

# 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.



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# Life cycle assessment (LCA) is a method that analyses the environmental impact of products or services throughout their life **LCA** 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.

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BIOMASS MANAGEMENT SCENARIOS

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.

BIOECONOMY

ENERGY ANALYSIS

BIOMASS MANAGEMENT SCENARIOS 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

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The aim of this study:

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

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#### BIOECONOMY

<u>System</u>

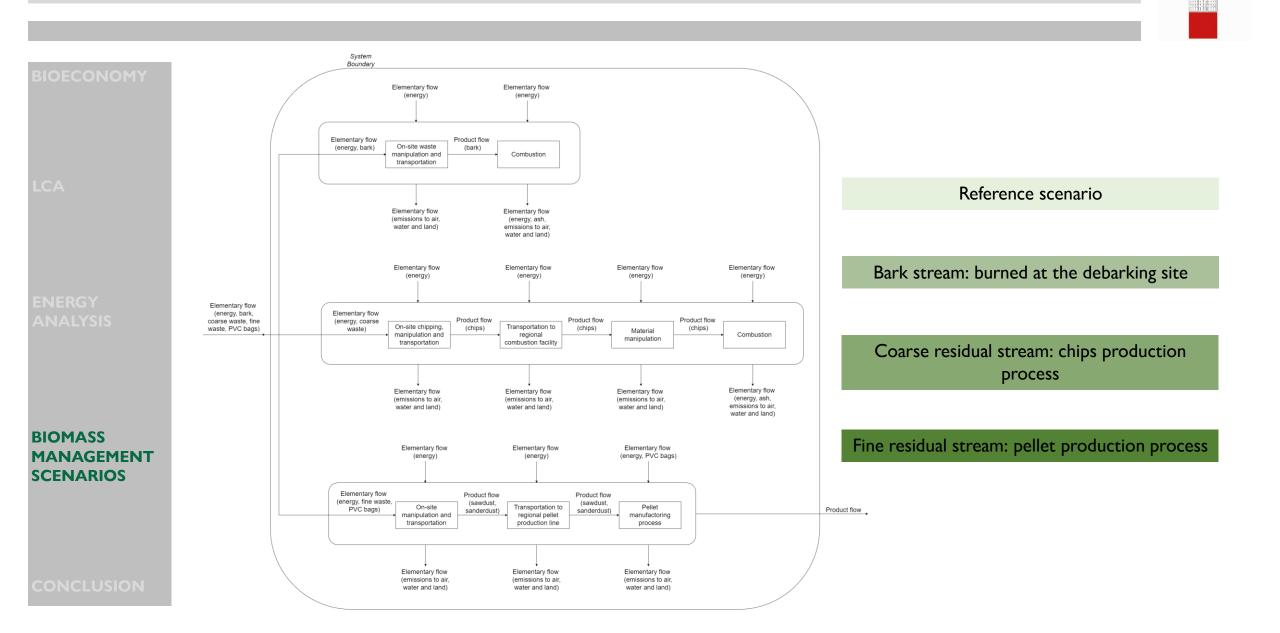
Boundary Product flow Product flow Product flow Elementary flow (debarked Product flow (wooden chair Product flow (timber) (wooden parts) Debarking Wood turning, Cutting, logs) (sawn wood) (planed wood) components) <u>Sanding</u> Sawing process Planing **CNC** milling Elementary flow Elementary flow Elementary flow Elementary flow Elementary flow (trimmings, shavings, (planer shavings, (woodturning shavings, milling (sander dust) (bark) sawdust) trimmings, sawdust) shavings) differences in moisture content, density and chemical  $\geq$ System input System input Type of wooden Percentage composition mass [kg] mass – dry wood [%] waste Functional unit: 1 tonne of lignin  $\geq$ [kg] 592 28% of lignin in spruce wood Bark 12 487,2  $\geq$ 56 2273,6 2762 **Coarse waste** Average EMC: 25%  $\geq$ 32 1199,2 1579 Fine waste Total mass input: 4993 kg  $\triangleright$ 

CONCLUSION

MANAGEMENT

**SCENARIOS** 

**BIOMASS** 



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#### BIOECONOMY

ENERGY ANALYSIS

#### BIOMASS MANAGEMENT SCENARIOS

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

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#### BIOECONOMY

ENERGY

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| Chips shredding<br>process   | 193,34                           |                             | -                                 |                             |                           |
| Pellet production process    | 742,13                           |                             | -                                 |                             |                           |
| Net combustion of bark       | -                                |                             | 1817,44                           |                             |                           |
| LHV chips                    | -                                |                             | 17621,56                          |                             |                           |
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| Total                        | 946,43                           |                             | 38639,64                          |                             | 37514,71                  |

Transport, fuel consumption and human labour

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**BIOMASS** MANAGEMENT **SCENARIOS** 

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| chips shiedding<br>process   | 193,34                           |                             | -                                 |                             |                           |
| Pellet production<br>process | 742,13                           |                             | -                                 |                             |                           |
| Net combustion of<br>bark    | -                                |                             | 1817,44                           |                             |                           |
| LHV chips                    | -                                |                             | 17621,56                          |                             |                           |
| LHV pellets                  | -                                |                             | 19200,64                          |                             |                           |
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|                              | 157,09                           | 789,34                      | 38639,64                          | -                           | Total scenario<br>balance |
| Total                        | 946,43                           |                             | 38639,64                          |                             | 37514,71                  |



Transport, fuel consumption and human labour

Production processes

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LCA

ENERGY ANALYSIS

BIOMASS MANAGEMENT SCENARIOS

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



Transport, fuel consumption and human labour

Production processes

Wood biomass

Energy equivalent outputs

[MJ]

-

-

balance

Transport, fuel consumption and human labour

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Production processes

Wood biomass

**BIOMASS** MANAGEMENT **SCENARIOS** 

Diesel burned by 117,21 lorry Chips shredding 193,34 proces Pellet production 742,13 process Net combustion of 1817,44 ban 17621,56 LHV chins -19200,64 LHV pellets -Non-Non-Renewable Renewable renewable renewable energy energy energy energy Total scenario 38639,64 157,09 789,34 -38639,64 Total 946,43 37514,71

Energy equivalent inputs

[MJ]

50

22,26

S1 (ref.)

human labour

Diesel burned by

forklift

System Boundary Elementary flow Elementary flow (energy) (energy) Elementary flow Product flow (bark) (energy, bark) On-site waste Cellulose production scenario Combustion manipulation and transportation Elementary flow Elementary flow (emissions to air, (energy, ash, water and land) emissions to air, water and land) Elementary flow Bark stream: burned at the debarking site (energy, chemicals, water, PP straps) Elementary flow (energy, bark, coarse waste, fine waste, PVC bags, Elementary flow chemicals, water, PP (energy, biomass) Product flow straps) Cellulose pulp production Cellulose production flow: pulp production, black liquor is evaporated and then burnt by gasification Elementary flow (emissions to air, Elementary flow Elementary flow water and land, (black liquor, (energy) waste water, energy) black liquor) **BIOMASS** MANAGEMENT **SCENARIOS** Product flow (black liquor) Evaporation Combustion process Elementary flow Elementary flow (emissions to water, air (energy, inorganic chemicals,

emissions to water and land)

and land, waste water)

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*Biotebniška* fakulteta BIOECONOMY

ENERGY ANALYSIS

BIOMASS MANAGEMENT SCENARIOS

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

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

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#### BIOECONOMY

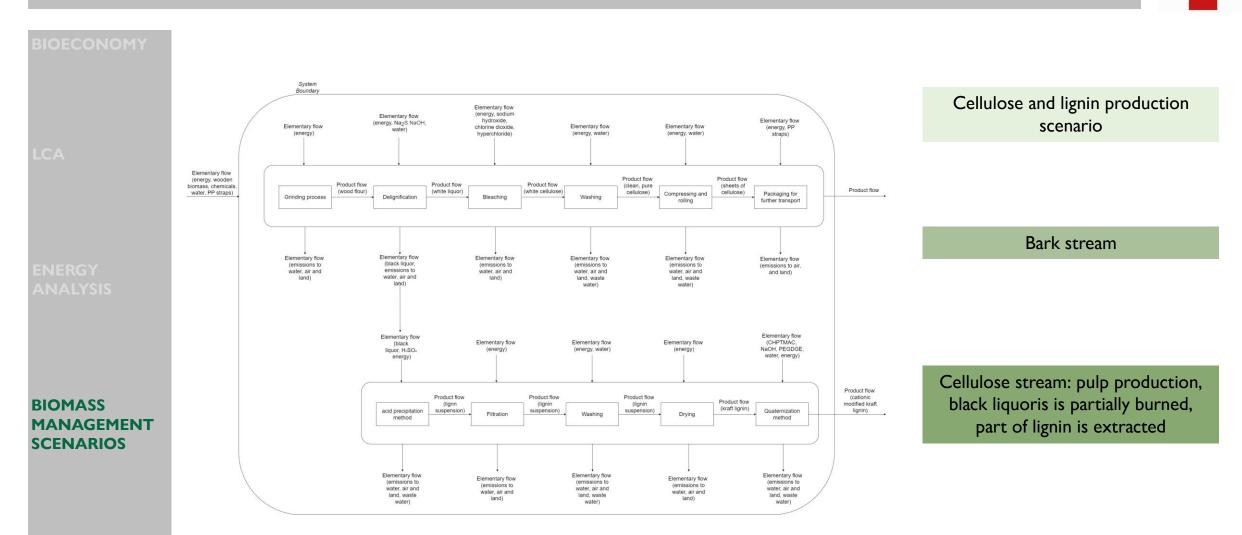
ANALYSIS

#### BIOMASS MANAGEMENT SCENARIOS

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

Chemicals - sulphur

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BIOECONOMY

ENERGY ANALYSIS

BIOMASS MANAGEMENT SCENARIOS

Energy equivalent inputs Energy equivalent outputs S3 [MJ] [MJ] 47 Human labour -Diesel burned by 11.84 forklift Diesel burned by 312.55 lorry 20706,57 Cellulose production -Black liquor 12502.08 evaporation Production of 200.55 chemicals 6598,32 Lignin extraction Net combustion of 1817,44 bark LHV pulp 40202 -LHV black liquor 22955,21 -LHV extracted lignin 1581.09 -Chemicals recovery 162,79 Non-Non-Renewable Renewable renewable renewable energy energy energy energy Total scenario 3248,83 26166.77 66555,75 162,79 balance Total 40378.92 66718.53 26339.62

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

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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 considred 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.<br>A possible solution would be to organise smaller <b>biomass plants at regional</b><br><b>level</b> and a larger one at <b>national level</b> . |
|--|
| All the scenarios we have analysed have a positive energy balance, with the second and third scenarios being highly energy <b>self-sufficient</b> .  |
|  |

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.



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## Thank you for your attention!



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