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STUDY REPORT

Establishment of GHG values in the french wood-energy sector (Renewable Energy Directive)

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This document translates version 2 of the report « Establishment of GHG values in the French wood-energy sector »

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RESUME

The objective of this report is to establish standard GHG emission values for wood fuels currently not represented in the European Renawable Energy Directive : wood outside forests (woodchips from bocage, from landscape/gardens, and chips from grubbing up orchards), waste wood (wood A and wood B) and residues from paper mills (paper sludge, black liquors). The JRC methodology is applied to these fuels, supplemented by references mainly from the literature, or in other words from experts in case of a lack of existing data. Figure 1 below shows the results obtained for the standard GHG emission values for a distance of 0 to 500 km.

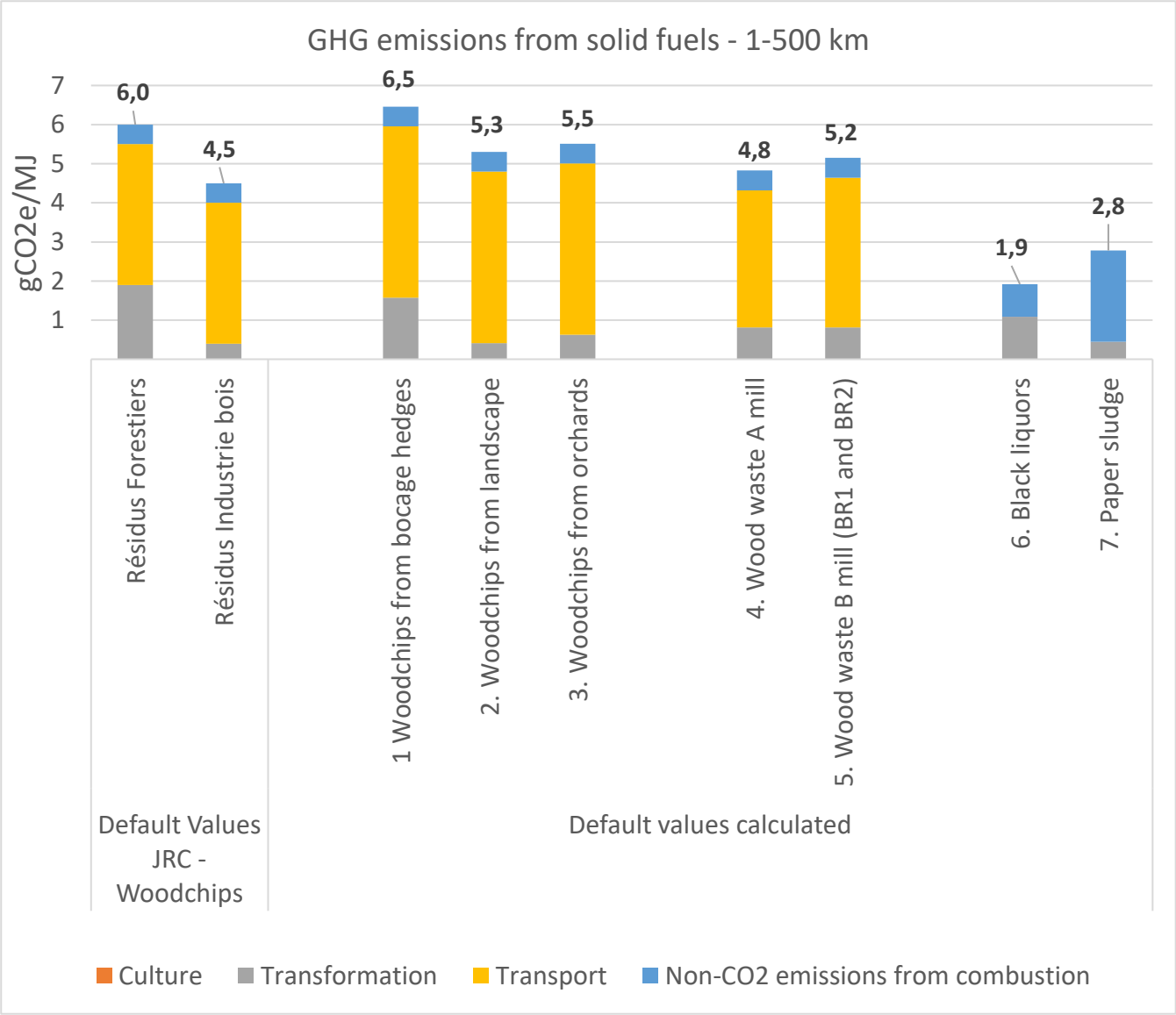

Figure 1 : Overview of results for the 1-500 km range (standard values)

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1 INTRODUCTION AND CONTEXT OF THE STUDY

1.1 Stakes of the directive RED in the wood-energy sector

Within the framework of the European directive on renewable energies (RED), it is necessary to estimate the reduction of GHG emissions from renewable energy production sectors. The annexes to the directive present default values for different fuels depending on their means of production. With regard to the wood-energy sector, default values for solid fuels are presented in Annex VI of the directive, but this one does not include certain key materials in the French sectors. This is particularly the case for wood outside forests (hedges, groves, parks and gardens...), wood waste (packaging, B-wood) and liquid residues from paper mills (black liquors, paper sludge). Furthermore, the directive specifies percentages of emission reductions compared to the fossil benchmark for thermal and electrical uses alone, but not for cogeneration uses. The french wood-energy players want to have reliable standard values of GHG emissions for these sectors and energy production in cogeneration.

This report aims to establish reference values for these different scenarios based on the GHG emissions calculation methodology of the RED directive (in particular that described by the JRC, 2017). These values are established in a rigorous and transparent manner so that they can also be recognized as reliable references by national and European authorities. Values are calculated for the French context when data is available.

1.2 Solid fuel production lines

GHG emissions are calculated for the following solid fuel production streams :

1. Woodchips from bocage
2. Woodchips from landscape
3. Woodchips from orchards
4. Waste wood chips A
5. Waste wood chips B (BR1 and BR2)
6. Black liquors
7. Paper sludge

Standard emission reduction rates for cogeneration will be given for cogeneration plants with an energy efficiency of at least 75%.

2 CALCULATION METHODOLOGY

2.1 Reminders of RED methodology

2.1.1 GHG emissions

In accordance with Annex VI of RED, the emissions expressed in gCO2e/MJ of fuel are calculated for all biomass as follows :

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

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;
e_p	=	emissions from processing;
e_{td}	=	emissions from transport and distribution;
e_u	=	emissions from the fuel in use;
e_{sca}	=	emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs}	=	emission savings from CO_2 capture and geological storage; and
e_{ccr}	=	emission savings from CO_2 capture and replacement.

Some of the terms in this equation must be specifically documented according to actual practices and therefore cannot be evaluated by default. Also, in establishing the default standard values for GHG emissions, only e_{ec}, e_p, e_{td} and e_u will be taken into account.

ADEME has developed a method incorporating a broader scope by integrating the effects of biogenic carbon variation, which would ultimately better shed light on the impact of wood energy on climate change. This approach is more complete, however it is still largely exploratory. The methodology adopted here is the more classical one used by the European texts.

2.1.2 Emissions savings

In accordance with Annex VI of RED, the emission savings associated with these fuels, expressed as a percentage saving compared to a fossil reference, are calculated as follows :

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

where

$EC_{B(h\&c,el)}$	=	total emissions from the heat or electricity,
$EC_{F(h\&c,el)}$	=	total emissions from the fossil fuel comparator for useful heat or electricity.

Fossil reference values are set as 80 gCO2e/MJ for heat-only use and 183 gCO2e/MJ for electricity-only use.

These fossil values shall be compared to the GHG emissions of energy from fuels, taking into account energy efficiency. In the case of simple thermal or electrical recovery, the emissions allocated to energy are respectively :

$$EC_h = \frac{E}{\eta_h} \qquad EC_{el} = \frac{E}{\eta_{el}}$$

With η_h the default thermal efficiency set at 85% in the Directive, and η_{el} the default electrical efficiency set at 25%.

In case of cogeneration, an exergetic allocation coefficient shall be used to distinguish the part of the emission coefficient associated with electricity production from that associated with heat production. This translates into :

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

where:

$EC_{h,el}$	=	Total greenhouse gas emissions from the final energy commodity.
E	=	Total greenhouse gas emissions of the fuel before end-conversion.
η_{el}	=	The electrical efficiency, defined as the annual electricity produced divided by the annual energy input, based on its energy content.
η_h	=	The heat efficiency, defined as the annual useful heat output divided by the annual energy input, based on its energy content.
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).

The Carnot efficiency, C_h, for useful heat at different temperatures is defined as:

$$C_h = \frac{T_h - T_0}{T_h}$$

where:

T_h	=	Temperature, measured in absolute temperature (kelvin) of the useful heat at point of delivery.
T_0	=	Temperature of surroundings, set at 273,15 kelvin (equal to 0 °C).

Furthermore, if the use temperature is used to heat buildings to less than 150°C, the Carnot efficiency used is that for a temperature of 150°C (= 0,3546).

For cogeneration use, the Directive currently does not provide default thermal and electrical efficiency values to establish emission reductions, which therefore need to be calculated independently. Furthermore, it does not specify whether and how electricity and heat emission savings can be aggregated within a single indicator.

2.1.3 Standard values and default values

In the Annexes to the Directive, and in particular in Annex VI, standard and default values for greenhouse gas emissions are established, together with associated emission

reductions. Typical values (emissions or emission reductions) are calculated based on the representation of typical production patterns. Default values, to be used in the absence of a specific calculation for one fuel, are determined for solid fuels by increasing emissions from the transformation process, transport and use of the fuel by 20 % (JRC, 2014[1]).

2.1.4 Existing GHG emission values and RED thresholds

By way of comparison, the GHG emission values currently covered by the Directive are presented in Table 1 below.

Table 1 : Typical and default values currently determined in the annex to RED

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/ MJ)	Greenhouse gas emissions – default value (g CO_2eq/ MJ)
Woodchips from forest residues	1 to 500 km	5	6
	500 to 2 500 km	7	9
	2 500 to 10 000 km	12	15
	Above 10 000 km	22	27
Woodchips from short rotation coppice (Eucalyptus)	2 500 to 10 000 km	16	18
Woodchips from short rotation coppice (Poplar – Fertilised)	1 to 500 km	8	9
	500 to 2 500 km	10	11
	2 500 to 10 000 km	15	18
	Above 10 000 km	25	30
Woodchips from short rotation coppice (Poplar – No fertilisation)	1 to 500 km	6	7
	500 to 2 500 km	8	10
	2 500 to 10 000 km	14	16
	Above 10 000 km	24	28
Woodchips from stemwood	1 to 500 km	5	6
	500 to 2 500 km	7	8
	2 500 to 10 000 km	12	15
	Above 10 000 km	22	27
Woodchips from industry residues	1 to 500 km	4	5
	500 to 2 500 km	6	7
	2 500 to 10 000 km	11	13
	Above 10 000 km	21	25

The Directive imposes a GHG emission saving of 70% or 80% depending on the case[2]. These thresholds make it possible to determine a maximum emission factor for solid fuels, which are presented in Table 2 :

Table 2 : Maximum GHG emissions from RED

	70% savings	80% savings
E max – thermal use only	24 gCO2e/MJ	16 gCO2e/MJ
E max – electric use only	55 gCO2e/MJ	37 gCO2e/MJ

The following scheme presents the requirements for saving GHG emissions according to the commissioning date of an installation and its power, based on the schedule provided by

[1] JRC. (2014). *Solid and gaseous bioenergy pathways, input values and GHG emissions*. Publications Office.

[2] Article 1(19) of Directive (EU) 2023/2413 (RED III), amending Article 29(10) of Directive (EU) 2018/2001 (RED II)

the directive. The GHG emission reduction results tables presented throughout the document show compliance with requirements before and after January 1, 2026.

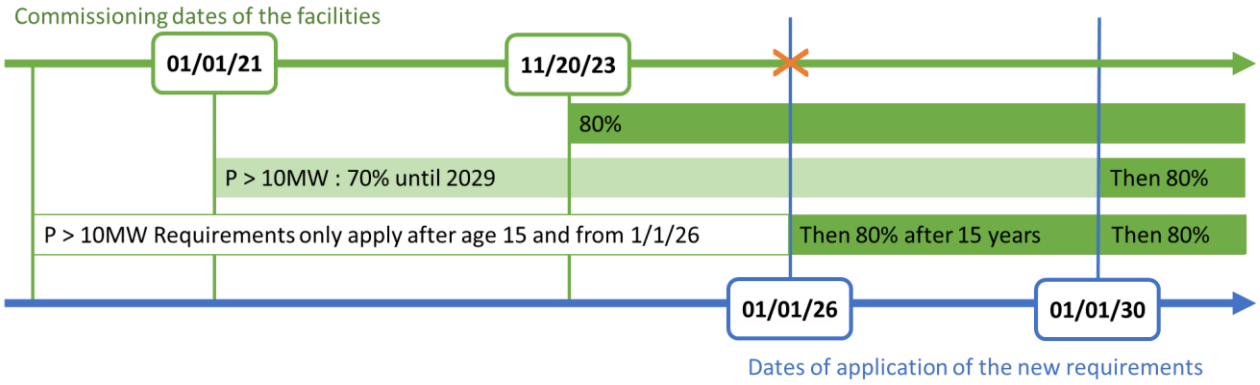

Figure 2 : GHG savings requirements for installations according to the REDIII evolution of Article 29.10 of RED II (CIBE)

2.2 Baseline data and assumptions

2.2.1 Main sources of data

The data used in this report are mainly based on two baseline studies and their sources :

- JRC. (2017). *Solid and gaseous bioenergy pathways : input values and GHG emissions*. https://doi.org/10.2790/27486,
  referred to as 'JRC'
- ADEME, Logel, X., Lhotellier, J., de Caevel, B., Alexandre, C., Cousin, S., Vial, E., Dubilly, A., Buitrago, M., Durand, M., Machefaux, E., & Mousset, J. (2022). *Analyse du Cycle de Vie du bois énergie collectif et industriel. Rapport final*.
  referred to as 'Ademe'

Other sources used will be specified in their contexts.

2.2.2 Pouvoir Global Warming Power

In line with the requirements of RED, GHG emissions other than CO_2 (CH_4 and N_2O) are taken into account. The global warming power of the various greenhouse gases is shown in Table 3.

Table 3 : Global warming power of Greenhouse Gases

	gCO2e/g
CO_2	1
CH_4	25
N_2O	298

2.2.3 Use of diesel

The main source of GHG emissions during fuel processing operations comes from the use of diesel-powered machinery. The emission factor is therefore generally calculated by estimating diesel consumption expressed $MJ_{diesel}/MJ_{produced}$. According to the JRC calculations, the emission factor used for the use of diesel (including supply and combustion) is 95.1 g CO_2e/MJ.

To this factor must be added the non-CO_2 emissions linked to the use of diesel, which depends in particular on the equipment used. The JRC documents these values for certain processes, based on non-CO2 emissions from diesel combustion in agricultural and forestry machinery (used in the schemes discussed in this note). Where only diesel consumption is known, non-CO2 GHG emissions are therefore added using the same methodology, applying the coefficients presented in Table 4 :

Table 4 : Non-CO_2 emissions from diesel combustion by agricultural and forestry machinery

	mg/MJ_{diesel}
CH4	1,14
N2O	3,20

Source : European Environment Agency (EEA). (2023). *EMEP/EEA Air pollutant emission inventory Guidebook* ; 1.A.4.c.ii - Table_3-1_02[3]
Note : LHV Diesel : 43,1 MJ/kg

In some cases, these emissions cannot be calculated because the only data available in the literature are global GHG emissions data, directly in gCO_2e (and not in diesel consumption).

2.2.4 Use of electricity and natural gas

When processes use electricity, the associated emission factor is that recommended by the RED-II delegated act, corresponding to the average french electricity mix, which differs according to the type of network (HT, MT, BT[4]). Where processes use natural gas, the natural gas emission factor shall be that given by the JRC for supply and combustion. These values are presented in Table 5 :

Table 5 : Emission factor for electricity and natural gas

	gCO_2e/kWh	**gCO_2e/MJ**	**Source**
High voltage electricity (100-400 kV) – France	81	22,50	1
Electricity Average tension (10-20 kV) – France	82	22,78	1

[3] This referencce is the one used by JRC for non-CO2 emissions of diesel.
[4] High Voltage, Medium Voltage, Low Voltage

Low voltage electricity (200-400 V) – France	86	23,89	1
Natural gas	237	65,9	2

Source :

(1) European Commission. (2022). COMMISSION IMPLEMENTING REGULATION (EU) 2022/996 of 14 June 2022 on rules for verifying compliance with the sustainability and greenhouse gas emissions saving criteria and the low indirect land-use change risk criteria. *Official Journal of the European Union*.

(2) JRC

2.2.5 Emissions from fuel use

Emissions from fuel use (E_u) take into account non-CO_2 biogenic GHG emissions. The JRC uses the GEMIS database to distinguish emissions from the combustion of wood chips and pellets (the latter not included in this study).

In this database, no distinction is made between unadjuvanted and adjuvanted wood in terms of non-CO_2 GHG emissions. At the same time, no indication of such an emission difference is documented in the other emission factor references (IPCC 2006, OMINEA). In addition, GHG emissions are not subject to emission limit values, and their accounting at installation exit is poorly documented in the technical literature. For these reasons, the same non-CO_2 GHG emission values will be applied to wood chips, regardless of their source (bearing, orchard, waste A, waste B).

For black liquors, the GEMIS database provides a non-CO_2 GHG emission value, which is therefore usable for this study.

For paper sludge, there are no specific references regarding their non-CO_2 GHG emission values. In the national GHG accounting database (OMINEA), the same values are used for ‘sewage treatment plant sludge’ and ‘wood waste’. These values, much higher than those used by the JRC for wafers, will be used for the combustion of paper sludge. Table 6 below summarizes the values used by the JRC (based on the GEMIS database), supplemented by the values required in this note for paper sludge and black liquor.

Table 6 : Non-CO_2 emissions based on fuel use

	CH_4 (g/MJ)	N_2O (g/MJ)	CO_2e (g/MJ)	Source
Combustion of wood chips	0,005	0,001	0,41	1
Combustion of black liquors	0,0031	0,0021	0,69	2
Combustion paper sludge	0,03	0,004	1,94	3*

Sources :

(1) GEMIS, version 4.9; wood-chips-forest-heat plant-1 MW-EU-2005 ; d'après JRC

(2) GEMIS, version 5.0; 2014 ; black-liquor-boiler-EU-2020 (with FGD)

(3) CITEPA, 2023. BDD OMINEA – Edition 20.1 ; OSNAP 030101 ; NAPFUE 116 et 118

* Extrapolated value based on wood waste and STEP sludge

2.2.6 Intermediate transport schemes

The JRC integrates only one road transport modality, which is the 90 m3 lorry (payload 27t). To represent the stages of intermediate transport, different types of trucks will be considered, using data from the Ademe carbon base. The emission factor chosen by the JRC corresponds to the Ademe factor for a 40 m3 truck with a load factor of 50% (empty return assumption). The same assumption is therefore taken on other types of vehicles. These values are shown in Table 7.

Table 7 : Vehicle types and associated emission factors

Type of truck (volume m³)	Total weight (t)	Payload (t)	Emission factor gCO2e/tkm	Reference
90 m³	40t	27	78	(1)
40 m³	25t	12	140	(2)
15m³	7,5t	4	267	(3)
other	<15	4	267	(4)

Sources :

(1) JRC[5]

(2) Base Carbone Ademe - Transport en camion 14-20t (10t) France (dont parc, utilisation et infrastructure) (50%) [tkm], FR

(3) Base Carbone Ademe - Transport en camion 7,5t (3t) France (dont parc, utilisation et infrastructure) (50%) [tkm], FR

(4) Base Carbone Ademe - Transport en camion non spécifié France (dont parc, utilisation et infrastructure) (50%) [tkm], FR

The distance travelled will be assessed in the same way as in the JRC, with values in tonne-kilometres, calculated as follows :

$$Distance\ [\frac{t.km}{MJ_{produits}}] = \frac{Load[t]\ \times\ [km]}{(Load - tank)[t].PCI_{sec}[\frac{MJ_{produit}}{kgMS}].tauxMS[\frac{kgMS}{kgMB}]}$$

With *Load* the payload of the truck and *tank* the weight of the container, which in this case is equal to 1t since all the substances transported are solid (according to the JRC calculation method).

[5]Cohérent avec Base Carbone Ademe Transport en camion 34-40t (25t) France (dont parc, utilisation et infrastructure) (50%) [tkm], FR

As regards the distance of intermediate transport, i.e. inputs on different platforms and processing sites, the assumptions are made by experts in each sector and maximised. In reference, the distance used in LCA by the Ademe is transport on a 40 km pellet preparation platform by a 90 m^3 lorry, and that used by the JRC is 50 km with the same type of lorry. The following choices were made:

(1) For wood outside the forest, the intermediate platforms are located close to the construction sites, with a distance of 20km, according to experts. Since the volumes do not necessarily justify transport by 90m^3 lorry, the type of vehicle in question is therefore a 40m^3 lorry.

(2) For wood waste, a distance of 50 km is considered expert (and consistent with the distances used by the JRC) as representative of the territorial mesh of wood waste management platforms A and B. In the case of wood B, several transports may be possible (for example, sorting platform then crushing platform). The chosen scheme is an increasing case involving two transports of 50 km, or 100 km in total. The type of vehicle considered is a 90m3 truck for wood waste (in line with the assumptions of the JRC and the Ademe).

(3) The transport of waste by consumers (waste dumps) is excluded from the framework, because in the logic of waste generation, this transport is carried out in all cases and is not specifically attributable to wood energy.

These assumptions are reflected in Table 8 :

Table 8 : Transport schemes for intermediate products according to the different sectors

	Distance (km)	Type of truck
References		
Ademe - transport to platform (except dry wafers for small boiler rooms)	40	90m^3 (25t)
Ademe - transport to boiler	35	90 m^3 (25t)
JRC - transport of intermediate products	50	90 m^3 (25t)
FACTORS USED IN THE STUDY		
Wood outside forests		
1. Bocage wood chips - Intermediate Storage Platform	20	40m^3 (12t)
2. Landscape wood chips	20	40m^3 (12t)
3. Wood chips from orchards	20	40m^3 (12t)
Wood waste		
4. Wood waste mill A	50	90m^3 (25t)
5. Wood waste mill B - Provided as a sorting platform (ground on site)	100	90m^3 (25t)
Stationery		
6. Black liquors	-	-
7. Paper sludge	-	-

2.2.7 Final products transports schemes

For the transport of the final products, we use the export schemes proposed by the JRC, recalled in Table 9. By way of comparison, the Ademe considers a transport distance to the boiler room of only 35 km. In order to better represent the real distances of subnational uses, a scale of 1-200 km is added to the JRC diagrams (with a minimum transport distance of 500 km).

Table 9 : Standard transport distances of final products. Source : JRC.
**This value has been added in addition to the other values*

	Road (90m3)	Railways	Maritime
1-200 km*	200	-	-
1-500 km	500	-	-
500 - 2 000 km	250	-	2 000
2 500 - 10 000 km	200	-	8 000
> 10 000 km	-	750	16 500

The transport distances of the intermediate stages, previously described in Table 8, do not vary according to the final distance scenarios[6].

Note :
Beyond 2000 km of transport, fuels cannot have been produced in France, and the data used in the French context are of little relevance. However, these values are calculated by analogy with the JRC method.

For maritime and rail transport, the distance is calculated according to the following JRC formula :

$$Distance\left[\frac{t \cdot km}{MJ_{goods}}\right] = \frac{x\,[km]}{LHV_{dry}\left[\frac{MJ}{kg_{dry}}\right] \cdot Solids\left[\frac{kg_{dry}}{kg_{tot}}\right]}$$

For maritime transport, the emission factor depends on the distance travelled and the apparent density of the materials. According to the methodology used by the JRC, considering an apparent density of 0,22 t/m3 (reference used for wood chips[7]), the emission

[6] In the existing JRC schemes, the distance of intermediate road transport varies, only in the case of a supply of more than 10 000 km. Their hypothesis is that the wood comes from Canadian forests in which the distances travelled before processing are greater. As in the schemes considered no input comes from the forest, this distinction was not repeated.

[7] This factor is applicable to all products because it concerns only the final transport. As part of this study and excluding paper mills, all final products are wafers.

factors used are described in Table 10. For rail transport, the JRC uses an emission factor associated with diesel consumption (used in Canadian platelet import schemes). These assumptions are retained for long-distance final product transport schemes, as well as the emission factor used by the JRC presented in Table 10.

Table 9 : Emission factors used for maritime and rail transport

Type of transport	Bulk density t/m3	Emission factor gCO2e/tkm	Reference
Maritime - Handysize (<=2000 km)	0,22	24,21	(1)
Maritime - Supramax (> 2000 km)	0,22	15,45	(1)
Ferroviaire diesel	/	24,09	(1)

Sources : JRC

2.2.8 Moisture schemes

Since transport is the main emission point in all the sectors considered, the moisture content of the materials transported plays a significant role in the total GHG emissions of fuels. The moisture values considered in the JRC and in the Ademe and the values used in the study are detailed in the table below.

Table 10 : Reference moisture patterns and assumptions used in the study

References		
Fresh wood	50%	(1)
Dried wood (natural drying)	30%	(1)
Fresh wood	45%	(2)
Dried wood (forced drying)	25%	(2)
Wood waste	20%	(2)
Valeurs retenues dans l'étude		
Bocage wood, landscape wood, orchards wood at harvest	40%	(3)
Bocage wood, landscape wood, orchards wood, after storage (uncontrolled drying)	37%	(3)
Wood waste (A and B)	20%	(2)

Note :
In the absence of existing generic data, moisture is considered to be identical to that of bocager and landscape wood (40%), but this is a pessimistic assumption given some existing data (e.g. 20% moisture on apple wood measured by CTIFL[8]).

Sources :
(1) JRC
(2) Ademe
(3) Expert speech - see section 2.3.3. Storage with loss of moisture

2.2.9 Calculating cogeneration efficiency

In order to determine GHG emission reduction values for cogeneration use, it is necessary to determine energy efficiency values for this type of installation :

- The electrical efficiency
- The heat efficiency
- With a operating temperature

As defined in the Directive (see section 2.1.2. Emission savings).

Cogeneration units vary widely from site to site, particularly with regard to the use of heat, which is highly dependent on local needs. For cogeneration plants that have committed to an energy efficiency of at least 75% (example: CRE 5_3 tender of 2019), the electrical and thermal efficiency values can be determined from :

- The regulatory obligations of the CRE (french Energy Regulation Commition) (Call for tenders 5_3 of 2019) to which all installations in France are subject.
- An assumption of electricity / heat production ratio between 0.2 and 0.35 (Source: BAT[9)]. The value of 0.2, which results in a slightly lower emission reduction factor, is used as a pessimistic assumption.
- A heat-use temperature of 150°C, as this is a floor value in the calculation of emission reductions associated with low-temperature uses. A low-temperature use value is retained due to the impossibility of generalising high-temperature use. This hypothesis penalises reductions in electrical emissions and promotes reductions in heat emissions. Data should be used that is consistent with the project and justifiable.

[8] Grasselly, D., Lescourret, F., & Colleu, S. (2019). Chapitre 2. Le service d'approvisionnement en fruits. La production de fruits en France métropolitaine. In M.-C. Bopp (Ed.), *Services rendus par les cultures fruitières*. Table 14.

[9] Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S., & Delgado Sancho, L. (2015). *Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board*. https://doi.org/10.2791/370629

The values used for the example of cogeneration units with an efficiency of at least 75% are given in Table 12 :

Table 11 : Example of values used to describe a cogeneration unit with an energy efficiency >75%

	Standards values	Source
Standard electrical efficiency in cogeneration	13%	1
Standard thermal efficiency in cogeneration	63%	2
Heat production temperature in cogeneration	150 °C	1

Sources :

(1) Ratio électricité / chaleur = 0,2 (BAT)

(2) Efficiency calculated according to the specifications of the CRE which cogeneration units whose target efficiency is at least 75%.

The emissions savings values for electricity alone and heat alone produced by the efficiencies described above in Table 12 can be calculated using the method described by the Directive. Furthermore, the Directive does not propose a method to synthesize the reduction of emissions from cogeneration. It is proposed to summarise the emission reductions associated with the electrical and thermal part in a single value, with the following aggregation formula :

$$SAVING = (x(FFC_e - EC_e) + y(FFC_h - EC_h))/(xFFC_e + yFFC_h)$$

with x and y the respective proportions of energy produced in relation to the total energy produced :

$$x = \eta_e/(\eta_e + \eta_h) \text{ and } y = \eta_h/(\eta_e + \eta_h)$$

Note :

It is also possible to make an energy allocation, i.e. use the same logic as the allocation of GHG emissions with :

$$x = \eta_e C_e/(\eta_e C_e + \eta_h C_{hl}) \text{ and } y = \eta_h C_h/(\eta_e C_e + \eta_h C_h)$$

This method of calculation was not used in this example because the exergetic allocation is already involved in the calculation of the GHG emission factors. Moreover, the choice of allocation method makes in practice very little difference in the final calculation.

It should be noted that since this summary calculation for cogeneration is not mentioned in the Directive, heat and electricity calculation is still necessary.

2.3 Selection of emission factors in the available bibliography

The representation of new pathways requires the determination of the emission factor at different sub-stages. This requires selecting relevant values from the available bibliography.

2.3.1 Harvest of wood from bocage

The different possible values for emissions from this stage are listed in Table 13. The JRC currently proposes two methods : the harvesting of forest residues and the production and harvesting of roundwood, for which it offers diesel consumption and associated non-CO_2 GHG emissions. The Ademe directly provides emission factors for different forestry management practices, of which three relevant practices are used in this study (deciduous shrubs, deciduous shrubs, and harvesting of deciduous woods under deciduous shrubs). All these factors are aggregated, so it is not possible to subdivide them to include only emissions related to the perimeter covered by the fuels in this study. In the sectors where the harvest must be taken into account, emissions factor used will be the one whose perimeter is closest to the reality of operations on the ground. In this case, the cutting of hedgewood can be adequately described by the perimeter of the « coppice of decidious trees » case of the Ademe. This amounts to attributing the entire harvesting operation to wood energy. This emission factor is slightly lower than that of the JRC's forest residue harvest, but the JRC incorporates drying that is not carried out when harvesting bocager wood (see Table 13). This Ademe factor does not detail diesel consumption but directly indicates the result in CO_2 emissions. This result is therefore considered to include non-CO_2 GHG emissions.

Table 12 : Emissions factors - Harvest of wood from bocage

	Diesel MJ/MJ	CH4 g/MJ	N2O g/MJ	CO2e gCO2e/MJ	Perimeter	Use in this study
JRC – Harvesting of forest residus	0,0120	9,2E-06	3,9E-05	1,15	Forwarding, Bundling/lifting; Oil use ; Forestry / Machinery transport ; Load/Unload ; Stump harvesting	
JRC - Production and harvesting of round wood (resinous)	0,0107	8,2E-06	3,4E-05	1,03	Seedling production and cultivation (from Aldentun (2002)); Soil scarification; Cut-over clearing; Fertilisation (energy for application of fertiliser); Cleaning; Regeneration; Logging; Forwarding to terminal	
Ademe – Coppice of decidious trees	**/**	**/**	**/**	**0,97**	**Harvesting, canopy dismantling and removal, skidding/collection**	**Figure 1**
Ademe - Timber of decidious trees	/	/	/	0,75	Provision of seedlings and transport, Planting, Thinning, Harvesting, Crown removal and disposal, Skidding/collection, Levelling and destruction of stumps	
Ademe - Timber of decidious trees - Twigs	/	/	/	0,58	Logging/collection	

2.3.2 Grinding, refining, deburring

The JRC and Ademe indicate diesel consumption values associated with the crushing operation, as described in Table 14. The JRC proposes a unique process, supposed to describe a diverse set of situations. The Ademe distinguishes between roadside grinding (which includes transporting the grinder to the site) and platform grinding, which is based on a more precise representation of the French sectors. In particular, it involves two stages of grinding: slow grinding (breaking) and rapid grinding, followed by a screening step. It is important to distinguish these different types of grinding.

The processes chosen according to the sectors are as follows :

- Mobile shredders (in the field, at the edge of the hedge/road) : the emission factor used is derived from the Ademe LCA method for roadside grinding. This value corresponds well to the specific case in question, and therefore includes the relevant scope. It is therefore more precise (in addition, higher) than that of the JRC, which aggregates very different situations.
- Grinding in landscaped wood platform (Figure 2) : according to industry experts, only one grinding step is carried out. It is a slow grinding process that generates few fine fractions, as these are not very valuable. No screening step after grinding is considered as screening is not necessary after slow grinding. Furthermore, it is also not required for the supply of boilers covered by RED. The process used to describe this step is that proposed by the JRC, which represents a generic grinding process (used for both forest residues and roundwood). This value is all the more relevant since the JRC uses it for the crushing of forest residues, a situation very close to that considered here.
- Platform grinding of waste wood (A and B) : This step takes into account the energy used for the grinding of wood waste A / packaging waste on the platform as well as the loading of this waste into the grinder. Defrosting is integrated into the grinding process and does not lead to significant additional energy consumption. The operations can be quite diversified for wood packaging. There may be one or two grindings, and potentially screening (ADEME, 2016[10]). The logic here has been to group this diversity under the generic name of grinding/refining/defrosting, and to adopt the principle that two operations are carried out on the platform : either two grindings or grinding and screening. The emission factor chosen to represent these two pieces of equipment is that given by the Ademe for the combination of crushing and rapid grinding.

*Table 13 : Emission factors – Grinding. *EEA_EMEP diesel ratio*

	Ratio intrant MJ/MJ	Diesel MJ/MJ	CH4 g/MJ	N2O g/MJ	CO2e gCO2e/MJ	Use in this study
JRC - Forestry residues grinding	**1,025**	**0,0034**	**2,6E-06**	**1,1E-05**	**0,32**	**Scheme 2**
Ademe - Roadside grinding	**1,00**	**0,0051**	**5,9E-06***	**1,6E-05***	**0,49**	**Schemes 1 and 3**

[10] ADEME, CEDEN, Biomasse Normandie, & FCBA. (2016). ERCIBEN. État de l'art de la gestion des déchets de bois en Europe.

Ademe - Crushing	1	0,0035	4,0E-06*	1,1E-05*	0,34	
Ademe - Quick grinding	1	0,0035	4,0E-06*	1,1E-05*	0,34	
Ademe - Crushing + Quick grinding	1	0,0067	7,6E-06*	2,1E-05*	0,64	
Ademe - Screening	1,176	0,0009	1,0E-06*	2,8E-06*	0,08	
Grinding - Refining – Derailage wood waste (Choice study methodology for wood waste)	**1**	**0,0067**	**7,6E-06***	**2,1E-05***	**0,64**	**Schemes 4 and 5**

2.3.3 Storage with loss of moisture

In non-forest wood sectors, there is no controlled drying, but temporary storage involving loss of moisture, which does not involve dedicated energy consumption. In the existing references, only drying processes involving a strong reduction in moisture are represented. The drying process has two key parameters:

- Loss of MS (natural degradation by micro-organisms) which increases the impact of the steps upstream of drying (because more MS is needed to reach 1 MJ final)
- Moisture loss, which reduces the impact of transport steps downstream.

Ademe and JRC offer two different drying processes which in both cases correspond to a moisture loss of 20%, and are distinguished by a different MS loss rate. The JRC value corresponds to an uncontrolled generic drying, similar to what is involved in the management of wood outside forests, while the Ademe values relate to controlled drying for small installations. These two references are therefore far removed from what is observed by the experts : a very low loss of moisture during storage on the intermediate platform. To represent storage with loss of moisture, the following methodological choices were therefore made :

- **Moisture loss :** determined to say expert, the moisture rises from 40% during collection to 37% during transport. The collection value is a median between the values of Ademe and JRC, and the low moisture loss does not reduce the share of downstream transport too much (the final moisture is higher than in both references).
- **Loss of MS :** the JRC value of 5% is chosen. This value increases the impact of the upstream stages (since this value is given for a moisture loss of 20%, whereas the moisture loss retained here is only 3%).

Table 14 : Drying processes

	Input ratio			
	MJ/MJ	**H in**	**H out**	Use in this study
JRC - Roadside Drying	1,05	50%	30%	
Ademe - Natural drying	1,15	45%	25%	

Storage with moisture loss (Methodological choice of the study)	**1,05**	**40%**	**37%**	**Schemes 1 and 2**

2.4 Establishment of process factors specific to the sectors studied

The sectors studied involve processes that have not been represented for GHG or LCA purposes. This section presents the methodology used on a case-by-case basis for these different processes.

2.4.1 Wood waste sorting

GHG emissions from sorting operations have so far been very poorly documented, especially in the wood sectors. Two sorting methods are possible : either automated and electrified sorting in mixed waste sorting plants, or manual sorting (by mechanical shovel) in wood platforms, aimed at separating waste wood intended for material recycling from that intended for energy recovery. For woods A and B management systems, sorting is mainly carried out manually before grinding[11]. To document the emissions of manual sorting in wood platforms, a consumption of diesel fuel was determined on the basis of the work of the Ademe, and supplemented by the non-CO_2 GHG emissions associated with this consumption. The emission factor is determined on the basis of the consumption and hourly rate of the shredder loader indicated in the Ademe, namely 5l/h and a rate of 150 map[12]/h (MAP = stacked cubic meter). Moreover, an undesirable rate of 2% is considered to be expert.

The process chosen is as follows:

Table 15 : Wood waste sorting processes in platform

Matter	IN / OUT	Quantity	Unit	Source
Wood waste	IN	1,02	MJ	(1)
Diesel	IN	0,00035	MJ	(2)
Wood waste sorted	OUT	1	MJ	(1)
CH_4	OUT	3,93E-7	g	(3)
N_2O	OUT	1,11E-6	g	(3)

[11] ADEME, CEDEN, Biomasse Normandie, & FCBA. (2016). ERCIBEN. État de l'art de la gestion des déchets de bois en Europe.

[12] Mètre cube apparent

Sources :

(1) From experts : Undesirable rate of 2%

(2) Ademe : shredder loader data for shredding operations (5 L/h, 150 map/h) (MAP = stacked cubic meter)

(3) European Environment Agency (EEA). (2023). *EMEP/EEA Air pollutant emission inventory Guidebook* ; 1.A.4.c.ii - Table_3-1_02.

2.4.2 Black liquor oven and evaporation of black liquors

The data available in the BAT on paper mills make it possible to determine energy consumption associated with the evaporation of black liquors.

*Table 16 : Assumptions for the evaporation of black liquors. *values used in calculations*

	Heat (MJ/tADpaste)	Electricity (kWh/tADpaste)	Source
Evaporation and stripping	3979 (4223*)	59	1
Black liquor oven	244 (0*)	122	1

Note :

1 tAD = tonne of 90% dried pulp

The ratio of 1.5 tMS of black liquors per tAD of pulp is used (2)

*To simplify the calculation, the heat consumption of the black liquor oven is allocated to evaporation, thus bringing the value to 4223 MJ/tAD paste.

Sources :

(1) BAT : Efficacité 88% : Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S., & Delgado Sancho, L. (2015). *Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board*. https://doi.org/10.2791/370629, Table 3.32, 4.7 and 4.8

(2) Tran, Honghi & Vakkilainen, Esa. (2016). THE KRAFT CHEMCIAL RECOVERY PROCESS.)

According to the BREF technical references, the efficiency for the black liquor oven is 88% (BAT). According to these assumptions, the combustion process in the black liquor kiln is therefore represented by The data available in the BAT on paper mills make it possible to determine energy consumption associated with the evaporation of black liquors.

Table 16 :

Table 17 : Heat production process by burning black liquors in a black liquor oven

Matter	IN / OUT	Quantity	Unit	Source

Dried black liquor	IN	1,136	MJ	(1)
Electricity	IN	0,027	MJ	(1)
Steam	OUT	1	MJ	(1)
CH_4	OUT	0,0035	g	(2)
N_2O	OUT	0,0024	g	(2)

(1) BAT : Efficacité 88% : Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S., & Delgado Sancho, L. (2015). *Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board*. https://doi.org/10.2791/370629

(2) GEMIS, version 4.9; 2014 ; black-liquor-boiler-EU-2020 (with FGD)

According to the assumptions made in The data available in the BAT on paper mills make it possible to determine energy consumption associated with the evaporation of black liquors.

Table 16, the evaporation process of black liquors is represented as follows :

Table 18 : Evaporation process of black liquors

Matter	IN / OUT	Quantity	Unit	Source
Crude black liquor (H = 85%)	IN	1	MJ	(1)
Heat	IN	0,256	MJ	(1)
Electricity	IN	0,018	MJ	(1)
Dried black liquor (H=20%)	OUT	1	MJ	(1)

The BREF provides guidance on the operations associated with paper sludge thickening. In addition, a RECORD study also documents the power consumption associated with sludge thickening across all industries. These values are shown in the following table :

Table 19 : Reference data available to represent paper sludge thickening

	Min (kWh/t)	Max (kWh/t)	Source	Use in this study
Thickening	1	10	(1)	

Dewatering (screw press)	10	15	(1)	
Dewatering (double wire press)	2	4	(1)	
Dewatering (screw press) + Thick.	**11**	**25**	**(1)**	**Pathway 7 (Max value)**
Dewatering (double wire press) + Thick.	3	14	(1)	
Strip filter	10	25	(2)	
Centrifugal filter	60	80	(2)	
Press filter	25	35	(2)	

Among these combinations, the retained value is the maximum value reported in the dedicated technical literature (BREF) : 25kWh/t of sludge. This value is consistent with and more specific than the RECORD study. The process is therefore represented as follows :

Table 20 : Paper sludge thickening processes

Matter	IN / OUT	Quantity	Unit	Source
Raw sludge	IN	1	MJ	(1)
Electricity	IN	0,0167	MJ	(1)
Thickened sludge	OUT	1	MJ	(1)

Note :

- LHV sludge : 1,5 MWh/tdry (3)

Sources :

(1) BAT : Efficacité 88% : Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S., & Delgado Sancho, L. (2015). *Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board*. https://doi.org/10.2791/370629, Table 2.11, 6.12 et 6.29

(2) Record. (2007). *Revue des filières de traitement/valorisation des boues Critères de choix d'une filière adaptée et arbre de décision associé*. www.record-net.org

(3) Centre Technique du Papier

3 WOOD OUTSIDE FORESTS

3.1 Pathway 1 : Woodchips from bocage hedges

Bocage wood chips comes from the maintenance of the hedgerows. Wood-energy sectors are a recovery sector in which they are mainly used in the form of wafers. Two methods of producing wafers have been identified :

(1) Storage on intermediate platform : the fresh wood is crushed at the edge of the hedge and then transported to an intermediate storage platform where it is stored until it is used. During storage, the moisture decreases slightly.

(2) Direct use in the boiler room : the fresh wood is crushed on the edge of the hedge and sent directly to a boiler room. This route mainly concerns lumber for which road access is directly available.

The intermediate storage chain generates more transport, and therefore a higher emission factor. For reasons of legibility for the actors of the sector, only this additional modality has been chosen.

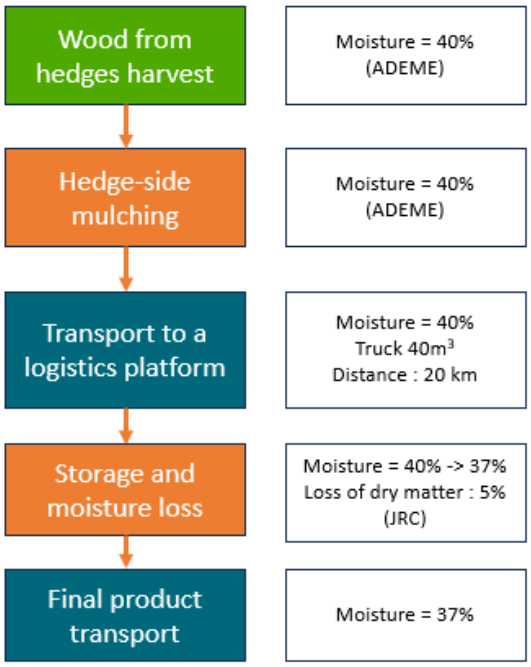

Figure 3 : Steps of woodchips from bacage production and moisture schemes

Step 1. Collecting bocager/alignment wood

This step corresponds to the energy consumed for the collection of bocager wood. According to the assumptions made (see section 2.3.1), the collection of bocager wood is described in Table 22 :

Table 21 : Bocage wood harvesting process

Harvesting of bocage wood					
IN			**OUT**		
Standing wood	1	MJ	Wood	1	MJ
			CO_2e emissions	0,972	g

Notes :

- LHV dry : 19 MJ/kg (JRC)
- Moisture : 40% (From experts)

Source : Ademe – Coppice of decidious trees

Step 2 : Grinding in edge of hedge

This step includes both the energy used by the shredder (diesel) and that related to the transport of the shredder. According to the assumptions made (see Chapter 2.3.2), edge grinding is described in Table 23.

Table 22 : Processus de broyage en bord de haie

Grinding in edge of hedge					
IN			**OUT**		
Bocage wood	1,00	MJ	Chips	1	MJ
Diesel	0,00515	MJ (1)	CH_4	5,85E-06	g (2)
			N_2O	1,65E-05	g (2)
Émissions	0,495	gCO2e			

Notes :

- LHV dry : 19 MJ/kg
- Moisture : 40%

Source :

(1) Ademe – broyage en bord de route

(2) European Environment Agency (EEA). (2023). *EMEP/EEA Air pollutant emission inventory Guidebook* ; 1.A.4.c.ii - Table_3-1_02

Step 3 : Transport to a logistics platform

The bocager wood pads are transferred to a nearby platform, for a distance of 20km with a 40m3 truck. See Chapter 2.2.6, Table 7 and Table 8.

Step 4 : Storage with loss of moisture

The wafers are stored on the platform and their humidity decreases slightly, although the purpose of the storage operation is not drying. According to the assumptions made (see Chapter 2.3.3), the storage process with loss of moisture is shown in Table 24.

Table 23 : Process of dryng in edge of hedge

Storage with loss of moisture					
IN			**OUT**		
Chips	1,053	MJ	Chips	1	MJ
Moisture IN	45%				
Moisture OUT	37%				

Notes : LHV dry : 19 MJ/kg
Source : JRC

Step 5 : Final transport

Final transport distances are described in Table 9.

3.2 Pathway 2 : Woodchips from landscape

Green space maintenance residues are generally not used in energy wood when crushed on site. Otherwise, they are transported unmilled on a platform. This configuration also represents the green waste brought to the landfill, which is also transported without crushing on a platform.

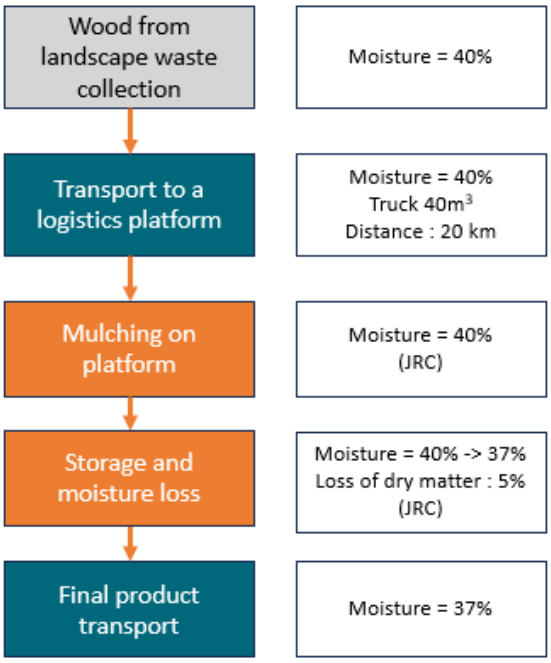

Figure 4 : Stages of production of landscape woodchips and moisture schemes

Step 1: Collection of pruning wood

This step is not included in the emission calculation as green area maintenance timber is considered as residues from the maintenance activity of green areas, parks and gardens. This maintenance is not motivated by the use of wood in the energy wood industry. The

moisture content of harvested wood can be considered to be 40%, according to experts (see section 2.2.8).

Step 2: Transport of pruning timber on platform

The pruning lumber is transferred to a nearby platform, for a distance of 20 km with a 40 m3 truck, following the same logic as in Figure 1 for bocager lumber. See Chapter 2.2.6, Table 7 and Table 8.

Step 3: Platform grinding

The process of grinding landscaped wood in a platform is described in Table 25 :

Table 24 : Platform pruning wood grinding process

Grinding of platform pruning wood					
IN			**OUT**		
Forest residues	1,025	MJ	Chips	1	MJ
Diesel	0,00336	MJ	CH_4	2,57E-06	g
			N_2O	1,07E-05	g

Notes :

- LHV dry : 19 MJ/kg(1)
- Moisture : 40%

Source : JRC, milling of forest residues

Step 4: Storage with loss of moisture

Same as pathway 1.

Step 5: Final transport

Final transport distances are described in Table 9.

3.3 Pathway 3 : Woodchips from orchards

Orchard maintenance wood is usually used directly by farms (grinding and return to the ground). However, fruit crop routes involve the renewal of orchards every 20 to 30 years, leading to the grubbing up and replacement of orchards. The wood obtained during this operation is now mainly unrecovered in energy wood. This path is nevertheless seriously considered by the actors of the sector, in view of the challenges related to the current management of these materials which are still often burned in the field (Grasselly et al. 2019) . The logic of representing the sector is made by analogy with that of bocage woods, by setting aside the harvesting stage, because orchard grubbing-up woods are part of a ‘waste’ logic.

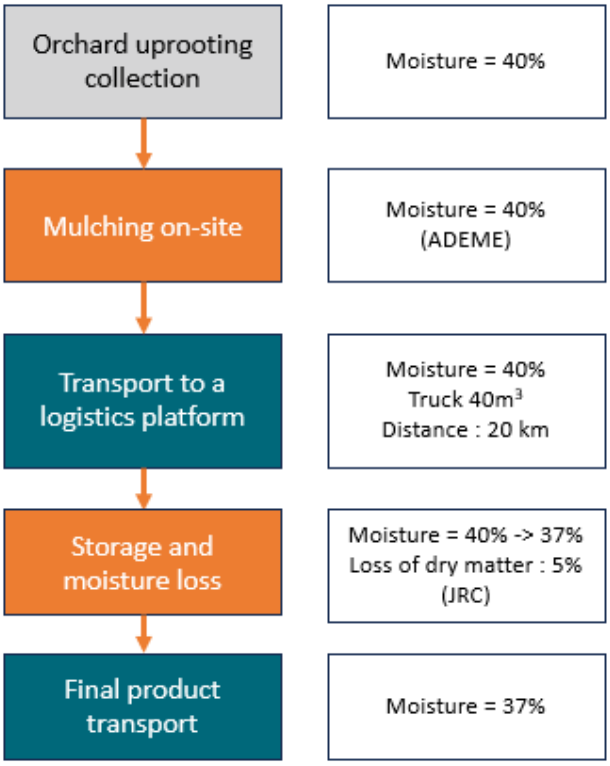

Figure 5 : Production stages of orchard wafers and moisture patterns

Step 1. Collection of grubbing-up wood from orchards

No emissions are attributed to this stage, as orchard grubbing-up timber is considered to be farm waste. The grubbing-up is indeed motivated by the re-cultivation of the plot.

Step 2: Grinding in the field

Same as pathway 1.

Step 3: Transport to a logistics platform

Same as Figure 1, by analogy with existing trays for bocager wood. See Chapter 2.2.6, Table 7 and Table 8.

Step 4: Storage with loss of moisture

Same as Figure 1, by analogy with existing trays for bocager wood.

Step 5: Final transport

Final transport distances are described in Table 9.

3.4 Results

For non-forest wood supply chains, GHG emissions are given in Table 26 and Table 27. These results take into account the operations detailed in the different schemes, plus CO_2 emissions at use (see 2.2.6).

3.4.1 GHG emissions from oustide forests wood sectors - Standard and standard values

Table 25 : GHG emissions from oustide forests wood sectors. Aggregate values.

		Typical value	Default value
1. Bocage wood chips	1-200 km	3,4	**4,0**
	1-500 km	5,4	**6,5**
	500 - 2 000 km	7,7	**9,3**
	2 500 - 10 000 km	13,7	**16,4**
	> 10 000 km	24,8	**29,8**
2. Landscape wood chips	1-200 km	2,4	**2,9**
	1-500 km	4,4	**5,3**
	500 - 2 000 km	6,8	**8,1**
	2 500 - 10 000 km	12,7	**15,3**
	> 10 000 km	23,9	**28,6**
3. Orchards wood chips	1-200 km	2,6	**3,1**
	1-500 km	4,6	**5,5**
	500 - 2 000 km	7,0	**8,3**
	2 500 - 10 000 km	12,9	**15,5**
	> 10 000 km	24,0	**28,8**

Table 26 : GHG emissions from oustide forests wood sectors. Disaggregated values.

		Typical value				Default value			
		Cultivation	Processing	Transport & distribution	Use	Cultivation	Processing	Transport & distribution	Use
1. Bocage wood chips	1-200 km	0,0	1,3	1,6	0,4	0,0	1,6	2,0	0,5
	1-500 km	0,0	1,3	3,7	0,4	0,0	1,6	4,4	0,5
	500 - 2 000 km	0,0	1,3	6,0	0,4	0,0	1,6	7,2	0,5
	2 500 - 10 000 km	0,0	1,3	12,0	0,4	0,0	1,6	14,3	0,5
	> 10 000 km	0,0	1,3	23,1	0,4	0,0	1,6	27,7	0,5
2. Landscape wood chips	1-200 km	0,0	0,3	1,6	0,4	0,0	0,4	2,0	0,5
	1-500 km	0,0	0,3	3,7	0,4	0,0	0,4	4,4	0,5
	500 - 2 000 km	0,0	0,3	6,0	0,4	0,0	0,4	7,2	0,5
	2 500 - 10 000 km	0,0	0,3	12,0	0,4	0,0	0,4	14,4	0,5
	> 10 000 km	0,0	0,3	23,1	0,4	0,0	0,4	27,7	0,5
3. Orchards wood chips	1-200 km	0,0	0,5	1,6	0,4	0,0	0,6	2,0	0,5
	1-500 km	0,0	0,5	3,7	0,4	0,0	0,6	4,4	0,5
	500 - 2 000 km	0,0	0,5	6,0	0,4	0,0	0,6	7,2	0,5

2 500 - 10 000 km	0,0	0,5	12,0	0,4	0,0	0,6	14,3	0,5
> 10 000 km	0,0	0,5	23,1	0,4	0,0	0,6	27,7	0,5

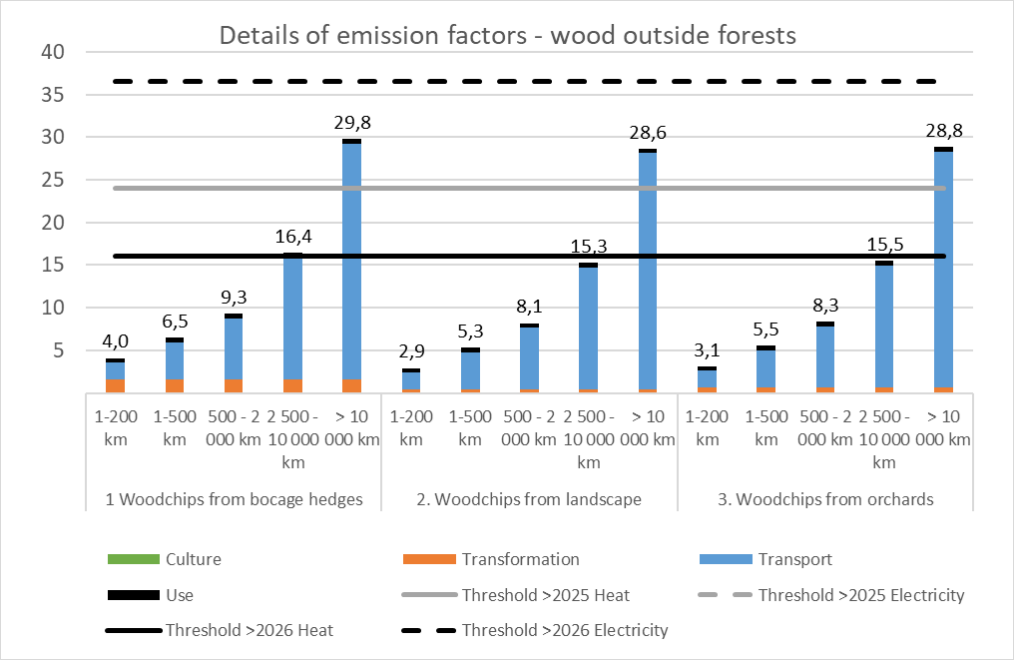

Figure 6 : Graphical representation of standard GHG emission values for oustide forests wood sectors

3.4.2 Emissions savings

Legend :

Compliant after 2026
Compliant before 2026

Table 27 : Savings of GHG emissions from oustide forests wood sectors. Typical and standard values for use in heat and electricity

		Typical value		Default value	
		Heat (%)	Electricity (%)	Heat (%)	Electricity (%)
1. Bocage wood chips	1-200 km	95%	93%	94%	91%
	1-500 km	92%	88%	90%	86%
	500 - 2 000 km	89%	83%	86%	80%
	2 500 - 10 000 km	80%	70%	76%	64%
	> 10 000 km	63%	46%	56%	35%
2. Landscape wood chips	1-200 km	96%	95%	96%	94%
	1-500 km	93%	90%	92%	88%
	500 - 2 000 km	90%	85%	88%	82%
	2 500 - 10 000 km	81%	72%	78%	67%
	> 10 000 km	65%	48%	58%	37%
3. Wood chips from orchards	1-200 km	97%	95%	96%	94%
	1-500 km	94%	91%	93%	89%
	500 - 2 000 km	91%	87%	89%	84%
	2 500 - 10 000 km	83%	75%	80%	70%
	> 10 000 km	69%	54%	63%	45%

4 WASTE WOOD

4.1 Pathway 4 : Wood waste A mill and wood packaging waste

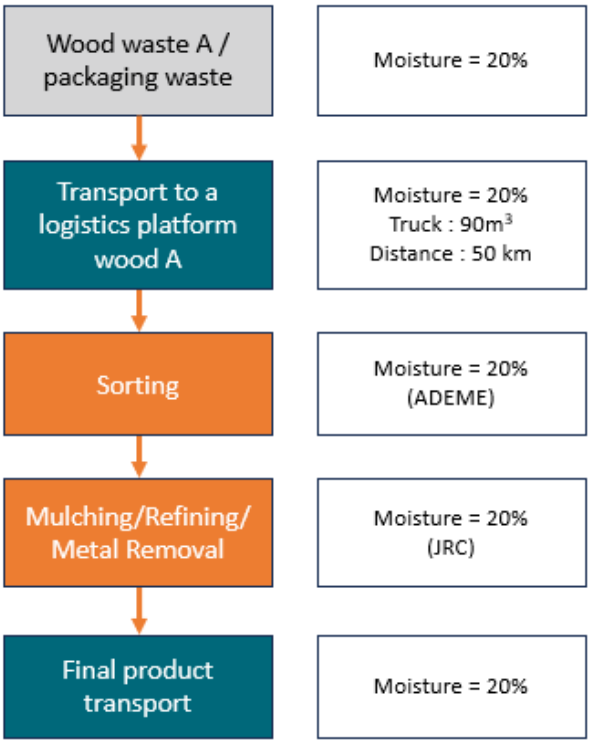

Figure 7 : Wood waste milling steps A and packaging waste and moisture schemes

Step 1: Production of wood waste A / packaging waste

No emissions are allocated to the production of wood A waste or packaging waste, as this is waste. The moisture content of wood waste is 20%, a value used in the Ademe LCA study.

Step 2: Transport to the SSD platform

Wood waste A / packaging waste is transferred to a platform at a distance of 50km with a 90m3 truck. See Chapter 2.2.6, Table 7 and Table 8.

Step 3: Sorting

The emission calculation takes into account the fuel consumption of the mechanical excavator used to sort wood A before grinding. The sorting process is represented by the following table.

Table 28 : Wood waste sorting process

Sorting					
Refusal to sort	2%	(1)			
IN			**OUT**		
Mixed wood waste	1,020	MJ (1)	Wood waste	1	MJ
Diesel	0,00035	MJ (2)	CH4	3,93E-07	g (3)
			N2O	1,11E-06	g (3)

Sources :

(1) From experts

(2) Ademe (Consommation du chargeur du broyeur)

(3) European Environment Agency (EEA). (2023). *EMEP/EEA Air pollutant emission inventory Guidebook* ; 1.A.4.c.ii - Table_3-1_02

Step 4: Grinding, refining, deburring

According to the assumptions made (see Chapter 2.3.2), the grinding/refining/defrosting process used is as follows :

Broyage – Affinage – Déferraillage					
IN			**OUT**		
Wood waste	1,00	MJ(1)	Mill	1	MJ(1)
Diesel	0,00668	MJ(1)	CH4	7,60E-06	g(2)
			N2O	2,14E-05	g(2)

Sources :

(1) Ademe (Cracking + Slow Grinding + Charger)

(2) European Environment Agency (EEA). (2023). *EMEP/EEA Air pollutant emission inventory Guidebook* ; 1.A.4.c.ii - Table_3-1_02

Step 5 : Transport of final product

Final transport distances are described in Table 9.

4.2 Pathway 5 : Wood waste B mill (BR1 and BR2)

The wood supply chains BR1 and BR2 are not clearly distinct, and it is therefore considered that these two types of materials follow the same pattern. A variety of situations have been identified, as B wood can either be brought to the landfill or brought directly to the platform. In addition, there may also be an intermediate sorting platform. For reasons of legibility for the actors of the sector, only one configuration has been chosen for the standard scheme. This configuration includes :

- A sorting step

- A generic transport term of 100 km (see intermediate transport schemes, Table 2.2.6).

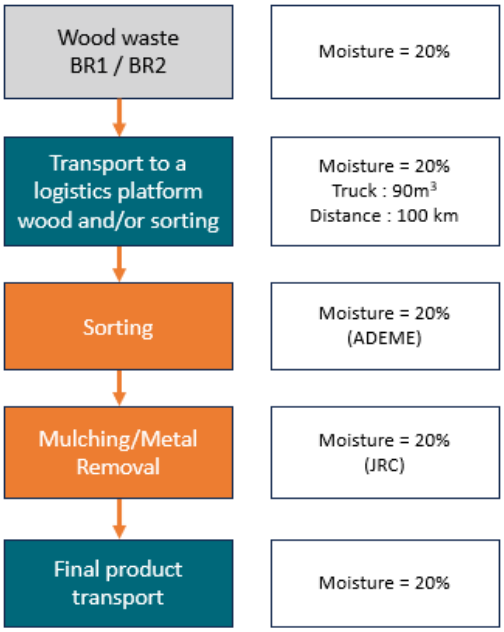

Figure 8 : Wood waste milling steps B and moisture patterns

Step 1: Wood waste generation

This step is common to all sectors. No emissions are assigned to the production of wood waste B. Their humidity is 20% (Source: Ademe).

Step 2: Transport to a wood platform and/or sorting platform

The waste wood B in the landfill is transferred to a wood platform and/or a sorting platform at a cumulative travel distance of 100km with a 90m^3 truck. The moisture content of wood waste B remains at 20% during the various transport operations. See Chapter 2.2.6, Table 7 and Table 8.

Step 3: Sorting

The sorting of wood waste is carried out on sorting platforms from pre-sorted B wood deposits. The emission calculation shall take into account the fuel consumption of the mechanical excavator used to separate wood B for energy use from wood B for material recycling. The sorting process is identical to Figure 4.

Step 4: Grinding / Refining / Derailing

Same as Figure 3.

Step 5: Transport of final product

Final transport distances are described in Table 9.

4.3 Results

For waste wood supply chains, GHG emissions are given in Table 30 and Table 31. The results take into account the operations detailed in the different pathways, plus CO2 emissions at use (see 2.2.6).

4.3.1 GHG Emissions Wood-Waste Lines

Table 29 : GHG emissions from waste wood industries. Aggregate typical and standard values.

		Typical value	Default value
4. Wood waste mill A	1-200 km	2,4	**2,9**
	1-500 km	4,0	**4,8**
	500 - 2 000 km	5,9	**7,1**
	2 500 - 10 000 km	10,6	**12,7**
	> 10 000 km	19,3	**23,2**
5. Wood waste mill B (BR1 et BR2)	1-200 km	2,7	**3,2**
	1-500 km	4,3	**5,2**
	500 - 2 000 km	6,2	**7,4**
	2 500 - 10 000 km	10,8	**13,0**
	> 10 000 km	19,6	**23,5**

Table 30 : GHG emissions from waste wood industries. Disaggregated typical and standard values.

		Typical value				Default value			
		Cultivation	Processing	Transport & distribution	Use	Cultivation	Processing	Transport & distribution	Use
4. Wood waste mill A	1-200 km	0,0	0,7	1,3	0,4	0,0	0,8	1,6	0,5
	1-500 km	0,0	0,7	2,9	0,4	0,0	0,8	3,5	0,5
	500 - 2 000 km	0,0	0,7	4,8	0,4	0,0	0,8	5,7	0,5
	2 500 - 10 000 km	0,0	0,7	9,5	0,4	0,0	0,8	11,4	0,5
	> 10 000 km	0,0	0,7	18,2	0,4	0,0	0,8	21,9	0,5
5. Wood waste mill B (BR1 et BR2)	1-200 km	0,0	0,7	1,6	0,4	0,0	0,8	1,9	0,5
	1-500 km	0,0	0,7	3,2	0,4	0,0	0,8	3,8	0,5
	500 - 2 000 km	0,0	0,7	5,1	0,4	0,0	0,8	6,1	0,5
	2 500 - 10 000 km	0,0	0,7	9,7	0,4	0,0	0,8	11,7	0,5
	> 10 000 km	0,0	0,7	18,5	0,4	0,0	0,8	22,2	0,5

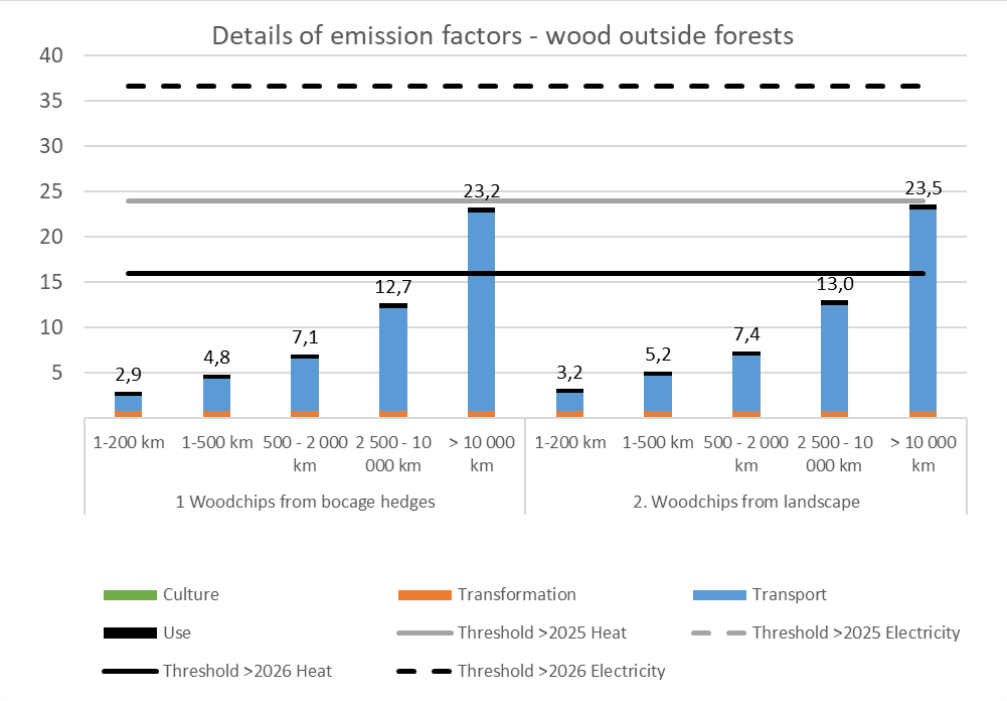

Figure 9 : Graphical representation of the standard GHG emission values of wood waste industries

4.3.2 Emissions savings

Legend :

Compliant after 2026
Compliant before 2026

Table 31 : Savings of GHG emissions from waste wood industries. Typical and standard values for use in heat and electricity.

		Typical value		Default value	
		Heat (%)	Electricity (%)	Heat (%)	Electricity (%)
4. Wood waste mill A	1-200 km	96%	95%	96%	94%
	1-500 km	94%	91%	93%	89%
	500 - 2 000 km	91%	87%	90%	85%
	2 500 - 10 000 km	84%	77%	81%	72%
	> 10 000 km	72%	58%	66%	49%
	1-200 km	96%	94%	95%	93%
	1-500 km	94%	91%	92%	89%

5 Wood waste mill B (BR1 et BR2)	500 - 2 000 km	91%	87%	89%	84%
	2 500 - 10 000 km	84%	76%	81%	72%
	> 10 000 km	71%	57%	65%	49%

5 PAPER INDUSTRY SECTORS

5.1 Pathway 6 : Black liquors

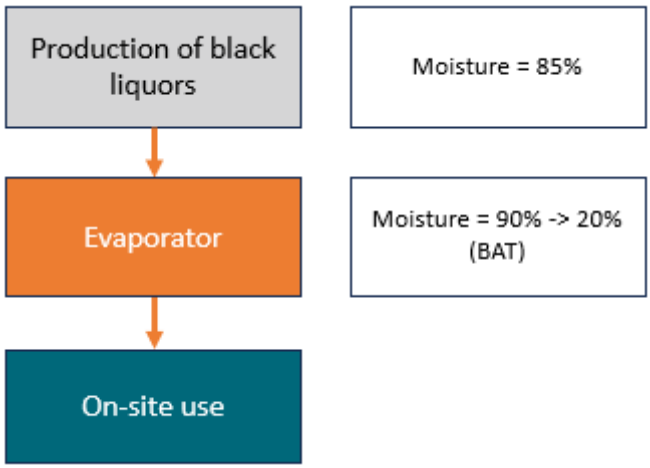

Figure 10 : Dried black liquor production steps and moisture pathways

Step 1 : Production of black liquors

No emissions are affected at this stage as black liquors are considered to be a residue from the production of cellulose pulp.

Step 2 : Evaporation / Concentration

In order to be used as fuel, black liquors are evapoconcentrated. According to the data available in the BREF on paper mills, the stages of preparation of black liquors for combustion can be represented as follows :

Black liquor evaporation					
IN			**OUT**		
Black liquors	1,000	MJ (1)	Dried black liquor	1	MJ (1)
Electricity	0,039	MJ (1)			
Heat	0,256	MJ (1)			

Notes :

- LHV : 11,67 MJ/kg at 8% moisture (2)
- Moisture : 85% to 20% drying
- High voltage electricity

Source :

(1) Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S., & Delgado Sancho, L. (2015). *Best Available Techniques (BAT) Reference*

Document for the Production of Pulp, Paper and Board. https://doi.org/10.2791/370629

(2) Berien Elbersen, Igor Staritsky, Geerten Hengeveld, Jan-Peter Lesschen, & Calliope Panoutsou. (2016). *Guidelines for data collection to estimate and monitor technical and sustainable biomass supply. Deliverable 2.2 of the Biomass Policies project.*

For energy inputs, the assumptions used from experts words are as follows :

- Electricity is supplied by the high-voltage electricity grid
- Heat is provided by excess heat from the liquor oven. This results in the self-consumption of dry black liquor in the processing chain to provide heat to the evaporator if necessary. The process is represented similarly to that of pellet production in the JRC document. The amount of additional dried black liquor required is therefore calculated by :

$$BL_{added} = \frac{Heat_{evap}}{\eta_{h,ovenBL} - Heat_{evap}} = \frac{0{,}256}{0{,}88 \ - \ 0{,}256} = \ 0{,}410 \ MJ/MJ \ BL \ dry \ produced$$

The production pattern for dried black liquors is therefore represented by the following pattern :

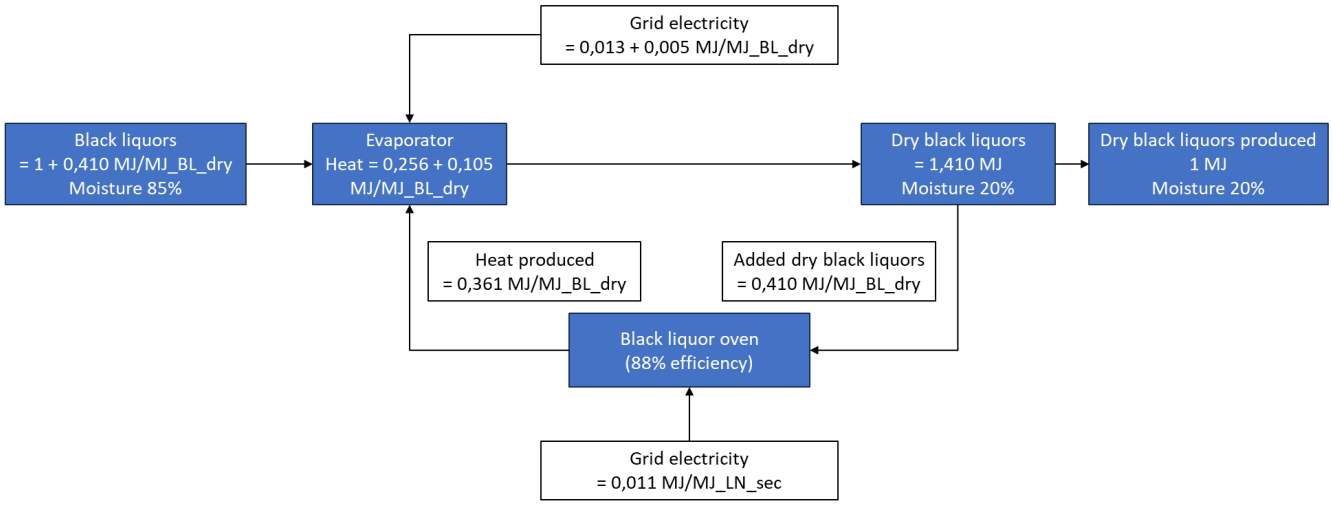

Figure 11 : Diagrams of self-consumption of heat from the black liquor oven by the process of evaporation of black liquors.

Note :

For calculation purposes and to take into account the fact that the heat comes from the combustion of the black liquor itself, the dried black liquor is artificially dissociated to show the fraction needed to dry 1 MJ of final fuel. In the reality of the process, all dried black liquor is recovered in the liquor oven.

Step 3: Direct on-site use

Black liquors are used directly at the stationery site, and are therefore not affected by a final transport stage.

5.2 Pathway 7 : Paper sludge

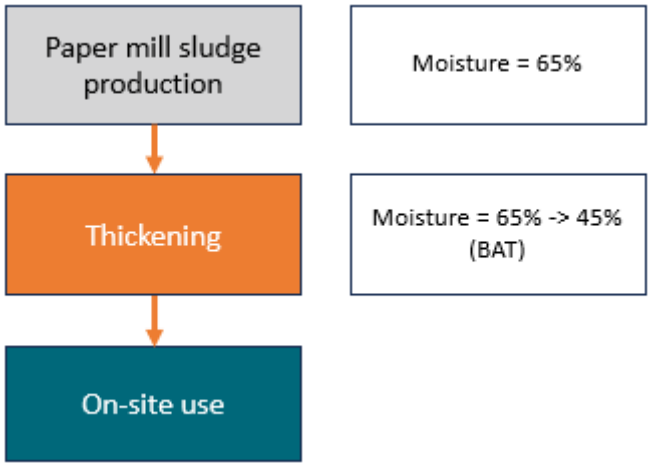

Figure 12 : Stages of production of dehydrated paper sludge and moisture patterns

Note : the following section describes the calculation methodology associated with the biogenic share of paper sludge. The potential non-biogenic part (which depends on the sites) is to be excluded from the energy produced, in the same way as it is done for the non-biogenic part of the CSRs..

Step 1: Production of paper sludge

No emissions are affected at this stage as paper sludge is considered to be a pulp or paperboard production residue.

Step 2: Thickening/dehydration of paper sludge

Before energy recovery, paper sludge is thickened and dehydrated using mechanical equipment such as screw presses or double-cloth presses. Based on averaged BREF data, the process chosen is as follows :

Thickening / dehydration of paper sludge

IN			OUT		
Liquid sludge	1,000	MJ	Thickened and dehydrated sludge	1	MJ
Electricity	0,017	MJ (1)			

Notes :

- LHV : 5,4 MJ/kg dry (2)
- Moisture : drying from 65% to 45%
- High voltage electricity

Source :

(1) Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S., & Delgado Sancho, L. (2015). *Best Available Techniques (BAT) Reference*

Document for the Production of Pulp, Paper and Board. https://doi.org/10.2791/370629
(2) Centre technique du papier

5.3 Results

For paper mill residue supply chains, GHG emissions are given in Table 33 and inTable 34. The results take into account the operations detailed in the different schemes, plus CO2 emissions at use (see 2.2.6).

5.3.1 GHG emissions from paper industries

Table 32 : GHG emissions from paper industries. Aggregate typical and standards values.

		Typical value	Standard value
6. Black liquors	on site	1,6	**1,9**
7. Paper sludge	on site	2,3	**2,8**

Table 33 : GHG emissions from paper industries. Disaggregated values.

		Typical value				Valeur standards			
		Cultivation	Processing	Transport & distribution	Use	Cultivation	Processing	Transport & distribution	Use
6. Liqueurs noires	sur site	0,0	0,9	0,0	0,7	0,0	1,1	0,0	0,8
7. Boues papetières	sur site	0,0	0,4	0,0	1,9	0,0	0,5	0,0	2,3

It should be noted that emissions for black liquors are lower due to self-consumption (no transport-related emissions). Emissions related to the production of black liquors are allocated to the production of paper.

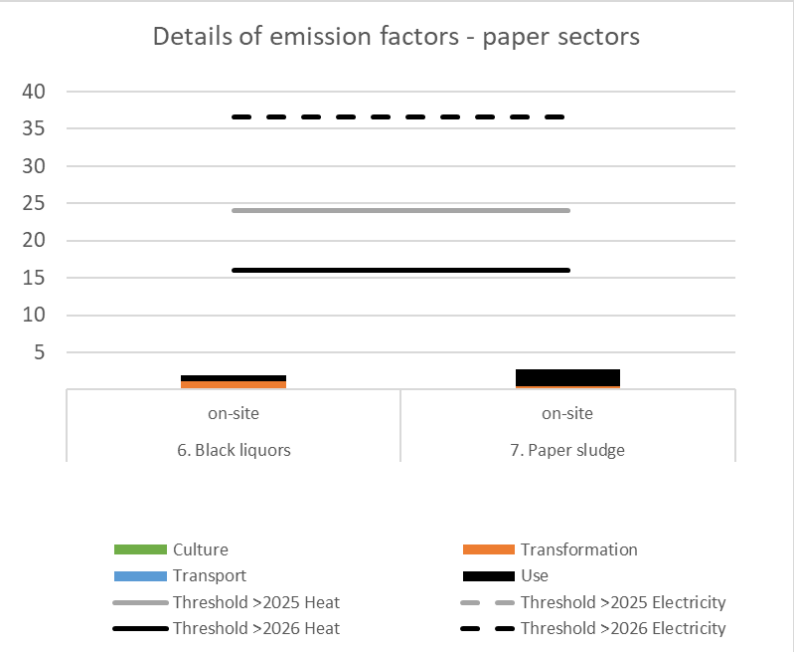

Figure 13 : Graphical representation of standard GHG emission values for paper industries

5.3.2 Emissions savings

Legend :

Compliant after 2026
Compliant before 2026

		Typical value		Default value	
		Heat (%)	Electricity (%)	Heat (%)	Electricity (%)
6. Black liquors	on site	98%	97%	97%	96%
7. Paper sludge	on site	97%	95%	96%	94%

6 COGENERATION

The tables below give the results obtained with the typical cogeneration yields considered (see section (3). Standard yields in cogeneration).

Legend :

Compliant after 2026
Compliant before 2026

6.1 JRC referent values

JRC – WOOD CHIPS SECTORS

Table 34 : Fuel emission savings in wafer format as described in RED for uses in cogeneration

		Cogeneration					
		Typical value			Default value		
		Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)	Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)
Woodchips from forest residues	1-500 km	94%	92%	93%	92%	91%	92%
	500 - 2 000 km	91%	89%	90%	88%	86%	88%
	2 500 - 10 000 km	85%	81%	84%	81%	76%	79%
	> 10 000 km	72%	65%	70%	65%	57%	63%
Woodchips from short rotation coppice (Eucalyptus)	2 500 - 10 000 km	68%	61%	66%	65%	57%	63%
Woodchips from short rotation coppice (Poplar – Fertilised)	1-500 km	90%	87%	89%	88%	86%	88%
	500 - 2 000 km	87%	84%	86%	86%	83%	85%
	2 500 - 10 000 km	81%	76%	79%	77%	72%	75%
	> 10 000 km	68%	61%	66%	62%	53%	59%
Woodchips from short rotation	1-500 km	92%	91%	92%	91%	89%	90%
	500 - 2 000 km	90%	87%	89%	87%	84%	86%

coppice (Poplar – No fertilisation)	2 500 - 10 000 km	82%	78%	81%	80%	75%	78%
	> 10 000 km	69%	62%	67%	64%	56%	62%
Woodchips from stemwood	1-500 km	94%	92%	93%	92%	91%	92%
	500 - 2 000 km	91%	89%	90%	90%	87%	89%
	2 500 - 10 000 km	85%	81%	84%	81%	76%	79%
	> 10 000 km	72%	65%	70%	65%	57%	63%
Woodchips from industry residues	1-500 km	95%	94%	95%	94%	92%	93%
	500 - 2 000 km	92%	91%	92%	91%	89%	90%
	2 500 - 10 000 km	86%	83%	85%	83%	80%	82%
	> 10 000 km	73%	67%	71%	68%	61%	66%

JRC – PELLETS SECTORS

Table 35 : Emission savings from pellet fuels described in RED for uses in cogeneration

			Type			Défaut		
			Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)	Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)
Wood pellets from forest residues	Cas 1	1-500 km	63%	54%	60%	55%	45%	52%
		500 - 2 000 km	63%	54%	60%	55%	45%	52%
		2 500 - 10 000 km	62%	53%	59%	54%	43%	51%
		> 10 000 km	57%	46%	53%	48%	35%	44%
	Cas 2a	1-500 km	80%	75%	78%	76%	70%	74%
		500 - 2 000 km	80%	75%	78%	76%	70%	74%
		2 500 - 10 000 km	78%	73%	77%	73%	67%	71%
		> 10 000 km	73%	67%	71%	68%	61%	66%
	Cas 3a	1-500 km	92%	91%	92%	91%	89%	90%
		500 - 2 000 km	92%	91%	92%	91%	89%	90%
		2 500 - 10 000 km	91%	89%	90%	90%	87%	89%
		> 10 000 km	86%	83%	85%	83%	80%	82%

Wood pellets from short rotation coppice (Eucalyptus)	Cas 1	2 500 - 10 000 km	48%	35%	44%	41%	27%	37%
	Cas 2a	2 500 - 10 000 km	62%	53%	59%	58%	48%	55%
	Cas 3a	2 500 - 10 000 km	73%	67%	71%	72%	65%	70%
Wood pellets from short rotation coppice (Poplar – Fertilised)	Cas 1	1-500 km	60%	51%	57%	53%	42%	49%
		500 - 10000 km	59%	50%	56%	51%	40%	48%
		> 10 000 km	54%	43%	51%	45%	32%	41%
	Cas 2a	1-500 km	77%	72%	75%	73%	67%	71%
		500 - 10000 km	74%	68%	73%	71%	64%	68%
		> 10 000 km	71%	64%	68%	65%	57%	63%
	Cas 3a	1-500 km	90%	87%	89%	88%	86%	88%
		500 - 10000 km	87%	84%	86%	86%	83%	85%
		> 10 000 km	83%	80%	82%	81%	76%	79%
Wood pellets from short rotation coppice (Poplar – No fertilisation)	Cas 1	1-500 km	62%	53%	59%	55%	45%	52%
		500 - 10000 km	60%	51%	57%	53%	42%	49%
		> 10 000 km	55%	45%	52%	48%	35%	44%
	Cas 2a	1-500 km	80%	75%	78%	76%	70%	74%
		500 - 10000 km	77%	72%	75%	73%	67%	71%
		> 10 000 km	73%	67%	71%	68%	61%	66%
	Cas 3a	1-500 km	92%	91%	92%	91%	89%	90%
		500 - 10000 km	90%	87%	89%	88%	86%	88%
		> 10 000 km	86%	83%	85%	83%	80%	82%
Wood pellets from stemwood	Cas 1	1-500 km	63%	54%	60%	55%	45%	52%
		500 - 2 000 km	63%	54%	60%	57%	46%	53%
		2 500 - 10 000 km	62%	53%	59%	54%	43%	51%
		> 10 000 km	57%	46%	53%	48%	35%	44%
	Cas 2a	1-500 km	80%	75%	78%	77%	72%	75%

Wood pellets from wood industry residues	Cas 3a	500 - 2 000 km	81%	76%	79%	77%	72%	75%
		2 500 - 10 000 km	78%	73%	77%	74%	68%	73%
		> 10 000 km	73%	67%	71%	68%	61%	66%
	Cas 1	1-500 km	94%	92%	93%	92%	91%	92%
		500 - 2 000 km	94%	92%	93%	92%	91%	92%
		2 500 - 10 000 km	91%	89%	90%	90%	87%	89%
		> 10 000 km	86%	83%	85%	85%	81%	84%
	Cas 2a	1-500 km	78%	73%	77%	73%	67%	71%
		500 - 2 000 km	78%	73%	77%	73%	67%	71%
		2 500 - 10 000 km	76%	70%	74%	71%	64%	68%
		> 10 000 km	72%	65%	70%	65%	57%	63%
	Cas 3a	1-500 km	88%	86%	88%	86%	83%	85%
		500 - 2 000 km	88%	86%	88%	86%	83%	85%
		2 500 - 10 000 km	87%	84%	86%	83%	80%	82%
		> 10 000 km	82%	78%	81%	78%	73%	77%
		1-500 km	96%	95%	96%	95%	94%	95%
		500 - 2 000 km	96%	95%	96%	95%	94%	95%
		2 500 - 10 000 km	94%	92%	93%	92%	91%	92%
		> 10 000 km	90%	87%	89%	87%	84%	86%

6.2 Values for new fuels

Table 36 : Example of emissions savings from outside forest woods for uses in cogeneration whose total energy efficiency is at least 75%

		Saving coefficients Cogeneration					
		Typical value			Default value		
		Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)	Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)
1. Bocage woodchips	1-200 km	96%	95%	95%	95%	94%	94%
	1-500 km	93%	92%	93%	92%	90%	91%
	500 - 2 000 km	90%	88%	89%	88%	85%	87%
	2 500 - 10 000 km	82%	78%	81%	79%	74%	77%
	> 10 000 km	68%	61%	66%	62%	53%	59%
2. Landscape woodchips	1-200 km	97%	96%	97%	96%	95%	96%
	1-500 km	94%	93%	94%	93%	92%	93%
	500 - 2 000 km	91%	89%	91%	90%	87%	89%
	2 500 - 10 000 km	84%	80%	83%	80%	76%	79%
	> 10 000 km	69%	62%	67%	63%	55%	61%
3. Orchards grubbing-up woodchips	1-200 km	97%	96%	96%	96%	95%	96%
	1-500 km	94%	93%	94%	93%	91%	92%
	500 - 2 000 km	91%	89%	90%	89%	87%	89%
	2 500 - 10 000 km	84%	80%	82%	80%	76%	79%
	> 10 000 km	69%	62%	67%	63%	55%	60%

Table 37 : Example of emissions savings from wood waste for uses in cogeneration whose total energy efficiency is at least 75%

	Typical value			Default value		
	Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)	Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)
1-200 km	97%	96%	97%	96%	95%	96%

4. Wood waste mill A	1-500 km	95%	94%	94%	94%	92%	93%
	500 - 2 000 km	92%	91%	92%	91%	89%	90%
	2 500 - 10 000 km	86%	83%	86%	84%	80%	83%
	> 10 000 km	75%	70%	73%	70%	63%	68%
5 Wood waste mill B (BR1 and BR2)	1-200 km	97%	96%	96%	96%	95%	96%
	1-500 km	95%	93%	94%	93%	92%	93%
	500 - 2 000 km	92%	90%	92%	91%	88%	90%
	2 500 - 10 000 km	86%	83%	85%	83%	80%	82%
	> 10 000 km	75%	69%	73%	70%	63%	68%

Table 38 : Example of emissions savings from paper sectors for uses in cogeneration whose total energy efficiency is at least 75%

		Typical value			**Default value**		
		Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)	Heat alone (Coge)	Electricity alone (Coge)	Global (Coge)
6. Black liquor	on site	97%	96%	97%	97%	96%	96%	97%
7. Paper sludge	on site	97%	96%	97%	96%	96%	96%	97%

7 BIBLIOGRAPHY

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8 ANNEXES

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