BIOMASS FUTURES

Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders . IEE 08 653 SI2. 529 241

Description of model links between PRIMES-biomass and RESolve

—

Harmonisation of the techno-economic data among ECN, ICCS, Oeko and IIASA

Deliverable D5.6

Ayla Uslu, Joost van Stralen –ECN

Alessia De Vita, Evi Apostolaki,
Pantelis Capros- E3MLab/ICCS

Contributions:
Hannes Bottcher-IIASA
Uwe Fritische-Oeko

March 2012

Preface

This publication is part of the BIOMASS FUTURES project (Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders - IEE 08 653 SI2. 529 241, www.biomassfutures.eu) funded by the European Union's Intelligent Energy Programme.

In this deliverable a comparison of the RESolve model set and the PRIMES biomass model outcomes is carried out. Key similarities and differences are presented, both from a modelling perspective and regarding the models results. Additionally, the techno-economic data provided by the Biomass Futures project partners are presented.

Contents

1

Introduction

Within the Biomass Futures project the two models RESolve of ECN and the PRIMES Biomass model of E3Mlab/ICCS of the NTUA have collaborated among each other and with other project partners on harmonising the input data both in terms of potentials and in terms of techno-economic technology data. On the basis of this harmonisation similar scenarios were run and the scenario outputs were compared.

This deliverable is divided into the following sections:

- A brief description of the models and their functionalities
- Differences between the models in construction and scope
- Harmonisation of the input data
- Development of scenarios and comparison of scenario results
- Conclusive remarks from a modelling perspective on the complementarities of the models and possible further research objectives, and from a policy perspective.

.

2

Functional description of RESolve Model set and PRIMES biomass model

2.1 Resolve model set

The ECN RESolve model consists of a set of three independent sub-models, known as RESolve-biomass (developed during Biomass Futures project to enable biomass allocation), RESolve-E (dedicated renewable electricity model) and RESolve-H (dedicated renewable heat model).

The RESolve-biomass model calculates the most cost effective[1] way to fulfil the specified bioenergy demand (for electricity, heating and cooling and the transport sector), given and constrained by a number of assumptions on economic and technological parameters in a specific target year, in terms of bioenergy production, cost and trade (trade of primary feedstock and/or biofuels). One of the most important features of the RESolve-biomass model is the ability to link the national production chains allowing for international trade. RESolve-biomass allows for trade of feed stocks and final products.

RESolve-E and RESolve-H are market simulation models that can reflect the complexities within renewable electricity and heat sector. Within RESolve-E the simulations are done for several target years up to 2030, taking account of various other factors complicating investment in renewables, such as (political) risks, transaction costs and delays due to planning and permitting processes. These factors contribute to a realistic simulation of the effectiveness of different policy instruments.

On the other hand RESolve-H is a simulation model that calculates the penetration of RES-H options based on a *dispersed S-curve* description of consumer's behaviour. This model covers the below sub-categories:

- Residential sector: space heating, water heating and cooking
- Tertiary sector: services and agriculture
- Industry: 14 subsectors, consisting of various industrial activities

In RESolve model life cycle GHG emission data for bioenergy pathways and the conventional fossil fuel energy system are derived from the GEMIS database. GEMIS is a full life-cycle/material flow analysis

[1] Most cost effective is defined here as the least additional costs with respect to fossil reference commodities.

model with integrated database; the model covers direct and indirect flows, construction/decommissioning, energy flows (fossil, nuclear, renewable), materials (metals, minerals, food, plastics) and transport services (person and freight), as well as recycling and waste treatment.

More details about the model set can be found in D5.1 Functional description of the RESolve model kit and the biomass allocation (van Stralen et al., 2012).

2.2 PRIMES Biomass model

The PRIMES Biomass Model is a model of the PRIMES family developed at E3Mlab/ICCS of the National Technical University of Athens and is used to complement the main PRIMES model by computing the optimal use of biomass resources for a given demand. The PRIMES Biomass model covers all EU 27 countries separately, as well as computing totals for the EU27, EU15 (old Member States) and NM12 (new Member States); the time horizon of the model is 2050, running by 5-years steps, as the other models of the PRIMES family.

The PRIMES Biomass Model is linked with the PRIMES large scale energy system model and can be solved either as a satellite model through a closed-loop process or as a stand-alone model. It is an economic supply model that computes the optimal use of biomass resources and investments in secondary and final transformation, so as to meet a given demand of final biomass energy products, projected to the future by the rest of the PRIMES model. The bio-energy commodity demand in PRIMES biomass model is defined as the bio-energy products used within the energy system; they can be secondary or final energy forms, such as solids or black liquor for combustion in power plants or biofuels for transportation. It does not include, as the RESolve model, electricity and heat from biomass, but only the inputs into power plants and boilers.

The model performs dynamic projections to the future from 2015 until 2050 in 5-year time periods with 2000 to 2010 as calibration years; it endogenously computes the energy and resource balances to meet a given demand by PRIMES model (or other external source), it calculates investments for technologies, costs and prices of the energy forms as well as the greenhouse gas (GHG) emissions resulting from the production of bio-energy commodities.

To compute the total CO_2 emissions and emission savings resulting from the use of different bio-energy commodities, emission factors from the PRIMES core energy model for electricity, diesel oil and natural gas are included as inputs of PRIMES biomass model. For electricity the values are country specific based on the mix of fuels in power generation and they change over the years based on the scenario projection. Moreover percentages that simulate the abatement of CO_2 emissions that need to be accomplished according to the EU Renewable Energy Directive are included. The IPCC methodology has been applied for the calculation of N_2O emissions and data from IFPRI have been included for the consideration of ILUC related emissions.

Furthermore, the PRIMES biomass supply model determines the consumer prices of the final biomass products used for energy purposes and also the consumption of other energy products in the production, transportation and processing of the biomass products. Prices and energy consumption are conveyed to the rest of the PRIMES model. A closed-loop is therefore established. Upon convergence, a complete energy and biomass scenario can be constructed.

3

Differences between the models in construction and scope

The two models analysed here, the RESolve model set and the PRIMES biomass model, are very different both in terms of the mathematics underlying their construction and in terms of scope.
The RESolve model set, as described in deliverable D5.1, is a modelling kit composed of three main elements determining the most effective way to supply the total RES to a given demand in the transport, heat and electricity sectors and a biomass allocation module. The latter allocation module takes the amount of electricity produced from biomass, heat produced from biomass and biofuel consumption for transport and optimally allocates the available primary biomass to these sectors, including the entire production chain.

The PRIMES biomass supply computes the optimal use of biomass resources for a given demand of bio-energy resources; the further transformation of bio-energy commodities into electricity or heat is not accounted for. This transformation takes place in the main PRIMES energy system model, which was not run within this project, but from which the demand for several scenarios analysed within the Biomass Futures project was taken. The scope of the model is to determine the prices of bio-energy commodities, the effects on land-use and of possible changes in policies regarding e.g. the sustainability criteria applied to biofuels.

The most important difference between the two models is that they operate with a different definition of biomass demand: in RESolve the “biomass demand” is described as in the NREAPs as the amount of electricity, heat or biofuels derived from biomass feedstock, whereas in PRIMES biomass the “biomass demand” is described as the amount of bio-energy commodities required by the energy system. The PRIMES biomass model therefore acts as a “refinery” for the raw biomass feedstock to transform them into secondary or final energy products, similarly to how a refinery transforms crude oil for further use in other energy sectors. The use of the bioenergy products is then accounted for in the main PRIMES energy system model.

Other important differences between the two models are the time horizon and the time resolution: the PRIMES biomass model runs all the way to 2050 in five year steps, whereas the RESolve model runs to 2030 and provides yearly outputs. The RESolve model is therefore more adequate for short to medium term analyses and can capture in a more detailed manner the transformations required, therefore the yearly development stages to obtain the targets. The model is able to capture yearly changes in policies and their effect towards the achievement of the EU targets. The PRIMES biomass model, on the contrary, is not able to capture short term changes with high amount of detail, as it can only reflect the effects in each five year time period; the model is built to perform analysis to capture the medium to longer-term effects of policies and climate targets on to the horizon of 2050. It is also conceived as a satellite model to the PRIMES model therefore can be considered as part of a total modelling system.

Both models can be used to verify the targets of the Climate and Energy package for 2020, however, whereas the RESolve model can compute the trajectory to obtain the targets, the PRIMES model provides the situation in the target year and can verify the effects over the longer time horizon; although no yearly trajectories are possible the accounting for vintages in the PRIMES biomass model implies that trajectories and technology developments are fully taken into account.

Table 1: Schematic comparison of the RESolve and PRIMES biomass models.

Model	**RESolve**	**PRIMES biomass**
Developer	ECN	E3Mlab/ICCS (National Technical University of Athens)
Mathematical basis	RESolve-biomass: linear programming RESolve-E: simulation RESolve-H: simulation	Non linear programming (as a standalone model) MCP (when linked with PRIMES energy system model)
Time horizon	2030	2050
Time resolution	1 year	5 year time periods
Geographic resolution	EU27, by Member State, Switzerland, Norway and Ukraine + import from the Rest of the World	EU27, by Member State +import from three world regions: CIS, North America and Rest of the World (representing mainly Brazil and Malaysia/Indonesia)
Definition of bio-energy demand	Demand for electricity, heat and biofuels produced from biomass	Demand for bio-energy products for further use in the energy system (e.g. pellets, large scale solid biomass, etc.)

The focus of the analysis within the Biomass Futures of the two models was the following: the RESolve model analysed in detail the achievement of the NREAPs, including the trajectory to achieve them on a yearly basis, the effects of changing the sustainability criteria and the possible effects of increasing the demand further; with the PRIMES biomass model the same scenarios were undertaken, the possibility of achievement of the NREAPs and the effects of modified sustainability criteria, as well as increased demand, but the analysis focused on the period beyond 2020 and up to 2050, including the analysis of the effects of the changed policies and increased demand for biomass in the context of achieving the decarbonisation targets of the EU, therefore 80% GHG emission reductions by 2050.

4

Harmonisation of the input data

Throughout the course of the project interaction between the modelling teams took place in order to arrive to a consistent set of inputs which are comparable and harmonised. The details of the process for the PRIMES biomass model can be found in deliverable D5.5 (Apostolaki et al.,2012); the details for the RESolve model set can be found in deliverable D5.1 (van Stralen et al., 2012) .

4.1 Potentials and the costs

In RESolve model set the main input data- feedstock potentials and the costs for domestic and imported biomass/biofuels are derived from D3.3 (Elbersen et al., 2012) and D3.4 Biomass availability & supply analysis (Böttcher et al., 2011).

For the construction of the PRIMES Biomass model feedstock potentials database various sources, including EUWood and EEA were used, while in the course of Biomass Futures project all the input data regarding feedstock potential used were crosschecked and harmonised with the data provided in D3.3 (Elbersen et al.,2012) by Alterra. For the feedstock prices the model uses country specific cost-supply curves. Concerning energy crops the model computes available energy crop potential based on available land for energy purposes. Land availability is based on exogenous assumptions. For the energy crop potential estimation specific land yields are used, which are assumed to increase overtime due to technology developments in agriculture and additional agricultural policies. The potentials for primary biomass used in the model for the period beyond 2030 were determined as follows: conservative extrapolation of the 2030 potentials (in case the feedstock was assumed to have been fully available by 2030) or, where possible, data from literature was used (e.g. maximum land availability for energy crops production). Concerning municipal waste and landfill potential an extensive analysis was carried out based on the population growth of each Member State according to Eurostat waste statistics.

4.2 Import data

The RESolve models include the import data derived from IIASA GLOBIOM modelling within this project. PRIMES biomass uses data from various sources, such as IEA, Enerdata, Eurostat, NREAPs, the U.S. DOE, FERN and FAOSTAT .

4.3 Techno-economic data

In the course of the project the bioenergy related techno-economic data have been harmonised among the project partners-ECN, Oeko, IIASA and NTUA. In Annex I techno-economic data per partner is presented. In PRIMES biomass technologies for heat and electricity are not provided within the overview. This is because the PRIMES biomass model does not include these technologies. The PRIMES biomass model produces bio-energy commodities which can be either secondary or final energy commodities; the model contrary to the ECN model does not produce electricity from biomass but the biomass input into e.g. power plants. The model produces the fuels (be it biofuels for transportation or bio-energy inputs for power plants or boilers) but does not include the technologies to produce final or useful energy (i.e. not the cars for transportation, the power plants producing electricity-or heat-, the boilers for space or water heating); the latter are included in the main PRIMES model only. The model therefore represents technologies which could be compared to the production processes in a refinery, in the sense that they represent the processing of primary energy to prepare goods for the secondary or final energy consumption (e.g. comparing to a refinery: the crude oil would be the biomass feedstock, and the outputs of a refinery –diesel, gasoline, etc.- can be used either in transportation or in other sectors of the energy system such as power generation, boilers for heating etc.). The PRIMES biomass model therefore acts as a “refinery” for the raw biomass feedstock to transform them into secondary or final energy products. The use of the bioenergy products is then accounted for in the main PRIMES model. The main use of the PRIMES biomass model within the PRIMES suite is to determine the prices of the bioenergy products and it is therefore often used in a closed loop system with the overall PRIMES model.

This is significantly different from the method of functioning of the model at ECN which covers the extended chain of production from the biomass feedstock to bio-energy commodities and then to final commodities including electricity and heat.

5

Comparison of the model outcomes

5.1 Scenario construction

The RESolve model and PRIMES biomass models have quantified the three scenarios agreed upon within the Biomass Futures projects (Uslu and van Stralen, 2012):

- a reference scenario with NREAP demand,
- a sustainability scenario and
- a “high” biomass scenario.
- Further the PRIMES modelling team updated, with the harmonised input data, the Reference scenario used for the 2050 Roadmaps of the European Commission and the main decarbonisation scenario of the Low Carbon Economy Roadmap “decarbonisation under effective technologies and global climate action”(EC,2011).
- The Reference scenario with NREAP demand used the demand as derived from the NREAPs delivered to the European Commission between June 2010 and January 2011. Details as to how the data was converted into model input data are below and in the specific deliverables of each modelling team (Apostolaki et al.,2012).
- The sustainability scenario is characterised by applying stricter sustainability criteria to the production of bio-energy commodities, by increasing the required GHG emission savings to 70% in 2020 and 80% in 2030 and by including indirect land use change (ILUC) emission factors. The sustainability criteria of this scenario are extended to apply to solid and gaseous biomass used in the electricity and heat sector, which until now are exempted. The RESolve team applied the stricter sustainability criteria to the NREAP demand scenario, whereas the PRIMES modelling team applied it to a decarbonisation scenario which achieves the targets of the Climate and Energy package for 2020, as well as the 80% emission reduction target for 2050.
- The maximum biomass scenario was implemented by increasing the demand for biomass energy products. The RESolve team applied an increase in demand in the time frame before 2030 and thus verifying the impacts of increased demand in the short to medium-term; whereas the PRIMES team increased the demand in the context of a decarbonisation scenario which aims at maximising overall RES consumption, and more use in the transport sector; details on determining the demand can be found below and in the specific deliverables.

Bioenergy demand

As described above there is a difference in the definition of bio-energy demand in the two models. The RESolve model used as a main scenario the demand from the NREAPs as the model is able to use directly the final energy consumption data for bio-electricity, bio-heat and biofuels as stated in the NREAPS. This demand was maintained also for the sustainability scenario. In RESolve the final energy demand for bio-electricity and bio-heat (derived from solid biomass) is increased by 25% in comparison to the reference scenario.

The PRIMES biomass model generally uses as input data the demand for bio-energy commodities as given by PRIMES. Within the Biomass Futures project a variant (NREAP variant) was quantified with the demand from the NREAPs transformed in the following way in order to be compatible with the necessary input for the PRIMES biomass model:

- The demand resulting from the transport sector was kept as it is expressed in the NREAPs; for 2020 it was assumed that most of the biofuels assumed are so-called first generation biofuels and are therefore not fully fungible with current engine technologies in the transport sector.

- In order to convert final energy demand figures of electricity production from biomass to primary energy data, country specific assumptions were made based on the main bio-energy commodity known to be used as fuel in the electricity sector and on expert judgement; a conservative efficiency for the electricity conversion was used ranging between 0.28 and 0.34 depending on the country, to transform the electricity of the NREAPs into biomass input into the power plants.

- The demand for years other than 2020 was calculated by applying a correction factor to the demand from the PRIMES Reference scenario, which has been used as a basis for all European Commission Roadmaps to 2050 (EC,2011),(EC,2011a).

For the sustainability scenario the PRIMES model used the demand of a decarbonisation scenario, in order to be able to verify the effects of the enhanced sustainability criteria also in the longer term in the context of the strong emission reduction targets. The overall difference in bio-energy commodities in 2020 between the NREAP scenario variant and the thus obtained sustainability variant is 8% less bio-energy commodity demand. Although this difference is not entirely negligible the demand as projected by this PRIMES decarbonisation achieves the targets of the Climate and Energy package nonetheless (with a different configuration of RES and total demand) and does not strain some resources as significantly as was found to be the case in the NREAP scenario variant.

- Also for the maximisation of the biomass demand, the decarbonisation scenario was assumed; the demand for biomass was increased mainly beyond 2030 to simulate a scenario maximising use of RES in all sectors (it is based on the high RES scenario of the EC Energy Roadmap 2050 (EC,2011a)) and for the transport sector high demand was taken based on a scenario which assumes less market penetration of electric vehicles, performed for the Clean Transport Systems Study by E3Mlab/ICCS with the PRIMES-TREMOVE transport model.

Table 2: Comparison of the scenarios

<table>
<tr><th>Scenarios</th><th>RESolve</th><th>PRIMES biomass</th></tr>
<tr><td rowspan="2">Reference with NREAP demand</td><td colspan="2">- Mitigation target for biofuels of 50% as compared to fossil alternative, excluding compensation of iLUC related emissions. Mitigation target for other biofuels must be positive.
- No use of biomass for biofuels cropped on biodiverse land or land with high carbon stock.</td></tr>
<tr><td>- NREAP demand as expressed in NREAPs</td><td>- NREAP demand transformed for input into model, through efficiency assumptions</td></tr>
<tr><td rowspan="2">Sustainability scenario</td><td colspan="2">- Mitigation target for bioenergy (fuels, heat and electricity) of 70% as compared to fossil alternative, including compensation for iLUC related emissions.
- No use of biomass cropped on biodiverse land or land with high carbon stock. For forests, strict biomass harvesting guidelines apply (application of fertilizer after logging residue and stump extraction not permitted, part of forests are set aside to protect biodiversity, limited intensification in forest exploitation).</td></tr>
<tr><td>- Variant of Reference scenario with NREAP demand.
- Included crop specific iLUC factors derived from Elbersen et al., 2012.</td><td>- Variant of PRIMES decarbonisation scenario, to observe effects of stricter sustainability on achievement of long-term decarbonisation targets
- Difference in total bio-energy demand compared to NREAP variant in 2020 - 8%
- Includes crop specific iLUC factors from IFPRI (IFPRI,2011)</td></tr>
<tr><td>Maximisation of biomass</td><td>- Increase of demand for bio-electricity and bio-heat (derived from solid biomass) by 25% in comparison to the reference scenario
- Considered stronger policy measures when compared with the reference scenario</td><td>- Variant of a decarbonisation scenario
- Demand derived as a combination of two scenarios: high RES scenario of the “Energy Roadmap 2050” and the maximum biomass of the Clean Transport Study Systems project</td></tr>
</table>

5.2 Analysis of scenario results

RESolve model results indicates that the demand for bioenergy cannot be met with the current policy framework. Besides, strengthening (including iLUC effect) and expending sustainability criteria to electricity and heat sector will result in more imports. With the PRIMES model the demand for all scenarios can be achieved, but it is important to notice that the achievement relies on specific technological developments, which are assumed to occur in the modelling. Whether these will be possible in the time frame assumed is questionable in some circumstances and may require strong policies both for R&D and for the uptake of production and demand side technologies. A detailed overview of the results from the RESolve and the PRIMES Biomass models can be found in D5.3 (Uslu et al.,2012) and in D5.7 (Apostolaki et al.,2012).

Reference scenario with NREAP demand

A scenario that utilises the bio-energy demand as projected by the Member States in the NREAPs was run by both the RESolve and the PRIMES Biomass models. The models found that similar amount of biomass feedstock is necessary to be used in order for the 20-20-20 targets to be achieved. However, the two models project different amounts of imports; RESolve finds that imports will cover approximately 15% of total primary biomass use while in the PRIMES Biomass model results the share of imports to the total is around 20% of total bio-energy commodities production for the year 2020 (when expressed as final bio-energy commodities).

The RESolve model results indicate that the NREAP targets for biomass based heat, electricity and transport will not be reached under the present regional and national policy/support schemes in most of the EU countries. While the level of support schemes play an important role they will not immediately lead to enough growth to meet the targets. Many other factors (such as administrative and regulatory conditions, permitting procedures, the maturity of the industry etc.) prevent such developments. In this respect, the time frame up to 2020 might be too tight to achieve the ambitious NREAP bioenergy targets in Member States level.

The PRIMES Biomass model suggests that the NREAPs demand is achievable, from a techno-economic perspective, on condition that development of the biomass conversion technologies for the production of 2nd generation biofuels takes place by 2020, although the majority of bio-energy commodities are produced with technologies already mature today. Furthermore, the projected demand for bio-energy commodities cannot be met unless a strong increase in the land use for the cultivation of energy crops takes place up to 2020.

Both models conclude that the high demand for gaseous biogas projected by the NREAPs strains the potentials of feedstock used for the production of biogas. The cheap biogas feedstocks are found not to be enough and the existing potential has to be exploited to the utmost. Thus, a strong intensification of the use of landfill and sewage has to take place in several countries. Since ambitions are higher and feedstock originating from waste and residues is used to the full extent by the vast majority of the Member States, more expensive feedstocks need to be utilised for the production of biogas, making the biogas production more costly and effort consuming.

Sustainability scenario

The results of both the RESolve model and PRIMES Biomass model found that if stricter sustainability are applied on the biomass supply system the rotational crops and therefore the production of 1st generation biofuels would be influenced. Imports of palm oil stop in both models as they are found not to comply with the stricter sustainability criteria, however, sustainably produced bioethanol and biodiesel continue to be imported. The additional sustainability criteria, including the consideration of the iLUC related emissions are not found to affect significantly the solid biomass potential and the lignocellulosic crops. RESolve furthermore predicts that, due to a reduction in agricultural residues, the production of biogas will decrease significantly.

The RESolve model concludes that such criteria would pressure the production of 1st generation biofuels to a great extent making the 10% renewable energy in biofuels target unlikely to be achieved. Since the quantities of 2nd generation biofuels up to 2020 are already quite ambitious in the reference scenario there is not much room for compensation by 2nd generation biofuels. Therefore the RESolve predicts a reduction in demand of biofuels of 45% in 2020.

The PRIMES Biomass model results indicate that the demand for biofuels in 2020 cannot be met unless a rapid and intensive development of the production technologies of 2nd generation biofuels takes place. In 2020 2nd generation biofuels represent 42% of total liquid biofuels for road transportation. However, the long term decarbonisation objectives of the scenario are not as difficult to be achieved as they rely on the development of the 2nd generation biofuels production technologies which are already assumed to take place by 2050 in the context of a scenario quantifying decarbonisation without increased sustainability criteria.

High biomass scenario

The High Biomass scenario was constructed in a different way by the two modelling teams. The High Biomass scenario quantified by ECN considers stronger policy instruments to harness larger amounts of biomass in the time period 2020-2030. The demand for electricity and heat using solid biomass is assumed to be 25% higher than the demand projected by the NREAPs. The PRIMES Biomass model on the other hand simulates the case that the assumed long term electrification of the private vehicles is delayed. Therefore, the transport sector relies strongly on biofuels in order to meet the long term decarbonisation objectives. Therefore, two different cases are simulated: one analysing the short to medium term impacts of increased bio-energy demand (RESolve model) and the other analysing the effect on the long-term decarbonisation targets (PRIMES biomass).

Both models find that increasing demand both in the short and in the long-term leads to a substantial increase in the imports levels, however, this leads to concerns on the sustainability of biomass feedstock supply. In the longer term projections there is also an intensification of domestic bio-energy commodity production, and a related increase in the land use for the production of energy crops, further questioning the sustainability of the scenario.

6

Concluding remarks

6.1 From a modelling perspective

The Biomass Futures successfully harmonised the input data for the two models, to the extent possible, therefore assuring comparability of results.

The functioning of the models is different because of the different mathematical basis, the different time horizons and the different temporal resolution. The difference in the models leads to the fact that the models can provide complementary analysis:

1) RESolve provides annual data and is therefore able to provide detailed trajectories and study in detail the effects of short term changes in policies

2) PRIMES biomass is able to expand the horizon and verify the impacts of policies in the medium to long-term. Working together with the overall PRIMES model suite, PRIMES is able to verify economic effects on the entire energy system, also in terms of costs.

Further research requirements and possibilities include:

1) Aim is to strengthen the elements which make each model “special” and relevant for policy impact assessment

6.2 Policy conclusions

Both models concur that achieving the NREAP scenario will pose significant challenges; in particular if these are to be fully achieved.

The RESolve model concludes that NREAP targets for biomass based heat, electricity and transport will not be reached under the present regional and national policy/support schemes and market developments in most of the EU countries. While the level of support schemes play an important role they will not immediately lead to enough growth to meet the targets. A less fragmented approach - implementing co-operation mechanisms that are included in the Renewable Energy Directive – can help Member States reach their targets and increase the cost-efficiency for bioenergy production.

Not only liquid biofuel imports but also the import of wood pellets will play an important role in the European bioenergy future. On the other hand , even when stricter sustainability criteria is considered, Europe holds a significant amount of domestic resources. There is a need for policies and measures within the EU to maximise indigenous biomass production and use. Policies and measures are required across all biomass categories, supply chains, and efficient conversion technologies, but most particularly in the agricultural sector, which has the greatest potential for increased domestic supply.

In 2020 GHG emissions can be avoided up to 500 Mton CO_2 eq. if the NREAP bioenergy targets are met, corresponding to 11 % of the total volume of GHG emissions in EU-27 in 2010[2]. This underpins the importance of bioenergy for meeting EU's future GHG reduction targets

[2] EU27 total GHG emissions in 2010 is indicated as 4 724.1 Mton CO_2 eq. by the EEA (2011)

The PRIMES Biomass model finds that from a techno-economical perspective, the demand projected by the NREAPs can be met, on the condition that development of the production technologies of 2[nd] generation biofuels take place and that land use for the cultivation of energy crops strongly increases by 2020. The high demand for gaseous biogas however strains the waste potential and leads to the utilization of more expensive feedstock.

To the time horizon of 2020 the implementation of stricter sustainability criteria, in which iLUC effect is included, would require intensive development of the so-called second generation biofuels. The PRIMES Biomass model finds that under the assumption of effective technology development, therefore for the biomass sector, the effect of stricter sustainability criteria on the biomass sector will be more limited in the long-run towards 2050 compared to the short term effects, as the strong development of technologies producing bio-energy commodities from lignocellulosic feedstock is already assumed to take place by 2050 in the context of a scenario that quantifies long term decarbonisation objectives without stringent sustainability criteria.

The provision of very high amounts of biomass in case of slower development in electric vehicles for the transport sector is possible by using almost all available land and increasing substantially the amount of imports. The sustainability of this scenario is debatable.

7

References

Apostolaki, E., Tasios, N., DeVita, A., Capros, P., New and updated database of the PRIMES Biomass Model, Deliverable 5.5 of Biomass Futures WP5, E3MLab – ICCS, 2012

Apostolaki, E., Tasios, N., DeVita, A., Capros, P., PRIMES Biomass model projections, Deliverable 5.7 of Biomass Futures WP5, E3MLab – ICCS, 2012

Böttcher, H., Frank, S., Havlik, P., Leduc, S., Elbersen, B., van Stralen, J., Draft Deliverable 3.4:Biomass availability & supply analysis. WP3, IIASA, 2011.

EC 2011, A Roadmap for moving to a competitive low carbon economy in 2050, 2011

EC 2011a, Energy Roadmap 2050 COM(2011), 2011
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0885:FIN:EN:PDF

Elbersen, B., I. Startisky, G. Hengeveld, M.J. Schelhaas, H. Naeff and H. Böttcher (2012): Atlas of biomass potentials – Spatially detailed and quantified overview of EU biomass

IFPRI, Assessing the Land Use Change Consequences of European Biofuel Policies, 2011
potential taking into account the main criteria determining biomass availability from different sources, Deliverable 3.3 of Biomass Futures WP3, Alterra, 2012.

Uslu, A. and van Stralen, J. Biomass Futures scenario set-up and the methodology for analysis - Deliverable D5.2. Biomass Futures project. 2012

Uslu, A., van Stralen, J., Beurskens L., Dalla Longa, F., Use of sustainable biomass to produce electricity, heat and transport fuels in EU27- A model-based analysis of biomass use for 2020 and 2030. Deliverable D5.3. biomass Futures project. 2012.

van Stralen, J., F. dalla Longa, L. Beurskens, J. Ros and A. Uslu (2012): Functional description of biomass allocation within the RESolve model kit, Deliverable 5.1 of Biomass Futures WP5, ECN, 2012.
.

Appendix A. IIASA techno-economic data

	Description		Technology data			Costs data						
Technology name	Technology description	Covers sector	Efficiency 1st main product [%]			Investment cost (€/GJ)			Fixed O&M costs			Unit
			2010	2020	2030	2000 Min	2000 Max	2030	2000	2020	2030	
Biogas LT-gasification CHP	Gasification of wood	T, H	0,45			24,62	34,55	-	80,47			€/ha
	Gasification of wood from short rotation plantings	T, H	0,45			22,92	32,17	-	5,47	-	-	€/GJ
BIGCC	Combustion of wood	H, E	0,60			3,09	9,45	-	80,47			€/ha
	Combustion of wood from short rotation plantings	H, E	0,60			2,87	8,80	-	4,10	-	-	€/GJ
Direct firing - heat	direct biomass use for cooking	H	1,00									
Cellulose Et-OH	Fermentation of wood	T, H, E	0,29			15,16	21,27	-	80,47	-	-	€/ha harvested area
	Fermentation of wood from short rotation planting	T, H, E	0,29			14,11	19,81	-	8,48	-	-	€/GJ
Starch EtOH	Corn to Ethanol	T	0,57			16,57	23,26	-	13,19	-	-	€/GJ
	Wheat to Ethanol	T	0,53			21,20	29,76	-	13,16	-	-	€/GJ

Sugar-EtOH	Sugar cane to Ethanol	T	0,32			3,02	4,24					
Transesterification of vegetable oil (no palm oil)	Rape to FAME	T	1,09			19,86	27,87	-	11,36	-	-	€/GJ
	soya to FAME	T	0,41			23,48	32,96	-	29,43	-	-	€/GJ
Transesterification of used fats/oils and palm oil	Palm oil to FAME	T	0,30			35,67	50,07	-				

Appendix B. Oeko Institute techno-economic data

	Description		Technology data							Costs data						
Technology name	Technology description	Covers sector	Efficiency 1st main product [%]			Efficiency 2nd main product [%]			Lifetime [yr]	Investment cost (€2010/kW)			Fixed O&M costs (€2010/kW)			Power/Size
			2010	2020	2030	2010	2020	2030		2010	2020	2030	2010	2020	2030	MW out
Direct co-firing coal	wood chips co-fired in new large ST plant	E	45,3	47	51				30	168,5	168,5	168,5	39,3	39,3	39,3	70
CHP electricity - liquid	diesel enginge	E, H	39	40	41	47	46,5	46	15	1000	1000	1000	30	30	30	1
CHP electricity - solid	ST BP	E, H	27,5	28,5	30	55	50	45	25	2000	1950	1900	40	40	40	20
Waste digestion CHP	gas engine	E, H	39	39,5	40	45	45	45	15	775	765	750	50	50	50	0,5
Biogas digestion CHP	gas engine	E, H	39	39,5	40	45	45	45	15	775	765	750	50	50	50	0,5
SNG from solids	syngas from CFB gasifier + steam reforming	intermediate		65	65				15		1125	1070		29	27	167
heat, wood chips boiler	small-scale system	H	85	86	87				15	687	647	637	21	21	21	0,01
heat, pellets boiler	small-scale system	H	86	87	88				15	860	836	812	26	26	26	0,01

2G EtOH from straw	assuming internal use of lignin	T		50	55				15		450	395		10	5	100
FT from solids	assuming no H2 input	T		45	45		4,5	6,75	20		2025	1875		85	54	500
Plant oil extraction (milling)	assuming rapeseedoil input	intermediate	66,25	66,25	66,25											12,5
wheat 1G EtOH	no internal biogas	T	58	58	58					860	775	730	20	17,5	15	96
Sugarcane 1G EtOH	data for Brazil	T	20,7	21	21				15	337	321	320	8,5	5,5	5	150
FAME from plant oil	assuming rapeoil input	T	99	99	99				15							12,5
FAME from used oil	assuming waste oil input	T	92,4	92,5	93				15							12,5

Appendix C. NTUA techno-economic data

Technology name	Output products of technologies	Covers sector	Output/Feedstock Ratio [%]			Lifetime [a]	Investment cost (€2010/KW)			Fixed O&M costs (€2010/KW)		
			2010	2020	2030		2010	2020	2030	2010	2020	2030
Fermentation of Starch (Starch Et-OH)	Bioethanol	T	27%	29%	29%	25	539	484	480	26	24	23
Fermentation of Sugar (Sugar-EtOH)	Bioethanol	T	28%	29%	30%	20	1045	836	829	13	10	10
Enzymatic Hydrolysis and Fermentation (Cellulose Et-OH)	Bioethanol	T	24%	26%	27%	25	2364	1856	1348	16	14	12
Enzymatic Hydrolysis and Fermentation & Catalytic Upgrading	Biogasoline	T	14%	15%	17%	25	3205	2557	1909	41	33	24
Enzymatic Hydrolysis and Fermentation & Hydro Deoxygenation	Biogasoline	T	14%	15%	17%	25	3416	2732	2049	47	37	28
Gasification & F-T Synthesis	Biogasoline	T										
Gasification & F-T Synthesis & Naphtha Upgrading	Biogasoline	T	15%	17%	19%	25	3330	2883	2647	237	184	156
Black Liquor Gasification & F-T Synthesis & Naphtha Upgrading	Biogasoline	T	11%	13%	14%	25	3330	2883	2647	237	184	156
HTU & Hydro Deoxygenation & Naphtha Upgrading	Biogasoline	T	14%	14%	15%	25	3234	2706	2179	100	76	53
Pyrolysis & Hydro- deoxygenation & Naphtha Upgrading	Biogasoline	T	12%	13%	14%	20	2462	2218	1974	82	73	63
Pyrolysis & Gasification Oil & F-T Synthesis & Naphtha Upgrading	Biogasoline	T	7%	8%	9%	20	3041	2833	2706	145	132	124

Transesterification of vegetable oil (not palm oil)	Biodiesel	T	50%	55%	56%	20	270	213	183	11	10	9
Transesterification of used fats/oils and palm oil	Biodiesel	T	85%	88%	90%	20	270	213	183	11	10	9
Enzymatic Hydrolysis of sugar & Hydro-deoxygenation	Biodiesel	T	16%	17%	18%	25	2185	1943	1700	34	26	18
Hydrolysis of starch & Enzymatic Hydrolysis & Hydro-deoxygenation	Biodiesel	T	15%	16%	17%	25	2713	2310	1908	37	28	20
Hydro-deoxygenation of vegetable oil	Pure Diesel	T	65%	66%	67%	25	1261	1051	841	32	24	16
Gasification and F-T synthesis (F-T Diesel)	Pure Diesel	T	16%	18%	20%	25	3250	2805	2571	232	178	151
Black Liquor Gasification & F-T Synthesis	Pure Diesel	T	12%	14%	15%	25	3250	2805	2571	232	178	151
HTU & Hydro Deoxygenation	Pure Diesel	T	15%	15%	16%	25	3154	2628	2103	95	71	47
Pyrolysis & Hydro-deoxygenation	Pure Diesel	T	13%	14%	15%	20	2382	2140	1898	76	67	58
Pyrolysis & Gasification Oil & F-T Synthesis	Pure Diesel	T	7%	8%	10%	20	2961	2755	2630	139	126	119
Gasification & F-T Synthesis	Biokerosene	T	16%	18%	20%	25	3250	2805	2571	232	178	151
HTU & Hydro-deoxygenation	Biokerosene	T	15%	15%	16%	25	3154	2628	2103	95	71	47
Pyrolysis & Hydro-deoxygenation	Biokerosene	T	13%	14%	15%	20	2382	2140	1898	76	67	58
Pyrolysis & Gasification Oil & F-T synthesis	Biokerosene	T	7%	8%	10%	20	2961	2755	2630	139	126	119
Gasification & Methanol Synthesis	Methanol	T	28%	30%	31%	15	2566	2174	1971	172	123	98
Gasification of Black Liquor & SynGas to Biogas	Biogas	H/E	29%	31%	32%	25	2599	2131	1888	174	127	104
Anaerobic Digestion	Biogas	H/E	56%	67%	67%	15	490	443	440	17	15	15
Gasification of Biogas & SynGas to biogas	Biogas	H/E	37%	38%	39%	25	1424	1134	985	45	37	34
Enzymatic hydrolysis	Biogas	H/E	29%	32%	34%	25	924	831	739	3	2	2

Catalytic Hydrothermal Gasification of wood & SynGas to biogas	Biogas	H/E	37%	39%	40%	25	899	696	593	17	19	20
Catalytic Hydrothermal Gasification of wet feedstock & SynGas to biogas	Biogas	H/E	22%	32%	40%	25	849	459	263	18	20	21
Gasification of Black Liquor & SynGas to Biogas & Biogas to Biomethane	Biomethane	T/H/E	14%	15%	16%	15	2807	2328	2076	178	131	108
Anaerobic Digestion & Biogas to Biomethane	Biomethane	T/H/E	28%	34%	34%	15	698	641	627	21	19	19
Gasification of Biogas & SynGas to biogas & Biogas to Biomethane	Biomethane	T/H/E	19%	19%	20%	15	1632	1332	1172	49	41	37
Enzymatic hydrolysis & Biogas to Biomethane	Biomethane	T/H/E	15%	16%	18%	15	1132	1029	926	7	6	6
Catalytic Hydrothermal Gasification of wood & SynGas to biogas & Biogas to Biomethane	Biomethane	T/H/E	19%	20%	20%	15	1107	894	780	21	23	24
Catalytic Hydrothermal Gasification of wet feedstock & SynGas to biogas & Biogas to Biomethane	Biomethane	T/H/E	11%	16%	20%	15	1057	657	450	22	24	24
HTU process	Bio heavy fuel oil	T/H/E	22%	23%	24%	25	1892	1577	1261	63	47	32
Pyrolysis of woody biomass	Bio heavy fuel oil	T/H/E	19%	21%	22%	20	1121	1089	1057	45	44	42
Catalytic Upgrading of Black Liquor	Bio heavy fuel oil	T/H/E	18%	19%	20%	25	1682	1402	1122	25	19	13
Landfill	Waste gas	H/E	100%	100%	100%	15	440	418	414	13	12	12
Anaerobic digestion	Waste gas	H/E	56%	67%	67%	15	490	443	440	17	15	15
RDF	Waste solid	H/E	82%	85%	85%	15	79	78	77	8	5	5
Small scale solid	Small scale solid	H/E	85%	85%	85%	15	182	137	136	18	14	14
Large scale solid from wood biomass	Large scale solid	H/E	90%	90%	91%	15	91	85	84	4	3	3

Note on production processes
1 The pretreatment cost of feedstock is excluded in all production pathways costs
2 Starch EtOH production pathway in PRIMES Biomass model is considered to use as feedstock crops such as maize, wheat, barley etc. An average of these crops has been used. The costs presented don't include pretreatment costs, which amounts to approximately 300 €/KW
3 Sugar feedstock is considered to be preprocessed when entering the conversion pathway

Appendix D. ECN techno-economic data

Technology name	Covers sector	Efficiency 1st main product			Lifetime [a]	Investment cost (€2010/kW)			Fixed O&M costs (€2010/(kW*yr)			Power / Size
		2010	2020	2030		2010	2020	2030	2010	2020	2030	MW out
Direct co-firing coal process	E	37,5%	41,8%	46,0%	12	220	220	220				100
MSW combustion	E	28,5%			15	2550			-	-	-	20-30
MSW-CHP	E,H	20,0%			15	2550			-	-	-	20-30
Solid combustion (electricity only)	E	27,0%			12	3725			270			~10
Liquid combustion (electricity only)	E	45,0%			12	1400			155			~10
CHP-liquid	E,H	39,0%	40%	41%	12	1600	1600	1600	175	175	175	~10
CHP-solid	E,H	27,5%	28,5%	30,0%	12	4018	3900	3800	298	298	298	~10
Waste digestion CHP	E,H	35,0%	35,5%	36,0%	12	2285	2255	2210	230	230	230	0,3
Biogas digestion CHP	E,H	39,0%	39,5%	40,0%	12	585			62,0			1.1-3.0
Waste combustion - heat only *	H	85,0%			10	12,67						
Residential-Pellet boiler	H	85,0%	86,0%	87,0%	17	671	650	629	25	25	25	
Local heating plant for wood pellets-small scale (0.5MW)	H	89,0%			15	704			21,243			
Local heating plants for processed energy crops i.e. miscantus)	H	86,0%			15	513			22,361			

Local heating plant for straw	H	90,0%			17	685			102,000			
wood chip boilers-medium size	H	80,0%	81,0%	82,0%	17	585	552	544	21,50	21,50	21,50	
local heating plant	H	86,0%			20	505	485		19,700			
Co-firing in a coal fired CHP plant	E,H	30,0%			25	224			137,517			
Cellulose EtOH	T	39,0%			20	3673	learning	learning	363	learning	learning	190 kton_output/yr
DME production	T	56,0%			20	1937	learning	learning	116	learning	learning	110
FT production	T	52,5%			20	2429	learning	learning	146	learning	learning	100
Oil extraction		39,0%			20	274	274	274	116	71	71	500 kton_output/yr
Starch EtOH	T	54,5%			20	1060	learning	learning	433	learning	learning	100 kton_output/yr
Sugar EtOH	T	44,7%			20	659	learning	learning	272	learning	learning	100 kton_output/yr
Transesterification of vegetable oil (no palm oil)	T	98,9%			20	201	learning	learning	81	learning	learning	100 kton_output/yr
Transesterification of used fats/oils and palm oil	T	99,7%			20	302	learning	learning	89	learning	learning	50 kton_output/yr
* : €2010/GJinput/yr												