Energy analysis of different scenarios for the management of wood biomass as a by-products in LCA

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Forest based products and by-products as a carbon storage.

Lignocellulosic biomass as a crucial pillar of bioeconomy.

European Green Deal:

- **Climate neutral Europe + SDG + Green Deal Industrial Strategy.**

Life cycle assessment (LCA) is a method that analyses the environmental impact of products or services throughout their life cycle – from the acquisition of raw materials to the end-of-life scenario in landfill.

It can also be combined with **net energy yield** (energy input-output analysis) to measure energy efficiency and estimate the amounts of energy consumed.

When analysing the mass flows of wood products in LCA, they are usually considered as **by-products**, which are often not considered relevant for the original analysis. In our study we decided to focus specifically on by-products.

Energy vs. Exergy vs. LCA analysis

Exergetic life cycle assessment (**ExLCA**):

Quantifying the environmental impacts associated with the **exergy losses** and exergy destruction within a system, process or product.

The potential to reduce environmental impacts by increasing exergy efficiency.

The first law of termomechanics: **the conservation of energy**

Calorific value vs. Enthalpy vs. Environmental Impacts

[MJ]

property of a thermodynamic system, the sum of the system's internal energy and the product of its pressure and volume

The aim of this study:

Energy evaluation of three possible scenarios of wood by-products management

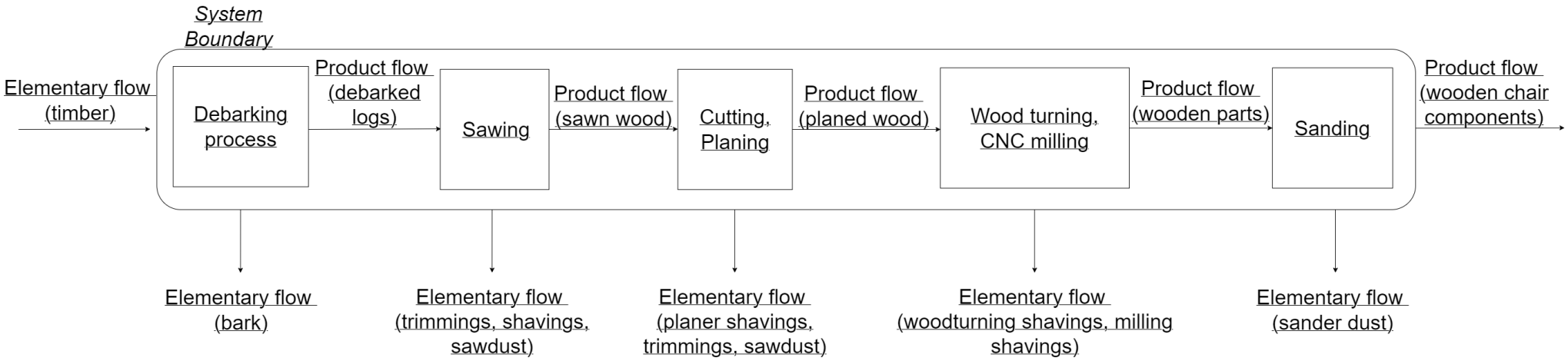
BIOECONOMY

LCA

ENERGY ANALYSIS

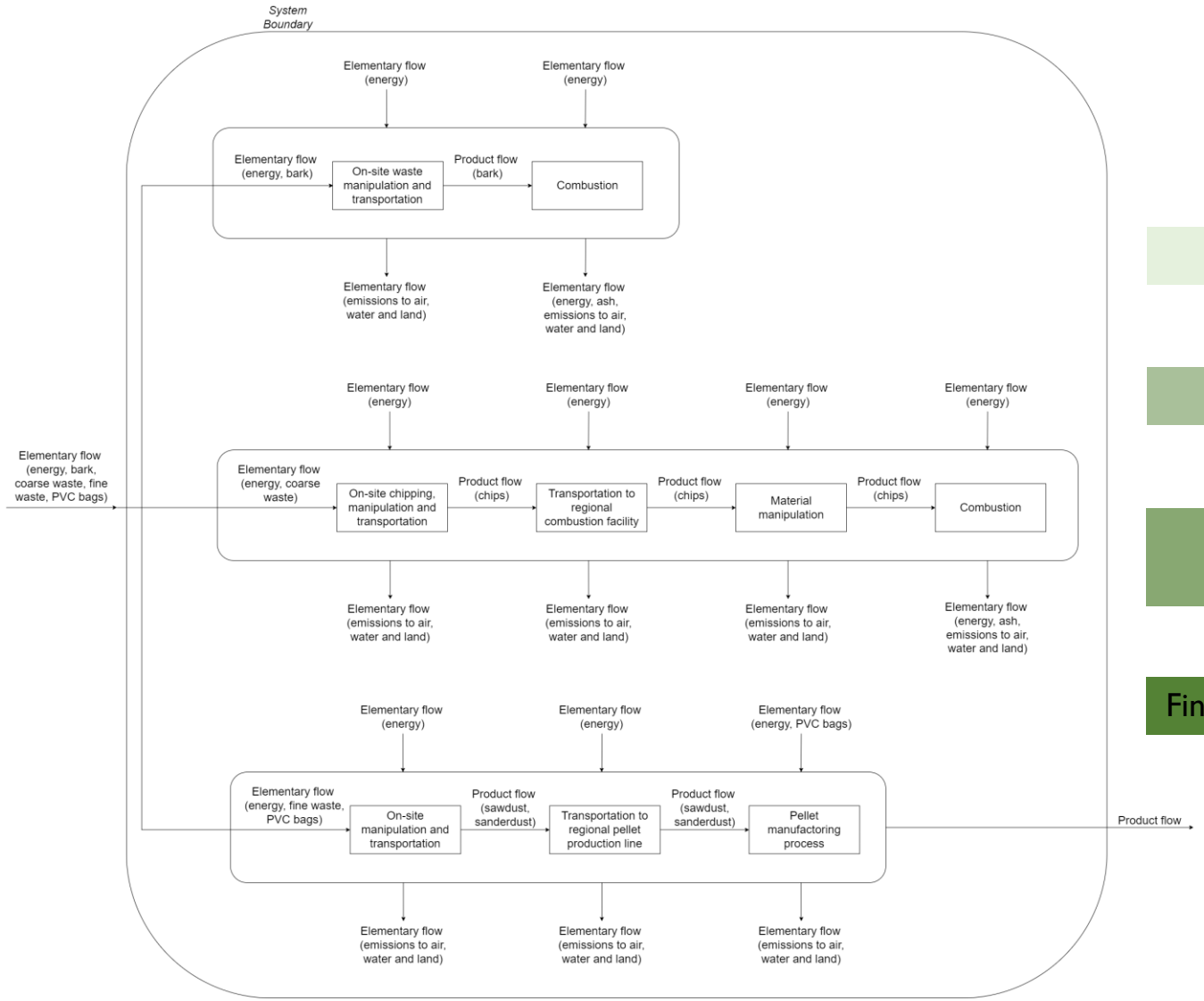
BIOMASS MANAGEMENT SCENARIOS

CONCLUSION



- differences in moisture content, density and chemical composition
- Functional unit: 1 tonne of lignin
- 28% of lignin in spruce wood
- Average EMC: 25%
- Total mass input: 4993 kg

Type of wooden waste	Percentage [%]	System input mass – dry wood [kg]	System input mass [kg]
Bark	12	487,2	592
Coarse waste	56	2273,6	2762
Fine waste	32	1199,2	1579



Reference scenario

Bark stream: burned at the debarking site

Coarse residual stream: chips production process

Fine residual stream: pellet production process

S1 (ref.)	Energy equivalent inputs [MJ]		Energy equivalent outputs [MJ]		
Human labour	50		-		
Diesel burned by forklift	22,26		-		
Diesel burned by lorry	117,21		-		
Chips shredding process	193,34		-		
Pellet production process	742,13		-		
Net combustion of bark	-		1817,44		
LHV chips	-		17621,56		
LHV pellets	-		19200,64		
	Renewable energy	Non-renewable energy	Renewable energy	Non-renewable energy	
	157,09	789,34	38639,64	-	Total scenario balance
Total	946,43		38639,64		37514,71

Transport, fuel consumption and human labour

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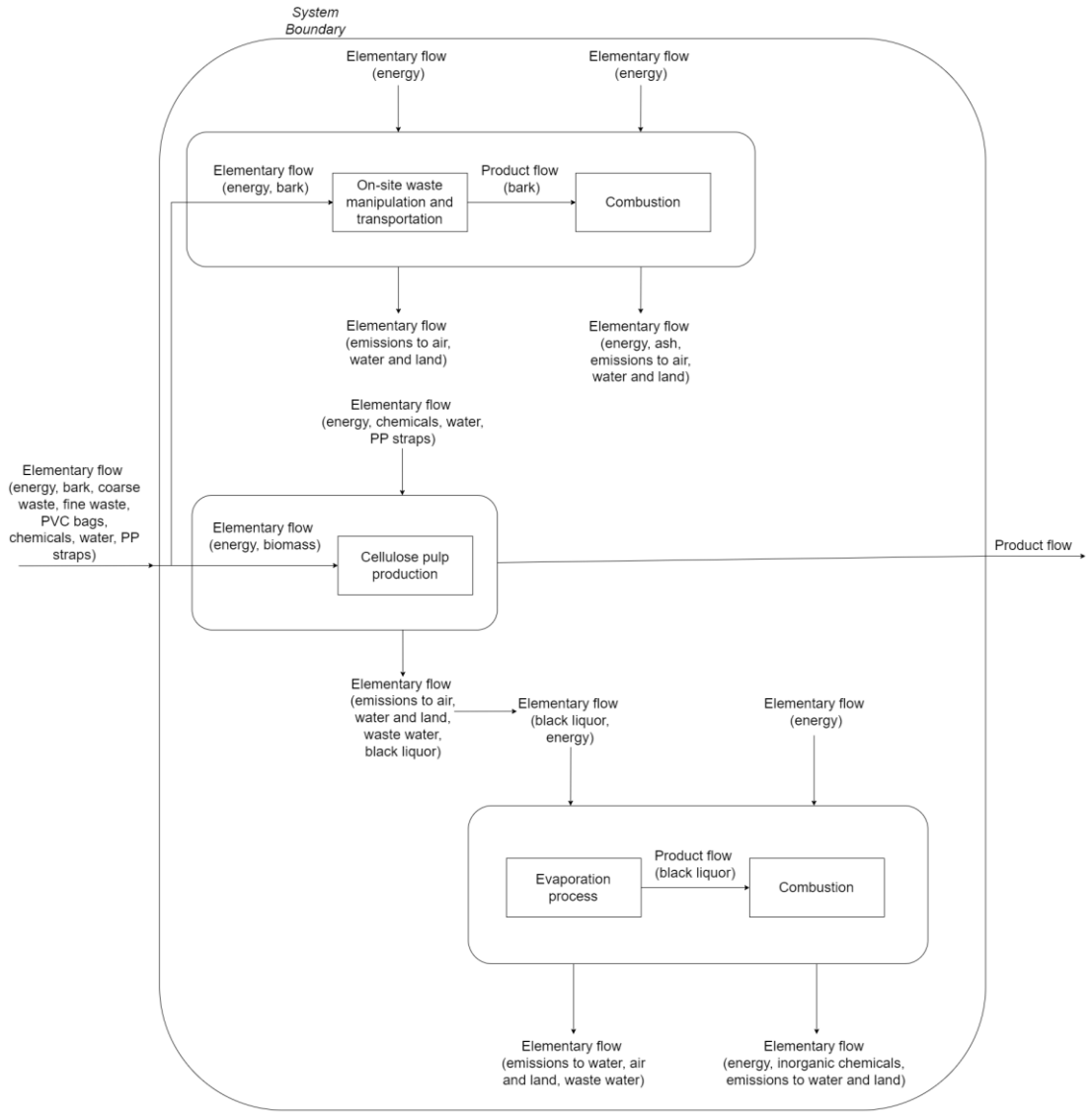

Cellulose production scenario

Bark stream: burned at the debarking site

Cellulose production flow: pulp production, black liquor is evaporated and then burnt by gasification

Highly self-sufficient: energy recovered from the black liquor covers ***74%*** *of the energy demand*

S2	Energy equivalent inputs [MJ]		Energy equivalent outputs [MJ]		
Human labour	47		-		
Diesel burned by forklift	11,91		-		
Diesel burned by lorry	314,71		-		
Cellulose production	20849,67		-		
Black liquor evaporation	12588,48		-		
Production of chemicals	201,94		-		
Net combustion of bark	-		1817,44		
LHV pulp	-		40479,83		
LHV black liquor	-		24739,86		
Chemicals recovery	-		163,91		
	Renewable energy	Non-renewable energy	Renewable energy	Non-renewable energy	
	6400,25	27613,46	67037,13	163,91	Total scenario balance
Total	34013,71		67201,04		33187,33

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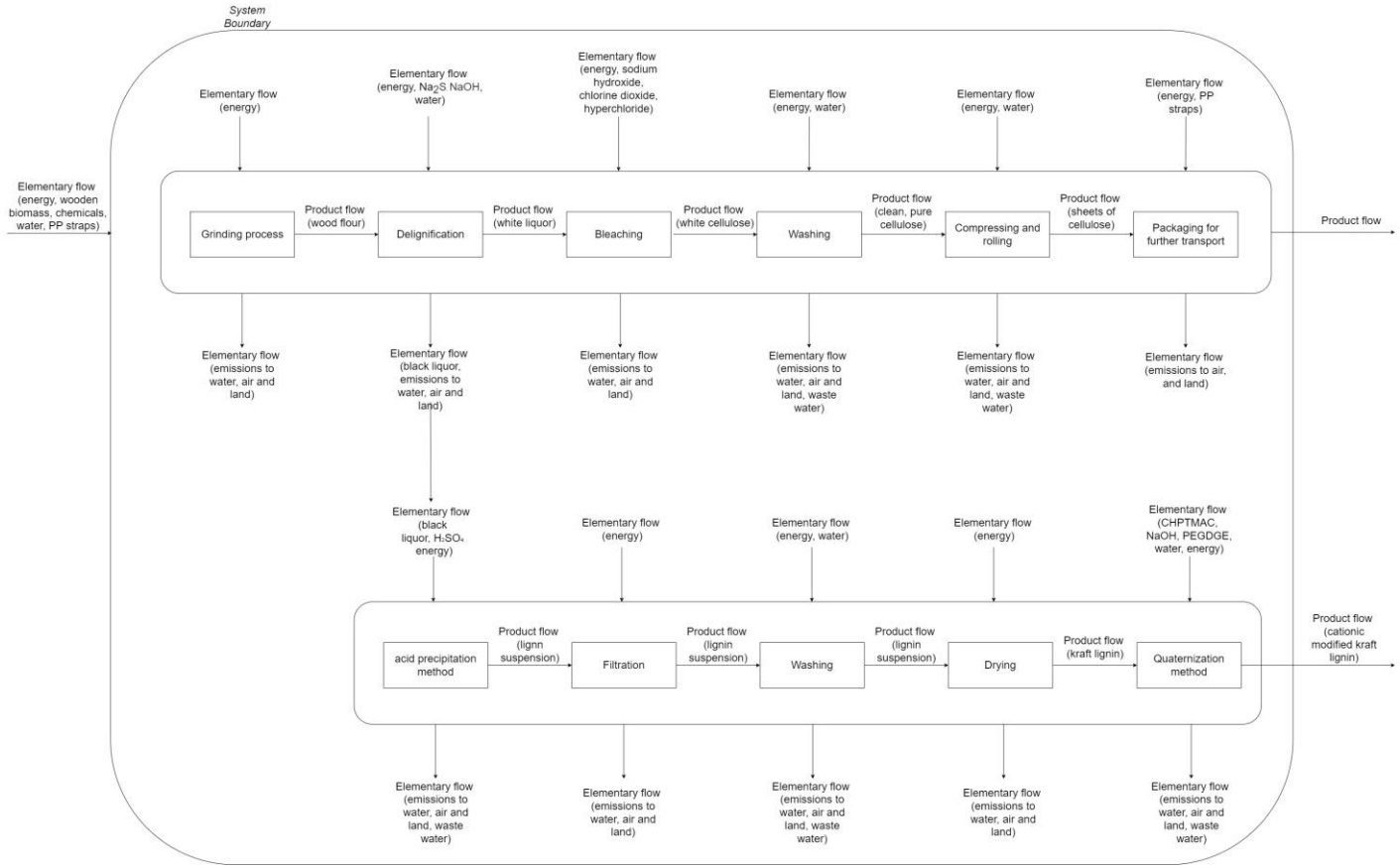
Chemicals - sulphur



Cellulose and lignin production scenario

Bark stream

Cellulose stream: pulp production, black liquoris is partially burned, part of lignin is extracted

S3	Energy equivalent inputs [MJ]		Energy equivalent outputs [MJ]		
Human labour	47		-		
Diesel burned by forklift	11,84		-		
Diesel burned by lorry	312,55		-		
Cellulose production	20706,57		-		
Black liquor evaporation	12502,08		-		
Production of chemicals	200,55		-		
Lignin extraction	6598,32		-		
Net combustion of bark	-		1817,44		
LHV pulp	-		40202		
LHV black liquor	-		22955,21		
LHV extracted lignin	-		1581,09		
Chemicals recovery	-		162,79		
	Renewable energy	Non-renewable energy	Renewable energy	Non-renewable energy	
	3248,83	26166,77	66555,75	162,79	Total scenario balance
Total	40378,92		66718,53		26339,62

Highly self-sufficient: energy recovered from the black liquor covers ***58%*** *of the energy demand*

Extraction rate of the lignin: ***80-90%****, the LHV of the black liquor drops below 10 MJ/kg and the whole process is no longer considered economic.*

The extracted lignin: raw material for ***value-added products*** *(chemicals)/ fuel to produce heat and bioelectricity (****cogeneration****).*

The main problem is managing the supply chain - collection, transport and storage. A possible solution would be to organise smaller **biomass plants at regional level** and a larger one at **national level**.

All the scenarios we have analysed have a positive energy balance, with the second and third scenarios being highly energy **self-sufficient**.

Scenarios consumes almost equal shares of renewable (**19%**) and non-renewable (**81%**) energy sources.

Scenarios number two and three are overall superior to the reference scenario, both from an **environmental and economic** point of view, as a significant part of the **biogenic carbon** is stored in high value-added products.

Thank you for your attention!