Guidelines for Sustainability Assessment

uP_running

Take-off for sustainable supply of woody biomass from agrarian pruning and plantation removal

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ABBREVIATIONS

APPR	Agrarian Pruning and Plantation Removal
GHG	Greenhouse Gases
LHV	Low Heating Value
PrMov	Prime Mover
SA	Sustainability Assessment
VC	Value Chain
VCA	Value Chain Actor

DEFINITIONS

APPR biomass value chain	The set of activities and stakeholders involved in the preparation and use of biomass products obtained out of Agricultural Pruning and Plantation Removal wood (APPR wood).
Prime mover	A stakeholder who has a strong interest and willingness to start a new APPR biomass value chain. It is the main actor in the value chain, the actor who engages the others and who makes the things happen. It is generally the more active actor and usually, the stakeholder taking the most of the risk when investing in the new value chain.

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1 INTRODUCTION

The present guidelines show how to perform the environmental assessment in order to evaluate the environmental impact of each APPR value chain. Via these guidelines, the partners will follow a common methodology in which they will collect/use environmental data from the demonstrations and perform environmental evaluations. The methodology described below, will calculate some environmental indicators that estimate, at the end, the savings of GHG (CO_2 equivalent) emissions by implementing the new APPR value chain, compared to conventional pathways for producing electricity, heat or cooling.

2 METHODOLOGY

The methodology to calculate GHG emissions emitted via an APPR value chain follows a simple methodology mainly based on: i) GHG accounting methodology presented in the Report of the European Commission COM (2010) 11[1] plus additions in the European Commission Staff Working Document SWD (2014) 259[2]; ii) JRC report EUR 27215 EN[3] and iii) European Project BIOGRACE II "Harmonised Greenhouse Gas Calculations for Electricity, Heating and Cooling from Biomass"[4].

Through the tool, GHG emissions from each value chain are calculated as ***CO_2 equivalent emissions***, according to the abovementioned methodologies. Through each process of the APPR value chain, some factors are estimated in order to calculate the total emissions before energy conversion as can be seen in the following equation:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - es_{ca} - e_{ccs} - e_{ccr},$$

Where,

E = total emissions from the production of the fuel before energy conversion;
e_{ec} = emissions from the extraction or cultivation of raw materials;
e_l = annualised emissions from carbon stock changes caused by land use change; (not considered in our tool)
e_p = emissions from processing;
e_{td} = emissions from transport and distribution;
e_u = emissions from the fuel in use, that is greenhouse gases emitted during combustion;
e_{sca} = emission savings from improved agricultural management; (not considered in our tool)
e_{ccs} = emission savings from carbon capture and geological storage; (not considered in our tool) and
e_{ccr} = emission savings from carbon capture and replacement (not considered in our tool).

[1] COM/2010/11, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0011:FIN:EN:PDF
[2] http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf
[3] https://ec.europa.eu/energy/sites/ener/files/documents/Solid%20and%20gaseous%20bioenergy%20pathways.pdf
[4] http://www.biograce.net/biograce2/

Emissions from the manufacture of machinery and equipment shall not be taken into account.

GHG gas emissions from the use of solid and gaseous biomass in producing electricity, heating or cooling, including the energy conversion to electricity and/ or heat or cooling produced shall be calculated as follows:

For the electricity or mechanical energy coming from energy installations delivering useful heat together with electricity and/or mechanical energy:

$$EC_{el} = \frac{E}{\eta_{el}} \left(\frac{C_{el} \cdot \eta_{el}}{C_{el} \cdot \eta_{el} + C_h \cdot \eta_h} \right)$$

For the useful heat coming from energy installations delivering heat together with electricity and/or mechanical energy:

$$EC_h = \frac{E}{\eta_h} \left(\frac{C_h \cdot \eta_h}{C_{el} \cdot \eta_{el} + C_h \cdot \eta_h} \right)$$

Where:

$EC_{h,el}$ = Total GHG gas emissions from the final energy commodity.

E = Total GHG gas emissions before end-conversion.

η_{el} = The electrical efficiency, defined as the annual electricity produced divided by the annual fuel input.

η_h = The heat efficiency, defined as the annual useful heat output divided by the annual fuel input.

C_{el} = Fraction of exergy in the electricity, and/or mechanical energy, set to 100 % (C_{el} = 1).

C_h = Carnot efficiency (fraction of exergy in the useful heat).

Carnot efficiency, C_h, for useful heat at different temperatures:

Where:

T_h = Temperature, measured in absolute temperature (kelvin) of the useful heat at point of delivery.

T_0 = Temperature of surroundings, set at 273 kelvin (equal to 0 °C)

For T_h, < 150 °C (423 kelvin), C_h can alternatively be defined as follows:

C_h = Carnot efficiency in heat at 150 °C (423 kelvin), which is 0.35

At the end, the tool calculates the GHG gas emission savings from implementing the APPR value chain (production of heat/cooling/ electricity from APPR biomass) compared to the emissions produced from the generation of heat/cooling/ electricity from fossil fuels. GHG emission savings from heating, cooling, electricity generation from biomass shall be calculated as:

SAVING = $(EC_{F(h\&c,el)} - EC_{B(h\&c,el)})/EC_{F\ (h\&c,el)}$, where

$EC_{B\ (h\&c,el)}$ = total emissions from the production of heat, cooling, electricity from biomass;

$EC_{F\ (h\&c,el)}$ = total emissions from the fossil fuel comparator for heating and cooling, electricity.

3 APPR VALUE CHAIN STEPS

In order to perform the Sustainability Assessment we firstly have to define the operations that may participate in each step of the value chain. However, each value chain varies from each other, thus it is difficult to examine each combination of different operations. In this light, a general scheme of value chain steps exist in the tool:

- Value Chain Step 1. Harvesting of APPR biomass: Activities that are performed for the harvesting of APPR (e.g. windrowing, harvesting of APPR with integrated mulcher etc.);
- Value Chain Step 2. First Haulage: Transportation of harvested APPR to the next step of value chain;
- Value Chain Step 3. APPR upgrading: Includes activities such as chipping and pelletizing of APPR biomass. These activities are foreseen to take place at a centralized facility;
- Value Chain Step 4. Transport to final consumer: Transportation of APPR fuel to the end user;
- Value Chain Step 5. Final Conversion: the conversion of APPR fuel into electricity, heat and cooling (e.g. power plant, CHP unit, biomass boiler, etc.).

4 SUSTAINABILITY ASSESSMENT

In this section the Excel tool for the sustainability assessment of the APPR value chain will be presented.

The excel file has 2 Sheets:

- “Calculations”: main sheet of the tool, used for data input and calculations. No-coloured and green cells are calculated automatically. Cells with yellow colour require user input.
- “Standard Values”: sheet with several default values that are used or can be used for the calculations (e.g. GHG emission coefficients of several fuels, processes, emission factors for power generation for each EU country etc.).

4.1 APPR Value chain “Calculations” Sheet

The first sheet “Calculations” is the main sheet of the excel file. It includes the activities that take place in an APPR value chain in order to record their GHG emissions and calculate at the end the GHG savings.

There are two main table areas on this sheet. The main area on the left where the APPR value chain steps are listed where the user inserts the corresponding input values and where the calculations are made in order to calculate GHG emissions and savings. A second table area on the right of the sheet entitled “Calculations/ Supporting Info” where some supporting values and equations appear to help the user calculate/ estimate the requested values of the activities on the APPR value chain.

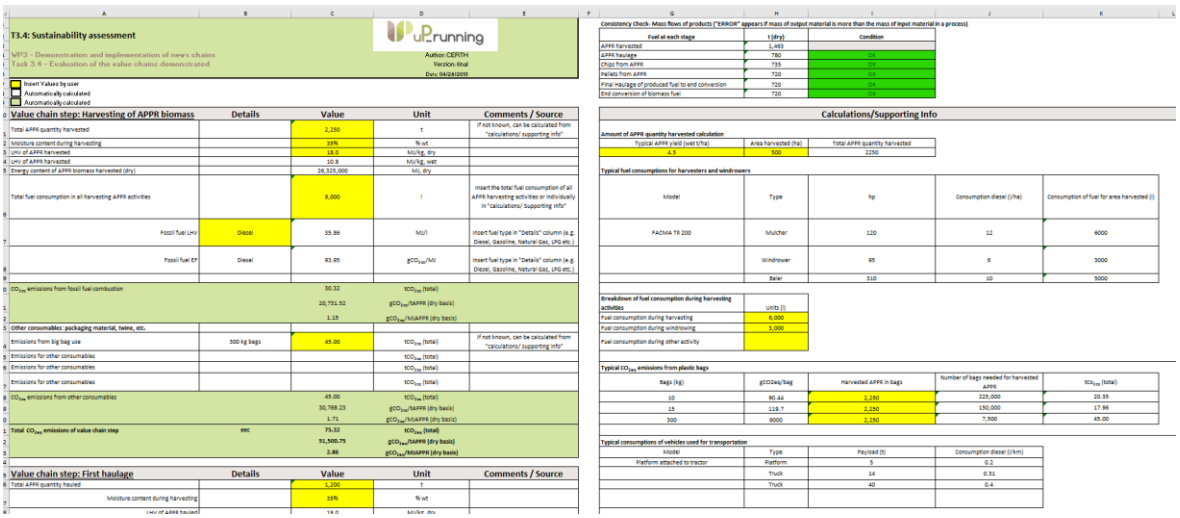


Figure 1. Overview of the main sheet "Calculations" of the excel tool

4.1.1 Harvesting of APPR biomass

At first, the value chain step regarding the harvesting of APPR biomass has to be completed. Information regarding the amount of APPR harvested is required. Continuously, information on the moisture content and LHV/ Lower Heating Value (dry) of APPR is requested in order to calculate the energy content of the APPR harvested and express the GHG emissions per MJ of APPR. The next cell that is needed to be filled is that of the total consumption of fuel in liters regarding the harvesting activities of APPR. If the total consumption of all the activities is not known, then the user can go to the "Calculation/ Supporting Info" where data regarding the harvesting activities (fuel consumptions based on the type of equipment used such as mulcher, windrower, baler) are there to help the user calculate the fuel consumptions needed. After defining the total fuel consumptions, the user has to insert the type of fuel consumed (e.g. diesel, gasoline etc.) and the corresponding fuel emission factor (gCO_{2eq}/MJ) is automatically inserted.

Next, green cells automatically show the CO_2 equivalent emissions of the activities so far, expressed in tonnes of CO_{2eq}, in gCO_{2eq}/tonne of APPR (dry basis) and in gCO_{2eq}/MJ of APPR (dry basis). Finally, additional CO_2 emissions from other activities that take place during this value chain step are inserted such as big bags (if used during harvesting). Again, in order to facilitate the user, some values regarding the gCO_{2eq}/bag appear on the "Calculations/ Supporting Info" table so as to calculate the total emissions of in gCO2eq from the usage of plastic bags or other consumables.

In brief, this step requires information on:

- Total APPR quantity harvested
- Moisture Content of APPR harvested
- LHV of APPR (dry)
- Total Fuel Consumption in all harvesting APPR activities (e.g. windrowing, integrated harvesting etc.) -The user can check "Calculations/ Supporting Info" table for help in calculations

- Emissions from consumables used (e.g. big bags to collect APPR) -The user can check “Calculations/ Supporting Info” table for help in calculations

After that, the green cells calculate automatically the total emissions of the APPR value chain step and calculate the e_{ec} emission factor.

Value chain step: Harvesting of APPR biomass	Details	Value	Unit	Comments / Source
Total APPR quantity harvested		2,250	t	If not known, can be calculated from “calculations/ supporting info”
Moisture content during harvesting		35%	% wt	
LHV of APPR harvested		18.0	MJ/kg, dry	
LHV of APPR harvested		10.8	MJ/kg, wet	
Energy content of APPR biomass harvested (dry)		26,325,000	MJ, dry	
Total fuel consumption in all harvesting APPR activities		9,000	l	Insert the total fuel consumption of all APPR harvesting activities or individually in “calculations/ Supporting info”
Fossil fuel LHV	Diesel	35.86	MJ/l	Insert fuel type in “Details” column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
Fossil fuel EF	Diesel	93.95	gCO_{2eq}/MJ	Insert fuel type in “Details” column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
CO_{2eq} emissions from fossil fuel combustion		30.52	tCO_{2eq} (total)	
		20,751.52	gCO_{2eq}/tAPPR (dry basis)	
		1.15	gCO_{2eq}/MJAPPR (dry basis)	
Other consumables: packaging material, twine, etc.				
Emissions from big bag use	300 kg bags	45.00	tCO_{2eq} (total)	If not known, can be calculated from “calculations/ supporting info”
Emissions for other consumables			tCO_{2eq} (total)	
Emissions for other consumables			tCO_{2eq} (total)	
Emissions for other consumables			tCO_{2eq} (total)	
CO_{2eq} emissions from other consumables		45.00	tCO_{2eq} (total)	
		30,769.23	gCO_{2eq}/tAPPR (dry basis)	
		1.71	gCO_{2eq}/MJAPPR (dry basis)	
Total CO_{2eq} emissions of value chain step	**eec**	**75.52**	**tCO_{2eq} (total)**	
		51,500.75	**gCO_{2eq}/tAPPR (dry basis)**	
		2.86	**gCO_{2eq}/MJAPPR (dry basis)**	

Calculations/Supporting Info

Amount of APPR quantity harvested calculation

Typical APPR yield (wet t/ha)	Area harvested (ha)	Total APPR quantity harvested
4.5	500	2250

Typical fuel consumptions for harvesters and windrowers

Model	Type	hp	Consumption diesel (l/ha)	Consumption of fuel for area harvested (l)
FACMA TR 200	Mulcher	120	12	6000
	Windrower	95	6	3000
	Baler	310	10	5000

Breakdown of fuel consumption during harvesting activities	Units (l)
Fuel consumption during harvesting	6,000
Fuel consumption during windrowing	3,000
Fuel consumption during other activity	

Typical CO_{2eq} emissions from plastic bags

Bags (kg)	gCO2eq/bag	Harvested APPR in bags	Number of bags needed for harvested APPR	tCO_{2eq} (total)
10	90.44	2,250	225,000	20.35
15	119.7	2,250	150,000	17.96
300	6000	2,250	7,500	45.00

Typical consumptions of vehicles used for transportation

Model	Type	Payload (t)	Consumption diesel (l/km)
Platform attached to tractor	Platform	3	0.1

Figure 2. Overview of the Harvesting of APPR biomass value chain step of the excel tool

4.1.2 Haulage of APPR to intermediate value chain step

The next step is to calculate the emissions regarding the first haulage of APPR to the next step of the value chain. The user has to insert the total amount of APPR that will be transported for upgrading along with the moisture of APPR. The LHV of the APPR is considered the same as during harvesting activities, thus it is completed automatically. The last thing is to insert the total fuel consumption of the transporting vehicles. If not known, again, in the “Calculations/ Supporting Info” there are values (e.g. fuel consumptions for trucks with several payloads) and simple methodology/ equations with which the user can calculate the total fuel consumptions of the examined value chain. In the end, the total emissions of value chain step and emission factor etd (green colored cells) are calculated.

In brief, this step requires information on:

- Total APPR quantity hauled
- Moisture Content of APPR
- Total Fuel Consumption during haulage of APPR activities -The user can check “Calculations/ Supporting Info” table for help in calculations
- Type of fuel consumed (e.g. diesel, gasoline etc.)

32		51,500.75	gCO_{2eq}/tAPPR (dry basis)	
33		2.86	gCO_{2eq}/MJAPPR (dry basis)	
34				
35	**Value chain step: First haulage**	**Details**	**Value**	**Unit**	**Comments / Source**
36	Total APPR quantity hauled		1,200	t	
37	Moisture content during harvesting		35%	% wt	
38	LHV of APPR hauled		18.0	MJ/kg, dry	
39	LHV of APPR hauled		10.8	MJ/kg, wet	
40	Energy content of APPR (dry)		14,040,000	MJ, dry	
41	Total fuel consumption during haulage of APPR (from field to "upgrading")		265.7	l	If not known, calculate from "Calculations/ Supporting info"
42	Fossil fuel LHV	Diesel	35.86	MJ/l	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
43	Fossil fuel EF	Diesel	93.95	gCO_{2eq}/MJ	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
44					
45					
46					
47	Total CO_{2eq} emissions of value chain step	etd	0.90	tCO_{2eq} (total)	
48			1,147.64	gCO_{2eq}/tAPPR (dry basis)	
49			0.06	gCO_{2eq}/MJAPPR (dry basis)	
50					
51					
52					
53	**Value chain step: upgrading (pelletization, chipping, etc.)**	**Details**	**Value**	**Unit**	**Comments / Source**
54	Chipping				

Typical consumptions of vehicles used for transportation

Model	Type	Payload (t)	Consumption diesel (l/km)
Platform attached to tractor	Platform	5	0.2
	Truck	14	0.31
	Truck	40	0.4

1st Haulage	Value	Units
Total APPR quantity hauled with 1st haulage vehicle	1,200	t, wet
Average payload of vehicle	14	t
Transport distance	5	km
Specific fuel consumption	0.31	l/km
Returning route	1	1: returning trip increases CO_{2eq} emissions, 0: returning trip does not count towards CO_{2eq} emissions
Consumption	265.7	l
More haulage activity (if more than one type of transportation vehicle is used)		
2nd Haulage	**Value**	**Units**
Total APPR quantity hauled with 2nd haulage vehicle	0	
Average payload of vehicle		t
Transport distance		km
Specific fuel consumption		l/km
Returning route	1	1: returning trip increases CO_{2eq} emissions, 0: returning trip does not count towards CO_{2eq} emissions
Consumption	0	l

Figure 3. Overview of the First Haulage of APPR biomass value chain step of the excel tool

4.1.3 APPR upgrading

The next value chain step is the upgrading of APPR via chipping, pelletizing or both. Information on the amount of incoming APPR biomass and chips produced, along with their moisture content is requested. The energy content of the produced chips is again considered the same with the previous value chain steps and completed automatically. Not significant variations in the energy content of APPR occurs during these processes, apart from the pelletization of APPR where the user will be asked to insert the energy content of pellets. Continuously, the amount of energy required for chipping is asked. If not known, some values/ calculations are available on the "Calculations/ Supporting Info" table from which the energy demand of a chipper can be calculated. After defining the energy consumption for chipping, the user has to insert the fuel that is consumed by the chipper in order to use the corresponding emission factor. For example, if the chipper consumes diesel, the user has to insert in the "Details" column the word "diesel" for which the value (emission factor gCO2eq/MJ) will be automatically retrieved from the "Standard values" sheet. If for example, gasoline is used, the user has to change the "Diesel" word in the "Details" column into "Gasoline".

After that, the pelletizing step is followed, on which again the user has to insert the data regarding the amount of incoming biomass and pellets produced, along with their moisture and energy content. The next step is for the user to insert the total energy demands of the pelletizing unit (electricity and heat). If not known, on the "Calculations/ Supporting Info" table, there are values/ equations to facilitate the user define the energy demands. After defining the heat demands, the user has to insert the amount of energy needed for the pelletizer that is produced from biomass feedstock, if that is the case. Based on the adapted methodologies, during biomass combustion, only the CH_4 and N_2O emissions are taken into consideration and calculated into CO_2 equivalent emissions. These emissions can be easily calculated through the "Calculations/ Supporting Info" table by providing information on heat content of combusted biomass, type of biomass and efficiency of the boiler used. If not biomass is consumed to cover some of the thermal needs of the pelletiziation, the user has to insert "0" on the corresponding cell entitled "Heat covered from burning biomass" (Cell C86).

The rest required heat amount for the pelletizer, that is going to be covered from fossils, is calculated automatically. Next, the user is asked to provide the thermal efficiency of the boiler from which the amount of fossil fuel will be calculated automatically. Continuously, the user has to

choose the feedstock used for producing the needed amount of heat, e.g. diesel, gasoline, natural gas etc. in order for the tool to calculate automatically the corresponding GHG emissions.

Regarding the electricity consumptions, after the user has defined the amount of electricity needed for the upgrading step, the user is asked to choose the country where the value chain takes place from a list. In this way, the GHG emissions from power generation according to each country are calculated. The emissions for electricity production of each country are available on the "Standard Values" sheet (Figure 10).

Moreover, after defining the electricity consumption of the upgrading step, the user can also add emissions from other consumables such as packaging material (bags) that is used for packing the produced pellets. Again if needed, the user can find supporting information to calculate packaging emissions on the "Calculations/ Supporting Info" table. Finally, the total emissions and emission factor e_p are calculated for this value chain step.

In brief, this step requires information on:

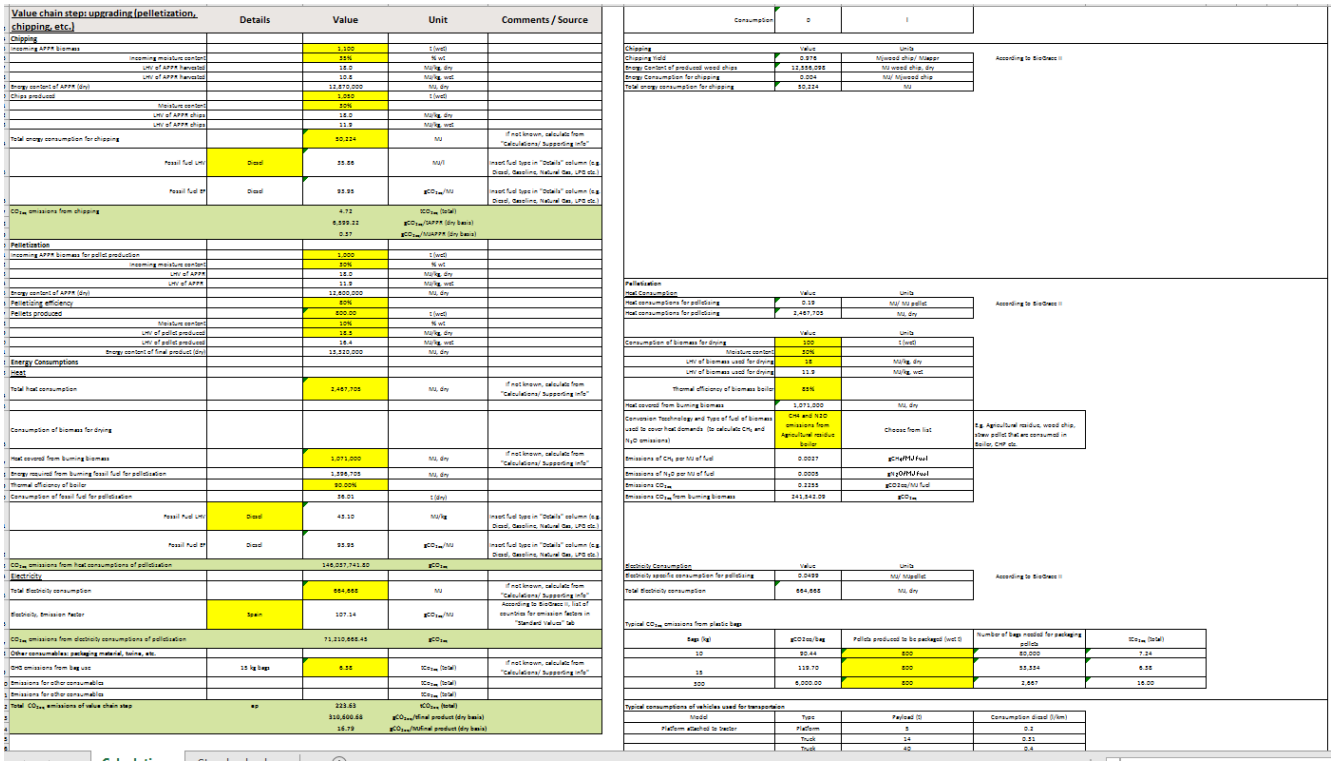
<u>If chipping occurs</u>:

- Total incoming APPR quantity for chipping
- Moisture Content of incoming APPR
- Amount of chips produced
- Moisture Content of chips
- Total energy consumption for chipping -The user can check "Calculations/ Supporting Info" table for help in calculations
- Type of fuel consumed for chipping (e.g. diesel, gasoline etc.)

<u>If pelletizing occurs</u>:

- Total incoming APPR quantity for pelletizing
- Moisture Content of incoming APPR
- Pelletizing efficiency (and pellets produced)
- Amount of pellets produced
- Moisture Content of pellets
- LHV of pellets (dry)
- Total heat consumption for pelletizing -The user can check "Calculations/ Supporting Info" table for help in calculations
- Amount of heat covered from burning biomass (if applicable) -The user can check "Calculations/ Supporting Info" table for help in calculations
- Type of fossil fuel used for covering heat demands of pelletization and thermal efficiency of boiler
- Total electricity consumption for pelletizing -The user can check "Calculations/ Supporting Info" table for help in calculations
- Country where pelletization takes place (to calculate GHG emissions for power generation of specific country)

- Emissions from consumables used (e.g. bags for packaging APPR pellets) -The user can check “Calculations/ Supporting Info” table for help in calculations



Value chain step: upgrading (pelletization, chipping, etc.)	Details	Value	Unit	Comments / Source
Chipping				
Incoming APPR biomass		1,100	t (wet)	
Incoming moisture content		35%	% wt	
LHV of APPR harvested		16.0	MJ/kg, dry	
LHV of APPR harvested		10.8	MJ/kg, wet	
Energy content of APPR (dry)		12,870,000	MJ, dry	
Chips produced		1,050	t (wet)	
Moisture content		30%		
LHV of APPR chips		16.0	MJ/kg, dry	
LHV of APPR chips		11.9	MJ/kg, wet	
Total energy consumption for chipping		50,224	MJ	If not known, calculate from "Calculations/ Supporting info"
Fossil fuel LHV	Diesel	35.86	MJ/l	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
Fossil fuel EF	Diesel	93.95	gCO_{2eq}/MJ	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
CO_{2eq} emissions from chipping		4.72 6,599.32 0.37	tCO_{2eq} (total) gCO_{2eq}/tAPPR (dry basis) gCO_{2eq}/MJAPPR (dry basis)	
Pelletization				
Incoming APPR biomass for pellet production		1,000	t (wet)	
Incoming moisture content		30%	% wt	
LHV of APPR		16.0	MJ/kg, dry	
LHV of APPR		11.9	MJ/kg, wet	
Energy content of APPR (dry)		12,600,000	MJ, dry	
Pelletizing efficiency		80%		
Pellets produced		800.00	t (wet)	
Moisture content		10%	% wt	
LHV of pellet produced		18.5	MJ/kg, dry	
LHV of pellet produced		16.4	MJ/kg, wet	
Energy content of final product (dry)		13,320,000	MJ, dry	
Energy Consumptions				
Heat				
Total heat consumption		2,487,705	MJ, dry	If not known, calculate from "Calculations/ Supporting info"
Consumption of biomass for drying				
Heat covered from burning biomass		1,071,000	MJ, dry	If not known, calculate from "Calculations/ Supporting info"
Energy required from burning fossil fuel for pelletisation		1,396,705	MJ, dry	
Thermal efficiency of boiler		90.00%		
Consumption of fossil fuel for pelletisation		38.01	t (dry)	
Fossil fuel LHV	Diesel	43.10	MJ/kg	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
Fossil fuel EF	Diesel	93.95	gCO_{2eq}/MJ	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
CO_{2eq} emissions from heat consumptions of pelletisation		146,057,741.80	gCO_{2eq}	
Electricity				
Total electricity consumption		664,868	MJ	If not known, calculate from "Calculations/ Supporting info"
Electricity, Emission factor	Spain	107.14	gCO_{2eq}/MJ	According to BioGrace II, list of countries for emission factors in "Standard Values" tab
CO_{2eq} emissions from electricity consumptions of pelletisation		71,210,868.45	gCO_{2eq}	
Other consumables: packaging material, twine, etc.				
GHG emissions from bag use	15 kg bags	6.55	tCo_{2eq} (total)	If not known, calculate from "Calculations/ Supporting info"
Emissions for other consumables			tCo_{2eq} (total)	
Emissions for other consumables			tCo_{2eq} (total)	
Total CO_{2eq} emissions of value chain step	ep	223.63 310,600.66 16.79	tCO_{2eq} (total) gCO_{2eq}/final product (dry basis) gCO_{2eq}/MJfinal product (dry basis)	

Consumption	0	t

Chipping	Value	Units	
Chipping Yield	0.976	MJwood chip/ MJapr	According to BioGrace II
Energy Content of produced wood chips	12,556,096	MJ wood chip, dry	
Energy Consumption for chipping	0.004	MJ/ MJwood chip	
Total energy consumption for chipping	50,224	MJ	

Pelletization			
Heat Consumption	Value	Units	
Heat consumptions for pelletising	0.19	MJ/ MJ pellet	According to BioGrace II
Heat consumptions for pelletising	2,487,705	MJ, dry	
	Value	Units	
Consumption of biomass for drying	100	t (wet)	
Moisture content	30%		
LHV of biomass used for drying	18	MJ/kg, dry	
LHV of biomass used for drying	11.9	MJ/kg, wet	
Thermal efficiency of biomass boiler	85%		
Heat covered from burning biomass	1,071,000	MJ, dry	
Conversion Technology and Type of fuel of biomass used to cover heat demands (to calculate CH_4 and N_2O emissions)	CHP and N2O emissions from Agricultural residue boiler	Choose from list	E.g. Agricultural residue, wood chip, straw pellet that are consumed in Boiler, CHP etc.
Emissions of CH_4 per MJ of fuel	0.0027	gCH_4/MJ fuel	
Emissions of N_2O per MJ of fuel	0.0005	gN_2O/MJ fuel	
Emissions CO_{2eq}	0.2255	gCO_{2eq}/MJ fuel	
Emissions CO_{2eq} from burning biomass	241,942.09	gCO_{2eq}	

Electricity Consumption	Value	Units	
Electricity specific consumption for pelletising	0.0499	MJ/ MJpellet	According to BioGrace II
Total electricity consumption	664,868	MJ, dry	

Typical CO_{2eq} emissions from plastic bags

Bags (kg)	gCO_{2eq}/bag	Pellets produced to be packaged (wet t)	Number of bags needed for packaging pellets	tCo_{2eq} (total)
10	90.44	800	80,000	7.24
15	119.70	800	53,334	6.38
500	6,000.00	800	2,667	16.00

Typical consumptions of vehicles used for transportation

Model	Type	Payload (t)	Consumption diesel (l/km)
Platform attached to tractor	Platform	5	0.2
	Truck	14	0.31
	Truck	40	0.4

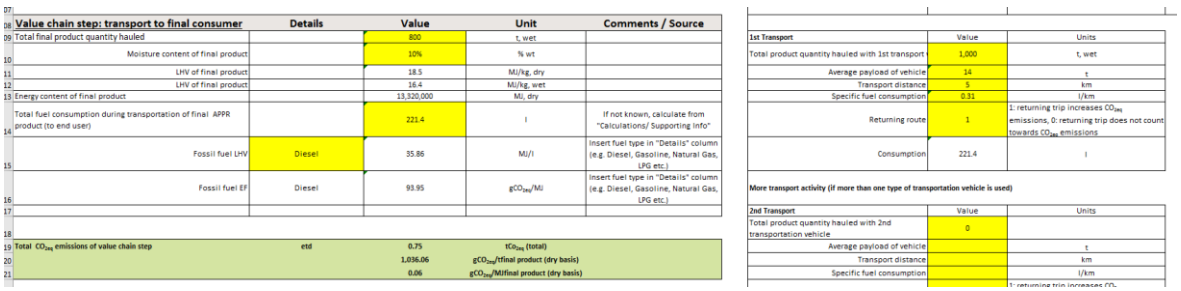
Figure 4. Overview of the Upgrading of APPR biomass value chain step of the excel tool

4.1.4 Transportation of APPR fuel to end user

The next step that is taken into consideration in the environmental assessment of the APPR value chain is that of the transportation of upgraded APPR fuel to the end user. The methodology is the same as in the first Haulage step.

In brief, this step requires information on:

- Total APPR fuel quantity transported to end user
- Moisture Content of APPR fuel
- LHV of APPR fuel (dry)
- Total Fuel Consumption during transportation of APPR fuel to end user
- Type of fuel consumed (e.g. diesel, gasoline etc.)



Value chain step: transport to final consumer	Details	Value	Unit	Comments / Source
Total final product quantity hauled		800	t, wet	
Moisture content of final product		10%	% wt	
LHV of final product		18.5	MJ/kg, dry	
LHV of final product		16.4	MJ/kg, wet	
Energy content of final product		13,320,000	MJ, dry	
Total fuel consumption during transportation of final APPR product (to end user)		221.4	l	If not known, calculate from "Calculations/ Supporting info"
Fossil fuel LHV	Diesel	35.86	MJ/l	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
Fossil fuel EF	Diesel	93.95	gCO_{2eq}/MJ	Insert fuel type in "Details" column (e.g. Diesel, Gasoline, Natural Gas, LPG etc.)
Total CO_{2eq} emissions of value chain step	etd	0.75 1,036.06 0.06	tCo_{2eq} (total) gCO_{2eq}/tfinal product (dry basis) gCO_{2eq}/MJfinal product (dry basis)	

1st Transport	Value	Units
Total product quantity hauled with 1st transport	1,000	t, wet
Average payload of vehicle	14	t
Transport distance	5	km
Specific fuel consumption	0.31	l/km
Returning route	1	1: returning trip increases CO_{2eq} emissions, 0: returning trip does not count towards CO_{2eq} emissions
Consumption	221.4	l

More transport activity (if more than one type of transportation vehicle is used)

2nd Transport	Value	Units
Total product quantity hauled with 2nd transportation vehicle	0	
Average payload of vehicle		t
Transport distance		km
Specific fuel consumption		l/km

Figure 5. Overview of the Transport of APPR fuel to final consumer value chain step of the excel tool

4.1.5 CH_4 and N_2O emissions from final conversion

After calculating the emissions from the transportation of APPR fuel to the end consumer, the next step of the value chain is the end conversion of APPR (conversion of APPR to power, heat, cooling). This step appears in order to calculate the CH_4 and N_2O emissions produced while converting the APPR biomass. Based on the methodologies adapted for this tool, only the CH_4 and N_2O emissions are taken into consideration during biomass combustion which are converted into CO_2 equivalent emissions. The user has to insert the total amount of APPR fuel that is consumed along with its characteristics (moisture and energy content). Continuously, the user has to pick the end conversion process of APPR from a list with several options (e.g. "CH_4 and N_2O emissions from Agricultural residue CHP" if APPR is consumed in CHP). As a result, the emission values of CH_4 and N_2O during end conversion are retrieved from a list in the "Standard Values" sheet. Finally, based on these emissions, the CO_{2eq}emissions during the end conversion of APPR and the emission factor e_u are calculated.

In brief, this step requires information on:

- Total APPR fuel used for end conversion into energy commodity
- Moisture Content of APPR fuel
- LHV of APPR fuel (dry)
- Type of End Conversion (choose from list)

Final conversion (CH_4 and N_2O emissions only)	Details	Value	Unit	Comments / Source
Amount of fuel for end conversion		800	t (wet)	
Moisture content of fuel		10%	% wt	
Fuel LHV		18.5	MJ/kg, dry	
Fuel LHV		16.4	MJ/kg, wet	
Energy content of fuel (dry)		13,320,000	MJ, dry	
End conversion and type of final fuel used (to calculate CH_4 and N_2O emissions)		CH4 and N2O emissions from Agricultural residue CHP	Choose from list	E.g. Agricultural residue, wood chip, straw pellet that are consumed in Boiler, CHP etc.. Source: BioGrace II
Emissions of CH_4 per MJ of fuel		0.0027	gCH_4/MJ fuel	
Emissions of N_20 per MJ of fuel		0.0005	gN_2O/MJ fuel	
Emissions CO_{2eq}		0.2255	gCO_{2eq}/MJ fuel	
Total CO_{2eq} emissions of value chain step	**eu**	**3.00**	**tCO_{2eq} (total)**	
		4,172.30	**gCO_{2eq}/tfinal product (dry basis)**	
		0.23	**gCO_{2eq}/MJfinal product dry**	

Figure 6. Overview of the Final Conversion value chain step of the excel tool

4.1.6 GHG emissions before energy conversion

Continuously, a table including all emission factors of the APPR value chain is automatically filled. This table presents an overview of each value chain step's tonnes of $CO2_{eq}$ produced.

CO_{2eq} emissions before energy conversion			
Total CO_{2eq} emissions from extraction of raw materials	e_{ec}	75.32	tCO_2eq
Total CO_{2eq} emissions from transport and distribution	e_{td}	1.64	tCO_2eq
Total CO_{2eq} emissions from processing	e_p	223.63	tCO_2eq
Total CO_{2eq} emissions from the fuel in use	e_u	3.00	tCO_2eq
Total CO_{2eq} emissions from production of fuel before energy conversion	**E**	**303.60**	**tCO_2eq**

Figure 7. Overview of the Emission Factors of the APPR value chain

4.1.7 Conversion efficiencies

The last part of the sustainability assessment requires additional information on the consumption of APPR fuel that is converted into energy commodity. The user has to insert the electrical, heat and cooling efficiencies of the end conversion, wherever applicable; if cooling (or other energy commodity) is not produced, insert 0%.

Based on the efficiencies that are inserted, the total GHG emissions in $gCO2_{eq}$ /MJ are calculated.

Finally, the savings of GHG emissions of the APPR value chain compared to Fossil Fuel Comparators (FFCs) are presented. Along with the calculated savings, the minimum requirements based on the current draft of RED II (GHG emissions savings at least 80 % for electricity, heating and cooling production from biomass fuels used in installations starting operation after 1 January 2021 and 85% for installations starting operation after 1 January 2026) are presented.

CO_{2eq} emissions from usage of biomass fuels	Details	Value	Unit
APPR biomass/fuel input to energy conversion process		800	t (wet basis)
Moisture content of product		10%	wet basis
LHV of biomass/ fuel		16.4	MJ/kg (wet basis)
Energy content of fuel		13,124,720	MJ, wet
Total CO_{2eq} emissions from production of fuel before energy conversion		23.13	gCO_{2eq}/MJ (wet basis)
Electrical efficiency	η_{el}	24.50%	
Heat efficiency	$\eta_{h\&c}$	60%	
Cooling efficiency- seasonal coefficient of performance (SCOP)	η_c	80%	
Temperature of useful heat at point of delivery	T_h	120	°C
Carnot efficiency in heat	C_h	0.35	
Total CO_{2eq} emissions from electricity production	**EC_{el}**	**50.53**	**gCO_{2eq}/MJ**
Total CO_{2eq} emissions from heat production	**EC_h**	**17.92**	**gCO_{2eq}/MJ**
Total CO_{2eq} emissions from cooling production	**EC_c**	**22.40**	**gCO_{2eq}/MJ**

Savings of CO_{2eq} emissions		Min. requirements - RED II
Savings, electricity	**72.39%**	80%
Savings, heating	**77.60%**	80%
Savings, cooling	**72.00%**	80%

Figure 8. Overview of the GHG Savings of the APPR value chain

4.1.8 Consistency check

The consistency check table appears on the upper right of the "Calculations" sheet. The APPR biomass quantity (in dry tons) of each step of the value chain is presented. The condition "OK" will appear if the mass flow of APPR is logical (e.g. equal or decreasing from each value chain step to the next one). However, if "ERROR" appears, that means the user has to check the masses of APPR that are inserted at each step of the value chain (e.g. it is not logical to produce more pellets than the biomass harvested).

Consistency Check- Mass flows of products ("ERROR" appears if mass of output material is more than the mass of input material in a process)

Fuel at each stage	t (dry)	Condition
APPR harvested	1,463	
APPR haulage	780	OK
Chips from APPR	735	OK
Pellets from APPR	720	OK
Final Haulage of produced fuel to end conversion	720	OK
End conversion of biomass fuel	720	OK

Figure 9. Consistency Check for mass flow of products in the APPR value chain

4.2 APPR Value chain "Standard Values" Sheet

The second sheet "Standard Values" include several values that are used in the calculations on the main sheet such as GHG emissions coefficients, electricity emissions (Figure 10) based on countries and more.

Electricity GHG emissions per country		
Country	Value	Units
Austria	52.39	gCo_{2eq}/MJ
Belgium	59.57	gCo_{2eq}/MJ
Bulgaria	191.80	gCo_{2eq}/MJ
Croatia	112.40	gCo_{2eq}/MJ
Cyprus	263.57	gCo_{2eq}/MJ
Czech Republic	197.25	gCo_{2eq}/MJ
Denmark	116.04	gCo_{2eq}/MJ
Estonia	321.28	gCo_{2eq}/MJ
Finland	63.93	gCo_{2eq}/MJ
France	22.73	gCo_{2eq}/MJ
Germany	170.31	gCo_{2eq}/MJ
Greece	243.27	gCo_{2eq}/MJ
Hungary	120.37	gCo_{2eq}/MJ
Ireland	164.37	gCo_{2eq}/MJ
Italy	138.30	gCo_{2eq}/MJ
Latvia	61.24	gCo_{2eq}/MJ
Lithuania	127.79	gCo_{2eq}/MJ
Luxemburg	82.64	gCo_{2eq}/MJ
Malta	356.74	gCo_{2eq}/MJ
the Netherlands	146.69	gCo_{2eq}/MJ
Poland	287.03	gCo_{2eq}/MJ
Portugal	137.31	gCo_{2eq}/MJ
Romania	176.61	gCo_{2eq}/MJ
Slovakia	69.64	gCo_{2eq}/MJ
Slovenia	122.22	gCo_{2eq}/MJ
Spain	107.14	gCo_{2eq}/MJ
Sweden	6.13	gCo_{2eq}/MJ
United Kingdom	165.48	gCo_{2eq}/MJ
Electricity EU mix (10-20 kV)	196.35	gCo_{2eq}/MJ
Electricity EU mix (0.4 kV)	208.83	gCo_{2eq}/MJ
Other (please specify)		gCo_{2eq}/MJ

Figure 10. Electricity GHG emissions per country in the "Standard Values" sheet of the excel

Apart from these values, the current sheet also includes the Fossil Fuel Comparators (FCCs) according to which the GHG emissions for producing electricity, heat, cooling and transportation fuels via fossil fuel pathways are presented (Figure 11). The FCCs are used to estimate the GHG emissions savings by implementing an APPR value chain.

Fossil Fuel Comparators (FCCs)			
Type	Value	Units	Source
Electricity	183	gCo_{2eq}/MJ	RED II proposal
Heat, cooling	80	gCo_{2eq}/MJ	RED II proposal
Heat for direct substitution of coal	124	gCo_{2eq}/MJ	RED II proposal
Transport fuels	94	gCo_{2eq}/MJ	RED II proposal

Figure 11. Fossil Fuel Comparators (FCCs) in the "Standard Values" sheet of the excel