Calculation of GHG emissions

Total GHG emissions of a bioenergy system are expressed as:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

where E is the total emission from production of the fuel before energy conversion and the e-terms are emissions (+) or emission savings (–) from the various stages of the production chain:

- Extraction or cultivation of raw materials (ec):
  Emissions from the production and use of fertilizers (both organic and chemical), pesticides and seeding material are taken into account, as well as emissions from the use of agricultural and forestry machinery. Emissions from fertilizers, pesticides and seeding material includes emissions from production, storage and transport of the material. Emissions are calculated as $e_{eci} = Q_i \cdot (F_{ip} + F_{is} + F_{it})$ where i is the fertilizer, pesticide or seeding material, Q_i is the consumption of the material and F_{ip}, F_{is} and F_{it} are emission factors for respectively production, storage and transport of the material. For fertilizers, field emissions are added (emission factor F_{if}, taken from IPCC emission factors). Emissions from application is covered by the emissions from the use of machinery. In case the seeding material is taken from own production, the biomass used as seed must be subtracted from the net yield. Emissions from machinery use are expressed as $e_{ecm} = Q_{mf} \cdot F_f$ where Q_{mf} is the fuel or energy consumption of the machinery and F_f is the emission factor of the energy source used.
- Carbon stock changes due to land conversion (l):
  Emissions from land carbon stock changes (e_l) due to direct land use change can be positive (net carbon release) or negative (net carbon gain). Because carbon stock changes happen gradually over a number of years, the EC proposes in its guidelines to annualise them over a period of 20 years. The e_l term includes emissions from direct land use changes as well as from changes in agricultural practices and is calculated according to the methodology explained in the Commission's decision on guidelines for the calculation of land use carbon stocks[1]: $e_l = (CS_R - CS_A) \cdot 3{,}664 \cdot 1/20 \cdot 1/P - e_B$ where CS_R is the carbon stock of the reference land (both soil and vegetation), CS_A is the carbon stock of the actual land use, P is the productivity of the crop and e_B is a bonus if biomass is obtained from restored degraded land.
- Processing (p):
  For the calculation of emissions from processing (e_p), the use of energy and different kinds chemicals is taken into account. Similar algorithms are used as for use of pesticides and machinery in the first e term (e_{ec}). Also emissions from waste and leakages during processing have to be included. In case electricity is consumed, the emission factor for production and use of electricity is consistent with medium voltage grid.
- Transport and distribution (td):
  Emissions from transport and distribution are calculated as $e_{td} = D_t \cdot C_t \cdot F_f$ where D_t is the transport distance (back and forth except if it is proven that the transportation mean came back loaded), C_t is the specific energy consumption of the transportation mean and F_f is the emission factor of the energy source used.

[1] European Commission decision of 10 June 2010 on guidelines for the calculation of land use carbon stocks for the purpose of Annex V of the Directive 2009/28/EC.

- The use of the fuel (u), soil carbon capture via improved agricultural management (sca), carbon capture and geological storage (ccs), and carbon capture and replacement (ccr):
  Since the eu term is deemed to be zero as the CO2 released is compensated by the CO_2 absorbed by the plants during biomass production, this term is not further addressed in the calculation as well as the terms eccs and eccr which do not apply to the actual bioenergy systems.

To obtain the total GHG emission from the final energy commodity, the total GHG emission E is divided by the energy efficiency in case a single commodity is produced. When more than one commodity is produced (CHP) the total GHG emission from an energy commodity is $EC_i = E/\eta_i$ ($C_i \cdot \eta_i$ / ($C_{el} \cdot \eta_{el} + C_h \cdot \eta_h$)) with EC_i the total GHG emission from final energy commodity i (electricity or heat), C_i the fraction of exergy in energy commodity i and η_i the efficiency of the conversion (η_{el} or η_h).

The GHG emission savings from heat and electricity being generated is then SAVING = ($EC_F - EC_i$)/EC_F where EC_F is the total GHG emission from the fossil fuel comparator and EC_i the total GHG emission of the production of heat, electricity or cogeneration.

Total GHG emissions from fossil fuel comparators are defined by the European Commission and are 198 g CO_{2eq}/MJ_{el} from solid and gaseous biomass [2], 87 g CO_{2eq}/MJ_h from solid and gaseous biomass2, 91 g CO_{2eq}/MJ_{fuel} in electricity production from bioliquids [3], 77 g CO_{2eq}/MJ_{fuel} in heat production from bioliquids3, 85 g CO_{2eq}/MJ_{fuel} in cogeneration from bioliquids3 and 67,59 g $CO_{2eq}/MJ_{green\ gas}$ [4].

[2] Report from the Commission to the Council and the European parliament on sustainability requirements for the use of solid and gaseous biomass resources in electricity, heating and cooling.
[3] Commission staff working paper – Impact assessment. Accompanying document to the communication from the Commission to the Council and the European parliament.
[4] Methodology CO_2-tool electricity, gas and heat from biomass, NL Agency 2011.