DEVELOPMENT OF STANDARD TOOL FOR EVALUATING GREENHOUSE GAS BALANCES AND COST-EFFECTIVENESS OF BIOMASS ENERGY TECHNOLOGIES

J. van Dam[a] , A. Faaij[a], E. Daugherty[b] , L. Gustavvson[c] , M.A. Elsayed [d] , R.E. Horne [d], R. Matthews[e] , N.D. Mortimer [d], B. Schlamadinger[b], S. Soimakallio[f] , P. Vikman[c]

[a] Department of Science, Technology and Society, Copernicus Institute, Utrecht University,
Padulalaan 14, NL-3584 CH, Utrecht, the Netherlands
Tel. + 31 30 253 7648, Fax +31 30 253 7601, e-mail j.vandam@chem.uu.nl
[b] Institute of Energy Research at Joanneum Research, Austria
[c] Department of Natural and Environmental Sciences, Mid Sweden University, Sweden
[d] Resources Research Unit, Sheffield Hallam University, UK
[e] Forest Research, UK
[f] VTT Processes at the Technical Research Centre, Finland

ABSTRACT: This paper describes the development of a user-friendly software tool that can be used to analyse GHG balances and cost-effectiveness of different biomass energy technologies. The tool has to be able to accommodate a diversity of biomass technologies. It has to be applicable for different user groups such as universities, policy-makers or companies involved in biomass technologies. As preparation for the development of the tool, a unified methodology is being developed to evaluate GHG-balances and cost-effectiveness of biomass energy technologies. Main characteristics of the software architecture of the tool are the flowchart design and the concept of working with different tiers of calculation and data input. This makes the tool applicable for a wide diversity of data availability and biomass technologies.

Keywords: software tool, greenhouse gas balances, cost-effectiveness

1 INTRODUCTION

Climate change is an issue of global concern, and in most scenarios expected to have major impact on ecological and social systems. The anthropogenic emissions of greenhouse gases (CO_2, CH_4, N_2O, and halocarbons) is considered to be a key factor, and since these emissions to a large extent are the result of energy use, implementation of new energy systems is an important strategy for the mitigation of climate change.

Therefore, the European Commission has set ambitious aims to promote the use of biomass energy in the European Union (EU). In recent years, various policy papers, targets and directives have been developed to promote the use of renewable energy, including bio-energy, in the EU. One of the targets is that almost 10% of the energy supply of the EU is to come from biomass in 2010. Beside this, almost all European countries have included bio-energy in their national energy and climate policies.

There are different biomass energy technologies that present considerable potential for the large-scale exploitation of renewable energy sources in the EU. These technologies offer significant prospects for reducing Greenhouse Gas (GHG) emissions. For the promotion and evaluation of these technologies, it is important to know their GHG reduction and reduction costs compared to conventional technologies. The results are not only important for policy-makers but also for the stakeholders who intend to invest in new biomass technologies. However, there are many factors that influence the results of GHG reduction and accounting, such as timing, accounting rules and definition of system boundaries.

At this moment, several tools are available in the EU for evaluating GHG-balances and cost-effectiveness of biomass energy technologies [3]. The disadvantage of these tools is that they are either complicated to use (i.e. the Australian model CAMFOR) or they are restricted to one biomass energy technology or resource (i.e. CO2Fix is limited to forestry). This makes it difficult to compare data of GHG-balances and cost-effectiveness of biomass energy technologies within the EU. A unified, standard tool, which enables user groups to compare results of biomass energy technologies throughout the EU is lacking at this moment.

The aim of the BIOMITRE project[1] is to develop a standard, user-friendly software tool that can be used to analyse GHG balances and cost-effectiveness of different biomass energy technologies. The tool has to be able to accommodate a diversity of biomass technologies. It has to be applicable for different user groups such as universities, policy-makers or companies involved in biomass technologies. As preparation for the development of the tool, a unified methodology is being developed to evaluate GHG-balances and cost-effectiveness of biomass energy technologies.

[1] BIOMITRE (BIOmass based Climate Change MITigation through Renewable Energy) - is a European Commission project, financed jointly by the Directorate-General for Energy and Transport and IEA Bioenergy Task 38 Greenhouse gas balances of biomass and bioenergy systems (http://www.joanneum.ac.at/iea-bioenergy-task38/).

REVIEW OF METHODOLOGIES

One of the main purposes of the BIOMITRE project is to unify methodologies into a standard approach for evaluating the greenhouse gas (GHG) balances and cost-effectiveness of GHG savings associated with biomass technologies. This unification of methodologies is based, crucially, on a review of the main existing methodologies.

For this review, literature was mainly collected from international databases. Research networks such as IEA Bioenergy Task 38, were consulted to assure that well-known suitable references were not missed in the database searches. The survey included refereed scientific papers, technical reports and books. About 500 references were originally collected. A shorter list of references was selected as representative for a detailed evaluation of methodological characteristics. The selection was mainly based on a selection of indexed keywords and on expert knowledge of the BIOMITRE research group [1].

The selected papers typically describe project level applications of analyses of GHG-emissions from bio-energy systems with a life-cycle perspective, including comparisons to fossil fuel references. Cost-assessments in relation to GHG reductions are of high interest to the BIOMITRE project, but since very few references contained such combined approaches, some of the selected papers have no cost assessments.

Current methodological approaches were evaluated (see figure 1) for their strengths and weaknesses in relation to the objectives for the BIOMITRE project, i.e. evaluating greenhouse gas balances and emissions-saving cost-effectiveness of prominent biomass energy technologies relevant to the European Union. Three categories of key questions (criteria are based on literature review) were recognized and applied to each method evaluated [1]:

- *Accuracy* of the methodology; considering *comprehensiveness* (functional unit, system boundaries in time and space, reference system etc.) and *consistency* (consistent treatment of actual and reference system, etc.)
- *Transparency* (assumptions clearly shown, use of flow charts and sensitivity analyses)
- *Efficiency* (appropriate level of detail balanced with ease-of-use, comparable output parameters)

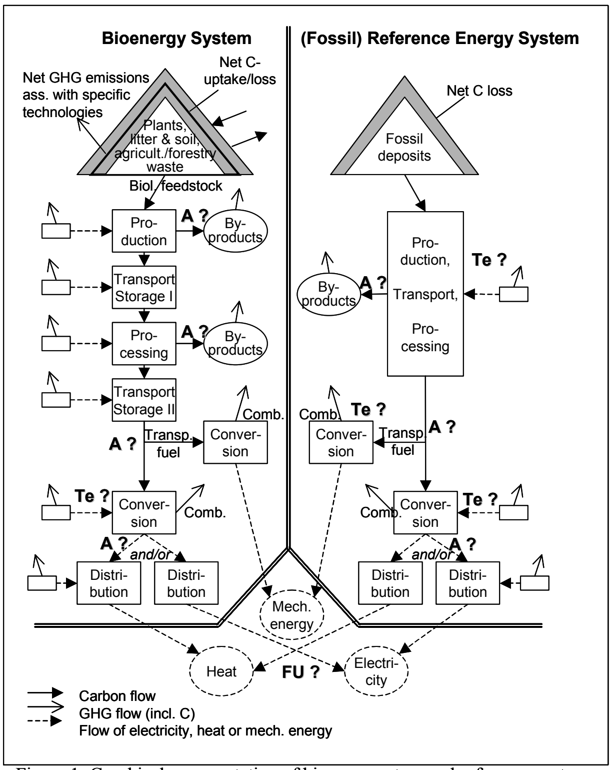

Figure 1: Graphical representation of biomass system and reference system used for characterization of reviewed reports. Question marks indicate examples of points of special methodological interest for allocation method (A?), choice of functional unit (FU?) and choice of technology (Te?) (Vikman, 2003)

2 UNIFICATION OF METHODOLOGIES

A main finding of the review of methodologies is that accuracy is the foremost methodological aspect to consider. Comprehensiveness and consistency are key factors of an accurate methodological approach. System boundaries, in time and space, should be set to include all differences in GHG emission and cost between the bio-energy and the reference system. For example, the functional unit should include end-use efficiency, if it varies between compared systems [1].

Two other relevant methodological issues are the choice of reference system and allocation. The review concludes that allocation should as far as possible be avoided by expanding system boundaries to include both main- and by-products. The best choice of reference system appears to be "the least-cost fossil energy system with the lowest GHG-emissions and minimized environmental impact, fulfilling the same goals as the bio-energy system, but several alternatives may have to be considered [1].

The methodology used to describe the compared systems, must be consistent and the same technical level should be used in all comparisons. All assumptions and calculations should be shown in a clear and structured way, and for good transparency, flow charts should be used to describe the process-trees of all systems studied, including the reference system [1].

From an efficiency point of view, details with a small impact on the results in relation to uncertainties of other parameters might be omitted, and the uncertainties of the other parameters should be reduced instead. Scenario studies and sensitivity analysis could be used to investigate the relative importance of a process unit, or the effect of varied assumptions [1].

Relevant output parameters should be used for comparison of results. For the scope of BIOMITRE the following parameters, are suitable ones; Cost efficiency (GHG reduction / costs), land use efficiency, primary energy efficiency (GHG reduction / input of bioenergy), and Biomass efficiency (GHG reduction / biomass input) [1].

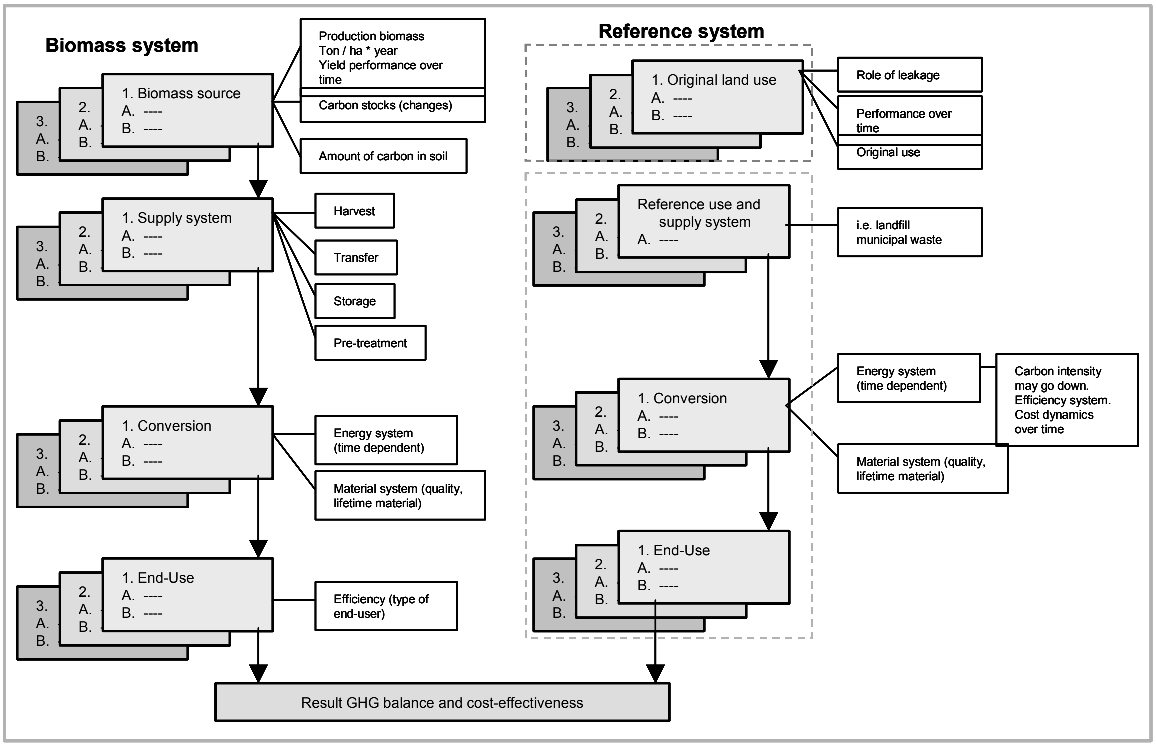

Figure 2: Flow chart design for software tool BIOMITRE

3 SOFTWARE TOOL DESIGN

The aim of BIOMITRE is to develop a standard, user-friendly software tool that can be used to analyse GHG balances and cost-effectiveness of different biomass energy technologies. The tool has to be able to accommodate a diversity of biomass technologies. It has to be applicable for different user groups such as universities, policy-makers or companies involved in biomass technologies.

The tool is developed in the software program Excel. The tool will be accompanied with a manual that will serve as background material and guide for the user. The tool will be accommodated with a set of established case studies that will demonstrate examples for the wide diversity of biomass technologies and resources that can be accommodated by the tool.

Table 1: Set of established case studies that will be used for BIOMITRE tool

Case study	Resource	Use	Reference system
1	Rapeseed	RME plant	Diesel /
2	Forest residues	F-Tropsch	Diesel, grid (electricity)
3	Wood	CHP plant	Heat and electricity
4	Miscanthus	Domestic heat	Oil fired heat

The tool will have three major components in the development of the software tool:

1. The greenhouse gas balance calculation determines the total greenhouse gas (CO_2, CH_4, N_2O) emissions associated with the biomass technology.
2. The cost-effectiveness calculation establishes the net costs of saving a given amount of greenhouse gas emissions by implementing the biomass technology.
3. Software tool design.

The first two components are based on the outcome of the unification of the methodologies. They are interrelated with the third feature of the tool: the software tool design, which is the framework of the tool. When looking at the design of the software tool, there are two practical challenges, which need to be dealt with in the architecture of the tool:

- First, the tool has to deal with a large variety of biomass technologies, which can be implemented to reduce greenhouse gas emissions on a national and international scale.
- A second challenge for the software tool is the variety in data availability for different biomass technologies, countries and user groups.

These challenges can be coped with by two specific characteristics of the tool:

- Flow charts and modules will summarize the characteristics of any given biomass technology.
- Successive disaggregating of data in tool.

3.1 Flow chart design

Flow chart design is governed by the need to summarize data so that the biomass technology is specified in a clear, unambiguous and transparent manner. Transparency is particularly important since this promotes confidence amongst subsequent users of the tool concerning key assumptions about the biomass technology under consideration.

Flowcharts represent all the inter-linked processes, which comprise a biomass technology. Each major process is identified and essential data are specified for the inputs and outputs associated with each process.

The flow chart design for the BIOMITRE tool is presented in figure 2. A main component of the tool is the resource module. The tool identifies as resources perennial crops, annual crops, forest and waste. In terms of supply, the main initial input resources (seed, cuttings, land, etc.) are indicated. Co- products and by-products that occur at any stage in the biomass technology are taken into account since these can have a significant role in final evaluation through allocation procedures.

A modular approach in accordance with the model developed by [4] is used for the logistics (train, ship, truck transport) to supply biomass to the conversion unit. The end-use possibilities are forms of delivered energy (solid, liquid, gaseous fuels, heat, electricity, heat, etc.).

Output of the tool is the representation of the GHG impact (per ton biomass, € / ton biomass) and the cost-effectiveness (€ / ton C avoided, total C avoided) for the project. Other options affecting the output are accounting procedures, cost calculation options (IRR, NPV, etc.) and sensitivity analysis.

3.2 Successively disaggregating data

The strength of the tool is the standard methodology and transparency for the user. The tool will make use of a set of case studies that will cover a range of biomass technologies for a defined location to show the user how to calculate greenhouse gases and cost-effectiveness. Of course, the tool cannot provide all data for the wide range of users because they are project specific and unique in location and site.

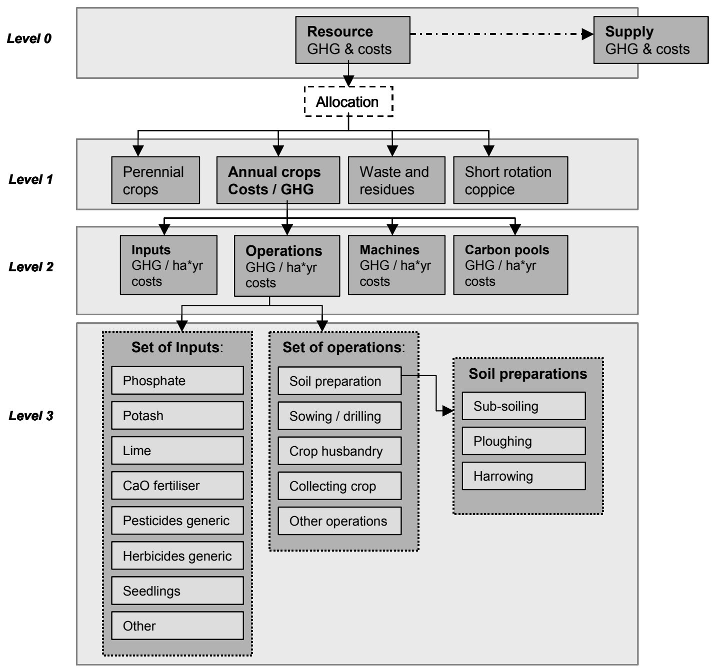

Figure 3: The tool provides the user different levels of calculation and thus data requirement. In this example the module "biomass resources: shows three different levels of calculation.

In general, there are three different possibilities for data input for the user:

- The data are already covered in the set of case studies
- The knowledge of the process system is available and the modules are included in the tool. The user has to collect its own data in international databases. References will be provided to the user.
- There is a lack of data, also in international databases (new technologies). The framework of the required module and data input for the process is presented in the tool. However, the user might have to do some adaptations in input and output data.

The variation in data availability has its impact on the levels of calculation within the software tool. Therefore, successively disaggregating is used to be able to cope with this data diversity. The key concept of the software tool design is that different "tiers" for greenhouse gas (and cost) calculations and, thus, data requirements are used. This will enable users to adopt either aggregated or disaggregated data for subsequent analysis.

Figure 3 shows this concept for the "resource module". The first tier is a very generic level of data collection and calculation. The second tier requires more specific data that can generally be found in literature or international sources. The third tier is project specific: the user will have to collect its own data for inputs, machinery, labour inputs, etc.

The three different tiers within the tool provide the user the possibility to choose its own attainable degree of data specificness. Of course, the output is related to the data input. This means that calculations in tier three generate a more exact data output than calculations in tier one.

5 STATUS OF THE WORK

This project BIOMITRE is still in implementation. The review of methodologies is completed and the partners agreed on the design of the software tool. Currently, data of the case studies are collected and the building of the tool is proceeding.

The results of the project will be available in 2005 and to become distributed via Task 38.

REFERENCES

[1] Vikman P., Klang A, Gustavsson L (2003) Evaluating greenhouse gas balances and mitigation costs of bio-energy systems – a review of methodologies, Mid Sweden University, Sweden
[2] Mortimer N., (2003), Deliverable BIOMITRE project: Outline of unified methodologies, Sheffield University, U.K.
[3] http://www.joanneum.ac.at/iea-bioenergy-task38/softwaretools/
[4] C.N. Hamelinck, R. Suurs, A. Faaij (2003), International bioenergy transport costs and energy balance, Copernicus Institute Utrecht University