

Supplementary Materials

Potential for thermo-chemical conversion of solid waste in Canada to fuel, heat and electricity

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Table S1. Solid waste definitions.

Waste Type	Definition and Reference
Biogenic organic	"Materials that are or were once living, such as leaves, grass, yard trimmings, agricultural crop residues, wood waste, and paper and paperboard products or food scraps [2]."
Food	"Includes food wastes and food scraps from households and non-residential sources such as grocery stores, restaurants, etc., destined for composting or anaerobic digestion [2]." "Discarded animal and vegetable matter from food and food preparation; sources include residences and commercial establishments, such as grocery stores, restaurants, produce stands, institutional cafeterias and kitchens, and industrial sources, like employee lunchrooms [3]."
Paper	"Post-consumer wastepaper is material discarded after consumer use, such as Old Corrugated Containers (OCC), boxboard (used in shoe boxes, cereal boxes, etc.), magazines, and newspapers [4]."
Wood	"The primary constituents of wood waste are used lumber, trim, trees, branches, and other wood debris from construction and demolition clearing and grubbing activities. It includes dimensional lumber, plywood, particle board and fibre board, crating, wood fencing, pressure treated lumber, wood shingles, wooden doors, creosoted wood products, demolition wood waste, painted wood [2]."
Yard & garden	"Vegetable matter resulting from gardening, horticulture, agriculture, landscaping, or land clearing operations, including materials such as tree and

	shrub trimmings, plant remains, grass clippings, leaves, trees, and stumps [3].”
Pet	Feces produced by dog, cat, or other pet animals [5].
Rubber and leather	Natural or synthetic rubber or leather products [6].
Other	Include other organics that do not fit into the secondary organic waste types. Waste such as soiled paper, including tissues, paper towel, and food packaging [7].
Non-biogenic organics	Materials that are made from fossil fuel sources such as natural gas, petroleum, or coal.
Plastics	End-of-life plastic from type 1 to type 7 [2]. Including recyclable plastics, refundable plastic beverage containers, plastics drink cups, drink cup lids, straws, stirrers, recyclable plastic film, recyclable single use grocery bags, expanded polystyrene, non-recyclable plastics [6].
Inorganics	Materials made from non-carbon elements [8].
Metals	Includes non-refundable recyclable metal, refundable metal beverage containers, recyclable miscellaneous metal, metals from disassembled household appliances, non-recyclable metals [6].
Glass	Includes non-refundable recyclable glass, refundable glass beverage containers, non-recyclable miscellaneous glass [6].
Combination	Waste material contains two or more primary waste types but is counted separately. Even if a specific material from a secondary waste type in this category belongs to another primary waste type, due to the wide crossover variation in primary waste materials, is categorized under combination. For example, textiles can be made of organic cotton (organics) or full synthetic nylon (plastics), but when textiles get disposed of, it is a cluster of all types of textiles exists on the market, so textiles are categorized as one type under the combination waste type.
Non-wood construction	“It generally includes materials such as brick, drywall, metal, cardboard, doors, windows, wiring, etc. It excludes materials from land clearing on areas not previously developed. Non-wood construction waste can come from residential sources such as house renovations or from non-residential sources for example the construction or demolition of office buildings [2].”
Diaper	Used diaper containing human urine and feces.
Tires	Recyclable tires include rubber tires from automobile, trucks, and bicycles [6].
Household appliances	“Includes metal items such as: stoves, fridges, freezers, air conditioners, dehumidifiers, washers, dryers, hot water tanks, metal sinks, microwaves, and various other metal items [2].”
Textiles	Natural or synthetic fibre clothing and linens [6].

Electronics	<p>“Electronics are items that function through the use of electricity and/or batteries. Also included are items that have a circuit board but do not necessarily require electricity from an outlet (such as telecommunication equipment). Examples are personal computers, laptops, monitors, peripheral devices (printers, scanners, etc.), telephones, cell phones, facsimile machines, stereos, portable music players and children’s toys containing electronic components [2].”</p>
Unclassified	<p>“Inerts and other material not included in any other type. This type may include items from different types combined, which would be very hard to separate. Also includes ceramics, porcelain toilets and sinks, clay roofing tiles and pottery. Articles made from clay and hardened by heat [6].”</p>
Other	<p>May include furniture, mattresses, box springs, gloves, masks, used carpet and underlays [6,9-12].</p>
Hazardous	<p>Hazardous waste is defined as materials that are corrosive, flammable, infectious, reactive, and toxic, and that are harmful or have the potential to be harmful to humans and the environment. Special handling, storing, transportation, treatment, and disposal are required for hazardous waste according to the Transportation of Dangerous Goods Regulations (TDGR), the Canadian Environmental Protection Act (CEPA), the Basel Convention, and the Export and Import of Hazardous Waste Regulations.</p>
Railway ties*	<p>Creosote-impregnated wood containing toxic polycyclic aromatic hydrocarbons used for railway construction [13]. “This substance has been added to the List of Toxic Substances. It is entering or may enter the environment in a quantity or concentration or under conditions that: have or may have an immediate or long-term harmful effect on the environment or its biological diversity [14].”</p>
Biosolids**	<p>“Organic product obtained from the physico-chemical and/or biological treatment of wastewater. Biosolids result from primary wastewater treatment (primary biosolids), or from secondary wastewater treatment (secondary biosolids), and these two types of biosolids are often combined (mixed biosolids). These biosolids can be derived from the treatment of either municipal wastewater or industrial wastewater [15].” “Insoluble material removed from wastewater treatment processes are referred to as ‘biosolids’. Biosolids can contain organic materials, nutrients, pathogens, metals, and organic chemicals. Some of these are NPRI substances. For NPRI purposes, biosolids (and the NPRI substances in the biosolids) are considered waste and are not an intentionally produced product. Wastewater treatment facilities must report the releases, disposals, and transfers of NPRI substances in biosolids [16].”</p>
Household Hazardous	<p>Hazardous waste generated from residential source, consisted of batteries (0.1 million tonnes), paint and solvent (0.07 million tonnes), medication (0.07 million tonnes), used engine oil and anti-freeze (0.03 million tonnes), medical sharps (0.02 million tonnes), and pesticides (3.5 thousand tonnes) [7,17]</p>

Table S2. Major metal species that exceed 1000 ppm on a dry basis, sulfur, and chlorine content in wt% on a dry and ash free basis for the solid waste studied [1].

Waste Type	Metal Contaminants (ppm), Sulfur (wt%), and Chlorine Content (wt%)												
	Al	Ca	Fe	K	Mg	Na	P	Pb	Si	Sb	Zn	S	Cl
Biogenic Organic													
Food		2100 0		1200 0	1600		1100		4400			0.1 6	0.2 2
Paper	7800	9300	1700						1900			0.0 9	0.9 6
Wood	3200	6900	1400	4700		2100			2500 0			0.1 8	0.1 7
Yard and garden	5400	2200 0	3500	4600	1800		1200		7100 0			0.1 8	0.0 2
Rubber and leather												1.9	0.7 1
Non-biogenic Organic													
Plastic		5600						1600		4700		0.0 9	3.6
Combination													
Tire												1.6	
Hazardous													
Railway ties		2200	2200						2200			0.0 9	0.0 3
Biosolids	1300 0	2500 0	1800 0	1000 0	5400	7700	3800 0		2400 0		130 0	2	0.5 6

Table S3. Entry names and codes used from ECN Phyllis database for data generated in Table 3 [1].

Waste Type	Sample Size	ECN Entry Name	ECN Entry Code
Biogenic Organics			
Food	42 for C, H, O; 43 for N; 36 for S; 25 for Cl; 42 for ash; 42 for HHV; 38 for MC	Brewery spent grains	#3578
		brewing rests	#1076
		Citrus peels	#3631
		Citrus peels	#3646
		Citrus peels	#3653
		coffee grounds	#1769
		Coffee grounds	#3592
		coffee husk	#2882
		domestic food waste, specified	#1589
		domestic food waste, specified	#1590
		domestic food waste, unspecified	#1587
		domestic food waste, unspecified	#1588
		Empty fruit bunch	#3580
		Empty fruit bunch	#3581
		Empty fruit bunch	#3582
		Empty fruit bunch	#3583
		Empty fruit bunch	#3584
		Empty Fruit Bunches palm oil	#2932
		flour byproducts	#1077
		grain screenings	#2805
		grain slop	#1075
		grape pomace	#1485
		Grape pomace (left over after juice extraction)	#1252
		grape skins and seeds, air dried	#2862
		grape skins, air dried	#2861
		grapefruit skin	#2286
		Litchi peel	#2923
		Litchi seeds	#2926
		Longan peel	#2924
		Longan seeds	#2927
		Mango peel	#2922
		Mango seeds	#2925
		molasse	#2626
		oil palm empty fruit bunch, pith	#2897
		Olive pomace	#3586
		Olive Pomace (Valesa)	#3654
		olive pomace pellets	#2893

		Onion peel	#3068
		orange husk	#2169
		orange peel and seeds	#2832
		orange skin, air dried	#2880
		palm oil kernel shell	#2940
		palm oil mesocarp fiber	#2936
		Palm olein	#3627
		pineapple bran	#2379
		pineapple waste	#1336
		potato	#1570
		potato fibres	#1065
		potato rests	#1068
		potato shreds, sorting waste	#1066
		potato sorting waste	#1067
		prerefining sediment (vegetable oil)	#2153
		remainder of baking product	#1063
		soybean oil cake	#2848
		spent coffee	#1788
		spent coffee	#2190
		sugarcane fiber	#2807
		tea waste	#980
		tea, leaves	#1612
		tea, leaves	#1613
		tomato pomace (left over after juice extraction)	#1434
		waste fat sediment, heavy phase	#2151
		waste fat sediment, light phase	#2150
		wheat dust	#1437
Paper	5 for C, H, O, N; 4 for Sulfur; 3 for Cl; 6 for ash; 4 for HHV; 4 for MC	paper mill waste	#2037
		paper waste "Rofire"	#2734
		paper, 20% kraft waste and 80% OCC	#2494
		paper, mixed waste	#2489
		paper, mixed waste	#2491
		paper, mixed waste	#2493
		paper, newsprint pre-consumer waste	#2501
		rejects from waste paper preparation	#412
		waste paper	#709
		waste paper	#1410
Wood	31 for C, H, O; 33 for N; 35 for S; 36 for Cl; 31	holocellulose from waste wood from mulberry	#950
		lignin from waste wood from mulberry	#949
		redwood, mill wastes	#1417
		sweep waste containing wood, paint, sand	#677

for ash; 24 for HHV; 18 for MC	urban waste wood	#1989
	urban waste wood	#2031
	waste wood	#2748
	Waste wood (BM3)	#3060
	waste wood from mulberry	#951
	wood waste	#710
	wood waste	#711
	wood waste	#1059
	wood waste, dust	#655
	wood, excess fraction wood from organic domestic waste composting plant	#1089
	wood, excess fraction wood from organic domestic waste composting plant	#1295
	wood, fir mill waste	#804
	wood, furniture waste	#397
	wood, furniture waste	#805
	wood, industrial wood waste, dust	#657
	wood, Jack pine waste (USA)	#880
	wood, lacquered waste wood	#400
	wood, mixed waste wood	#276
	wood, park waste wood	#912
	wood, park waste wood bio-dry	#1088
	wood, uncontaminated waste wood	#309
	wood, waste wood	#310
	wood, waste wood	#311
	wood, waste wood	#312
	wood, waste wood	#313
	wood, waste wood	#314
	wood, waste wood	#315
	wood, waste wood	#316
	wood, waste wood	#317
	wood, waste wood	#318
	wood, waste wood	#319
	wood, waste wood	#320
	wood, waste wood	#321
	wood, waste wood	#322
	wood, waste wood	#323
	wood, waste wood	#324
	wood, waste wood	#325
	wood, waste wood	#326
	wood, waste wood	#327
	wood, waste wood	#328

		wood, waste wood	#329
		wood, waste wood	#330
		wood, waste wood	#331
		wood, waste wood	#332
		wood, waste wood	#333
		wood, waste wood	#334
		wood, waste wood	#335
		wood, waste wood	#336
		wood, waste wood	#337
		wood, waste wood	#338
		wood, waste wood	#339
		wood, waste wood	#340
		wood, waste wood	#341
		wood, waste wood	#342
		wood, waste wood	#926
		wood, waste wood	#2809
Yard	3 for C, H, O, N, S; 3 for Cl; 1 for ash; 2 for HHV; 3 for MC	mowing waste	#1058
		Urban leaf litter	#3590
		Urban leaf litter	#3591
		Withered leaves	#3065
Rubber and leather	2 for C, H, O, N, S; 2 for Cl; 2 for ash; 1 for HHV; 2 for MC	leather waste	#2930
		waste rubber chips	#1775
Other bio-genic organ-ics	47 for ash; 28 for HHV; 40 for MC	Greenhouse waste (sweet pepper residues)	#3537
		agrarian residues	#1069
		beet tail and beet green	#1053
		cane tops	#1792
		cane trash	#1906
		cassava residues	#2596
		cellulose	#389
		cellulose	#1720
		cellulose	#1734
		cellulose	#2741
		cellulose, dissolving	#2525
		compost	#391
		Compost	#3488
		Compost	#3489
		Compost	#3490
		digestate	#2646
		Digestate	#3593
		digestate from organic waste	#2907

domestic food waste, specified	#1589
domestic food waste, specified	#1590
domestic food waste, unspecified	#1587
domestic food waste, unspecified	#1588
domestic organic waste from municipal collection	#393
domestic vegetable + fruit waste	#1591
Dutch organic domestic waste (GFT)	#1716
Eggplant residues 650°C	#3641
flesh residues (tannery waste)	#2300
fresh Dutch domestic organic waste	#1765
garlic waste	#2070
greenhouse residues	#1055
hair residues (tannery waste)	#2298
hemicellulose	#1736
holocellulose from waste wood from mulberry	#950
humus from digested MSW	#2132
humus from digested MSW	#2133
kale, stalk	#1559
Kraft lignin from Eucalyptus	#944
leather waste	#2930
leather waste, gasifier cyclone ash	#2931
leather, dark brown	#2755
lignin (Indulin ATR-CK1)	#1694
lignin from poplar	#1999
lignin from softwood	#2000
lignin from waste wood from mulberry	#949
lignin kraft	#2457
lignin soda	#2458
MSW compost	#1527
MSW compost	#3345
MSW organic wet fraction	#3199
Mushroom manure	#3066
organic domestic waste (ODW)	#1300
organic domestic waste, the Netherlands	#1341
organic domestic waste, the Netherlands	#1342
organic domestic waste, the Netherlands	#1343
organic domestic waste, the Netherlands	#1344
organic domestic waste, the Netherlands	#1345
organic domestic waste, the Netherlands (GFT)	#1060
Organic fertilizer	#3495
Organic wet fraction municipal waste	#3198

		organosolv lignin (ALCELL)	#1735
		palm fibre	#2237
		palm fibres	#1914
		paper waste "Rofire"	#2734
		pepper waste	#1915
		rape seed extraction material	#1442
		skin residues (tannery waste)	#2299
		stubble turnip	#2262
		sugarbeet, leaves and tops	#2622
		sugarbeet, leaves and tops, 90 days ensilaged	#2623
		sweet patato vines	#2590
		sweet pepper, greenhouse waste	#2539
		tofu residues	#2591
		tomato plant waste	#2261
		tomato plant, greenhouse waste	#2538
		tomato plant, greenhouse waste	#3517
		waste from brewing-industries	#422
		waste from malt-industries	#423
Non-biogenic Organics			
Plastics	3 for C, H; 2 for O; 3 for N; 3 for S; 3 for Cl; 3 for ash; 3 for HHV; 1 for MC	plastic fraction (the Netherlands)	#1877
		plastics from waste from electrical and electronic equipment (WEEE) material, mix 1	#2178
		plastics from waste from electrical and electronic equipment (WEEE) material, mix 2	#2179
Combination			
Tires	3 for C, H, O, N, S; 0 for Cl; 3 for ash; 3 for HHV; 3 for MC	rubber tyre waste	#918
		waste tyres	#1495
		waste tyres	#1687
Hazardous			
Railway ties	5 for C, H, O, N; 7 for S; 5 for Cl; 5 for ash; 5 for HHV; 3 for MC	railroad ties, sleepers	#406
		railroad ties, sleepers	#407
		railroad ties, sleepers	#654
		railroad ties, sleepers	#853
		railroad ties, sleepers	#854
		railroad ties, sleepers	#876
		railroad ties, sleepers	#885
Biosolids	10 for C, H, O, N, S; 7 for Cl; 9 for ash; 8 for HHV; 10 for MC	sewage sludge (mech. dried)	#1777
		sewage sludge digestate, dried	#2913
		sewage sludge, dried	#960
		sewage sludge, dried	#961
		sewage sludge, dried	#2158

sewage sludge, dried	#2899
sewage sludge, dried	#2919
sewage sludge, dried	#3188
sewage sludge, dried (thermal)	#2191
sewage sludge, dried for cocombustion in PF boiler UNA Amsterdam	#2188

4. Sample Calculation of Energy Potential for Heat Generation

The following calculation is done for waste plastic using the quantity generated and fraction disposed from Table 2, average higher heating value from Table 3, and conversion efficiency for incineration from Table 1.

Energy Potential

$$\begin{aligned}
 &= \text{Quantity Generated} \times \text{Fraction Disposed} \times \text{Heating Value} \times \text{Conversion Efficiency} \\
 &= 3,625,479,000 \frac{\text{kg}}{\text{yr}} \times 0.89 \times 30,000,000 \frac{\text{J}}{\text{kg}} \times 0.6 = 5.8 \times 10^{16} \text{J} \times \frac{\text{TJ}}{10^{12} \text{J}} = 58,000 \text{ TJ}
 \end{aligned}$$

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