Optimal development of the Canadian forest sector for both climate change mitigation and economic growth

Using the North American TIMES Energy Model (NATEM)

ETSAP Workshop Turino
17th of November 2023
Outline

1. Project goals
2. The NATEM model in brief
3. Methodology:
   • Building construction sector
   • Modelling of harvested wood products
   • Biogenic carbon accounting
4. Results: Net-zeros scenarios analysis
5. Conclusions
Project Goals

Develop a model with the capacity to define strategies for optimal use of harvested wood products (HWP)

A comprehensive, state-of-the-art model integrating detailed forestry sector modeling into an economy-wide energy system model

Understand forestry sector contributions in achieving climate targets and economic development

Describe forest industries as sources of bioenergy, building materials, and their associated emissions with causal relationships to other competing sectors
Methodology: The North American TIMES Energy (NATEM) model in brief
NATEM Scope

**Canada:** 13 Provinces/Territories
**USA:** 9 Census Regions + CA, NY, TX
**Mexico:** 1 Region

**Temporal resolution**
- Annual database 2016-2060
- Flexible time period definition
- Flexible sub-annual disaggregation
  - 4 Seasons
  - 4 Intraday periods or 24h days

All energy sectors and non-energy sectors
- Industrial processes, Agriculture, Waste
- 75 demands for energy services
- **5000 technologies**

All GHGs (replicating the National Inventories)
ESMIA Optimal Development of the Canadian Forest Sector
SECTION 2

Methodology: Extending NATEM modelling capacity
Methodology – Extending NATEM modelling capacity

• **Extend representation of HWPs for building construction**
  • Wood harvesting
  • Wood processing mills
  • Construction domestic demand and international exports

• **Capture interplay between building construction materials**
  • Iron and steel and cement supply chain were already model in detail
  • Extension to concrete demand
  • Creation of a separation node between construction demand and other use of concrete and iron & steel
  • Representation of the building construction sector

• **Capture interplay between short- and long-lived HWPs**

• **Capture the interplay between Canadian jurisdictions**

• **Extend capacity to track carbon retention profiles of HWPs**
  • Extend model horizon to 2070
  • Biogenic carbon, decomposition emissions, carbon content of wood product
Disaggregation of the construction sector

- Disaggregation into 8 subsectors depending on building types and heights (non-building construction, 3 for commercial building construction, 4 for residential building construction)
- Add materials used in construction sector (in addition to energy consumption)
- **Two types of construction**: wood-based and non-wood-based (concrete and steel)
- Maximum shares between wood construction and other construction are based on technical potential by building type and height
Harvested wood product supply chain

- **Implementation of a competitive node between wood for long-lived HWP and short-lived HWP**, i.e., for wood construction materials, pulp and paper industries or bioenergy production.
- Residues from mills can be reused for other purposes (pulp and paper or energy production).
- Addition of the accounting of carbon content in HWPs.
- Carbon stock of HWPs is counted at the production point (for energy emissions it is at the consumption point), so **emissions of HWPs that are exported are counted in Canada.**
Carbon accounting – Carbon content of HWP


Estimation of changes in carbon stock in “products in use” may be obtained by using Equation 12.1:

**Equation 12.1**

**Estimation of Carbon Stock and its Annual Change in HWP Pools of the reporting Country**

Starting with $i = 1900$ and continuing to present year, compute

(A) $C(i+1) = e^{-kt} \cdot C(i) + \left[ \frac{g - e^{-kt}}{k} \right] \cdot \text{Inflow}(i)$

with $C(1900) = 0.0$

(B) $\Delta C(i) = C(i+1) - C(i)$

Note: For an explanation of technique used in Equations 12.1A to estimate first-order decay see Priguid and Wagner (2006).

Where:

- $i =$ year
- $C(i) =$ the carbon stock of the HWP pool in the beginning of year $i$, Gg C
- $k =$ decay constant of first-order decay given in units, yr$^{-1}$ ($k = \ln(2) / HL$, where HL is half-life of the HWP pool in years. A half-life is the number of years it takes to lose one-half of the material currently in the pool.)
- Inflow($i$) = the inflow to the HWP pool during year $i$, Gg C yr$^{-1}$
- $\Delta C(i) =$ carbon stock change of the HWP pool during year $i$, Gg C yr$^{-1}$
**Carbon accounting – Carbon content of HWP**

**HWPCO2**: CO2 content of produced HWPs in period t equal to Inflow

**HWPCO2Ea**: Portion of HWPCO2 that is emitted in year t

**HWPCO2S**: Portion of HWPCO2 that is stored, i.e., enters in the HWP CO2 pool.

**HWPCO2Eb**: Loss of emissions from the HWP CO2 pool (from previous years) in year t

**HWPCO2E**: HWPCO2Ea + HWPCO2Eb emissions emitted in year t
Wood harvesting supply chain

• Replacement of forest residues mining process by a combination of forest management strategy and a harvest process (extracted from the forestry sector)

• Forest management strategy includes quantities of biomass harvested per year (kt) and CO2 sink associated to the forest (tCO2)

• Decomposition emissions from wood left in the forest is added.
Carbon accounting – Biogenic carbon

- Carbon emissions when biomass or biofuel are burnt are added. CO2 emissions coefficient are taken from IPCC (2006)

<table>
<thead>
<tr>
<th>Source</th>
<th>t CO2/TJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural residues</td>
<td>100.00</td>
</tr>
<tr>
<td>Forest residues</td>
<td>112.00</td>
</tr>
<tr>
<td>Municipal organic waste</td>
<td>100.00</td>
</tr>
<tr>
<td>Wood pellet</td>
<td>100.00</td>
</tr>
<tr>
<td>Black liquor</td>
<td>95.30</td>
</tr>
<tr>
<td>Hogfuel</td>
<td>100.00</td>
</tr>
<tr>
<td>Renewable natural gas</td>
<td>54.60</td>
</tr>
<tr>
<td>Gasoline substitutes</td>
<td>70.80</td>
</tr>
<tr>
<td>Diesel substitutes</td>
<td>70.80</td>
</tr>
<tr>
<td>Biojet</td>
<td>79.60</td>
</tr>
</tbody>
</table>
SECTION 3

Results: Net-zeros scenarios analysis
## Scenario Design

<table>
<thead>
<tr>
<th>Category</th>
<th>Name</th>
<th>Type</th>
<th>Baseline or HWP modeling</th>
<th>CO2 sink assumptions</th>
<th>Harvest level assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>REF – base</td>
<td>Reference</td>
<td>Baseline</td>
<td>Baseline</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>NZ50 – FMS</td>
<td>Reference</td>
<td>With HWP + FMS</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td></td>
<td>NZ50 – base</td>
<td>Net-zero by 2050</td>
<td>Baseline</td>
<td>Baseline</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>NZ50 – FMS</td>
<td>Net-zero by 2050</td>
<td>With HWP + FMS</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>REF – FMS 2</td>
<td>Reference</td>
<td>With HWP + FMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NZ50 – FMS 2</td>
<td>Net-zero by 2050</td>
<td>With HWP + FMS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FMS: Forest Management Strategy  
HWP: Harvested Wood Products

**ESMIA** Optimal Development of the Canadian Forest Sector
Total GHGs

“FMS” scenarios have higher GHG emissions than “base” scenarios by 6-18%.

Addition of HWP and biogenic emissions result in higher GHGs. The “neutral assumption” for biomass emissions may not be completely accurate with current forest management strategies.
Comparison of models with and without HWP + FMS
GHGs by sector

Forest sink does not counterbalance HWP and biogenic emissions

- Emissions are higher in the FMS scenarios
- NZ50 – FMS requires more DAC than the NZ50 - Base
- Biomass + CCS technologies do not get negative emissions anymore; therefore, these technologies are not used anymore in NZ50 scenario.
More energy is needed to reach net-zero by 2050

- Less biofuel is produced and used, as biomass is better used elsewhere.
- Synthetic fuels are now necessary to reach NZ50.
- More energy is needed overall as more energy intensive processes are needed (DAC and synthetic fuel production).
Biomass feedstock consumption

The way biomass feedstock is used changes radically

- No more biomass is used for electricity production and hydrogen production
- Less biomass is used to make biofuels
- Biomass is redirected to produce long-lived harvested wood product.

ESMIA Optimal Development of the Canadian Forest Sector
Study of different forest management strategies
GHGs by sector and HWP emissions

FMS with less forest sink potential uses more DAC but goes deeper in reduction in other sectors

- NZ50 - FMS 2 (more harvest, less forest sink) in 2050-2070 has less emissions in almost all energy sectors (Buildings, Industrial, energy production, electricity)

NZ50 targets lead to a decrease in biogenic carbon emissions and slight increase in long-lived HWP emissions

- NZ50 - FMS2 (with higher harvest level) has more HWP emissions
Biomass feedstock consumption

When more wood/residues are available, it goes to HWP and biofuel production

- In 2050, in NZ50 scenarios we see less use of biomass in space heating, industry and electricity production. But there is more wood going into HWP production and biofuels production (including RNG).
- In NZ50 - FMS2 (more harvest, less forest sink), we see more biomass going into HWP production and RNG, and less going in liquid biofuel production compared to NZ50.
- From 2050 upward, compensating biomass emissions is more and more difficult as we come close to Canadian sequestration limits.
Wood harvested and usage

NZ50 target leads to a better utilization of wood and residues than REF

• Less residues and wood are left to decompose in the forest with NZ50 targets.
• The model still chooses to consume all the wood available when the harvest levels are higher (NZ50 FMS2)
• Small quantities of residues are sent to landfill (residues from wood processing mills)
• Residues for energy production increase with net-zero targets (going to biofuel production)
• Wood and residues sent to pulp and paper decrease with NZ target.
• The additional wood available in FMS 2 is used for energy production and long-lived HWP production
Construction materials

Concrete production decreases with a net-zero target and HWP increases

- In a net-zero context, concrete decreases, iron and steel production stay relatively flat and HWP quantities increase.
- For HWP, we see a significant increase in exports.
- For iron and steel, there is a shift from other uses to construction.

In a net-zero context, concrete share decreases and is replaced by iron and steel and HWPs

- We can see a small increase of the HWPs share with time, higher in net-zero scenarios than REF.
- The HWP shares might be limited by technical potential as most of the extra HWP production goes to exports.
Conclusions and future work
Conclusions and Future Work

Key Findings

• **Use of harvested wood products for building construction** may be more optimal than other uses, such as electricity or hydrogen production – especially in achieving climate targets.

• Emissions impacts from biomass use may be **significantly higher** than expected.

• GHG accounting rules may change in the near future: we should be prepared to **support policy makers** in making decisions in this area.

Potential Refinements

• Collaborate with industry to refine techno-economic parameters of wood processing mills.

• Account for **recent forest fires** as part of management strategies.

• Refine construction sector by building type and height to represent the diverse technical potential of wood construction.

• Development of updated GWP factors with radiative forcing calculation.
Thank you.

Questions?

Marie Pied
marie@esmia.ca

Kathleen Vaillancourt
kathleen@esmia.ca

ESMIA Consultants Inc
Montreal, Canada