Life cycle assessment of different energy production scenarios in a paper and pulp mill

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15.06.2022
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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 764713
Challenges of the Paper and Pulp Industry

- High energy intensity
- Rely on fossil resources
- Waste/secondary raw materials
Aim of this research

- What are the **environmental advantages/limitations** of different energy production scenarios in the P&P industry compared to the benchmark process?

Heat and electricity requirements of a pulp & paper mill located in South Africa
Life cycle assessment (LCA) framework

Goal And Scope

• To ‘prospectively’ assess the environmental performance of different energy production scenarios in a P&P mill located in South Africa.
• To support stakeholders in the decision-making about alternatives for energy production in the P&P mill.

Scope ➔ Cradle to gate (Extraction of wood until pulp production)

Functional unit: 1 kilogram of unbleached pulp (soft and hardwood) at the factory gate in a P&P mill located in South Africa.

Life Cycle Inventory

• Data collected from P&P mill in South Africa.
• Background data ➔ Ecoinvent V3.7

Allocation method

• Economic allocation ➔ Forestry products

Impact Assessment

• Global Warming Potential (GWP)
• Fossil depletion potential (FDP)
• Agricultural land occupation (ALOP)
• Water depletion potential (WDP)
Environmental impacts of benchmark scenario

Global Warming Potential

- CO2 emissions
- Natural gas
- Electricity prod
- Sludge
- Others

Agricultural Land Occupation Potential

- Fossil depletion Potential

- Water Depletion Potential

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Environmental impacts of benchmark scenario

Global Warming Potential

- CO2 emissions
- Natural gas
- Energy production
- Sludge
- Others

Fossil depletion Potential

- Hard coal
- Crude oil
- Natural gas
- Others

Agricultural Land Occupation Potential

- Natural gas
- Coal
- Eucalyptus & Pine Bark
- Wood Logs
- Makeup Chemicals

Water Depletion Potential

- Gas Turbine
- Power Boiler
- Screen rejects
- Woodyard
- Wood chips
- Lime recovery
- Chemical Recovery
- Exhausted BL
- Energy Recovery
- Black liquor
- White Liquor
- Unbleached fibre

System boundary

- Green Dregs
- Slaker Grits
- Sludge

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Environmental impacts of benchmark scenario

Global Warming Potential

- CO2 emissions
- Natural gas
- Electricity prod
- Sludge
- Others

- Benchmark

Fossil depletion Potential

- Hard Coal
- Crude Oil
- Natural gas
- Others

- Benchmark

Agricultural Land Occupation Potential

- Pulpwood, hardwood
- Pulpwood, softwood
- Forest residues

- Benchmark

Water Depletion Potential

- Green Dregs
- Slaker Grits
- Sludge

Energy Requirements

- Natural Gas
- Coal
- Eucalyptus & Pine Bark

Power Boiler

- Screen rejects
- Wood chips
- Woodyard

Gas Turbine

- White Liquor
- Burnt Lime
- Lime recovery

Chemical Recovery

- Exhausted BL
- Black liquor

Energy Recovery

- Hardwood and Softwood Fibreline

System boundary

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Environmental impacts of benchmark scenario

Global Warming Potential

- CO2 emissions
- Natural gas
- Electricity prod.
- Sludge
- Others

Fossil depletion Potential

- Hard Coal
- Crude Oil
- Natural gas
- Others

Agricultural Land Occupation Potential

- Pulpwood, hardwood
- Pulpwood, softwood
- Forest residues

Water Depletion Potential

- Others
- Natural gas
- Fischer-Tropsch
- Methyl Oil Ester
- Pulpwood, hardwood
- Sugarcane

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Scenario Analysis

Scenario 1
- Natural Gas
- Screen Rejects
- Forestry Residues
- Coal
- Gas Turbine
- Power Boiler
- Gasifier
- Synthesis Gas
- Energy requirements
- Lime recovery

Scenario 2
- Natural Gas
- Screen Rejects
- Forestry Residues
- Coal
- Gas Turbine
- Power Boiler
- Gasifier
- Synthesis Gas
- Energy requirements
- Lime recovery

Scenario 3
- Eucalyptus tree tops
- Natural Gas
- Screen Rejects
- Forestry Residues
- Coal
- Gas Turbine
- Power Boiler
- Gasifier
- Synthesis Gas
- Energy requirements
- Lime recovery

Scenario 4
- Sugarcane Bagasse
- Natural Gas
- Screen Rejects
- Forestry Residues
- Coal
- Gas Turbine
- Power Boiler
- Gasifier
- Synthesis Gas
- Energy requirements
- Lime recovery

Global Warming Potential
- CO2 emissions
- Natural gas
- Electricity prod.
- Sludge
- Others

Fossil Dep
- Hard Coal
- Crude Oil
- Natural gas

*No biogenic carbon was included in the modeling*
Scenario Analysis

Scenario 1
- Natural Gas
- Screen Rejects
- Gas Turbine
- Power Boiler
- Energy requirements
- Lime recovery

Scenario 2
- Forestry Residues
- Natural Gas
- Screen Rejects
- Gas Turbine
- Gasifier
- Energy requirements
- Lime recovery

Scenario 3
- Eucalyptus tree tops
- Forestry Residues
- Natural Gas
- Screen Rejects
- Gas Turbine
- Gasifier
- Energy requirements
- Lime recovery

Scenario 4
- Sugarcane Bagasse
- Forestry Residues
- Natural Gas
- Screen Rejects
- Gas Turbine
- Gasifier
- Energy requirements
- Lime recovery

Agricultural Land Occupation Potential

- Benchmark
- Sc.1
- Sc.2
- Sc.3
- Sc.4

Fuels
- Electricity
- Machinery
- Agrochemicals

Cultivation & Harvesting
- Branches
- Stumps
- How are these emissions distributed?

Roundwood

Multiproduct portfolio!
Scenario Analysis

Scenario 1
- Natural Gas
- Screen Rejects
- Gas Turbine
  - Power Boiler
  - Gasifier
  - Synthesis Gas
  - Energy requirements
  - Lime recovery
- Forestry Residues

Scenario 2
- Natural Gas
- Screen Rejects
- Gas Turbine
  - Power Boiler
  - Gasifier
  - Synthesis Gas
  - Energy requirements
  - Lime recovery
- Forestry Residues

Scenario 3
- Natural Gas
- Screen Rejects
- Gas Turbine
  - Power Boiler
  - Gasifier
  - Synthesis Gas
  - Energy requirements
  - Lime recovery
- Forestry Residues
  - Eucalyptus tree tops
  - Suckarcane Bagasse

Scenario 4
- Natural Gas
- Screen Rejects
- Gas Turbine
  - Power Boiler
  - Gasifier
  - Synthesis Gas
  - Energy requirements
  - Lime recovery
- Forestry Residues

Water Depletion Potential

- Others
  - Natural gas, Fischer-Tropsch
  - Methyl Oil Esters
  - Pulwood, hardwood
  - Sugarcane

Benchmark Sc.1 Sc.2 Sc.3 Sc.4

- Natural gas, Russia
- Natural gas, Russia
- Liquified Natural gas
- Natural gas, Russia
Conclusions

• **Forest residues (tree branches and top trees) and sugarcane bagasse** are good alternatives for energy production in P&P mill → Mitigate negative impacts (most impact categories).

• Impacts on **land use** → Methodological choices (allocation approaches).
• Impacts on **water use** → Other sources of natural gas and crop irrigation.

• **Natural Gas Prod.** in South Africa was the hotspot in most categories → Biomass availability to supply extra energy demand.
Thanks for listening!

Any question/comment you can contact me

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Get in touch! 😊