Greenhouse Gas Implications of a Waste Management Strategy (Canada)

IEA-Bioenergy Task 36 Topic Report

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BACKGROUND

In Canada approximately 23 million tonnes of residential, industrial, commercial and institutional waste – municipal solid waste (MSW) – is disposed of each year. (Note: this figure does not include more than 10 Mt of construction and demolition waste generated annually.) Under the worst-case scenario, this waste is collected, transported to landfill with no recycling or composting, and allowed to decompose. Under these circumstances, 23 Mt of MSW (approximately 30% carbon content) will eventually produce 10.4 Mt of CO_2 and 5.4 Mt of CH_4. Using IPCC's recently modified 100-year global warming potential of 23 for CH_4, equivalent CO_2 emissions from this quantity of MSW will amount to 135 Mt.

At the opposite end of the spectrum (best-case scenario), the MSW can be source-separated, organics can be composted, glass/metals/paper/plastics can be recycled, and the remaining waste–refuse derived fuel (RDF)–can be gasified, combusted, pyrolyzed and/or anaerobically digested to produce steam, fuel gas and/or electricity. Under optimal conversion conditions, this same 23 Mt of MSW can produce approximately 26,000 GWh (at 35% overall electrical efficiency), the equivalent of a 3 000 MW fossil fuel-fired power plant operating at full capacity. CO_2 emissions from this plant (again at 35% efficiency) would be 25 Mt, a reduction of 80% over the worst-case scenario.

An important point to consider regarding MSW is that much of the carbon content is contained in biomass, and is thus considered CO_2-neutral. Electricity produced from this fraction may displace electricity derived from fossil fuels and, thus, generate an equivalent CO_2 credit. Further, recycled materials such as aluminum and glass save some quantity of energy, compared with production from virgin materials, thus generating additional CO_2 credits. Considering the overall picture, depending on the makeup of the MSW and the management strategy employed, final disposition could result in a situation where CO_2 emissions are actually less than zero, a far cry from the worst-case value of 135 Mt. And, unlike the worst case, valuable electricity has been generated, some raw materials have been conserved, and landfill requirements have been reduced by approximately 90%.

IEA Bioenergy Task 36 (2004–2006) aims to accelerate the use of environmentally sound and cost-competitive bioenergy on a sustainable basis. Municipal solid waste (MSW) can be a liability if requiring disposal but also represents a considerable resource that can be beneficially recovered, *e.g.*, by recycling of certain materials or through energy recovery operations. However, significant quantities of MSW continue to be disposed of to landfill largely due to its low cost and ready availability. In the EU the Landfill Directive and many national regulations will forbid landfilling of combustible or biodegradable materials in the near future. These legislative drivers provide the impetus to develop and deploy cost-competitive energy recovery waste treatment technologies. In order to effectively advance development of the waste management infrastructure it is vital that policy- and decision-makers have access to the latest information on the potential and application of technology and be aware of international trends in this sector. The work involved in this Task Topic aims to provide such information in a form that is readily accessible by decision-makers.

An environmental analysis model called "ICF" was recently commissioned by ICF Consulting Corp, to evaluate the life cycle environmental and energy effects of waste management processes as a tool to guide municipal waste managers in the evaluation of waste management systems. While the model calculates GHG emissions from several waste management technologies on a life cycle basis, no information of any kind is generated on the capital, operating and maintenance costs of these technologies. This project, therefore, involves the development of an economic model to be used in conjunction with the ICF, such that waste management scenarios can first be ranked on a GHG basis, and then optimized on a cost basis. This is important because, despite the altruistic tendencies of some people with respect to climate change, businesses and municipalities are very aware of the bottom line. In the absence of regulations that force GHG reduction/capture whatever the cost, in a society where free will predominates, GHGs will be reduced only if it makes economic sense. Thus combined use of ICF data and our economic model, while maybe not resulting in maximum GHG reductions, nevertheless can pinpoint the method or combination of methods that result in least-cost GHG reduction.

ICF MODELS

The ICF consulting firm provided Environment Canada and Natural Resources Canada (NRCan) with a report: "Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions, 2005 Update". This report is very convenient because it provides simple factors for equivalent CO_2 emissions and energy impacts. The variety of wastes and management options makes this report complete and a good reference for people concerned by their Municipal Solid Wastes (MSW) or their Industrial, Commercial and Institutional (IC&I) wastes. The report includes the goods and technologies enumerated below:

Goods

- *Papers:*
  - *Newsprint;*
  - *Fine Paper;*
  - *Cardboard;*
  - *Other Paper.*
- *Metals and Glass:*
  - *Steel;*
  - *Copper Wire;*
  - *Glass.*
- *Plastics:*
  - *High Density Polyethylene (HDPE);*
  - *Polyethylene Terephthalate (PET);*
  - *Other Plastics.*
- *Organic Goods:*
  - *Food Scraps;*
  - *Yard Trimmings.*
- *Electronics:*
  - *White Goods;*
  - *Personal Computers;*
  - *Televisions;*
  - *Microwaves;*
  - *Video Cassette Recorders (VCRs).*
- *Tires*

Technologies

- *Recycling;*
- *Anaerobic digestion;*
- *Composting;*
- *Combustion;*
- *Landfilling without gas collection;*
- *Landfilling with gas collection and flaring;*
- *Landfilling with gas collection and energy recovery.*

The ICF report covers the life cycle of a product as much as possible. It contains the raw materials acquisition, transport to the manufacturing plant, the manufacturing itself, transport to the consumers, transport from the consumers to the waste management plant and final disposal. The only function not included in the report is the product's use, because it is not relevant to waste management. Of course, depending on the chosen option, modifications are made to any related life cycle steps. For example, it is possible to make a new tonne of aluminum with 95% recycled material; so it means less bauxite used and a reduction in the raw materials' acquisition emissions.

Unfortunately, factors from the report are not at all region-dependent. They are based on a Canadian average, wherever the province or the municipality might be located. So garbage trucks in a rural region or in an urban region travel the same distance. Another example is that a municipality can have a reduction in GHG emissions by recycling aluminum even if the province doesn't produce a gram of it. That is why the report has one factor per good per waste treatment. The following equations can be useful to aid in understanding the basics of ICF:

*Net GHG emissions without carbon sinks = Gross GHG emissions –
Avoided utility GHG emissions* *Eq. (1)*

*Net GHG emissions with carbon sinks = Gross GHG emissions –
(Increase in carbon stocks + Avoided utility GHG emissions)* *Eq. (2)*

Net energy consumption = Gross energy consumption –

(Energy saved from raw material acquisition + Energy produced) *Eq. (3)*

Here, the concept of carbon sinks in GHG emissions is introduced. ICF defines them like this: *"…carbon cycles through the earth's air, water, land and biota. Carbon sink is the process to remove carbon from the atmosphere. Carbon is stored in pools – forests, soils, landfills – and is not in the atmosphere contributing to the greenhouse effect (i.e., trapping of heat close to the earth's surface). The whole process is considered to be the opposite of emissions."*

This concept is dependent on two factors: the region and the goods being consumed. The simplest example of this concept is paper products. By recycling paper, fewer trees are cut and more carbon is processed by photosynthesis. The effect is minimal in urban regions because deforestation is already a fact of life. If urban regions do not recycle paper, they are not penalizing themselves, but rural regions farther away.

As the users navigate through the program, they will eventually come across a waste sorter. The Mineral and Mining Statistics (MMS) branch of NRCan was kind enough to provide a table where Canadian MSW is listed by goods and provinces. However, because some of the goods from the MMS table do not match the goods from the ICF report, the sorter's accuracy is difficult to determine. These data are from February 2006 and include:

- Waste statistics for British Columbia, Alberta and Saskatchewan, characterized into paper, organics, plastics, wood, ferrous, textiles/rubber, glass, sanitary, renovation, and other; further divided into residential, IC&I, and CR&D materials.
- A report prepared for Environment Canada's Transboundary Movement Division, containing information on MSW programs across Canada.
- Information on glass and cement manufactories in Canada.

ECONOMIC METHODOLOGY

MSW management options being considered include only those technologies that are currently commercially available:

- Anaerobic digestion
- Composting
- Recycle of metals, glass, paper and plastics
- Incineration
- Landfill gas capture/utilization
- Fluidized bed combustion
- Gasification/gas co-firing (Lahti-type)

For each of these waste management technologies, a comprehensive case study has been produced, outlining how the technology works, the type of equipment required, emissions, costs, *etc*., from an operating plant (preferably Canadian, if such a plant exists here). These case studies focus mainly on successful plants, but where available, will also include actual operational problems/solutions. Thus they, in conjunction with the ICF model and economics data, will act as an educational tool to assist municipal staff in evaluating approximate costs, operating complexities, and GHG implications of various waste management scenarios.

Equipment costs were found *via* multiples sources: Internet, the literature and external contracts. The next step is to size the plant depending on user inputs. The following equation was used:

$$C_a = C_b\ (S_a/S_b)^f \qquad \textit{(Eq. 4)}$$

Where C_a *is the sized cost,*

C_b *is the source cost (from previously enumerated plants),*

S_a *is the required size of the plant determined by the user,*

S_b *is the size of the source plant, and*

f *is a factor.*

The value of the factor *f* is 0.6 by default. However, in some cases we gathered costs for more than one plant using a specific technology, so when it was possible, by power regression, we calculated more accurate values (always close to 0.6 for some reason).

The goal of the economic methodology is to achieve, with a precision of ± 30%, cost predictions of wastes treatment plants depending on the quantity of MSW and the selected strategies. To do so, detailed breakdowns of all pieces of equipment are required. The sources of the equipment lists are the following:

- The Dufferin organics processing facility owned by the City of Toronto, Ontario, Canada (anaerobic digestion);
- The Edmonton composting facility in Alberta, Canada (composting);
- The Guelph dry recovery plant in Ontario, Canada (recycling);
- The Burnaby waste-to-energy facility (WTEF) in Vancouver, British Columbia, Canada (incineration);
- The Lachenaie landfill facility in Quebec, Canada (landfill);
- The Robbins resource recovery facility in Illinois, USA (combustion); and
- The Kymijarvi power station in Lahti, Finland (gasification/co-firing).

<u>Case Study Format</u>

For ease of use, it was decided that the seven case studies would have a common look and feel. As a result, the following format was developed:

- **Background**
- **Process Technology**
  - Main Reactor
  - Fuel Preparation/Handling/Characteristics
  - Air Pollution Control System
  - Balance of Plant
- **Performance**
  - Mass and Energy Balances

    - Environmental Emissions
- **Capital, Operating and Maintenance Costs**
    - Costs for this and other Plants of this Type
- **Problems/Solutions**

PROGRAMMING CONCEPT

Graphic interfaces

Excel Visual Basic offers forms and spreadsheets commonly seen and understood by computer users. The main objective was to create a very simple way to enter the inputs so that users can obtain a quick order-of-magnitude idea and a good basis of comparison.

The graphic interfaces for the inputs are Visual Basic forms and they consist of cells, where a number must be entered, option buttons and command buttons.

While the users implement their data, subroutines modify spreadsheets where the calculations take place. Once the users are done, the spreadsheets are copied into a new workbook that can be saved and manipulated at will. This protocol is not the fastest or smallest in memory requirement, but it insures an intellectual protection (where the code and calculations are hidden from the users).

The results, in a new workbook, are displayed in multiple spreadsheets. The economic breakdowns for the management plants can be available also with emissions data, comparison between two scenarios and summary. The spreadsheets are normally easy to understand, and include a color legend to help the user to interpret them. A users' guide, describing rigorously how to run the program, can be found in Appendix I. The program, called MSWMCT, is presented in a separated file in MS Excel format.

Inputs and navigation

A minor objective of the program was to simplify the inputs as much as possible. The users basically need to know two things: their province and the amount of MSW they have per year. With the “waste generator”, it is not even necessary to know how the MSW is sorted into different goods. However, if the users already have their own data, it is possible to input them and obtain more accurate results. This is the same process that would be employed by someone outside Canada, who will have to manually sort the MSW data into different components.

The graphic forms handle the navigation step by step through the program. From the three possibilities (create a new scenario, compare two scenarios, or open an existing scenario), nothing varies drastically, meaning the forms have distinct headers and the command buttons are always at the bottom, well identified. More details are available in the users’ guide in the Appendix.

HOW TO INTERPRET THE RESULTS

Single scenario

The resulting single scenario workbook contains economic spreadsheets, detailed emissions and a summary. The economic spreadsheets are the plant breakdowns selected by the users. All parts have a short description. It is to be noted that the program deals with one process per management strategy. Figure 1 in Appendix II is an example of a recycling plant.

The detailed emissions spreadsheet, named “Final Results”, shows the equivalent CO_2, in tonnes, and the energy impact, in GJ, separated into goods categories and management strategies. On this spreadsheet, it is also possible to compare the emissions with and without carbon sinks. Refer to Figure 2 in Appendix II for an example. In interpreting these numbers, the ICF report specifies this limitation:

"GHG emissions and energy factors in this study only serve as a common basis for comparison. They are not intended for, nor should they be used in GHG inventories or for quantifying emissions reduction offsets."

Finally, the summary spreadsheet regroups emissions, energy and cost results in a single table, sorting them into management strategies. It readily gives an overall look and a rapid idea. Figure 3 in Appendix II illustrates how.

Comparison of two scenarios

When this option is selected, the first spreadsheet is the "Compare" one. Here, the emissions and energy impacts from the first selected option are subtracted from the second option. A color legend helps to locate the points of interest where one scenario shows an advantage over the other.

The second spreadsheet, labeled "Summary", is the difference between the two individual scenario "Summary" spreadsheets. Because it can be a little bit confusing, both tables are reproduced just below the main one. Once again, a color legend is available.

The last spreadsheet consists of four graphics. They give visual support so the comparison is not only numerical. Refer to Figures 4, 5 and 6 in Appendix II to have a better idea of the comparison results.

PROGRAM PROS AND CONS

Pros:

- The inputs are easy to obtain and enter into the program.
- A scenario is quite simple and quick to elaborate.
- The navigation through the graphic interfaces is straightforward.
- The program verifies all inputs carefully so that dubious data will not be processed.

- The emissions and energy impacts from the ICF report are quite accurate and updated continuously.
- If permission is granted, it is possible to update the program without going into the source code or the calculations.
- The economic spreadsheets give a first look, and work well for this function.

<u>Cons:</u>

- The program is not region-specific; everything is based on a Canadian average.
- In the economic section, there is only one process per management strategy, which is not realistic. There is a big difference between an anaerobic digester owned by a small group of individuals and the one owned by Toronto. So it is important to be cognizant of the program's scope, which probably excludes very small and very large operations. The idea behind this program is to cover Canadian municipalities from 15,000 to approximately 1,000,000 of population, where each citizen produces approximately 365 kg of solid wastes per year.
- In one management strategy, there are process alternatives that are not covered by the program.

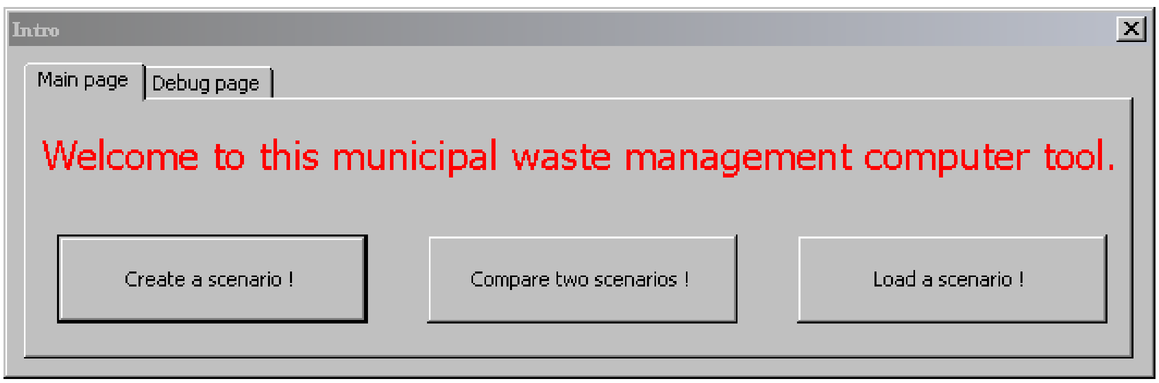
CONCLUSION

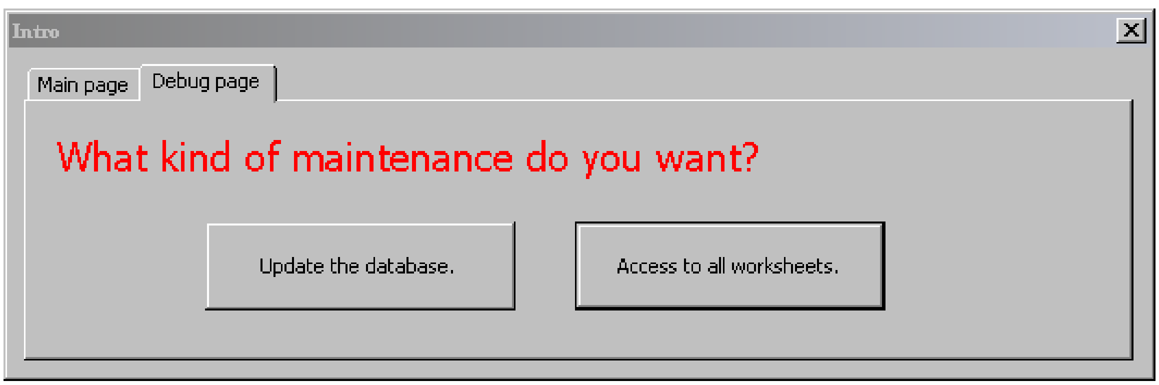
We sincerely believe that the MSWMCT will provide helpful assistance to city managers and other people concerned. It is a reliable tool, simple to operate, and that can be upgraded over time. It can become the first step for all new projects involving MSW management in Canada.

APPENDIX I: USERS' GUIDE

<u>I. Starting a session:</u>

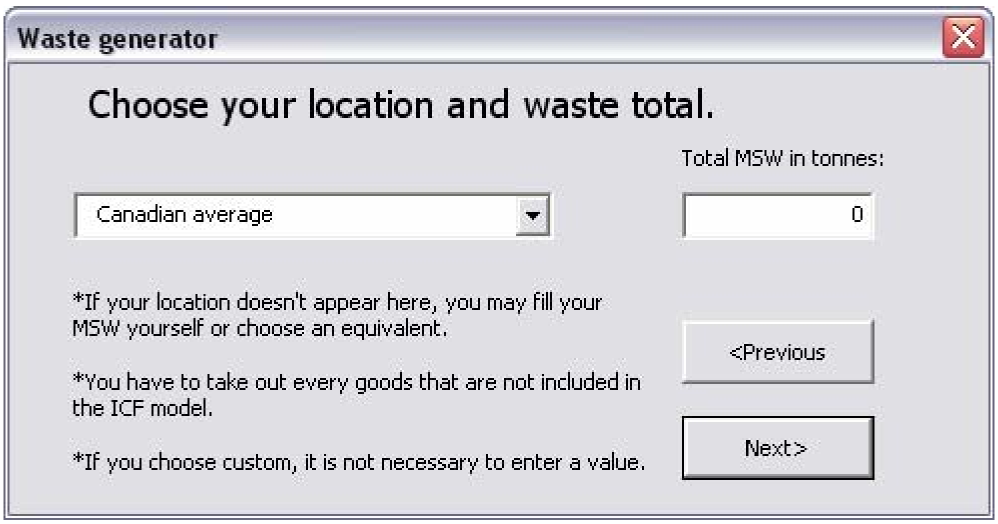
1. At the beginning, there is only one spreadsheet available from the MSWMCT, which is the introduction sheet. Some general information is accessible, but mainly, the active button "Begin" is the point of interest. It will start a session by opening the first user form.
2. The "Intro" user form gives you the choice between five options: create a scenario, compare two scenarios, load a scenario, access to the database spreadsheets and access to all processing spreadsheets.





II. Creating a scenario:

1. Entering this option, the “waste generator” user form will appear on the screen. Read carefully the comments on this user form. A location is required in the combo box and the total mass of wastes per year in the text box. If the desired location is not available, the “Custom…” option allows a manual sorting of the wastes (refer to point 5).

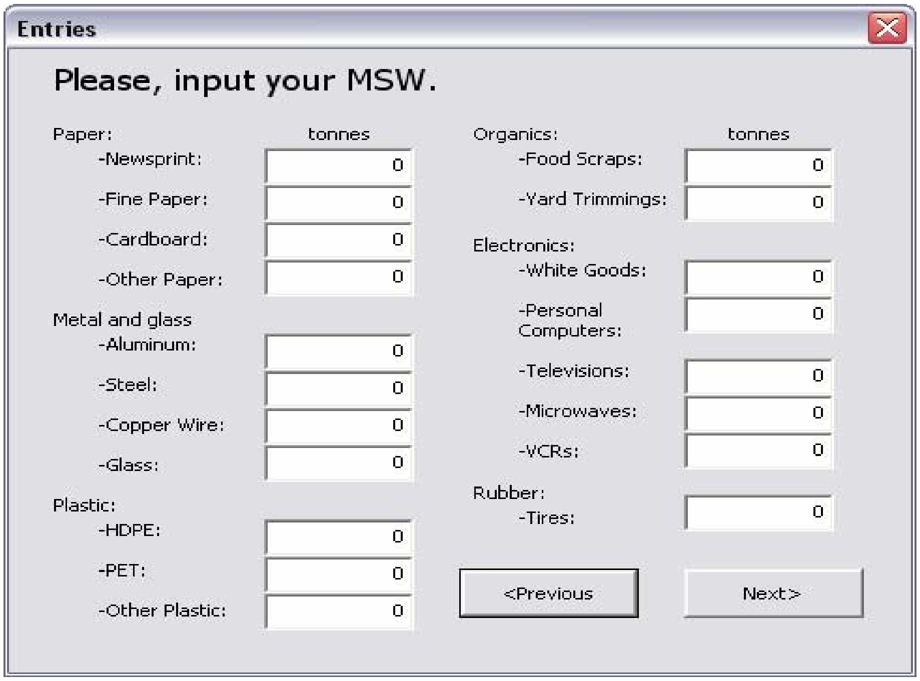


2. If the desired location is there and has been selected, the “quick sorting” user form will come into view. This form allows the user to select only one management strategy for all their MSW. It is the fastest way to create a scenario. If the user does not choose the recycling or the “No thanks” option, the program is done and a scenario has been created. For the “No thanks” option, please refer to point 4.

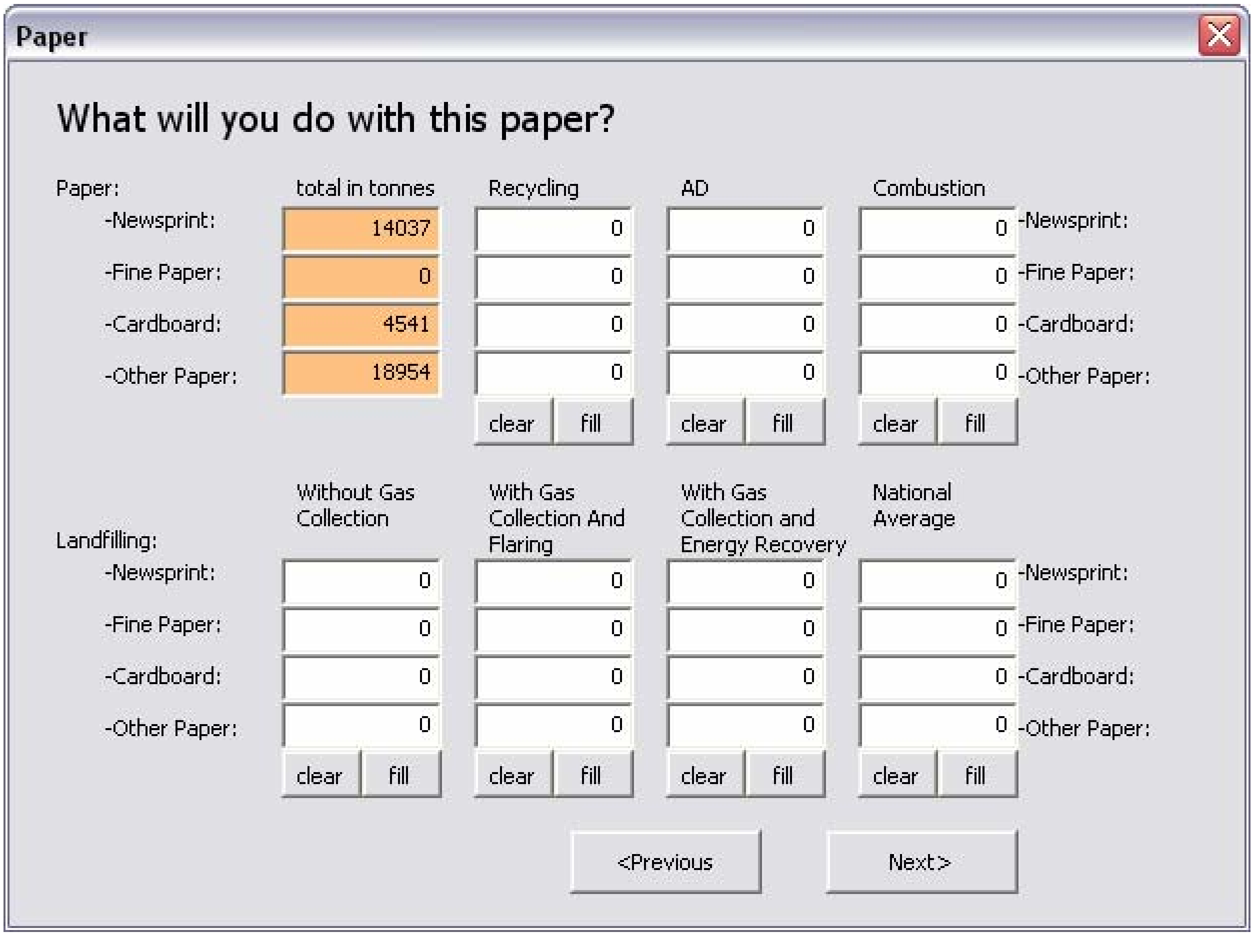
3. The “quick sorting” user form works well, but if the recycling option is selected and the users have organic wastes to treat (which is most likely to happen), another treatment is required to dispose of them. That is why the next form will appear. After that, the scenario is done and the program will terminate.

4. On the “quick sorting” form, if the “No thanks” option is selected, the users will have to pick a management strategy for all the goods separately. This may sound laborious, but it is quite simple.

5. If the “waste generator” tool has been avoided by choosing “custom…”, the “Entries” form will allow the users to input their goods manually, carefully, one by one. While this method takes more time, it produces more site-specific results.

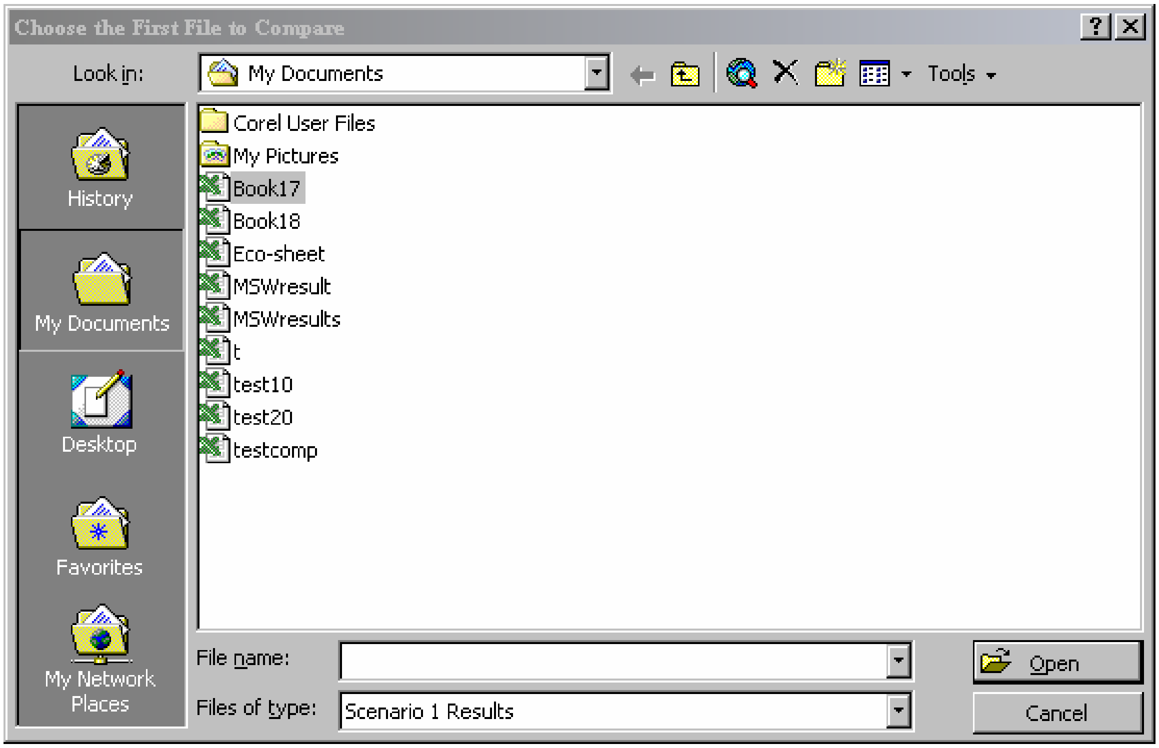


6. Finally, when it comes to choose a strategy for all the goods, one form per goods category will guide the users in this process. The “fill” and “clear” buttons can accelerate the procedure by going faster through the cells. If the “fill” button is clicked, the whole strategy column will have a copy of the total. If the “clear” button is clicked, the column is reset with zeros. Here is an example with paper goods:



III. Comparing two scenarios:

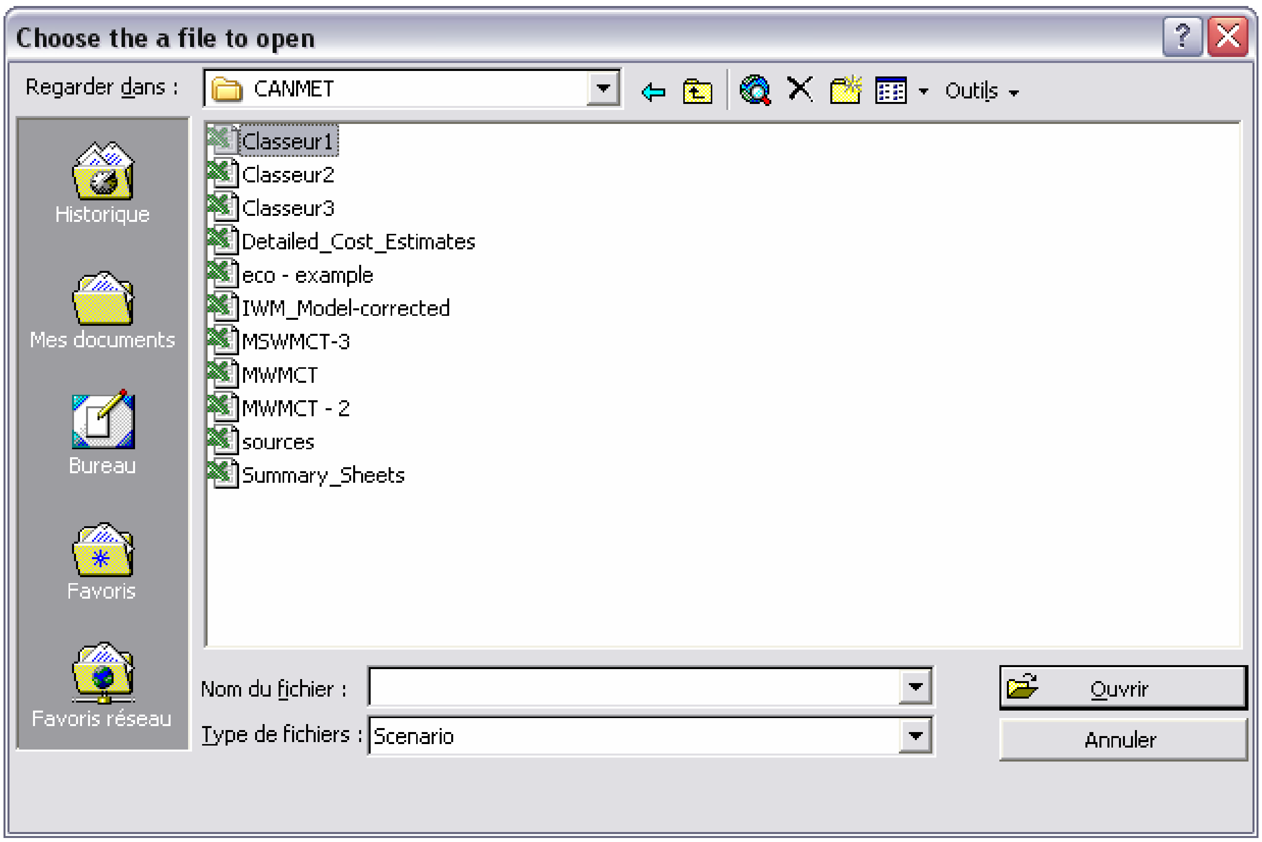
1. If two scenarios were created and saved, it is possible to compare them with the MSWMCT. By clicking on this option on the "Intro" user form, two computer browsers will appear, one after the other. It is quite important to select valid scenarios or the program will close every worksheet open, related to MSWMCT or not.



2. As simple as that, the final results will appear in a new worksheet. Three spreadsheets are now available. The "Compare" spreadsheet subtracts each CO_2 emission and energy impact for the first scenario from the second scenario selected. The "Summary" spreadsheet does the same with the summary tables and brings back those ones to help the user to remember. Finally, the "Graphics" spreadsheet is useful to visualize the information contained in the tables.

IV. Loading a scenario:

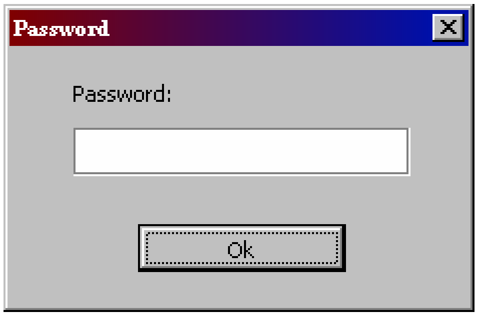
1. To slightly modify a previously created and saved scenario or just to make sure that the results are correct, it is possible to load a scenario with the MSWMCT. By choosing this option on the "Intro" user form, a computer browser will appear on the screen. It is quite important to select a valid scenario or the program will close every worksheet open, related to MSWMCT or not. Once this is done, it is just like creating a scenario (see II.2) except that all values are initialized with the values from the selected scenario.



2. Passing through all user forms again allows the user to modify selected values. After all changes have been made, updated results will appear in a new worksheet.

V. Updating the database:

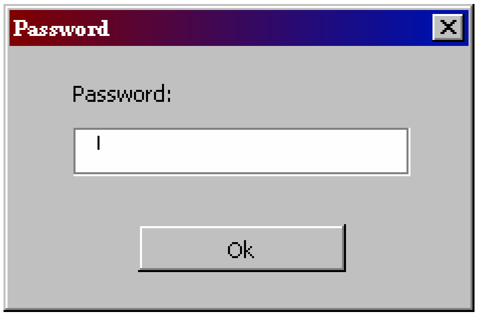
1. To update the database, a password is required. For the moment, only NRCan can provide that password.

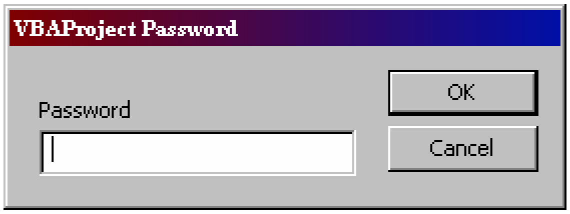


2. Enter the correct password and four spreadsheets will appear. Before changing values, it is important that cells are not moved; otherwise the program will not be able to function correctly. For the CO_2 and the energy coefficients, the labels are pretty clear and it should be easy to update without problems.
3. To update the "Waste generator", the "Generate" spreadsheet needs to be changed. The principal coefficients are from B53 to M71. It is important, when changing these coefficients, to make sure that the sum for each column stays at unity, or the waste generator will generate something other than 100% waste.
4. To close the new spreadsheets, the following command must be used:
   Tools -> Macro -> Macros or Alt+F8.
   For the Macro name, write "CloseUp" and then, by clicking Run, each spreadsheet except the "Main" one will close.

VI. Updating the whole program:

1. To update the program, three passwords are required. For the moment, only Natural Resources Canada can provide those passwords. One is asked by the "Intro" user form, one by the Visual Basic© interface and a last one by Excel© itself to unprotect the "Main" spreadsheet (Tools -> Protection -> Unprotect Sheet…).





2. Once everything is unlocked, it is possible to modify the program at will.

APPENDIX II: FIGURES

Figure 1. Example of a plant cost/equipment breakdown

Recycling			
A list for building a dry recovery plant like Guelph, Canada:			
-For a capacity of :	73313	Tonnes of MSW	
item	**cost**		
SITE DEVELOPMENT			Demo version
Allowance for General Excavation of Plant Area to a depth of 0.5 Metres (150m x 70m)	64 150,37 $		
Allowance for Structural Backfill of Plant Area (150m x 70m)	273 708,23 $		
Water Supply System	467 584,90 $		
Sewage System (connection to municipal system)	187 359,80 $		
Roads, Parking, Fencing and Gates	641 503,67 $		
Site Lighting (compost curing area)	217 907,60 $		
Site Electrical Services (power to site)	226 053,67 $		
SUB-TOTAL	**2 078 268,24 $**		
MATERIAL RECOVERY FACILITY (DRY WASTE) (60m x 120m x 14m)			Demo version
Excavation of Receiving/Separating Building to a depth of 1.5 Metres (62m x 122m)	138 686,98 $		
Structural Backfill of Receiving /Separating Building	437 933,17 $		
Perimeter concrete walls .6m thick x 2m high	1 550 170,20 $		
Ground Structural Concrete floor slab. (0.3m)	3 695 061,14 $		
Concrete col's fdn .9m x .9m x 2m high (39 ea)	862 180,93 $		
Structural Concrete beams	735 346,49 $		
Structural Steel for building	3 480 249,05 $		
Insulated Metal Siding	1 744 889,98 $		
Insulated Roofing installed on roof decking.	1 935 508,21 $		
Overhead Doors (5)	248 455,39 $		Demo version
In feed conveyors (1067 mm x 100 m)	1 193 889,24 $		
MSW Shredder (20 ton per hr.)	582 444,60 $		
Baling Machine (20 tons per hour)	643 540,19 $		
Eddy current separators	190 414,58 $		
Glass Recovery System	515 239,46 $		
Suspended self cleaning magnet	40 730,39 $		
Air Classifier	161 292,35 $		
Ballistic Separators	258 637,99 $		
Compactors	392 030,02 $		
Bottle Perforators	392 030,02 $		
Storage Bins	71 685,49 $		Demo version
Overhead crane (5 mt)	44 803,43 $		
Allowance for Interior Works (office, lunchroom)	570 225,48 $		
SUB-TOTAL	**19 885 444,80 $**		
SUB - TOTAL DIRECT COSTS	**21 963 713,03 $**		
General Electrical Charges	2 251 280,59 $		
Instrumentation and Control Charges	768 729,96 $		
TOTAL DIRECT COSTS	**24 983 723,58 $**		Demo version
Site Construction Management	1 798 822,51 $		
Commissioning	732 020,83 $		
Temporary Construction Facilities	149 901,88 $		
Miscellaneous Site Costs	299 803,75 $		
Engineering and Project Management	2 123 609,90 $		
Miscellaneous Engineering Costs	124 918,23 $		
Contingencies (20 %)	6 042 544,61 $		
SUB-TOTAL	**11 271 621,70 $**		
			Demo version
Allowance for Owner's Costs	499 672,92 $		
Allowance for Environmental reviews	374 754,69 $		
Allowance for Interest During Construction (8 % over 12 months)	1 450 210,71 $		
TOTAL PROJECT COST (Excluding OWNERS)	**38 579 905,95 $**		
Others			
item1	- $		
item2	- $		
item3	- $		Demo version
item4	- $		
item5	- $		
REVISED PROJECT COST	**38 579 905,95 $**		
TOTAL PROJECT COST / TONNE	**526,24 $**		

Figure 2. Example of a "Final results" spreadsheet

Final Results

equivalent C02 | with carbon sinks | (eCO2 tonnes)

	Net recycling emissions	Net composting emissions	Net AD emissions	Net combustion emissions	Net landfilling emissions - national	NLE without LFG collection	NLE with LFG collection and flaring	NLE with LFG collection and energy recovery	
Papers	-115384,99	n/a	0	0	0	0	0	0	Papers
Metals	-60605,01	n/a	0	0	0	0	0	0	Metals
Glasses	-23,4	n/a	0	0	0	0	0	0	Glasses
Plastics	-33184,93	n/a	0	0	0	0	0	0	Plastics
Organics	n/a	-18404,16	0	0	0	0	0	0	Organics
Electronics	-3320,11	n/a	0	0	0	0	0	0	Electronics
Tires	-9172,52	n/a	0	0	0	0	0	0	Tires

equivalent C02 | without carbon sinks | (eCO2 tonnes)

	Net recycling emissions	Net composting emissions	Net AD emissions	Net combustion emissions	Net landfilling emissions - national	NLE without LFG collection	NLE with LFG collection and flaring	NLE with LFG collection and energy recovery	
Papers	-9903,21	n/a	0	0	0	0	0	0	Papers
Metals	-60605,01	n/a	0	0	0	0	0	0	Metals
Glasses	-23,4	n/a	0	0	0	0	0	0	Glasses
Plastics	-33184,93	n/a	0	0	0	0	0	0	Plastics
Organics	n/a	1533,68	0	0	0	0	0	0	Organics
Electronics	-3320,11	n/a	0	0	0	0	0	0	Electronics
Tires	-9172,52	n/a	0	0	0	0	0	0	Tires

Energy impacts | (GJ)

	Net recycling energy	Net AD energy	Net combustion energy	Net landfilling energy - national	NLE without LFG collection	NLE with LFG collection and flaring	NLE with LFG collection and energy recovery	
Papers	-269681,28	0	0	0	0	0	0	Papers
Metals	-812920,06	0	0	0	0	0	0	Metals
Glasses	-360,36	0	0	0	0	0	0	Glasses
Plastics	-919905,68	0	0	0	0	0	0	Plastics
Organics	n/a	0	0	0	0	0	0	Organics
Electronics	-41208,17	0	0	0	0	0	0	Electronics
Tires	0	0	0	0	0	0	0	Tires

*Note: There is no energy impacts composting coefficients.

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Legend: Unsuitable (red), Recommended (green), Neutral (grey)

Figure 3. Example of a "Summary" spreadsheet for a single scenario

Summary

	Emissions (eCO2 tonnes) with carbon sinks	Emissions (eCO2 tonnes) without carbon sinks	Energy impacts (GJ)	Cost US $	Tonnes	Cost (US $/tonne)
Net recycling	-221690,96	-116209,18	-2044075,55	38 579 905,95 $	73313	526,24 $
Net composting	-18404,16	1533,68	n/a	104 080 005,51 $	76684	1 357,26 $
Net AD	0	0	0	0,00 $	0	0,00 $
Net combustion	0	0	0	0,00 $	0	0,00 $
Net landfilling - national average	0	0	0		0	
NL without LFG collection	0	0	0		0	
NL with LFG collection and flaring	0	0	0		0	
NL with LFG collection and energy recovery	0	0	0	0,00 $	0	0,00 $
Total	-240095,12	-114675,5	-2044075,55	142 659 911,46 $	149997	

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Legend: Unsuitable (red); Recommended (green); Neutral (grey)

Figure 4. Example of an emissions comparison between two scenarios

Comparison: Classeur2.xls - Classeur1.xls

equivalent C02 with carbon sinks (eCO2 tonnes)

	Net recycling emissions	Net composting emissions	Net AD emissions	Net combustion emissions	emissions - national average	NLE without LFG collection	NLE with LFG collection and flaring	collection and energy recovery	
Papers	115384,99	n/a	0	-1641,65	0	0	0	0	Papers
Metals	60605,01	n/a	0	-5074,64	0	0	0	0	Metals
Glasses	23,4	n/a	0	2,34	0	0	0	0	Glasses
Plastics	33184,93	n/a	0	42354,48	0	0	0	0	Plastics
Organics	n/a	0	0	1447,03	0	0	0	-8998,34	Organics
Electronic:	3320,11	n/a	0	-125,09	0	0	0	0	Electronic:
Tires	9172,52	n/a	0	-1366,12	0	0	0	0	Tires

equivalent C02 without carbon sinks (eCO2 tonnes)

	Net recycling emissions	Net composting emissions	Net AD emissions	Net combustion emissions	emissions - national average	NLE without LFG collection	NLE with LFG collection and flaring	collection and energy recovery	
Papers	9903,21	n/a	0	-1641,65	0	0	0	0	Papers
Metals	60605,01	n/a	0	-5074,64	0	0	0	0	Metals
Glasses	23,4	n/a	0	2,34	0	0	0	0	Glasses
Plastics	33184,93	n/a	0	42354,48	0	0	0	0	Plastics
Organics	n/a	0	0	1447,03	0	0	0	-21705,45	Organics
Electronic:	3320,11	n/a	0	295,61	0	0	0	0	Electronic:
Tires	9172,52	n/a	0	-1366,12	0	0	0	0	Tires

energy emissions (GJ)

	Net recycling energy	Net AD energy	Net combustion energy	energy - national average	NLE without LFG collection	NLE with LFG collection and flaring	collection and energy recovery	
Papers	269681,28	0	-89913,15	0	0	0	0	Papers
Metals	812920,06	0	-52318,74	0	0	0	0	Metals
Glasses	360,36	0	44,46	0	0	0	0	Glasses
Plastics	919905,68	0	-70197,372	0	0	0	0	Plastics
Organics	n/a	0	-55745,39	0	0	0	31821,65	Organics
Electronic:	41208,17	0	-15929,48	0	0	0	0	Electronics
Tires	0	0	-1087,32	0	0	0	0	Tires

*Note: There is no energy impacts composting coefficients.

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Legend:		
(red)	Advantage	Classeur1.xls
(green)	Advantage	Classeur2.xls
(grey)	Neutral	

Figure 5. An example of a comparison of summaries

Summary: Classeur2.xls - Classeur1.xls

	tonnes) with carbon sinks	tonnes) without carbon sinks	Energy impacts (GJ)	Cost US $	Tonnes	Cost (US $/tonne)
Net recycling	221690,96	116209,18	2044075,55	38 579 905,95 $-	-73313	526,24 $-
Net composting	0	0	n/a	0,00 $	0	0,00 $
Net AD	0	0	0	0,00 $	0	0,00 $
Net combustion	36017,05	36017,05	-285146,992	$169 447 624,95	149997	1129,67 $
average	0	0	0		0	
HL without LFG collection	0	0	0		0	
HL with LFG collection and flaring	0	0	0		0	
HL with LFG collection and energy recovery	-8998,34	-21705,45	31821,65	31 916 856,58 $-	-76684	416,21 $-
Total	248709,67	130520,78	1790750,208	$98 950 862,42	0	

Classeur1.xls

	tonnes) with carbon sinks	tonnes) without carbon sinks	Energy impacts (GJ)	Cost US $	Tonnes	Cost (US $/tonne)
Net recycling	-221690,96	-116209,18	-2044075,55	38 579 905,95 $	73313	526,24 $
Net composting	0	0	n/a	0,00 $	0	0,00 $
Net AD	0	0	0	0,00 $	0	0,00 $
Net combustion	0	0	0	0,00 $	0	0,00 $
average	0	0	0		0	
HL without LFG collection	0	0	0		0	
HL with LFG collection and flaring	0	0	0		0	
HL with LFG collection and energy recovery	8998,34	21705,45	-31821,65	31 916 856,58 $	76684	416,21 $
Total	-212692,62	-94503,73	-2075897,2	70 496 762,53 $	149997	

Classeur2.xls

	tonnes) with carbon sinks	tonnes) without carbon sinks	Energy impacts (GJ)	Cost US $	Tonnes	Cost (US $/tonne)
Net recycling	0	0	0	0,00 $	0	0,00 $
Net composting	0	0	n/a	0,00 $	0	0,00 $
Net AD	0	0	0	0,00 $	0	0,00 $
Net combustion	36017,05	36017,05	-285146,992	169 447 624,95 $	149997	1129,67 $
average	0	0	0		0	
HL without LFG collection	0	0	0		0	
HL with LFG collection and flaring	0	0	0		0	
HL with LFG collection and energy recovery	0	0	0	0,00 $	0	0,00 $
Total	36017,05	36017,05	-285146,992	169 447 624,95 $	149997	

*Note: There is no energy impacts composting coefficients.

Legend:		
(red)	Unsuitable or advantage	Classeur1.xls
(green)	Recommended or advantage	Classeur2.xls
(grey)	Neutral	

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Figure 6. Examples of graphics obtained after a comparison