Programme Area: Bioenergy

Project: Biomass Value Chain Modelling

Title: Integrated Case Study Report

Abstract:

This deliverable provides a short description of all updates made to the BVCM toolkit in Phase 2. The Phase 2 updates to the BVCM toolkit can be broadly grouped into 4 types: improvement to the optimisation model, improvement in model settings, improvement in the technology representation, and improvement in the resources representation.

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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Biomass System Value Chain Modelling

P2_3

Update report

Version 2.0

The BVCM Consortium

For the Energy Technologies Institute
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Contents

Executive summary

The objective of this report is to provide a short description of all updates made to the BVCM toolkit in Phase 2.

The Phase 2 updates to the BVCM toolkit can be broadly grouped into 4 types: improvement to the optimisation model, improvement in model settings, improvement in the technology representation, and improvement in the resources representation.

These updates constitute a significant improvement to the BVCM toolkit. In general, the updates:

- ensure a wider, more detailed representation of possible bioenergy pathways
- raise the overall data quality and level of confidence in the model
- improve the user interface
- increase the options for use cases and scenarios

Overall, the BVCM model delivered at the end of Phase 2 provides a very robust tool to identify promising resource-technology combinations to be considered for acceleration by the ETI.

1 Introduction

1.1 Objectives

The main objective of this report is to provide a short description of all updates made to the BVCM toolkit in Phase 2.

1.2 Rationale for updates in Phase 2

The BVCM project, as initially scoped, was delivered at the end of Quarter 2 in 2012. Following discussions within the ETI and between the ETI and the BVCM consortium, it was recommended to fund an extension to the project within 2012, in order to build on the existing model and consortium's expertise and expand on the functionality and usability of the model.

1.3 Acceptance Criteria

As per the technology contract, the acceptance criterion for the deliverable WP4-D5 states:

"Brief description of the updates applied to the IP toolkit (why, what, how)"

2 Updates

The updates to the BVCM toolkit made in Phase 2 can be broadly grouped into 4 types:

1. Improvement to the optimisation model. This covers improvements (both amendments and additions) to the formulation and architecture of the optimisation model developed in AIMMS, including the ability to perform stochastic runs.
2. Improvement in settings. This covers the explicit introduction of certain key parameters as modelling variables (e.g. CO_2 prices, CO_2 sequestration budget, crop-specific emission factors for the GHG-balance, etc.).
3. Improvement in the technology representation. This covers both additional resource-technology pathways (e.g. energy from waste, coal retrofit technologies) and improvements in the existing technologies in Phase 1 (including more refined technology modelling – e.g. constraints on minor constituents – and technology database revision). These improvements concern directly the technology database (in Excel), which is a key input dataset into the AIMMS model.
4. Improvement in the resources representation. This covers improvements in the biomass resources data in terms of yield, costs and emissions and the ability to model resource imports. These improvements resulted in updated resource datasets, which are inputs to the AIMMS model.

In the next section we will briefly illustrate each improvement, mainly focusing on the added functionalities the user can enjoy in the model as a result of Phase 2. For more details on how the new functionalities and dataset have been derived, the user should refer to Deliverable P2_4 "Updated Model Documentation and User Manual". For a description of the functionalities, data, limitations and assumptions behind the IP toolkit as delivered at the end of Phase 1, the reader should refer to Phase 1 deliverables.

2.1 Improvement of the optimisation model

- The user is now able to run the BVCM model in "stochastic mode". This means that the user can define the uncertainty range for key model parameters (biomass yields, biomass cost, technology efficiency, and technology capital costs) via selecting different distribution functions for the uncertainties, and number of stochastic runs to be executed.

  The model then automatically generates stochastic model parameter datasets and a script executes all the runs automatically. A dedicated analysis tool (in Excel) linked to the model allows the user to explore the solution in line with the analysis capabilities of ESME (e.g. with histograms on bioenergy system costs and emissions, and likelihood of technology appearance; box and whisker plots of technology capacities).

- The basic model user interface has been significantly improved in Phase 2, so that the user has a better understanding of the data underpinning the model and its results. In particular, we have:
  - added units throughout

  - added information on economic parameters (e.g. discount rates)
  - added information on co-product credits
  - added information on power with CCS technologies, imports, and waste
  - added visualisation of technology location restrictions (e.g. for power with CCS technologies)
  - added more flexible optimisation options e.g. cost minimisation with/without CO_2 prices; GHG minimisation; and options of solution accuracy and solution search methods[1]
  - improved the excel analysis tool, by adding e.g. system cost and GHG breakdowns, biomass import contribution, etc.

- Close coastal shipping has been implemented as additional transport mode, together with definition of port locations and capacities (these are used for imports as well – see below). The user can choose the ports to use as well as their maximum import capacity. Default values have been provided for this.

- The user can now choose whether biomass imports contribute to the bioenergy provision in the UK, along with UK-grown resources, or not. Supply scenarios (cost, GHG, and availability) of key biomass imports have been generated, and imports can enter in specified port locations (with defined capacity). In principle, the user can run the BVCM model in "imports only" mode, by choosing not to include any UK-grown feedstock.

- Transport of CO_2 (e.g. from biomass CCS plants to CO_2 network point onshore) is now enabled, including pipeline, truck, and ship. The user can now take advantage of this functionality to understand, when using BioCCS technologies, whether the biomass should move to near-shore CCS plants, or biomass should be converted near source and CO_2 moved to appropriate cells for sequestration.[2]

2.2 Improvement in settings

- The user can now explicitly chose CO_2 prices for each decade as input to the model. We have provided as default CO_2 prices based on the DECC guidance for future CO_2 prices, but the user can amend these if required.

- The user can explicitly set an overall net CO_2e sequestration budget for the whole time period covered by the BVCM. In Phase 1, the budget was split into CO_2 and non-CO_2 GHG and was expressed in gross terms (i.e. it did not include the positive emissions from non-CCS activities). This can be subject to a cost ceiling.

[1] For example, by relaxing the integer variables or approaching an energy target from below to improve chances of finding a feasible solution.
[2] This feature is still under development at the time of writing, but we plan to have it completed in time for the final deliverables.

2.3 Improvement of technology representation

- The user can now limit the location of any technology to any cell in the UK. This functionality is typically used to constrain the location of CCS technologies on e.g. coastal sites.

- The user can now choose whether the amount of ash and key impurities (also known as minor constituents) - sulphur (S), chlorine (Cl), potassium (K), and sodium (Na) - in the feedstock should limit the use of certain feedstocks to certain technologies (or require blending with other feedstock with lower ash and impurities).

- The user can now use the model with waste resources and technologies. By selecting the right technologies and resources, the user can potentially run the BVCM into three modes:

  1. Biomass only (as in Phase 1)

  2. Biomass and waste together

  3. Waste only

  A variety of waste-using technologies have been implemented.

- The user can now visualise, along with all other results in the analysis tool, the total estimated amounts of key non-GHG pollutant emissions (NOx, SOx, particulate matter, CO and metals) associated with the bioenergy system.

- Pyrolysis oil pathways. We have now included the possibility of pyrolysis oil (without significant upgrade) to be used in large scale internal combustion engine, organic Rankine Cycle and Stirling Engine technologies[3], and we have also added an oil-fired combined cycle technology that can use pyrolysis oil as input. The user can also simply include pyrolysis oil as a final energy vector (like e.g. bioethanol, biodiesel, etc.) in its own right if desired.

- Coal retrofit. We have increased the technology portfolio to include a coal retrofit option. The technology landscaping and associated parameterisation have been executed in the same manner as all previous technology investigations.

- We have expanded the portfolio of possible pathways by adding a series of biorefinery concepts (or multi-product technologies). For non-energy products, monetary and emissions credits are accounted for. The biorefinery concepts include:

  - Integrated sugar beet biorefinery for the production of food (sugar), bioethanol, and animal feed
  - Lignocellulosic (straw) biorefinery for the production of bioethanol, molasses (animal feed), electricity and heat

[3] In both cases, it is assumed that the pyrolysis oil is burnt in an oil boiler to generate the heat to drive the thermodynamic cycle.

  - Extension of first generation biodiesel production, now including both glycerine and animal feed as co-products
  - Integrated pyrolysis-based biorefinery for the production of electricity and heat.

- Biochar. We have added to the technology database a slow pyrolysis technology producing – besides syngas for energy purposes – biochar for carbon sequestration.[4]

2.4 Improvement of resource modelling

- Crops can now be limited to a certain land type only (e.g. arable crops are now by default limited to arable land – as defined in the Corine Land Cover database - only).

- Biomass availability is now limited to areas within certain constraints on soil carbon, slope and elevation. This makes the estimate of biomass availability in Phase 2 more realistic than that in Phase 1.

- Further yield gap[5] analysis/updated yields. New yields have been produced for winter wheat, sugar beet, oilseed rape and Miscanthus using two different rates of technology advancement for potential crop yield improvement with and without closing current yield gaps in the future. In Phase 1, we calculated crop yields in future decades until 2050s assuming that potential crop yield will increase at current historic rate (i.e. business as usual). We now calculated the crop yields assuming (1) a best crop improvement scenario case in which potential crop yield will increase at a maximum possible rate of 2% per annum (highest rate possible consented by most experts) and the yield gap will gradually close to a minimum 10%; and (2) a worst crop improvement scenario case in which potential crop yield will increase at only half of the current business as usual rate and the yield gap still remains unchanged in the future decades until 2050s.

- The user can now choose to have the carbon accumulation from long rotation forestry contribute to the CO_2 budget (via negative emissions) or not. This can be done for both forestry grown for biomass production (via thinning) and for forestry grown for afforestation and carbon sequestration purposes only (i.e. with no thinning).

- We have expanded the model functionality to include seasonal effects on the biomass availability, i.e. the fact that most crops are harvested in certain seasons only.

- Improved GHG. Where possible, the Methodology of the GHG model used in Phase 1 has been expanded from Tier 1 to Tier 2 using crop specific emission factors (EF) compiled from the latest international literature.

[4] This feature is still under development at the time of writing, due to unexpected delay in the provision of data from a BVCM subcontractor. We plan to have it completed by the end of October 2012 at the latest, and added on the final deliverables shortly after that.
[5] I.e. the difference between yields obtained on farms and those on research stations.

- Further validation of resource costs. The Phase 1 production and opportunity cost datasets and their assumptions have undergone a first round of validation with a subset of Regional Farm Business Unit survey data. A first round of amendments has been made to some of the resource unit cost and price assumptions as well as the assumptions concerning the operational management of growing each crop resource. The revised cost data and assumptions are currently being harmonised with the new crop resource yields that have been produced as part of Phase 2 to generate new cost and gross margin datasets. These will then be further validated before integration into the model.[6]

[6] This activity is still on going at the time of writing. We plan to have it completed by the end of October 2012 at the latest, and included in the final deliverables shortly after that.

3 Data quality and limitations

In this section we give a high level judgment on data quality and limitations related to the main updates in Phase 2. The user should refer to deliverable P2_4 "Updated model documentation and user manual" for more details on data quality and limitations.

Update	Data quality	Limitations
Stochastic functionality	**n/a** User defined ranges on key parameters	None.
Close coastal shipping	**High** Based on published data (UK Ship Emissions Inventory – Final Report, DEFRA, ENTEC UK Limited, London, UK, 2010).	Only a single type of ship carrier (average bulk carrier size suitable for domestic transportation) is considered for simplicity, as emission and cost factors are fairly constant with ship size.
Imports	**Medium** Data based on robust analysis and aligned with those used in the UK e.g. by DECC. However, an intrinsic uncertainty exists about availability, price and emissions associated with imports.	Certain import data have been calculated assuming representative scenarios, e.g. transport emissions have been calculated assuming certain feedstock will come from certain countries only. This is a reasonable approach, but extreme cases are not covered.
Transport of CO_2	**Medium/High** Realistic CO_2 transport costs are considered from literature. However uncertainty exists related to e.g. business model of CO_2 transport, hence its cost. User can vary the parameter.	Does not consider relief topography or land-use restrictions, and uses expected tortuositities.
Minor constituents	**High** Values from reputable literature have been used. These have been also reviewed by ETI members.	Certain specific technology configurations may require different (more stringent) limitations. Also, evolution in regulation may impose more stringent limits.
Waste resources	**High** Based on bottom up analysis from the ETI Energy from Waste Project.	We have assumed that waste comes at no cost, although this may not always be the case. Also, for modelling reasons, we have assumed that unprocessed waste does not travel beyond each cell (50 x 50 km).
Waste technologies	**Medium** Up to date, real-life cost and	No legislation or regulation is explicitly considered in the model,

Update	Data quality	Limitations
	performance values have been considered in most cases. However, for most waste technologies, planning permission etc. may impose higher real life costs. Also, the implications of using waste feedstock in certain biomass technologies (e.g. pyrolysis etc) are not fully understood.	which may affect the deployment of waste technologies in real life.
Non-GHG pollutants	**Medium** Operational data availability is very poor, therefore limits coming from regulations have been considered in most cases. In practice, it is very likely that plants will be operated not too far off the regulatory limits.	The amount of non-GHG pollutants should be considered as a high level estimate only, as in practice pollutants are very much dependent on plant operating conditions. Also, non-GHG pollutant amounts should not be considered reliable when significant amount of waste resources are used, as it is not possible to estimate at BVCM level the effect of pollutants in the waste streams.
Coal retrofit	**High** Latest data from industrial partner have been used.	None
Multi-product	**Medium** Sourcing data for biorefinery costs and performance is challenging, due to the limited amount of data in the public domain, but the few sources used are of good quality.	We have not included all potential products e.g. polymers from pyrolysis.
Biochar	**Low/Medium** The modelling is limited by the paucity of data regarding costs and efficiency.	Only direct carbon sequestration benefits are accounted for. This includes the carbon stably sequestered in the biochar, but excludes e.g. the CO_2 savings associated with using biochar as fertiliser.
Updated yields for Miscanthus	**Medium** Miscanthus is still a relative new crop. Crop improvements will be	Unlike arable crops such as cereals and sugar beet, Miscanthus yield will not reach its optimal level as

Update	Data quality	Limitations
	slow unless a rapid uptake in its use will happen soon. But, crop improvements in other arable crops such as wheat, oilseed rape and sugar beet can act as good guides for the rates at which Miscanthus yield is likely to be increased.	modelled for use in this project until it has undergone an initial period of establishment. This establishment period can vary from 2 to 5 years depending on how the crop is managed.
Long rotation forestry carbon stock	**Medium** Carbon fluxes in forests are enormously complex, depending on many parameters other than simply the yield. In this respect our approach is limited, but fluxes considered still provide a good indication of the sequestration potential of long rotation forestry.	Carbon stocks do not include changes in soil carbon. Also, only the period from 2010 to 2050s is covered, and the final destiny of the tree (and its carbon) is not covered in the model.
Seasonality	**High** Biomass supply windows from real life practices have been used.	We have not considered the effect that seasons may have on minor constituent and moisture content in the biomass.
Improved GHG	**Medium** Update information has been used for greenhouse gases emissions. Most important components were taken into account in the life-cycle of cultivation and production of the resource crops.	Land use change emissions are not included in the model. Also, changes in future needs of crop fertilizers could alter the CO_2e per tonne of dry matter. The inclusion of fertilisers other than nitrogen (e.g. phosphate and potash) can easily be implemented.
Improved resource costs	**Medium/High** The cost and operational assumptions underpinning the resource cost and gross margin data have been benchmarked, and are currently being harmonised with the new crop resource yield datasets.	The validity of the final datasets will be highly sensitive to a number of factors, including: - significant within region variability in crop resource production costs given wide differences in farm structure and production efficiency between farms. - uncertainty over the future evolution of crop resource input prices. - uncertainty over price developments in relatively immature bioenergy feedstock

Update	Data quality	Limitations
		markets (as well as in the agricultural sector given their linkages). - as with the yield estimates, uncertainty exists as to the true cost of being able to attain the yields of some crop resources in those regions where the crops have not been previously produced.

4 Conclusions

The updates carried out in Phase 2 constitute a significant improvement to the BVCM IP toolkit. In general, the updates:

- ensure a wider, more detailed representation of possible bioenergy pathways
- raise the overall data quality and level of confidence in the model
- improve the user interface
- increase the options for use cases and scenarios

Overall, the BVCM model delivered at the end of Phase 2 provides a very robust tool to identify promising resource-technology combinations to be considered for acceleration by the ETI.

We consider the BVCM model as a “live” tool, which should be kept updated whenever new data become available (e.g. new information on technology performances, new biomass yields estimates, etc.), and we have designed the model so that this can be done in the most straightforward way. This includes – inter alia – any data coming from other ETI projects, e.g. the ELUM project. In addition, further improvements could be still envisaged for the future, including for example value maximisation protocols, biochemicals, CCS technologies applied to non-power energy vectors (e.g. H_2 and BioSNG), new resources (e.g. energy grasses). The BVCM consortium can also be called upon to design and implement new case studies (including focussed regional case studies) of interest to the ETI.