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in

Global Political Economy

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IPEG Papers in Global Political Economy No. 45 September 2010

From a fossil fuel to a bio-based economy? Reframing the third wave of biotechnology

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Abstract

White biotechnology involves the replacement of petro-chemical processes and inputs with more efficient and renewable biological ones. Within the European Union, the orthodox way in which these technological possibilities have been understood has been through the narrative of the Knowledge-Based Bio-Economy. This has framed white biotechnology as a means of reducing environmental degradation *and* increasing economic competitiveness. In contrast, putative alternatives drawing on ecological modernisation and agrarian discourse have begun to draw attention to different political issues concerning its adoption. The paper concludes that these frames – dubbed 'ecological democracy' and 'the industrialisation of nature' respectively – offer an entry point for more radical voices in the social appraisal of white biotechnology and an incipient critique targeted at the elitism and macro-level impact of its techno-fixes.

[1] I would like to thank Wyn Grant, Les Levidow, Louise Strong and Matthew Watson for reading and commenting on earlier drafts of this paper.

Introduction

> Biotechnology, probably more than any other technology, offers full or partial solutions to major societal problems like healthcare, environmental degradation, food security and safety, and energy supply. Biotechnology has the potential both to allow truly sustainable development and contribute to value creation in all sectors of society (EuropaBio and ESAB 2006: 9).

Humanity's addiction to fossil fuels has been repeatedly invoked as a fundamental constraint on the emergence of sustainable economic growth. The issue has reappeared in different forms according to the global challenge of the day. For instance, during the 2007-08 food crisis when crop prices spiked on world markets, fingers were pointed at the excessive dependence of our farming system on fossil fuel inputs and the likely recurrence of the problem as energy reserves dwindle. In another example, during the international climate negotiation in Copenhagen in 2009, serious questions were asked about the extent to which greenhouse gas (GHG) emissions could be reduced whilst still retaining the energy-intensive consumption patterns of the world's growing middle classes? As illustrated in the opening quote, biotechnology has been portrayed as being able to mitigate these and other problems besides, whilst also helping reinvigorating capital accumulation in faltering Northern economies. Conceived in this multi-purpose fashion, it is perhaps no wonder that many people in the policy-making community have suggested that biotechnology must be further embraced in society (Barroso 2007; Collier 2008; OECD 2009).

Biotechnology is defined here as 'any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for a specific use' (FAO 2001: no page numbers). To date, most literature within the social sciences on biotechnology has focused either on green biotechnology or red biotechnology (see Bridge *et al.* 2003). The former is directed toward the agricultural sector, with notable applications including chemically-resistant crops and market-enhanced fresh produce. The latter is directed toward the health sector and centres on the emergence of genetic cures and organisms designed to produce human antibodies. In contrast, this paper addresses what *The Economist* (2009) has called the 'third wave' of biotechnology designed to replace 'big, dirty chemical factories' with a cleaner, greener means of production – that is, white biotechnology.

White biotechnology is directed toward the industrial sector and is based on the use of fermentation and catalysis to perform chemical transformations on organic compounds. Thus, among other things, it offers the possibility of replacing energy-intensive chemical processes with more efficient biological ones, and replacing fossil fuel-derived products with renewable ones derived from the natural sugars found in plants.[2] The most notable instance of this technique has been the production of biofuels from maize, sugar cane and wheat, but other markets for 'bio-based' products are also evident in industries as varied as textiles, packaging, food and cosmetics. Such substitution has enlivened both supporters and critics of white biotechnology, with the former heralding it as 'enabling the big sustainability breakthroughs' and the

[2] It also encompasses bio-remediation, i.e. processes of cleaning water, industrial effluents and solid wastes, using microorganisms, but since the focus of the advocacy strategy has been on the use of enzymes in manufacturing, the paper limits its scope to this field.

latter wary of the 'extreme genetic engineering [in] the post-petroleum sugar economy' (EuropaBio 2002: 1; ETC Group 2008: 1).

Reacting to this widening and deepening of the bio-based economy, this paper attempts two things. First, it seeks to move the focus of existing debates around the use of agriculture for non-food purposes from the analysis of a single product to that of a general process. This refers in particular to the literature around the sustainability of biofuels, which, while lively and provocative, does not speak directly to the broader social questions raised by the use of white biotechnology. Second, the paper seeks to map out the orthodox and alternative frames through which this technological trajectory is understood. The importance of framing can be seen clearly in the previous two biotechnology waves. As Falkner writes: 'Whereas agricultural biotechnology came to be framed in public discourses as an inherently risky technology, medical uses of genetic engineering continued to enjoy relatively high levels of popular support and industrial backing. The EU accordingly came to emphasize different principles in these two areas: innovation and growth in medical biotechnology, and precaution and consumer protection on the agricultural side' (Falkner 2007: 514).

Thus, as discussed in the next section, the development of genetic-level intervention in fermentation and catalysis has been depicted as opening a new frontier in the low-carbon economy. As taken up by the European biotechnology trade association, EuropaBio, it has also been presented as a means to boost EU competitiveness and meet the Lisbon Agenda objectives for sustainable economic growth. The argument is made that among a group actors based in Brussels – namely EuropaBio, the European Technology Platforms, and the European Commission and its Directorate-Generals for Research and for Trade and Industry – these twin functions cohered in the narrative of the Knowledge-Based Bio-Economy. The language and logic of this narrative staked a central role for public authorities in supporting sector-wide innovation, and its resultant policy has been instrumental in articulating and advancing further investment in the bio-based economy among EU Member States.

The third section considers how this orthodox view might be reframed. It does so by turning to discourse that already speaks to the application of biotechnology in the contemporary capitalist economy, namely ecological modernisation and agrarianism. Ecological modernisation is shown to be compatible with perspectives ranging from the Promethean view of technology visible in the KBBE to a more precautionary view redolent of social conservatism. Based on this latter view, an alternative frame dubbed 'ecological democracy' is delineated, which calls for greater participation in shaping white biotechnology and a greater understanding of its adaptation by society. Agrarianism, meanwhile, offers a frame that highlights the ongoing 'industrialisation of nature' and the risks attached to rapid commercialisation of the biosphere.

The fourth section provides a conclusion that champions the politicisation of the bio-based economy by these two alternative frames. This returns us to the question mark in the paper's title. It is not there to ask whether a reduction and replacement of fossil fuel inputs is technically feasible but rather whether it is desirable, and, if so, in what forms and at what cost. As Frow *et al.* have noted 'the vision of a bio-based economy grounded in principles of sustainability and environmental health is powerful in part because it speaks to groups with quite different motivations and priorities – there

seems to be something in it for everyone' (Frow *et al.* 2009: 18). Thus the paper concludes that the distributive and normative risks highlighted by alternative visions remain vital to informing people about other sustainability strategies that could be supported, as well as holding the bio-based economy to account against its promises.

Renewing white biotechnology: From cellular to genetic intervention

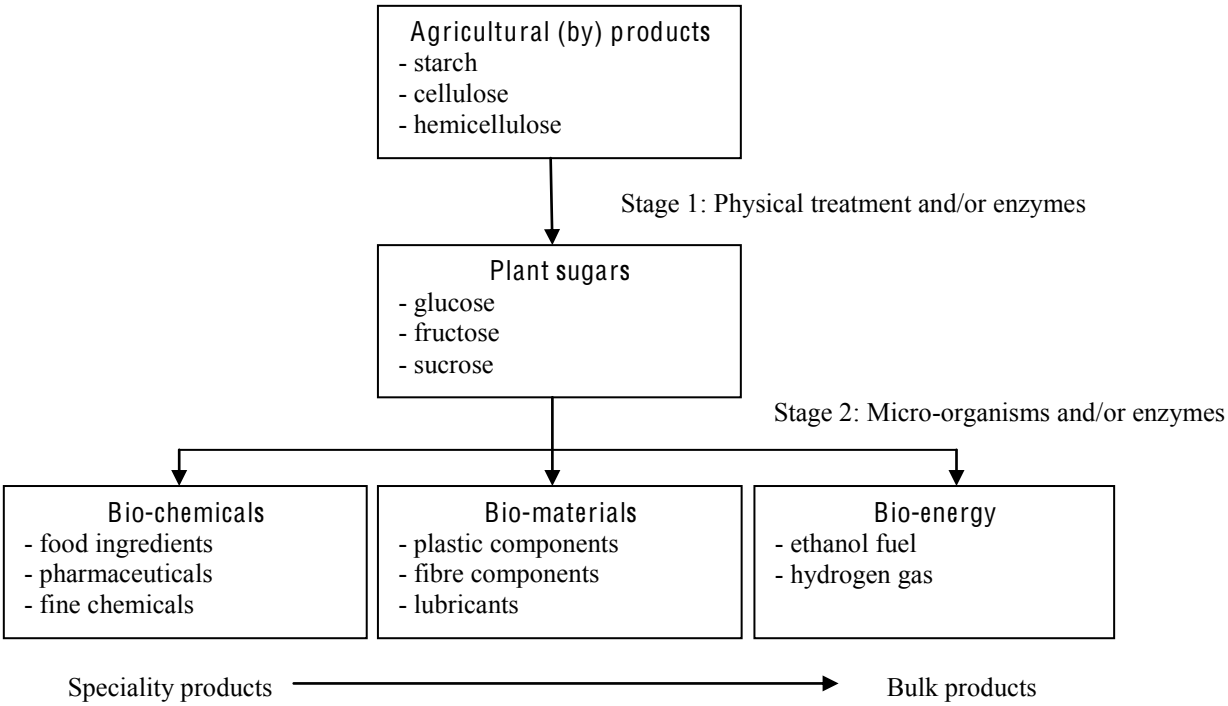
In the generic sense of using biological processes to produce chemical compounds for industry, white biotechnology has been around for over one hundred and fifty years. In 1820 Americans consumed two tonnes of biomass for one tonne of minerals. While most of this was biomass was used in a relatively unprocessed state – for example, wood in construction or hemp in rope – many plants were used as the primary raw material in the production of dyes, paints, solvents and more. Indeed, the first plastic was made in the 1840s using a cotton-based product called collodion and the first type of photographic film made from cotton-based celluloid (Morris 2006: 1743). Hedging his bets on the material base of industry, Henry Ford in fact designed his first car, the Model T, so that it could run on corn ethanol as well as oil, and by the 1930s, every vehicle to come off the Ford production line contained sixty pounds of soy in paint and plastics! (Crawford 2009).

These early biomaterials and biofuels were produced by breaking down biomass using heat and acids, before fermenting the resultant mash using naturally occurring enzymes and micro-organisms. But with the advent of synthetic chemistry and heavy fossil fuel extraction, chemical compounds that were previously thought to be the exclusive preserve of nature could now be manufactured in factories. By 1920 the pendulum had swung and Americans consumed one tonne of biomass for two tonnes of minerals, a trend that was accelerated by war when the country found itself cut off from supplies of natural rubber and nitrogen (Morris 2006: 1744). Repeated across the industrial world, this shift ensured that it would be mineral hydrocarbons, rather than plant carbohydrates, on which the late-20th century economy would be built.[3]

During the post-war era, the first leaps in white biotechnology were made in the food and pharmaceutical industries, where it was used to produce substitutes to natural substances such as *Humalin* insulin, Vitamin B, and refined sugar (Buttel 1989: 252). A breakthrough came in 1988 when the Danish company Novozymes produced the first genetically engineered enzyme, which was used in detergents to digest fat. Following this, organisms began to be genetically modified so that they would also produce greater amounts of enzymes, and thereby lower the cost of using white biotechnology. The power and efficiency enabled by these advances enabled a wider range of speciality and bulk products to be produced from biomass, as illustrated in Figure 1. Notable examples of these include Coca-Cola's substitution of petroleum-derived plastic bottles with ones made partially from sugar cane, and in a fitting renewal of Ford's earlier efforts, Toyota's bioplastic car, made with a body and interior derived from sweet potatoes and sugar cane (Crawford 2009).

[3] Carbohydrates are organic compounds consisting of carbon, hydrogen and oxygen. Fossil fuels are simply carbohydrates subjected to anaerobic digestion, squeezing out the air to leave a dense energy source.

Figure 1: Making plant sugar products using white biotechnology



At present, white biotechnology is typically used to make a single product using a single food crop as a feedstock. Looking to the future, the vision put forward by advocates of white biotechnology has been for these separate production streams to be brought together in the 'integrated biorefinery'. Dotted around the countryside, these would be the agricultural equivalent of oil refineries, capable not only of 'fractioning' crops to make a range of chemicals, materials and fuels, but also of using plant residues and process wastes (Georgiadou 2010). To move toward the use of waste biomass and ultimately a 'closed loop system' capable of recycling any biodegradable material into new industrial inputs requires the development of commercial 'cellulolysis'. This refers to the breakdown of cellulose, the structural component in the cell walls of plants. It is hard to isolate because it is tightly bound with lignin, a more complex chemical compound, but once these bonds have been broken, the cellulose can be fermented like other carbohydrates. To make this possible and transform roughly one third of all plant matter into a potential feedstock, powerful enzymes have been developed. At the time of writing two Danish biotechnology firms – Novozymes and Genencor – were partnering with first generation biofuel producers in the US to launch the world's first commercial scale, cellulosic biofuel plants in 2011.[4]

The orthodox framing of white biotechnology in the EU: the Knowledge-Based Bioeconomy (KBBE) narrative

The preceding account might suggest that it has been scientific advance alone that has propelled the changing applications of white biotechnology. This would be a

[4] 'Third generation' biofuels, made from algae, have been shown to be biologically viable but even more economically prohibitive, at least at the time of writing, than 'second generation'.

misnomer. In all countries where the substitution of fossil fuel-based goods has emerged, the state has been closely engaged. The European Union is no different in this respect, though it is distinct in the sense that it has been policy emanating from Brussels, rather than state bureaucracies, that has tended to define national biotechnology strategy. In this respect, the biotechnology trade association EuropaBio has been the most prominent organisation in building links with EU-level policy-makers, and, in doing so, has also come to articulate the orthodox frame through which white biotechnology has been understood.

Two broad developments form a backdrop to this. One is the environmental agenda institutionalised within the EU, which following active engagement in the 1997 Kyoto Agreement has focused on measures to provide clean energy and tackle GHG emissions (Falkner 2007: 509). Of particular relevance to our case is the support lent to renewable transport fuels. In 2002 the European Commissioner for Research announced that €3.4bn would be devoted to the 'Clean Technologies' programme and the following year, an indicative target for biofuel usage in Member States had been set at 5.75% of transport fuel. Alongside this, the EU taxation framework was restructured to allow Member States to exempt biofuels from domestic taxes and a common external tariff was levied on imports.

The second development shaping the orthodox frame of white biotechnology was the discourse of the Knowledge-Based Economy (KBE). According to Jessop, this became popular during the 1990s and arose out of the search for a new economic paradigm following major crises in Atlantic Fordism. It cohered around common ideas on the technological and economic factors of competitiveness, a belief in the valorisation of a creative and flexible entrepreneurial culture, and commitment to the dynamic contribution of lifelong learning (Jessop 2005: 144). Dovetailing with 'disciplinary' neo-liberalism, the industrial policy accompanying the KBE was thus set around 'horizontal' supports that facilitated technology transfer across borders and sectors, and which increased the innovation and adaptability of firms (McGuire 2006). This discourse subsequently informed strategic thinking among EU policy-makers, not least in the 2002 Commission publication *Life Sciences and Biotechnology: A Strategy for Europe*. In the wake of information technology, life sciences and biotechnology were depicted here as the next wave of the knowledge-based economy and an essential means of meeting the Lisbon Agenda goal of sustainable economic growth with more and better jobs (CEC 2002: 3-4). Accordingly, it ended with infant industry action plans to facilitate the use of biotechnology in the manufacturing sector as well as the energy sector.

It was out of this environmental agenda and economic strategy that the narrative of the Knowledge-Based *Bio*-Economy (KBBE) was born. It offered a specific reading of the place and purpose of white biotechnology in 21st century Europe, defined as the process of 'transforming life sciences knowledge into new, sustainable, eco-efficient and competitive products' (CEC 2005: 1). Led at the policy-level by DGs Research and Enterprise and Industry, as well as senior figures in the Commission itself, it found institutional expression in a series of major stakeholder conferences held under the auspices of the European Commission and the creation of EU-funded industry-led forums known as Technology Platforms. These platforms were tasked with advising the EU on research priorities, and white biotechnology gained specific advocacy via

the 'Plants for the Future', 'Biofuels' and 'SusChem' (Sustainable Chemistry) platforms.

Within these institutions, as well as the EuropaBio literature, white biotechnology was packaged together with red and green biotechnology as complementary life science innovations, capable of addressing environmental concerns and economic competitiveness (CEC 2005; EuropaBio and ESAB 2006; SusChem 2006). The former were met by the reduction in energy use and replacement of non-renewable resources made possible by white biotechnology. In contrast to the 'end of pipe' technologies that removed pollution before it was released into the environment, 'eco-efficient' technology promised to prevent such pollution happening in the first place. The latter issue was addressed by 'adding value' to manufacturing industries, particularly the chemicals industry and those dependent on it. White biotechnology would allow these companies to reduce input costs, market 'green' products capable of attracting a consumer premium, and develop entirely novel products based on new materials and ingredients (EuropaBio and ESAB n.d.). Enhanced competitiveness was also expected to filter down to the agricultural sector. A bio-based economy was reckoned to both drive farm innovation as biorefineries would demand novel types of crop, and where cellulosic production took place, also allow more value to be captured by creating a market for 'agricultural waste which currently has no economic value' (EuropaBio and ESAB 2006: 11).

From the mid-2000s EuropaBio took the lead in cementing white biotechnology as a cornerstone of the KBBE. It did so via its Industrial Biotechnology Council, headed by Jack Huttner, who had recently served in the equivalent body of the US biotechnology trade association. Perhaps not surprisingly, the policy agenda put forward by EuropaBio closely mirrored US legislation enacted in this area, with many proposals finding their way into the Commission's mid-term review of the *Life Sciences and Biotechnology* strategy (EuropaBio and ESAB: 2006; CEC 2007).[5] Three of these proposals have since passed into policy. The first was increased research funding for the KBBE totalling €1.9bn under the EU's Seventh Framework Programme activities.[6] The second was the idea of 'lead markets' used to stimulate demand through public co-ordination efforts. Measures included the option for governments to favour bio-based products in tender specifications, the standardisation and labelling of bio-based products, and the consideration of binding provision targets for certain products, e.g. 10% of supermarket plastic bags to be 'bio-based' (CEC 2009a). The final policy idea was financial support for companies to build research-oriented plants – forerunners of the integrated biorefinery – which could provide a 'proof of concept' for bio-based production (EuropaBio and ESAB: 2006).

The other major push by EuropaBio during the mid-2000s was on the second phase of biofuel legislation. Since the initial target had been set in 2003, concerns had arisen that the use of food crops for biofuels had pushed up food prices and caused an expansion of agriculture into biodiverse areas. The Gallagher Review subsequently carried out at the behest of the UK government recommended a more cautious and

[5] The US policies mirrored include the 2002 'buy bio' programme inserted into the Farm Bill, the 2003 biomass utilisation research programmes and the biorefinery demonstration projects.
[6] Alongside Framework Programme funding, white biotechnology also featured as a topic within the European Research Area Networks which co-ordinate Member States research, with national budgets ranging up to €100m (IB-IGT 2009).

discriminatory approach to the promotion of biofuels, and was influential in taming earlier enthusiasm within the Commission for the technology (Harvey and McMeekin 2010: 22). Reflecting the now qualified support for biofuels, EuropaBio emphasised to a greater degree the necessity of using white and green biotechnology to develop 'second generation' cellulosic biofuels. It was argued that this technology would permit greater use of European feedstock, thereby reducing demand for environmentally damaging imports from developing countries, as well as sidestep the 'food versus fuel' trade-off (EuropaBio 2007). Passed in 2009, the Renewable Energy Directive echoed this request. It required Member States to use 10% of renewable energy in the transport fuel mix by 2020 and allowed cellulosic biofuels to count double in meeting this target (Harvey and McMeekin 2010: 22).[7]

In sum, white biotechnology has been framed in the EU as part of a broader shift to a KBBE and the construction of 'a competitive, connected and greener economy' (EuropaBio 2010). Within this narrative, there has been a singular focus on innovation as the wellspring of value and on economic growth as a means of raising living standards in a 'depressed rural economy' – conditions met by the application of biotechnology to industry and the integration of farmers into bio-based supply chains (EuropaBio and ESAB 2006: 11). Crucially, governments have been tasked with lending public support to this technology and have themselves acknowledged that without this 'it may never get off the drawing board' (Mandelson 2009). This support has involved state targets for the substitution of bio-based products and standardisation of their 'green' credentials, as well as funding for further research and commercialisation at the EU and Member State level.

Reframing white biotechnology: Extant discourse, incipient critique and putative alternatives

Working in the field of science and technology studies, Stirling has noted how a range of academic disciplines have converged around the idea that new technology should no longer be seen as inevitable, unitary, and awaiting discovery in nature. Against this recognition, he then pointed to the irony evident in the 'exclusive, linear, deterministic notions of technological progress [that] still dominate policy debates' (Stirling 2008: 264). The orthodox framing of white biotechnology can certainly be seen to encourage this disjuncture. As the launch document for the European Research Area on Industrial Biotechnology described it: 'Industrial Biotechnology embodies the attempt to unlock the secrets of nature, to benefit humankind...ERA-IB wants to ensure that European scientists are in the driver's seat for this revolution' (ERA-IB 2006). Facing such teleological accounts, what interested Stirling was how different types of knowledge, understanding and evaluation could be constructed to inform alternative socio-political appraisals of technology.

This contested process of appraisal framing takes place through industry briefings, state strategy papers and stakeholder conferences – the communications used to inform our account of the KBBE – but also through the rationales and imperatives expressed in things like government consultations, academic assessments, media

[7] With a stress on renewable fuel in general rather than biofuel specifically, in order to leave the door open for hydrogen- and electric-powered vehicles

interventions and NGO initiatives. The values, facts and arguments expressed through these displays could offer up alternative routes to appraisal, especially in the embryonic stages of application where the aims and consequences of a given technology appeared ambiguous and uncertain (Stirling 2008: 266). As cautioned by Jasanoff, however, once specific frames have been established, they are often hard to revise or dislodge. This can deny novel viewpoints or radical critiques a hearing. Consequently, frame analysis 'remains a critically important, though neglected, tool of policy-making that would benefit from greater public input' (Jasanoff 2003: 241). Speaking to this requirement, we now discuss the incipient critiques of white biotechnology within the public domain and suggest how they could be constructed into wider-ranging and appealing alternative frames.

Alternative frame I: Ecological democracy, informed by reflexive ecological modernisation

Ecological modernisation was first conceptualised in the early 1980s by German social scientists Huber and Jänicke as a vision of how capitalist society could be guided into an environmentally enlightened era. As outlined by Toke three core elements characterise work from this perspective: the notion (1) that ecological and economic rationalities can be reconciled with a positive sum outcome; (2) that environmental protection and economic development are compatible and mutually desirable for the future; and (3) that these two trends will be achieved in the context of a market economy with active governmental intervention (Toke 2000).

Teasing out the discursive manifestations of these elements, Hajer (1995) has contrasted two versions of ecological modernisation. One is a techno-corporatist version that facilitates a search for the most effective technological solutions to unequivocal anthropocentric problems. This has clear overlap with the ontological suppositions and normative imperatives of the KBBE narrative. These include a view of nature as an adjunct to the human economy, and a preference for corporatist style of policy-making monopolised by scientific, economic and political elites. Indeed, the work of Huber on 'Technological Environmental Innovations' is mirrored closely in EU legislation on 'Key Enabling Technologies', both of which designated biotechnology as one of the innovations capable of assisting in the transition to a low carbon, knowledge-based economy (Huber 2008; CEC 2009b).

The second version, however, has more critical potential on the KBBE. What Hajer calls reflexive ecological modernisation is a discourse that attempts to strengthen public forms of debate in order to contextualise expert opinion and make environmental politics a matter of deliberate and negotiated social choice (Hajer 1995: 282). This is redolent of the work of Dryzek, who emphasised the need for an 'ecological democracy' that was able to offer a structural critique of the liberal capitalist political-economy and facilitate social learning (Dryzek 1997: 198). Reflexive ecological modernisation was reckoned to promote such possibilities through the emphasis it laid on macro-level analysis and authentic communication. Practically, spurring this communication involved reforming institutional arrangements, making debate more visible and vibrant through societal inquiry or discursive law, and involving people in constructing the social problem and not just the technological solution (Dryzek 1997; Dryzek, Goodin and Tucker 2009).

It would be incorrect to suggest that communication has been entirely sidelined from the promotion of the KBBE so far. Indeed, many of its advocates have taken pains to mention the importance of engagement with the public through things such as non-specialist briefing papers, organised visits to industry sites, and major stakeholder conferences on white biotechnology (EuropaBio and ESAB n.d.: IB-IGT 2009: 63). As made clear by EuropaBio:

> On an objective level, we know that industrial biotechnology has great potential to solve some of the difficult problems facing modern societies: environmental degradation, climate change, reliance on imported oil and gas, etc. However, we cannot assume that the average citizen will necessarily be comfortable with widespread use of biological processes by industry, particularly in instances where genetically modified micro-organisms are used (although in contained environments). In order to assure society's consent, society must be involved in an open dialogue at an early stage (EuropaBio and ESAB n.d.: 22).

As hinted at in this statement, genetic modification remains a sensitive issue and one closely entwined with white biotechnology. To meet the increased demand for fermentable biomass and to match petro-chemical processing costs, scientists have been tasked with developing both GM enzymes *and* GM crops/trees (Bevan and Franssen 2006). Indeed, in March 2010 the European Commission approved the cultivation of a GM potato specially bred for use as an industrial starch; the first GM crop approved since 1998 (CEC 2010). It is important, too, in a historic sense. Put simply, scientists and policy-makers in the EU want to avoid a repeat of the GM controversy that upheld the release of transgenic crops into the food chain. However, it is not immediately evident that the epistemological assumptions and normative visions underpinning public engagement has transformed significantly from the GM debate. Specifically, the role of deliberation remains marginalised. A number of social scientists working around industrial biotechnology have noted how the predominant objective has been to treat potential concerns as barriers to be overcome and to present technology as fixed and ready to be implemented (Calvert and Martin 2009; Schuurbiers et al. 2007). As a result, a danger remains that 'public dialogue' will be constructed more as means of legitimising a given technology, rather than an opportunity to shape research in the collective interest through ongoing dialogue and an openness to persuasion on all sides.

One instance where deliberation over white biotechnology has been attempted is in the UK. In 2008, the former Department for Business, Enterprise and Regulatory Reform (it is now the Department for Business, Innovation and Skills) commissioned two 'Citizen's Meetings' on the public perceptions of industrial biotechnology. These meetings lasted three days, with the first introducing the notion of white biotechnology and gathering participant questions, and the other two a series of presentations from experts, followed by group discussion and feedback to the assembled experts and policy-makers.

In its evaluation of the dialogue, the commissioned organiser Opinion Leader noted the success of the meeting in making the science accessible to participants and enabling feedback that addressed key policy questions. However, they also noted that:

> [B]ecause of the difficulty recruiting speakers from organisations that might be expected to hold less positive views about some of the uses of industrial biotechnology, there was a clear emphasis on the potential benefits of industrial biotechnology at the second Citizens Meeting,

> from both industry and independent speakers. This influenced the response of at least some participants to industrial biotechnology and also meant that the public's response to arguments against industrial biotechnology was not thoroughly explored (Opinion Leader 2009b: 2-3).

It should be stressed that NGOs and consumer groups were invited to participate in the meeting, but since the issue was an embryonic one and low on their list of priorities, they were unable to offer their assistance. This limited capacity for NGOs to articulate and promote their position is problematic since the involvement of civil society actors has been one the main reasons for introducing deliberative and inclusive policy processes in the first place (Newell 2010). Indeed, the participants themselves were keen to hear what groups such as Greenpeace and Friends of the Earth thought about these emergent technologies since 'the views of these organisations, and others independent of government and industry, such as think tanks, are largely perceived as credible sources' (Opinion Leader 2009a: 5-7).

Where debate is seen to be lacking democratic legitimacy, scepticism is likely to creep in over the supposed virtue of white biotechnology. It is against this background that the central involvement of WWF at the European level might be subject to enquiry within the frame of ecological democracy. In contrast to most other NGOs, WWF, and particularly its Danish branch, has been active in discussions about white biotechnology. In 2009 the NGO published a positive paper on the contribution that white biotechnology could make to climate change, suggesting that if properly nurtured it could prevent between 1 billion and 2.5 billion tonnes of CO_2 equivalent from being emitted per year from 2030 – more than Germany's entire emissions in 1990 (WWF 2009: 3). These figures have since been cited by EuropaBio in open letters and submissions to the European Commission (EuropaBio 2009b; 2010). The organisation also sits on the Biofuels Technology Platform's 'Sustainability Working Group', is one of only two NGOs in the 146 strong membership of the SusChem Technology Platform, and the only NGO to speak at the last three European Forums on Industrial Biotechnology. Many civil society actors have already criticised WWF for its pro-business approach to environmental reform, and particularly its tacit support for GM technology (see Corporate Europe Observatory 2009a). Given that WWF Denmark is chaired by Steen Riisgaard, a Board Member of EuropaBio and Chief Executive of Novozymes, one of the world's biggest enzymes producers, such involvement might be expected to come under further scrutiny and dissent.[8]

According to Dryzek, reflexive ecological modernisation is also conducive to the airing of a precautionary worldview, in contrast to the Promethean worldview that promotes new innovations as intrinsically beneficial. Such precaution is compatible with precepts of ecological modernisation in the sense that it is not necessarily anti-technological but simply maintains that particular technologies should be assessed in terms of how they interact with other aspects of social and natural systems (Dryzek, Goodin and Tucker 2009). It is in this light that incipient critique of bioplastics can be seen. Bioplastic packaging has been touted as environmentally beneficial since it can be 'easily discarded with the rest of organic waste and left to decompose on the compost heap, eliminating the need for expensive recycling or waste disposal by

[8] WWF Sweden also has links to biotechnology companies. Its chairman, Björn Hägglun, is also the board chairman of SweTree Technologies, a Swedish company involved in the development of GM trees. It should be noted, however, that the UK Chapter WWF has exhibited more interest in sustainable transport systems vis-a-vis its continental European counterparts.

burning or landfill' (EuropaBio 2004). However, in the US where bioplastics are a commercial reality, sceptical voices have quickly emerged. Some in recycling networks have suggested that most bioplastics still end up in landfill sites where it breaks down at the same rate and extensity as any other form of plastic. Others, such as the Berkeley Ecological Centre, have gone further and argued that the real problem remains over-consumption of resources through single-serving, over-packaged foods; a trend that if anything is obscured by the use of bioplastics (Royte 2006).

Thus, while the carbon savings of bio-based products are not disputed, this framing does question the aggregate consumption of such products and argues that eco-innovations must be supported by structural policies that address consumer behaviour and demand. In doing so it illuminates the danger of the 'rebound effect', whereby the carbon savings resulting from technological improvements in energy consumption are offset by an increase in consumption itself. Within the European setting, this has been evident in the debate around transport emissions and the argument that GHG savings from using lower carbon fuels are eroded by increased amounts of driving (Rayner, Russel and Lorenzoni 2008). Reflecting such concerns, in its summary report on the transport sector the UK government's Environmental Audit Committee stressed that policy focus should prioritise a 'modal shift towards lower carbon modes of transport.' This required moving 'the balance of affordability more in favour of trains, buses, and lower carbon cars and lorries' as well as tackling the demand-side of transport usage through policies such as road-use charges, cycling schemes and better town planning (House of Commons 2006: 3-13).

In sum, an 'ecological democracy' frame draws attention to the reasons given for the push toward a bio-based economy and asks policy-makers to take seriously the views and ideas of the public. In supporting deliberation in this way, this frame challenges policy-makers and trade associations to engage a wider set of actors in this issue-area and could expose them to difficult and overtly political decisions should support for white biotechnology not be forthcoming. It also challenges policy-makers to treat questions of human behaviour and social acceptability more centrally in the uptake of new technology and changing patterns of energy use. This could be a particular problem for the environmental credentials of white biotechnology should the rebound effect be taken seriously.

Alternative frame II: The industrialisation of nature, informed by agrarianism

The second discourse out of which a popular and cohesive frame on white biotechnology could emerge is agrarianism. According to the philosopher Paul Thompson, agrarianism offers a normative position on the role of agriculture in the modern economy: whereas an industrial view sees agriculture as just another economic sector to be charged with delivering outputs in the most efficient way possible, agrarianism sees agriculture as shaping individual and social values through its 'place-based' production (Thompson 2008). Working within the parameters of this perspective, a number of rural sociologists and political economists have addressed the subsumption of agriculture into industrial production processes and the challenges this poses to the cultural role played by farming.

The keystone work in this field is by Goodman, Sorj and Wilkinson (1987). This identified three structural barriers to the ascent of capital over nature. These were the inability of capital to fully control: (1) inputs, such as rainfall; (2) processing time, given the fixed crop seasons and animal gestation periods; and (3) production locale, which was determined by the quality of land. Yet by the same token, the authors also identified two ways by which capital could outflank nature by squeezing biological constraints out of the production process. One strategy was 'appropriationism', whereby firms would take control of discrete input factors such as manure or indigenous plant varieties by replacing them with industrially-produced fertilisers and commercialised seeds. The second strategy was 'substitutionism', which involved firms producing the chemical constituents of crops in factories rather than the field. Examples include the production of High Fructose Corn Syrup, a sweetener made from maize starch used to substitute for refined sugar, and mycoprotein, the meat substitute used in vegetarian meals (Goodman *et al.* 1987). Together these strategies were seen as responsible for greater industry control over agriculture and a profit-squeeze on those farmers increasingly dependent on the 'technological treadmill' (Goodman and Redclift 1989).

To suggest that these concerns may be raised in connection with the growth of the bio-based economy might at first appear ill-founded. Sensing an opportunity to sell produce into additional markets and/or the possibility of rising agricultural prices, farm groups have been in fact been supportive of the use of crops for biofuels and other non-food uses (COPA and COGECA 2007). Forming a politically expedient alliance, proponents of white biotechnology have also been at pains to point out the benefits of the technology for rural communities in the EU. This not only includes increased biomass production and new markets for agricultural crops, but also new conversion technologies which will create jobs in the rurally-based integrated biorefineries (Bevan and Franssen 2006: 727; EuropaBio and ESAB 2006: IB-IGT 2009: 15).

It is notable, however, that these outcomes jar with the express requirements of crop processors for cheap, reliable supplies of feedstock. To this end, EuropaBio have established a special working group to look at the availability of biomass in Europe and at the impact of EU policies on the price of agricultural raw materials (EuropaBio 2009a: 13). As already discussed, one policy to improve the supply based involves the promotion of GM crops. A policy that might be expected to cause a wider rift with farm groups, however, is in further liberalisation of the Common Agricultural Policy. An example of this occurred during the 2005 reform of the EU's sugar regime. Legislation on sugar already granted the European chemical industry production refunds on the commodity, since its use of protected EU sugar put it at a disadvantage vis-á-vis its international competitors who could access it at world prices. Seeing an opportunity to extend this system, EuropaBio lobbied during the reform process for the EU to adopt a two-tier price system whereby sugar for *all* non-food use would be priced at world market levels accessible through duty-free imports (EuropaBio 2005). Wary of such competition, in its policy proposals on the bio-based economy the European agricultural lobby group COPA-COGECA has maintained some clear blue water from EuropaBio. It has continued to lobby for restrictions on import of biomass, especially from Latin America, and, to make sure processors are not able to exert excessive pressure on farmers, has called for minimum prices or refunds on a wide range of crops (COPA and COGECA 2007).

Despite highlighting the contest over farm gate revenues, agrarian discourse is somewhat muted on this issue, at least within the EU, since these contests tend to involve clashes between agri-business and large commercial farmers. Neither of these actors elicits much sympathy from advocates of 'multifunctional' farming and 'place-based' production. To the extent agrarian discourse has offered prescriptions on the value chains emerging in the bio-based economy, it has been via the ownership of the proposed integrated biorefineries. Specifically, it has been suggested that rural development will be better aided if these processing plants are owned by farming co-operatives rather than agri-businesses; the latter option simply replicating the current market asymmetries seen in the bulk food and feed value chains (Morris 2006; Paula and Birrer 2006: 258).

Where this discourse has greater resonance is in the treatment of nature within capitalist economies and the political power of capital spawned by the industrial penetration of agriculture. Chiming with work on linked ecologies, recent agrarian scholarship has suggested that nature should not simply be seen as a series of obstacles or constraints facing capital but also as an arena of opportunity and surprise (Boyd, Prudham and Schurman 2002). It was considered an opportunity since capital sought not just to 'get round' biology but also work 'through it' by increasing biological productivity. This could happen through things such as greater yields, metabolic rates of growth or photosynthetic efficiency. Based on this reading, biotechnology was seen as a tool to make nature 'work harder, faster, and better' (Boyd *et al.* 2002: 564). The element of surprise was introduced to nature, meanwhile, to account for the tendency of industrial production to degrade the environment in unforeseen ways, altering the 'conditions of production' on which it depended by creating super weeds, draining underground aquifers or depleting soil fertility.

Traces of these arguments can be seen in some of the incipient critique on 'second generation' cellulosic biofuels. Within the KBBE the use of cellulose from plant 'wastes' and 'residues' such as straw is framed resolutely as a way to avert the problems linked to excess land-use and rising food prices. Civil society actors by contrast have been more sceptical of what they see as disingenuous claims of natural abundance. The environmental organisation 'The Action Group on Erosion, Technology and Concentration' (ETC Group) for example has suggested that the use of plant sugars for bio-based products and fuels will come hand-in-glove with use of genetically engineered, and one day fully synthetic, microbes that convert sugars into high-value molecules. Aside from the safety risks it perceives in 'extreme genetic engineering', the organisation also questioned the extent to which cellulosic biomass will be available in the quantities needed, suggesting that its proponents have failed to learn from the unforeseen effects of first-generation food-crop biofuels in which food prices rocketed (ETC Group 2008). Likewise, *The Ecologist* magazine has raised the issue of a 'corporate grab on plant-life' as the shift to a cellulosic material base provides the opportunity to commercialise a wider amount of plant matter. The danger attached to this is that is treats non-commodified nature simply as a 'surplus', underplaying the role of forests in cleaning air and water, algae in regulating climate, and crop wastes in renewing soil (Thomas 2009).

Based on the notions of opportunism and surprise, civil society groups have stressed the limits of technical arguments in assessing the merits of the bio-based economy

and pointed to what they see as the nefarious political role played by companies in convincing policy-makers to lend their support. Drawing ire in particular have been the new alliances among multinational companies, necessitated by the large and multifaceted investment required in white biotechnology refineries and commodity chains (World Rainforest Movement 2008: 6). These alliances typically involve combinations of energy companies, chemicals manufacturers, crop processors, enzyme producers, and agricultural input companies. Many of the same companies re-appear in different national advisory boards that effectively lobby on white biotechnology policy, often in the name of national competitiveness. Again, this stands in contrast to the perspective offered within the KBBE vision, which emphasizes instead the benefits of white biotechnology for small and medium-sized enterprises able to profit from intellectual property innovations (EuropaBio 2010).

The corporate alliances are criticised by civil society actors for their 'excessive' control over natural resources and economic sectors. On the one hand, this is reckoned to weaken the accountability of those companies simultaneously engaged in 'primitive accumulation' in the Global South (see Thrift 2006: 300). This refers to fossil fuel extraction and plantation monoculture, which many NGOs oppose for causing ecological degradation and social exploitation in the first place (Friends of the Earth n.d.: 6). On the other hand, within developed countries, these alliances are said to capture public funding and bureaucratic support in the interests of the private sector. For instance, the Corporate Europe Observatory has noted that the EU has spent millions of Euros under its Framework Programme 7 on research into GM trees and the effective promotion sugar cane monoculture in Brazil – decisions hardly in keeping with public sentiment. The NGO notes while the European Commission has a list of independent experts to approve funding projects, a number of these in fact work for biotechnology companies and the Commission never discloses which experts decide on which project (Corporate Europe Observatory 2009b). As an alternative, many of these groups advocate 'ecologically compatible farming'. Chief among these is organic farming, which has been promoted as a more reliable and cheaper way of reducing GHG emissions and promoting rural development than biotechnology (Friends of the Earth 2007). By way of example, the UK's organic trade body has suggested that if all farmland in the country was converted to organic farming, over 93,000 direct jobs would be created and at least 3.2 million tonnes of carbon taken up by the soil each year – the equivalent of taking nearly 1 million cars off the road (Soil Association 2006 and 2009).[9]

Conclusions

In providing ways to replace energy intensive chemical processes and substitute for fossil-fuel derived products and fuels, white biotechnology is already reshaping the material base of the industrial economy. Thus far, analysis by social scientists of this shift has generally been discussed in relation to a particular end-product, namely biofuels, or in relation to the broader promotion of biotechnology within the knowledge-based economy. This paper has attempted to focus analysis on the initial

[9] The Soil Association (2009) considers organic farming a more energy efficient system of food production since it does not use inorganic nitrogen fertiliser, which is produced from petro-chemicals. It also offers the prospect of additional GHG savings through soil carbon sequestration, which arises since more grass, legumes, compost and farmyard manure is kept on the land.

framing, and putative reframing, of white biotechnology itself and the socio-economic issues that the use of this technology arouses. Following literature in the discipline of science and technology studies, it is maintained that during the embryonic stages of the commercialisation of new technology, especially when political support remains paramount, framing remains an important route for agency and contingency. The choice of policy questions to be answered, the remit of specific institutions, the prioritisation of research and the setting of agendas can all be reshaped through alternative discursive frames (Stirling 2008).

The discourse with most resonance to the public appraisal of white biotechnology in the EU has been ecological modernisation. This spawned two discernible, though not entirely distinct frames. One of these has been the orthodox frame of the Knowledge-Based Bio-Economy (KBBE). This was a narrative formed within the milieu of Brussels in the mid-2000s that fused the techno-corporatist environmentalism of ecological modernisation with the logics of competitiveness contained in discourse on the Knowledge-Based Economy. It laid emphasis on the prevention of environmental degradation through upstream technology and the necessity of greater innovation to enable European agriculture to compete on the global level and create 'better' jobs – i.e. more qualified with higher productivity – in its manufacturing sectors (Joint Research Centre of the European Commission 2007; DG Research 2008). This focus on the techno-fix has helped motivate greater research funding and its commercial application as a route to achieving the EU's Lisbon Agenda. In doing so it has also implicitly challenged budgetary support to be reoriented away from redistributive purposes and towards tackling common challenges (CEC 2005: 5).

Drawing on Hajer's and Dryzek's notion of reflexive ecological modernisation, an alternative to the KBBE narrative was identified in the 'ecological democracy' frame. Like its techno-corporatist sibling, this perspective recognised that environmental protection and economic development were compatible and mutually desirable, and recommended that policy-making and delivery involve state, industry and civil society actors. However, more emphasis was placed on the participation of 'lay' people in technological appraisals, informed to a greater degree by civil society actors independent of the vested interests perceived amongst government bureaucracies and corporate beneficiaries of biotechnology. Related to this, proponents of this frame have questioned the mechanistic metaphors accompanying the KBBE narrative and instead conceived white biotechnology in open-ended terms. Allowing for the 'interference' of society in the adoption and adaptation of technology, this has resulted in the advocacy of supporting institutions and practices to enable the bio-based economy to function properly. At points, it has gone further by directing attention to the rebound effect and the need to 'reduce, re-use and recycle' to limit ever-increasing consumption.

The third putative frame on white biotechnology was labelled the 'industrialisation of nature'. This was rooted in agrarian discourse and its critique of the increasing penetration of agriculture by industrial capital. This concerned the reductive process by which field crops were transformed into chemical constituents for industrial products, which was reckoned to lead to a greater price competition among different commodity producers, the deskilling of farmers, and the concentration of production in companies developing proprietary knowledge. Taking the re-worked account of appropriationism and substitutionism provided by Boyd *et al.*, the replacement of

chemical processes and fossil-fuel derived products enabled by white biotechnology has been understood in this frame not only as making nature work 'harder, faster and better' but also making it work *further.* By moving into non-food commodity chains long dissociated from agriculture, the bio-based economy is seen as a route for the biotechnology industry the opportunity to realise and extend investments previously stymied by European regulations on GM organisms. In doing so, it has reignited concerns, mainly among NGOs, of the effects of expanding capital-intensive agriculture including dispossession in developing countries and a privatisation of the commons.

As a final thought, it is worth considering to what extent these alternative frames are truly oppositional to the orthodoxy. As a broad brush statement, the 'ecological democracy' position can be seen as enabling an instrumental critique of the KBBE linked to its ability to deliver environmental gains, while 'the industrialisation of nature' narrative encourages a more normative critique linked to the role of farming in the contemporary global economy. Where they overlap at present is in the precaution exhibited over the macro-level impacts of a bio-based economy and recognition that private sector-led techno-fixes cannot by themselves 'solve' the crises confronting capitalism. The persuasiveness of this argument, if not always its accuracy, was demonstrated in the reform to EU biofuels legislation following clamour over their link to food insecurity and deforestation in the Global South.

However, notable fissures between the ecological democracy and industrialisation frames remain. Support for participation and authentic communication is one, since many NGOs and corporations remain reluctant to work with one another. As Gillian Madill, former genetic technologies campaigner at Friends of the Earth turned industry consultant has argued: 'Many environmental groups are consumed with trying to hold these large firms accountable for past environmental harms they attribute to these companies, making it difficult to foster a collaborative relationship between these firms and environmental groups' (Madill 2009: 215). Another is the belief about the true limits on growth imposed by agro-ecological frontiers. For instance, more radical campaign groups have called the use of industrial biotechnology a 'green mirage' and suggested that policy-makers must instead support 'solutions that we know work' (Greenpeace, ETC Group and Biofuelwatch 2009). The resultant calls for a moratorium on biofuel production, better energy-saving policy and more small-scale agriculture instead return us to a deep-seated critique of capitalism evident since Marx, namely the inability of the biosphere to sustain life as long as the drive to capital accumulation operates. Where scepticism over the compatibility between growth and sustainability remain, opportunity for collective endeavour is unlikely.

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