LIRIDE
Laboratoire Interdisciplinaire de Recherche en Ingénierie Durable et en Écoconception

NSERC CRSNG

CIRCERB
CHAIRE INDUSTRIELLE DE RECHERCHE SUR LA CONSTRUCTION ÉCORESPONSABLE EN BOIS

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Enhancing consistency in consequential life cycle inventory through material flow analysis

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Agenda

I. Context

II. Research question

III. Objectives

IV. Building Material Estimation

   a) Method

   b) Results

   c) Sensitivity analysis

V. Wood Product flows

VI. Conclusion

I. Context

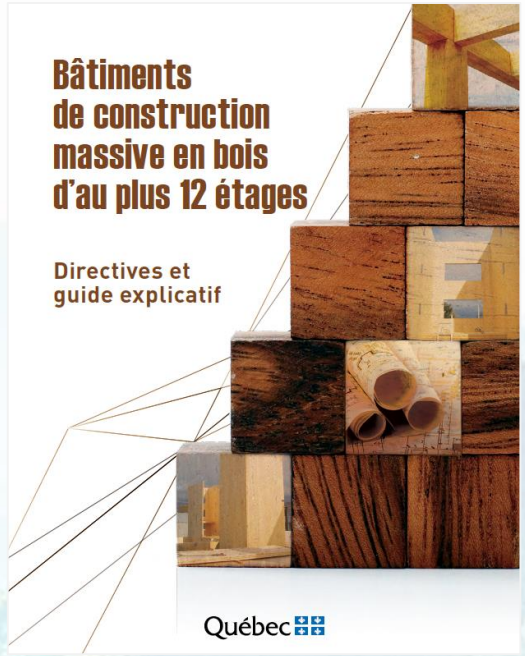
Quebec: Wood Charter

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.

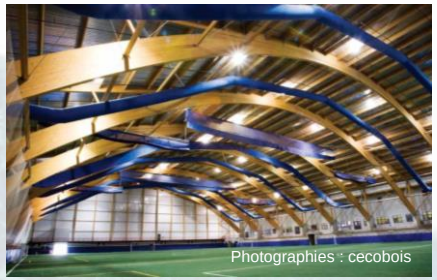
www.mffp.gouv.qc.ca

May 2017



www.rbq.gouv.qc.ca RBQ – FPInnovations

Veilleux et al. (2015)



Bois-de-Boulogne Sports centre, Laval (*Cecobois*)

Expansion of the UQAT campus, Rouyn-Noranda (*Cecobois*)

L'édifice Fondaction CSN, Qc (*Cecobois*)

II. Research Question

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 residentials 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)

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

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)

From the building stock
To the wood consumption

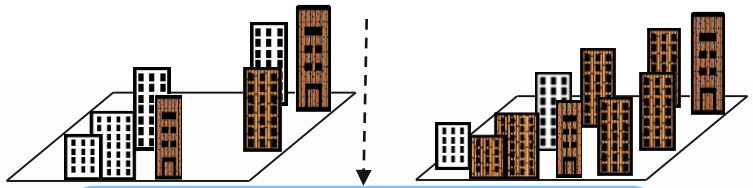
Parameter projections (retrospective, prospective or with endogenous drivers)

- 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 %

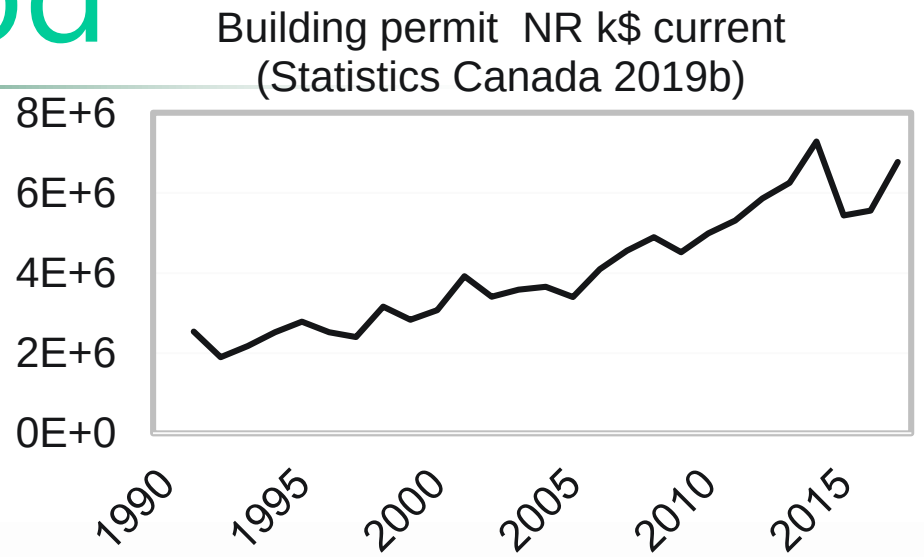
Sensitivity Analyses

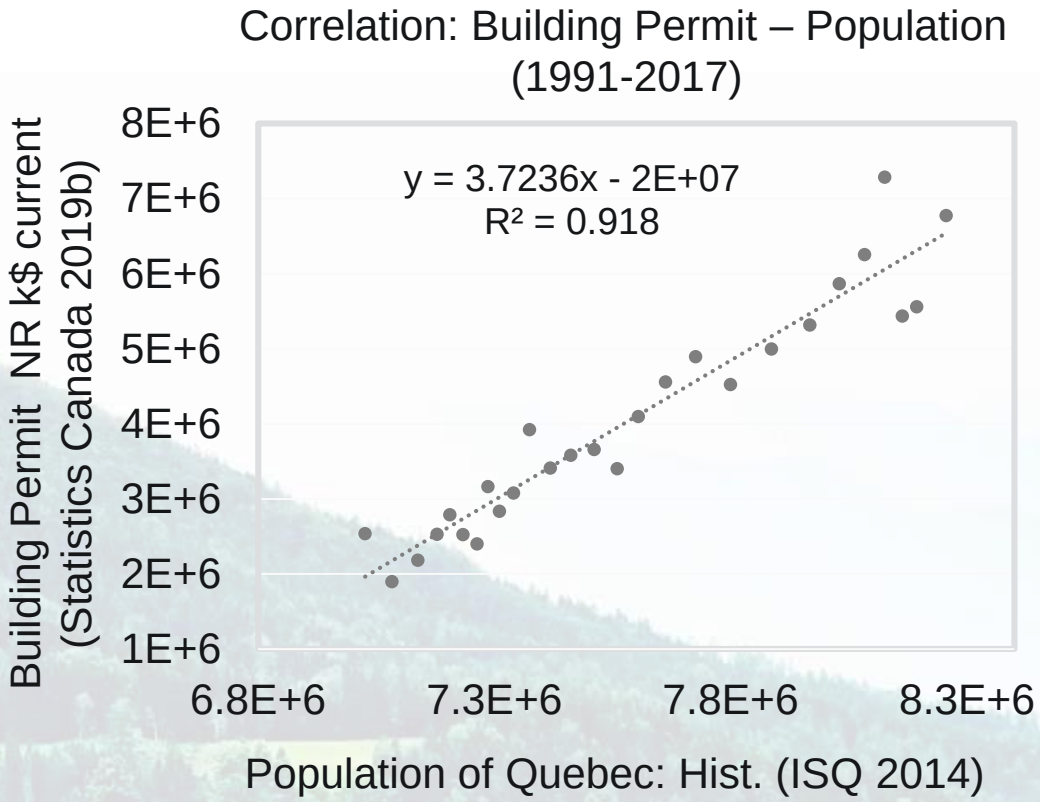
Results: Volume of Wood Structure & Harvesting (m^3/year)

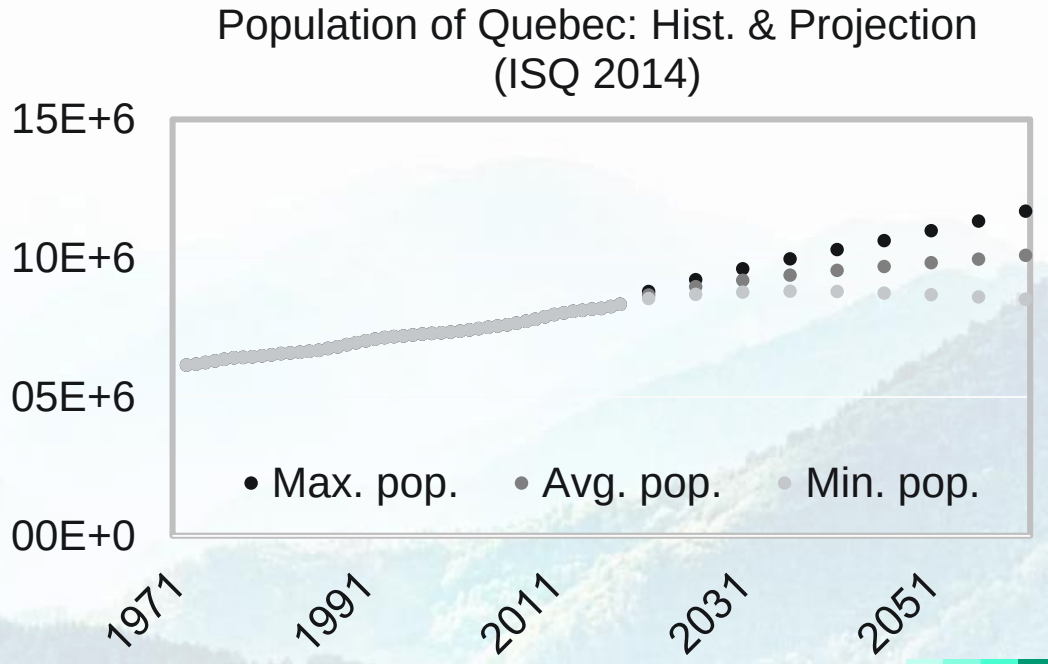
$$\frac{BP\ (\$) * SCs\ (\%) * WBs\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

IV. a) Method

Projections: Building Permits - $
population as a driver



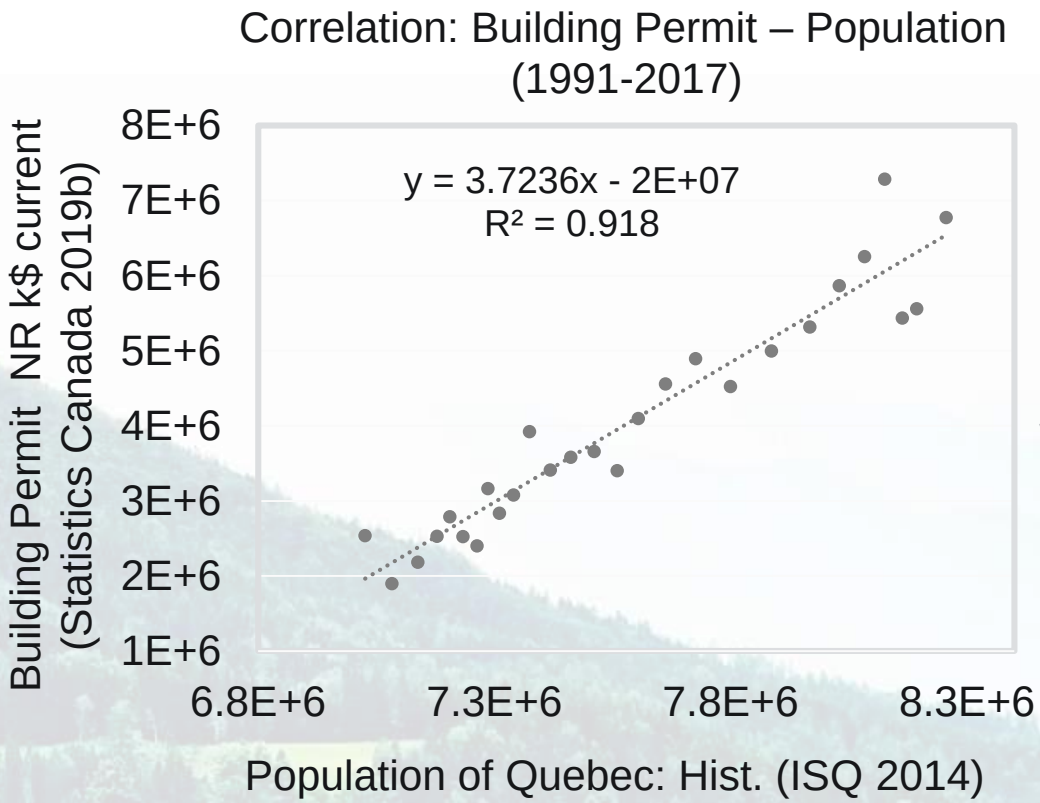


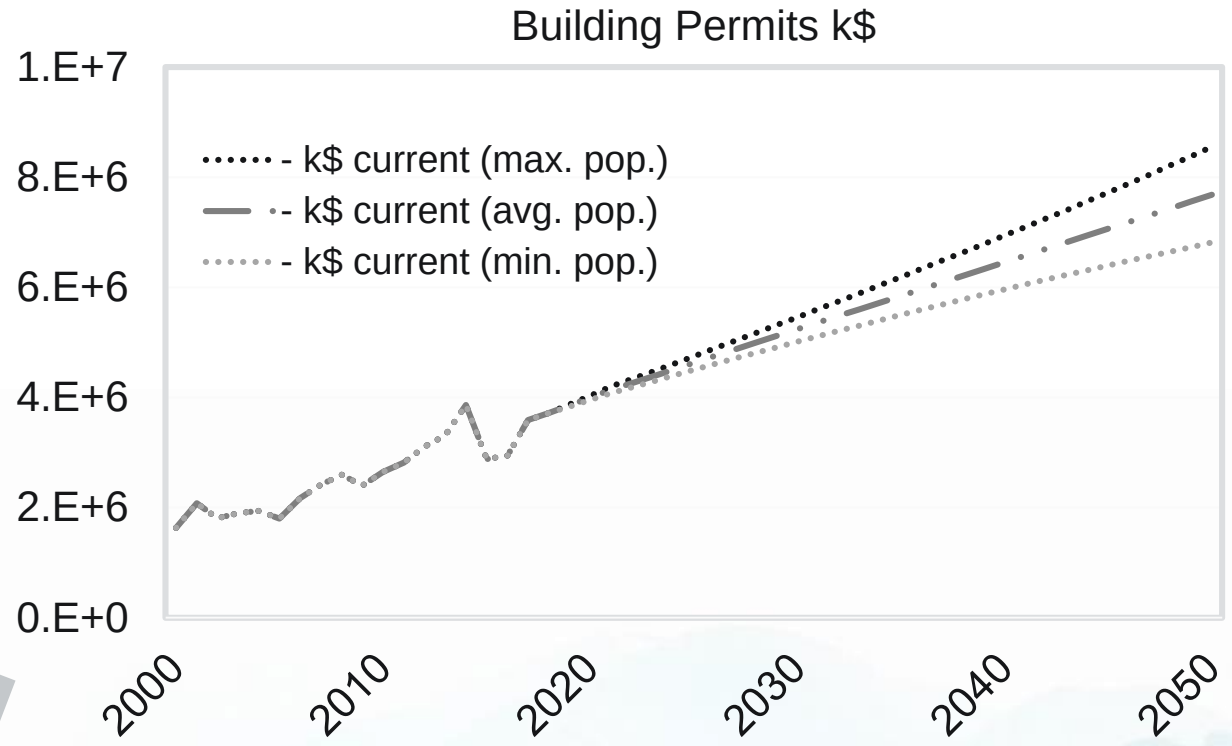


$$\frac{\boldsymbol{BP}\ (\$) * SCs\ (\%) * WBs\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

IV. a) Method

Projections: Building Permits - $
population as a driver





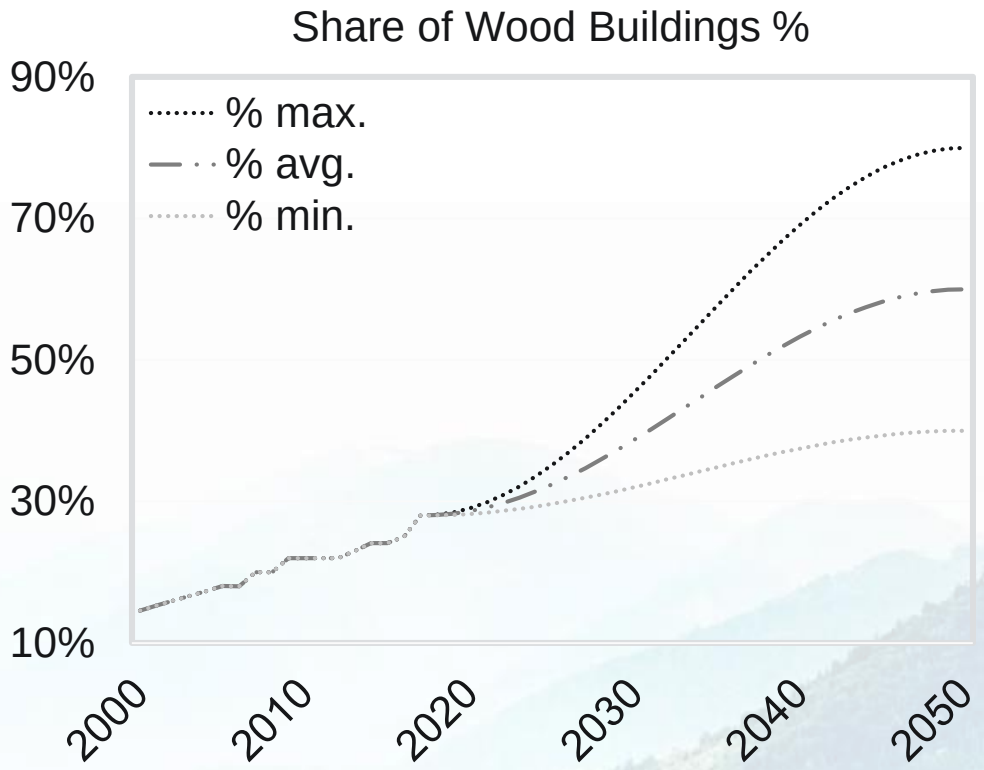
$$\frac{BP\ (\$) * SCs\ (\%) * \boldsymbol{WBs}\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

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).

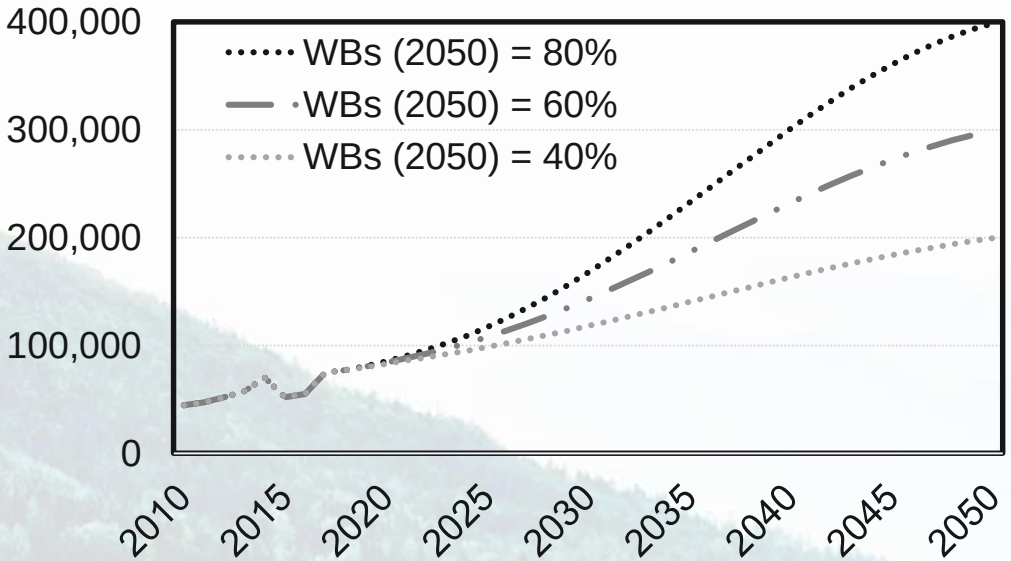


Hist. values (Robichaud 2017)

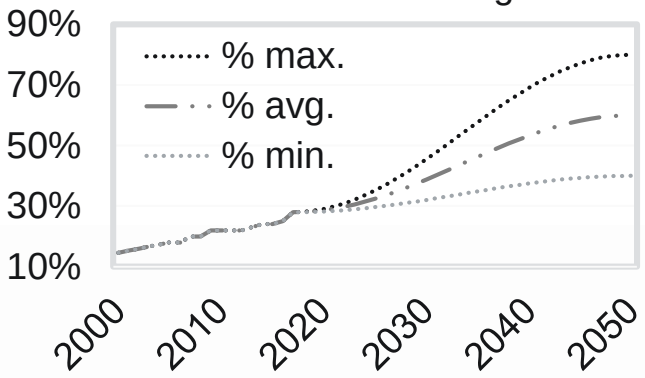
IV. b) Results

Scenarios with average/projections of parameters

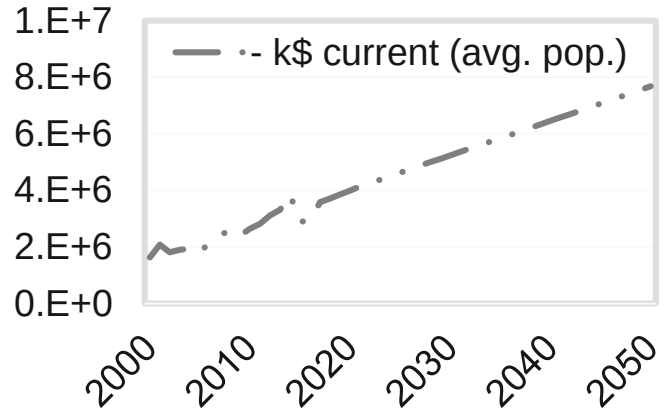
Volume of Wood products in new NR Structures (m^3) according to the share of wood structures



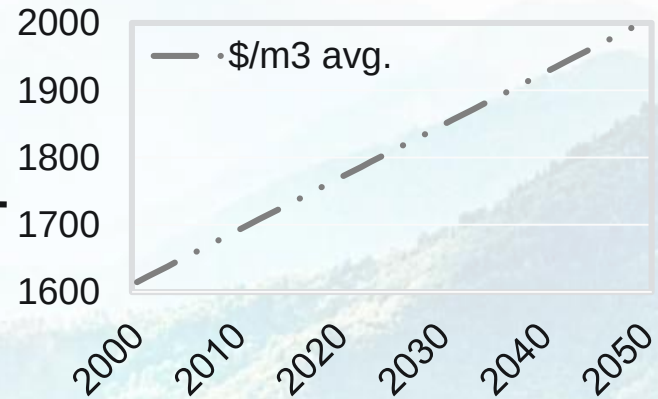
Share of Wood Buildings %



Building Permits - BP (k$)



Wood Structure Price WSp ($/m^3)

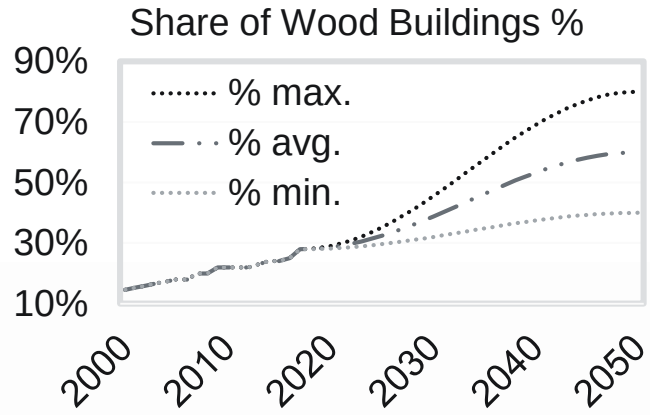


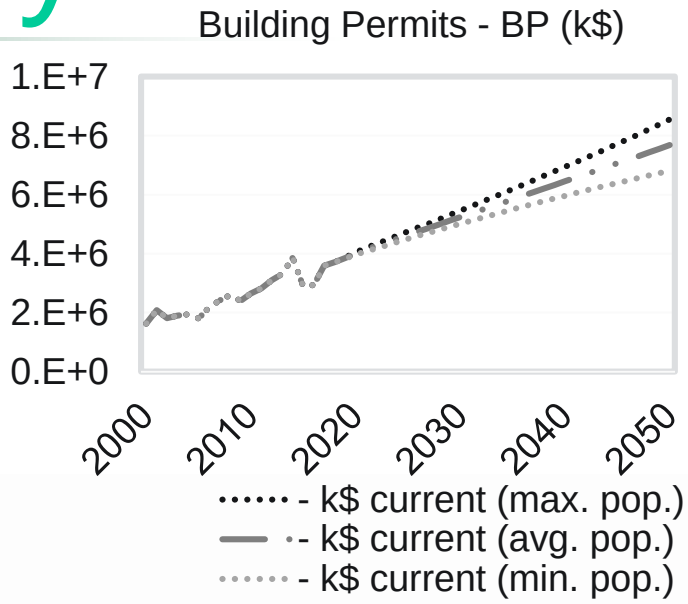
SCs (%) = 13% (average)

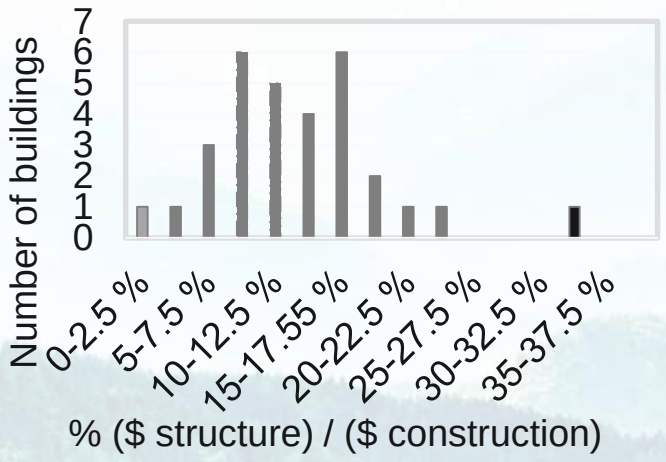
(Cecobois n.d.; INTRA-BOIS and MFFP 2015)

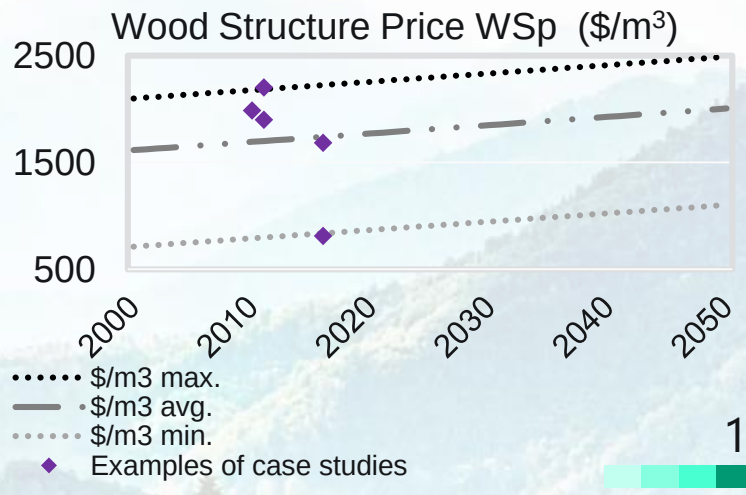
IV. c) Sensitivity Analysis

Scenarios with extreme values



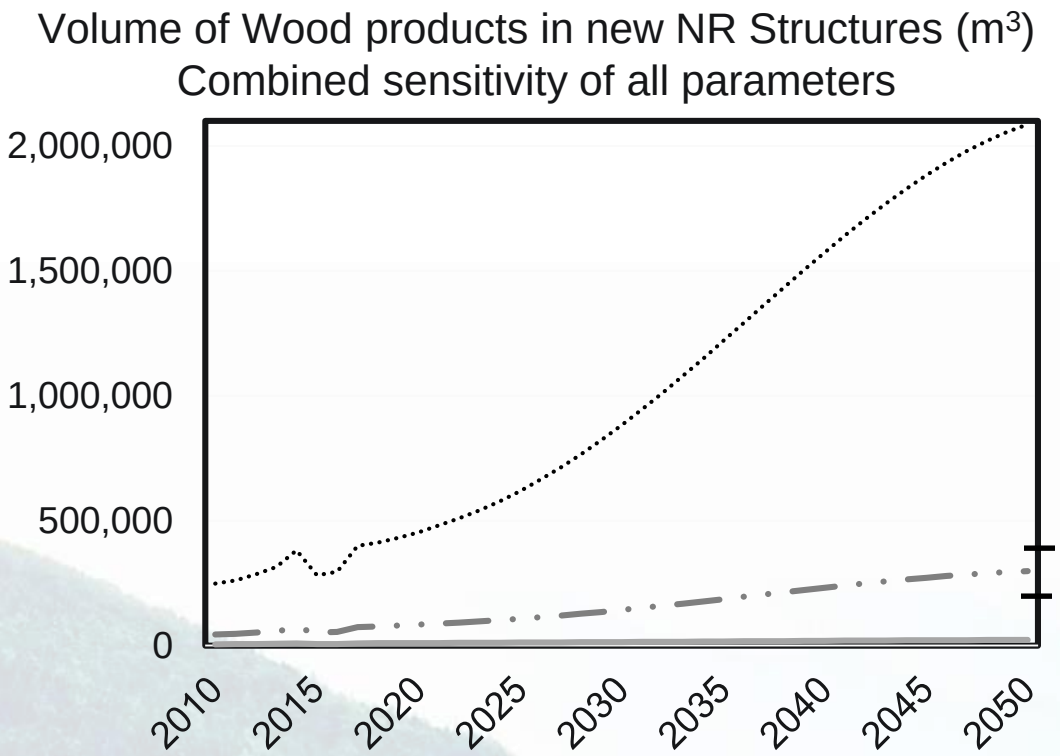


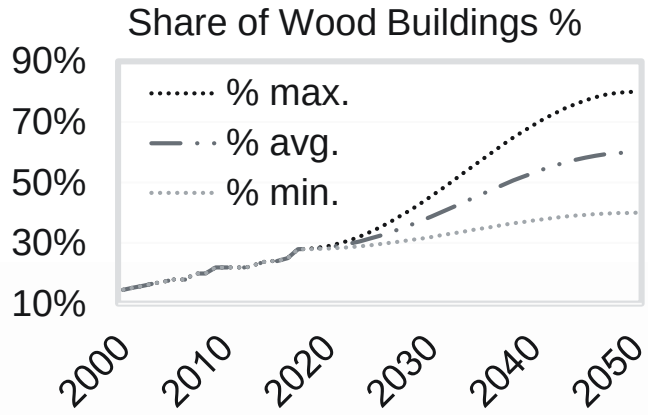


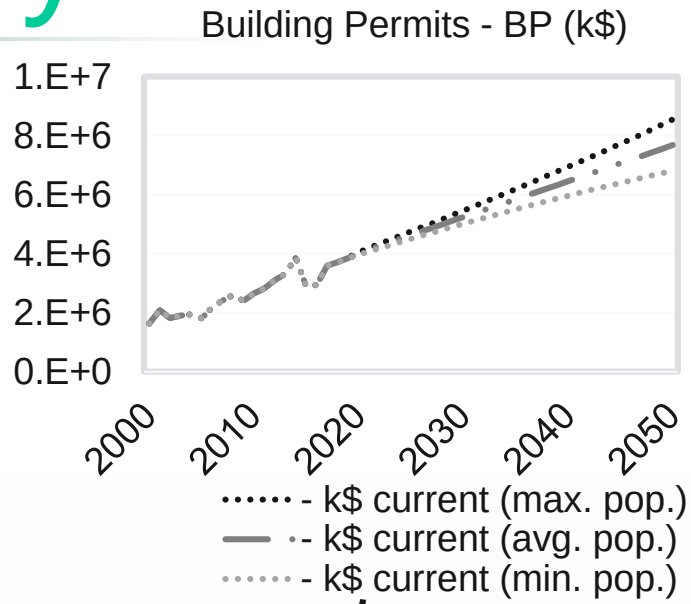


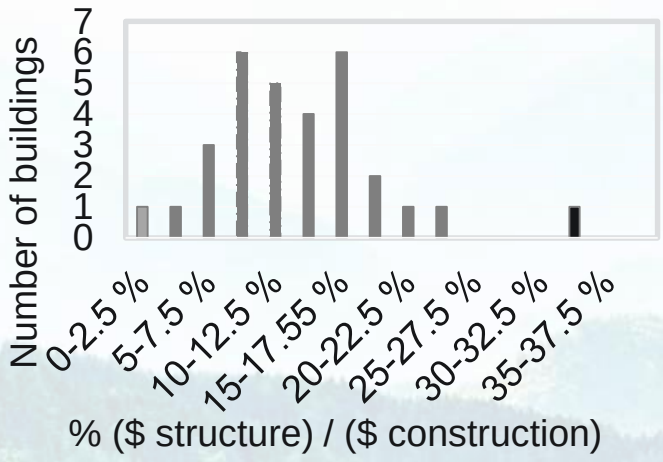
IV. c) Sensitivity Analysis

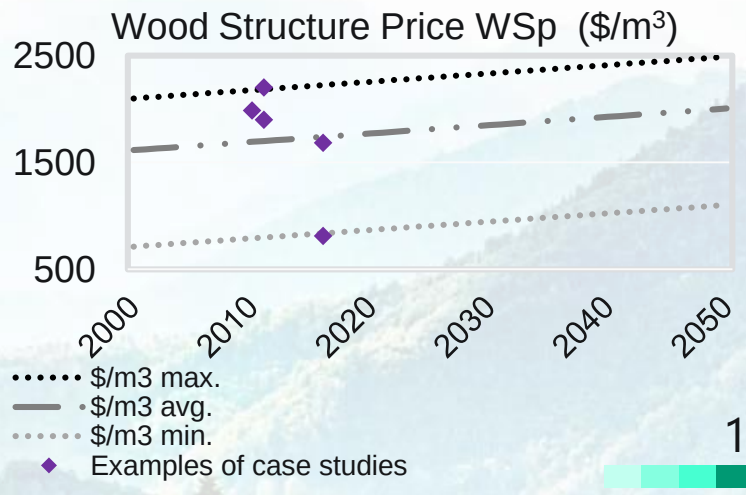
Scenarios with extreme values



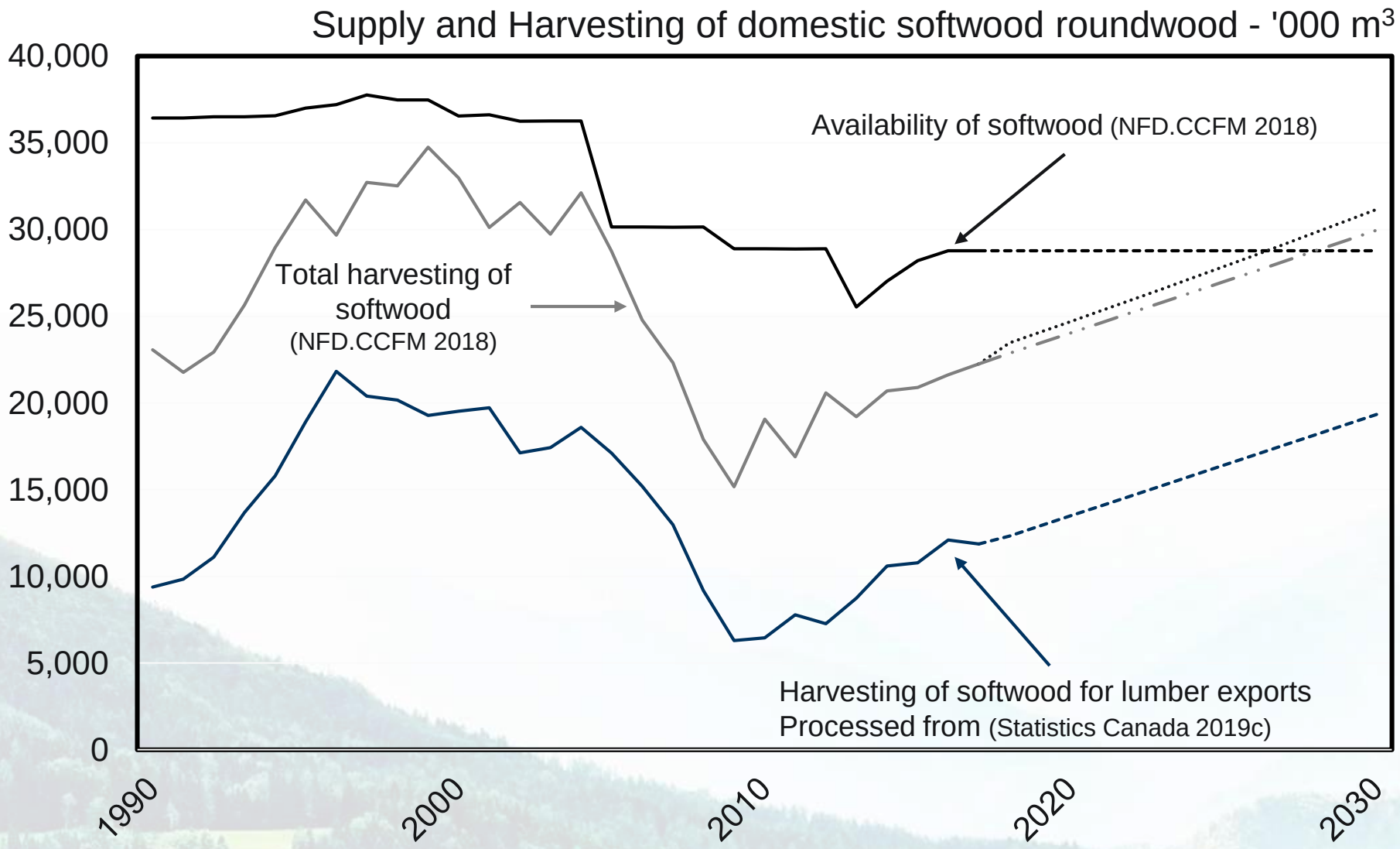








IV. c) Sensitivity Analysis



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)*

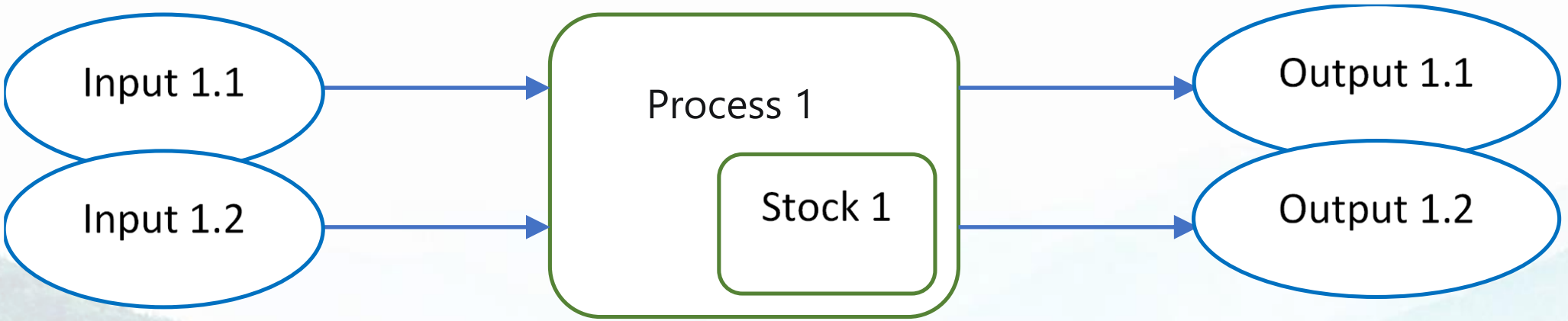
of the total softwood harvesting

V. Wood Product Flows

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)

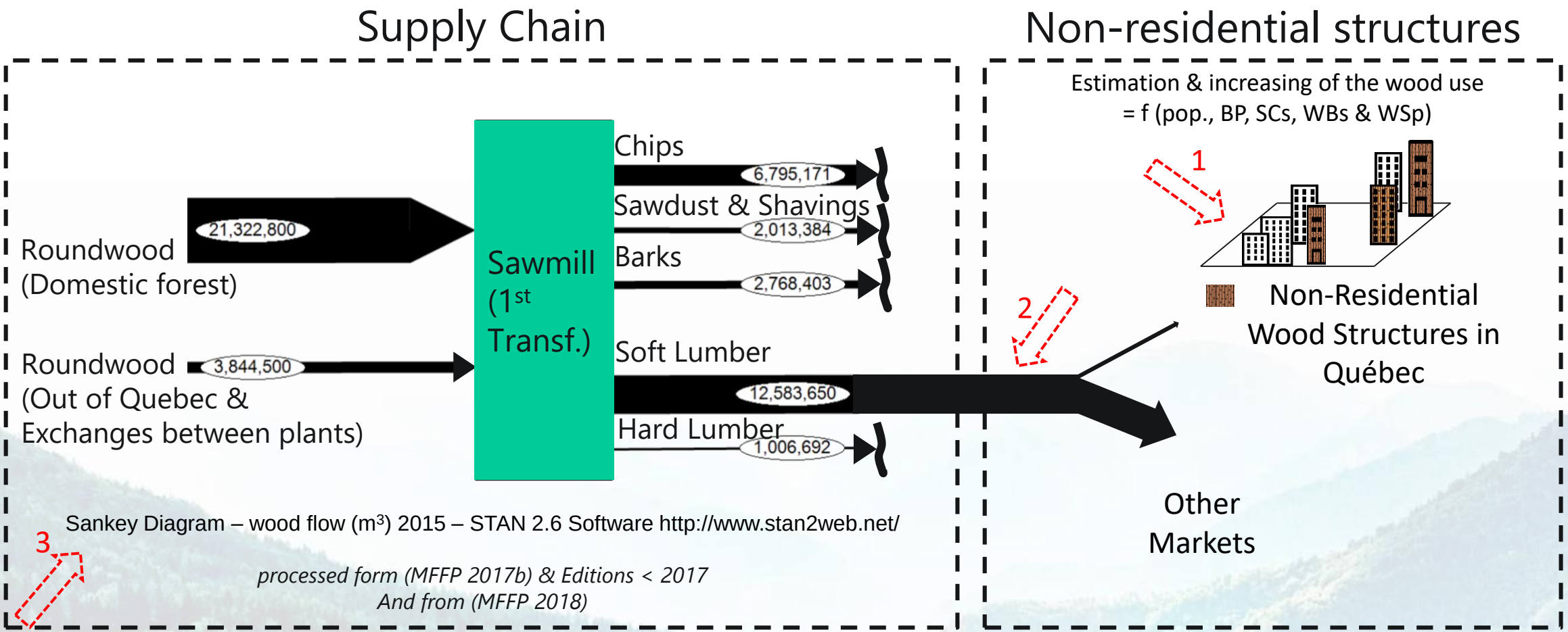
$$\sum (Inputs\ i) = \sum (Outputs\ i\ ) + \Delta \text{ Stock i-1, i}$$



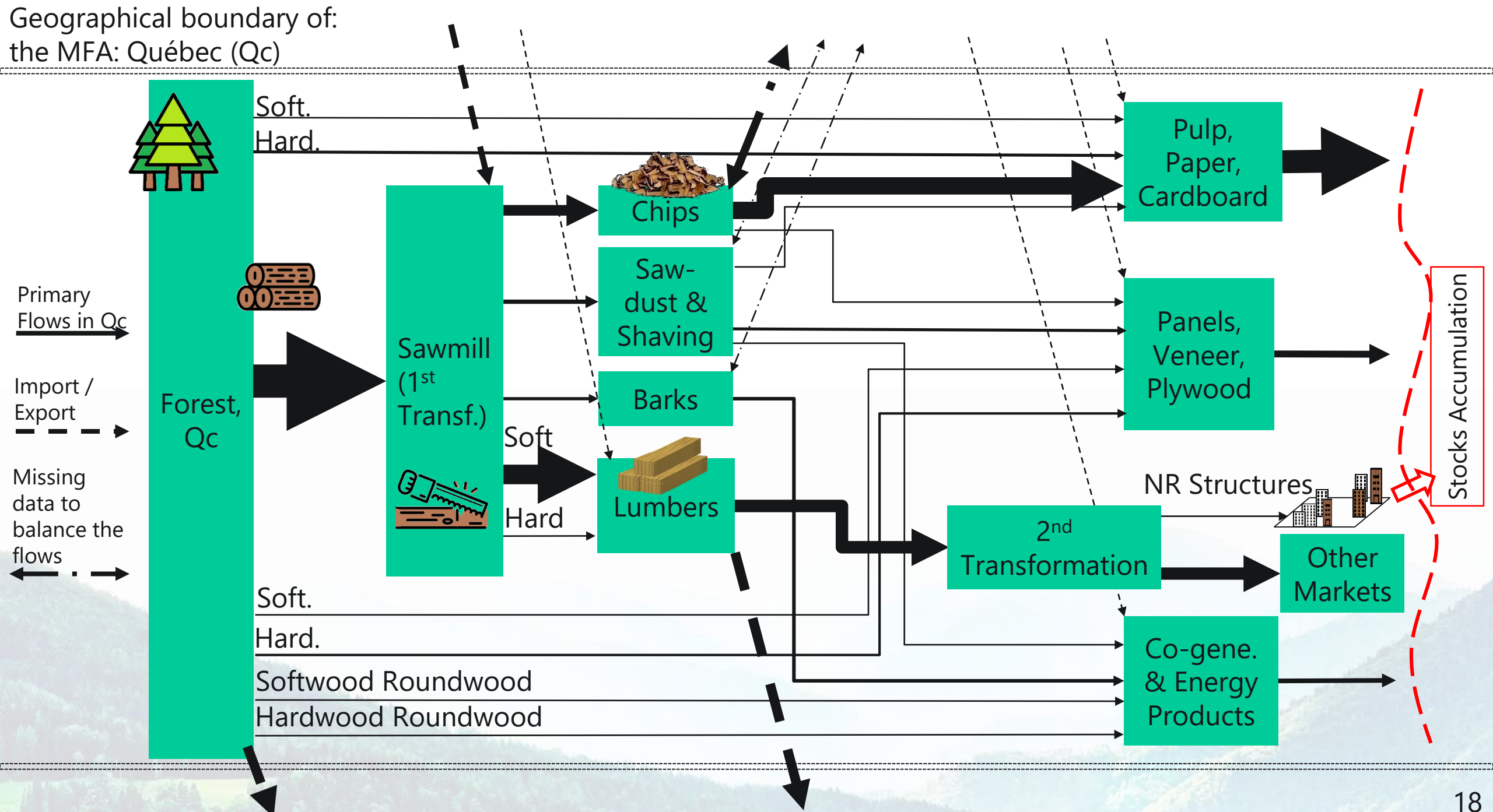
MFA helps to identify data gaps by respecting the balance between inputs, outputs, and stocks.

V. Wood Product Flows

Material Flow Analysis



Geographical boundary of:
the MFA: Québec (Qc)



Sankey Diagram – wood flow (m^3) 2015; processed with STAN 2.6 Software form (MFFP 2017b) & Editions < 2017, Statistics Canada 2019c, and NFD.CCFM 2018, 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 !

Back-Up Slide . References

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I. Context

Examples of NR wood buildings

Tanguay's Commercial building Trois-Rivières (*Cecobois*)

Le CLSC, Naskapi (*Cecobois*)

Bois-de-Boulogne Sports centre, Laval (*Cecobois*)

Maheu&Maheu's head office, first wooden load-bearing glass wall, Qc (*Cecobois*)

GlaxoSmithKlined's office building, Qc (*Cecobois*)

L'édifice Fondaction CSN, Qc (*Cecobois*)

Expansion of the UQAT campus, Rouyn-Noranda (*Cecobois*)

Complan bulding, Qc (*Cecobois*)

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 m^2 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." *Buyle, M. (2018).*

$$\frac{BP\ (\$) * SCs\ (\%) * WBs\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

IV. c) Sensitivity Analysis

High variability of the parameters
&
Interdependency of between the parameters

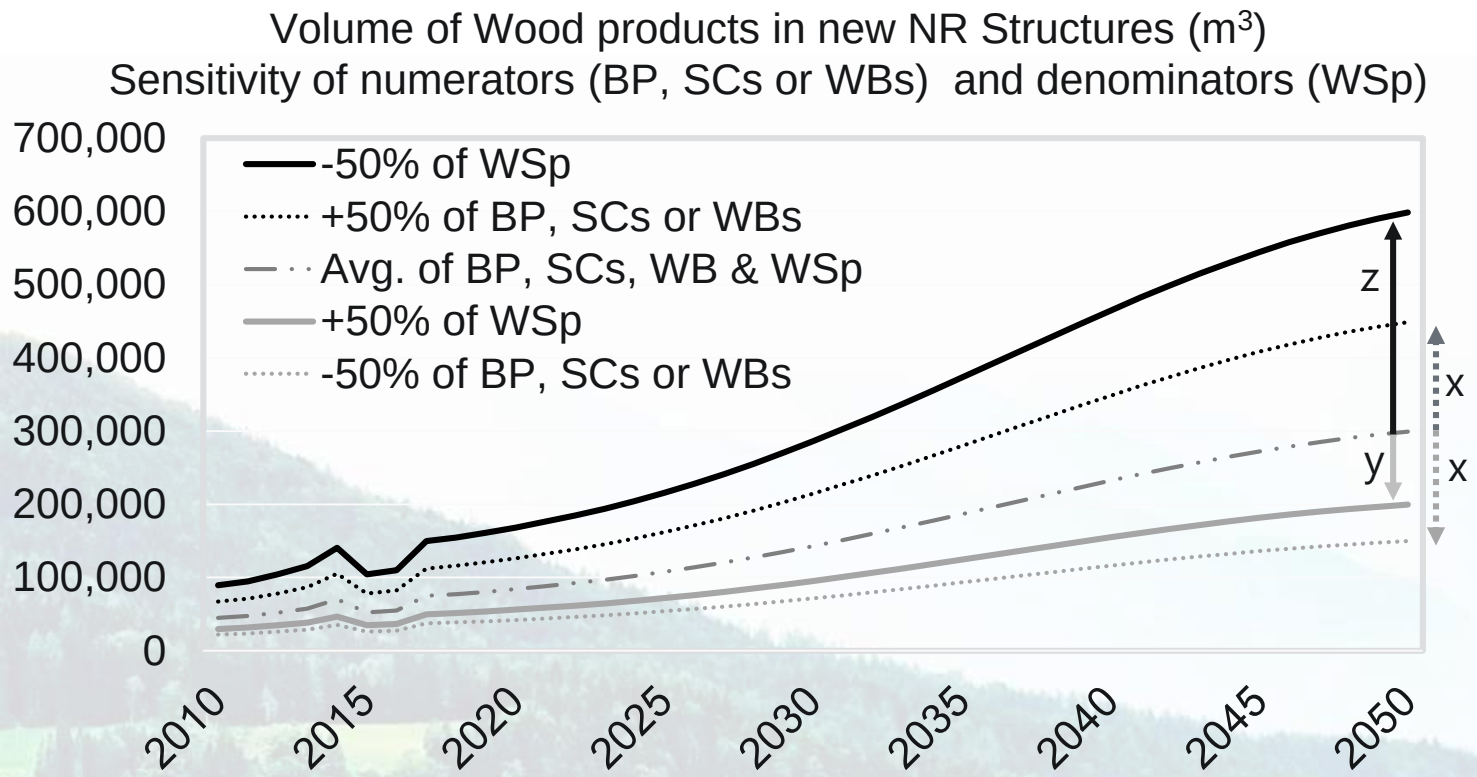
$$\frac{BP\ (\$) * SCs\ (\%) * WBs\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

Sensitivity Analysis

BP, SCs, WBs versus WSp

+/- 50% around the average

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



Only Wood Structure Price (WSp) at the denominator, has

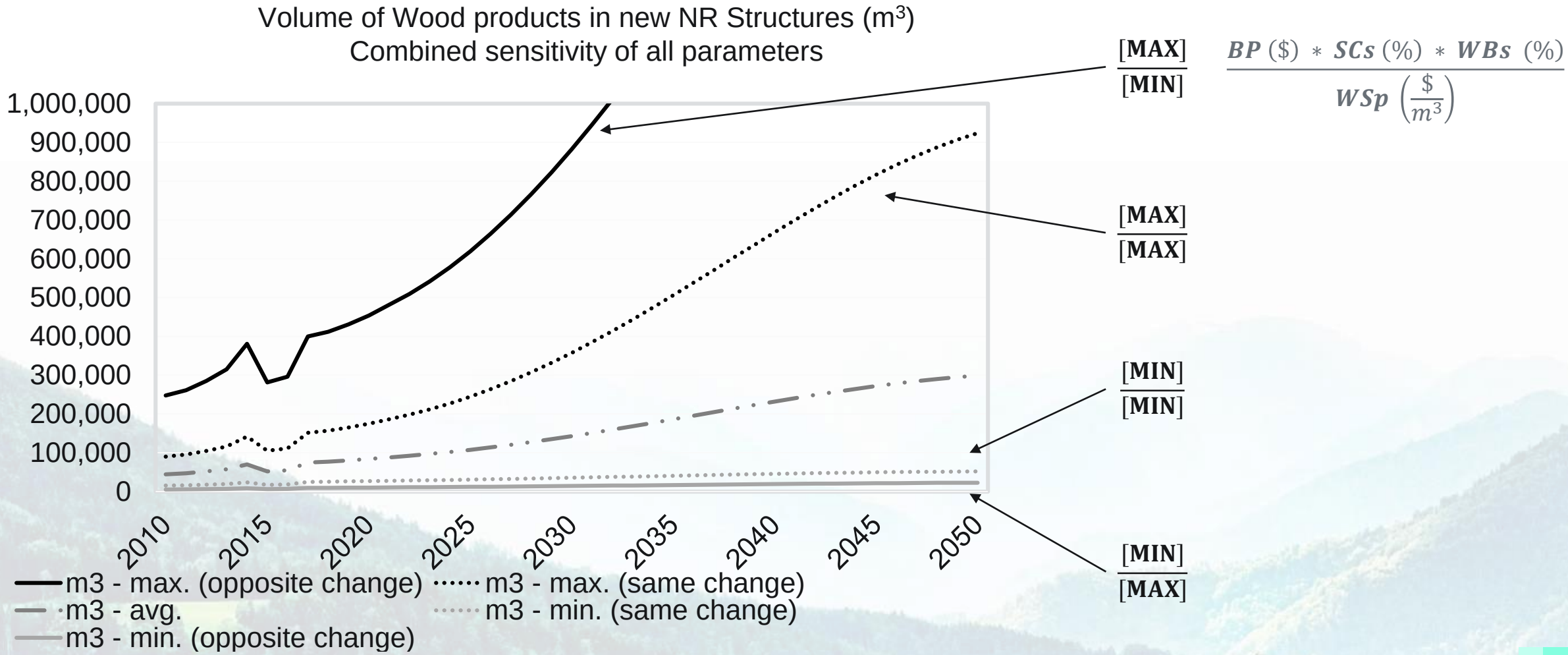
=>the less influence when it increases

&

=>the most when it decreases

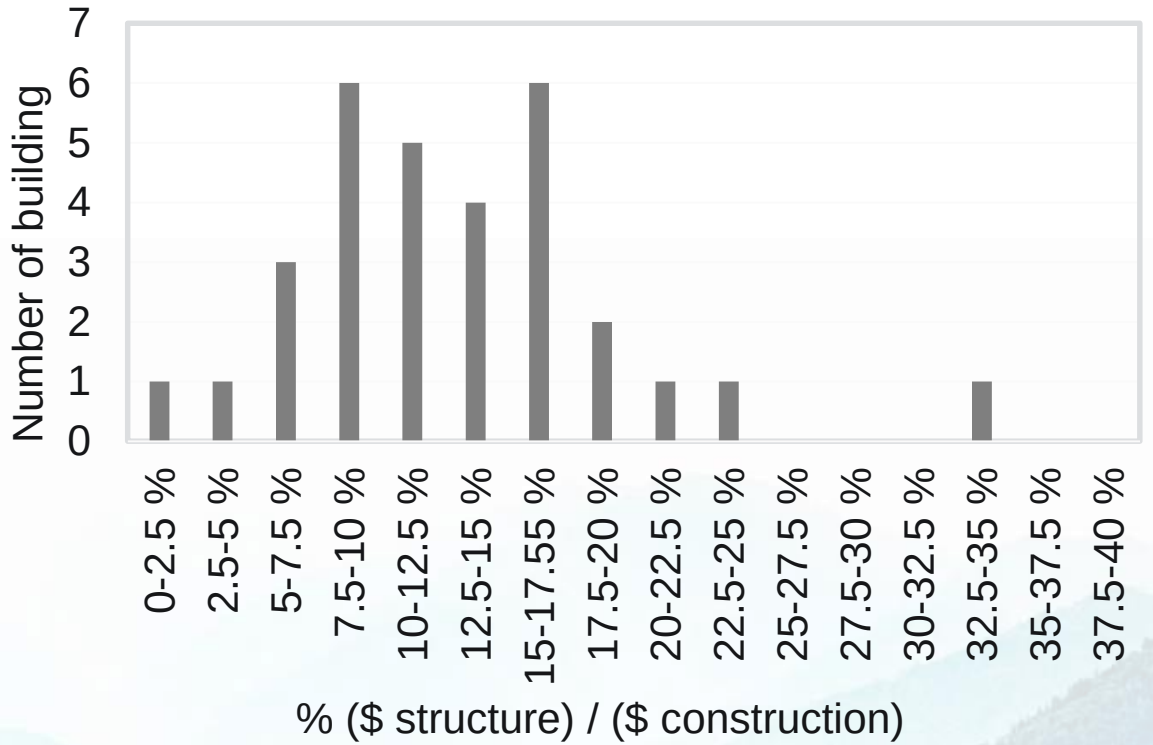
Back-Up Slide . Sensitivity Analysis

Scenarios with average projections of BP, SCs & WSp



Back-Up Slide . Sensitivity Analysis

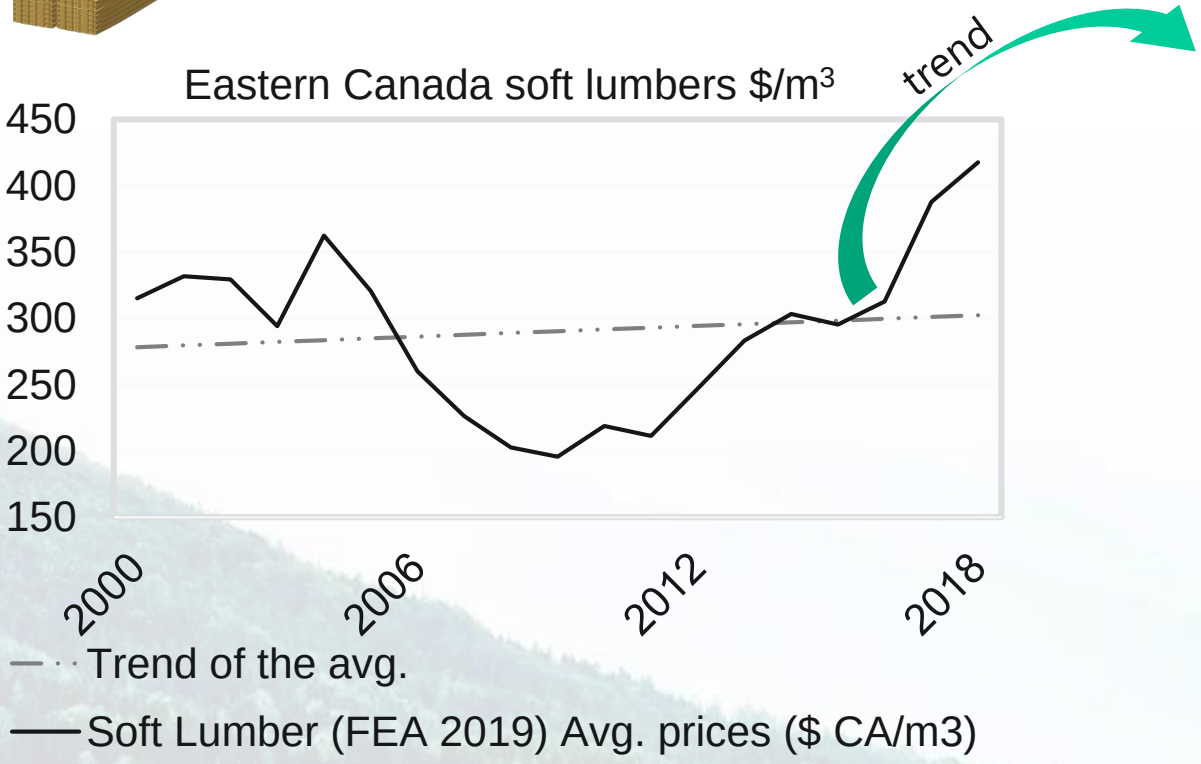
Projections: Share of the Structural Cost - %

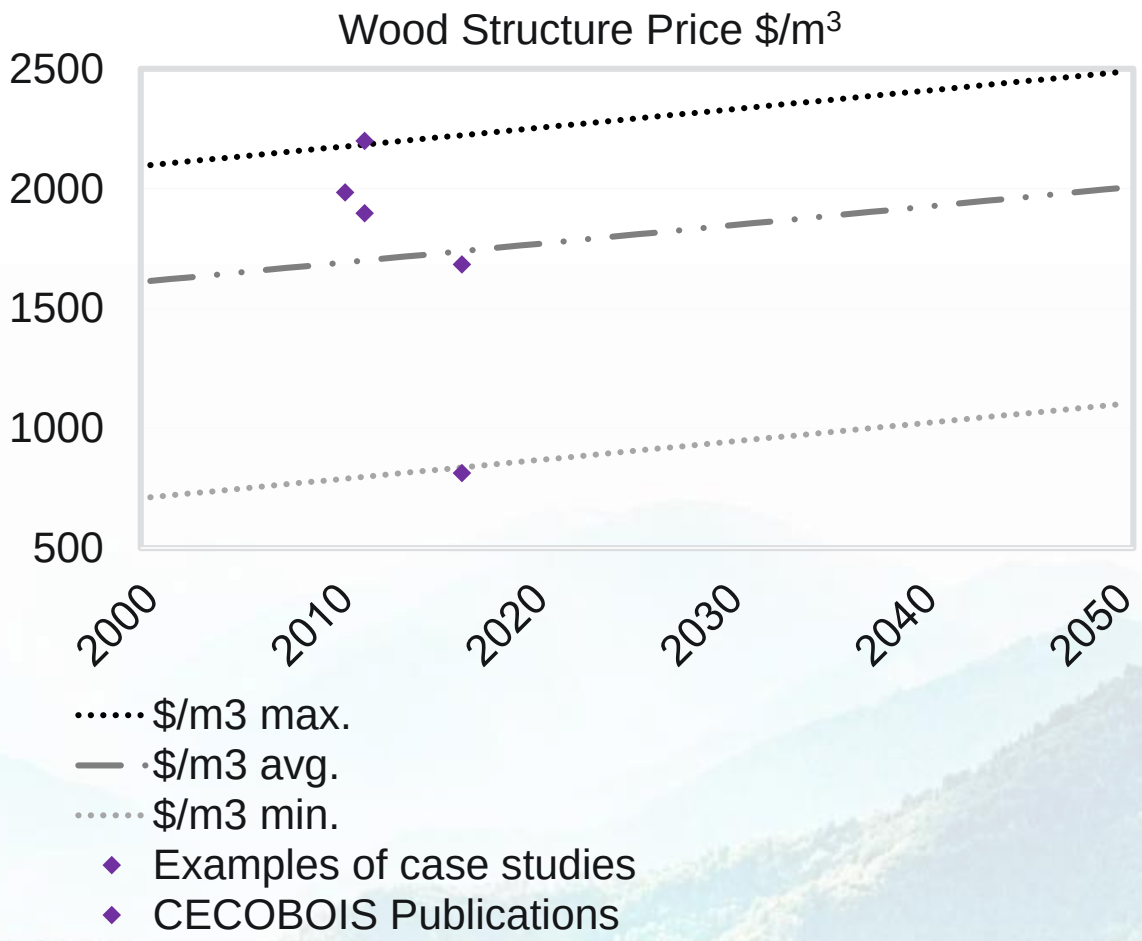


Distribution from examples of case studies
Public report (Cecobois n.d.)
&
Confidential review (on behalf of the Ministry of Forests, Wildlife, and Parks) (INTRA-BOIS and MFFP 2015).

Back-Up Slide . Sensitivity Analysis

Projections: Wood Structure Price - $/m³



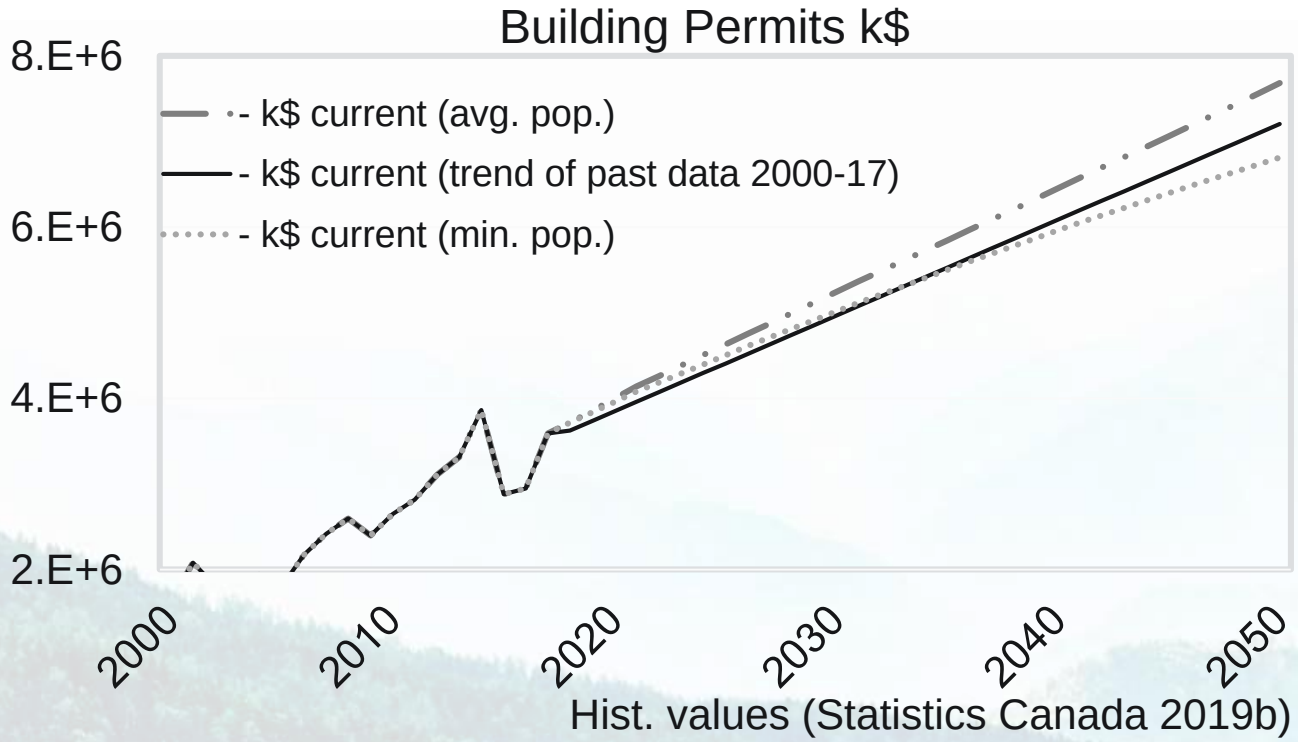


$$\frac{BP\ (\$) * SCs\ (\%) * WBs\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

Back-Up Slide . Sensitivity Analysis

Projections: Building Permits - $

population as a driver **vs** retrospective (historical trend)

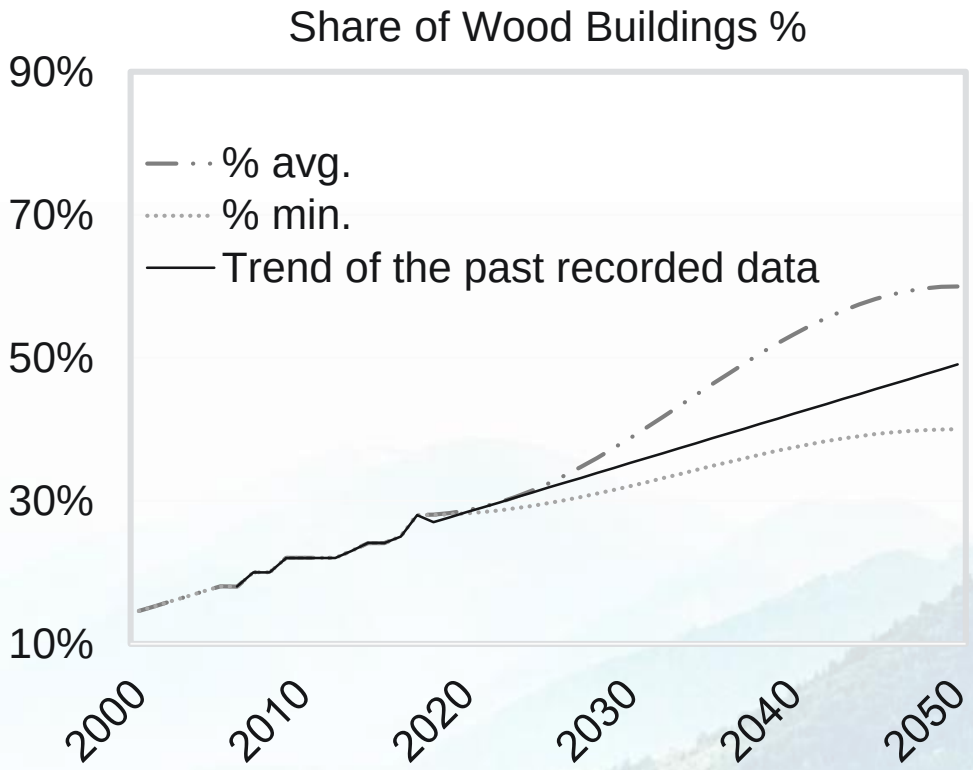


$$\frac{BP\ (\$) * SCs\ (\%) * \boldsymbol{WBs}\ (\%)}{WSp\ (\frac{\$}{m^3})}$$

Back-Up Slide . Sensitivity Analysis

Projections: Share of new Wood building (with wood structure) - %
prospective approach S-shaped curve **vs**
retrospective (historical trend)

- Trend C [avg. ; min.]



Hist. values (Robichaud 2017)

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CHAIRE INDUSTRIELLE DE RECHERCHE SUR LA CONSTRUCTION ÉCORESPONSABLE EN BOIS

SBE19 Graz – September, 13th 2019

Enhancing consistency in consequential life cycle inventory through material flow analysis

Sylvain Cordier, Civil and Building engineering (Ph.D. Candidate)
Ben Amor (supervisor)
Pierre Blanchet (co-supervisor1)
François Robichaud (co-supervisor2)