Waste Management and Greenhouse Gas Emissions in Canada

When considering the environmental impacts of their decisions, municipalities have traditionally focused on cost, and to a lesser extent, resource conservation, air quality, water quality, and land-use issues. Recently, however, more and more municipalities have been taking into account the effects of greenhouse gas emissions, which lead to climate change. This brochure provides a comprehensive view of climate change, explains the relationship between climate change and waste management, discusses Canada's ongoing efforts to reduce waste-related greenhouse gas emissions, and introduces municipalities to tools that can assist them in estimating the greenhouse gas impacts of their decisions.

Environment Canada Environnement Canada

WHAT IS CLIMATE CHANGE?

Climate change has emerged as one of the most important environmental issues of modern times. In 1988, the World Meteorological Organization and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change (IPCC) to assess the understanding of all aspects of climate change, including the contribution of human activities and the impacts of climate change on human settlements. The IPCC has completed three such assessments, culminating in the IPCC's Third Assessment Report. The report concluded that much of the warming over the last 50 years is attributable to human activities, and projected that global average temperature will continue to rise.

The average global temperature is determined by the balance of radiation received from the sun and radiation reflected back into space. Any factor that upsets this balance alters the Earth's climate. Greenhouse gases warm the surface of the earth by absorbing some of the solar radiation that would otherwise be radiated to space. For billions of years, this warming – known as the "greenhouse effect" – has kept surface temperatures warm enough to sustain life. Naturally occurring greenhouse gases include carbon dioxide, ozone, methane, nitrous oxide, and water vapor.

Since the Industrial Revolution, human activities have caused an increase in the concentration of these gases. In addition, human activities have produced emissions of several greenhouse gases that do not occur naturally in the atmosphere, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Key Findings of the IPCC Third Assessment Report

Some of the major findings in the IPCC's "Summary for Policymakers" are:

- An increasing body of observations gives a collective picture of a warming world and other changes in the climate system.
- Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate.
- Confidence in the ability of models to project future climate has increased.
- There is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities.
- Human influences will continue to change atmospheric composition throughout the 21st Century.
- Further action is required to address remaining gaps in information and understanding.

Human contributions of greenhouse gases have led to an enhanced greenhouse effect, which in turn is changing the climate of Canada and the rest of the world.

International efforts to slow climate change have focused on reducing emissions of greenhouse gases through improved technologies and modified practices in five key sectors: energy, industrial processes, agriculture, forestry, and waste. Each sector offers a variety of options for reducing emissions that range dramatically in cost and effectiveness.

Waste Management: A Life-cycle Assessment of Greenhouse Gas Emissions

The waste sector provides a wealth of opportunities for reducing greenhouse gas emissions. In Canada, existing municipal reduction, reuse, and recycling programs divert approximately 29 percent of residential waste from disposal. As mentioned below, these efforts can have significant greenhouse gas benefits.

The waste sector is a significant source of greenhouse gas emissions on the national level, accounting for 3.5 percent of Canada's total emissions (see Figure 1). Landfills account for the majority of waste sector emissions as well as 24 percent of national methane emissions in 1999. Emissions of carbon dioxide and nitrous oxide from waste combustion are much lower, each comprising less than one percent of total national carbon dioxide and nitrous oxide emissions in 1999.

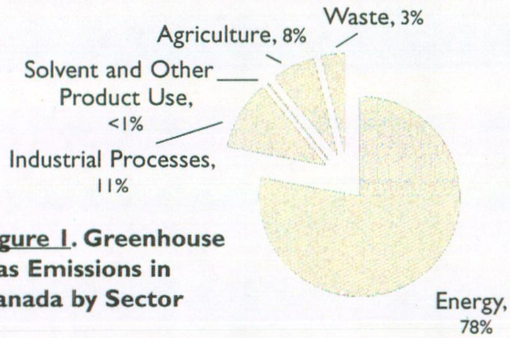


Figure 1. Greenhouse Gas Emissions in Canada by Sector

Note: Carbon removals associated with land use change and forestry represent negative emissions and are not included in this figure.

In accordance with international greenhouse gas accounting guidelines, national estimates of emissions from landfilling and combustion consider only those emissions *directly* associated with waste management. However, waste management decisions *indirectly* impact emissions that are reported in several other inventory sectors, including energy, forestry, and industrial processes. The importance of waste management decisions can therefore have a much wider reach than is commonly

> **Expressing Emissions of Different GHGs in Common Units**
>
> Several different greenhouse gases are emitted at different stages of the life cycle, and these gases have different effects on the earth's heat balance. To put the warming effect of the different gases on a common footing, scientists use a concept called "global warming potential." Carbon dioxide, the most prevalent greenhouse gas, is used as the benchmark, and emissions of other gases are expressed in terms of the equivalent amount of carbon dioxide that would have the same warming effect. Thus, emissions are expressed in units of tonnes of "carbon dioxide equivalent."

understood and reported in national greenhouse gas inventories.

In an effort to quantify the full range of greenhouse gas impacts associated with waste management decisions, Environment Canada funded a life-cycle assessment of greenhouse gas emissions for various waste management options and material types. This approach considers the greenhouse gas impacts associated with activities that are both upstream and downstream of waste disposal. Upstream greenhouse gas emissions include energy-related emissions from raw materials extraction and manufacturing, carbon storage in forests, and carbon storage in soils. Downstream emissions vary significantly, depending on the disposal practice. In a landfill, the decomposition process generates methane emissions. For an incinerator, emissions include carbon dioxide from burning plastics and other materials that are derived from fossil sources of carbon. The life-cycle stages and greenhouse gas emissions and removals included in Environment Canada's life-cycle assessment are listed below in Table 1.

WASTE MANAGEMENT PRACTICES AND HOW THEY AFFECT GREENHOUSE GASES

There are a variety of waste management practices available to provincial and municipal planners. Each waste management option has unique impacts on greenhouse gas emissions and removals from the atmosphere. Therefore, it is important to weigh the relative impacts of a practice, as compared to other practices, before making waste management decisions. Figure 2 (page 4) illustrates the greenhouse gas emissions and removals, from a life-cycle perspective, for the most common material in the Canadian wastestream – paper – when it is either landfilled or recycled. Figure 3 (page 5) shows how landfilling and recycling influence greenhouse gas emissions for metals (such as aluminum or steel cans). Starting with these illustrations, we discuss the effect of landfilling, recycling, and other waste management options below.

Landfilling

As shown in Figure 2, when paper and other organic matter is landfilled, a portion of the matter decomposes anaerobically and releases methane (CH_4). At most landfills in Canada, virtually all of the methane produced is released to the atmosphere. Other landfills limit this release by capturing methane for flaring or combustion with energy recovery, such as electricity production or direct use. This recovered energy can substitute for utility-generated electricity.

Metals and plastics do not degrade in the landfill, and thus do not release methane.

Some of the organic matter never decomposes at all, remaining in the landfill as stored carbon (labeled "C" in Figure 3). Materials degrade at different rates in the landfill, depending on their composition. For example, materials with high lignin content, such as newspaper and yard trimmings, will degrade more slowly than materials with lower lignin contents, such as food discards. Some of the carbon in organic materials remains trapped in landfills indefinitely, resulting in long-term

Table 1: Scope of the Life-Cycle Analysis

Life-Cycle Stages	Emissions and Removals
Raw materials extraction Manufacturing Materials Management - Source reduction - Recycling - Composting (aerobic, anaerobic) Disposal - Landfilling - Incineration	Energy-related emissions Carbon removals - Forests - Landfills - Soils Landfill gas emissions Emissions from incineration Avoided utility emissions

carbon storage. This observation is supported by the findings of landfill researchers who have excavated landfills and discovered fifty-year old newsprint that is still legible. Thus, to some extent, landfills act as reservoirs of carbon – in essence, an "avoided emission."

Once the material is disposed, the demand for material to replace it requires that more raw materials be acquired and processed. In the case of paper, the raw material is trees; for metals, it is ore. Raw material acquisition and manufacturing processes use considerable energy, and much of the energy is supplied by fossil fuels. Burning those fuels releases CO_2, as shown in Figures 2 and 3. In our accounting framework, we assume that the ongoing raw material acquisition and manufacturing is a "baseline" activity; continued manufacturing at current rates has no net GHG emissions.

Recycling

When a material is recycled, it is used in place of raw material inputs in the manufacturing process, thereby reducing greenhouse gas emissions from mining ore, harvesting trees, or extracting other types of raw materials. In addition, using recycled materials tends to reduce the energy required during the manufacturing stage. To the extent that recycled products can be produced with lower GHG emissions than products using virgin inputs, our accounting framework treats the reduction in emissions as a "negative emission."

As shown in Figure 2, compared to landfilling, recycling paper products yields another benefit—increased carbon storage in forests. When recycled paper takes the place of virgin inputs, it reduces the quantity of wood harvested, and leaves more carbon in growing trees.

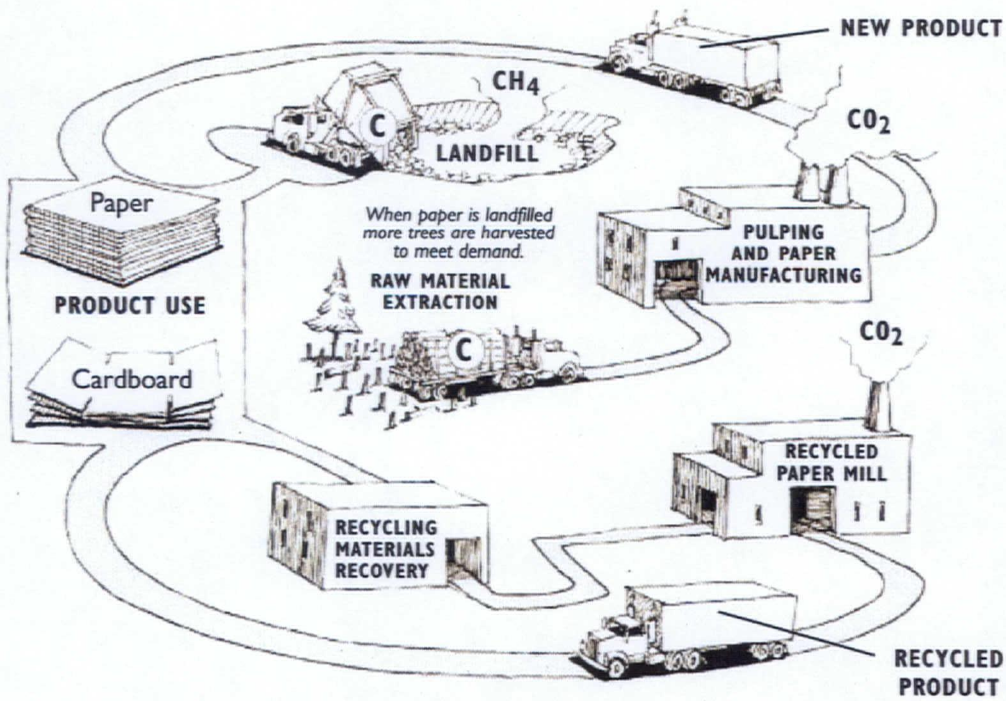
The quantity of greenhouse gases reduced by recycling varies widely by material type, with materials that require energy intensive primary processing providing the greatest benefits. For example, recycling products such as plastics and aluminum can yield carbon dioxide emission reductions of about two tonnes of carbon dioxide per tonne of product, compared to manufacturing the same products with virgin materials.

Composting

Composting refers to the decomposition of organic materials, such as yard trimmings and food discards, in the presence of oxygen. These materials quickly decompose and emit carbon dioxide. However, because organic materials are derived from trees or other plants, the carbon dioxide emitted during decomposition is considered part of the natural carbon cycle and is therefore not counted in greenhouse

Figure 2. **GHG Emissions and Sinks for Paper**

Life Cycles for Landfilling vs. Recycling



gas emission estimates as part of the national inventory.

According to compost researchers, decomposing organic materials in a well-managed compost pile will not produce methane. Instead, composting results in minimal carbon dioxide emissions from mechanical turning of compost piles and some carbon storage as the nutrient-rich material remaining at the end of the composting process is applied to the soil.

Anaerobic Digestion

Anaerobic digestion promotes rapid decomposition of solid waste in the absence of oxygen. As the organic materials decompose, methane is produced. This methane is collected and used as a clean source of energy, thereby offsetting emissions associated with fossil-derived energy. As in composting, applying organic material remaining at the end of the composting process to soils results in a small increase in soil carbon storage.

Waste Incineration

Waste Incineration results in emissions of carbon dioxide and nitrous oxide. In accordance with international greenhouse gas accounting guidelines, carbon dioxide emissions from incineration are only counted for fossil-derived materials (e.g., plastics). Carbon dioxide emissions from other materials are assumed to be part of the natural carbon cycle. Some waste combustion projects serve the dual purpose of combusting waste and producing electricity that substitutes for utility-generated electricity. The electricity generated as a result of this process reduces the need for electric utilities to burn fossil fuels, thus creating an "offset" of emissions from utilities.

Source Reduction

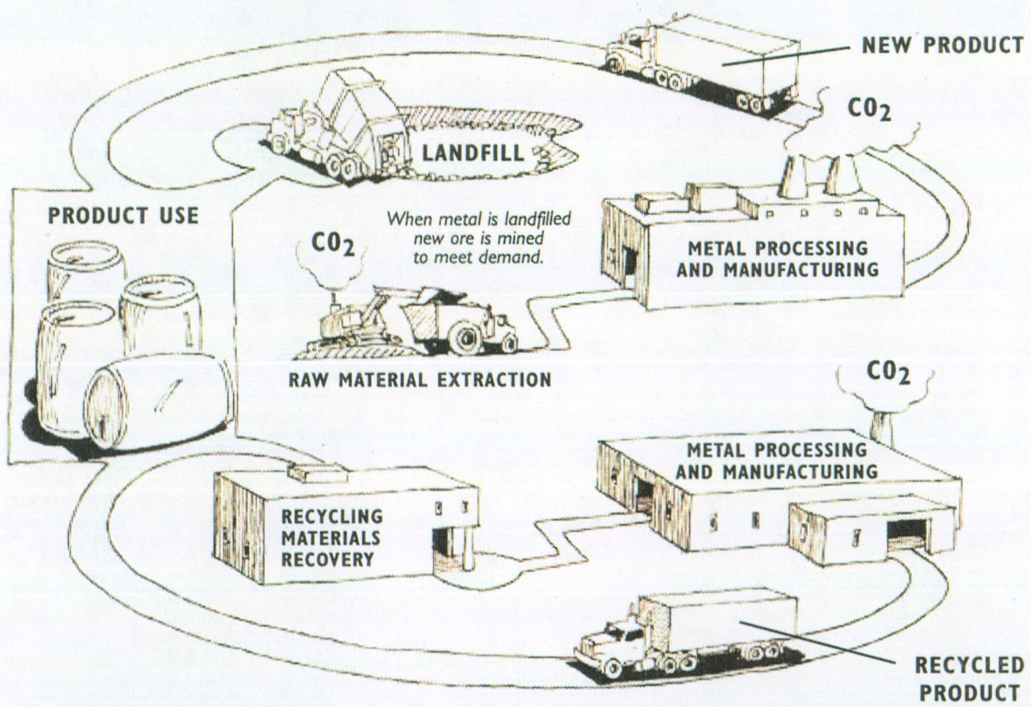
Source reduction is the most effective way to reduce greenhouse gas emissions through waste management. By reusing or reducing materials that would otherwise be discarded as waste, all life-cycle emissions are avoided, including upstream emissions from raw materials acquisition and manufacturing and downstream emissions associated with disposal.

LIFE-CYCLE EMISSION FACTORS

Environment Canada developed life-cycle emission factors that reflect the impacts of waste management options on greenhouse gases. The emission factors cover the life cycle of twelve materials occurring in the municipal solid waste stream for each of six waste management options.

Comparing the emission factors for different waste management options reveals the relative GHG impacts of

Figure 3. **GHG Emissions for Metals**
Life Cycles for Landfilling vs. Recycling



1 Tonne of CO_2

Greenhouse gases are measured in terms of their potential to warm the earth. CO_2 is the most prevalent of these gases. Emissions of the other gases are expressed in terms of their warming potential relative to 1 tonne of CO_2. To envision this amount of CO_2, imagine a hockey rink: 1 tonne of CO_2 would fill a volume equivalent to the area from the blue line to the end of the rink, up to the height of the boards around the rink.

those options. For example, the difference between the emission factors for fine paper for recycling and landfilling is about 4.8 tonnes of CO_2 equivalent per tonne of paper. Thus, for every tonne of fine paper recycled rather than landfilled, emissions are reduced by 4.8 tonnes of CO_2 equivalent.

The life-cycle greenhouse gas emission factors in Table 2 reflect the life-cycle greenhouse gas emissions associated with choosing a single waste management scenario. The factors become more meaningful when the emissions associated with the current waste management scenario are compared to those of alternative scenarios. Such a comparison reveals the potential greenhouse gas savings achievable through integrated waste management strategies.

It is important to note that Environment Canada developed these factors using national average conditions and data. As a result, they provide an estimate of the order of magnitude of the impacts of various practices on greenhouse gas emissions but should not be viewed as providing exact estimates of specific local operations.

Waste managers interested in finding out more about the impact of provincial or local waste management decisions on greenhouse gas emissions should consider one of the decision support tools described later in this brochure.

WASTE-RELATED GREENHOUSE GAS MITIGATION EFFORTS IN CANADA

Federal, provincial, and local governments in Canada have undertaken several initiatives related to climate change and/or waste reduction. These initiatives are described briefly below.

National Climate Change Process

Canada's NCCP recognizes that informed waste management strategies can reduce greenhouse gas emissions. The Municipalities Table announced an enhanced waste diversion target of 50 percent waste diversion by 2010 and extensive waste diversion target of 70 percent by 2020 in their December 1999 Municipalities Options Paper. In addition, the Municipalities Table developed 24 specific measures to encourage increased landfill gas recovery for flaring and energy generation.

Partly as a result of these measures, landfill gas recovery is increasing. There were 47 landfill sites actively collecting landfill gas in Canada during 2001. The total amount of methane captured and destroyed was 340 kilotonnes (kt), of which 208 kt (61% from 16 sites) were used to produce energy or electricity, and the remaining 132 kt (39% from 31 sites) were flared. Of the 16 installations that utilized the gas, 8 facilities generated a total of 85 megawatts (MW) of electricity from 194 kt of methane. The remaining 8 facilities utilized 14kt of methane for heating applications ranging

Table 2: Greenhouse Gas Emissions from Waste Management Options (tonnes eCO_2/tonne)

	Net Source Reduction Emissions	Net Recycling Emissions	Net Anaerobic Digestion Emissions	Net Combustion Emissions	Net Landfilling Emissions (no gas recovery)	Net Landfilling Emissions (gas recovery for energy)
Newsprint	(3.64)	(2.69)	(0.38)	(0.26)	(1.15)	(1.39)
Fine Paper	(5.60)	(3.12)	(0.28)	(0.22)	1.70	(0.23)
Cardboard	(4.97)	(3.31)	(0.20)	(0.22)	0.74	(0.95)
Other Paper	(5.24)	(3.17)	(0.19)	(0.22)	1.18	(0.55)
Aluminum	(1.40)	(1.93)	0.00	0.01	0.00	0.00
Steel	(1.59)	(0.90)	0.00	(0.78)	0.00	0.00
Glass	(0.29)	(0.07)	0.00	0.01	0.00	0.00
HDPE	(1.77)	(1.40)	0.00	2.39	0.00	0.00
PET	(2.72)	(2.82)	0.00	1.89	0.00	0.00
Other Plastic	(2.00)	(1.11)	0.00	2.27	0.00	0.00
Food Scraps	NA	(0.03)*	(0.19)	(0.05)	1.13	(0.12)
Yard Trimmings	NA	(0.03)*	(0.27)	(0.07)	(0.14)	(0.86)

*Reflects value for composting.

from simply heating buildings, to providing fuel for a gypsum manufacturing plant, a steel refinery, a greenhouse, and a recycling plant.

Emissions Trading Pilot Programs

In June 1998, the Canadian federal government partnered with a number of provinces and industry, labor, and environmental groups to launch the Greenhouse Gas Emission Reduction Trading Pilot (GERT), based in British Columbia. GERT was designed to help participants gain practical experience in greenhouse gas emissions trading. It also provided a basis for assessing environmental and economic benefits of GHG mitigation projects, and designing effective trading mechanisms and policies. Parties interested in participating were accepted from June 1998 through December 2001 for reductions generated since January 1, 1997.

During the Pilot, buyers and sellers of emission reductions submitted documentation on traded projects to a multi-stakeholder committee for review. If the emission reductions satisfied the requirements of the GERT Pilot, they were registered and eligible for recognition against future compliance obligations. The incentive to buy credits was two-fold: buyers could use emissions reductions to meet voluntary greenhouse gas reduction targets at lower cost, and credits incurred during the pilot will be recognized if emissions trading is enforced on a national level. For example, companies and municipalities can include GERT trades as part of their action plans registered with the national Voluntary Challenge and Registry Program (VCR Program). In the longer term, the government partners may recognize emission reductions from trades registered under the Pilot as progress towards possible compliance obligations in the context of a future greenhouse gas trading regime.

The Pilot Emission Reduction Trading (PERT) project started as an industry-led multi-stakeholder initiative established in 1996 to evaluate emission reduction trading (ERT) as a tool to assist in the reduction of air pollution in the Ontario airshed. PERT has addressed several pollutants, including NOx, SOx, greenhouse gases, and volatile organic compounds, and found that a multi-gas approach offers significant potential for sustained environmental benefits. Other important findings are that the development of baseline procedures is integral to a successful trading program, and that guidelines for inter-jurisdictional cooperation are necessary. Since its establishment, PERT has evolved into CleanAir Canada Inc., an umbrella organization for clean air projects. CleanAir Canada is an independent, not-for-profit organization committed to the development, operation and expanded use of local and global emission reduction market mechanisms in Canada.

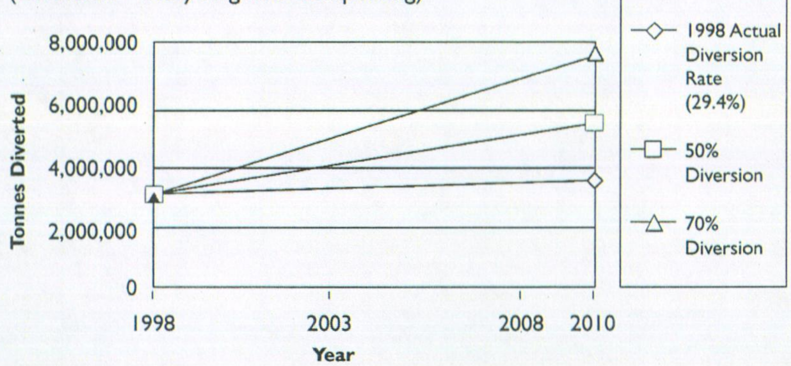
Partners for Climate Protection Program

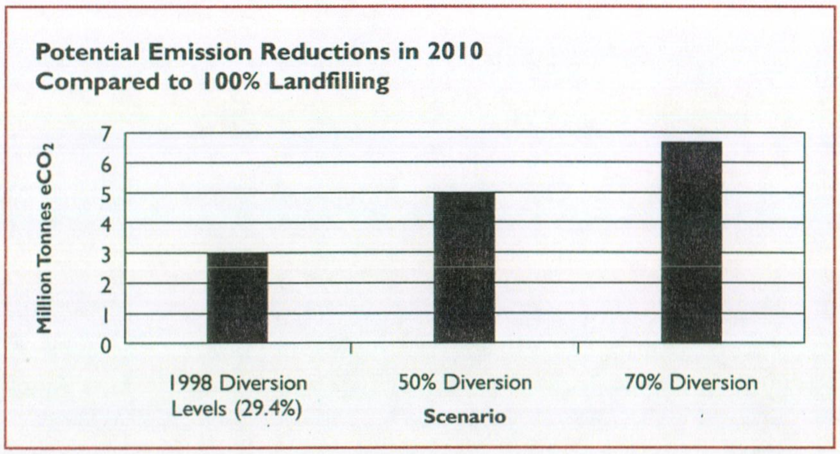
In an effort to combat climate change at the local level, the Federation of Canadian Municipalities and the International Council for Local Environmental Initiatives (ICLEI) teamed up to form the Partners for Climate Protection Program. A joint effort of federal and community organizations, the program seeks to reduce greenhouse gas emissions from municipal operations by 20 percent below 1990 levels within ten years of their membership. In addition, the program seeks to reduce community-wide greenhouse gas emissions by six percent below 1990 levels within ten years of membership. The Partners for Climate Protection Program aims to achieve that goal through forming partnerships within local communities; building capacity by providing workshops and training; providing cutting edge research on climate change science and policy; surveying progress of its members; and supporting champions by sharing their success stories and strategies with other members.

POTENTIAL EMISSION REDUCTIONS FROM WASTE MANAGEMENT PRACTICES.

Municipal waste recycling and composting efforts currently divert approximately 29 percent of waste from disposal. Environment Canada estimates that by sustaining current diversion rates (rather than disposing waste in landfills), we can reduce potential greenhouse gas emissions by 2.9 million tonnes of CO_2 equivalent (tonnes eCO_2) by 2010. Increasing diversion rates to 50 percent would reduce

Diversion Scenarios for 2010
(Diversion = Recycling and Composting)





emissions by an additional 2.0 million tonnes eCO_2 by 2010, with a total reduction of 5.1 million tonnes eCO_2. A more ambitious effort attaining 70 percent waste diversion would result in emission reductions totaling 6.9 million tonnes eCO_2, more than twice the amount of emissions reduced by current diversion. In addition, waste diversion provides numerous environmental co-benefits that enhance community welfare. These benefits include:

- Improved air quality and reduced water pollution;
- Enhanced natural resources;
- Reduction in displacement of agricultural land, natural habitat, and community residents;
- Reduced or deferred costs; and
- Increased local economic activity, business tax revenues, and job opportunities.

In short, improving waste diversion efforts will lead to environmental benefits that help to slow climate change and enhance local communities.

TOOLS TO QUANTIFY BENEFITS OF INTEGRATED WASTE MANAGEMENT

Although the qualitative benefits of recycling, composting, and other forms of integrated waste management have long been known, until recently municipalities have lacked tools to quantify these benefits. Several tools are now available for this purpose, thus enabling waste planners to better evaluate the effects of national, provincial, and local waste reduction efforts.

As noted earlier, Environment Canada has sponsored work to illuminate the relationship between greenhouse gas emissions and national waste management practices, and has developed national-scale emission factors that allow comparison of different waste management options for 12 materials. Provincial and local waste planners can assess the greenhouse gas impacts of waste management practices at a more local level by using one of two models designed to support local decision making: Environment Canada's Integrated Solid Waste Model and ICLEI's Greenhouse Gas Emissions Software.

Environment Canada's Life Cycle Inventory Model for Integrated Solid Waste Management enables municipalities to identify the environmental and economic effects of their current waste management systems. The tool determines the impacts of modifying waste management systems based on an examination of materials in the municipal waste stream including paper, glass, ferrous materials, aluminum, plastics, food waste, yard waste, and "other waste" such as textiles and diapers. The tool allows decision makers to view the range of potential impacts of a decision prior to implementation.

ICLEI's Cities for Climate Protection Greenhouse Gas Emissions Software assists Cities for Climate Protection Campaign members in developing their local action plans. The tool allows users to quantify both community-wide greenhouse gas emission reductions and reductions from direct municipal operations. Users can calculate the results of waste reduction, source reduction, energy savings, and fuel switching. In addition, the tool can help users gauge financial savings, criteria air pollutant emission reductions, and other benefits of climate protection strategies.

Summary

Integrated waste management can significantly contribute to Canada's efforts to reduce greenhouse gas emissions. We've long known that recycling conserves resources and saves landfill capacity. But now we know that it is also one of our most effective options for combating climate change.

Climate change is a large and complex problem, and if we are to solve it, we will need to find many solutions. Through recycling, composting, and other measures, Canada has dramatically increased the diversion of waste from disposal over the past decade. If we can build on our success, we will generate even more environmental benefits, including reductions in greenhouse gases. ◆

For Additional Information, please contact: Environment Canada, National Office of Pollution Prevention, Place Vincent Massey, 351 St. Joseph Blvd, Hull, Quebec K1A 0H3

GOPF