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Deliverable D5.1

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Functional description of biomass allocation within the RESolve model kit

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Content

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.

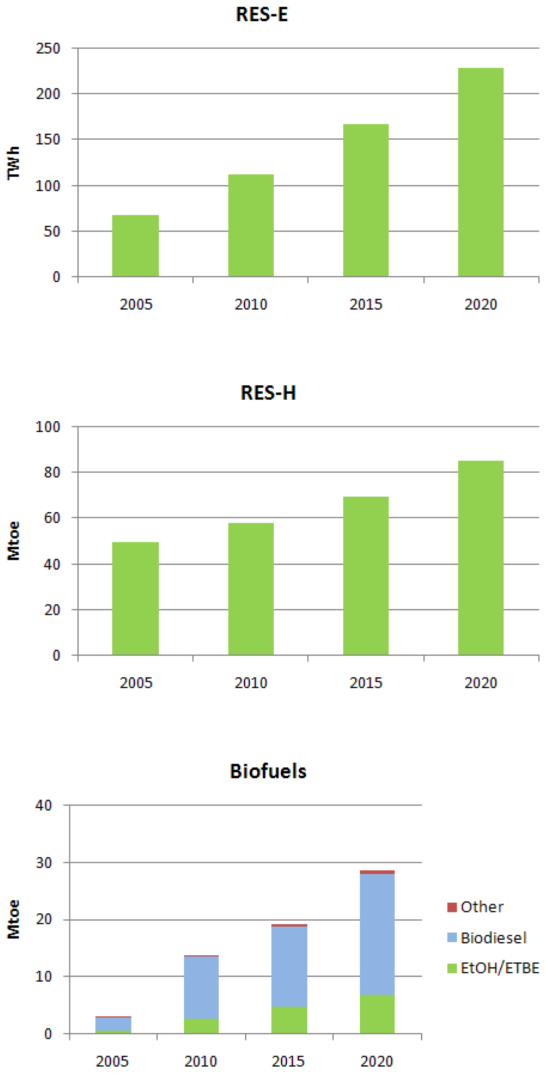
In this report the ECN model used within Biomass Futures to quantitatively estimate how the different biomass sources can be allocated in a cost-effective way to the different energy uses is described. This biomass allocation model is based on an interaction between existing ECN submodels within an iterative scheme. Each submodel addresses the role of renewable energy in a different sector: RESolve-E deals with the electricity sector, RESolve-H with the heating sector, RESolve-T with the transport sector. The three submodels are briefly described, and an overview on the interaction scheme is presented.

Within Work package 5 of the BIOMASS FUTURES project, a very important aspect is the linkage with the PRIMES model. Biomass feedstock and technology related data harmonization and linkage with the PRIMES model will not be covered within this report. Room for a description of this topic is reserved in D5.6 of this work package.

1 Introduction

The Renewable Energy Directive (RED) (Directive2009/28/EC, 2009) sets mandatory renewable energy targets for each Member States to meet 20 % of the EU's final energy demand from Renewables by 2020. As part of the overall target, a binding minimum target for each Member State to achieve at least 10 % of their transport fuel consumption from renewable sources is also included. In 2007, around 67 % of the EU gross renewable energy consumption was met with biomass resources and its absolute contribution is expected to grow significantly according to the National Renewable Energy Action Plans (NREAPs) (Fig. 1.1).

Fig. 1.1: Expected contribution of biomass in the electricity, heating and transport sectors for 26 countries of the EU27 according to the NREAPs (Beurskens and Hekkenberg, 2010)



However, biomass resources, differently from many other renewable options, can serve many different sectors, among which electricity, heat and transport sector are the centre of attention in this study. The Biomass Futures project, funded by the IEE programme of the EC, aims at using modelling frameworks in order to inform policy makers with quantitative information on the role biomass can play to meet the GHG emission reduction targets and the renewable energy targets included in the Climate Action and Renewables Policy Package of the European Commission (as adopted by the European Parliament on December 17, 2008), and the new Renewable Energy Directive.

In particular, the problem of allocation of biomass resources among the different possible uses will be investigated using the modelling tools described in this report. In principle, if the biomass availability is cost competitive and unlimited, the full demand for biomass of all three sectors can be addressed. However, in the real world situation this demand might exceed the supply, creating competition for the same resources. In order to mimic such competition and estimate the role biomass can play in the EU energy system from 2010 to 2030 (with intermediate 2020) the ECN *RESolve* model set will be used.

The RESolve model kit consists of three independent sector models, known as RESolve-T, RESolve-E and RESolve-H for the transport, electricity and heat sector respectively (see Table 1.1). Each of these models has a specific renewable energy demand, for transport (RES-T), electricity (RES-E) and heat (RES-H). Part of this demand might be filled in using biomass as feedstock. By making the three models interact within an iterative scheme it is thus possible to assess the most economic ways of allocating biomass among the three different sectors.

Within WP5 of Biomass Futures a *biomass allocation model* will be created based on such an interaction among the models.

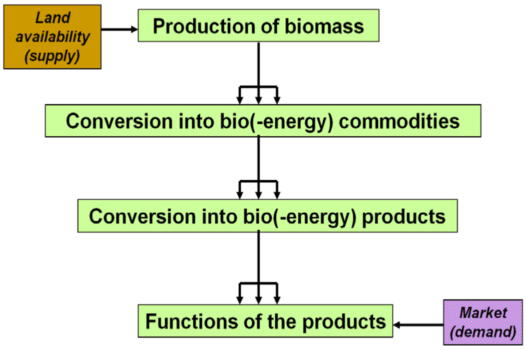
In this report first the structure of the allocation model is briefly introduced (chapter 2), followed by a high level description of the three sector models (chapters 3, 4 and 5). Finally the interaction scheme is revised in more detail (chapter 6) and conclusions are drawn (chapter 7).

Table 1.1: RESolve model kit

SECTOR	MODEL	OLD NAME
Electricity	RESolve-E	ADMIRE-REBUS
Transport	RESolve-T	BoiTrans
Heat	RESolve-H	RES-H/C

2 Biomass allocation in RESolve model kit

Fig. 2.1: Biomass production–consumption chain



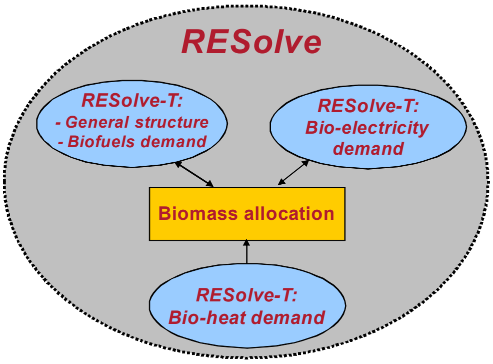
In Fig. 2.1 a high-level scheme representing the biomass production-consumption chain is depicted. The initial supply is determined by the amount of land that is available for growing energy-related biomass (this is an external input); the produced biomass is then converted into energy commodities and products that can be sold in the market. Competition among different biomass sources, as well as among different energy sources will take place within the different demand sectors. As outlined in chapter 1, the demand sectors electricity, transport and heat are considered in the model. This means that the potentials only include biomass for energy generation; other important uses of biomass (such as e.g. food and biochemicals) are not considered in the model.

As it will be seen in chapter 3, the production-consumption chain as depicted in Fig 2.1 resembles the one considered in the model RESolve-T, dealing with the use of biomass in the transport sector. Therefore the biomass allocation model inherits its structure from RESolve-T, and is implemented within RESolve-T itself. The following demand segments are considered:

- Biofuels demand
- Bioelectricity demand
- Bioheat demand

While the biofuels demand is already present in RESolve-T, the other two demand segments are added specifically for the allocation model. The biofuels demand is calculated within RESolve-T, based on biofuels targets. The bioelectricity and bioheat demands are calculated using RESolve-E and RESolve-H, respectively, based on RES policies and technology costs. RESolve-T then calculates the minimum cost allocations along the bioenergy supply chain. The results of the allocation model can then serve as new inputs for RESolve-E and RESolve-H, thereby generating new bioelectricity and bioheat demand data. Therefore an iterative scheme can be achieved, where the calculation is repeated

Fig. 2.2: Interaction among RESolve models



until a consistent solution in terms of cost allocations, demands and potentials is achieved. The interaction between the models is summarized in Fig. 2.2.

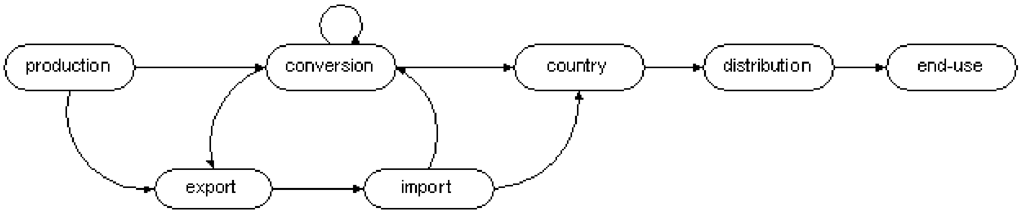
In order to clarify how the iterative scheme works and understand how the results of the allocation model can be used to generate new bioelectricity and bioheat potentials, in the following chapters the three RESolve sub-models are introduced.

3 RESolve-T

3.1 Introduction

The RESolve-T model, formerly known as BioTrans, calculates the most cost effective way to full fill the specified biofuel demand (i.e. EU biofuel targets), given and constrained by a number of assumptions on economic and technological parameters in a specific target year, in terms of biofuel production, cost and trade (Lensink et al, 2007; Lensink & Londo, 2010; Faaij & Londo, 2010). The RESolve-T model includes biofuel feedstock production, processing, transport and distribution. The model essentially aims at finding the minimal cost allocation along the supply chain, given projections of demand (policy targets), feedstock and conversion potentials and technological progress, see Fig. 3.1. Constraints on avoided emissions, over the entire chain, can be included in the model as well.One of the most important features of the RESolve-T model is the ability to link the national production chains allowing for international trade. By allowing trade, the future cost of biofuels can be approached in a much more realistic way than when each country is evaluated separately.

Fig. 3.1: Supply chain in RESolve-T (Lensink et al, 2007)



RESolve-T allows for trade of feed stocks and final products by means of trucks, trains and short sea shipments. The only costs associated with international trade are transport costs (including handling), for which generalised distances between countries are used. All domestic transport is assumed to take place using trucks. Moreover, the possible economical benefits of important byproducts are taken into account.

The RESolve-T model includes:

- 10 crop/non-crop raw materials (feedstocks)
- 12 conversion steps with 2 intermediate products, 1 auxiliary and 6 byproducts
- 7 biofuels and associated distribution technologies
- 30 countries: EU27 and Switzerland, Norway and Ukraine + import from Brazil and Malaysia.

3.2 Production

It is assumed that every country in the model has one production plant for each raw material and one processing plant for each conversion (sub) process. Feedstock production costs and potentials are provided as input for the model (de Wit et al, 2007). The feedstocks included in the RESolve-T model are:

Energy crops categories:

- Grassy crops
- Oil crops
- Starch crops
- Sugar crops
- Woody crops

Import:

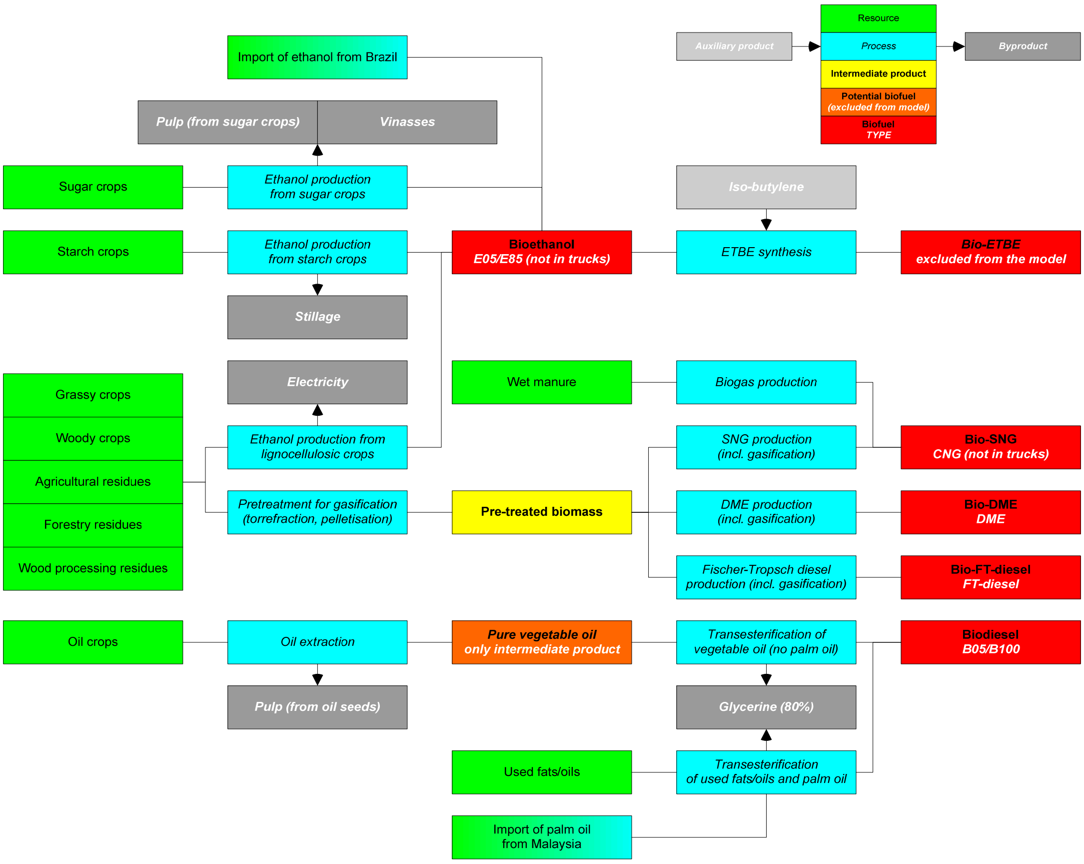
- Palm oil import from Malaysia
- Ethanol import from Brazil

Non-crops:

- Agricultural residues
- Wood processing residues
- Liquid manure
- Used fats and oils
- Pre- treated biomass (for gasification)
- Pure vegetable oil

3.3 Conversion

Fig. 3.2: Overview of conversion processes in RESolve-T



In order to produce biofuel from the biomass feedstocks, one or more conversion steps are needed. Each country has a complete chain of conversion facilities, with country and process specific costs for each conversion step. For each step, different indicators are used to calculate costs and output:

- Raw material costs [€/GJ]
- Full load hours [hours/year]
- Lifetime [year]
- Operations and Maintenance costs (O&M costs) [€/(GJinput/year)]
- Specific investment costs [€/(GJinput/year)]
- State of the technology
- Yield of product (Efficiency)

The investment costs reduce in time depending on the past cumulative output volumes of the technology. As such, the model includes endogenous learning (de Wit et al, 2007).

The conversion processes included in RESolve-T are:

- Vegetable oil extraction
- Transesterification of vegetable oil
- Transesterification of used oil and fats
- Ethanol production from sugar crops, starch crops, grassy crops and woody crops
- Biogas production from liquid manure
- Pre-treatment of biomass for gasification (torrefaction,pelletisation and pyrolosis oil)
- FT diesel production (incl. gasification)
- DME production (incl. gasification)
- SNG production (incl. gasification)
- ETBE synthesis

The final products included in the RESolve-T model are:

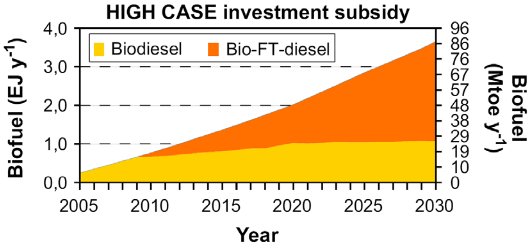
- Bioethanol (1st and 2nd generation)
- Biodiesel
- Bio-FT-diesel
- Bio-DME
- Bio-SNG
- Bio-ETBE

A schematic overview of all production routes considered in RESolve-T is shown in Fig. 3.2.

3.4 Output

Given feedstock supply curves and conversion processes (Fig. 3.2) RESolve-T calculates the minimum cost allocations for biofuels that satisfy the policy-determined demand, allowing for trade between the countries. Typical outputs of the model are yearly penetration rates of different biofuels in the market under different subsidies schemes (e.g. investment subsidies, crop premiums, etc.). An example is presented in Fig. 3.4 (Lensink & Londo, 2010), where the penetration of Biodiesel and Bio-FT diesel under an investment subside scheme are assessed, in the case of a *high* demand target of 25% of biofuels in 2030. The model also provides additional outputs, such as the biofuel prices and the avoided CO_2 emissions.

Fig. 3.4: Penetration of biofuels products under an investment subside scheme, in the case of *high* demand target of 25% by 2030 (From Lensink et al., 2010)



4 RESolve-E

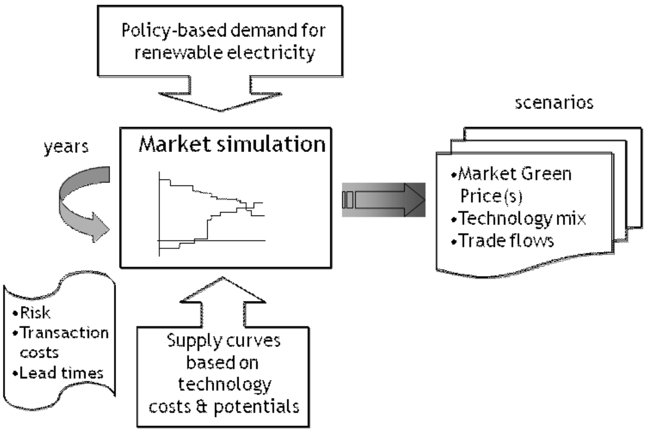
4.1 Introduction

For the simulation of the renewable electricity (RES-E) developments in the EU the RESolve-E model, formerly known as ADMIRE-REBUS, is used (Daniëls & Uyterlinde, 2005). The RESolve-E model is based on a dynamic market simulation in which national RES-E supply curves are matched with policy-based demand curves. The supply and demand curves are constructed as follows:

- Future potentials are estimated for all technology bands within a country, based on a consistent approach, which allows for technology development and learning effects through time. In the model, realisable potentials are used, meaning that all restrictions except economic ones are accounted for.
- An endogenous cost calculation module determines the costs of renewable technologies, using a net present value calculation. This calculation includes all costs and revenues expected over the lifetime of a technology, and thus incorporates the effect of different support policies in a straightforward way. Costs are expressed in terms of the ‘Required Green Price’, the average minimal green price that the investor has to obtain from the market over the lifetime of the production capacity in order to make the construction of additional green capacity (or the production with existing capacity) attractive.
- Thus, supply curves, based on costs and potentials, are constructed, and their development is simulated through time.
- In parallel, policies acting on the demand side, such as price support of the demand or quota’s on consumers or suppliers, are translated into national demand curves.
- Based on technology, market and political risks, a technology and country-specific adder to this Required Green Price is calculated.

The results are calculated in a way that takes into account the discriminative characteristics of some policies, and the ability of producers to choose whether they produce for the domestic market or wish to trade their production. Because of the different levels and conditions of national support schemes, there will not be a single market equilibrium for the EU, but rather different submarkets emerge with local equilibria. Another important model result is the technology mix per country and for the complete EU, e.g. the expected deployment of renewable technologies.

Fig. 4.1: Schematic overview of the RESolve-E model



The simulations can be 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.

A schematic overview of the RESolve-E model is presented in Fig. 4.1.

Policies included in *RESolve-E* are:

- Obligations on renewable electricity consumption
- Feed-in tariffs and Feed-in premiums
- Consumer and supplier premiums
- Tenders
- Investment subsidies
- Fiscal investment measures
- Low interest loans

Input needed for the calculation of the Required Green Price (RGP) is listed below.

Technical parameters:

- Raw material costs [€/GJ]
- Efficiencies [%]
- Full load hours [hours/year]
- Technical lifetime [year]
- Fixed Operations and Maintenance costs (O&M costs) [€/kW/yr]
- Variable O&M costs [€ct/kWh]
- Investment costs [€/kW]
- Maturity of the technology
- Value of byproducts (in the case of electricity production heat can be a byproduct).

Financing parameters:

- Debt/Equity ratio [%]
- Return on equity [%]
- Return on debt [%]
- Debt period [year]
- Depreciation period [year]
- Tax rate [%]
- Inflation rate [%]

The *RESolve-E* model includes:

- 13 crop/non-crop raw materials
- 13 technologies, of which 5 different biomass technologies
- 27 EU countries, Switzerland and Norway

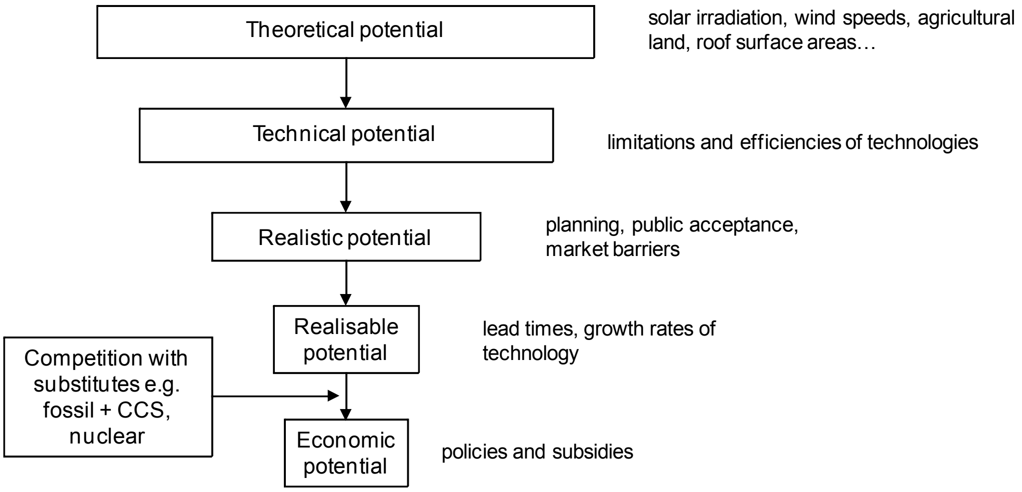
4.2 Potentials and production

In the assessment of potentials, a clear distinction must be made between the following definitions (Daniëls et.al. 2005):

1. The theoretical potential of a renewable energy source is the total physical energy flow of that source. For example the total energy content of solar radiation on the whole area of a Member State during one year.
2. The technical potential takes into account all technical constraints that may reduce the theoretical potential. For example wind energy: it is technically not possible to convert all the energy in the wind into electricity. Another reducing factor in this matter is the availability of potential sites or primary fuel stream for biomass. Large wind turbines for example are not installed in urban areas, and not all wood residues from forestry are available for electricity production.
3. The realistic potential also takes into account non-technological factors. At this point planning issues and acceptability problems play a role. Although there might be enough space or resource technically available for renewable electricity production, it is not always desirable or feasible to deploy all the technical potential. The realistic potential may vary in time due to changes in technology, but it is independent on past developments of the renewable electricity market.
4. The realisable potential takes into account various limitations on the deployment growth and is linked to a certain year. In any given year, the realisable potential takes into account constraints due to the limited production capacity of the capital goods industry, the limited speed of opening up the available resources (e.g. biomass), the limited amount of potential entering exploratory courses (‘pipeline potential’) and the limited amount of investment plans passing these courses and the accompanying legal procedures successfully. For the actual size of the realisable potential, past developments in the renewable electricity market are very important. In the model, the realisable potential incorporates the model results of past years using a vintage approach.
5. The economical potential is the potential that will be used for a specific year. An economical potential is the result of the interaction between demand and supply.

For a graphical overview of the different potentials, see Figure 4.2.

Fig. 4.2: Potentials in RESolve-E



In RESolve-E theoretical and technical potentials are not considered The highest level of potentials used as indicated in Fig. 4.2 are the realistic potentials. This realistic potential, for each technology and country, is determined exogenously.The realistic potentials as used in RESolve-E can be defined as what is maximally achievable in 2040 if there are no economical constraints, i.e. that the technology is economically feasible. Realistic potentials differ from technical potentials in the sense that social acceptance and environmental constraint are implicitly taken into account. There is, for example, a limit to the amount of wind mills that people find acceptable to have in their country, even though physically there is still enough space left. The production capacity of renewable energy per technology can never exceed this potential. In the model the realistic potential is defined for 2040, i.e. what is maximally achievable in the far future. The realisable potential for a particular running year is dependent on existing capacity and the maximum growth rate of the potential, as described above. The realisable potentials are the potentials that are directly reflected in the cost supply functions, they determine the width of a supply segment.

Production costs and realistic potentials are provided as input for the model for each country, see (de Noord et al, 2004). On the basis of realistic potentials, the Dynamic Module of RESolve-E calculates the realisable potentials and costs in GWh and €ct/kWh.

RESolve-E does not allow for trade of biomass feedstocks between the countries involved, however, we will include the import/export of biomass through RESolve-T, see chapter 6.

The feedstocks included in the RESolve-E model are:
- Energy crops category (general)
- Forestry
- Manure (solid and liquid)
- Agricultural residues
- Municipal Solid Waste and Industrial waste
- Sewage sludge and Landfill gas

The assumption is made that there will only be competition for energy crops, forestry feedstocks, liquid manure and agricultural residues between the three sectors. Municipal and industrial solid waste, sewage sludge, landfill and solid manure are feedstocks that are almost exclusively used for electricity production and for this reason these feedstocks are only used in the RESolve-E model[1]. The contribution of these non-crops feedstocks is subtracted from the bioelectricity demand in each EU member state. In the allocation model model only the competing feedstocks are included.

4.3 Conversion

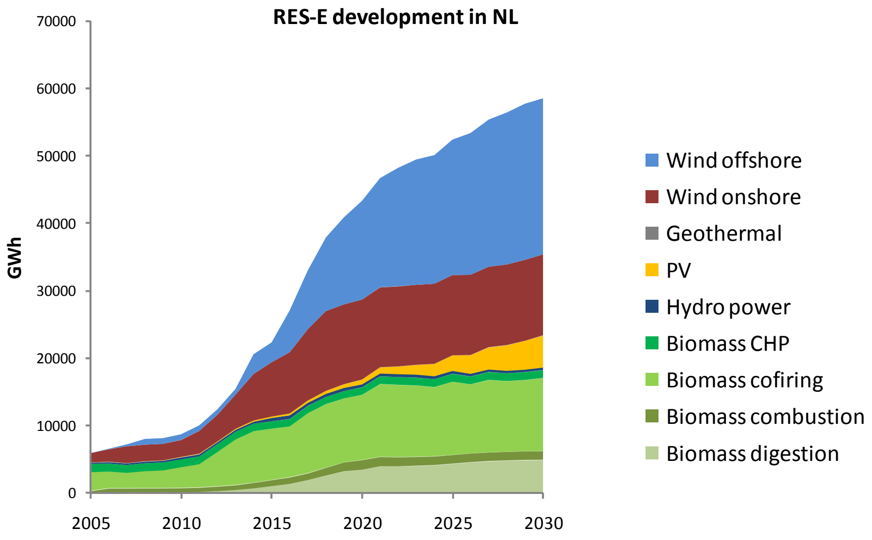
The technologies and the conversion processes, included in the RESolve-E model are:

- Wind onshore
- Wind offshore
- Small and medium hydro power
- Large hydro power
- Solar PV
- Geothermal electricity
- Tidal
- Wave
- Biomass
  -Direct co-firing coal
  -Gasification: indirect co-firing in coal and gas fired plants
  -Gasification: Biomass Integrated Gasification Combined Cycle (BIGCC)
  -Combustion
  -CHP
  -Digestion-CHP

4.4 Output

Summarizing, given policy data, costs and realistic potentials, RESolve-E constructs the supply and demand curves for each RES-E technology. By matching supply and demand, the RES-E mix and the market prices are then calculated. As an example, the RESolve-E projection of RES-E development in the Netherlands is presented in Fig. 4.3. The projection of the bioelectricity use will be used as an input for

Fig. 4.3: Example of REsolve-E output



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[1] Note that, if present, the modest amount of heat production as a byproduct from electricity generation will be bookkeeped.

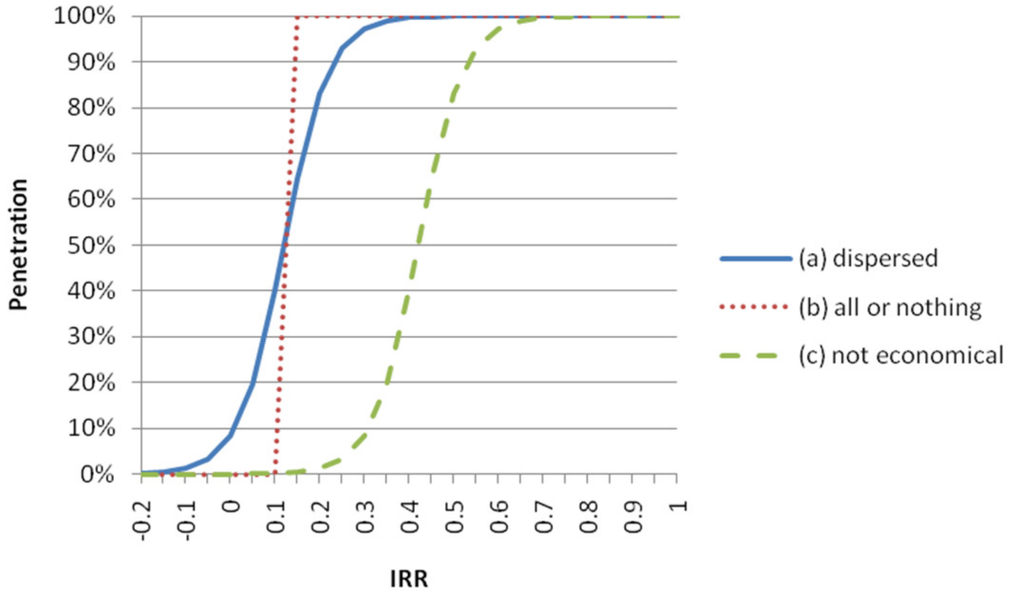
the allocation model (in the form of a bioelectricity demand).

5 RESolve-H

5.1 Introduction

RESolve-H is a simulation model that calculates the rate of penetration of RES-H options based on a *dispersed S-curve* description of consumer’s behaviour, Fig. 5.1 (a).

Fig. 5.1: Penetration vs. Internal Rate of Return (IRR) in RESolve-H



Each RES-H option has a cost to the consumer, but it also brings some benefits, namely the avoided costs of using non-RES fuels. When the benefits for a certain option are comparable to the costs, the option starts to become economically attractive for the consumer. This is modelled by considering the Internal Rate of Return (IRR) of a certain option, taking explicitly into account the avoided costs of not using fossil fuels. In the example of Fig. 5.1 (b) all consumers immediately switch to RES-H as soon as the IRR is higher than 0.15. This *all or nothing* case is obviously not very realistic, and the real consumer behaviour is better modelled by a *dispersed* S-curve such as the one in Fig. 5.1 (a).

The influence of policies on consumer’s behaviour can be modelled by:

- direct relations between policies and the cost-benefit ratio (for example subsidies, measures that are related to performance and cost such as standards and codes)
- shifting the S-curve (Fig. 5.1 (c)) or changing its shape, to simulate other impacts of policies on consumer behaviour: increased awareness, targets, measures on suppliers

5.2 Production

The potentials in RESolve-H are calculated taking the following limiting factors into account:

- constraints on the fuel supply (biomass feedstock)
- constraints on the equipment supply
- constraints on the demand side, i.e. the maximum growth rate and planning constraints.

- constraints because of competition between the technologies, different biomass processes might depend on the same resource potential.

After potentials have been determined, the extent to which the technology will penetrate the market is limited by:

- constraints determined by the cost-benefit ratio, i.e. when the technology is more expensive than the fossil fuel route even with policy support, the penetration of the technology will not be very high
- constraints related to consumer behaviour and policy measures (shape of the S-curve)

5.3 Conversion

The technologies considered in the RESolve-H model are summarized in Table 5.1.

Table 5.1: RESolve-H technologies

Technology type	Technology
Biomass	Combustion
	CHP
	Digestion (SNG)
	Gasification (SNG)
Geothermal	Geothermal Hot Dry Rock (HDR)
	Geothermal Conventional
Solar Thermal	Domestic hot water solar (collector liquid)
	Services hot water (collector liquid)
	Domestic hot water (PVT liquid)
	Domestic hot water and space heating (collector liquid)
	Domestic hot water and space heating (PVT liquid)
	Domestic hot water and space heating (collector air)
	Services space heating (collector air)
	Domestic hot water, space cooling and heating (collector liquid)
	Services space cooling and heating (collector liquid)
	Industrial hot water (Vacuum tube liquid)
	Agricultural crop drying (collector air)
Ambient heat	Residential domestic, space and water heating, electric
	Residential domestic, space and water heating and space cooling, electric
	Residential services, space and water heating, electric
	Residential services, space and water heating and space cooling, electric

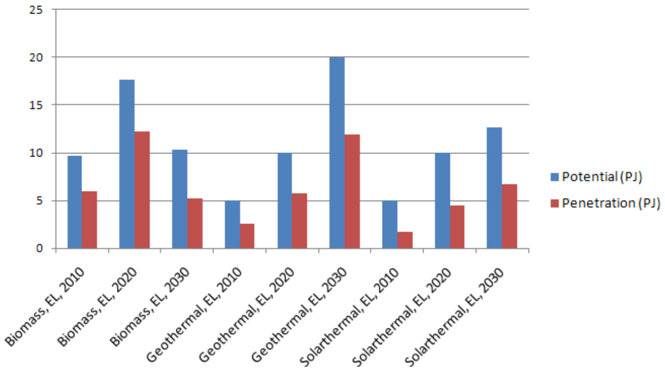
For each technology type, the following input parameters are used:

- Investment costs [€/kW$_{th}$]
- O&M costs [€/kW$_{th}$/yr]
- Conversion efficiency [%]
- Full load hours [hours/year]
- Fuel costs [€/GJ]
- Lifetime [year]

These parameters vary between the EU27 member states depending on climate and other conditions.

5.4 Output

Fig. 5.2: Example of RESolve-H output



Given techno-economic and cost data of RES-H technologies, fuel prices, policy measures, and a representation of consumer behaviour (shape of S-curve), RESolve-H calculates the potential and penetration of renewables in the heating sector. As an example, potentials and penetration data calculated with RESolve-H for the industry sector in Greece in the years 2010, 2020 and 2030 is presented in Fig. 5.2.

The penetration data will be used as an input (bioheat demand) for the biomass allocation model.

6 Biomass allocation model

6.1 Introduction

As anticipated in chapter 1, the biomass allocation model is based on an upgraded version of RESolve-T. In particular, two extra demand segments are added, namely bioelectricity and bioheat demand[2]. The input data for these additional segments come from RESolve-E and RESolve-H respectively. The allocation of biomass then happens the same way as in the original RESolve-T: the most cost-effective way of filling the demand for biofuels, bioelectricity and bioheat is calculated. Feedstock production, processing, transport and distribution steps are considered in the model. The model essentially aims at finding the minimal cost allocation along the supply chain, given projections of demand for biofuels, bioelectricity and bioheat, potentials, technological progress and policy support. International trade is possible between the different steps in the supply chain, see Figure 3.1. Note that import of products from outside the EU can easily be included in the chain.

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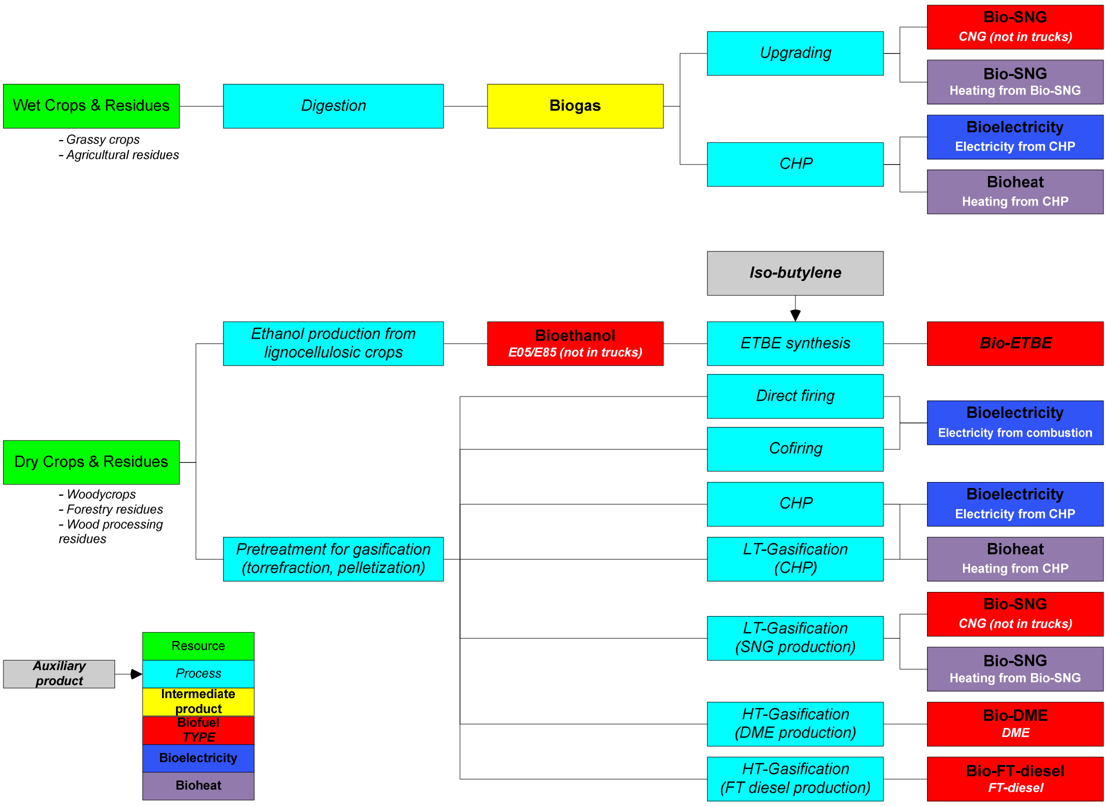
[2] Note that in our implementation, the demand for bioelectricity and bioheat will consist of subsegments based on different conversion technologies, for example co-firing in the case of electricity.

6.2 Feedstocks, technologies and conversion routes

The feedstock and technology combinations considered in the biomass allocation model are summarized in Table A.1 in Appendix A. Compared to the case when only biofuel routes were available, see Figure 3.2, it is clear that the number of conversion routes has been extended significantly with the inclusion of bioelectricity and bioheat demand segments.

As an illustration Figure 6.2 shows all conversion routes from residues, grassy and woody crops to final products.

Fig. 6.2: Examples of conversion processes included in the biomass allocation model.



6.3 Production

The biomass allocation model is based on an interaction between the three RESolve submodels within an iterative loop. This is accomplished as described in the following steps:

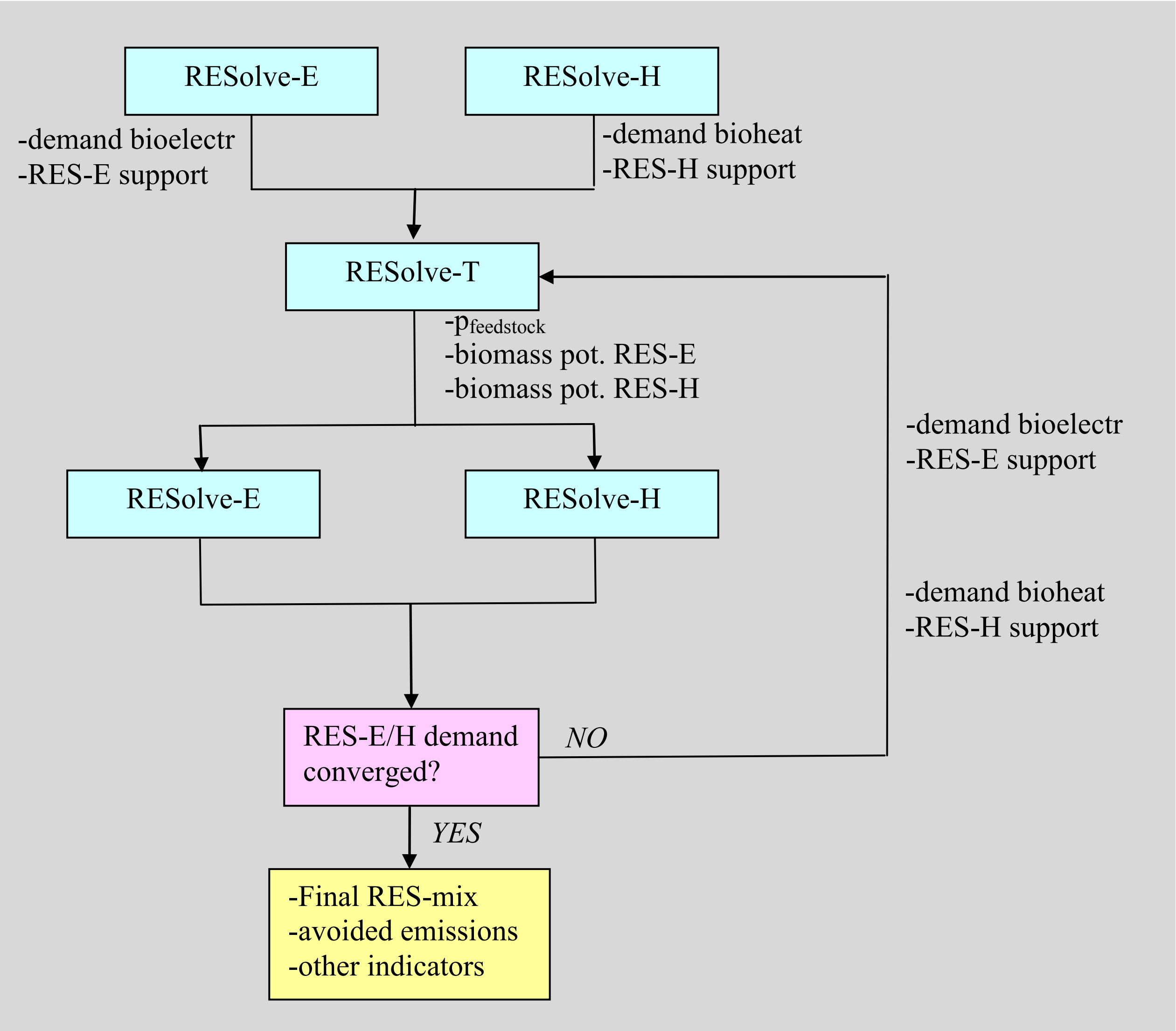
1. *RESolve-E calculates the initial bioelectricity demand* based on the economic parameters and the available policy support for RES-E such as feed-in tariffs, investment subsidies, etc.
2. *The initial bioheat demand is determined in RESolve-H*, based on techno-economic and cost data of RES-H technologies, fuel prices, policy measures, and a representation of consumer behaviour (shape of S-curve).
3. In the previous two steps the effective support per unit of electricity and heat for each technology, country and year are considered. In particular, effective support per unit of bio-electricity and bioheat for each different technology and, where applicable, crop is calculated. Note that RESolve-E and RESolve-H include not only biomass but also other renewable energy

technologies. Thus, *the demand for bioelectricity and bioheat is determined in relation to the costs and the potentials of other renewable energy sources.*

4. The demand figures derived from the previous steps serve as an input to RESolve-T. In addition, within RESolve-T, *a certain share of the renewable energy target for transport is assumed to be met by biofuels*.
5. *RESolve-T combines the three biomass demands and calculates the feedstock prices per country, technology and year*. These feedstock prices are determined as the marginal feedstock option from the cost supply curves. Note that also feedstock that is imported is covered.
6. *The resulting feedstock prices and available biomass feedstock potentials are fed back to RESolve-E and RESolve-H*, which in return calculate a new demand distribution over the different technologies, taking into account the other renewable electricity and heat sources and technologies.
7. *The process is then iterated* until equilibrium in biomass demand, potentials and prices in the three models is reached.

A schematic overview of how the different RESolve sub-models interact with each other is shown in Figure 6.3.

Figure 6.3: Biomass allocation in RESolve: interaction between the submodels and iterative scheme



6.4 Current status of development and outlook

The status of the biomass allocation model as of December 2010 is summarised in Table 6.2; an outlook as to the actions that need to take place is also presented.

Table 6.2: Current status and outlook

ITEM	**CURRENT STATUS (01-12-2010)**	**FUUTURE ACTIONS**
RESolve-E	Fully operational	Update input data (e.g. policies)
RESolve-H	Operational, but only industry sector considered	- Consistency checks - Update input data - Include other sectors (e.g. residential, agriculture, etc.) in the calculation
RESolve-T	Fully operational, a separate bioelectricity demand has been added	- Add separate bioheat demand - Consistency checks
Interaction between models	No interaction so far	- Common databases will be created where the three submodels can read, write and exchange data - At first bioelectricity and bioheat demand will be fed into RESolve-T by hand and the iterative scheme will be tested - Then a special interface will be created to do this operation automatically - A special procedure has to be implemented to deal with the situation when demand exceeding supply

An important issue that needs to be addressed is the situation of demand for biomass exceeding the available supply. A situation that is not very unlikely, since the demand for biomass from the three sectors is expected to increase significantly (Figure 1.1). In the real world this situation would lead to an increase in feedstock prices. In order to mimic this market mechanism within our model a special procedure needs to be created that takes care of increasing the feedstock prices via a suitable price adder. This will in turn lead to a lower demand for biomass. This procedure needs to be repeated until the price is at such a level that supply equals demand.

7 Conclusions

A methodology has been set up that allows for the calculation of the distribution of biomass for energy purposes over the transport, electricity and heating sector within the EU. Three independent renewable energy sector models, RESolve-T, RESolve-E and RESolve-H, will interact via an iterative scheme. The RESolve-T model will function as the base model for the allocation of biomass by adding demand segments for bioelectricity and bioheat. The demand for bioelectricity and bioheat comes from RESolve-E and RESolve-H respectively. Since RESolve-T optimizes over the entire chain, from feedstock to endues, inclusion of import-export of biomass and emission constraints are rather straightforward.

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APPENDIX A

Table A.1: Feedstock-technology matrix

	Biomass resource	Energy crops							Forestry		Biowaste	Biowaste	Biowaste
		Herbaceous ligno.crosp (i.e. canary reed, miscantus, switchgrass)	**Lignocell. Crops(i.e ecalyptus, poplar, willow)**	**Sugar crops (i.e sugar beet, sugar cane)**	**Strach crops(i.e. barley, maize, wheat)**	**Oil crops (rapse seed, sunflower)**	**Sweet sorghum**	**Used fat/oil/fatty acid**	**Forestry residues**	**Additio-nal fellings**	**Solid manure**	**Liquid manure**	**Municipal Solid Waste**
Electricity	Direct co-firing	X	X	X	X				X	X	X		
	Combustion	X	X					X	X	X	X		X
	Gasification	X	X						X	X	X		
	Digestion-CHP	X		X	X							X	
	CHP	X	X			X			X	X	X		
Biofuel	Biodiesel					X		X					
	EtOH production from sugar crops			X									
	EtOH production from starch crops				X		X						
	EtOH production from lignocellulosic crops	X	X				X		X				
	FT diesel production (incl. gasification)	X	X						X	X			
	DME production (incl. gasification)	X	X						X	X			
	SNG production (incl. gasification	X	X						X	X		X	
Heat	Combustion	X	X			X			X	X			
	CHP	X	X			X			X	X			
	Gasification (SNG)	X	X						X	X	X		
	Digestion (SNG)											X	

Table A.1 continued: Feedstock-technology matrix

	Biomass resource	Agricultural residue						Biowaste	Biowaste	Industrial waste	Black liquor	Grass cuttings	Palm oil
		Barley residues	**Maize residues**	**Oil crops residues**	**Rapeseed residues**	**Wheat residues**	**Secundary agriculatural residues**	**Landfill gas**	**Sewage sludge**	**Industria l waste**	**black liquor**	**Grass cuttings**	**Palm oil**
Electricity	Direct co-firing	X	X	X	X	X				X	X	X	
	Combustion	X	X	X	X	X				X	X		X
	Gasification	X	X	X	X	X					X		
	Digestion-CHP	X	X	X	X	X		X	X				
	CHP	X	X	X	X	X	X			X			X
Biofuel	Biodiesel												x
	EtOH production from sugar crops												
	EtOH production from starch crops												
	EtOH production from lignocellulosic crops	x	x	x	x	x	x						
	FT diesel production (incl. gasification)	x	x	x	x	x	x			x	x		
	DME production (incl. gasification)	x	x	x	x	x	x			x	x		
	SNG production (incl. gasification	x	x	x	x	x	x			x	x		
Heat	Combustion									x			
	CHP	x	x	x	x	x				x			
	Gasification (SNG)	x	x	x	x	x				x			
	Digestion (SNG)	x	x	x	x	x	x			x			