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Bioenergy value chains: Whole systems analysis and optimisation

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Overall project objectives

- Understanding the “merit order” of biomass technologies
- Explore interfaces between competing uses eg biomass and food supply
- Understanding cost reductions, lifecycle environmental profiles and system implications of bioenergy and biorenewables
- Understanding what it would take to achieve a significant (e.g. 10%) contribution from biomass for the bio-economy in the UK
- Developing scenarios describing what policies, infrastructure, institutions etc. would be needed and where they would be best allocated/implemented
- Understanding the international economics of bioenergy under different global scenarios, including the global costs and prospects for different bioenergy technologies
- Understanding what role the UK might have in global biomass trade.
- Benchmarking existing policy approaches for their current and expected market impact
- Lifecycle, techno-economic and socio-technical evaluation of the value chains associated with a material level of bioenergy in the UK

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Project elements

- Using global energy system and shipping models to understand the global economics of bioenergy and to examine how the global trade in bioenergy commodities might develop in the future under different global decarbonisation scenarios.
- Coupling UK energy system models with a detailed bioenergy system model including global commodity trade scenarios.
- Examining the role of bioenergy and interactions with other energy vectors in the UK energy system, taking account of spatial using the coupled models.
- Internalising domestic food staple production in the bioenergy value chain model (rather than the use of side-constraints)
- Developing quantitative evaluations of the differences in ecosystem services and impacts between sample bioenergy value chains and a reference trajectory
- Developing a set of technology risk/option and implementability analyses

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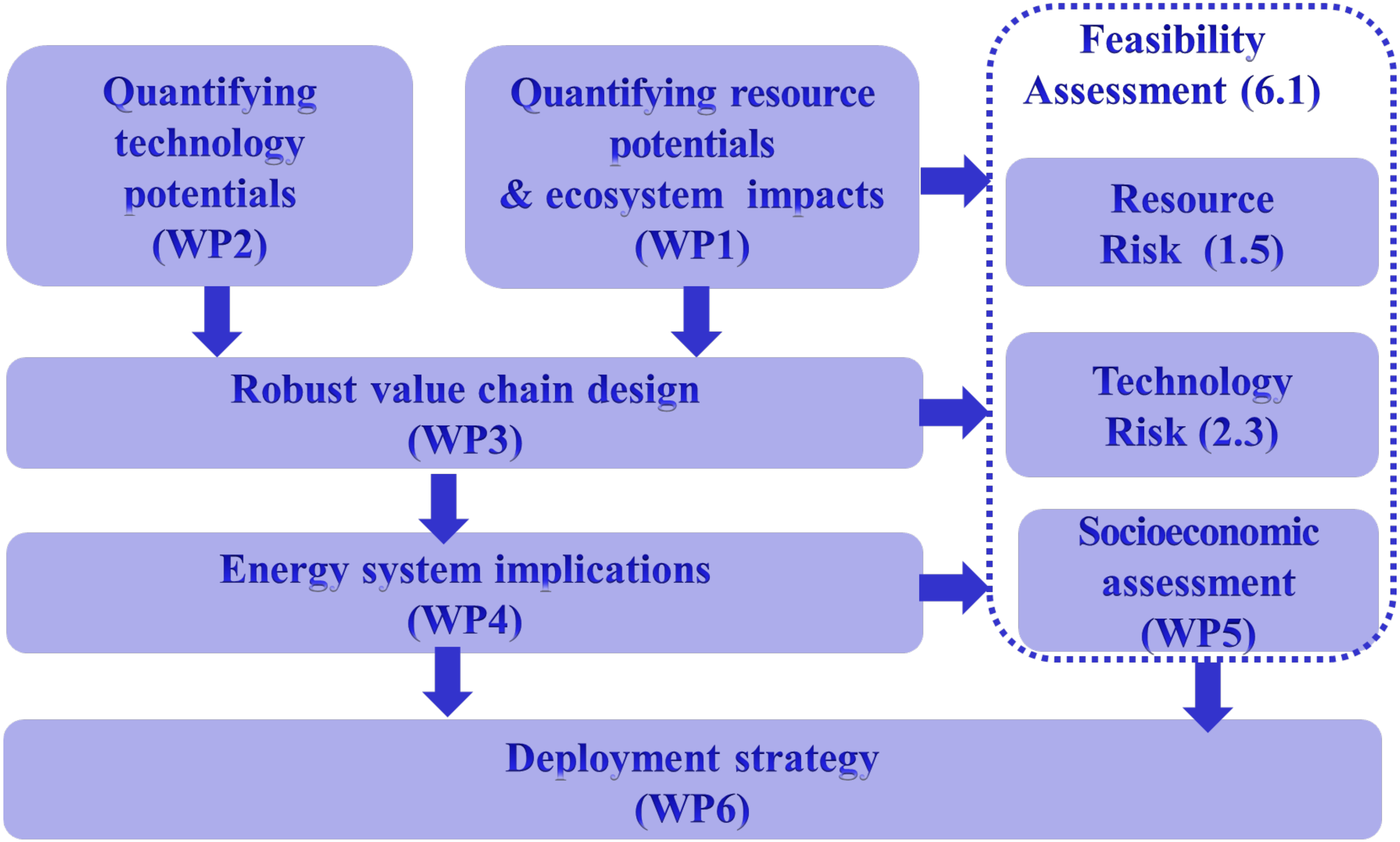
Project overview



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Model will build on BVCM project (ETI funded)

BVCM: A UK-wide optimisation model

Models pathway-based bioenergy systems over five decades (from 2010 to 2050)

Based on spatially explicit, flexible modelling methodology

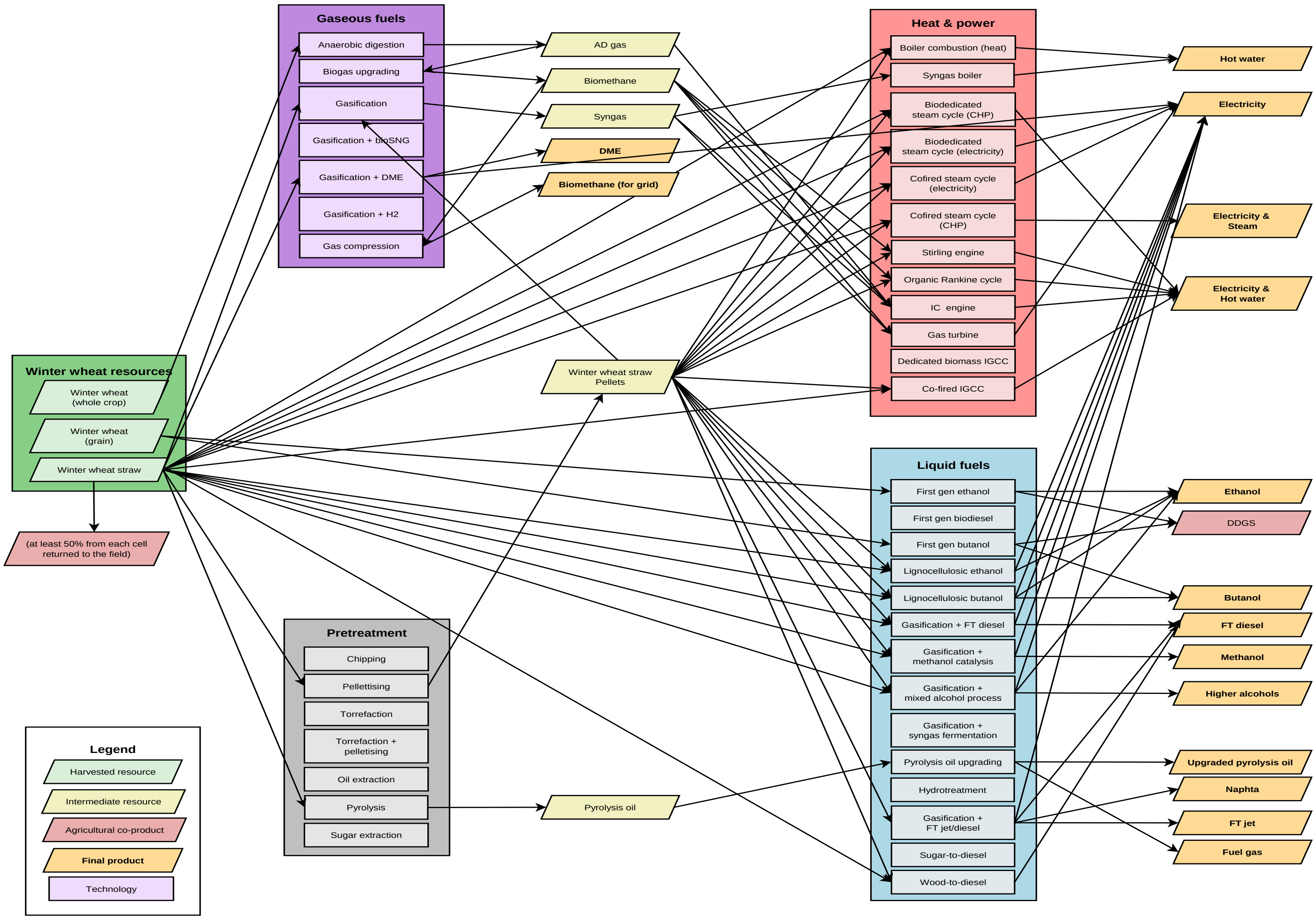
Biomass resource data (1G, 2G, waste)
Technology options
Energy vector demand data
Logistics

→

National bioenergy value chain structures
-What to grow?
-How to convert it?
-By time and space

Some **key extensions**: integrated food production, ecosystem services, detailed modelling of imports

Example of a Resource-Technology Chain: Winter Wheat

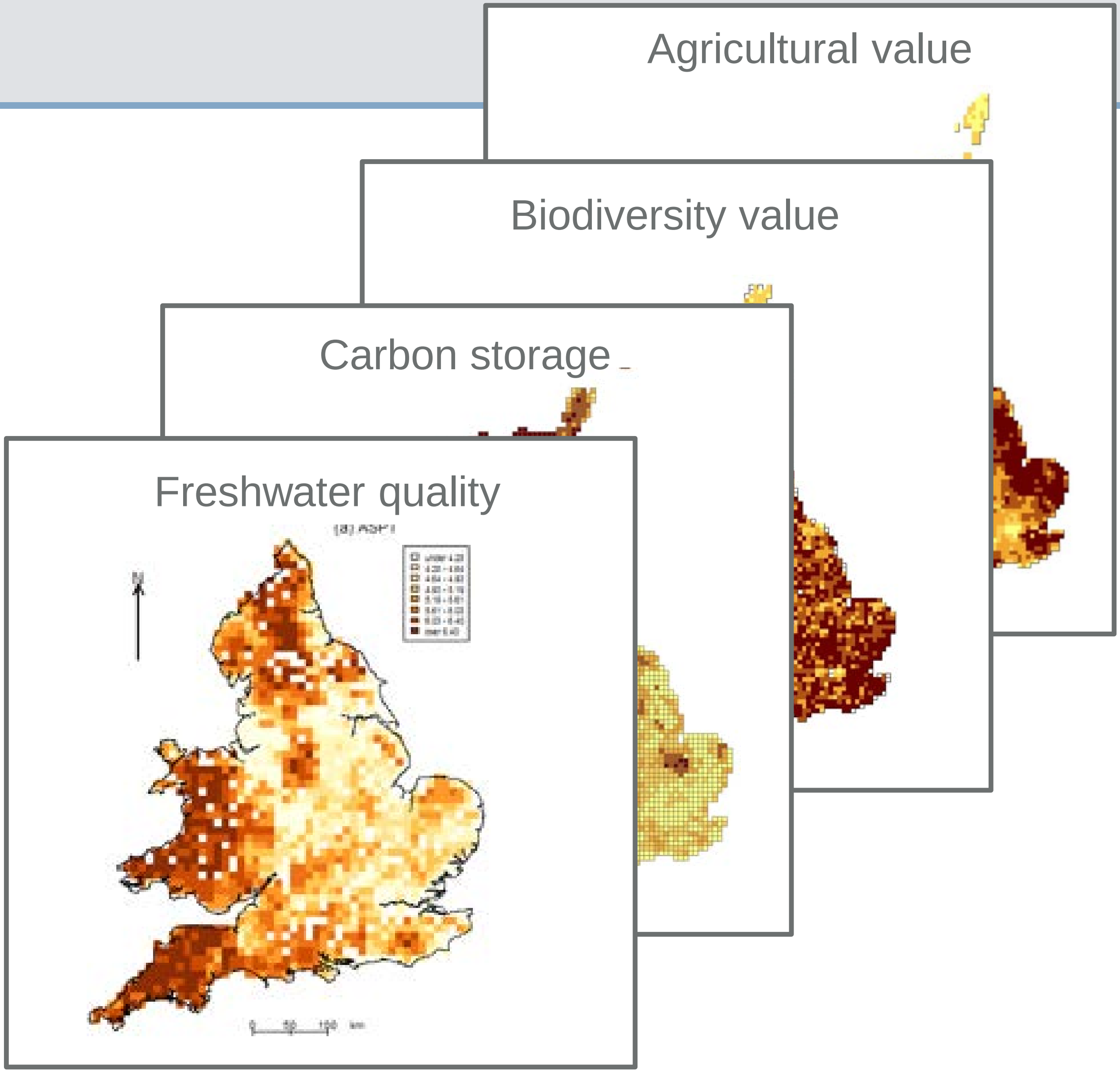


Incorporate ecosystem services

AIM: To incorporate a consideration of ecosystem services into the model

Provide a holistic view of impacts of differing bioenergy strategies. Identify win-wins and trade-offs.

Identifying key ecosystem services including (provisionally): energy productivity, food productivity, water availability, biodiversity, carbon, landscape value.



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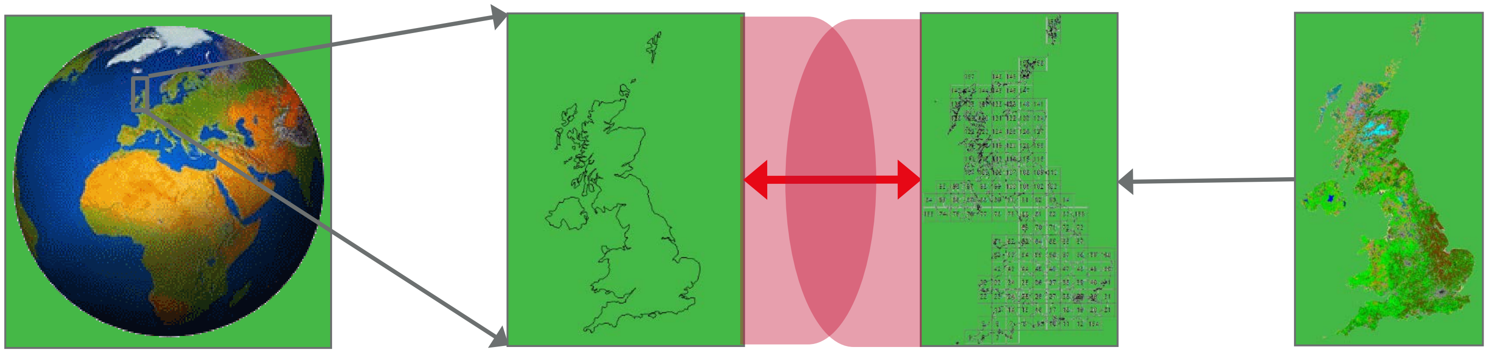
Implications of land use transitions (cf ETI ELUM project)

For individual 10 x 10 km grid cells develop crop and feedstock specific data on affect of land use transition.

This feeds into the BVCM model allowing us to examine implications of different deployment strategies.

Can run under different scenarios such as maximising conservation value, bioenergy production, food production etc.

Model data flows



TIAM-UCL (16 regions)

UKTM-UCL (1 region)

BVCM (157 regions)

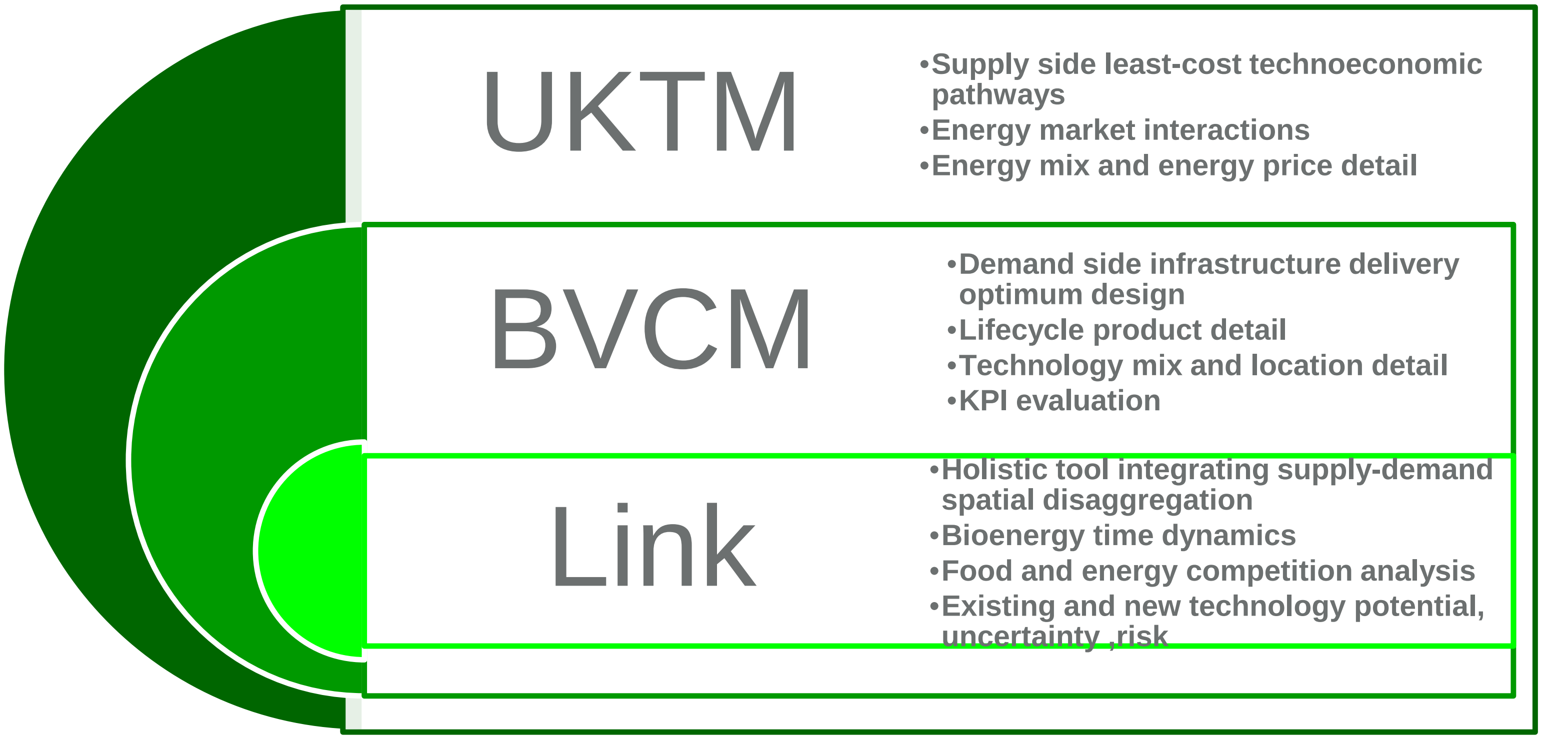
UK resource model

Global energy systems model gives insights on the likely availability of bioresource imports in the future, considering the global trade of biocrops and accounting for global demand in a decarbonising world.

A UK energy systems model, UKTM-UCL, will examine the role of bioenergy in the UK energy system using bioresource imports from TIAM-UCL, and supplies boundary conditions for the BVCM. BVCM data are fed back into UKTM-UCL and the soft-linked models are iterated.

Energy system and optimisation model linkage

Bioenergy pathway tool integrating energy market interactions and infrastructure optimisation detail



Issues with existing energy system models

Most existing energy systems models, particularly global models, have a number of important shortfalls when representing bioenergy:

1. a lack of spatial detail for biomass production and transport costs;
2. limitations on the location of biomass CCS plants are not considered;
3. trade-offs of centralised versus decentralised production are analysed under generic assumptions.
4. limited interactions with non-energy sectors (e.g. agriculture and forestry);
5. inconsistencies with other related processes, such as afforestation, where the same land is used twice in the model;
6. the lifecycle impacts of bioenergy are not fully represented so the GHG emissions from bioresources are underestimated;
7. The flexibility to introduce different KPI (i.e., environmental or social impact metrics) is limited, making it difficult to fully evaluate the sustainability of the solutions obtained.
8. the carbon debt of bioenergy, for example the 20 years required to regrow a forest after the wood has been burned, is not considered; and,
9. the time-dependent dynamics of bioenergy, for example the time required to grow a forest or even to grow a short-rotation coppice, are not considered.

Improving bioenergy in energy system models

These issues are being addressed in the global TIAM-UCL and national UKTM-UCL energy systems models by:

Representing land as a finite resource within the models. Different land types are represented separately and the model chooses the proportions of land use for different purposes (food crops, biocrops, grassland, forests, etc.) in order to meet food production and other constraints.

Calculating cost curves for biomass transportation, both within and between world regions, to better represent the costs of importing both raw and refined fuels.

Incorporating all direct and indirect GHG lifecycle emissions related to bioenergy.

Including bioenergy related socio-economic key performance indicators

Introducing lead times required to cultivate biocrops.

More details: Paul Dodds (p.dodds@ucl.ac.uk) and Nagore Sabio (n.sabio@ucl.ac.uk)

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WP6: Simulating value chain deployment

Aim: explore critical time-dependent characteristics of bioenergy implementation in the short (5-10 years) and medium (10-20 years) term, assessing alternative implementation strategies.

Whole systems feasibility assessment

Characterise value chains with potential for short-term deployment (drawing on WPs 1-5).

- Technological maturity
- Short-run feasibility
- Opportunity costs of deployment
- Sensitivity to scale/time effects

Dynamic simulation

Develop a dynamic simulation framework to:

- Compare alternative implementation strategies
- Assess robustness of strategies to external shocks

Causal relationship mapping

Map structure of value chains including causal relationships and key decision-making variables.

Develop roadmaps to show:

- Value chain dynamics
- How dynamics affect implementation
- Potential deployment pathways

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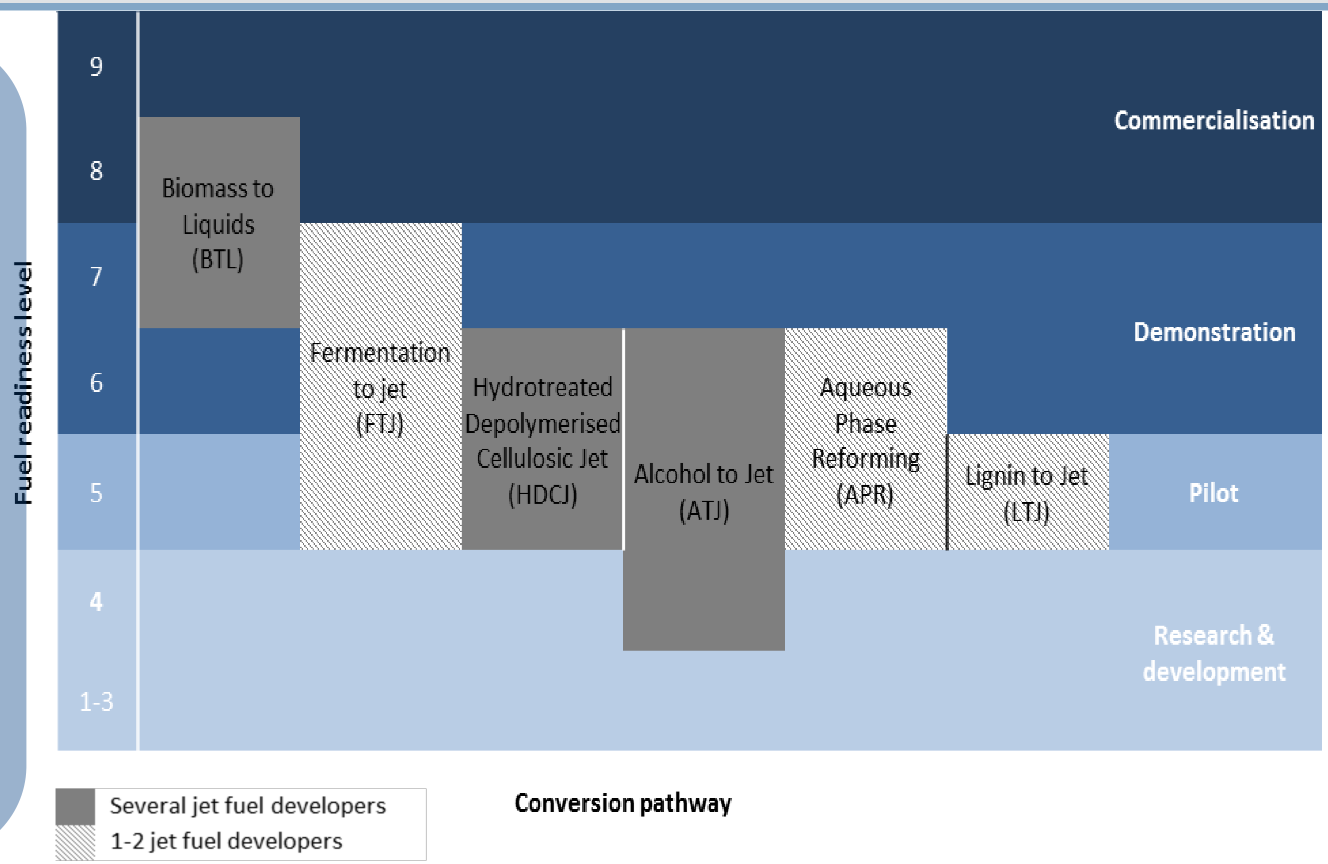
WP6: Mapping aviation biofuels

Comparative assessment of biojet value chains:

- Technological / commercial maturity
- Economic viability
- Focus on technologies with potential for deployment by 2020



WP6 next steps:

- Characterise second UK value chain (miscanthus/SRC)
- Develop first value chain simulation

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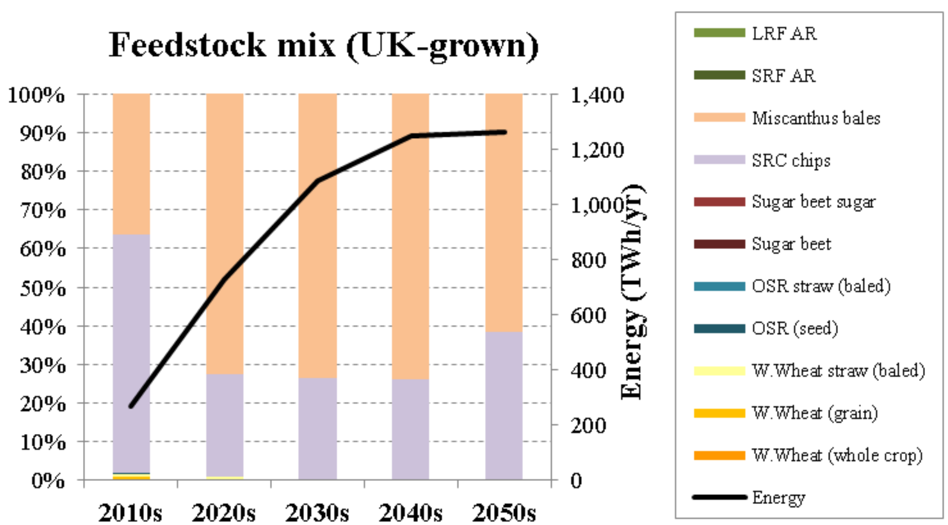
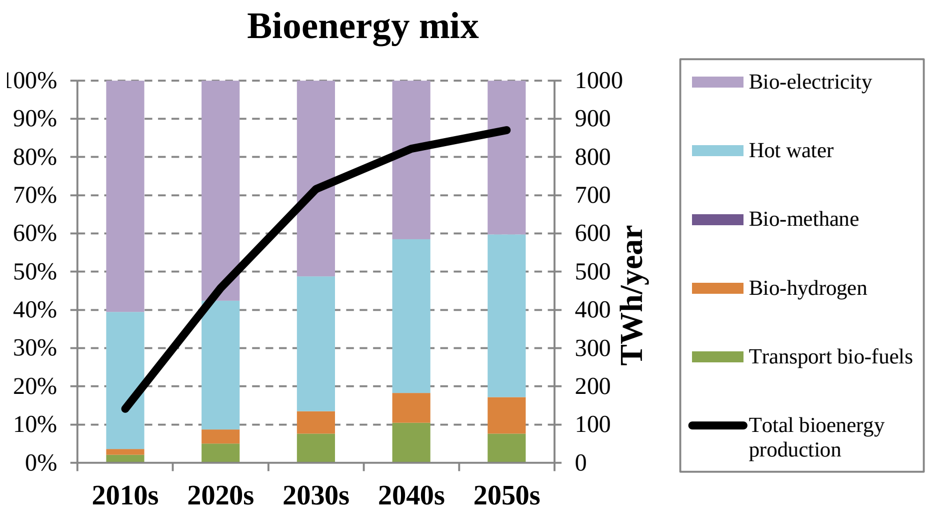
Example bioenergy chains

An illustrative example: note that solutions are shaped by user input





- Wheat and potato food production/demand included

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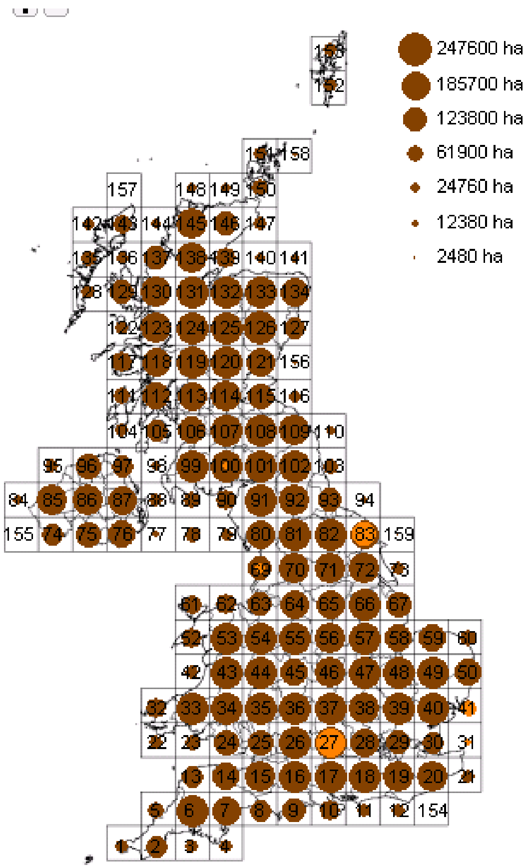
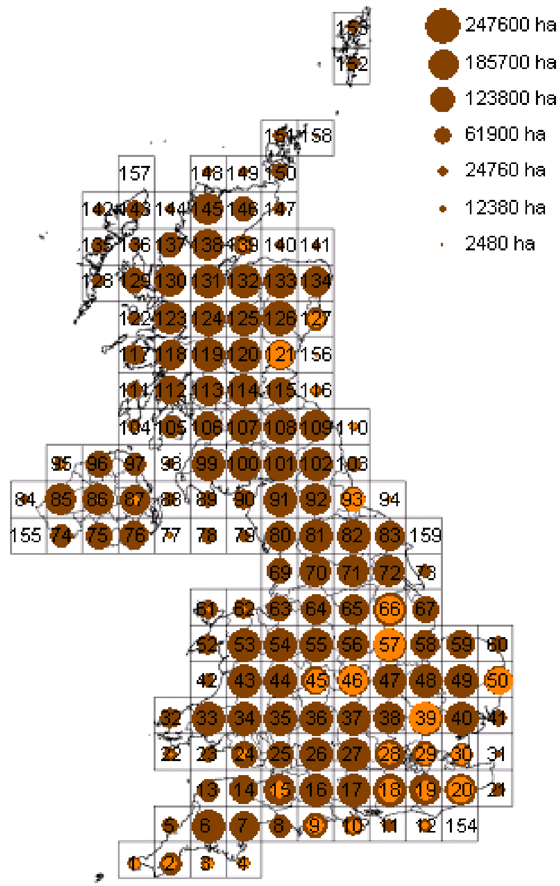
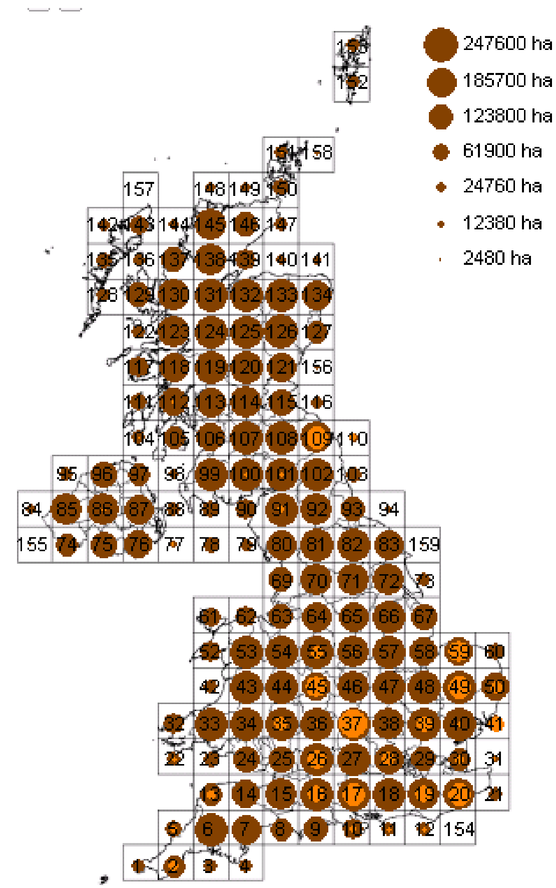
Example food production maps (illustrative]



Potato, 2010s

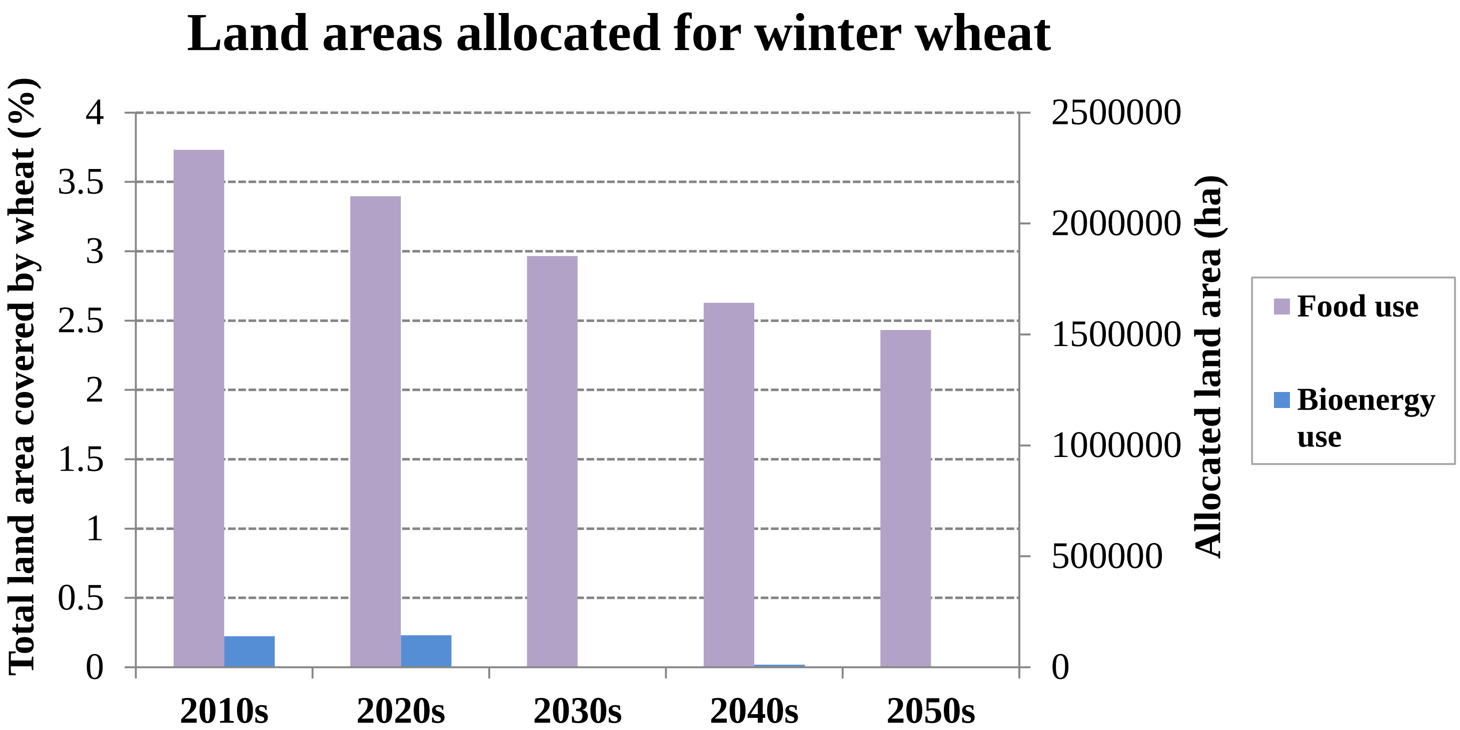


Winter wheat, 2010s



Winter wheat, 2050s

1G crop areas: food and fuel [illustrative]



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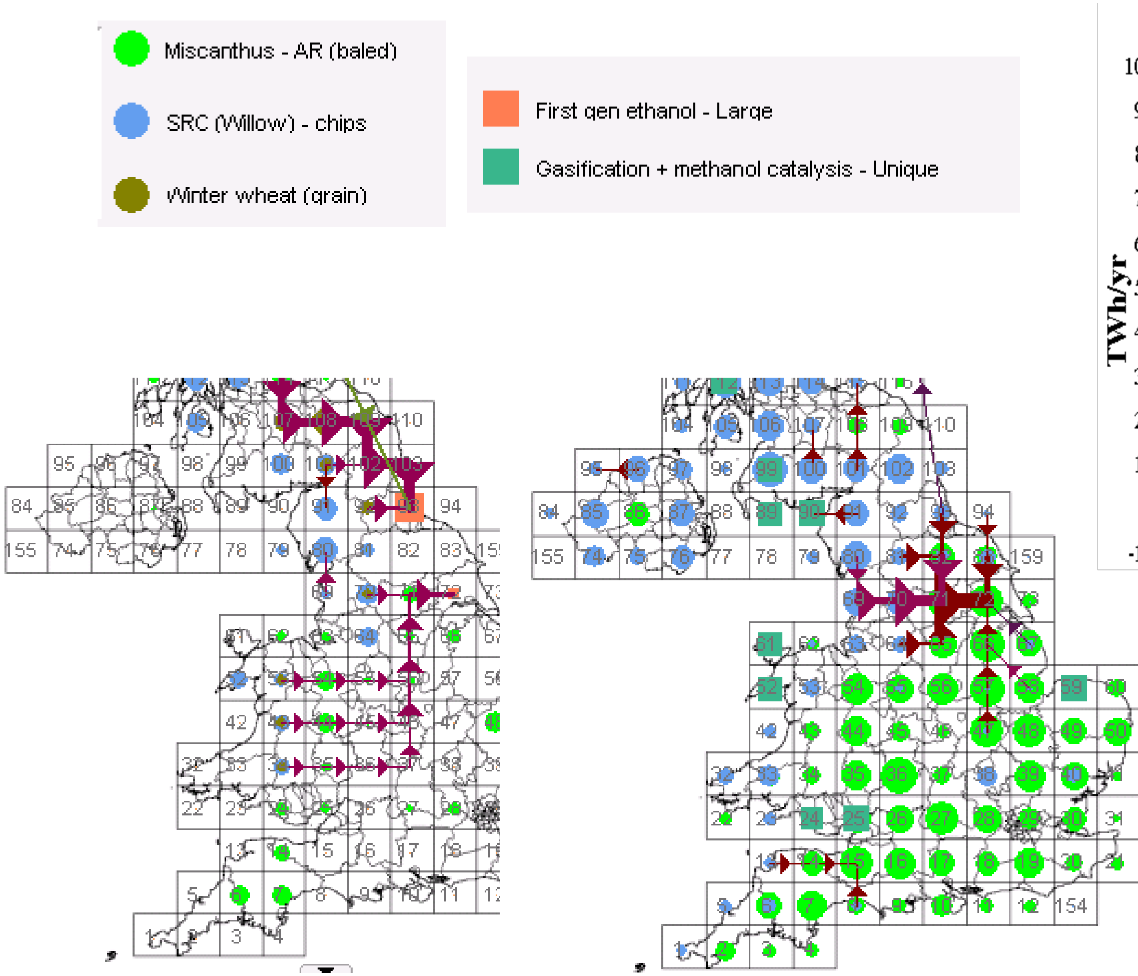
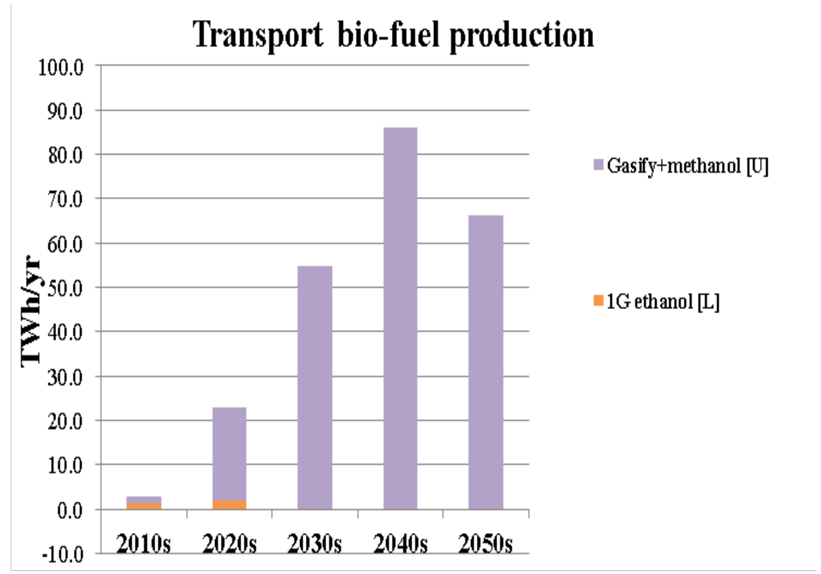
Example transport fuel supply chains [illustrative]



2010s

2050s



(unconstrained case – for illustration only)

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SUPERGEN Bioenergy "Advancing UK Bioenergy"