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Aims of the review and approach

Aims:

Assessment of the potential role for bioenergy in meeting carbon budgets given:

- lifecycle emissions and other sustainability concerns
- alternative uses for bioenergy feedstocks (e.g. wood in construction)

Approach:

Blocks of analysis

- Lifecycle emissions (Chapter 2)
- Sustainable bioenergy supply (Chapter 3)
- Appropriate use of bioenergy (Chapter 4)
- Conclusions and recommendations
  - Bioenergy role and support
  - Sector use
  - Lifecycle emissions
  - Carbon budgets strategy (Chapter 5)
What is bioenergy?

Source: Bauen et al, 2009
Current UK bioenergy use is small, but a large increase is expected to 2020.

Data is on an output basis. On an input basis, 2010 bioenergy use is 79 TWh.
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Today’s report - key messages

• Around 10% bioenergy penetration plus CCS may be required to meet the 2050 target, and could be sustainable
  - Lower penetration requires unforeseen technology breakthroughs or radical behaviour change
  - Higher penetration would be unsafe from a sustainability perspective (e.g. encroaching on land required for food production, or of high biodiversity value).

• Lifecycle emissions of bioenergy can be significant – regulatory frameworks at EU and UK levels need to be strengthened to make sure bioenergy is truly low-carbon.

• Bioenergy is a scare resource and should be used to maximise abatement:
  - without CCS: wood in construction, industrial heat, aviation and shipping
  - with CCS: wood in construction, various CCS applications
  - not in power without CCS, or cars and vans

• Key priorities should be to develop CCS, develop bioenergy options, invest in a range of other low carbon technologies (e.g. electric vehicles, heat pumps).
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Bioenergy crops absorb carbon from the atmosphere as they grow.

Incomplete carbon accounting under international rules – partially addressed through EU and UK bioenergy sustainability criteria.

‘Zero’ rated in carbon budgets.

And release the carbon when combusted.

Additional emissions due to cultivation, production, transport, land-use change (direct and indirect).
Liquid biofuel feedstocks - cultivation, production and transportation emissions

Combined emissions could potentially be significant, but can be reduced through choice of crop and production process.
We also need to take account of land use change emissions (direct and indirect)

Direct Land Use Change

- Arable land growing maize for food
- Divert some land to grow bioenergy crops

Indirect Land Use Change

- Tropical forest
- Convert forest to grow displaced maize production
- Displaces food production to elsewhere
- Releases emissions
Direct land use emissions can result in very long carbon payback periods (e.g. up to hundreds of years)

Source: Fargione (2008)
Indirect land use change emissions are highly uncertain but estimates suggest risks of increased emissions through use of biofuels.

Source: CE Delft (2010)
EU framework should be extended to cover indirect land use impacts

- The current sustainability framework under EU RED does not include indirect land use impacts
- Therefore risks possibility of increased emissions where these impacts occur
- Framework should be extended to cover indirect land use impacts
- Two options: ILUC factors (i.e. uplift lifecycle emissions estimates); cap use of feedstocks at sustainable levels.
- Crediting growth of feedstocks on degraded land would complement both
- UK Government should support extension to cover indirect land use impacts
Implications of including ILUC emissions

Might result in need to adjust targets for biofuels downwards (e.g. Gallagher Review questioned whether 10% penetration achievable). This would not compromise the achievement of carbon budgets.

Source: EU-RED, IFPRI (2011)
Solid biomass feedstocks - ambition in power and heat generation will have to be met largely through imports.

Power and heat sectors may require ~30 million tonnes of solid biomass in 2020 (UK Renewable Roadmap, 2011) = total amount currently used by all wood consuming sectors (primarily construction, wood panels, pulp & paper).
EU 2020 biomass ambition goes beyond estimates of global sustainable supply

- 2020 EU ambition (solid biomass)
- Power generated from combusting global forest biomass (200 Modt + implied shortfall)

- Implied shortfall to be met from other sources (e.g., increased forest management, dedicated plantations, agricultural residues)
- Global forest biomass resource
- Heat energy
- Power generation
There is a risk is that the 2020 ambition could be achieved using forest biomass with relatively high emissions and displacing current wood demand to unsustainable sources.

Source: Environment Agency BEAT2
Need to strengthen sustainability framework under RO / RHI

• Current sustainability framework under RO / RHI limits risks of direct deforestation, but not indirect (i.e. displacing current wood demand to unsustainable supply sources)
• Emissions saving under current framework is low, particularly given risk of indirect impact; small saving relative to CCGT
• Increase required emissions saving (tighten standard for biomass from 285 gCO₂/kWh to 200 gCO₂/kWh)
• Consider broader sustainability standard for all wood in UK / EU
• May need to adjust ambition if sustainable supply not forthcoming
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We have developed four scenarios of bioenergy supply from growing dedicated energy crops.

Our aim is to illustrate a broad range of alternative futures. In doing this we have to be aware of sustainability constraints as well as recognising the uncertainty in our results.

**Food security:** Even now at a relatively low level of bioenergy use, there is some evidence that biofuels is one of many significant factors driving food price spikes in recent years.

**Biodiversity:** Abandoned agricultural land often has high biodiversity value.

**Water stress:** may constrain ability to grow energy crops / or development may exacerbate water shortages.

**Ethical and social issues:** “abandoned” land rarely unused and serves a variety of purposes, e.g. subsistence farming and common grazing.

Uncertainty is inherent in bioenergy supply estimates:

- Land use data
- Impacts of future climate change
- Complexity of factors affecting global land use and agricultural production
A rising and increasingly wealthy global population will lead to a 70% increase in food demand by 2050.

Global population to reach almost 9 billion by 2050

Incomes grow by 2.7% per year between 2030 and 2050

Average daily consumption rises from c.2820 to over 3130 kcal per day between now and 2050

Meat consumption Increases from 37 kg to 52kg/person/yr

The UN FAO forecast a small increase (5%) in the amount of arable land required for food production on the basis that increased demand can largely be met through agricultural productivity improvement.

Productivity improvement at historic rate - 2% per year for cereals - would free-up additional land but this is unlikely going forward

Sustainable intensification and innovative farming practices will be required to make more effective use of land and water resources.
Limited scope for bioenergy on land required for food: we identify abandoned agricultural land* as potentially suitable for bioenergy crops.

FAO/IIASA estimate ~4,200 Mha of land suitable for crop production.

BUT most of this land is/should be protected: any future expansion should focus on abandoned agricultural land*, which will not compete with food production.

* Abandoned agricultural land is land previously used for cultivating crops but is no longer in production due to a variety of reasons, as estimated by Campbell et al., (2008); Cai et al., (2011).
Our core scenarios focus on the use of abandoned agricultural land – we also include two further land conversion scenarios, which are highly uncertain.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Area (Mha)</th>
<th>Constraints/Conditions</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constrained land use (CLU)</td>
<td>100</td>
<td>Low yield, stringent nature conservation and water constraints</td>
<td>Low yield (5)</td>
</tr>
<tr>
<td>Extended land use (ELU)</td>
<td>400</td>
<td>Relax environmental constraints on abandoned agricultural land</td>
<td>Low yield (5)</td>
</tr>
<tr>
<td>Further land conversion (FLC) (Agricultural land)</td>
<td>700</td>
<td>Implies productivity improvement OR diet shift</td>
<td>Yield 5 - 15</td>
</tr>
<tr>
<td>Further land conversion (FLC) (Natural habitats)</td>
<td>700</td>
<td>Implies conversion of unprotected woodland/grassland</td>
<td>Yield 5 - 15</td>
</tr>
</tbody>
</table>

We assume in the longer term dedicated energy crop feedstocks are a mix of fast growing trees and grasses, as these crops are potentially more suitable to land of low productivity, have low lifecycle emissions and can be converted for use across the range of sectors.
The IEA Blue Map scenario is within our range – between our Extended and Further Land Conversion scenarios.

Global potential from dedicated energy crops (2050)

IEA Blue Map scenario assumes 11% of total primary energy demand could be met by energy crops by 2050, our scenarios represent 1, 5 and 18%.
There is a wide range of estimate, and our scenarios are at the low end of the range from the literature.
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Global potential from dedicated energy crops: land area and energy potential

Chart adapted from Slade, et al., (2011)
Our UK scenarios give a range of bioenergy penetration in 2050 from 5 to 22% of primary energy demand. Our analysis suggests that a reasonable share of potential sustainable bioenergy supply could extend to around **10% of primary energy demand in 2050**. Unsafe to assume higher levels of supply and even the 10% might require some trade-offs with other desirable objectives (e.g. biodiversity loss).
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Limited supply relative to potential demand mean trade-offs between sectors will be required.
Scarce bioenergy supplies should be allocated where they are most highly valued

Energy service demands
Bio supply
Available technologies
CO₂ emissions constraint

after efficiency improvements

Least cost optimisation

Full bioenergy lifecycle emissions included

Bio
Other

Heat
Transport
Power

Aim to identify robust strategies across the range of abatement options and uncertainties
10% bioenergy penetration together with CCS will be required to meet long term targets.
Hierarchy of appropriate use

Desirable
- Wood in construction, industrial heat

Desirable depending on circumstances
- Power/heat production with CCS
- \( \text{H}_2 \) production with CCS
- Liquid biofuels with CCS for aviation/shipping

CCS available

CCS not available
- Liquid biofuels for aviation/shipping

Undesirable
- Liquid biofuels for surface transport, biomass power without CCS
There is a transitional role for use in surface transport.
Power sector implications

**Long-term** (large-scale power generation)
- If CCS viable
- If CCS not viable

**Short-term**
Transitional role to meet renewables target

**Options:**
- New large-scale dedicated plants
- Co-firing / conversion of existing coal plants
- Small-scale plants (using local resources)
- Combined heat and power plants (e.g. using biogas)
There is a significant cost-effective opportunity for biomass conversion and co-firing, but not new dedicated biomass plant.

Conversion: Over 100 TWh of generation at 80-90/MWh (central fuel prices) - enough to meet Renewables Roadmap ambition.
UK Govt is proposing 1.5 ROCs for new dedicated plant versus 1 ROC for conversion / enhanced co-firing.

But Scottish government has proposed to limit support to small-scale plant and CHP.

Proposed levels of support under RO risk new capacity at considerable additional cost to consumers (e.g. 3-4 GW in the pipeline would cost consumers £175 million/GW/yr)

We recommend a focus on co-firing/conversion, some small scale / CHP but no / very limited support for new large scale biomass.
Key conclusions for appropriate use

Wood in construction and industrial heat are always desirable. For other uses, the availability of CCS is a key determinant of how desirable they are.

**Power sector**: very limited role for new biomass power plants without CCS

**Industry**: clear role for the long-term use of bioenergy in energy-intensive industry

**Aviation and shipping**: important in world without CCS, otherwise depends on the viability of CCS in aviation/shipping biofuel plant

**Surface transport**: transitional use with only niche use of biofuels in the long-term; possible use of hydrogen from bioenergy with CCS.

**Heat in buildings and biogas**: role for biomass boilers in off-grid areas and combined heat and power using local resources (e.g. waste anaerobic digestion)

A range of small-scale applications using local resources are also sensible
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Future work of the Committee

Scotland 1st progress report (January 2012)

Advice on inclusion of aviation and shipping (March 2012)
  - Required under CC Act to enable Government decision by end 2012
  - Build on considerations of 4th carbon budget report & Shipping Review

Advice on the role of local authorities in emission reduction (April 2012)

UK Progress Report (June 2012)

Wales 2nd progress report (October 2012)

Adaptation - 3rd Assessment of UK preparedness (July 2012)

Review of the 4th carbon budget (2013-2014)