Enhancing consistency in consequential life cycle inventory through material flow analysis

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Agenda

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III. Objectives
IV. Building Material Estimation
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   b) Results
   c) Sensitivity analysis
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VI. Conclusion
Quebec: Wood Charter

The government provides a roadmap to increase the use of wood in non-residential (NR) construction.

Ex: Financial support for R&D and Development of training programs.

I. Context

Bois-de-Boulogne Sports centre, Laval (Cecbois)

Expansion of the UQAT campus, Rouyn-Noranda (Cecbois)

L’édifice Fondaction CSN, Qc (Cecbois)
The examples may represent a technical reality at the scale of the building itself, but not a large-scale feasibility for an entire building cohort.

The emerging market for NR building may imply changes in the:

• Supply chain of raw materials
• Management of wood products

Resulting in changes of environmental impacts.

What are the changes and their environmental impacts?
III. Objectives

What are the changes and their environmental impacts?

We need a model to:

- Estimate the Building Wood Consumption for Life cycle Inventory
- Understand the Wood Product Flows out of the NR building sector and its changes
IV. Building Material Estimation

Common methodology for building material consumption

a) Material Compositions Indicators - mainly in kg/m² per building archetypes;
b) Size of the building stock – mainly the m² of total floor space (per building archetypes);

(Bergsdal et al. 2007; Huang et al. 2013; Ortlepp et al. 2016; Shi et al. 2012)

Limitation of studies:

- Restriction to the residential because of lack of official statistics to build the MCI;
- Large disparate of functionalities, sizes, and safety requirements

(Augiseau and Barles 2017; Göswein et al. 2017; Ortlepp et al. 2016)
IV. Building Material Estimation

Building Wood Estimation in Non-Residential structures adapted from Geskin Conseil (2008)

$$Estimation\ of\ structural\ wood\ (m^3) = \frac{BP\ (\$) \times SCs\ (%) \times WBs\ (%)}{WSp\ \frac{\$}{m^3}}$$

**BP**: Building permits values = Construction Costs ($) of buildings (new + additional structures)

**SCs**: The share (%) of the structural cost in the construction (material and installation)

**WSp**: The price of installed wood structure (\(\frac{\$}{m^3}\))

**WBs**: Share of new Wood building (% with wood structure)

Parameter projections (retrospective, prospective or with endogenous drivers)

- Interest in the effects of increasing use of wood
IV. a) Method

System Definition: Wood structures

Data collection

Building Wood Estimation
- $BP$ ($)
- $SCs$ (%)
- $WBs$ (%)
- $WSp$ ($\frac{$}{m^3}$)

Drivers and Projection

Parameter projections

Upstream the Building sector

Sawmill yield %

Results: Volume of Wood Structure & Harvesting (m$^3$/year)

Sensitivity Analyses
IV. a) Method

Projections: Building Permits - $ population as a driver


\[ y = 3.7236x - 2E+07 \]
\[ R^2 = 0.918 \]

Population of Quebec: Hist. & Projection (ISQ 2014)

Building permit NR k$ current (Statistics Canada 2019b)
IV. a) Method

Projections: Building Permits - $ population as a driver


\[ y = 3.7236x - 2E+07 \]
\[ R^2 = 0.918 \]
IV. a) Method

Projections: Share of new Wood building (with wood structure) - % prospective approach S-shaped curve.

- Developments of engineering wood product for building structures are not an obvious linear process (Ettwein et al. 2014).

- After the first successful projects and approvals, from the concerned public, of the technological breakthroughs the development may follow a typical logistic S-growth (Hänninen et al. 2014).
IV. b) Results

Scenarios with average/projections of parameters

Volume of Wood products in new NR Structures (m$^3$) according to the share of wood structures

- WBs (2050) = 80%
- WBs (2050) = 60%
- WBs (2050) = 40%

Share of Wood Buildings %

- % max.
- % avg.
- % min.

Building Permits - BP (k$)

Wood Structure Price WSp ($/m$^3$)

Scenarios with average/projections of parameters

SCs (%) = 13% (average)

(Cecobois n.d.; INTRA-BOIS and MFFP 2015)
IV. c) Sensitivity Analysis

Scenarios with extreme values
IV. c) Sensitivity Analysis

Scenarios with extreme values

Volume of Wood products in new NR Structures (m$^3$)

Combined sensitivity of all parameters

Building Permits - BP (k$)

Wood Structure Price WSp ($/m$^3$)

Share of Wood Buildings %

- % max.
- % avg.
- % min.

Number of buildings

0-2.5% 5-7.5% 10-12.5% 15-17.5% 20-22.5% 25-27.5% 30-32.5% 35-37.5% 40%

% ($ structure) / ($ construction)

$/m^3$ max. $/m^3$ avg. $/m^3$ min.
IV. c) Sensitivity Analysis

Supply and Harvesting of domestic softwood roundwood - '000 m$^3$

In 2030, the harvesting for NR structures account for:
- 0.08% (Sc. min)
- 0.78% (Sc. avg.
- 4.61% (Sc. max)

of the total softwood harvesting

In 2050, the harvesting for NR structures account for:
- 0.06% (Sc. min)
- 0.58% (Sc. avg.
- 3.43% (Sc. max)

of the total softwood harvesting
Material Flow Analysis

“Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time” (Brunner and Rechberger, 2004)

\[
\sum (\text{Inputs } i) = \sum (\text{Outputs } i) + \Delta \text{ Stock } i-1, i
\]

V. Wood Product Flows

MFA helps to identify data gaps by respecting the balance between inputs, outputs, and stocks.
Material Flow Analysis

Supply Chain

Roundwood (Domestic forest) 21,322,800
Roundwood (Out of Quebec & Exchanges between plants) 3,844,500

Sawmill (1st Transf.)

Chips 6,795,171
Sawdust & Shavings 2,013,384
Barks 2,768,403
Soft Lumber 12,583,650
Hard Lumber 1,006,692

Non-residential structures

Estimation & increasing of the wood use = f (pop., BP, SCs, WBs & WSp)

Non-Residential Wood Structures in Québec

Other Markets

Sankey Diagram – wood flow (m³) 2015 – STAN 2.6 Software http://www.stan2web.net/

processed form (MFFP 2017b) & Editions < 2017
And from (MFFP 2018)
VI. Conclusion

Material Flow Analysis (MFA) allows to track physical flows throughout their life cycle to build an inventory associated to a given economic sector.

Respecting the balance between inflows, outflows, and stock implies transparent highlighting in missing data (at the discretion of the user).

MFA provides information about both the dependence to some resource and its resource recovery potential.

⇒ determining required action to supply a demand.
⇒ showing the possible scenarios of direct consequences.

But keep in mind the consistency in the life cycle inventory is related to the direct consequences in the system boundary.
Thank You !
References

- Statistics Canada. (2019b). "Building permits, by type of structure and type of work (x 1,000)." Table: 3410006601
I. Context

Examples of NR wood buildings

- Tanguay's Commercial building, Trois-Rivières (Cecbois)
- Le CLSC, Naskapi (Cecbois)
- Bois-de-Boulogne Sports centre, Laval (Cecbois)
- Maheu&Maheu’s head office, first wooden load-bearing glass wall, Qc (Cecbois)
- GlaxoSmithKlined's office building, Qc (Cecbois)
- L’édifice Fondaction CSN, Qc (Cecbois)
- Expansion of the UQAT campus, Rouyn-Noranda (Cecbois)
- Complan bulding, Qc (Cecbois)
IV. Building Material Estimation

Other methods (for NR Buildings)

• Schebek et al. (2017): Use of geographical information systems (GIS) and data from investigations on different building typologies

• Nepal et al. (2015): Use of economical parameters to disaggregate the total demand of wood products into residential and NR buildings. Combination of the yearly shift in demand and the price elasticity of for the total and the NR demand

• Ortlepp et al. (2016): Use of correlation between economical and physical data:
  a) Size of the non-domestic buildings value (gross stock of fixed assets);
  b) Conversion of monetary values into m² floor space (with correlation);
  c) allocation to each building types
IV. a) Method

Projections (retrospective or prospective or with endogenous drivers)
- To better understand possible futures
- Interest in the effects of increasing use of wood
  => Projection of each parameters

BP (t), SCs (t), WSp (t) and WBs (t) ???

- “Most reviewed studies [on consequential LCA] only adopt[ed] a retrospective approach, assuming past trends are representative for long-term future changes.”
IV. c) Sensitivity Analysis

High variability of the parameters & Interdependency of between the parameters
BP, SCs, WBs versus WSp
+/- 50% around the average

Sensitivity Analysis

If one numerator is changed by + x%, then the result is changed by + x% - x% - x% + x% - y% (|y| < |x|) - x% + z% (|x| < |z|)

If one denominator is changed by - x%, then the result is changed by - x% + x% - x% - x% + x% - y% (|y| < |x|) + z% (|x| < |z|)

Volume of Wood products in new NR Structures (m$^3$)
Sensitivity of numerators (BP, SCs or WBs) and denominators (WSp)

Only Wood Structure Price (WSp) at the denominator, has => the less influence when it increases & => the most when it decreases
Scenarios with average projections of BP, SCs & WSp

Volume of Wood products in new NR Structures (m$^3$)
Combined sensitivity of all parameters

- [MAX] $BP (\$) \times SCs (\%) \times WBs (\%)$
- [MIN] $WSp \left( \frac{\$}{m^3} \right)$

Graph showing the volume of wood products in new NR structures from 2010 to 2050, with different lines indicating max, min, and avg values for opposite and same changes.
Back-Up Slide . Sensitivity Analysis

Projections: Share of the Structural Cost - %

Distribution from examples of case studies
Public report (Cecobois n.d.)
&
Confidential review (on behalf of the Ministry of Forests, Wildlife, and Parks) (INTRA-BOIS and MFFP 2015).
Back-Up Slide . Sensitivity Analysis

**Projections: Wood Structure Price - $/m³**

- Trend of the avg.
- Soft Lumber (FEA 2019) Avg. prices ($ CA/m³)

Wood Structure Price $/m³

Eastern Canada soft lumbers $/m³ trend

BP ($) * Scs (%) * WBs (%)

WSp ($/m³)

- $/m³ max.
- $/m³ avg.
- $/m³ min.
- Examples of case studies
- CECOBOIS Publications
Projections: Building Permits - $ population as a driver vs retrospective (historical trend)
Projections: Share of new Wood building (with wood structure) - %
prospective approach S-shaped curve vs retrospective (historical trend)

- Trend C [avg.; min.]

Share of Wood Buildings %

- % avg.
- % min.
- Trend of the past recorded data

Hist. values (Robichaud 2017)
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