Ontario Agricultural Waste Study: Measuring the Environmental Benefits of Recycling Agricultural Wastes

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Final Report

August 8, 2011

Executive Summary

Every year in Canada, recyclable agricultural packaging materials made from plastic and paper fibre are landfilled or burned. Open pile burning (pile or forced air) has a series of health and safety hazards, including air pollution, impacts on groundwater and soil contamination from ash disposal, and fire hazards.

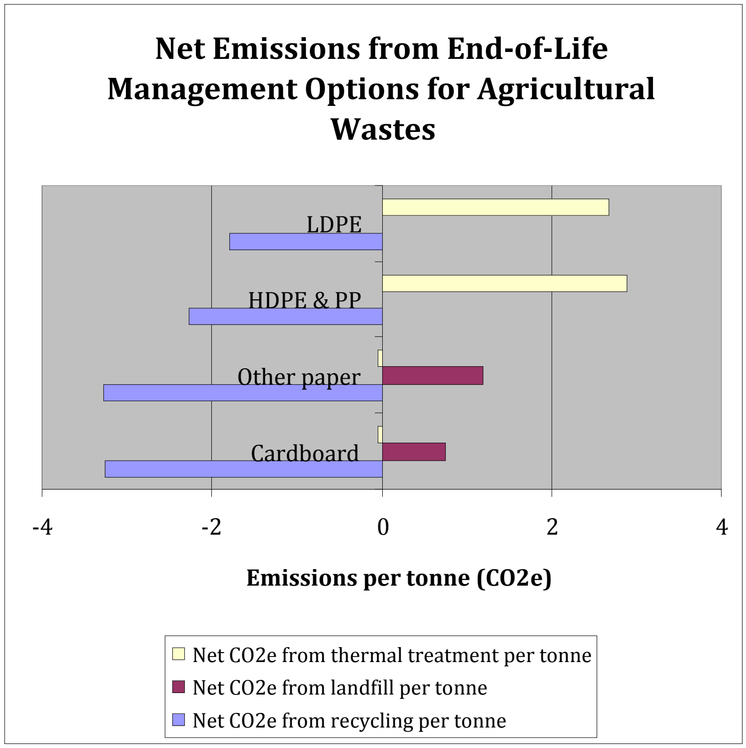
Energy is also lost because the material was not recycled. Making products from recycled raw material requires much less energy than virgin resources because all the primary extraction functions for the raw materials are avoided. In terms of plastics like HDPE, PP and LDPE, recycling avoids having to extract and process crude oil and natural gas, produce Olefins and polymerize.

In the case of paper-based packaging, manufacturing corrugated packaging with old cartons requires no roundwood harvesting, wood residual production, sodium and sulfate mining, soda ash production, or corn starch manufacture. Keeping trees standing also has the added benefit of carbon sequestration, which further contributes to an overall positive impact on greenhouse gas (GHG) emissions reduction.

Using Life Cycle Analysis (LCA) models available from Environment Canada, the "net benefit" of end-of-life management options for waste can be measured. In the case of agricultural wastes, like plastic film, twine, bale wrap, drums and pails; paper bags and corrugated boxes, the benefits are recycling instead of disposal (landfill or thermal treatment) are significant.

Specifically:

- Recycling paper and plastic-based agricultural wastes avoids from 1.8 to 3.26 tonnes of greenhouse gas emissions (CO2e) per tonne of paper and plastic based agricultural wastes recycled respectively;
- Disposing paper and plastic-based agricultural wastes in a landfill (with methane capture for flaring) creates from 0.01 tonnes of GHG emissions (CO2e) from plastics to 1.2 tonnes of GHG emissions per tonne of paper landfilled;
- Disposing paper and plastic-based agricultural wastes through thermal treatment (with electricity production) creates nearly three tonnes of greenhouse gas emissions (CO2e) per tonne of plastics;



- Recycling paper and plastic-based agricultural wastes conserves considerably more energy than landfilling and thermal treatment. Specifically, three times more for cardboard; more than 4 times more for paper, and greater than 10 times more energy conserved when recycling plastics instead of thermal treatment, and even greater amounts compared with traditional landfilling (with methane flaring).

But these recycling benefits are measured against more traditional waste management options, like landfill and thermal treatment (or incineration) which burns materials in a controlled environment, allowing the facility to manage emissions. However today a significant amount of farm waste is buried or burned on-site. Environment Canada suggests that "barrel burning" (burning garbage on-site without controlled conditions and pollution prevention) may be the largest remaining single source of anthopogenic dioxins. Burning garbage on-site releases thousands more dioxins and furans than burning the same amount of waste in a municipal incinerator[1].

Unfortunately, data for many of the emissions than directly impact human health, like dioxins and furans; fine particulate matter (PM); heavy and metals are not readily available and highly dependent on individual system parameters (burn temperature; material burned; air flow etc.)

[1] Environment Canada

Applying Life Cycle Analysis to Measure the Benefits of Recycling Agricultural Wastes over Disposal

1. Method

Life Cycle Analysis (LCA) attempts to measure these net impacts in terms of reduced greenhouse gas emissions and conserved energy from recycling instead of disposal. Environment Canada's GHG Calculator for Waste Management (2009)[2] calculates the GHG emissions for baseline and alternative waste management practices, including recycling, composting, combustion and landfilling. The model calculates emissions in tonnes of carbon dioxide equivalent (CO_2e) across a wide range of material types commonly found in the waste stream. These include paper-based and plastic (HDPE & LDPE) packaging used for agricultural products. The calculator applies material specific emissions and energy savings that will result from implementing the alternative scenario.

Using Environment Canada's *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions*, (2005 & 2009), the following summarizes the benefits in terms of reduced greenhouse gases and energy conservation from recycling agricultural packaging instead of landfilling it.

The agricultural packaging material stream is defined as:

Waste Stream	Material Description
Film Plastic – incl. Silage/Bale Wrap	LDPE, HDPE
Woven Bag Plastic	PP
Twine Products – incl. Net Wrap	PP
Plastic Jugs, Pails and Drums – Pesticide	HDPE, LDPE
Plastic Jugs, Pails and Drums – Sanitation Products	HDPE, LDPE
Plastic Jugs, Pails and Drums – Oil	HDPE, LDPE
Greenhouse and Nursery potted plant insets, trays pots	PP, PS
Potted Plant Sleeves	PP, LDPE, HDPE, PS
Unlined Paper Bags – seed	Paper fibre
Lined Paper Bags – incl. Laminates – feed	Paper fibre and
Cardboard Boxes	Paper fibre
Cardboard Boxes Waxed	Paper fibre, coated

[2] Environment Canada, 2005 & 2009, ICF Consulting

2. Results

Table 1a and 1b provide an illustration of the GHG benefits from recycling over disposal. The table provides a summary of the upstream benefits (avoided primary extraction and production stages from recycling) and the avoided landfill benefit measured in tonnes of carbon dioxide equivalent (C02e) emissions realized from recycling one tonne of each of the materials in the agricultural packaging material stream.

Table 1a: Summary of Net Emissions from Recycling versus landfill** (note: negative number is avoided emissions)

Material	Net CO_2e from recycling per tonne	Net CO_2e from landfill per tonne	Net CO_2e from recycling instead of landfill per tonne
Cardboard	-3.26	0.75	**-4.01**
Other paper	-3.27	1.20	**-4.47**
HDPE & PP*	-2.27	.01	**-2.28**
LDPE	**-1.80**	**.01**	**-1.81**

*PP is not a category in the LCA analysis, but is likely to have a similar LCA profile to HDPE due to similar characteristics.
**Landfill assumes flaring and no methane recovery

Table 1b: Summary of Net Emissions from Recycling versus Thermal Treatment** (note: negative number is saved energy)

Material	Net CO2e from recycling per tonne	Net CO2e from thermal treatment per tonne	Net CO2e emissions from recycling instead of thermal treatment per tonne
Cardboard	-3.26	-.04	**-3.22**
Other paper	-3.27	-.04	**-3.23**
HDPE & PP*	-2.27	2.89	**-5.16**
LDPE	**-1.80**	**2.67**	**-4.47**

*PP is not a category in the LCA analysis, but is likely to have a similar LCA profile to HDPE due to similar characteristics.
**Thermal treatment assumes energy recovery

2. Results – Energy Conservation (GJs)

Table 2a and 2b provide energy conservation benefits from recycling over disposal. The tables show the summary of the upstream (avoided primary extraction and production stages from recycling) and the avoided landfill benefits measured in gigajoules (GJs) of energy.

Table 2a: Summary of Net Energy from Recycling versus landfill**
(note: negative number is avoided emissions)

Material	Net GJs from recycling per tonne	Net GJs from landfill per tonne	Net energy from recycling instead of landfill per tonne
Cardboard	-8.56	0.15	**-8.71**
Other paper	-9.49	0.15	**-9.64**
HDPE & PP*	-64.27	0.15	**-64.42**
LDPE	**-52.09**	**0.15**	**-52.24**

*PP is not a category in the LCA analysis, but is likely to have a similar LCA profile to HDPE due similar characteristics.
**Landfill assumes flaring and no methane recovery

Table 2b: Summary of Net Energy from Recycling versus thermal treatment**
(note: negative number is avoided emissions)

Material	Net GJs from recycling per tonne	Net GJs from thermal treatment[3] per tonne	Net energy from recycling instead of thermal treatment per tonne
Cardboard	-8.56	-2.31	**-6.25**
Other paper	-9.49	-2.25	**-7.24**
HDPE & PP*	-64.27	-6.30	**-57.97**
LDPE	**-52.09**	**-4.76**	**-47.33**

*PP is not a category in the LCA analysis, but is likely to have a similar LCA profile to HDPE due similar characteristics.
**Thermal treatment assumes energy recovery

[3] Source: ICF Report: Assumes: **Marginal Electricity from Natural Gas;** Marginal emission coefficient 60.20 kg/GJ; Generation efficiency: 50%; T and D Losses: 10%; End Use Electricity Coefficient: 133.78 kg/GJ

3. Calculating Equivalencies

Using an input value of 100 tonnes of recycling for each packaging material stream, the results are meaningful and illustrate the value of diversion programs in the agricultural sector. Table 3 provides the results of benefits derived from recycling plastic and paper-based packaging.

Table 3: Summary of the net energy and emissions saving benefits and equivalencies

Tonnes Recycled (user input)	100	100	100	100	100	100	100	100
MATERIAL	LDPE	Polypropelyne (PP)				HDPE	Fibre	Fibre
CATEGORY	Film Plastic	Woven Bag Plastic	Twine Products	Greenhouse and Nursery Potted Plant Inserts	Potted Plant Sleeves	Plastic Jugs, Pails, and Drums	Cardboard Boxes	Other Paper
GHG FACTOR (CO2e/tonne)	1.82	2.28	2.28	2.28	2.28	2.28	4.01	4.49
ENERGY FACTOR (GJ/tonne)	52.24	64.42	64.42	64.42	64.42	64.42	8.71	9.64
Avoided Emissions (in CO2e) from recycling plus avoided landfill per	182	228	228	228	228	228	401	449
Energy Conserved (in GJ) from recycling and avoided landfill	5,224	6,442	6,442	6,442	6,442	6,442	871	964
Equivalent number of cars off the road for one year	36	45	45	45	45	45	79	88
Equivalent number of Canadian energy needs for one year	49	61	61	61	61	61	8	9
Equivalent gallons of gasoline consumed	39,878	49,176	49,176	49,176	49,176	49,176	6,649	7,359
Equivalent barrels of oil	856	1,056	1,056	1,056	1,056	1,056	143	158
Value of equivalent barrels	$ 78,737	$ 97,095	$ 97,095	$ 97,095	$ 97,095	$ 97,095	$ 13,128	$ 14,530

4. Other Benefits of Recycling

Today a significant amount of farm waste is buried or burned on-site. Environment Canada suggest that "barrel burning" (burning garbage on-site without controlled conditions and pollution prevention) may be the largest remaining single source of anthopogenic dioxins. Burning garbage on-site releases thousands more dioxins and furans than burning the same amount of waste in a municipal incinerator[4].

But the data for many emissions, like dioxins and furans; fine particulate matter (PM); heavy and metals are not readily available and highly dependent on individual system parameters (burn temperature; material burned; air flow etc.) Currently there is no reliable emissions data because they depend on the temperature of the burn. Earlier tables which show greenhouse gas emissions (expressed as CO2e) are for thermal treatment in which waste is burned for energy in a controlled environment. This method of disposal differs significantly from barrel burning, where little emission monitoring is performed.

Some data has been published by the Environmental Protection Agency. These data are based on sampling from test burning of plastic film waste. Table 4 provides a summary of the data presented for Volatile Organic Compounds (VOCs) and Polycyclic Aromoatic Hydrocarbon (PAH) Emissions.

Table 4: US EPA reported Volatile Organic Compounds (VOCs) and Polycyclic Aromoatic Hydrocarbon (PAH) Emissions (1992)

Volatile Organic Compounds (VOCs) mg/kg of plastic		
	Pile	**Forced Air**
Benzene	0.0123	0.0244
Toluene	0.0033	0.0124
Ethyl benzine	0.0012	0.0056
Hexene	0.0043	0.0220
Polycyclic Aromatic Hydrocarbon Emission Factors (PAHs) ug/kg of plastic		
Anthracene	1.32	0.40
Benzo(A)pyrene	7.53	0.00
Benzo(B)flouranthene	9.25	0.93
Benzo(e)pyrene	9.65	0.00
Benzo(G,H,I)perlene	14.93	0.00
Benzo(K)flouranthene	2.51	0.00
Benz(A)anthracene	14.41	1.19
Chrysene	17.18	1.19
Flouranthene	107.05	39.12
Indeno(1,2,3-CD)pyrene	10.70	0.00
Phenanthrene	24.05	8.72
Pyrene	58.81	5.95
Retene	18.77	3.04

[4] Environment Canada

Sources:

Source for avoided energy multipliers: *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update Final Report, ICF Consulting, Environment Canada & Natural Resources Canada, October 2005.*
Each scenario includes carbon sequestered from reduced tree harvest)

Source for avoided emission multipliers: Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2009 Update (in excel input model) ICF Consulting, Environment Canada & Natural Resources Canada, October 2005.

Source for VOcs and PAHs emissions: USEPA, 1992. *Emission Factor Documentation for AP-42 Section 2.5, Open Burning.* Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. September 1992

Equivalencies

FACTOR DESCRIPTION	FACTOR	SOURCE
Tonnes of CO2e/vehicle/year	**5.1**	http://www.epa.gov/cleanenergy/energy-resources/refs.html#vehicles
GJs for household energy needs/home/year	**105.6**	http://oee.nrcan.gc.ca/publications/statistics/parliament08-09/index.cfm
GJs of embodied energy/gallon of gasoline	**0.131**	http://www.epa.gov/cleanenergy/energy-resources/refs.html#gasoline
GJ of embodied energy/barrel of oil	**6.1**	http://www.aps.org/policy/reports/popa-reports/energy/units.cfm
$/Barrel of oil (June 23, 2011)	**$ 91.94**	http://www.bloomberg.com/energy/