EST Biomass Module

Basic features, mathematical structure and input-output data

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Scope

➢ Familiarize with the use of EST Biomass Module
  ➢ Concepts and features
  ➢ Function
  ➢ Mathematical structure and GAMS representation
  ➢ Input & output files
Introduction

- Biomass is one of the most promising energy sources as alternative to conventional ones
  - Sources are basically forests and agro-industrial plantations, bush trees, urban trees, and farm trees, crop residues (such as straw, leaves, and plant stems), processing residues (such as saw dust, bagasse, nutshell, and husks), and domestic wastes (such as food residues and sewage) as well as aquatic biomass (algae).
  - Through the application of biomass processes, these feedstocks are transformed into final bioenergy commodities in order to produce electricity or heat.

*The EST Biomass Module simulates the economics of supply of biomass and waste & projects the primary energy/feedstock consumption required to meet bioenergy demand of the system.*
Basic features
In the EST Biomass Module

- biomass technologies compete with each other based on their techno-economic characteristics in order to enter into the market.
- the optimal use of the available resources (feedstock) & the optimum technology type mix of investments are chosen to meet the demand of biomass in Demand and Power/Heat Modules
- imported amounts of biomass feedstock and biofuels are decided
- biofuel prices are calculated as the total average of production costs

Optimization is based on the minimization of the cumulative supply costs throughout the whole projection period (inter-temporally):

- cost and availability of domestically produced primary energy feedstock of biomass & waste
- cost and availability of imported feedstock
- cost of imported final bioenergy commodities
- required investment costs in biomass technologies
Calculation Sequence

Demand & Power/Heat Modules Run:
First run based on initial prices & then updated

Biopricing:
Calculation of updated bioenergy commodity prices

Biomass consumption calculation:
Total consumption of Modules after the run

Biomass Module run:
Market Clearance under least cost objective
## Processes – Overview (1/6)

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Process/Technology</th>
<th>Output/Final Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignocellulosic &amp; food crops, Wood and wood waste, imported wood</td>
<td><strong>Enzymatic hydrolysis of lignocellulose</strong></td>
<td>Advanced Biofuels</td>
</tr>
<tr>
<td>Lignocellulosic &amp; food crops, Wood and wood waste, imported wood</td>
<td><strong>Hydro Thermal Upgrading</strong></td>
<td>Advanced Biofuels</td>
</tr>
<tr>
<td>Lignocellulosic &amp; food crops, Wood and wood waste, imported wood</td>
<td><strong>Gasification and Fischer-Tropsch Conversion</strong></td>
<td>Advanced Biofuels</td>
</tr>
<tr>
<td>Lignocellulosic &amp; food crops, Wood and wood waste, imported wood</td>
<td><strong>Catalytic Pyrolysis</strong></td>
<td>Advanced Biofuels</td>
</tr>
<tr>
<td>Food crops</td>
<td><strong>Fermentation of crops</strong></td>
<td>Conventional Biofuels</td>
</tr>
<tr>
<td>Food crops sunflower</td>
<td><strong>Transesterification of crops</strong></td>
<td>Conventional Biofuels</td>
</tr>
<tr>
<td>Agricultural &amp; animal waste</td>
<td><strong>Anaerobic digestion of organic waste to biogas</strong></td>
<td>Biogas</td>
</tr>
<tr>
<td>Algae</td>
<td><strong>Advanced processes, aquatic, microbial, photosynthesis</strong></td>
<td>Biogas</td>
</tr>
<tr>
<td>Wood and wood waste, imported wood</td>
<td><strong>Biomass solids processing</strong></td>
<td>Biomass solids</td>
</tr>
<tr>
<td>Solid &amp; liquid waste</td>
<td><strong>Waste solids &amp; liquid collection &amp; processing</strong></td>
<td>Waste solids</td>
</tr>
<tr>
<td>Waste gas</td>
<td><strong>Waste gas collection and processing</strong></td>
<td>Waste gas</td>
</tr>
</tbody>
</table>
• First-generation biofuels (conventional)
  • produced from sugars and vegetable oils found in food crops, using standard processing technologies

• Second-generation biofuels (advanced)
  • produced from non-food feedstocks such as lignocellulosic biomass or woody crops, agricultural residues or waste, as well as dedicated non-food energy crops grown on marginal land unsuitable for crop production, using more ‘advanced’ technologies

• The term **second-generation** is used to describe both the 'advanced' process, but also the use of non-food crops (second-generation feedstocks).

• The second generation technologies have been developed because of concerns to food security caused by the use of food crops for the production of first-generation biofuels.
Enzymatic hydrolysis

- currently the most mature technology for the production of advanced biofuels
- still under development, though a lot of research taking place both in Europe and USA, implying significant future development potential
- Feedstock: Lignocellulosic biomass
- Output: advanced bio-ethanol, bio-diesel and bio-kerosene (substitutes of fossil diesel and kerosene)

Hydro thermal Upgrading (HTU)

- Not technologically mature yet, highly energy intensive process (reducing its economic performance)
- Utilization of wide variety of feedstock
- biomass is decomposed in water to produce a crude oil-like liquid called ‘bio-crude’, further upgraded through hydrogenation methods to achieve fossil diesel quality
- Feedstock: Lignocellulosic biomass
- Output: advanced bio-ethanol, bio-diesel and bio-kerosene blended in any proportion with conventional fossil diesel
Gasification and Fischer-Tropsch conversion

• Conversion of biomass into synthesis gas (or syngas: fuel gas mixture consisting primarily of hydrogen, carbon monoxide, carbon dioxide)
• Feedstock: Lignocellulosic biomass, etc.
• Output: syngas
  • used as fuel in gas engines and power & steam generation units
  • mixed in the natural gas supply network, if further cleaned and upgraded to natural gas quality
  • converted into bio-diesel by processes such as Fischer-Tropsch process (well-established technology)

Catalytic Pyrolysis

• Not technologically mature yet
• significant potential for future deployment due to utilization of wide variety of feedstock
• Feedstock: Lignocellulosic biomass, etc.
• Output: Pyrolytic oil
  • produced by a thermo-chemical conversion process called flash pyrolysis, then upgraded and stabilised to reach specific quality requirements in order to be used as transport fuel.
  • not mixable with fossil diesel, used directly in modified diesel engines
  • used also for co-firing in power & steam generating units, or gasified for the production of syngas.
Transesterification

- well-established technology and largely deployed in Europe
- Feedstock: vegetable oils
  - commonly coming from rapeseed in Europe
  - vegetable and animal fats as well as used oils
- Output: Bio-diesel
  - similar properties with fossil diesel
  - used in conventional engines as blended up to a proportion of 20% with fossil diesel or in modified engines in higher proportions.

Fermentation

- Feedstock: mainly sugar crops, sugar beet, sweet sorghum, starch crops
- Output: Bio-ethanol
  - used in spark ignition vehicle engines either blended with gasoline or in pure form, if the engines are properly modified.
Anaerobic digestion

- well-established technology and largely deployed in Europe
- Feedstock: organic residues (agricultural and animal waste)
- Output: biogas
  - used to produce green electricity, heat or as vehicle fuel

Co-digestion of animal manure with various biomass substrates increases the biogas yield and offers a number of advantages for the management of manure and organic wastes.

Advanced processes, aquatic, microbial, photosynthesis

- currently much higher costs for aquatic biomass production than those for land-based crop production
- Feedstock: aquatic biomass such as algae
  - considered as advanced or third generation feedstock due to high biomass yield potentials and high photosynthetic efficiency, high diversity, no need for fertile agricultural land for cultivation and thus, no direct competition with food production
- Output: Biogas
GAMS Model
Relevant GAMS files

• **00_EST_Main**: invokes the Biomass Module
• **Data Module .gms files (01-01e)**: includes the definitions of sets and parameters and reads the exogenous data
• **01d_EST_modelV**: includes the equations of Biomass Module
• **04_EST_runBio**: calls the following .gms files related to Biomass Module
  • **04a_EST_BiolinkageIN**: loads results from Demand and Power/Heat Supply Module, includes assignments and calculation of parameters as well as fixed values for variables (initialization)
  • **04b_EST_run_Biomodel**: solves Biomass Module
  • **04c_EST_Biopricing**: calculates the prices of bioenergy per type of biofuel and per sector
  • **04d_EST_BiolinkageOUT**: calculates reporting parameters of Biomass Module as input in other Modules, such as bioenergy commodity prices, domestic production and imports of feedstock, etc.
### Main Sets (1/2)

- **$SF_{\text{bio}}$: biomass production processes**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS_EHY</td>
<td>Enzymatic hydrolysis of lignocellulose to ethanol to biofuel advanced</td>
</tr>
<tr>
<td>BS_HTU</td>
<td>HydroThermal Upgrading of lignocellulose to biofuel advanced</td>
</tr>
<tr>
<td>BS_GFT</td>
<td>Gasification and Fischer-Tropsch conversion of lignocellulose to biofuel advanced</td>
</tr>
<tr>
<td>BS_CPY</td>
<td>Catalytic Pyrolysis of lignocellulose to biofuel advanced</td>
</tr>
<tr>
<td>BS_FRM</td>
<td>Fermentation of crops to ethanol to biofuel conventional</td>
</tr>
<tr>
<td>BS_TRS</td>
<td>Transestereification of crops to biodiesel to biofuel conventional</td>
</tr>
<tr>
<td>BS_ADB</td>
<td>Anaerobic digestion of organic wastes to biogas to Biogas</td>
</tr>
<tr>
<td>BS_ADV</td>
<td>Advanced processes, aquatic, microbial, photosynthesis to Biogas</td>
</tr>
<tr>
<td>BS_BMS</td>
<td>Biomass solids processing to Biomass Solids</td>
</tr>
<tr>
<td>BS_WSD</td>
<td>Waste solids and liquid collection and processing to Waste Solids</td>
</tr>
<tr>
<td>BS_WSG</td>
<td>Waste gas collection and processing to Waste Gas</td>
</tr>
<tr>
<td>BS_IMPwd</td>
<td>Imports of wood</td>
</tr>
<tr>
<td>BS_IMPbf</td>
<td>Imports of ready biofuels conventional</td>
</tr>
<tr>
<td>BS_IMPbfa</td>
<td>Imports of ready biofuels advanced</td>
</tr>
</tbody>
</table>
Main Sets (2/2)

- **f_biofeed**: feedstock fuels of Biomass Module

<table>
<thead>
<tr>
<th>CRP_fd</th>
<th>Food Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRP_fdI</td>
<td>Food Crops sun flower</td>
</tr>
<tr>
<td>CRP_wd</td>
<td>lignocellulosic crops</td>
</tr>
<tr>
<td>WDW</td>
<td>wood and wood waste</td>
</tr>
<tr>
<td>WSLD</td>
<td>Waste solid</td>
</tr>
<tr>
<td>WLQD</td>
<td>waste liquid</td>
</tr>
<tr>
<td>WGAS</td>
<td>waste gas</td>
</tr>
<tr>
<td>WRES</td>
<td>agricultural and animal waste</td>
</tr>
<tr>
<td>IMP_wd</td>
<td>Imported Wood</td>
</tr>
<tr>
<td>ALG</td>
<td>Algae</td>
</tr>
<tr>
<td>IMP_bfc</td>
<td>Imported Biofuel Conventional</td>
</tr>
<tr>
<td>IMP_bfa</td>
<td>Imported Biofuel Advanced</td>
</tr>
</tbody>
</table>

- **f_bioout**: output fuels of Biomass Module

<table>
<thead>
<tr>
<th>BMS</th>
<th>Biomass Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSD</td>
<td>Waste Solids</td>
</tr>
<tr>
<td>BGS</td>
<td>Biogas</td>
</tr>
<tr>
<td>WSG</td>
<td>Waste Gas</td>
</tr>
<tr>
<td>BFC</td>
<td>Biofuel Conventional</td>
</tr>
<tr>
<td>BFA</td>
<td>Biofuel Advanced</td>
</tr>
</tbody>
</table>

- **biofeed**: mapping of processes and feedstocks

- **bioout**: mapping of processes and output fuels
**Input data/Parameters**

- **prob_surv_bio**: Probability of survival of an equipment per technology & vintage
- **lifetime_bio**: Lifetime of equipment per technology
- **bio_esurv**: Economic survival per technology
- **bio_tsurv**: Technical survival per technology
- **sva_bio**: Scale parameter of survival function of equipment per technology
- **svt_bio**: Survival rate of equipment at the end of lifetime per technology
- **sv80_bio**: Survival rate of equipment at 80% of lifetime per technology
- **bio_ann**: Annuity factor of investment cost per technology & vintage
- **wacc_bio**: Discount rate per vintage
- **bio_heatrate**: Heatrate of equipment per technology
- **bio_self_fuel**: Heatrate of fuel consumption per technology & vintage
- **bio_self_elec**: Heatrate of electricity consumption per technology & vintage
- **bio_respotential**: Availability potential of feedstock
- **bio_invcost**: Investment cost of technology per vintage
- **bio_omcost**: O&M cost per technology & vintage
- **bio_omgr**: O&M cost growth rate per technology & vintage
- **bio_varcost**: Variable cost of technology per vintage
- **mc_resourcebio**: Cost of feedstock excluding the cost impact potential exhaustion
- **nc_resourcebio**: Nonlinear parameter of cost supply curve of feedstock
- **Subs_bio**: Learning-by-doing parameter per technology & vintage
- **RESvalue_bio**: Renewable value of bioenergy fuel
- **utilSFbio**: Utilization rate per technology
- **operBioCAP**: Operating capacities of a base year
Policy drivers

The policy drivers of EST Biomass Module are available mostly in the supply-related input file ("ScenarioName”_Input_supply) and can be modified by the user:

• **Carbon Price**: The price of emission allowance in a cap-and-trade system affects also the choice of fuel consumption in the biomass technologies. The user can specify this price for each projected year in the demand-related input file ("ScenarioName”_Input_demand) (applied previously to model EUAs – EU emission Allowances).

• **RES value per output fuel (RESvalue_bio)**: RES value represents non-identified policies aiming at the increase of RES use, reflecting the shadow cost (marginal benefit) of the implicit RES target.

• **Learning-by-doing/LBD (Subs_bio)**: this parameter represents the reduction of total biomass production costs of a new technology, via a learning-by-doing process. The LBD parameter of a biomass technology is multiplied with the bioenergy production of this technology, implying that increased use of a biomass technology for bioenergy production reduces the cost of production of the specific technology.
**Variables**

- **BIO_SUPP**: Production of bioenergy per output fuel, technology and vintage
- **CAP_SUPP**: Operating capacity per biomass technology and vintage
- **INV_SUPP**: Investment capacity per biomass technology and vintage
- **BIO_FEEDSTOCK**: Consumption of feedstock fuels per biomass technology and vintage
- **BIO_FUEL**: Consumption of fuel per biomass technology and vintage
- **BIO_RESCONS**: Total consumption of feedstock fuels per feedstock subject to potential constraints
- **PRICE_Sfbio**: price of a biomass product in EUR per kWh

**Note:** In the EST model, variables are written in capital letters while parameters and sets in small letters.
Structure of equations

- Balancing biomass supply with biomass demand
- Balancing the demand and supply of feedstock
- Calculating self-consumption of electricity and conventional fuels
- Constraints on the potential of feedstock resources
- Non linear costs that increase when approaching the maximum feedstock resource
- Objective function – Solution with non-linear programming
Equation **QB_demand**

- Equation that balances biomass supply with biomass demand.
- Biomass demand concerns the demand of biomass solids, biogas, biofuel (advanced and conventional) and waste (gas and solids) in demand and power/heat sectors.
- The sum of biofuels produced by each process should be greater than or equal to biomass consumed in demand and power/heat sectors.
- Apart from the transformation processes, biomass processes are considered also imports of wood, conventional and advanced biofuels.

\[
\sum_{S F_{bio}} \sum_{v \leq t} BIO_{SUPPSF_{bio}, v, fout, t} \geq bio\_demand_{fout, t}
\]
• Capacity constraint: Capacity of biomass process SFbio (multiplied by the annual utilization rate) should be able to cover the annual supply for bioenergy (bio – fuels).

\[ \text{CAP\_SUPPSF}_{bio}, v, t \times \text{utilSF}_{bio} \times 8760 \geq \sum_{f\_bioout} \text{BIO\_SUPPSF}_{bio}, v, f\_bioout, t \]
• Annual capital stock of biomass processes in GW is equal to the survived installed capacity of the previous year plus the new investment of the current year.

• CAP_SUPP_L2 is a parameter denoting exogenous capacity. The parameter is assigned by an internal table, showing the capacity of certain biomass processes for the years 1995-2010. The part that has survived is used for the base year 2015.

• Probability of survival (prob_surv_bio) is taken into account. The Gompertz survival probability function uses 3 parameters which are defined exogenously and are:
  • the scale parameter of survival function of equipment (sva_bio)
  • the survival rate of equipment at the end of lifetime (svt_bio)
  • the survival rate of equipment at 80% of lifetime (sv80_bio)

• technical survival (bio_tsurv) are taken into account.

\[
CAP\_SUPP = INV\_SUPP + prob\_surv\_bio \times \sum_{year\_lag} (CAPP\_SUPP + CAPP\_SUPP\_L2) \times bio\_tsurv
\]
Equation **QB_FEEDSTOCK**
• For each process, biomass output should be covered (less than) by the total process feedstock

$$
\sum_{f\text{feed}} \text{FEEDSTOCK}_{SFbio,v, f\text{feed}, t} / \text{heatrate}_{SFbio,v} \geq \sum_{f\text{out}} \text{BIOPROD}_{SFbio,v, f\text{out}, t}
$$

Equation **QB_FUEL**
• The total fuel consumption (except for electricity) of the biomass processes should be greater than or equal to the biomass supply (output) multiplied by the heat rate (self-consumption in GWh fossil fuel/GWh output)
• The fuels used in biomass processes (apart from feedstock) are: diesel, natural gas, clean gas, hydrogen and electricity.

$$
\sum_{f\text{not elec}} \text{BFUEL}_{SFbio,v, f, t} / \text{heatrate}_{fuel_{SFbio,v,t}} \geq \sum_{f\text{out}} \text{BIOPROD}_{SFbio,v, f\text{out}, t}
$$
Equation **QB_ELEC**

- The total electricity consumption of the biomass processes should be greater than or equal to the biomass supply (output) multiplied by the heat rate of electricity.

\[
\frac{BFUEL_{SFbio, v, elec, t}}{\text{heatrate}_{SFbio, v, elec, t}} \geq \sum_{fout} BIOPROD_{SFbio, v, fout, t}
\]

Equation **QB_RESCONS**

- Consumption of feedstock per feedstock and year as the sum of the consumption of feedstock of all processes and vintages.

\[
BIO\_RESCONS_{\_biofeed, t} = \sum_{SFbio} \sum_{v \leq t} BIO\_FEEDSTOCKSFbio_{\_v, f_{biofeed, t}}
\]
Equation QB_Resource

• Availability potential constraint
• Consumption of feedstock per feedstock and year should comply with (less than or equal to) the maximum availability potential of feedstock.

\[ bio\_respotential_{\text{biofeed, } t} \geq BIO\_RESCONS_{\text{biofeed, } t} \]
**Equation QB_Obj: Least-cost Objective function**

The goal is to solve an optimization problem: the satisfaction of biomass demand of the energy system with simultaneous minimization of cumulative biomass supply costs for the whole projection period (2020-2070).

\[
\begin{align*}
\text{min obj} &= \sum_t \sum_{v \in SFBio} \sum_{SFBio} \left( \text{invcost}_{SFBio,v} \cdot \text{anfact}_{SFBio,v} \cdot \text{INV}_{SFBio,v} \cdot e_{\_surv}_{SFBio,v,t} + \text{omcost}_{SFBio,v} \right) \\
& \quad \cdot \left( 1 + \text{omgr}_{SFBio,v} \right)^{t-v} \cdot \text{CAP}_{SFBio,v,t} \cdot t_{\_surv}_{SFBio,v,t} + \text{varcost}_{SFBio,v} \\
& \quad \cdot \sum_{f_{out,t}} \text{BIOPROD}_{SFBio,v,f_{out,t}} + \sum_{f_{feed}} \text{FEEDSTOCK}_{SFBio,v,f_{feed,t}} \cdot \text{FEEDCOST}_{SFBio,v,f_{feed,t}} \\
& \quad + \sum_{f} \text{BFUEL}_{SFBio,v,f,t} \cdot \left( \text{pribfuel}_{SFBio,f,t} + \text{emf}_{f} \cdot \text{carbonprice}_{t} \right) \\
& \quad - LBD_{\_bio}_{SFBio,v,t} \sum_{f_{out}} \text{BIOPROD}_{SFBio,v,f_{out,t}} - \sum_{f_{out}} \text{resvalue}_{f_{out,t}} \cdot \text{BIOPROD}_{SFBio,v,f_{out,t}} \right)
\end{align*}
\]
QB_Obj: Least-cost Objective function

- Annualized investment/capital costs (economic survival for amortization is taken into account)
- Fixed O&M costs with growth rate according to vintage (technical survival is taken into account) and variable costs
- Cost of feedstock including the cost impact of potential exhaustion: a non-linear cost is added which increases when approaching the biomass feedstock potential (non-linear cost-supply curve)

\[
FEEDCOST_{SF_{bio,v,ffeed,t}} := mc_{feed,ffeed,t} - nc_{feed,ffeed,t} \cdot \log\left(1 - \frac{RESCONS_{ffeed,t}}{respot_{ffeed,t}}\right)
\]

- Cost of fuels consumed in the biomass processes (diesel, electricity, etc.)
- Cost of emissions (carbon price – emission trading)
- Minus LBD parameter (modelled as subsidies) & RES value multiplied by the biomass supply
After optimization, biofuel prices are calculated as the total average price of the production costs and are provided as input to the Demand and Power/Heat Modules.

\[
\text{price}_{\text{SFbio}_{\text{bio}, t}} = \frac{\text{Cost}_{\text{SFbio}_{\text{bio}, t}}}{\sum_{v \in t} \sum_{\text{f out}} \text{BIOPROD}_{\text{SFbio}, v, \text{f out}, t}}
\]

\[
\text{Cost}_{\text{SFbio}_{\text{bio}, t}} = \sum_{v \in t} \left( \text{invcost}_{\text{SFbio}, v} \cdot \text{anfact}_{\text{SFbio}, v} \cdot \text{INV}_{\text{SFbio}, v} \cdot e_{\text{surv}_{\text{SFbio}, v, t}} + \text{omcost}_{\text{SFbio}, v} \cdot (1 + \text{omgr}_{\text{SFbio}, v})^{t-v} \cdot \text{CAP}_{\text{SFbio}, v, t} \cdot t_{\text{surv}_{\text{SFbio}, v, t}} + \text{varcost}_{\text{SFbio}, v} \right) \\
\cdot \sum_{\text{f out}} \text{BIOPROD}_{\text{SFbio}, v, \text{f out}, t} + \sum_{\text{f feed}} \text{FEEDSTOCK}_{\text{SFbio}, v, \text{f feed}, t} \cdot \text{mc}_{\text{feed}, \text{f feed}, t} \\
+ \sum_{f} \text{BFUEL}_{\text{SFbio}, v, f, t} \cdot (\text{pribfuel}_{\text{SFbio}, f, t} + \text{emf}_{f} \cdot \text{carbonprice}_{t}) \\
- \text{LBD}_{\text{bio}, \text{bio}, v, t} \sum_{\text{f out}} \text{BIOPROD}_{\text{SFbio}, v, \text{f out}, t}
\]
Pricing (2/2)

- Commodity price of bioenergy, as the average cost of production for the biomass technologies used/chosen.
- Calculation of price per bioenergy commodity and by sector (heating, transport, power)

\[
price_{bio_{fout},t} = \frac{\sum_{SF_{bio}} price_{SF_{bio},t} \cdot \sum_{v \leq t} BIOPROD_{SF_{bio},v, fout, t}}{\sum_{v \leq t} \sum_{SF_{bio}} BIOPROD_{SF_{bio},v, fout, t}}
\]
Input & Output files
Sheet “Techdata_bio” contains the full techno-economic data for biomass technologies:

- Utilization rates
- Lifetime
- Capital and O&M costs
- Heat rates
- Self-consumption rates
- Feedstock potential, etc.

Note: This is just a fraction of the Excel file.
Sheet “Policy_biofuels” contains policy drivers that represent different policy measures applied on Biomass Module

1. RES value per output fuel and year in USD’15/KWh
2. Subsidies/LBD parameter per biomass technology and vintage in USD’15/KWh

Note: This is just a fraction of the Excel file.

<table>
<thead>
<tr>
<th>Parameter/Policy driver</th>
<th>Output fuel</th>
<th>C</th>
<th>D</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Renewable value - Biofuels</td>
<td>BMS</td>
<td>dummy</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3. Renewable value - Biofuels</td>
<td>WSD</td>
<td>dummy</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>4. Renewable value - Biofuels</td>
<td>BGS</td>
<td>dummy</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5. Renewable value - Biofuels</td>
<td>WSG</td>
<td>dummy</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>6. Renewable value - Biofuels</td>
<td>BFC</td>
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<tr>
<td>7. Renewable value - Biofuels</td>
<td>BFA</td>
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<td>0.00</td>
<td>0.00</td>
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<td>8. Renewable value - Biofuels</td>
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<tr>
<td>9. Subsidies - Biomass Technologies</td>
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<td>2015</td>
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<tr>
<td>10. Subsidies - Biomass Technologies</td>
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Sheet “Prices_data” contains the initial prices of bioenergy commodities per sector.

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<tr>
<th>Parameter/Price</th>
<th>Fuel</th>
<th>Sector</th>
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<tr>
<td>Prices in power generation or wholesale supply in USD'15/MWh fuel</td>
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<td>Bio_prices</td>
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<td>Prices of new transport fuels in USD’15/MWh fuel</td>
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<td>Additional cost for Industrial use in USD’15/MWh fuel</td>
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<td>Additional cost for domestic use in USD’15/MWh fuel</td>
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</table>
Sheet “**Drivers_data**” contains the data on parameter Carbon Price- ETS

**Note:** This is just a fraction of the Excel file.

| A          | E   | F   | G   | H   | I   | J   | K   | L   | M   | N   | O   |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| CarbonPriceETS | -   | -   | -   | -   | 38.01 | 47.66 | 56.73 | 78.29 | 99.85 |     |     |     |
| CarbonPriceDHH | -   | -   | -   | -   | 38.01 | 47.66 | 56.73 | 78.29 | 99.85 |     |     |     |
| CarbonPricePower | -   | -   | -   | -   | 38.01 | 47.66 | 56.73 | 78.29 | 99.85 |     |     |     |
| CarbonPriceInd | -   | -   | -   | -   | 38.01 | 47.66 | 56.73 | 78.29 | 99.85 |     |     |     |
| CarbonValueNETS | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
| CarbonLeakage  | -   | -   | -   | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |     |
In the **2 output Excel files (report & database) per scenario of EST model** there are dedicated parts for the results of Biomass Module:

- Demand of bioenergy per fuel
- Domestic production of Biomass Feedstock
- Net Imports of Biomass Feedstock
- Net imports of Bioenergy
- Bioenergy Production
- Installed Capacity of Biomass Technologies
- Capacity Expansion of Biomass Technologies
- Fuel Consumption
- Total Cost of Biomass Supply
- Commodity Price per fuel type