Biomass and bioenergy: a vital component of the UK’s green economy?

Patricia Thornley, Mirjam Röder & Dan Taylor - Aston University
Andrew Welfle – University of Manchester

We work with academia, industry, government and societal stakeholders to develop sustainable bioenergy systems that support the UK’s transition to an affordable, resilient, low-carbon energy future.
Role of bioenergy in UK decarbonisation to date


Peter Coleman, BEIS
Potential of bioenergy in future UK energy supply

The power(?) of models

- **Specialist Models**
  - Deterministic:
    - Highly Focused Analyses of Complex Systems
    - Analysis of all technical aspects of bioenergy feedstock supply, conversion & use.
    - Validation of other bioenergy studies with broader scopes.
  - Probabilistic:
    - Sector impacts of bioenergy policies on agriculture, forestry, land use change, energy systems etc.
- **Energy System Models**
  - Deterministic:
    - Impacts of policy on energy generation, economics, GHG emissions etc.
  - Probabilistic:
    - Bioenergy's contribution to long term climate policy.
    - Impacts of bioenergy policies on global land use, water, biodiversity etc.
- **Integrated Assessment Models**
  - Deterministic:
    - Bioenergy resource potentials based on varying assumptions & criteria.
How does using trees reduce carbon emissions?

- Carbon sequestration during growth
- Combustion returns (relatively) recently sequestered CO2 to atmosphere
- Supply chain emissions usually low unless intensive farming or land-use change
- Sequestration fastest in earliest phases
- Main product from trees is saw-log timber (high value)
- Management of trees requires thinning
- Trees use land and need to provide a return to the land-owner

https://www.supergen-bioenergy.net/comic/
Conditions for significant carbon reductions

Sustainable growth (low input and land-use change) removing atmospheric carbon dioxide

Low supply chain emissions

Displacing carbon intensive incumbents
Low input

## Land-use change

<table>
<thead>
<tr>
<th>Biodiesel Type</th>
<th>% GHG saving assuming land converted from cropland (a)</th>
<th>% GHG saving assuming land converted from forestland (b)</th>
<th>% GHG saving assuming land converted from grassland (c)</th>
<th>Payback time (years) (a)</th>
<th>Payback time (years) (b)</th>
<th>Payback time (years) (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy (Brazil)</td>
<td>9</td>
<td>-2550</td>
<td>-699</td>
<td>0</td>
<td>5503</td>
<td>1523</td>
</tr>
<tr>
<td>Soy (Argentina)</td>
<td>44</td>
<td>-1134</td>
<td>-109</td>
<td>0</td>
<td>533</td>
<td>69</td>
</tr>
<tr>
<td>Palm (Malaysia)</td>
<td>48</td>
<td>-135</td>
<td>-12</td>
<td>0</td>
<td>77</td>
<td>25</td>
</tr>
<tr>
<td>Palm (Indonesia)</td>
<td>48</td>
<td>-185</td>
<td>-84</td>
<td>0</td>
<td>98</td>
<td>55</td>
</tr>
<tr>
<td>Rapeseed (UK)</td>
<td>36</td>
<td>-569</td>
<td>-123</td>
<td>0</td>
<td>335</td>
<td>88</td>
</tr>
<tr>
<td>UCO (UK)</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sugarcane (Br)</td>
<td>72</td>
<td>-299</td>
<td>-30</td>
<td>0</td>
<td>103</td>
<td>28</td>
</tr>
<tr>
<td>Soy (US)</td>
<td>27</td>
<td>-1143</td>
<td>-100</td>
<td>0</td>
<td>875</td>
<td>95</td>
</tr>
</tbody>
</table>

Upham, Thornley, Tomei & Boucher, Substitutable biodiesel feedstocks for the UK: a review of sustainability issues with reference to the UK RTFO
BIOENERGY -- LAND USE CHANGE

Biomass production changes the way land is used, and this can have positive and negative impacts - depending on where you start and where you finish.

IF YOU START WITH A FOOD CROP:
- HIGH CHEMICAL FERTILISER INPUTS
- OFTEN LOW BIODIVERSITY
- NEGATIVE IMPACTS ON WATER QUALITY
- SOIL DEGRADATION
- LOSS OF CARBON STORED IN SOIL

CONVERT TO A FOOD CROP USED FOR ENERGY:
- SAME ENVIRONMENTAL IMPACTS FROM CULTIVATION
- LOSS OF PRIME AGRICULTURAL LAND
- COULD DISPLACE FOOD PRODUCTION ELSEWHERE

CONVERT TO GRASSES (LIKE Miscanthus) OR WOODY CROPS (LIKE WILLOW) USED FOR ENERGY:
- IMPROVEMENTS IN BIODIVERSITY (IN SOME CASES)
- LOWER FERTILISER USE (IN SOME CASES)
- POTENTIAL TO INCREASE CARBON STORED IN SOIL
- LOSS OF PRIME AGRICULTURAL LAND
- COULD DISPLACE FOOD PRODUCTION ELSEWHERE

CONVERT TO AGROFORESTRY (A MIXTURE OF ENERGY AND FOOD CROPS):
- FEWER FERTILISERS
- IMPROVES SOIL QUALITY
- PROTECTS WATERWAYS
- INCREASES BIODIVERSITY
- INCREASES CARBON STORED IN SOIL
IF YOU START WITH "MARGINAL LAND" (ABANDONED OR DEGRADED AGRICULTURAL LAND):

- LOW BIODIVERSITY
- SOIL EROSION

CONVERT TO GRASSES (LIKE MISCANTHUS) OR WOODY CROPS (LIKE WILLOW) USED FOR ENERGY:
- PROTECTS SOILS FROM EROSION
- IMPROVED BIODIVERSITY
- INCREASED USE OF FERTILISERS

CONVERT TO FOREST FOR WOOD PRODUCTS AND BIOENERGY:
- DECREASED SOIL EROSION
- LARGE INCREASE IN CARBON STORED IN SOIL
- PROTECTS WATERWAYS AND WATER QUALITY
- LARGER INCREASE IN BIODIVERSITY
As well as the above, we also have to be careful that a change in one place doesn't cause a change somewhere else -- often far away.

This is termed 'indirect land use change (ILUC)."
Supply chain emissions

Röder, Whittaker & Thornley, How certain are greenhouse gas reductions from bioenergy? Life-cycle assessment and uncertainty analysis of wood pellet-to-electricity supply chains from forest residues, Biomass and Bioenergy, 79, 2015
Displacing carbon-intensive incumbents

Maximizing the greenhouse gas reductions from biomass: The role of life cycle assessment

Patricia Thornley a,*, Paul Gilbert a, Simon Shackley b, Jim Hammond b

a Tyndall Centre for Climate Change Research, School of Mechanical, Aerospace and Civil Engineering, University of Manchester, M13 9PL, UK
b UK Biochar Research Centre and School of Geosciences, University of Edinburgh, Craigmillar Campus, The King's Buildings, Edinburgh, EH9 3JN, UK

ABSTRACT

Biomass can deliver significant greenhouse gas reductions in electricity, heat and transport fuel supply. However, our biomass resource is limited and should be used to deliver the most strategic and significant impacts. The relative greenhouse gas reduction merits of different bioenergy systems (for electricity, heat, chemical and biochar production) were examined on a common, scientific basis using consistent life cycle assessment methodology, scope of system and assumptions. The results show that bioenergy delivers substantial and cost-effective greenhouse gas reductions. Large scale electricity systems deliver the largest absolute reductions in greenhouse gases per unit of energy generated, while medium scale wood chip district heating boilers result in the highest level of greenhouse gas reductions per unit of harvested biomass. However, anaerobic and biochar costs deliver the most cost-effective carbon reductions while biochar costs reduce.

Fig. 2 — Absolute greenhouse gas savings per unit of energy delivered.
Carbon debt? Depends on start and end-points

Roeder et al., Understanding the timing and variation of greenhouse gas emissions of forest bioenergy systems, Biomass and Bioenergy, February 2019
Allocating carbon emissions

- Emission intensity of bioenergy (supply chain emissions only)
- Emission reductions compared to emission intensity of UK grid (40-60%)

Sustainability beyond carbon

Thornley & Gilbert, “Biofuels: Balancing risks and rewards”, Interface Focus, 2013
Coffee production

Freites, Thornley & Roeder, Environmental trade-offs associated with bioenergy from agri-residues in sub-tropical regions: A case study of the Colombian coffee sector, Biomass and Bioenergy, 2020
Rice straw to energy

- Biogas pilot facility in the Philippines
- Provide a low-cost technology adapted to the needs of the location to manage rice straw, support energy access and socio-economic empowerment
- Test solutions for technical barriers (straw collection, handling, AD operations)

- **Assess environmental performance of biogas system**
Rice straw bioenergy emissions including use

Rice straw bioenergy socio-economic trade-offs of different business models

- Change of business model changes implications of different criteria
- Biogas business models socio-economic more beneficial than current agricultural and post-harvest practices

Sugar cane production

Sugar cane residues to bioenergy

Sugarcane bioenergy impacts

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Pathway A)</th>
<th>Pathway B)</th>
<th>Pathway C)</th>
<th>Pathway D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing agricultural emissions</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Dealing with residues and wastes</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Renewable energy</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Reducing health impacts from traditional biomass use</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Agronomic benefits</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Economic</td>
<td>Pathway A)</td>
<td>Pathway B)</td>
<td>Pathway C)</td>
<td>Pathway D)</td>
</tr>
<tr>
<td>Economic development</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Create employment</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Increased cost (labour and logistics)</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Fits into existing infrastructure</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Operational complexity</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Energy security domestic</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Energy security local</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
<td>😊</td>
</tr>
<tr>
<td>Access to investment</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Social</td>
<td>Pathway A)</td>
<td>Pathway B)</td>
<td>Pathway C)</td>
<td>Pathway D)</td>
</tr>
<tr>
<td>Empowerment of local population</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Justice and equality of electricity supply</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Decentralised energy infrastructure</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Horizontal supply chains</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Supporting ownership rights and equality in decision making</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Policy</td>
<td>Pathway A)</td>
<td>Pathway B)</td>
<td>Pathway C)</td>
<td>Pathway D)</td>
</tr>
<tr>
<td>Supporting policy framework</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
<tr>
<td>Crime and mismanagement</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
</tr>
</tbody>
</table>

Measuring sustainability in SGBH
Sustainable?

@SupergenBioHub
@EBRI_UK

Supergen Bioenergy Hub

www.supergen-bioenergy.net

p.thornley@aston.ac.uk