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Sustainable Bioenergy:
What UK innovation priorities? Sustaining what futures?

Introduction

As a central feature of UK energy policy, bioenergy has been defined as 'sustainable' (or not) according to its biomass sources, conversion methods, products and uses. Given future limits of sustainably sourced biomass, UK policy seeks to broaden the range of biomass convertible to energy in cost-effective and environmentally sustainable ways, especially from non-food sources. Technoscientific innovation is promoted for this aim and for wider economic benefits.

Bioenergy expansion and innovation have been driven partly by targets. Under the 2009 Renewable Energy Directive, EU member states must obtain 10% of their transport fuel from renewable sources – mainly meaning biofuels in practice by the 2020 deadline. The UK must obtain 15% of all its energy from renewable sources by 2020 and seeks ways to fulfil more than half through bioenergy. The UK has more ambitious longer-term targets, beyond renewable energy per se: the Climate Change Act 2008 mandates GHG reductions of at least 34% by 2020 and 80% by 2050, relative to a 1990 baseline. Bioenergy has been also advocated for benefits such as energy security, technology export and waste management.

Bioenergy innovation has been promoted through various support measures –R&D funds, scale-up investment and operational subsidy. Questions discussed here:
What have been innovation priorities for bioenergy in UK public-sector funds?
What has shaped these priorities?
What potential paths remain marginal?
What are implications for future priorities?

Steering priorities through state-industry arrangements

More so than other European countries, the UK government is dependent on large multinational companies for bringing energy R&D to the commercial stage – which could happen anywhere in the world. Policy language is ambiguous about responsibility for fulfilling environmental targets, which will be delivered by 'technology' or 'the market', as if these were independent external forces. Likewise policy language is ambiguous about techno-scientific priorities for bioenergy innovation: policy makers say, 'We do not pick winners; industry is better at it.'

Despite such ambiguous language, support measures for bioenergy innovation have been steered in practice through arrangements between state bodies and industry, e.g. the Technology Strategy Board. Scientists' R&D proposals advocate specific technological pathways as means to fulfil various policy aims and to attract private-sector sponsors; such co-funding has been an advantage (or even a requirement) for gaining Research Council grants.

Through the Energy Technologies Institute (ETI), scale-up projects depend on agreement among several multinational companies sharing financial risks and benefits. Such capital investment is meant to bridge the 'valley of death' between research and commercial application.
Operational subsidy has aimed to incentivise techno-scientific innovation but has played a marginal role in doing so, especially given the high investment costs.

Linking environmental and economic benefits as drivers

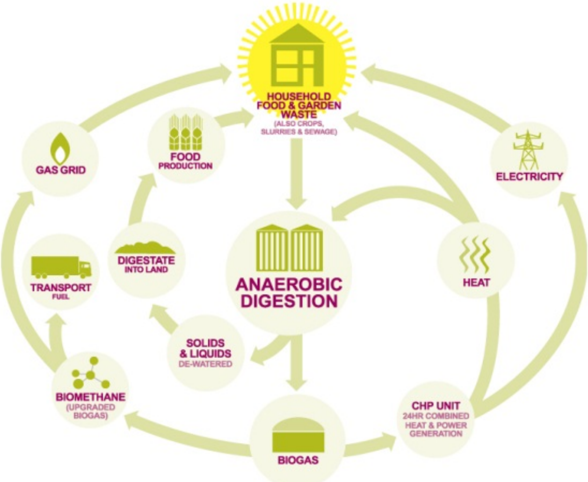
Environmental aims have tensions between different targets and timeframes. Bioenergy expansion is most immediately driven by 2020 targets for renewable energy. But the most cost-effective, feasible pathways may not be optimal for reducing GHG emissions. Under budget constraints, support measures have favoured the most feasible pathways to fulfil renewable energy targets for 2020, especially biomass-to-electricity. This priority has limited support for some longer-term pathways seen as offering greater GHG reductions.

Various R&D priorities have been promoted by linking expectations for environmental and economic benefits. Multiple criteria for benefits offer opportunities to advocate many different innovation pathways. But some have mobilised resources more successfully than others (see Table on final page).

Prospective economic benefits have two main categories: reducing the national costs of GHG savings (relative to other available means), and enhancing or capturing economic value. The latter includes: building on or contracting out UK technoscientific expertise, gaining patents and globally licensing them, creating employment in 'green-collar jobs', maintaining the capital-investment value of current infrastructure, reducing the costs of waste management, etc.

The strategy anticipates a national competitive advantage. By targeting technoscientific areas of particular national strength, 'the UK could potentially capture 5-10% of the global market within select niches of bioenergy', according to the 2012 Bioenergy Technology Innovation Needs Assessment (TINA). Yet UK research institutes and companies have been competing against each other for arrangements with overseas partners. Thus the search for economic value involves tensions between cooperation and competition, both nationally and globally.

Innovation priorities favour bioenergy mainly as input-substitutes within centralised large-scale infrastructures, especially current ones. But there are exceptions. Support measures have recently favoured R&D for biowaste conversion through anaerobic digestion, which can help to decentralise energy systems and has prospects for greater sustainability through technoscientific innovation. Beyond GHG savings, other foreseen benefits are lower economic costs of waste management and technology export for converting food waste.



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Combined heat & power (CHP) offers a relatively more sustainable use of biomass – through conversion efficiency, heat usage and decentralisation – according to UK policy over the past decade. CHP's environmental sustainability can be further enhanced through technoscientific innovation such as pyrolysis. Biomass CHP depends on institutional innovation through new infrastructure for district heating, but this has lacked investment for significant expansion, except for energy use by some local authorities and companies.

Anticipating benefits, allocating funds

While seeking future benefits, UK bioenergy strategy also anticipates risks – e.g. high uncertain cost, unsustainability, biomass competition and lock-in. Such risks converge somewhat with potential investors' uncertain costs of bringing R&D to commercial application; they seek ways of de-risking innovation, e.g. by reducing or sharing costs through government assistance. But investors seek a long-term commitment to specific pathways, along lines that the policy framework may see as a lock-in risk, especially through commitments to specific infrastructure and employment.

To avoid various risks, UK bioenergy strategy identifies medium-term 'low-risk' innovation pathways. Rather than new dedicated biomass plants, for example, the strategy promotes more biomass co-firing with coal, whose current plants are expected to become obsolete by the 2020s. Yet such expansion meanwhile reinforces electricity-only production (losing the heat), still largely dependent on fossil fuels.

UK strategy also advocates three innovation pathways – biohydrogen, advanced biofuels and gasification – as longer-term 'hedging options' to deal with future uncertainties. Such pathways could more effectively convert various forms of waste. Future expectations have played roles in R&D funding priorities, as follows:

Biohydrogen: For at least a decade the UK government has advocated hydrogen fuel cells, powered from renewable energy sources, as a replacement for fossil fuels. Such fuel cells in electric vehicles were anticipated for significant commercial adoption by 2020. Modest R&D funds have been allocated to biomass conversion to hydrogen, i.e. biohydrogen. This has been advocated as a sustainable transition beyond the internal combustion engine and current vehicle infrastructure. Partly for this reason, biohydrogen attracts little industry support and remains marginal as an innovation pathway.

Advanced biofuels: In 2007 advanced biofuels were expected to make a significant contribution to the 2020 target for transport fuel, thus helping to justify UK policy to increase biofuel targets (at least through 2013). By 2010 the earlier expectations were postponed until the 2020s, yet the original policy rationale has continued to drive both the targets and R&D funds. These support measures are also driven by expectations for economic benefits from building on UK technoscientific strengths, especially through research co-funding from companies and research institutes abroad. R&D agendas seek 'drop-in fuels' as exact substitutes, thus protecting past investment in fuel and vehicle infrastructure. Regardless of whether current biofuel expansion locks out advanced biofuels, innovation priorities may reinforce dependence on liquid fuel.

Gasification: To promote gasification, in the late 1990s the government funded an expensive scale-up project; it was expected to achieve commercial application but soon ended in failure. Other technical failures have followed in the past decade. Despite such difficulties, gasification has recently gained greater priority for funding. It is foreseen as a flexibly facilitating various bioenergy pathways, especially for biowaste conversion, for which UK companies could gain a competitive advantage. Whenever advanced technologies make biowaste-CHP more economically viable, however, such plants may be sited near large waste-handling facilities, generally distant from potential heat users.

Amongst those various pathways, then, some expectations for technoscientific progress have become more uncertain or longer-term over the past decade, though without necessarily undermining support measures. Expert reports have evaluated technical progress and future feasibility, but technical prospects alone do not explain the funding priorities. Expectations for future economic benefits have played a strong role, while conflating national benefits with private-sector interests.

Sustaining what future society?

In anticipating environmental and economic benefits, state bodies have promoted visions of societal futures (see Table). In continuity with fossil-fuel systems, bioenergy has been largely promoted as an input-substitute within current infrastructure. Such pathways have gained relatively stronger support measures for technoscientific innovation. Despite the policy aim to avoid lock-ins, UK innovation priorities reinforce high-carbon, energy-intensive infrastructure such as electricity-only production and the internal combustion engine dependent on liquid fuel.

From a different societal vision, bioenergy has been advocated as a means to decentralise energy systems, given the spatially distributed character of biomass. Likewise bioenergy can facilitate community and consumer involvement, e.g. through biomass micro-generation or CHP. Through their design, users' knowledge of renewable sources can be linked with behaviour reducing energy use and GHG emissions.

But such pathways have received little state support, so opportunities are being lost. The policy framework makes several assumptions about feasible futures – e.g., that large-scale centralised systems are more cost-effective for GHG savings (except small-scale anaerobic digestion); and that input-substitution invisible to consumers is more reliable for GHG savings, which thereby should not depend on behavioural changes by energy users.

Questions about policy implications:
How are bioenergy innovation pathways being steered and limited by policy assumptions about feasible futures?
What prospects to open up broader options offering greater societal benefits?

Diverse state visions of UK bioenergy innovation

The Table summarises linkages between state visions and UK bioenergy innovation pathways, as listed in the first column. Each vision anticipates environmental and economic benefits. Through such expected benefits, UK innovation funds have favoured some innovation pathways (e.g. biofuels and AD) more strongly than others (CHP, energy crops and biohydrogen).

Issue	Environmental sustainability	Economic advantage
VISION *+ innovation pathways*		
Decentralisation: Promoted by DTI, BIS, DEFRA	Develop more efficient means to recover local bio-resources, especially waste, thus supplying local energy needs and complying with EU rules on waste disposal.	Reduce cost of biowaste management and generate products with commercial value. Provide an economically viable energy source independent of centralised supply.
Combined Heat & Power (CHP)	Convert local biowaste into CHP near heat users, thus minimising energy loss. Increase conversion efficiency via pyrolysis and optimal boiler design.	Licence patent on small-scale CHP (e.g. pyrolysis, gasification, etc.). Attract investors to a small-scale system more efficiently converting biowaste.
Anaerobic Digestion (AD)	Expand AD to recover and even re-cycle biowaste, so that the digestate is no longer classified legally as waste (i.e. as a burden).	Promote a competitive domestic base for manufacturing and exporting AD technology.
Agri-diversification Promoted by DEFRA	Improve & diversify crops for the environmentally most sustainable uses, e.g. materials as well as energy.	Diversify the added-value of agri-inputs and outputs that can help maintain farmers' livelihoods and the rural economy.
Perennial energy crops: Promoted by DECC & Research Councils – but not DEFRA	Identify/improve crop varieties so that their cultivation better sequesters soil organic carbon, minimises external inputs and produces biomass more easily convertible into bioenergy.	Develop UK plantations, biorefineries and necessary infrastructure, which together can provide skilled green-collar jobs, support the rural economy and enhance social sustainability.
Oil substitution	Develop more efficient methods to convert non-food biomass for cleaner fuel.	Develop proprietary knowledge for global competitive advantage.
Advanced biofuels: Promoted by DECC, DfT & Research Councils	Convert biomass into advanced biofuels and co-products, save more GHG emissions than conventional fuels can do, and avoid conflict between 'food vs fuel'. Build on UK strengths in crop and enzyme research to develop more environmentally sustainable inputs and processes for bioenergy. Fulfil more stringent EU requirements for GHG savings by converting non-food biomass, especially waste.	Convert waste/surplus biomass more efficiently into competitive biofuels. Prioritise strategic research that can enhance the competitiveness of UK bioscience and industry to gain economic benefit from international co-operation. Develop drop-in biofuels as direct substitutes, thus maintaining the economic value of current infrastructure and individuals' access to private transport.
Hydrogen fuel cells (using biohydrogen): Promoted by DfT and CCC	Improve biowaste conversion to bio-hydrogen in order to reduce pollution, improve air quality, recycle sewage sludge and reduce GHG emissions.	Gain a competitive advantage for fuel-cell technology export, so that innovation leads growth and employment.