellulosic material in transport” (HM Government, 2010, page 14). The UK report did not explain the zero figure, nor even mention the usual techno-optimistic terms—for example, second-generation or advanced biofuels; indeed, the report has not been cited by any other official UK document.

Despite the distant prospect of advanced biofuels, the NNFCC still extended earlier techno-optimistic visions linking environmental sustainability and economic benefits. According to their 2011 report, advanced biofuels could meet up to 4.3% of the UK's renewable transport fuel target by 2020: “At this scale advanced biofuels would save the UK 3.2 million tonnes of CO<sub>2</sub> each year—equivalent to taking nearly a million cars off the road—and create 6000 full-time construction jobs and over 2000 permanent jobs supplying and operating the plants” (Natrass et al, 2011). Such visions have informed both the mandatory targets and R&D commitments for biofuels.

### 5 Biofuels R&D: priorities and visions

Within a UK policy framework anticipating future ‘sustainable biofuels’ from technoscientific innovation, the government expanded R&D budgets for bioenergy in general, especially for advanced biofuels. In 2008–09 new programmes were announced for research councils (see below). Since 2010 there have been more formal efforts to coordinate UK bioenergy R&D across funding sources. Such coordination has several wider aims, including the following:

- overcoming barriers, often called ‘death valley’, which have so often kept UK science distant from commercial application;
- reorienting national research priorities so that UK projects become more attractive to research bodies abroad for international cooperation.

Those efforts towards commercial prospects have specific ambitions. The strategy targets UK technoscientific expertise at specific stages of the global value chain. For overall bioenergy the UK could “licence some of the fundamental underlying innovation or build companies which then operate around the world” (DECC interview, 1 April 2011). For advanced biofuels their “Highest value to the UK is found in specific high tech component processes, which are more exportable, protectable through IP and well-aligned with the UK's academic and commercial strengths”, according to the government's assessment (LCICG, 2012, page 25).

For such commercial ambitions, the UK remains dependent upon foreign investors and their R&D agendas. UK-based companies have invested little in biofuels R&D. Commercialising such R&D remains dependent upon agendas and investment decisions by large companies based abroad.

UK biofuel R&D priorities can be illustrated by the BBSRC. In 2009 the BBSRC had a major expansion of funds for bioenergy research, especially for novel biofuels. The multisite BSBEC became “the UK's largest ever public investment in sustainable bioenergy”.

In its future vision, the UK has no alternative: “Biofuels are the only viable option we have for replacing petrol, petrochemicals, in transport” (BSBEC, 2009). As an R&D priority, future biofuels provide a direct substitute for fossil fuels and so complement current economic–technological infrastructures:

“Reducing our reliance on fossil fuels and making the transition to a low carbon economy is one of the greatest challenges the world faces. Sustainable biofuel has an important contribution to make, and is one of the few alternative transport fuels that we could roll out quickly using current infrastructure” (Professor Douglas Kell, BBSRC Chief Executive, in *BBSRC News* 2009).

The 2009 R&D expansion followed from a 2006 Review linking bioenergy with policy needs. It advocated expansion into new areas, in particular: facilitating modification and conversion of lignocellulosic material—that is, from cell walls; “optimising the sustainable production of biomass; and optimising biomass processing efficiencies to maximise extractable calorific value” (BBSRC, 2006, page 8). These priorities recast some basic research as strategic for future bioenergy: “we have to provide the underpinning technology, and that provides the UK with a good scientific base within the world and for itself” (BBSRC interview, 5 April 2011).

The BBSRC’s overall vision can be interpreted from strategy documents (BBSRC, 2006; 2010; 2011). In its imaginary, bioscience can serve societal needs by addressing several related problems—expensive and finite fossil fuels, energy insecurity, CO<sub>2</sub> emissions, and competition for land use. Such problems already drive bioscience in searching for bioenergy solutions, thus implying that R&D inherently addresses all those problems, without any conflict among the many aims. This overall imaginary links specific forms of economic advantage, environmental sustainability, and knowledge relevant for more efficiently using renewable resources, especially biofuels. These three aspects are analysed next in turn, with some overlaps.

### 5.1 Economic competitiveness

Overall strategy envisages UK research itself becoming more competitive: “We fund internationally competitive research to improve the fundamental understanding of the biological systems upon which all human life depends.” Also it emphasises suppliers in the commercial or geographical sense—for example, “more competitive chemistry-using industries” (BBSRC, 2010, pages i, 11). Along similar lines, bioenergy R&D priorities are explicitly directed at economic competitiveness, consequently generating tensions between forms of competition and cooperation.

Bioenergy research is imagined as giving the UK a competitive advantage, as if the entire nation were a unit of economic competition:

“The research investment by these two Institutes in long-term trials, extensive germplasm collections and genetic mapping populations could give the UK an internationally competitive advantage in the development of lignocellulosic feedstocks for bioenergy, biofuels and biomaterials” (*BBSRC News* 2011).

In practice, BSBEC researchers compete against each other for private sector partners, who could be based anywhere. It is difficult to find a UK partner because most relevant companies are based elsewhere in Europe or the US. In developing partnerships with them, research aims to develop technology that could be marketed globally:

“Even if the UK is one small country and what we can do in this small land area may be limited, if we can come up with technologies that are applicable worldwide, we will get economic benefit by exporting those technologies” (BSBEC interview, 4 August 2011).

The BBSRC incentivises bioenergy projects to have industry cofinancing, especially as an indicator of commercial prospects:

“If they get an industrial partner to come in with a 10% stake, then industry can help steer that project to a very considerable extent” (BBSRC interview, 5 April 2011).

Even where a company’s financial role is minimal, its technological needs can define what counts as relevant, useful research for commercial application. Public sector researchers attempt to anticipate and accommodate those needs. For example, second-generation biofuels depend on GM microbes for producing enzymes which can break down lignocellulose; such processes would be globally amenable to proprietary knowledge and commercial application.

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From UK-funded bioenergy research, national benefits are expected but remain dependent on global partnerships, amidst global competition:

“Anything that the UK can come up with is going to be immediately applicable to our competitors, especially the US; we have an opportunity to sell our expertise there or collaborate with our expertise” (BSBEC interview, 6 July 2011a).

To fully participate in and benefit from the envisaged solutions, therefore, UK research must change its institutional arrangements. By complementing research priorities elsewhere, UK institutes can gain a stronger basis for international cooperation. For example:

“Collaboration has a tension between competition and cooperation, so we are seeking win–win partnerships. For example, Brazil wants our scientists, while the UK wants commercial applications, so we are networking to accommodate both aims” (BBSRC interview, 5 April, 2011).

In setting R&D priorities, then, BSBEC envisages the needs of global companies that could eventually commercialise novel bioresources and/or conversion processes for industrial products including liquid fuels. Companies want R&D results that enhance the bottom line: maximising the income—either by reducing expenditure or by maximising income. Thus the ‘competitive’ drive has tensions around the units of global competition—Europe, UK, specific institutes, even individual researchers—and thus tensions around how best to link cooperation with competition for research investment.

Since 2010 bioenergy research has been envisaged within an EU-wide knowledge-based bio-economy, which offers the UK opportunities for European leadership to address sustainability challenges. A sustainable future needs to integrate agriculture with various industrial sectors through industrial biotechnology using biological means (BBSRC, 2011, page 3). A bioeconomy imaginary features a terminological shift from ‘energy crops’ to ‘biomass’ crops for cross-sectoral industrial integration. Industrial biotechnology offers novel solutions through the use of plants, bacteria, algae, and fungi as nonfossil sources of renewable energy, materials, and chemicals.

Exemplifying industrial biotechnology, BSBEC research accommodates companies’ interest in more efficient, flexible ways to break down ‘biomass crops’ into valuable products beyond biofuels. On this basis, BSBEC researchers attempt to obtain research contracts with companies.

“Our research emphasises means to break down biomass, not specific end-products. The [model] organism grows on sugar to make biobutanol at the moment, but you can alter the metabolic pathway so that it produces something else ... All the companies are using synthetic biology to chase bio-substitutes as precursors for whatever you want to make, eg, rubber, nylon, all sorts of things” (BSBEC interview, 6 July 2011a).

Economic benefits have been discursively linked with the common interest through social or human sustainability. New agricultural applications are expected to create skilled ‘green-collar jobs’ in the UK, thus providing employment for rural areas (BSBEC interview, 4 August 2011; cf BBSRC, 2010). Future bioenergy is foreseen as needing more skilled labour than other forms of renewable energy:

“Green-collar jobs’ mean engineering jobs in renewable energy or in low-carbon technology areas, probably wider than engineering. There are so many potential gaps to be filled in the engineering sectors. We have got an ageing engineering work force whose skills are primarily in oil and gas, so we need to get them into other technology areas. I used to look at potential jobs in bioenergy and broke them down by sector—for example in feedstock, production, processing, haulage, plant construction, and plant operation” (NNFCC interview, 3 November 2011).

Likewise the extra employment is meant to maintain the rural economy, communities, and thus social sustainability. As a major obstacle, however, farmers see no incentives to make a long-term investment in perennial crops for bioenergy. Within the imaginary, such external constraints explain why the beneficent vision is not yet fulfilled.

## 5.2 Useful knowledge

Bioscience research seeks to generate and integrate basic knowledge for relevance to industrial priorities, initially for second-generation biofuels, as a step towards more diverse applications. The UK can build on its scientific strengths in plant science and microbial enzymes, as a basis for proprietary knowledge that can be commercialised globally. For example, commercial viability depends on producing ethanol at as high a level as possible:

“But we are not trying to design an industrial process to do that; rather, we are looking at the fundamental science underlying those steps” (BSBEC interview, 6 July 2011a).

Likewise the research seeks flexibly global results:

“The research is developing all the technologies that you need to make any chemical that we currently get from fossil fuel, so I look at what we do as portable technology that can be applied across the board. Biofuel is just the stimulus” (BSBEC interview, 6 July 2011b).

Researchers try to choose priorities whose results would have a commercial outlet:

“Companies are looking at our technical results and they are interpreting it in terms of their industrial processes and their industrial knowledge. They give us guidance by saying, for example, ‘This is a particular problem we are facing.’ It helps us to refine our priorities (BSBEC interview, 6 July 2011a).

At a formal level, BBSRC rules indirectly give companies great influence over R&D priorities, especially as a means of derisking them:

“We take a lot of risk out of the early fundamental research that most industry does not want to do . . . . We derisk their fundamental research. And if they’d like to give us some guidance as to where that research could go, there are various ways. For instance, if they take a 10% stake in a project, then it will automatically get lifted up the priority scale by an automatic mechanism” (BBSRC interview, 5 April 2011).

This arrangement is seen as more accountable for public funds:

“Our funding Council wants appropriate output for British taxpayers’ money; there must be some output to it. The best way to prove that is to have a company on board, and they then influence what you do” (BSBEC interview, 6 July 2011b).

Given the close involvement of companies, bioenergy research has tensions between public versus proprietary knowledge. Industry partners seek proprietary knowledge, which can be protected from competitors through secrecy and/or through patents. Such protection remains a matter for specific researchers and their arrangements with industry. In public sector arrangements with industry sponsors, formal agreements require commercial confidentiality, thus potentially limiting free exchange of knowledge and research cooperation, even within the same research programme.

Research progress needs a free exchange of knowledge, but this is restricted by confidentiality agreements with companies for intellectual property, to varying degrees (BSBEC interview, 6 July 2011a). Some scientific knowledge is kept confidential even among BSBEC’s six sites, also known as hubs. Each has its own Scientific Board, including company investors, which vets scientists’ publications to avoid premature disclosure of commercially confidential information (BSBEC interview, 4 August 2011). In seeking proprietary knowledge, moreover, companies compete to make contractual arrangements with scientists—even in the same institute, without each other knowing.

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“So the confidentiality means that you wouldn’t need to know whether someone in notionally the same university is [also involved]. If you have a confidentiality agreement with the company, then strictly speaking that covers the university . . . I would not share that information with any other scientist within [the university]. If they asked me, I would say it’s confidential” (BSBEC interview, 6 July 2011b).

Companies’ interest in proprietary knowledge reduces the visibility of research. Much research has been kept quiet, in both the public and private sectors:

“A company wants to keep knowledge to itself until a production facility is up and running, getting a share of the market” (BSBEC interview, 4 August 2011).

As a related tension, staff time is squeezed between patents and journal publications, as two different indicators of valuable knowledge:

“On the one hand your funding council wants you to have output and impact to give taxpayers a return for their investment, and on the other hand they want you to publish in the best journal possible. And the two things don’t necessarily go together” (BSBEC interview, 6 July 2011b).

### 5.3 Environmental sustainability

Liquid transport fuel is widely seen as less environmentally sustainable than other uses of equivalent biomass (DEFRA and DTI, 2007, pages 7, 15). Nevertheless, the unfavourable comparison is turned into grounds to prioritise research on novel biofuels from nonfood biomass. Its conversion will become more efficient and therefore sustainable, as a feasible goal for the 2020 EU target; future biofuels are promoted as essential means towards a low-carbon economy. Sustainable bioenergy is understood mainly as expanding the availability of renewable resources and more efficiently converting them, while also reducing GHG emissions relative to the fossil fuels being replaced.

In the prevalent imaginary, low-carbon resources will be sustainably renewed on a much larger scale by various means—eg, by cultivating plants on ‘marginal land’, needing fewer external inputs, converting nonedible biomass (eg, lignocellulose and biowaste) and sequestering carbon in the soil. Dedicated perennial ‘energy crops’ are expected to capture more carbon in at least two senses—by selecting genotypes in which more of the carbon in the cell-wall component can be captured for bioenergy, and by increasing soil organic carbon when grown on arable land.

In this imaginary, moreover, greater degradability facilitates more efficient use and thus greater environmental sustainability. Biomass has been defined as “the biodegradable fraction of a wide range of materials”, which thereby can be turned into “renewable energy, materials and chemicals” (BBSRC, 2006, page 56). Plant cell walls will be more easily digested via pretreatments and subsequently by natural enzymes simulating moulds and/or by redesigning plants. Using surplus materials, especially wheat straw, these novel processes and products will substitute for fossil fuels in more environmentally more sustainable ways than food crops can do. In such ways, advanced biofuels will avoid the conflicts over ‘food versus fuel’.

For example, efforts towards second-generation biofuels target straw residues, which are abundant but have other uses, including soil fertility. Likewise biowaste could be recycled in ways saving more GHG emissions than conversion to energy. GHG savings are compared in lifecycle analyses for evaluating various bioenergy trajectories, especially prospects for replacing oil with advanced biofuels.

Other analyses compare different trajectories for the environmentally optimal use of biomass, especially for materials, which is favoured by the official “waste hierarchy” (DEFRA and DTI, 2007, pages 7, 15). To promote both environmental sustainability and farmers’ livelihoods, innovative biomass uses were funded through the Renewable Materials LINK Programme; but this was transferred from DEFRA to DECC at its 2009 inception

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and then was soon completed (interview, DEFRA, 3 November 2012). Biomaterials remain marginal to R&D priorities, subsidies, and targets.

Illustrating the tension, even some scientists researching novel biofuels question this priority:

“I see liquid fuels for car transportation as a stop-gap before hydrogen fuel cells for electric cars come on stream and with a much longer timeframe” (interview, BSBEC, 6 July 2011a).

“We need to get rid of the internal combustion engine. We shouldn’t be wasting our valuable biomass by turning it into ethanol. We should be turning it into chemicals that might be more difficult to make” (interview, BSBEC, 6 July 2011b).

Amidst explicit aims for environmental sustainability, then, this concept has tensions between optimising biomass usage for GHG reductions versus fulfilling mandatory targets. Managing these tensions, quantitative comparisons with oil usage and its GHG emissions reduce environmental issues to carbon accounting (cf van der Horst and Evans, 2010). Such accounting also reinforces an image of some resources as ‘waste’: that is, as a burden lacking other potential uses, thus justifying conversion to energy.

## **6 Conclusion: imaginaries reshaping institutions**

This paper has analysed the central role that technoscientific innovation plays in UK biofuel policy. The UK had a high-profile controversy over ‘unsustainable biofuels’ in 2007–09, when the government was proposing mandatory targets, largely in response to EU requirements. The controversy was channelled into future prospects for more sustainable biofuels, to be realised through stringent sustainability criteria and technoscientific advance. These future prospects have been a means to manage tensions among policy aims and actors. This role has been analysed here by combining the concepts of economic imaginary (as a community of interest) and sociotechnical imaginary (as the public good through a national project), while also building on our earlier analyses of EU innovation policy.

As we have argued, the ‘advanced biofuels’ vision serves as an imaginary—a feasible, desirable future which can be institutionalised as a strategy. In the overall imaginary, future advanced biofuels will convert nonfood biomass, substitute for fossil fuels, and contribute to low-carbon economy, while avoiding or limiting harm from conventional biofuels. Such future benefits have been mutually elaborated by UK policy makers, research managers, and expert reports.

The prevalent imaginary links specific models of economic competitiveness, useful knowledge, and environmental sustainability. These three models have both overlaps and tensions, seeking to reconcile global competitiveness with domestic needs. These three models conflate national economic benefits with private sector interests.

As a technofix imaginary, the advanced biofuels vision has provided a cultural resource for UK biofuel policy in managing tensions between different aims and key actors such as industry lobbies and NGOs. UK policy had promoted hydrogen fuel cells for electric vehicles as the preferable future pathway, whenever the technology became available. But the government became dependent upon an incipient biofuel industry to fulfil mandatory targets. As a future prospect, advanced biofuels offered a means to deflect and accommodate criticism of conventional biofuels as unsustainable.

Given such a role, UK biofuel policy has faced a dilemma: advanced biofuels have been envisaged as a significant contribution to the 2020 target—but may contribute nothing, as the government acknowledged in 2010. To comply with EU obligations on transport fuels, government policy may become locked in to available biofuels through new infrastructure



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for producing them; a modest 5% target by 2013 was meant to avoid that problem. Despite those difficulties, the imaginary facilitates two institutional changes.

First, the state becomes more dependent upon a new industry expanding production of conventional biofuels, as the predominant means to fulfil targets in transport fuel. At best, biofuels substitute for some of the greater fuel consumption, given the rising demand in the transport sector. The EU target was not initially welcomed but was eventually taken up as a new economic opportunity, justified by the imperative of climate protection.

Second, public sector research becomes more dependent on private sector interests in R&D. UK public sector research contributes knowledge to commercial strategies directed from elsewhere. UK science and industry are meant to become more competitive, implying a common national interest in economic growth (cf Nuffield Council on Bioethics, 2012). Yet in practice UK research managers compete against each other, while strategically realigning their priorities towards investment from foreign counterparts and global energy companies. Public sector R&D prioritises liquid fuels for several aims—to convert nonfood biomass more efficiently, to diversify biomass sources, to generate higher value end-products via future biorefineries, to generate proprietary knowledge, and thus to valorise a wider bioeconomy.

Both institutional changes naturalise current infrastructure for liquid fuel powering the internal combustion engine. This reinforcement potentially delays or marginalises alternative biomass uses—for example, for powering hydrogen fuel cells, or for producing materials—which the government has advocated as environmentally more sustainable for the past decade. As a cultural resource, then, a ‘sustainable biofuels’ imaginary informs policy frameworks promoting or reinforcing one future rather than potential alternatives. Complementing a broader pattern, economic growth is discursively reconciled with climate protection through future technoscientific advance for more efficient resource usage.

By historical analogy, technoscientific innovation has often envisaged that future benefits will avoid any need for fundamental change in socioeconomic patterns:

“Calling for innovation, paradoxically, is a common way of avoiding change when change is not wanted. The argument that future science and technology will deal with global warming is an instance. It is implicitly arguing that, in today’s world, only what we have is possible” (Edgerton, 2006, page 210).

Regardless of whether advanced biofuels reach the commercial stage, this future prospect facilitates policy measures which ‘will still shape society’ through institutional changes (Felt et al, 2007). In this case study, such changes are new forms of state–industry dependence through a larger biofuel industry and public sector research reoriented towards global competitive advantage. Although an imaginary can be turned into reality (Fairclough, 2010), future technoscientific advance may be less significant than the institutional changes supposedly necessary to realise it.

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