Life cycle carbon analysis of packaging products containing purposely grown non-wood fibers

Antonio Suarez, Ashok Ghosh, Fritz Paulsen, Peter Hart

WestRock

Agenda

- Motivation of this work
- Objectives
- Methodology
- Results
  - Life Cycle Carbon Analysis (LCCA) of switchgrass
  - Life Cycle Carbon Analysis (LCCA) of linerboard containing switchgrass – Cradle-to-gate

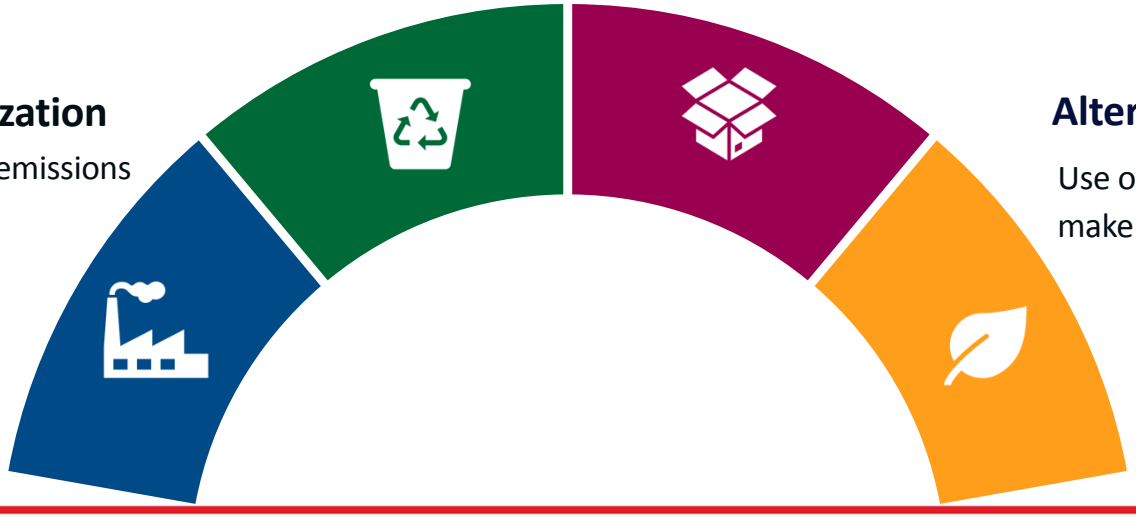
Sustainability trends in the pulp and paper industry - Packaging

Recyclability

Increase in recyclability of products

Plastic replacement

Innovation to substitute plastic



Decarbonization

Reduction in carbon dioxide emissions

Alternative materials

Use of non-conventional fibers to make paper (i.e., non-woods)

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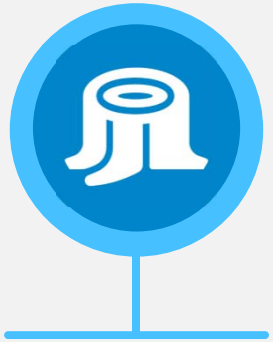
Non-wood fibers

PERCEPTION

- Increase in customers' attention on non-wood fibers **perceived by them** to offer unique and positive benefits compared to wood sources.

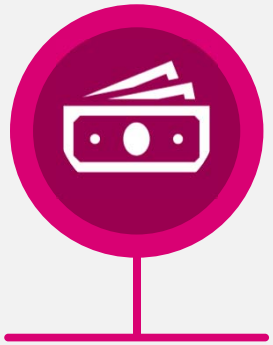


MARKETING

- Marketing of non-wood fibers has been focused on deforestation.
- The P&P industry in North America does not contribute to deforestation[1-3].

SUPPLY CHAIN

- There is not enough national supply of non-wood fibers (very region specific - unstable).
- Possible supply from from other countries (China: Bamboo…).



COST

- Higher cost associated with non-wood fibers.

RECYCLABILITY

- Recyclability of some non-wood fibers has been reported to be lower than wood fibers[4].

[1]Two Sides. (2018). "In North America, we grow many more trees than we harvest." https://twosidesna.org/paper-production-supports-sustainable-forest-management/ (accessed in April 2023). [2]Fisher International. (2020). "Pulp & Paper Products Consume 50% of Harvested Timber in US." https://www.fisheri.com/blog/pulp-paper-products-consume (accessed in April 2023). [3]Forest2Market. (2017). "Historical Perspective on the Relationship between Demand and Forest Productivity in the US South." https://www.forest2market.com/hubfs/2016_Website/Documents/20170726_Forest2Market_Historical_Perspective_US_South.pdf (accessed in April 2023). [4]Jirarotepinyo et al. (2022). The Impact of multiple recycle loops on the yield and properties of softwood kraft fibers and of non-wood fibers for packaging TAPPI PEERS Conference Proceedings.

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Switchgrass: Current status

- Non-woods represent ca. 1% of the global pulp production (straw and bagasse are the most used residues)[1].
- In the US, non-wood pulp is less than 0.1% of the total pulp production
  - Switchgrass and sorghum are the most used purposely grown non-wood fibers[1].
  - Soda, kraft, neutral sulfite semi-chemical and chemi-mechanical pulping are used to process these materials[1].

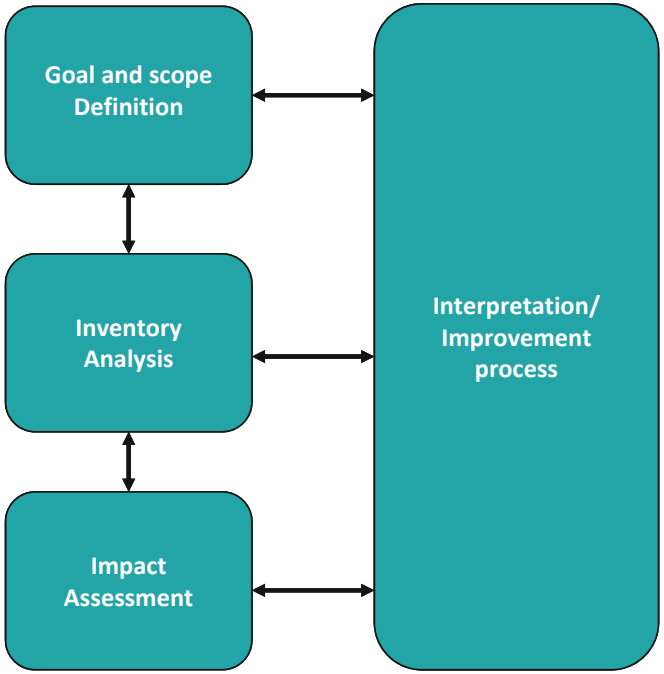
[1]FisherSolve Next, 2022

Objectives

- Evaluate the life cycle carbon analysis (LCCA) of switchgrass produced in the US compared to non-wood residues.
- Evaluate the life cycle carbon analysis (LCCA) of packaging made from switchgrass.

Opportunity: Evaluate the environmental sustainability of non-wood fibers transformed into the same product in the same geography (United States), under more realistic processes, and with the same LCA methodology.

Methodology



ISO 14040 Framework[1]

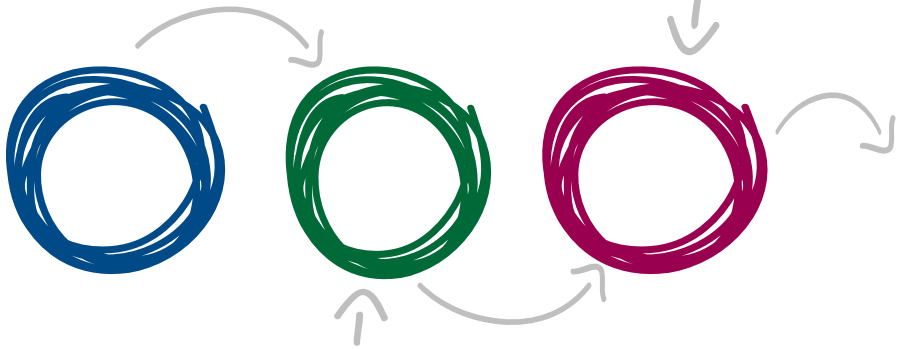
Process flowsheet

- Product flows
- Emissions
- Raw materials
- Energy flows

Life cycle impact analysis

Characterization factors to convert elementary flows into impacts

- **Global warming**
- *Ozone depletion*
- *Acidification*
- *Eutrophication*
- *Smog*
- *Human health*
- *Ecotoxocity*
- *Human health*
- *Land-use*
- *Others*



Database of processes with inputs and outputs

Life cycle inventory

[1] International Organization for Standardization, "ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework." p. 20, 2006

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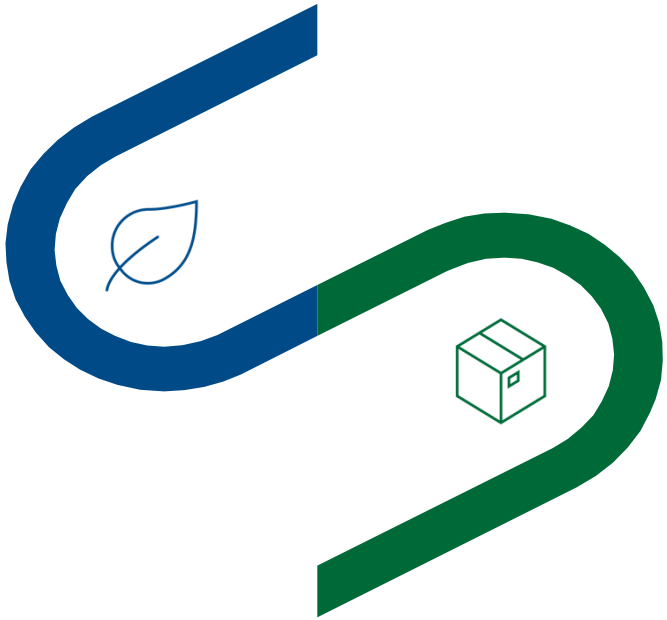
Methodology

1

- **Goal:** Evaluate the GWP of switchgrass and compare to results for wheat straw and sugarcane bagasse.
- **Scope:**
  - **Boundaries:** Cradle-to-gate
  - **Functional unit:** 1 dry ton
  - **Data source:** USLCI, and Ecoinvent



2

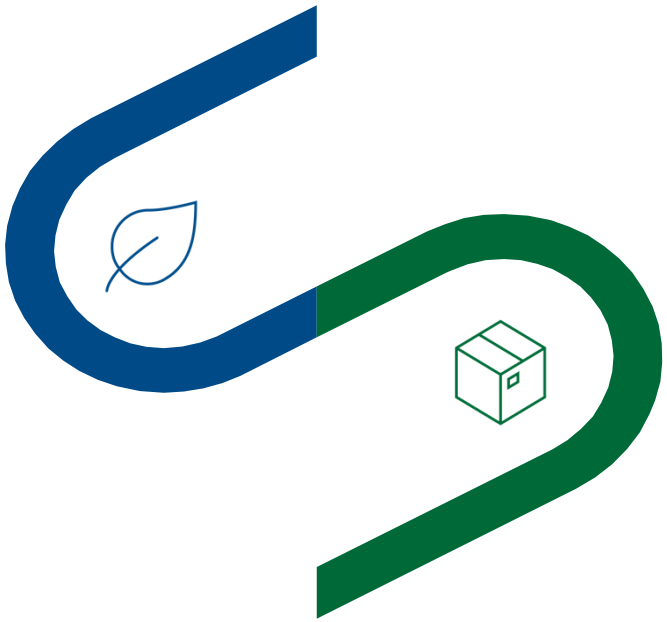
- **Goal:** Evaluate the impact on GWP of replacing wood fiber with non-wood mechanical wet lap pulp in linerboard and corrugated medium. The replacement rate was 30%.
- **Scope:**
  - **Boundaries:** Cradle-to-gate
  - **Functional unit:** 1 ton of paper
  - **Data source:** USLCI, Ecoinvent and FisherSolve Next

LCCA of switchgrass, wheat straw and bagasse

1

- **Goal:** Evaluate the GWP of switchgrass compared to selected non-wood residues (wheat straw and bagasse).

- **Scope:**
  - **Boundaries:** Cradle-to-gate
  - **Functional unit:** 1 dry ton
  - **Data source:** USLCI, Ecoinvent, and literature



For wheat straw and bagasse:

- How to deal with multi-functional non-wood fiber systems*? Allocation methods:
  - **Cut-off (CO):** No emissions allocated to Ag residues (e.g. straw, bagasse).
  - **System expansion (SE):** Additional emissions due to removing Ag residues from original system are allocated to Ag residues (e.g. additional fertilizer, fuels).
  - **Mass allocation (MA):** Emissions are allocated based on mass basis (main product and Ag residues).
  - **Economic allocation (EA):** Emissions are allocated based on economic basis

*Multi-functional systems produce more than one product. Therefore, total emissions need to be shared. Examples include wheat and wheat straw production or sugar, molasses and sugarcane bagasse production

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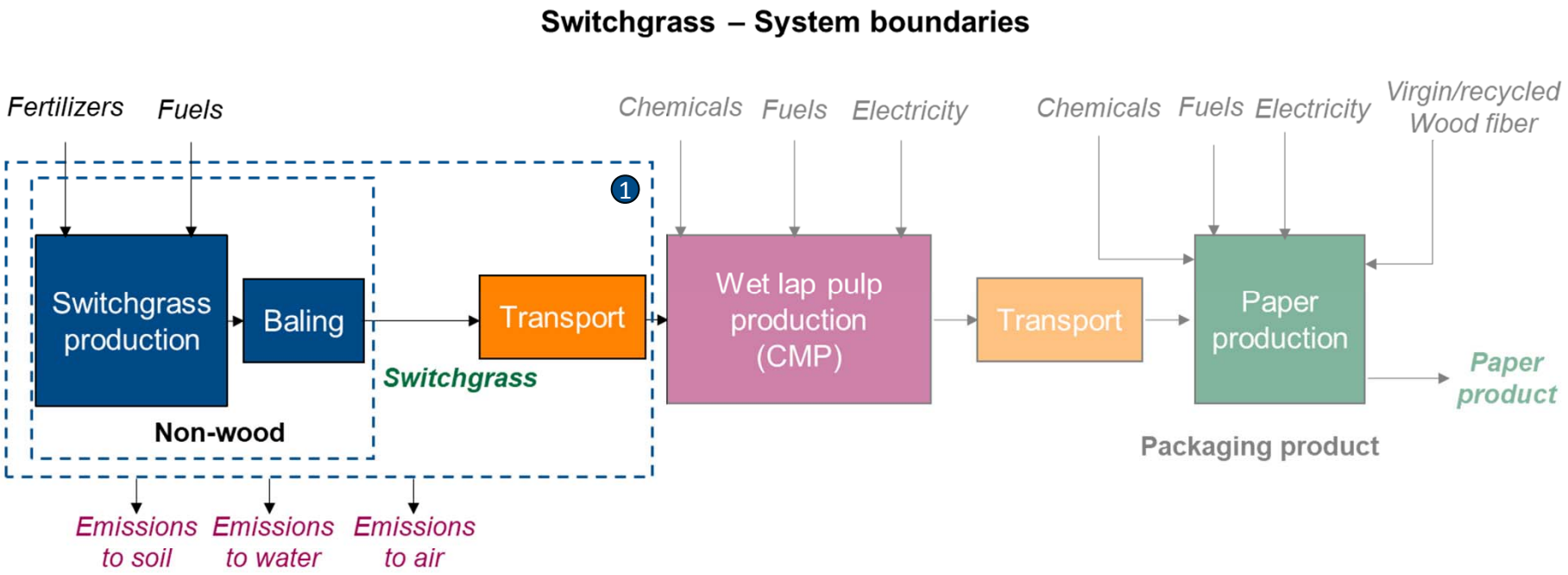
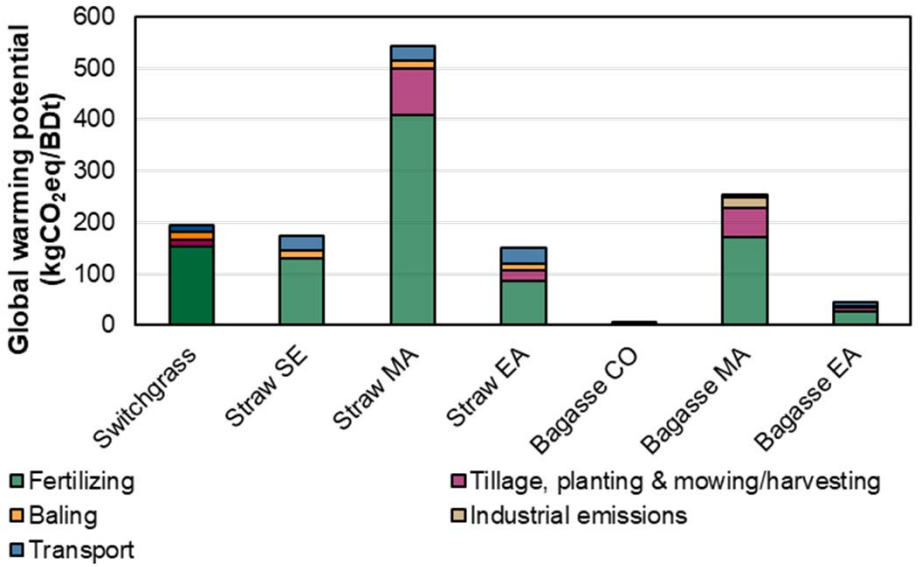
LCCA of switchgrass



System boundaries for LCCA of switchgrass

LCCA of switchgrass

- Fertilizers (soil emissions) are the largest GWP contributors for switchgrass.
- Results for non-wood residues are highly dependent on allocation methods.
  - CO[a]: Lower impacts. Only handling and transportation emissions are accounted for.
  - MA[b]: Higher impacts. Primary product and residue share burdens based on mass.
- Switchgrass presented higher GWP than residues (except for MA).
- Lower transportation emissions for switchgrass are related to lower distances and higher capacity truck utilization (bulk density).



Global warming potential for switchgrass compared to selected non-wood residues

[a]CO: Cut-off; [b]MA: Mass allocation ; [c]SE: System Expansion; [d]EA: Economic allocation

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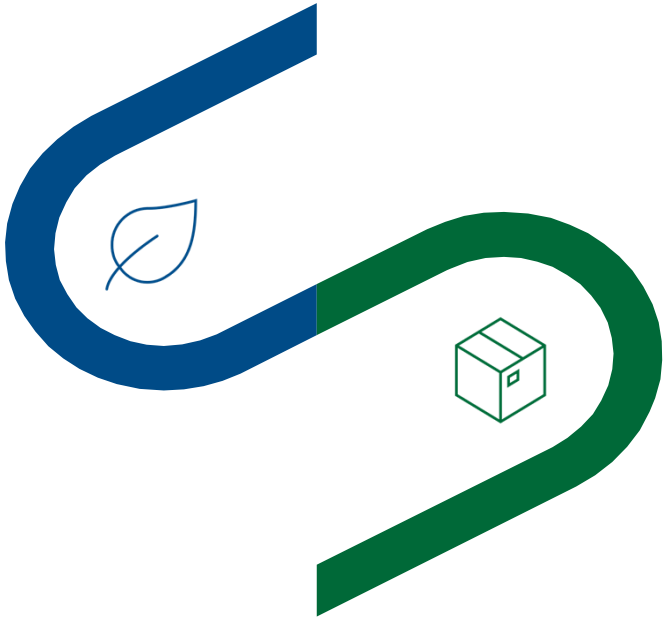
LCCA of linerboard from switchgrass

2

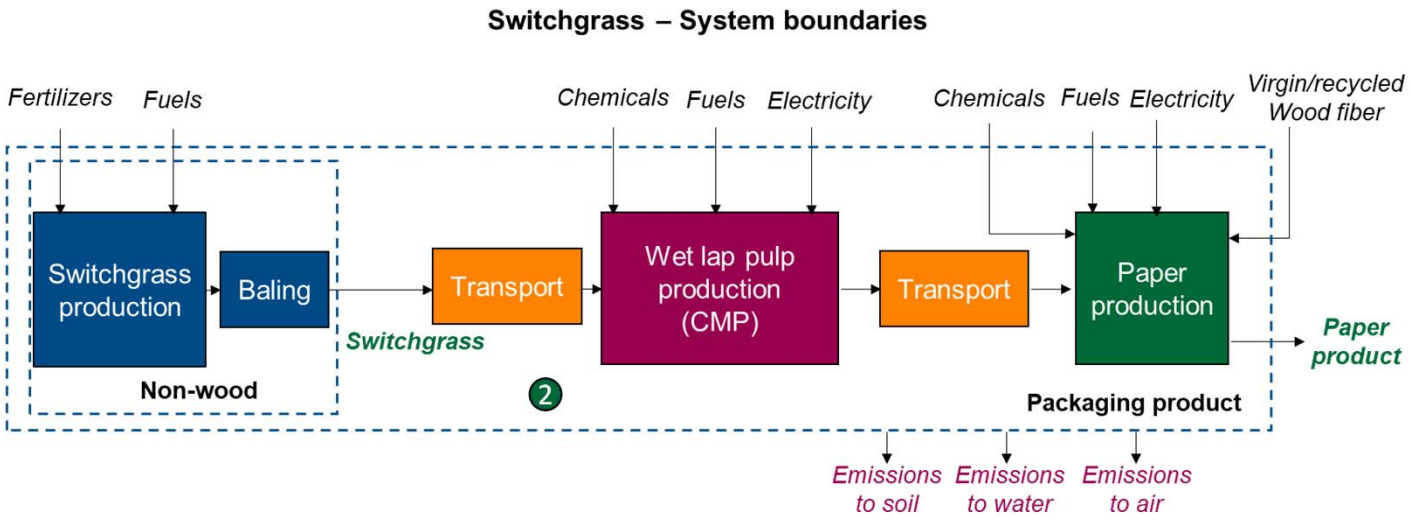
- **Goal:** Evaluate the impact on GWP of replacing wood fiber (30%) with non-wood mechanical wet lap pulp in linerboard and corrugated medium.

- **Scope:**
  - **Boundaries:** Cradle-to-gate.
  - **Functional unit:** 1 ton of paper.
  - **Data source:** USLCI, Ecoinvent and FisherSolve Next.

- **Main assumptions:**
  - Geography focuses on Southeast US (SEUS).
  - Data for wet lap non-wood pulp was obtained from FisherSolve Next and benchmarked against literature data.
  - Generic Ecoinvent processes were used for paper and modified based on wood substitution.



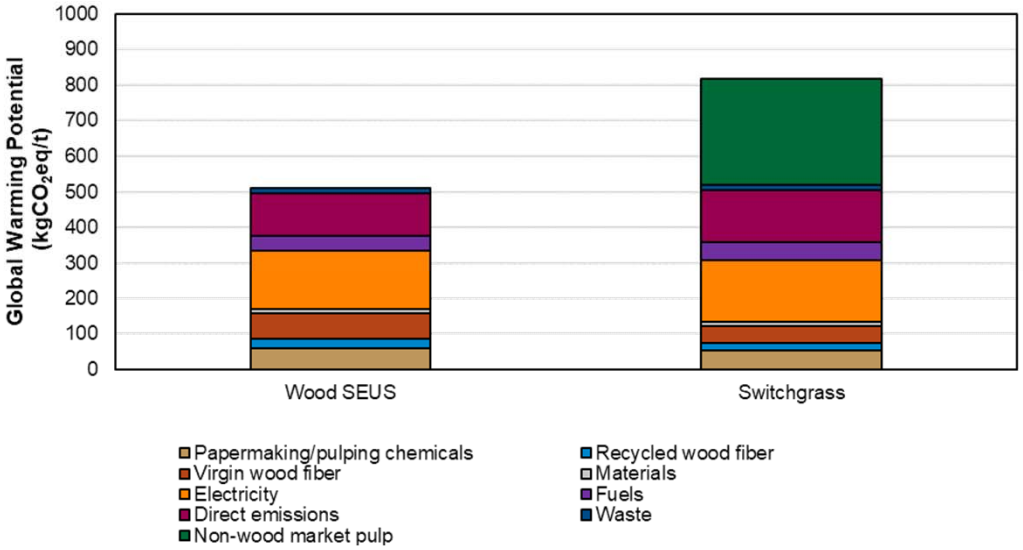
LCCA of linerboard from switchgrass



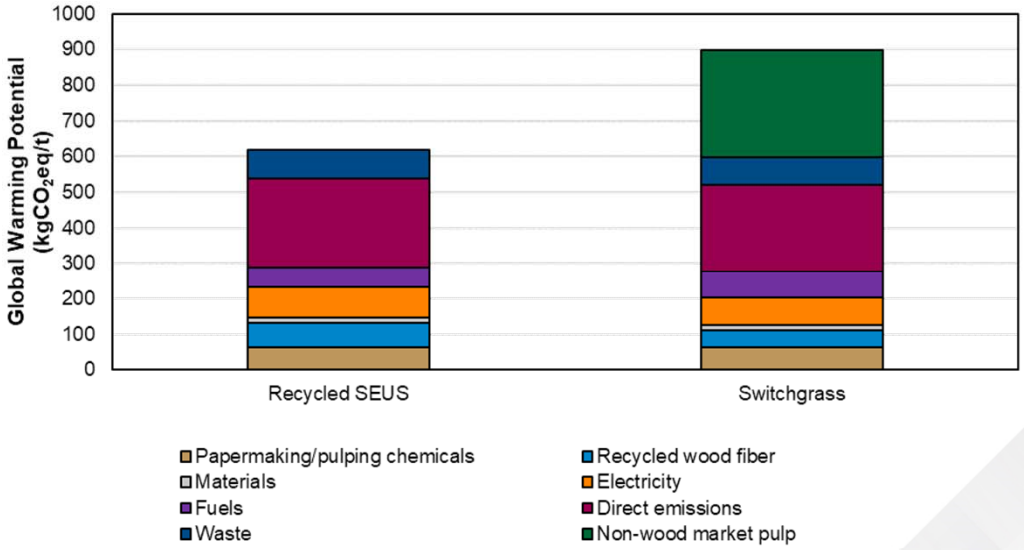
System boundaries for LCCA of paper made from switchgrass

LCCA of linerboard from switchgrass

- Overall increase in GWP when replacing virgin and recycled fiber with wet-lap non-wood pulp.
- Non-wood pulp is the largest contributor to GWP.



Global warming potential for virgin linerboard containing switchgrass pulp



Global warming potential for recycled linerboard containing switchgrass residue pulp

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LCCA of linerboard from switchgrass

- LCA is dependent on life cycle inventories and assumptions.
- Sensitivity analyses allow to mitigate uncertainty and understand the impact of data variation.

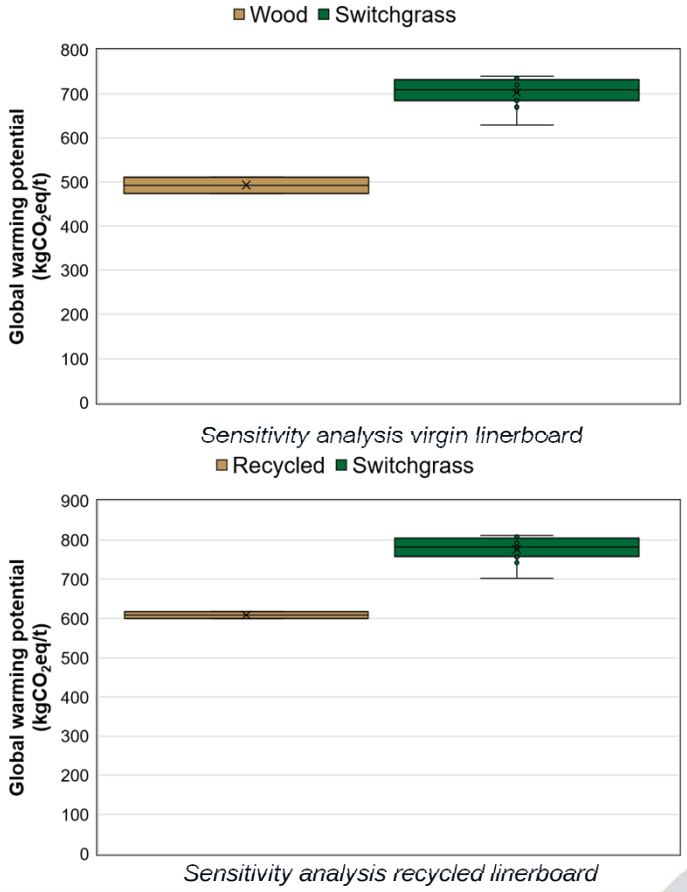
Parameters for sensitivity analysis of non-wood pulp

Variable	Negative variation from the average scenario	Positive variation from the average scenario
Chemical charge	-35%[1]	+35%[1]
Power purchased	-10%	+50%[2]
External fuel usage	-20%[2]	+20%[2]
Yield	-15%[1]	+25%[2]
Pulping chemical	Potassium hydroxide[1] or sodium hydroxide[2]	
Allocation for liquor residue/by-product	Cut-off and mass allocation	

[1]Fisher International, "FisherSolve® Next," Fisher International, Charlotte, NC, United States.; [2]Hart, P., TAPPI J. 19(1): 41(2020). https://doi.org/10.32964/TJ19.1.41

LCCA of linerboard from switchgrass

- LCA results highly dependent on life cycle inventory assumptions.
- GWP of non-wood-based packaging between 15-50% higher than benchmarks.
- The most influent factors are:
  - Allocation methods around by-products of non-wood pulping.
  - Type of pulping chemicals.
  - Chemical charges.



Conclusions

- The environmental impact of non-wood residues and derived products highly depends on allocation methods. This is not the case for switchgrass (all the burdens are allocated).
- Under the studied conditions, increased GWPs were observed when conventional kraft or recycled fiber was replaced with non-wood wet lap pulp. Intermediate non-wood wet-lap pulp was the driver for this impact.
- Sensitivity analyses showed that assumptions around the production of pulp greatly influenced results. Thus, the GWPs of packaging products containing residues can be 15%-50% higher than benchmarks under the studied scenarios.

Thank you

Antonio Suarez, Ashok Ghosh, Fritz Paulsen, Peter Hart

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