Programme Area: Bioenergy

Project: Biomass Value Chain Modelling

Title: Executive Summary

Abstract:

A summary of the intital BVCM model development

Context:

The development of the BVCM model has been ongoing since the project first started in 2011. The documents published here relate to the intial phases of model development. They do not included later developments and are therefore not representative of the current BVCM model, or in some cases, its findings. For a more recent overview of BVCM and the findings derived from it, readers are encouraged to look at the insights and reports published by the ETI, here: http://www.eti.co.uk/insights and here: http://www.eti.co.uk/library/overview-of-the-etis-bioenergy-value-chain-model-bvcm-capabilities

BVCM is now managed by the Energy Systems Catapult (ESC). Any questions about the ESC should be directed to them at: info@es.catapult.org.uk

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Purpose: **Arising IP**
Restrictions: **No additional restrictions**

ETI Executive Summary

Programme: Bioenergy

Project Name: Value Chain Modelling Project

Deliverable: BI2002 / WP4-D4 "Opportunity Identification and Roadmapping Report"

Introduction

This document presents technology opportunities and bioenergy roadmapping, based on the case study analysis carried out with the Biomass Value Chain Model (BVCM). The main objective of this report is to identify the opportunities for the development and deployment of promising technologies based on the output of the optimisation runs of the Biomass Value Chain Model (BVCM).

The Biomass Value Chain Model is a UK-wide spatially-explicit national optimisation model. It models pathway-based bioenergy systems over five decades (from 2010 to 2059). It currently includes seven bioresources (winter wheat, oilseed rape, sugar beet, Miscanthus, Short Rotation Coppice Willow, Short Rotation Forestry, and Long Rotation Forestry), and more than 50 distinct technologies for preatreatment and densification, gaseous and liquid fuel production, and power, heat, and combined heat and power generation (including carbon and capture technologies for power generation). The model either minimises a combined metric (referred to as objective function) which is a weighted sum of discounted whole system cost, CO_2 and non-CO_2 GHG emissions, or maximises energy production under a set of constraints, including cost, emissions, and minimum levels of demand of any energy vector (or total amounts of energy) to be met through bioenergy.

Approach

The model has been used to investigate a series of case studies, designed to explore different scenarios in relation to resources, technologies, end uses, infrastructures and objective functions. For each case study a series of runs has been executed to explore trends and analyse the sensitivity and the resilience of the results.

Results and insights summary

The main insights from the case study analysis are:

Demand, resources and land uses

- Bioenergy can meet 10% of estimated UK energy demand in 2050 by using about 11% to 15% of total UK land. As a theoretical upper limit, up to 32% of estimated UK energy demand in 2050 could be met by bioenergy, by using about 42% of total UK land.

- Different biomass types will be grown in different parts of the UK in order to meet the demand from bioenergy, with SRC-Willow and Miscanthus typically dominating the feedstock mix.
- Biomass resource choice, and their availability, is resilient to climate scenarios, at least till 2050.

Technologies

- Heat production – via large scale boilers and combined heat and power (CHP) plants with district heating networks - is a mature and relatively inexpensive route to bioenergy penetration, and low cost, low GHG emissions bioenergy systems are dominated by heat production especially till 2030s.
- Biogenic Synthetic Natural Gas (BioSNG) emerges as one of the dominant bioenergy vectors post 2040.
- Significant opportunity exists for negative emissions (in the range of 50 to 100 million tonnes of CO2 sequestered per year) via carbon capture and storage technologies in the power sector, with bio-dedicated chemical looping being the most promising one.
- Biomass to hydrogen routes, as well as other routes to fuels (e.g. aviation fuels) are relatively high cost, but may be important for the UK due to strategic and whole-energy system considerations.
- Biomass pyrolysis combined with pyrolysis oil upgrading is the preferred technology route for liquid transport fuels, except in the early years, when first generation ethanol may be used.
- First generation biodiesel (via oilseed rape) is likely to play a marginal role in the UK bioenergy system.

Logistics

- Limited transport of resources (both bioresources and intermediates) occurs. In particular, some transport of densified biomass takes place when land use is constrained and biomass must be grown sparsely over larger land areas. This may change further if imports are allowed, or if more stringent limits on the land locally available for bioenergy in given areas are applied.

Based on these insights, acceleration opportunities were identified for technologies in line with the ETI focus on the Technology Readiness Levels (TRL) 3 to 6. These are:

- Gasification coupled with synthesis of intermediates and fuels (bioSNG, FT fuels, and hydrogen)
- Pyrolysis oil upgrading
- Bio-dedicated chemical looping

Based on the results from the case study analysis, roadmaps for the whole bioenergy sector are provided.

Key findings

The key messages from Phase 1 of the project can be summarised as:

Bioenergy can meet 10% UK energy demand in 2050 by using 12% to 15% of total UK land

Up to 32% of UK energy demand in 2050 can be met from bioenergy under an extreme (theoretical) case of land use. However a share around 10% of UK energy could be realistic, putting the use of land for bioenergy at a level similar in magnitude to current arable land, and with enough high grade land set aside for food production.

Different biomass types for different parts of the UK

There appears to be a North/South split in biomass type, typically with Miscanthus grown towards the South and SRC Willow in the North.

Heat is low cost but liquid fuels may have additional value

Heat production is a mature and relatively inexpensive route to bioenergy penetration. However, fuel and electricity from biomass may be required in the context of a whole energy system optimisation, and may also command higher value. Of course, this comes at extra costs and might be a good reason to explore technology acceleration and cost reduction.

Gasification to fuels is an effective pathway

Gasification and subsequent conversion to hydrogen and particularly synthetic natural gas are cost-effective and resource-efficient pathways. Other products such as FT jet do incur significant additional costs, but may be important for the UK.

Limited opportunities exists for first generation biodiesel (via oilseed rape)

Our runs have shown that, unless a given quota is mandated, first generation biodiesel (as FAME, Fatty Acid Methyl Esters) seldom appears as a transport fuel, under all optimisation scenarios.

Significant opportunity exists for negative emissions

Figures in the range of 30-100M tonnes per year of CO_2 can be sequestered via BioCCS. This is in line with other estimates (e.g. AVOID project). A range of BioCCS technologies are available, with amine based processes used early on and oxy-combustion and looping combustion later on.

Feedstock supply chains are important and ensure flexibility.

Dedicated bioenergy crops are developed in all solutions; what is interesting is the fact that their conversion and utilisation transitions over time from applications such as co-firing and CHP to more sophisticated ones such as gasification. This finding corroborates many others which indicate that mature bioenergy technologies are important to give growers confidence in a long-term market for their crops, given the longevity of most bioenergy crop investments.

Predominant value chains

The following technologies appear to be predominant in the results from the case studies (in bold those with high level of resilience):

	TRL 3-6	TRL > 6
Pre-treatment and densification technologies	• Pelletising if there are tight land constraints	• Pyrolysis
Technologies for gaseous fuel production	• **Gasification + bioSNG** • Gasification + H_2	
Technologies for liquid fuel production	• Pyrolysis oil upgrading	
Technologies for heat, power, and combined heat and power generation	• **Dedicated chemical looping CCS** • Co-fired and dedicated oxy-fuel CCS • Cofired combustion + amine CCS	• **Biomass co-fired steam cycle (CHP)** • **District heating network** • **Boiler combustion (for heat)**

Next steps

a) Consortium

Possible further model developments have been identified based on the Consortium's judgement and on the experience gained from the runs and sensitivity analysis runs so far. Some of these developments have been already identified in the course of the project and will be covered in Phase 2:

- Seasonality effects. Improvement of the model functionalities by taking into account seasonal effects on biomass characteristics and availability.

- Value of strategic transport fuels. At the moment, when optimising on costs and/or energy, the model typically chooses road transport fuels over jet fuel. This is mainly due to the extra costs and emissions associated with the hydrogenation required for achieving jet fuel specifications. However, from a UK-wide strategic point of view, it may make more sense to generate jet fuel, as this may have more economic value. A possible model development is therefore to implement an objective function that maximises the value of the biogenic energy vectors.

- Value of carbon sequestration of long rotation forestry. The current model does not take into account the potential benefit of storing carbon stocks by means of long term forestry, and additional functionality in this regard can be added.

- Improved modelling of credits (economic and GHG) from co-products, e.g. by modelling how credits will vary in the future, and including possible saturation effects.

- Improved modelling of land constraints, i.e. limiting the area in each cell than can be realistically used to produce biomass for bioenergy.

- Constrain the location of CCS technologies to areas where it is expected that CCS infrastructure will be located (e.g. Thames Estuary, Humberside).

- Further alignment between the BVCM and the ESME model, i.e. aggregating and feeding back BVCM technology and resource data to ESME.

b) ETI

The case study results have been extensively discussed by the Bioenergy SAG, which subsequently led to further model runs within this Project. The insights generated are key to understanding the overall shape and size of the UK's future bioenergy opportunity. Dominant biomass value chains, including crop type and availability, conversion technologies and associated end-user energy vectors have been identified. This has allowed the project team to focus on a handful of key potential conversion technologies in the following deliverable "Benefits assessment report (WP04.05)" and has enabled the ETI and its members to gain confidence in the potential of bioenergy sector in the UK to deliver 10% of the 2050 energy demand at 80% reduction in GHG. The key findings of the value chain model are entirely consistent with ESME v2.0.

Appendix

1) The Biomass Value Chain Model

The Biomass Value Chain Model used for generating the results of this report is a fully-formed national optimisation model. It allows the development of pathway-based bioenergy systems over five decades (from 2010 to 2059). The model has been tested in a large number of configurations.

The various elements of model content are described below. An overview of model architecture and data flows is shown in

Figure 1.

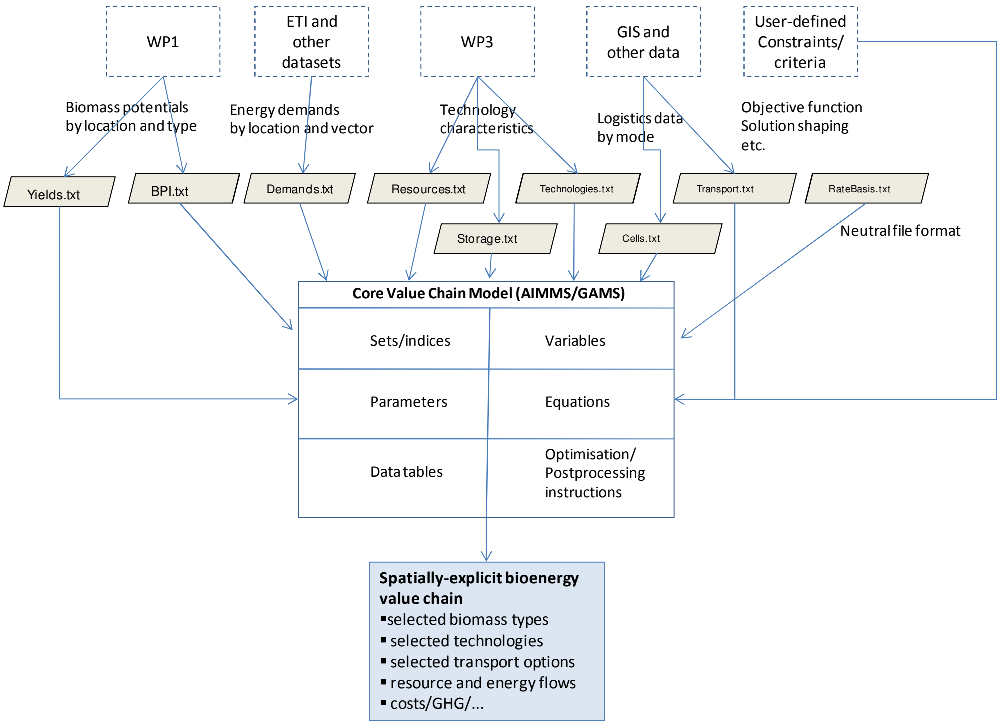

Figure 1. BVCM architecture and data flows

2) Example Biomass Value Chain – an example (*Miscanthus*) is shown below

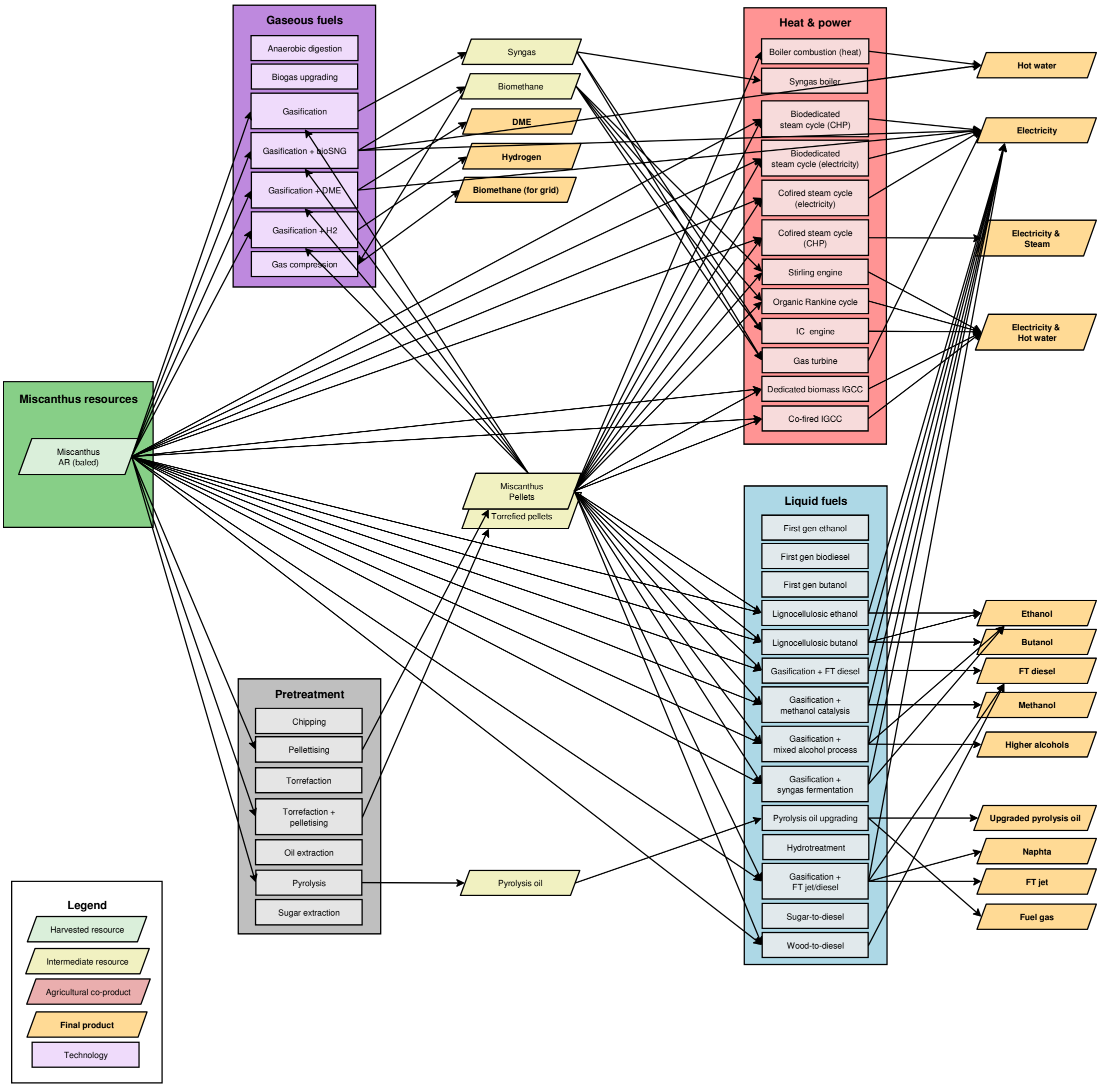

Figure 2 Miscanthus bioenergy chains

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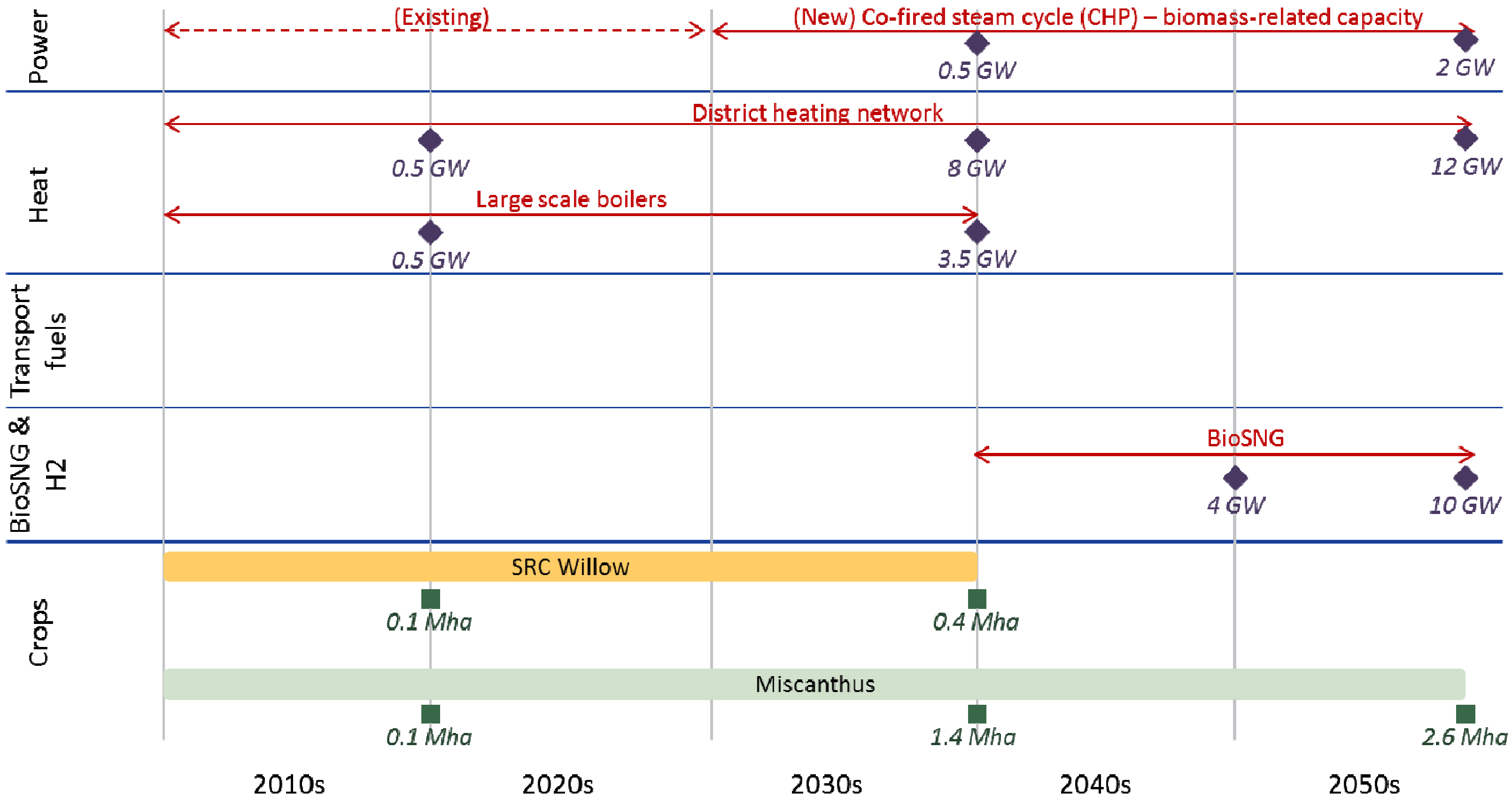
Appendix 3 - Roadmaps

a) 10% of UK 2050 energy demand at minimum cost



b) Roadmap 2: ESME case, minimum cost, with CCS