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What Next For Bioenergy?

Chair's Summary Report on behalf of the Advisory Board Convened for the Committee on Climate Change's Bioenergy Review Report

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Disclaimer: This report is written by the chair of the Advisory Board convened by the Committee on Climate Change to provide expert advice in relation to its bioenergy review. It endeavours to provide summary of some of the key issues discussed during the review, but does not claim any consensus from board members in relation to particular issues.

1. Introduction

The Committee on Climate Change (CCC) convened an independent, expert advisory board (AB) to support its bioenergy review, comprising:

Dr. S. Cornelius, WWF
Prof. I. Donnison, University of Aberystwyth
Dr. J. House, University of Bristol
Prof. R. Murphy, University of Surrey
Prof. P. Smith, University of Aberdeen
Prof. G. Taylor, University of California Davis
Prof. P. Thornley, Aston University **(chair)**
Mr I. Tubby, Forestry Commission
Prof. K. Willis, Kew Science

The board met 5 times: in February, April, June, July and August and contributed to additional meetings to gather evidence on particular issues e.g. governance, greenhouse gas (GHG) emissions. The AB reviewed and provided feedback on the CCC's objectives, progress and interim findings. This report summarizes the main significant themes which emerged during those discussions. They are presented independent of the CCC's main report and capture the general priorities and advice given by the AB, particularly where this challenged existing assumptions.

2. Sustainable bioenergy potential

Decarbonisation of the energy system is essential to meet climate commitments. Various low carbon energy options exist; of which bioenergy is one. An ideal energy system would provide energy of the desired type and quality on demand with no environmental impact or cost, but such a system does not exist. The reality is that we must "pay" for our energy needs. This includes direct economic costs as well as environmental and social costs. Different resources and conversion technologies provide energy with different associated impacts and there are generally trade-offs between these; no system is impact-free. The challenge for sustainable energy provision is maximizing energy security, while minimizing environmental and economic costs. Bioenergy provides storable, dispatchable energy (and fixed carbon), which can be a significant energy system/security asset. However, there are 3 key challenges around its use:

1. The occupation of land gives rise to significant physical and market interfaces e.g. with water, food, land, transport and material/product systems, resulting in (potentially positive and negative) ecosystem and socio-economic impacts.
2. Biomass can be converted into many different energy and product vectors with different markets, commercial values, carbon abatement and energy service potential and identifying the optimal use from the variety of conversion/use pathways can be challenging and uncertain
3. Efficient bioenergy systems often rely on multiple actors in a bioenergy value chain who have diverse priorities and incentives to engage in bioenergy provision. Alignment of individual priorities is key to satisfying higher level sustainability objectives and needs to be taken into account for effective governance frameworks.

Biomass production could deliver ecosystem benefits and dispatchable bioenergy can be deployed to support low carbon energy systems, but some biomass production systems have negative impacts and not all bioenergy vectors are low carbon. Global implementation to date has included some facilities that are delivering low carbon energy while supporting wider industrial and social development but also ill-conceived plants that are not making positive greenhouse gas impacts, have caused negative ecological impacts and/or social disturbance. This diversity has resulted in a contested landscape where bioenergy is often viewed as contentious and stakeholders may be polarized. Recent research has improved the scientific data and engineering understanding to facilitate more confident identification of "good" and "bad" feedstocks and practices and more realistic projections of achievable engineering performance. This report summarizes how the AB used that knowledge to support the CCC review.

3. Biomass production: challenges and opportunities

Biomass production can broadly be categorized into the following feedstock categories:

- Oil bearing plants
- Starchy plants
- Sugar containing plants
- Ligno-cellulosic materials including forest products, energy crops, agricultural residues and other waste materials

While there is a huge variation from one crop to another and even for different management regimes within a crop the yield of the energy relevant part of the crop increases as we move down through each of these categories, while the level of agrochemical input required broadly decreases. However, the most appropriate conversion technologies also change, influencing the energy and product vectors to which the raw biomass can be converted. Each biomass category also has different typical ecosystem impacts. Oil bearing crops often have high levels of pesticides that impact on biodiversity, starch crops frequently require high nitrogen application levels giving rise to poor greenhouse gas balances, sugary crops are often associated with water pollution and in some places field burning after harvest.

3.1 Land use

Bioenergy is part of an energy system, with demand from the energy sector, dictating feedstock requirements. However, biomass production is also part of a land system with finite assets to provide multi-functional uses. When land-use models are deployed to explore different levels fo biomass production this can become polarized as a conflict between food production and fuel production. However, crop cultivation may confer other valuable (particularly eoc-system) benefits. The AB shared with the CCC various examples of appropriately planted system conferring ecosystem benefits of improved biodiversity, increased soil carbon and fertility, protection from extreme weather events (including flood mitigation) and restoration of contaminated sites. These are real, tangible benefits of biomass production that are not generally measured, maintained or monetarily valued. Most AB members concurred that a UK bioenergy strategy should be part of a land management strategy that integrates food production and delivers ecosystem service provision, while conserving biodiversity. This holistic approach cannot be delivered by focusing on energy demands or land use separately.

3.2 Climate Interface

The reality of living with environmental change is that we need to mitigate our carbon emissions, but simultaneously adapt to the impact of climate change. This will be particularly important in the UK agricultural sector, where climate change may influence crop viability and yields. Successful adaptation is underpinned by the maintenance of ecosystem service provision to ensure continued plant and crop growth. Therefore there is an opportunity to encourage appropriate biomass production as part of an integrated land management strategy that incorporates food production, eco-system service provisioning and land amenity and recreational value.

3.3 UK Supply

This integrated land strategy would include maintenance/expansion of primary forest cover and bioenergy has the specific advantage here that it could provide and intermediate source of income for long term afforestation strategies. A relatively high proportion of UK forests are certified as "sustainable" and this supports confidence in biomass sustainability. While UK supply may be limited stimulating a domestic supply chain would support transparency and build confidence in certification efficacy.

3.4 International Supply

Biomass production can also provide valuable ecosystem services overseas. The AB gave examples of overseas production of biomass conferring wider ecosystem benefits and being deployed as part of an adaptation-mitigation strategy. Also concerns were expressed about countries where governance and institutions were not sufficiently well developed to ensure regulatory compliance.

3.4 Waste Management and Circular Economy Opportunities

Biomass feedstocks include agricultural residues and wastes from conservation/land management. These are often preferred because they are readily available, give rise to minimal sustainability concerns and are considered "carbon neutral" under some incentive or reward schemes. However, the AB warned that real GHG impact is acutely sensitive to the use context and counterfactual (what would have happened to the material if it were not used for bioenergy). While it may make sense to encourage sustainable behaviour (reuse of waste materials) by ascribing incentives it must also be recognized that conversion of these materials do result in tangible GHG emissions to atmosphere and so consideration of whether significant carbon is sequestered during the life cycle is still relevant.

4. Bioenergy Technology: challenges and opportunities

4.1 Agricultural Technology

The yield of an energy crop, agricultural residue or forestry system has a strong influence on achievable decarbonisation, with higher yielding plants generally preferred if they can be efficiently converted. Research to improve yield via breeding and biotechnology should result in higher commercial yields with the critical time frames for decarbonisation objectives.

4.2 Biomass Energy with Carbon, Capture and Storage (BECCS)

BECCS is often prioritized in energy system models because of its negative emissions potential. The separate components of some BECCS technologies are technically feasible, but the engineering challenges associated with practical implementation should not be underestimated. Innovation mechanisms that allow research community knowledge and understanding to be integrated with industrial deployment could accelerate progress.

The UK's science and engineering base in solid fuel conversion, process and subsurface engineering, position it well to lead global BECCS deployment with other nations. Therefore CCC scenarios evaluating the potential of a UK are very pertinent. However a key obstacle to BECCS development is the lack of a governance framework that will actually incentivize a sustainable global biomass system. It is vitally important that any BECCS facility really achieves maximum greenhouse gas reductions across the implemented system. This can only be effectively managed by having oversight and adaptive control of the whole system, which is not encouraged by the current territorial accounting framework for GHG emissions and there is no appropriately positioned international body that could effectively monitor or incentivise this.

4.3 Renewable gas (Hydrogen and syngas potential)

Future UK bioenergy could use gasification to produce a syngas that could be upgraded to methane and injected into the gas grid or used directly as an alternative to natural gas. In addition the CO/CO_2 could be removed and hydrogen distributed. It is important to reflect the synergy between BECCS and hydrogen in energy system projections and ensure that biomass-derived hydrogen pathways are adequately considered alongside other methods of hydrogen production.

Gasification is a key enabling technology here and, while there is significant UK expertise and ongoing activity the technical and engineering challenges should not be underestimated. Innovation mechanisms that accelerate two-way knowledge transfer between the research and industrial communities and develop strategic international partnerships could support deployment.

4.4 Aviation biofuels

Biofuels are a near-term, viable option for aviation fuel decarbonisation. However, it is important that we ensure projections of high levels of biofuel penetration adequately consider the need to adapt the wider fuel system. Additionally caution is needed to ensure that the carbon intensity assumed for aviation biofuels takes full account of the substantial processing and upgrading requirements and their associated energy/carbon burdens.

An alternative would be to consider a fuel that had a different specification from the current standard and it would be interesting to evaluate the extent of carbon reductions that could be achieved by that route in order to judge whether the carbon benefits would justify the corresponding innovation and economic needs.

5. Enhancing Climate benefits of bioenergy systems

Bioenergy systems can deliver low carbon energy but performance varies immensely. Recent academic research has improved understanding of the key drivers of GHG emissions and how carbon sequestration benefits can be maximized. It is therefore critical to ensure that energy system and land-use models are informed by the latest scientific understanding and performance projections and the advisory board worked with the CCC to review assumptions and suggest detailed modifications. Some AB members felt future yield assumptions were more pessimistic than technical improvement potential through R&D would suggest while some felt engineering plant performance often had optimistic projections based on theoretical models that were unlikely to reflect actual future performance.

Board members were keen that we aim for maximum climate benefit from the sustainably available biomass resource and noted that a focus on minimum performance standards fails to incentivize best performance. Given the myriad of feedstock, technology and product options the only way of incentivizing the best performing systems seems to be measuring and rewarding the carbon impact. However, doing this in a way that will ensure real climate benefits requires consideration variation and variability in bioenergy system performance.

5.1 Variation

Variation may be connected to system choices e.g. the chosen crop has a higher yield than a previous crop, a higher set of steam conditions delivers higher boiler efficiency; an additional cleaning step results in an additional energy penalty. These are definable, deterministic and can be controlled or regulated.

5.2 Variability

Biomass is a natural material with associated natural variability e.g. nitrous oxide emissions after fertiliser application may vary with weather conditions, soil carbon uptake during crop growth may vary with previous land use, losses during storage can vary with moisture content and weather conditions. Statistical techniques allow us to account for the uncertainty and we may identify and manage risk factors but full control of the variability may not be possible.

5.3 Measuring carbon performance

Attributional life cycle assessment is commonly used to assess the environmental performance of bioenergy systems. This is appropriate for assessment of a single supply chain and can deliver a sound assessment of the potential impact of a bioenergy system, though the actual impact may still differ because of natural variability.

Consequential life cycle assessment must instead be used to adequately understand the environmental implications of policy changes and large scale changes in agricultural production patterns or energy/commodity demands. That is a challenging and complex task and there are very few examples of appropriately framed consequential LCA assessments that have been adequately informed by real world understanding of both the biomass production and engineering conversion systems. That makes decision making challenging. However, it is essential to consider the impact of implementation of a particular bioenergy strategy. Therefore policy decisions on bioenergy strategy should be informed by consequential life cycle assessment e.g. of the scenarios in the main report.

While there have been many bioenergy system models created at different scales, only limited validation has been carried out. The board was aware of significant advances in land use data sets from satellite and other sources and it was suggested more could be done to monitor impacts and inform/validate models. This is particularly for “indirect land-use change”, where it should now be possible to measure the extent to which projections of land-use change have actually manifested and use real data to validate model projections and calibrate accordingly.

The UK is committed not just to long term climate targets, but to interim emission budgets and concerns have been raised that life cycle assessments miss the dynamics of a carbon debt being incurred that may take years to “repay”. In reality the outcomes of such calculations are extremely sensitive to boundary conditions, time-consuming to carry out and complex to interpret. However, it is important that the temporal emissions associated with future bioenergy options for the UK are considered with a cumulative emissions framing at least for key potential futures.

5.4 Ensuring sustainability

The black and white nature of dealing with either "certified" or "uncertified" feedstocks does not encourage continuous improvement or sharing of good practice. The overhead cost of certification was seen as a barrier to market access by some of the producers who would benefit most from the socio-economic benefits associated with supply trade and there were repeated concerns raised about the prospect of "cherry-picking", the wisdom of applying one standard to a crop grown for bioenergy and a different one to the same crop grown for another purpose and the need to understand the consequences of the UK securing "certified" supplies from particular countries/suppliers.

6. Conclusions

- Bioenergy deployment should ensure minimum performance thresholds that are better than the fossil fuel alternative
- Sustainability is about more than carbon and trade-offs between environmental, social and economic impacts should be considered as part of an integrated land management strategy
- International imports are a significant opportunity (for the UK and producer countries) **IF** we can be confident they are sustainable. The UK has led global certification and supply chain assessment and a high level of transparency and a focus (initially at least) on lower risk production areas would instill confidence in their utility
- There were concerns about the limits of certification as the primary response to sustainability concerns and establishing a governance framework that promotes and builds confidence in sustainable supply chains was viewed by some as the biggest single barrier to sustainable bioenergy implementation.
- We know what the lower risk feedstocks and regions are and that there is sufficient scientific understanding to identify the most appropriate bioenergy solutions, but these are not being incentivized by the current policy framework.
- A robust, flexible governance framework is needed that excludes the detrimental systems, incentivizes best practice (incorporating recognition of eco-system and natural capital values) and recognizes the realty of system trade-offs in a contextually appropriate way.
- Such a framework could recognize variable global governance capacity by requiring different compliance standards in different regions, informed by an overall risk assessment.
- Where governance is weak the lack of institutional frameworks may have to be weighed against the potential of modern bioenergy to shift unsustainable wood use to productive uses that support economic development and growth in emerging economies. Sustainability is balancing the needs of today's generation against those of future but we also need to contextually balance the present needs of different global communities, given their different development trajectories.

Despite the urgency of the climate change challenge and availability of bioenergy systems that could deliver today against climate and other environmental objectives, deployment is much too slow and strong policy commitment is now needed to drive this forward.