Programme Area: Bioenergy

Project: Biomass Value Chain Modelling

Title: Technology Modelling Report

Abstract:

This deliverable is intended as an accompanying document of the technology database (which is not publically available). However, in isolation the document provides useful information on the technology database structure, a user guide (e.g. for adding new technologies to the database), an explanation of the overall modelling approach, an outline of the database content, and a discussion on data quality and data gaps at the time the report was written.

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

WP03.03

Technology Modelling Report

Version 2.0

The BVCM Consortium

For the Energy Technologies Institute
17 November 2011

Title	Technology Modelling Report	
Client	Energy Technologies Institute	
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Contents

Executive summary

This report is intended as an accompanying document of the technology database. The technology database will contain all the technology data to be inputted in the BVCM model. The database is currently under development in WP3 as a standalone Microsoft Excel workbook file, and its first working version is provided separately.

The main objectives of this report are to detail the technology database structure, to provide a user guide for e.g. adding new technologies to the database, to explain the overall modelling approach, to outline the database content, and to discuss data quality and current data gaps.

Next steps are outlined in terms of improving the database based on the preliminary model results and feedback already received by the ETI on the Technology Landscaping report (WP3-D1).

1 Introduction

1.1 Overview of WP3 process, its relation to WP4, and deliverable dependencies

The overarching objective of WP3 is to develop a technology parametrisation building block for the value chain optimisation model. To this end, an initial biomass technology landscaping exercise is needed – inter alia – to make sure that all relevant, up-to-date information on the technologies included in the Project are considered. Also, importantly, the technology landscaping will be the starting point of the technology roadmap exercise that will be carried out in WP4b for those technologies identified as having significant deployment potential by the value chain optimisation.

Building on the knowledge arising from the technology landscaping, as well as the background knowledge and data available to Black and Veatch, E4tech and Imperial, we will then develop a set of parameterised equations for each technology selected for inclusion in the modelling (the technology database). These parameterised equations will be integrated in the value chain optimization framework developed in WP2 and in the optimisation runs in WP4a. The development of the technology database will be an iterative process, in which the learning from the first optimisation runs will be used for any further model refinements (e.g. considering technology at different scale, applying different build rates, etc).

In WP4b we will identify promising technologies (and technology chains) based on the outputs of the spatial and energy system analyses carried out in the case studies, and based on a number of criteria such as technology readiness level, development needs, attractiveness of end use, cost potential, specific GHG savings, and other sustainability considerations. The following roadmapping exercise will focus on the technologies identified for acceleration. It will build on the technology status and barrier analyses carried out in WP3 and will outline what is required to overcome the innovation and commercialisation challenges, and when. In other words, the roadmap will provide actions required and indicators to track progress against the optimized biomass value chains for the UK as found by the model. For example, for selected technologies or technology chains, the roadmap will detail:

- possible development, demonstration and deployment sequence(s) from current status to 2050, and the associated investment needs (e.g. number of plants and capital expenditure);
- cost, efficiency, and GHG emissions targets;
- technical innovations required to overcome existing barriers and ensure that targets are met;
- type and level of support needed, as any successful implementation of a bioenergy technology roadmap is only likely to be possible if a supportive policy framework is in place.

After the roadmapping, we will quantify the benefits to the ETI of accelerating selected biomass technology options.

An overview of the overall WP3 process, of its relation to WP4, and of deliverable dependencies is given in Figure 1-1.

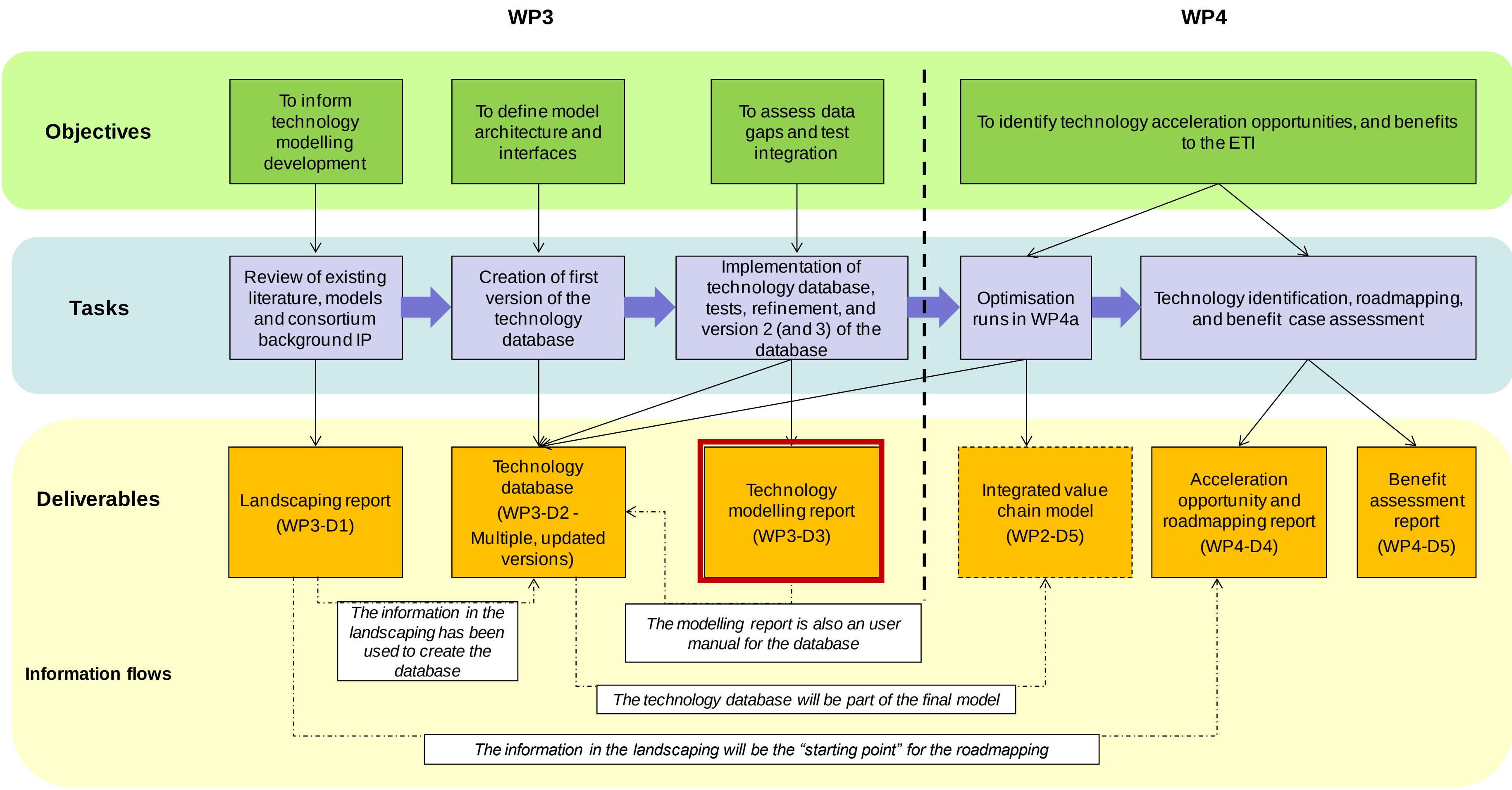

Figure 1-1 Process overview for WP3 and WP4. Current deliverable in red box.

1.2 Overview of the technology database

As already stated, the main objective of WP3 is to develop a set of parameterised equations (technology database) for all relevant technologies in bioenergy chains, to be fed into the value chain optimisation model under development in WP2 and for the use in the optimisation runs and analysis in WP4.

The technology database currently includes the following technologies (some of them modelling at different scales)[1]:

- pre-treatment and densification technologies, which include:
    - chipping
    - pelletising[2]
    - torrefaction
    - oil extraction
    - pyrolysis[3]
    - biomethane compression
    - stand-alone gasification module

- technologies for gaseous fuel production, which include:
    - anaerobic digestion
    - landfill gas[4]
    - biogas upgrading
    - gasification with catalytic methane synthesis
    - gasification with catalytic dimethyl ether synthesis
    - gasification with hydrogen production
- technologies for liquid fuel production, which include:
    - first generation ethanol
    - first generation biodiesel
    - first generation butanol
    - lignocellulosic ethanol
    - lignocellulosic butanol
    - gasification with catalytic Fischer-Tropsch synthesis
    - gasification with catalytic methanol synthesis
    - gasification with catalytic mixed alcohol synthesis
    - gasification with syngas fermentation

[1] Technologies related to infrastructures, e.g. natural gas and hydrogen piping will be covered in the development of the optimisation model itself in WP2
[2] In general, if any drying requirements (which depend on the input) apply, those are included in the technology modelling
[3] In principle, pyrolysis oil could be also used for heat, power and combined heat and power generation
[4] Assuming to use MSW. This could be used if and when data on waste from other ETI projects become available.

  - pyrolysis oil upgrading
  - hydrotreatment[5]
  - sugar-to-diesel technology[6]
- technologies for heat, power, and combined heat and power generation, which include:
  - boiler combustion (for heat application)
  - dedicated biomass steam cycle
  - biomass co-fired steam cycle
  - Stirling engine
  - organic Rankine cycle
  - internal combustion engine
  - syngas boiler
  - gas turbine
  - close-coupled gasification
  - biomass co-fired integrated gasification combined cycle
  - dedicated biomass integrated gasification combined cycle
  - gasification for power generation[7]

The technology database covers key technology performance parameters, for each decade from 2010 to 2050, in order to meet the functionality requirements of the BVCM toolkit. These parameters will be explained in more detail in Chapter 5 of this document.

The technology database has been developed using, inter alia, the literature, information, and insights acquired by the BVCM consortium during the previous Technology Landscaping task in WP2.

1.3 Objectives of this document

This report is intended as an accompanying document of the technology database, with the objectives of explaining:

- database structure
- guide on how to add new technologies in the database and change scenarios
- modelling approach
- database content
- data quality and current data gaps

As such, it can be considered as a user guide for the technology database.

The technology database, which is provided separately, has been developed in Microsoft (MS) Excel workbook format. It is a fully annotated workbook, with clear reference to sources of data, assumptions, and any intermediate calculations from original data to the data inputted in the database and which will be used by the optimisation model. As it is

[5] For the production of Hydrotreated Vegetable Oil (HVO) and Hydrotreated Renewable Jet (HRJ).
[6] This technology is currently not included in the Technology Contract. However, for completeness' sake, we plan on including it in the technology database. Depending on the effort required, we may need to cover this via a Contract Variation Request.
[7] Via internal combustion engine or gas turbine

reasonable to expect the database to be amended in the future, this report contains no data. Being the database a fully annotated workbook, there is no need to ensure data concurrency between an MS Excel file and a MS Word document.

Amendments in the database will occur due to the following reasons: some technology parameterisation may need refinement depending on the preliminary result of the optimisations runs (e.g. different scales of a technology need to be considered), new technologies may be added, some parameters may need to be updated, and standard troubleshooting. Therefore, in order to consult and review the data, the reader should refer directly to the database (in Excel).

2 Technology database structure

The database has been developed as a standalone 2007 MS Excel worksheet. It contains the following tabs:

- “Contents”, which provides a high level description of the database contents
- “Questions”, where the database developers have been logging all questions and issues, including how/when/by whom these have been addressed. This sheet is for quality control and database development purposes only
- “Instructions”. A sheet with instructions on how to use the database and how to add new technologies
- “Control”. A sheet where the user can control the selection of the scenarios for each and all technologies
- “Change Log”, which contains a log of all main database changes
- “{Resources}”, where all the information related to the resources (i.e. any input and output of a technologies) are recorded
- “{Technologies}”, where a list of modelled technologies (at relevant scale) is provided
- “TRLs”, which contains information on how technology performance and cost will evolve over time depending on technology type and maturity
- “General assumptions”, which contains any global (i.e. that may affect all technologies) data, e.g. fuel prices
- “Emission factors and costs”, with greenhouse gases (GHG) emission factors and costs for all relevant resources (fuels, chemicals, etc.).
- “Conversions”, which contains conversion factors from/to different units
- “Currencies”, with exchange rates and capital cost indices used across the model
- “Constants”, with any relevant constant values used in the model
- “TXX-Template”, which is a template tab for any new technologies to be added in the database
- More than 70 tabs, with a “Txx-Z” name format, for each technology in the database at a relevant scale (where “xx” is a unique number, and “Z” can be “S” for small, “M” for medium, “L” for large, and “U” for a unique size)

Content of the tabs will be explained in more detail in the following sections

3 Modelling approach and general assumptions

3.1 Technology modes

Each technology at a relevant scale can operate in several modes, whereby a mode is a combination of a given main input and a given main output. For example, for a biomass boiler, different feedstocks correspond to different modes. In general, efficiencies will vary depending on the mode.

The rationale behind the introduction of technology modes in the modelling architecture is to allow for the functionality of representing technologies operating with multiple of feedstocks. This functionality is important to allow for feedstock blending in order for the technology to operate in compliance to limits on e.g. ash and moisture content of the feedstocks. If for example a certain maximum ash content requirement exists for the input to a biomass boiler, the optimisation model will choose a combination of biomass boiler modes (i.e. feedstocks) such that the given ash threshold is not exceeded.

3.2 Scenarios

In line with what is proposed in the "Case Study Definition Report" (WP4-D2), technology-related scenarios exist in the database for technology efficiencies and capital costs.

For each technology, three different levels (low, medium, high) of efficiency and capital costs have been modelled for each decade. Typically, medium values refer to average values from the literature or consortium background IP, with low and high values representing the level of variation and/or uncertainty around these.

Future values for capital costs and efficiency are based on "evolution curves" depending on current TRL levels or based on existing work on technology evolution, such as the Technology Innovation Needs Assessments work funded by the Department of Energy and Climate Change. This ensures consistent levels of optimism/pessimism over technology evolution over the time horizon covered by the BVCM. Parameters for the TRL-dependent evolution curves are stored in the "TRLs" tab.

Scenarios are a built-in feature of the database. This means that the user, through the switches in the "Control" tab, can centrally control scenarios for a single technology, a group of technologies (e.g. pre-treatment technologies), or all technologies. Efficiency and capital cost values of all relevant technology, which are stored in the related tabs, will automatically update when scenarios are changed.

3.3 Efficiencies

For modelling reasons, efficiencies in the database are expressed in terms of amount of a given input per unit of a given main output[8]. Efficiencies are based on a net energy basis (i.e. based on the lower heating value) and include all processing losses occurring to get from a given input to the main output.

[8] This means that, strictly speaking, we are dealing with "activities" and not "efficiencies".

3.4 Cost modelling

All costs (capital and operating) in the database are in real values and refer to the year 2010.

Capital costs are intended to be for installed plants and therefore include cost items such as engineering and supervision, construction expenses, legal and contractor's fees, besides the costs of purchased equipments. Capital costs from sources issued in a year other than 2010 have been adjusted based on location specific (European or North American) power capital cost indices, and assuming fixed currency exchange rates. Details on capital cost indices and exchange rates can be found in the "Currencies" tab of the database. Evolution of capital costs for each decade to 2050 is based on the scenario dependent, TRL-dependant evolution curves (see above)

Operating costs are split into fixed operating costs and variable operating costs, in line with what done in ESME. Fixed operating costs refer to costs which are incurred regardless of level of usage. Variable operating costs are costs which are in proportion to the level of usage. However, variable operating costs do not cover the costs related to inputs (biomass, utilities, etc.) to a given technology, as these are calculated endogenously by the model. For example, if oilseed rape, electricity, hexane are the inputs to the oil extraction technology, the operating costs associated with sourcing oilseed rape, electricity and hexane will be calculated within the model, depending on the utilisation of that technology.

3.5 GHG emissions

There are four categories of emissions associated with biomass technologies:

1. emissions associated with biomass feedstocks, e.g. the emissions associated with the cultivation, harvest, and transport of wheat as input to an ethanol plant
2. emissions associated with utilities consumption, e.g. the amount of electricity and natural gas consumed in an ethanol plant
3. emissions associated with construction of the plant itself, e.g. those emissions arising from fabricating the equipments and the civil works of a plant
4. emissions generated when a feedstock material is converted into an output, e.g. the carbon dioxide emitted when biomass is gasified

The technology database will cover these categories in the following way[9]:

1. emissions associated with biomass feedstocks. These will be calculated in WP1 and are excluded from the technology database[10]. The optimisation model will calculate how much emissions associated with the biomass feedstocks are produced based on the actual amounts used in the optimised value chains

[9] A separate note on GHG modelling has been produced in response to the Stage Gate Review.
[10] With the exception of data placeholders for imported feedstocks in the "{Resources}" tab.

2. emissions associated with utilities consumption. The technology database includes the amount of all utilities consumed by a technology and their emission factors. The optimisation model will calculate how much emissions associated with utilities are produced based on the actual number of technologies and their utilisation in the optimised value chains. Emissions factors for utilities such as electricity will be given as fixed parameters in the model, i.e. they will be generated exogenously (e.g. from ESME model runs) rather than calculated endogenously in the model.

3. emissions associated with construction of the plant itself. These will not be covered in the technology database nor in the optimisation model. Our experience and previous work tell us that such emissions are typically a minor contribution to the total lifecycle emissions, and therefore can be safely ignored for modelling exercises such as the BVCM. For example, construction emissions are not included when calculating the emissions in the RTFO Carbon Calculator.

4. emissions generated when a feedstock material is converted into an output. In general, these emissions are not included in the database, based on the assumption that a biogenic carbon returned to the atmosphere (e.g. by burning biomass) has a zero net GHG impact. This holds true if the biogenic carbon is emitted as CO_2. However, when the carbon is emitted as a different GHG molecule, those emissions need and will be accounted for. This is the case, for example, of biogenic methane leaks from an anaerobic digester, for which the different global warming potentials of carbon dioxide and methane need to be accounted for.

Emissions will be expressed in $kgCO_2eq$. and will be split into CO_2 and non-CO_2 contributions.

3.6 Maximum build rates

For each technology, the database includes parameters (one for each decade) for the maximum build rate in the UK (expressed in appropriate unit, e.g. how many biomass power plants can be build in a decade, or how many kW of capacity can be installed in a decade).

The optimisation model will choose to build in a decade up to as many plants of a given technology as set in the maximum build rate parameters. This ensures that unrealistic technology deployment does not occur in the model.

Build rates are typically determined by a series of factors such as number of technology developers, skill base and availability of labour, availability of resources, availability of finance, etc.

In the technology database we have typically assessed build rates for each technology independently, based on the number of existing developers, the number of existing plants, and the likely maximum share of global market that the UK may cover. All assumptions and calculations can be found in the database.

We are aware that build rate constraints is typically an area of optimisation modelling that needs care and scrutiny, as the deployment of certain technologies can impose bottlenecks on the deployment of other technologies. For example, accelerated deployment of Fischer-

Tropsch technologies may impose supply chains bottle necks on integrated gasification combined cycle technologies, as both rely on gasification equipments. However, the modelling of cross-technologies supply chain capacity and bottlenecks requires efforts beyond the scope and the timeline of the BVCM. For the BVCM, we suggest using the preliminary results of the optimisation model to understand if and how supply chain effects across technologies need to be taken into account, and include any refinement or reconciliation of build rates at a later stage in WP4.

4 Resource data description

In the technology database, as well as in the BVCM model, we intend resources as a general term for any input or output to a technology.

In the technology database, each resource is defined by the following categories:

- unique ID
- description, e.g. describing the process by which the resource has been produced
- unit
- density
- lower heating value (LHV)
- moisture content (average, and seasonal[11])
- ash content
- alkali/alkaline metals content
- halides content
- silica content
- chlorine content[12]
- number of seasons it can be stored
- cost of storage per season
- GHG emissions (if applicable, e.g. not biogenic resources, or in case the resource is imported)
- cost of imports

A list of the resources currently in the database is given below in Table 4-1[13].

Biogenic solids biomass	Biogenic liquids	Gases	Others
Winter wheat (grain)	Rapeseed oil	Syngas	Coal
DDGS	Bio-diesel (HVO)	Landfill gas	Hot water
Winter wheat straw (baled)	Bio-diesel (FAME)	AD gas	Low pressure Steam
Winter wheat straw pellets	Ethanol	Methane (including Biomethane)	High pressure Steam
Oilseed rape	Butanol	Natural gas	Electricity
Rapeseed meal	Higher alcohols	DiMethyl Ether (DME)	MSW
Sugar beet	Acetone	Propane mix gas	Digestate
Sugar beet tops	FT diesel	Hydrogen	CO_2
Sugar beet pulp	FT jet	Fuel gas	S_2O

[11] The database has currently numerical values for average moisture content only. However, architecture is in place, e.g. in the forms of placeholders, for seasonal values.
[12] Numerical values for alkali/alkaline metals, halides, silica, and chlorine content in the inputs will be derived in Phase 2.
[13] DDGS = Dried Distillers Grains with Solubles, HVO = Hydrotreated Vegetable Oil, AD = Anaerobic digestion, FAME = Fatty Acid Methyl Ester, MSW = Municipal Solid Waste, FT = Fischer-Tropsch, DME = Dimethyl ether, SRC = Short Rotation Coppice, AR = As Received.

Maize	Hydrotreated renewable jet (HRJ)		All min constituents (lumped)
Maize silage	Methanol		Additives
Grass silage			Glycerine - crude
SRC (Willow) - chips	Diesel		Sodium methoxide
SRC (Willow) - torrefied chips	Gasoline		HCL
SRC (Willow) - pellets	Naphtha		H_3PO_4
SRC (Willow) - torrefied pellets	Pyrolysis oil		Water
Miscanthus - AR (baled)	Upgraded pyrolysis oil (UPO)		Carbon
Miscanthus - pellets	Hexane		Enzymes
Miscanthus - torrefied pellets			Caustic soda
SRF - AR			Urea
SRF - chips			Pulp
SRF - torrefied chips			Sulphuric acid
SRF - pellets			Char
SRF - torrefied pellets			
Forestry residues - AR			
Forestry residues - chip			
Forestry residues - torrefied chips			
Forestry residues - pellets			
Forestry residues - torrefied pellets			

Table 4-1 Resouces in the technology database

5 Technology data description

The parameterisation data contained in each technology tab can be divided into the following data groups:

1. Modes definition data
2. Mode-dependent data
3. Mode independent data

5.1 Mode definition data

For each technology, modes are defined as a combination of main input and main output resources (as listed in the "{Resources}"). There is no limit on the number of modes can be represented for each technology, beside the limits on computational complexity.

5.2 Mode-dependent data

For each technology, for each mode and for each decade, the following data are given:

- the amount of main input per unit of main output
- the amount of any additional input (per unit of main input or main output)
- the amount of any addition output (per unit of main input or main output)

5.3 Mode-independent data

For each technology and for each decade, the following data are given:

- Technology availability. A binary flag depending on whether a technology is available (1) or not (0) in a given decade
- Minimum and maximum nameplate capacity
- Fixed operating costs, in £ per year per capacity unit (of input or output)
- Variable operating costs(excluding all feedstock costs, as these will be calculated internally by the optimisation model) in £ per year per capacity unit (of input or output)
- Capital costs, per capacity unit
- Economic life, in years
- Technical life, in years
- Availability, in percentage of operating hours in a year
- Allowable turndown, in percentage
- Build rates, in unit of main outputs or inputs or in number of plants at maximum nameplate capacity
- CO_2 emissions (not from inputs/ouputs), in tonnes of CO_2eq. per capacity unit
- Non-CO_2 emissions (not from inputs), in tonnes of CO_2eq. per capacity unit
- Minimum moisture content in main input, in percentage
- Maximum moisture content in main input, in percentage
- Maximum ash content of main input, in percentage
- Maximum alkali/alkaline metals content in main input, in percentage
- Maximum halides content in main input, in percentage
- Maximum silica content in main input, in percentage

- Maximum chlorine content in main input, in percentage

5.4 Other technology data

In addition to the three groups of data illustrated above, in each technology tab the following data are reported:

- Scenarios. These are flags (Low, Medium, and High) about the scenario currently chosen for the technology efficiency and costs, as set in the "Control" tab[14]
- TRL. These describe the TRL level currently chosen for the given technology, and the technology group (preprocessing, gaseous fuels, liquid fuels, electricity/power/CHP) the technology belongs to. Both these values are set in the "{Technologies}" tab.

5.5 Auxiliary calculations and data

In addition to the technology parameters for data extraction (illustrated above), any other data, assumptions, calculations, references, etc. used to derive the technology data are reported as well in the relevant technology tab.

5.6 Technology and scale coverage

Each technology is modelled at different scale, depending on whether key performance factors such as efficiency and costs are dependent on scale. Technology performances at a given scale are assumed to be constant between the minimum and the maximum nameplate capacity, in accordance to the piecewise linear nature of the model.

Relevant scales considered for each technology are summarised below, where "S" stands for small, "M" for medium, "L" for large, and "U" for a unique size. Nameplate capacity ranges for each technology can be found in the database

Technology	Size	Technology	Size	Technology	Size
Chipping	S/M/L	First gen ethanol	S/M/L	Boiler combustion (heat)	S/M/L
Pelletising	S/M/L	First gen biodiesel	S/M/L	Biodedicated steam cycle (CHP)	S/M/L
Torrefaction	U	First gen butanol	S/M/L	Biodedicated steam cycle (electricity)	M/L
Oil extraction	S/M/L	Lignocellulosic ethanol	U	Cofired steam cycle (CHP)	U
Pyrolysis	S/M/L	Lignocellulosic butanol	U	Cofired steam cycle (electricity)	U
Anaerobic Digestion	S/M/L	Gasification + FT synthesis	U	Stirling engine	U
Landfill gas	U	Gasification + methanol catalysis	U	Organic Rankine Cycle	S/L
Biogas upgrading	S/M/L	Gasification + mixed alcohol processing	U	IC engine	S/M/L
Gasification	S/M/L	Gasification + syngas	U	Gas turbine	S/M/L

[14] A placeholder for scenarios on different discount rates exists as well

(generic)		fermentation			
Gasification + bioSNG	M/L	Pyrolysis oil upgrading	U	Syngas boiler	S/M/L
Gasification + DME	U	Hydrotreatment	U	Dedicated biomass IGCC	M/L
Gasification + H2	U			Cofired IGCC	U
Gas compression	U				

6 Fuels emissions factors and costs

Emissions factors for fossil-based fuels and chemicals are from the Carbon Calculator used for the UK Renewable Transport Fuel Obligation and from the Renewable Obligation. Emissions factors for electricity to 2050 will be taken from DECC[15] or otherwise agreed with the ETI. Fuel prices are from ESME. They are expressed on a decal basis and include multiple options (high/medium/low prices).

[15] E.g. from AEA, Pathways to 2050 – Key Results. MARKAL Model Review and Scenarios for DECC's 4th Carbon Budget Evidence Base Final Report. May 2011.

7 Current data gaps

A first working version of the technology database has been developed to date and supplied to Imperial College for the prototyping of the data extraction and for use of data in the existing prototype model. Although the database contains most of the data to be delivered in its final version at the end of the project, some data gaps still exists at the moment. Main current data gaps, which are not on the critical path to the development of the prototype model, are listed below. Unless otherwise specified, data gaps will be filled during the project.

- Resources data.
    - Some resources lack values for lower heating value, ash content, and moisture content
    - Some resources lack values for ash content
    - All resources lack data on storage (i.e. number of allowed seasons and cost per season)
    - Only one type of syngas is included in the technology list. We may investigate the option of including one or more additional syngas types, in order to take into account how composition (and heating value) changes depending on feedstock
    - Data on seasonal moisture content. These data will be generated in BVCM Phase 2.
- Technology data.
    - Data are currently missing for gas turbines and sugar-to-diesel route (this is due to the fact gas turbines were not actually in the Technology Contract, but we do believe are part of the scope)
    - The database currently includes a generic gasifier module at small, medium and large scale, for a total of three standalone gasifier technologies. The small gasifier is derived from costs for a fixed bed technology, the medium based on fluidised bed technologies, and the large based on entrained flow technology. However, based on the feedback received on the technology landscaping review, we may increase the number of these generic gasifier modules in order to better represent different gasifier technologies
    - Data are currently missing for close coupled gasification technology and gasification combined with open cycle gas turbine/gas internal combustion engine. The closing of this data gap depends on the development of the gasifier modelling (above).
    - Data are missing for existing technology stock and their retirement plan
    - Data on minor constituents (besides total ashes). These data will be generated in BVCM Phase 2.

8 Data quality

The table below gives a high level qualitative overview of the level of data quality for each technology currently in the database, as judged from the consortium. Data quality is usually associated with factors such as number of references in the literature, their date and their authoritativeness, correctness of assumptions, how realistic the consortium thinks the values in the source are, their level of uncertainty, how specific values are to a certain plant configuration only, etc.

Areas where data quality is low need to be tracked in order to assess the robustness of the model solutions to inputs and parameters by means of sensitivity analysis and case study analysis.

Technology	Data quality	Comment
Chipping	High	Mature technologies with good, detailed, recent, references
Pelletising	High	Mature technologies with good, detailed, recent, references
Torrefaction	High	Recent reference, based on detailed design. May refer to a small scale plant, though
Oil extraction	High	Mature technologies with good, detailed, recent, references
Pyrolysis	Medium	Several recent, good, detailed engineering studies, and meta-analysis of academic literature, although large differences between feedstocks and oil quality
Anaerobic Digestion	High	Mature technologies with good, detailed, recent, references
Landfill gas	High	Mature technologies with good, detailed, recent, references
Biogas upgrading	High	Mature technologies with good, detailed, recent, references and updated by emerging trends based on recent experience
Gasification (generic)	Low	No references consider gasifiers producing syngas as a stand-alone plant, hence all costs were backed out of integrated heat, power or fuel systems. Costs vary widely according to feedstocks, syngas quality, gasifier technology, and some of the available academic literature is old
Gasification + bioSNG	High	Academic literature is limited, but we have used a recent, good, detailed engineering study, which matches with planned plants of the few developers
Gasification + DME	Medium	Only one detailed study available, based on the design of the one developer, no academic literature. Some proxies from methanol plants used
Gasification + H2	Medium	Much of the academic literature is outdated, but one good detailed engineering study has been recently updated. There are no developers or plants, i.e. cross-referencing with reality is not possible

Gas compression	High	Mature technologies with good, detailed, recent, references
First gen ethanol	High	Mature technologies with good, detailed, recent, references
First gen biodiesel	High	Mature technologies with good, detailed, recent, references
First gen butanol	High	Mature technologies with good, detailed, recent, references
Lignocellulosic ethanol	High	Numerous recent, good, detailed engineering studies and academic literature available
Lignocellulosic butanol	Low	No literature or detailed engineering studies, and very few developers. The only references are recent, but cost estimates have to combine the front-end of a lignocellulosic ethanol plant with the back-end of a first gen butanol plant, with other future proxies taken from lignocellulosic ethanol plants
Gasification + FT synthesis (FT diesel only or FT diesel/FT jet)	High	Numerous recent, good, detailed engineering studies and academic literature available
Gasification + methanol catalysis	Medium	Good, detailed engineering studies and academic literature available, although not up-to-date
Gasification + mixed alcohol processing	Medium	A few good, detailed engineering studies and pieces of academic literature available. However, differences in ratio of plant outputs (ethanol, methanol, higher alcohols) between sources, and variation between efficiencies quoted by developers
Gasification + syngas fermentation	Low	Only one detailed study, but missing cost of the microbes, and efficiency much lower than developer press-releases
Pyrolysis oil upgrading	Medium	A few good, detailed, and recent engineering studies and literature available. However, no real data, and wide range in costs and efficiencies according to plant configurations/refinery integration chosen
Hydrotreatment (HVO only or HVO/HRJ)	Medium	No detailed engineering studies available and proxy used for estimating other HRJ inputs. However, technology is early-commercial, and literature agrees with costs for the large plants already built
Boiler combustion (heat)	High	Numerous data sources and analysis. Mature technologies with good, detailed, recent, references using data from recent UK installations
Biodedicated steam cycle (CHP)	High	Numerous data sources and analysis. Mature technologies with good, detailed, recent, references
Biodedicated steam cycle (electricity)	High	Numerous data sources and analysis. Mature technologies with good, detailed, recent, references
Cofired steam cycle (CHP)	High	Numerous data sources and analysis. Mature technologies with good, detailed, recent, references and supported by commentary given recent legislation
Cofired steam cycle (electricity)	High	Numerous data sources and analysis. . Technology with good, detailed, recent, references
Stirling engine	Medium	Recent reference, based on detailed design. May be

		too optimistic, though. Feasibility with some feedstocks is uncertain.
Organic Rankine Cycle	Medium	Recent reference, based on detailed design. However, it is based on a unique design by single developer. Also: may be too optimistic, and feasibility with some feedstocks is uncertain.
IC engine	High	Mature technologies with good, detailed, recent, references
Gas turbine	Data missing in current version of the database	
Syngas boiler	Low	No references consider syngas boilers burning syngas as a stand-alone plant – gasifier/boiler systems are always integrated as close-coupled systems. However, since the technology is commercial, a reasonable proxy can be drawn from natural gas boilers, which have numerous data sources
Dedicated biomass IGCC	Medium	Several pieces of academic literature and detailed engineering studies, although old, hence fit with coal IGCC costs at large-scale is poor. Existing plants all closed in 1990's, although new plants currently under construction, i.e. no real world experience
Cofired IGCC	High	Numerous literature sources, recent good industry meta-review of coal IGCC costs and efficiencies. Co-firing is also a commercial technology, and additional costs to a coal IGCC plant are known
Gasification + gas ICE	Known data gap to be filled	Already have data from several developers and literature, wide range of costs and efficiencies expected due to different system designs and feedstocks
Gasification + gas turbine	Known data gap to be filled	Fewer developers compared to biomass IGCC (similar technology), but some estimates available from literature and planned plants
Close-coupled gasification	Known data gap to be filled	Already have data from several developers and literature, wide range of costs and efficiencies expected due to different system designs and feedstocks

9 Next steps

Next steps in WP3 regarding the technology database development are:

- liaise and assist Imperial College in developing automatic database data extraction tools
- liaise and assist Imperial College in augmenting the prototype model with an increasing number of technologies
- fill in current data gaps. Input from WP1 partners will be sought for issues like storability
- include any missing technologies, e.g. further generic gasifier modules
- harmonise evolution curves for efficiency and capital costs
- harmonise technology maximum build rates, and if necessary introduce build rates for groups of technologies
- carry out further quality control checks to maintain the database quality
- carry out routine troubleshooting