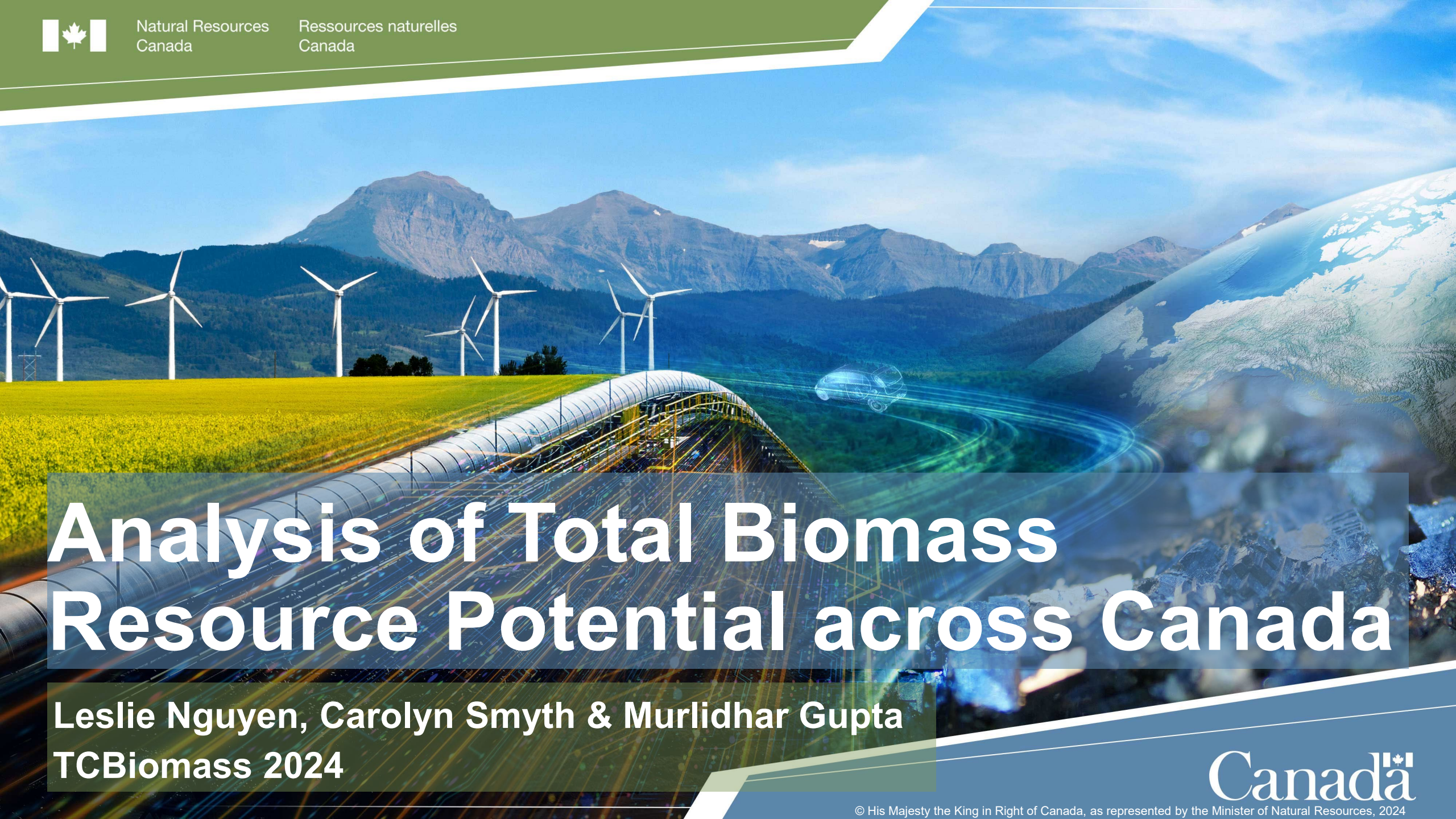

Analysis of Total Biomass Resource Potential across Canada

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TCBiomass 2024

Canada

About CanmetENERGY

- CanmetENERGY is a science and technology (S&T) branch of Natural Resources Canada and operates three labs across Canada with over 450 scientists, engineers and technicians
- CanmetENERGY-Ottawa's mission is to lead the development of energy S&T solutions for the environmental and economic benefit of Canadians

Outline

- Background and Motivation
- Objectives and Scope
- Guiding Terms and Definitions
- Forest Biomass Subcategories
- Agriculture Biomass Subcategories
- Waste Biomass Subcategories
- Canada's Untapped Biomass Potential
- Closing Remarks

Background and Motivation

- The global community has signaled the importance of mitigating climate change with ambitious emissions reduction targets.
- Enhanced biomass utilization is one of few methods enabling negative emissions and acceleration towards net-zero goals.
- Despite this, biomass use for energy, industrial raw materials and vectors for carbon-negative sequestration in Canada remains relatively untapped.
- Understanding and consensus on available biomass and potential impact to reduce Canada's emissions is a key gap.

Objectives and Scope

To estimate quantities of biomass available across all of Canada

- Development of precise language guiding estimates and identification for major pools of biomass
- Derivation of biomass estimates based on reliable, peer reviewed methods and data sources that are updated regularly
- Include considerations ensuring estimates of biomass potentials are sustainable
- Provide estimates in annual dry metric tonnes of biomass, metric tonnes of carbon, tonnes of CO_2 equivalence and energy content to better convey GHG reduction potential

Guiding Terms and Definitions

- **Sustainable** – a state that can be maintained at a certain level in a continuous manner, but also preserving human and ecological values
- **Current** – can be deployed in near term (i.e. algae and energy crops out of scope)
- **Theoretical Potential Biomass** – total biomass generation less unavoidable, natural or inherent losses and excludes biomass restricted by law (i.e. managed vs. unmanaged forests)
- **Net Growth or Total Increment** – covered by the term Theoretical Potential Biomass, but based specifically on total biomass growth less losses from natural turnover, old age and natural disturbances
- **Unavailable Biomass -** includes biomass slated for conventional goods, required for basic life necessities (i.e. firewood for remote/rural/residential heating), but excludes large scale combustion for energy and electricity production, and biomass retained for sustainability values

Forest Biomass Pools Considered

- Merchantable stem wood – bark-free log within merchantability thresholds (i.e. stump height and top threshold diameter)
- Bark accompanying merchantable stem
- Stumps and roots below stump height
- Tree-tops, branches and foliage (commonly known as harvest residues, roadside, etc.)
- Wood processing residues comprised of stem wood (fines, sawdust, shavings, etc.) and bark
- Deadwood (snag stems, snag branches, BG Fast DOM and Medium DOM)
- Trees outside forestry (whole-trees) and urban trees (whole-trees)

Canada Tree Cover (CFS, NRCan 2015)

BG – Belowground
AG – Aboveground
DOM – Dead Organic Matter
snag – refers to standing deadwood

Key Forest Biomass Factors

- Derived from Canada's Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) and biomass equations developed from dry mass of biomass compartments from 9000 trees
- CBM-CFS3 is applied in Canada's annual National Inventory Report (NIR) to UNFCCC for carbon balance reporting around Canada's managed forests

CBM CFS 3

Parameter	Units	Softwood	Hardwood
Oven Dry Density	$t\ m^{-3}$	0.455	0.527
Bark Expansion Factor	$kg_{bark+stem}\ kg_{stem}^{-1}$	1.110	1.150
Tops Stem Fraction	$kg_{tops}\ kg_{total\ stem}^{-1}$	0.027	0.049
Stump Stem Fraction	$kg_{stump}\ kg_{total\ stem}^{-1}$	0.047	0.044
Merchantable Stem Fraction	$kg_{merchantable\ stem}\ kg_{total\ stem}^{-1}$	0.927	0.907
Branch Expansion Factor	$kg_{branches+total\ stem}\ kg_{total\ stem}^{-1}$	1.170	1.280
Foliage Expansion Factor	$kg_{foliage+total\ stem}\ kg_{total\ stem}^{-1}$	1.100	1.040
Root-to-Shoot Ratio	$kg_{BG\ Biomass}\ kg_{AG\ Biomass}^{-1}$	0.222	0.341
Carbon Content	$kg_{C}\ kg^{-1}_{biomass}$	0.5	0.5

Forest Data Requirements – Part 1

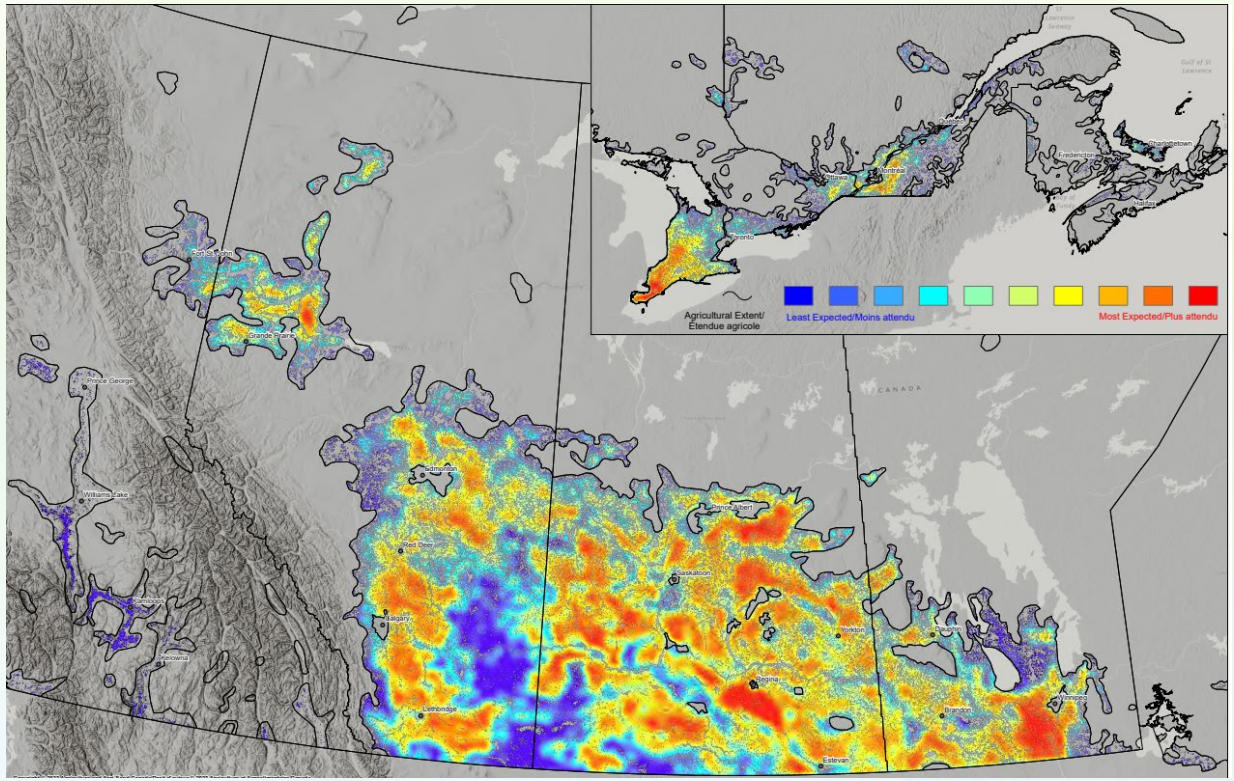
	A	B	C
1	**Biomass Pool**	**Theoretical Potential**	**Competitive Uses or Unavailable**
2	Merchantable stem	Harvest limit as merchantable volume informed by growth modeling, forecasts of losses to forest fires and insect infestation and adjusted after catastrophic events; oven dry density	Harvest quantities in merch. volume and oven dry density
3	Bark w/ merch. stem	Info from **B2**, bark expansion factor	Info from **C2**, bark expansion factor (allocated to wood processing residues)
4	Tops, branches & foliage	Info from **B2**, merch. stem fraction, tops stem fraction, branch expansion factor, foliage expansion factor	For sustainability values, 50% of total from **B4**
5	Stumps & roots	Info from **B2**, merch. stem fraction, stump stem fraction, total AG biomass (sum of **B2**, **B3**, **B4** and stump weight), root-to-shoot ratio	100% of **5B** because disturbance of forest floor and soil is widely discouraged

Forest Data Requirements – Part 2

	A	B	C
1	**Biomass Pool**	**Theoretical Potential**	**Competitive Uses or Unavailable**
2	Wood Processing Residues	Harvested bark calculated in cell **C3** from **slide 9**. Production of stem wood-derived mill residues from lumber and pulp production mass balances	Consumption of fines, sawdust, shavings for wood composites and wood pellets for residential heating estimated from infeed mass balances
3	Deadwood	Total increment of deadwood from forest stock – see CBM-CFS3 for details. Production of deadwood from wildfires and insect infestation – total area affected and average production of deadwood per unit area affected. (AG deadwood only: 6306 t km^{-2} for fire, and 250 t km^{-2} for fire and insect, respectively; AG+BG deadwood: ~8702 t km^{-2} and ~280 t km^{-2} for fire and insect, respectively)	Total increment from forest stock in cell **B3** because of sparsity Non-standing deadwood from wildfire and insects – forest floor (i.e. stumps) and BG deadwood – because forest floor and soil disturbance discouraged Reduction of remaining wildfire and insect deadwood by percent area wildfire not in tenured forest (~33% in Canada)

Agriculture Biomass Pools Considered

- Primary crop residues – includes all biomass left in the field after harvest of primary product
- Secondary crop residues – covers waste produced during the processing of primary product
- For completeness, consistency and future considerations, belowground biomass was quantified, wherever applicable.
- Energy crops – crops grown solely for energy or biofuels production
- Manure - excrements from livestock and food production



Spatial density of Crop Occurrence (AAFC 2021)

Crop Agriculture Biomass Factors – Part 1

- Single, comprehensive source of agriculture crop biomass yields used in Canada's NIR
- Numbers are two decades old, thereby underestimating present yields and mitigates overestimation

Crop	Moisture (wt%)	Dry Matter Allocation			Duration (yrs)
		Product	Aboveground (w/o Product)	Belowground (w/o Product)	
Wheat, all	12	0.34	0.51	0.15	1
Oats	12	0.33	0.47	0.20	1
Barley	12	0.38	0.47	0.15	1
Rye	12	0.34	0.51	0.15	1
Flaxseed	8	0.26	0.60	0.15	1
Canola (rapeseed)	9	0.26	0.60	0.15	1
Corn for grain	15	0.47	0.38	0.15	1
Soybeans	14	0.30	0.45	0.25	1
Mixed grains	12	0.33	0.47	0.20	1
Buckwheat	12	0.24	`0.56	0.20	1
Peas, dry	13	0.29	0.51	0.20	1
Beans, all dry	13	0.46	0.34	0.20	1
Mustard seed	9	0.26	0.60	0.15	1
Sunflower seed	2	0.27	0.53	0.20	1
Lentils	13	0.28	0.52	0.20	1

H. H. Janzen *et al.*, "The fate of nitrogen in agroecosystems: An illustration using Canadian estimates," *Nutr. Cycl. Agroecosystems*, vol. 67, no. 1, pp. 85–102, Sep. 2003, doi: 10.1023/A:1025195826663

Crop Agriculture Biomass Factors – Part 2

- Figures are used in carbon and nitrogen balancing for estimates of CO_2 and NO_x emissions
- "Duration" reduces residue yield for applicable crops

Crop	Moisture (wt%)	Dry Matter Allocation			Duration (yrs)
		Product	Aboveground (w/o Product)	Belowground (w/o Product)	
Corn for silage	70	0.72	0.08	0.20	1
Canary seed	12	0.20	0.60	0.20	1
Summerfallow	0	0.00	0.00	0.00	1
Tame Hay	13	0.18	0.12	0.70	5
Safflower	2	0.27	0.53	0.20	1
Potatoes	75	0.68	0.23	0.10	1
Tobacco	20	0.64	0.16	0.20	1
Sugar beets	80	0.76	0.19	0.05	1
Forage for seed	13	0.12	0.48	0.40	5
Vegetables	80	0.40	0.40	0.20	1
Other field crops	10	0.28	0.55	0.16	1
Tree fruits & nuts	84	0.04	0.67	0.30	10
Berries & grapes	85	0.03	0.48	0.50	5
Chick peas	15	0.25	0.57	0.18	1

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Livestock Manure Factors

- Manure production is primarily livestock population driven.
- Default IPCC figures for volatile solids (VS) production applied for cattle. Canada-specific values are used for other categories.
- Proportions of manure produced on pastures come from Canada's NIR that is available annually.

Category	VS (kg head^{-1} day^{-1}, Dry)	Manure Stored (%)	Pasture Manure (%)
Dairy Cattle	5.40	84	16
Non-Dairy Cattle	2.40	55	45
Sheep & Lambs	0.60	33	67
Swine	0.24	100	0
Buffalo	3.10	50	50
Llamas and Alpacas	0.60	30	70
Deer & Elk	0.30	50	50
Goats	0.72	41	59
Horses	3.50	32	68
Poultry	0.02	99.5	0.5
Rabbit	0.10	100	
Fox	0.14	100	
Mink	0.14	100	
Wild Boars	0.24	100	
Mules and Asses	0.94	100	

Agriculture Data Requirements, Part 1

	A	B	C
1	**Biomass Pool**	**Theoretical Potential**	**Competitive Uses or Unavailable**
2	Primary Crop Residues	Total primary product production (i.e. yield of grain, seed, fruit), moisture content, dry matter allocations and rotation/duration years, where applicable, from tables on **slides 12** and **13**.	Deficit of livestock forage requirements not met by biomass from pasture, range and paddocks. Total production of compressed residue products. 50% remaining after reductions of previous two items from **B2** for soil conservation.
3	Secondary Crop Residues	Total primary product production, moisture content, fraction of primary product as waste	Non-forage-based feed requirements for livestock
4	Manure	Livestock populations, total dry volatile solids production per head	Fraction of manure stored, collected and spread onto cropland. Fraction of manure produced on pasture

Waste Biomass Pools Considered

- Post-consumer wood waste – end-of-life wood-containing products from residential and ICI (industrial, commercial and institutional) sources including construction and demolition waste
- Sewage sludge – organic solids from municipal, manufacturing and industrial sewage handling systems and wastewaters
- Fishery waste – unused waste portions of live fish landings (i.e. head, skin, trimmings, bones, non-edible portions, etc.)
- Municipal solid waste – organic portions of garbage (may overlap with other waste biomass subcategories)

Waste Data Requirements, Part 1

	A	B	C
1	**Pool**	**Theoretical Potential**	**Competitive Uses or Unavailable**
2	Post-consumer wood waste	Total wood waste generated, which includes sum of quantities landfilled, diverted, incinerated and exported; moisture content, biogenic content	Quantities from **B2** diverted and exported
3	Sewage Sludge	Population size, daily organic loading of 0.06 kg BOD_5 per capita, 1.25 correction factor for industrial and commercial inputs, typical total suspended solids (TSS) to BOD_5 ratio	Quantities of sludge from **B3** processed by wastewater treatment and quantities applied to lands as biosolids
4	Fishery Waste	Wet weight of total landings, moisture content (~65-85 wt%), fish waste fraction	Fish waste fraction; moisture content; 50% of wet weight of live, fresh or chilled fish exports, prepared and preserved fish exports and domestic consumption; 4.24 times fish meal production and 5.24 times fish oil production
5	MSW	Remaining quantities of wastes containing biogenic material landfilled, incinerated, diverted and exported; moisture content; biogenic content	Quantities from **B5** diverted, exported and incinerated for hazardous materials disposal (excludes energy production)

Biomass Category	Biomass Subcategory	Theoretical Potential (10^6 dry tonnes)	Unavailable (10^6 dry tonnes)	Surplus (10^6 dry tonnes)	Carbon content (mf)	Carbon potential (10^6 tonnes)	CO_2 potential (10^6 tonnes)	Energy density (MJ kg^{-1})	Total energy (PJ)
Agric.	Residues	178	125	53	0.45	24	88	17	905
	Manure	15	15	0	0.35	0	0	10	0
Forest	Stems	102	67	35	0.50	18	64	18	630
	Bark	12	8	5	0.50	2	8	18	81
	Tops, branches & foliage	39	20	20	0.50	10	36	18	355
	Stumps & roots	47	47	0	0.50	0	0	18	0
	Deadwood	283	219	64	0.50	32	117	18	1,152
	Trees outside forestry	3	1	2	0.50	1	3	18	31
	Processing residues	17	4	12	0.50	6	22	18	219
Waste	Post-consumer wood	3	0	3	0.50	1	5	18	46
	Sewage sludge	1	1	0	0.45	0	1	10	4
	Fishery waste	0	0	0	0.45	0	0	21	1
	MSW	9	5	5	0.50	2	9	17	79
	Exported waste	1	0	1	0.50	1	2	18	19
Total	All	710	511	199		97	355	237	3,522

Canada's Untapped Biomass Potential

- It is estimated that Canada produces 710 million dry tonnes of biomass annually (considers only tree biomass from managed forests and also includes belowground biomass, where applicable).
- In total, 511 million dry tonnes of biomass is considered unavailable.
  - 105 million dry tonnes is slated for conventional markets but excludes large-scale energy and utilities.
  - 406 million dry tonnes are unavailable due to sustainability values.
- Approximately 199 million dry tonnes of surplus biomass are potentially available per year.
  - One third (64 million tonnes) may be subject to high intra-year variation (i.e. deadwood from wildfire and insect infestation) and inaccessibility.
  - Agriculture crop residues represent possibly the largest biomass pool, second to deadwood, that is most readily accessible in Canada.

Closing Remarks

- The CO_2 equivalence associated with untapped biomass potential in Canada amounts to 355 million tonnes and corresponds to an energy value of 3522 PJ, annually.
- In 2022, Canada emitted 708 million tonnes of CO_2 and consumed 8585 PJ of energy domestically
- Future work to enable more regional biomass estimates with geospatial data products and integration with TEA and LCA of value-chains to understand economic potential, life cycle impacts and realistically achievable emissions reductions.
- Work described in this study would not have been possible without the great body of research and work that contributes to understanding of annual Canadian GHG emissions and the many survey programs and participants that support it

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