SWM GHG Calculator – a Tool for Calculating Greenhouse Gases in Solid Waste Management (SWM)

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EXECUTIVE SUMMARY

The waste management sector contributes to the greenhouse effect primarily through emissions of carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). But in the greenhouse gas (GHG) inventories based on IPCC methodology, positive impacts of reducing, re-using or recycling of waste as well as waste-to-energy strategies on climate protection are either attributed to other source categories – in particular to the energy sector and to industrial processes - or they are not accounted for at all.

Developing countries and emerging economies could not only considerably reduce their GHG emissions at comparably low costs but also significantly contribute to improve public health conditions and environmental protection if they were to put in place sustainable waste management systems. GHG produced by the waste management sector in developing countries and emerging economies are highly relevant, in particular because of the high percentage of biodegradable components contained in the waste streams. Stepping up recycling could further reduce emissions by energy savings.

KfW Entwicklungsbank in cooperation with German Technical Cooperation agency (GTZ) commissioned the elaboration of a tool to calculate GHG emissions in solid waste management (SWM) with a focus on low- and middle-income countries. The objective of the SWM-GHG Calculator, which was elaborated by IFEU (Institute for Energy and Environmental Research), is to help to understand the effects of proper waste management on GHG emissions. It allows to quantify and to compare the GHG emissions of different waste management strategies already at the early beginning of the decision making process. The SWM-GHG Calculator provides orienting information about associated costs of different waste management strategies.

The methodological basis for this tool is the life cycle approach. Different waste management strategies can be compared by calculating the GHG emissions of the different recycled and disposed of waste fractions over their whole life cycle. The tool sums up the emissions of all residual waste respectively recycling streams.
The paper and the presentation describe the *SWM-GHG Calculator* and its functions. A case study of the city of Cairo is presented. There, the tool has been applied to analyse the GHG effects of different waste management scenarios. It became clear that choosing different waste management options can have huge effects on GHG production in the sector. It also shows that a consequent recycling and composting approach can even lead to a negative emissions balance, meaning that the SWM sector is a net sink.

**INTRODUCTION**

Climate change is considered one of the greatest global challenges of the 21st century. A general consensus exists among the vast majority of climate experts that global warming is the result of rising concentrations of greenhouse gases in the Earth's atmosphere. Since industrialisation began, human activities have intensified the natural greenhouse effect, which is caused largely by water vapour, carbon dioxide, methane and ozone in the atmosphere, through anthropogenic emissions of greenhouse gases, resulting in global warming.

The waste management sector contributes to the greenhouse effect primarily through emissions of carbon dioxide (CO$_2$), methane (CH$_4$) and nitrous oxide (N$_2$O). The IPCC’s Fourth Assessment Report puts the contribution made by the solid waste and wastewater management sector to global greenhouse gas emissions at 2.7%, which might at first sight appear to be comparatively low. But in fact, waste management can contribute indirectly to significantly larger GHG emissions reductions.

**CONTRIBUTIONS OF THE WASTE MANAGEMENT SECTOR TO GHG EMISSIONS: “END-OF-PIPE” VS. LIFE-CYCLE APPROACHES**

The 2.7% of global GHG emissions assumed for the waste sector by IPCC do not fully reflect the actual potential for reducing GHG emissions by the waste management sector. The IPCC calculations take into account only end-of-pipe solid waste management strategies, such as:

- Landfill/waste dumping
- Composting
- Waste incineration (in case the generated heat energy is not utilised)
- Sewage disposal

In this way, potential emissions reductions in the waste sector are assumed to exist predominantly in avoiding methane production from landfills. The positive impacts of reducing, re-using or recycling waste, as well as waste-to-energy solutions on climate protection are either attributed to other source categories – in particular to the energy sector and to industrial processes – or they are not accounted for at all in the GHG inventories reported to the United Nations Framework Convention on Climate Change (UNFCCC) under the Kyoto Protocol.

Experts of integrated waste management approaches, on the contrary, see significant potentials for GHG emissions reductions in waste management through several strategies:
• Methane reduction: Collection and flaring of landfill gas can already cut the emissions in half because it leads to CO2 emissions instead of methane emissions. Even more, waste incineration or composting have significantly less global warming potential than landfilling.

• Recycling: The use of secondary raw materials instead of primary raw materials reduces the energy consumed in industrial processes. In glass production, 35% of energy can be saved, in paper production 50% and in Aluminium production, the use of secondary raw materials can even save 90% of energy use compared to the use of primary raw materials. In addition to the savings in energy, recycling also avoids the emissions and environmental impact resulting from the exploitation of primary raw materials. Composting of organic waste generates alternative fertilizer which leads to less energy consumption for producing chemical fertilizer.

• Energetic use: Waste can be used energetically in many ways. Waste fractions with a high calorific value can be used as alternative fuel resources, and organic waste can be digested to produce biogas. When waste is used to substitute primary fossil fuels in these processes, this leads to reductions of emissions.

The emission savings resulting from recycling processes vary significantly according to the material recycled. When for example waste paper is recycled and not disposed on a landfill, this results not only in reducing the emissions that would have occurred by the material degradation on the landfill, but also in reducing the emissions caused by cutting trees as well as the energy and emissions from processing wood for paper production and part of the energy used for processing cellulose.

Especially in developing countries and emerging economies, greenhouse gas emissions produced by the waste management sector are highly relevant, in particular because of the high percentage of biodegradable components contained in the waste streams. The potential to reduce greenhouse gas emissions is significantly higher than the 2.7% figure in the IPCC statistics would lead us to assume. A study conducted on behalf of the Federal Ministry for Economic Cooperation and Development (IFEU 2008) estimates that developing countries and emerging economies could reduce their national GHG emissions by around 5% merely by adopting municipal waste management systems. The authors reckon that if other waste types, especially waste containing high levels of biodegradable organic matter, in particular the residues of agricultural activities and the food industry or other, similar industrial wastes are included in the waste management system, the reduction of greenhouse gas emissions in these countries could be doubled, i.e. in the order of 10%. IFEU and Ökoinstitut (2010) determined that in Tunisia, Turkey and Brazil, between 10 and 16% of national GHG emissions could be reduced through changes in the waste management sector.

THE GHG CALCULATOR FOR SOLID WASTE MANAGEMENT – OBJECTIVE AND METHODOLOGY

Decision makers, technicians and advisors working in waste management are not always aware of the contributions that sustainable waste management options can make to GHG emissions reduction. In order to support decision making, KfW in collaboration with GTZ commissioned IFEU to elaborate a simple Excel tool for quantifying GHG emissions in different waste management scenarios.
The objective of this "Tool for Calculating GHG Emissions in Solid Waste Management" (SWM-GHG Calculator) is to aid in understanding the effects of proper waste management on GHG emissions. The SWM-GHG Calculator allows quantification and comparison of GHG emissions for different waste management strategies at an early stage in the decision making process. Default values allow approximations to be made even if basic data are not (yet) available. Additionally, the SWM-GHG Calculator provides guidance information on the costs associated with different waste management strategies.

Basically, the calculation method used in the SWM-GHG Calculator follows the Life Cycle Assessment (LCA) method. Different waste management strategies can be compared by calculating the GHG emissions of the different recycled (typically glass, paper and cardboard, plastics, metals, organic waste) and disposed of waste fractions over their whole life cycle – from "cradle to grave", in a manner of speaking. The tool sums up the emissions of all residual waste or recycling streams respectively and calculates the total GHG emissions in CO2 equivalents. The emissions calculated also include all future emissions caused by a given quantity of treated waste. This means that when waste is sent to landfill, for example, the calculated GHG emissions, given in tonne CO2 equivalents per tonne of waste, include the cumulated emissions generated during waste degradation. This method corresponds to the "Tier 1" approach described in IPCC (1996, 2006).

HOW TO USE THE SWM GHG CALCULATOR

The use of the SWM-GHG Calculator does not require profound professional experience in solid waste management. It can even be used by persons having only basic knowledge in the sector, e.g. by decision makers or mayors, as default values are offered during the calculation process. Nevertheless, the SWM-GHG Calculator can be better used and the results are better understood the more experience users have.

The SWM-GHG Calculator comprises different sheets where the users enter basic information and can define the status quo waste management practices as well as scenarios for future waste management options.

Waste characteristics:
In a start sheet, users specify the waste amount, waste composition, and the country-specific electricity grid.

Definition of waste recycling options:
In the "recycling" sheet, users define the percentage of different waste fractions (organic and non-organic) that are currently recycled or valorized. For organic waste, there are the options of composting and digestion. In this sheet, users can also define up to three scenarios in addition to the status quo in order to compare the impacts of higher or lower recycling rates on GHG emissions.

Definition of disposal options:
For the residual waste remaining after recovery, specifications have to be introduced regarding different treatment and disposal options in the "disposal" sheet. Manifold treatment types and technologies exist. Some should be avoided at all costs as they pose health hazards to the population and damage the environment, some are very simple but at least less hazardous, and finally there are sophisticated or advanced treatment
technologies. The treatment technologies represented in the SWM-GHG Calculator are presented below. The first group includes common present practices that should be avoided at all costs. They affect waste which is not regularly collected but usually scattered or delivered to a wild dump site. Additionally, scattered waste is sometimes burned in the open (including directly at households), producing huge amounts of extremely toxic substances (in particular dioxins, furans, aromatic hydrocarbons ...). The second group is that of simple treatment and disposal technologies. Apart from disposal to controlled landfills (with or without landfill gas collection) this includes simple biological stabilisation (BS) before disposal whereby methane emissions are reduced. The third group includes advanced technologies. Apart from waste incineration this includes treatment options with the purpose of separating recyclable fractions before stabilising the remaining waste biologically prior to sending to landfill (Mechanical-biological treatment + further treatment + landfill) or to produce a refuse-derived fuel that may be co-incinerated, e.g. in cement kilns (Mechanical-biological stabilisation or Mechanical-physical stabilisation + co-processing).

Costs:
In a separate sheet, users can specify the costs for waste recycling, waste treatment and disposal. This information serves to determine the total costs for a waste management scenario as well as the cost for mitigating one tonne of CO2-equivalents by implementing different waste management options.

Results:
The impacts of the different waste management options on GHG emissions are shown in several results sheets, individually for each of the scenarios and comparing the scenarios.

Recommendations for defining scenarios:
- All scenarios should refer to the same region, waste quantity and waste composition.
- Describe the Status Quo as realistically as possible. Initially collect only easily accessible or available basic input data (population figures, waste quantities and compositions, present waste disposal practice). Don’t waste time on ambitious data research. If data are not easily available, use the default values provided.
- Define Scenario 1 as the probable future business-as-usual development scenario, e.g. solutions in neighbouring regions, solutions discussed on political and professional levels. Try to estimate the quantities of waste already being recycled, in particular by the informal sector, as accurately as possible, but do not overestimate them! Keep in mind that even comprehensive informal recycling schemes do not recover more than about 50% of the generated recyclable waste components (paper, cardboard, plastics etc.).
- Define Scenario 2 as a more advanced solid waste management system. For example, extension of waste collection services to as yet unconnected municipalities or city quarters; optimisation of recycling activities, e.g. by cooperation with the informal sector or supportive measures; introduction of composting for selected waste streams (garden, park, market waste); possible pre-treatment/biological stabilisation of residual waste before sending to landfill.
- Define Scenario 3 as a modern solid waste management system according to the advanced standards and strategies of western European countries, e.g. closed-loop-recycling systems, waste-to-energy strategies, etc.; stay realistic with achievable
recovery rates. Figures of more than 80% - 90% material recycling are not achievable even with very advanced strategies and technologies.

An example describing a possible Status Quo-scenario and three waste management scenarios are given in the tool to the GHG calculator.

**CASE STUDY: SCENARIOS FOR GHG EMISSIONS IN CAIRO**

In a GTZ study on solid waste management in Cairo in 2006, different scenarios have been defined regarding the reduction or integration of informal recycling activities. The inner city of the Egyptian capital had a population of 7.9 million in 2006 and produced more than 3.3 million tonnes of waste per year. 60% of the waste was organic. The waste composition is shown at the right.

Around 30% of the waste were not collected in 2006, these were either burned by households or scattered in an uncontrolled manner.

In 2006, an important fraction of waste in Cairo was collected by informal workers who recovered dry waste for recycling and organic waste for pig breeding (“recycling” in the figure below). The formal waste collection providers conducted some composting activities, but on a rather small scale. The remaining waste was deposited on controlled dumpsites.

The data on waste recycling and disposal were accounted for in the GHG calculator\(^1\). Then, three scenarios were defined comprising significant changes in waste management strategies. In scenario 1, valorisation of waste would cease and all waste amounts would be disposed in controlled dumpsites without landfill gas collection. In scenario 2, valorisation of organic waste by the informal sector would cease due to new regulations, and only recyclable waste fractions would be conducted on a lower scale. In a third scenario, the recycling and composting activities would be broadened, which would result in a larger fraction of recyclable and organic waste being valorized.

\(^1\) For reasons of applicability of the tool, the feeding of pigs with organic waste was treated as composting in the baseline scenario, even if it can be argued that pig breeding might cause other emissions than composting. It was assumed that pig breeding would also happen if they would not be fed with organic waste. Therefore it can be argued that the use for pig breeding does not cause significantly more emissions than composting.
The calculations with the GHG calculator demonstrate that enormous reductions of GHG gas emissions could be achieved by pursuing an approach facilitating consequent recycling and composting. Waste management strategies only focusing on land filling will lead to higher GHG emissions. An integrated approach maximizing recycling and composting of waste can even lead to negative emissions. This means that the emissions reduced by less consumption in energy and primary raw materials through recycling processes compared to primary production processes outweigh the emissions produced in waste management. The GHG emissions in the different scenarios are shown below:

If you assume extended composting activities for scenario 3, this scenario would result in higher system costs. Calculated in relation to the reduced CO2 equivalents, additional costs of 5 Euro per tonne of saved CO2eq would occur.

**LIMITS TO THE USE OF THE SWM GHG CALCULATOR**

For methodical and practical reasons it was necessary to design the tool by applying various simplifications. It must be emphasized that the SWM-GHG Calculator can by no means represent a fully-fledged Life Cycle Assessment (LCA). For example, most GHG calculations for the recycling chains are based on emission factors which account for specific treatment options in Germany and Europe. This is why the SWM-GHG Calculator delivers common results based on average data for recycling. Nevertheless, the variations are not serious or critical for drawing conclusions. Details of the main assumptions made are explained in the manual. Also, it should be noted the calculator addresses only climate change as an environmental impact. For decision making in waste management, other potential environmental and health effects have to be taken into account.

Furthermore, the SWM-GHG Calculator is not suited to calculating the anticipated quantity of Certified Emission Reductions (CER) in the framework of the Clean Development Mechanism (CDM) or of Emission Reduction Units (ERU) in the framework of the Joint Implementation (JI). Firstly, the CDM and JI refer to individual projects and must take into account the theoretical generation of GHG that would occur during waste degradation if a CDM or JI project where not implemented ("baseline"). The SWM-GHG Calculator, on the other hand, compares different solid waste management systems or strategies. Secondly,
the CERs and ERUs must be calculated and are compensated on an annual basis; i.e. only the GHG emissions caused by a given quantity of treated waste per year are considered – calculated in compliance with the "Tier 2" approach (IPCC 1996, 2006) – and only a time period of either once every ten years or three times in seven years can be chosen. The CDM or JI crediting periods are therefore much shorter than the waste degradation period, which is 50 years or more. Only around 50% - 80% of the total gas generation potential of a given quantity of waste would have been emitted within the CDM or JI crediting period. Accordingly, only this portion of the effective GHG reductions induced by CDM projects in the waste management sector is compensated. Methodologies for recycling activities are still not established within the CDM.

CONCLUSIONS

The GHG calculator is innovative in the sense that it follows the approach of life-cycle assessment and thus does not only account for emissions reductions potentials in solid waste management from an “end-of-pipe” perspective. In addition to the emissions reductions that are recognized for the waste management in instruments like the CDM, the GHG calculator shows that there are important additional emissions reductions that can be achieved by implementing integrated solid waste management. The logic in which the calculator has been elaborated does not want to question the IPCC categorization of sectors that are source to GHG emissions. It just wants to point out that in order to achieve emissions reductions in other IPCC sectors, waste management measures are sometimes necessary.

The first applications of the GHG calculator show that the tool is accessible to professionals from the waste sector and gives relevant information about the potential emissions reductions. The simplifications discussed above were necessary and had to be accepted for the benefit of better manageability of the SWM-GHG Calculator. Against the background of the tool's objective – to aid in understanding the consequences of waste management activities with respect to the related GHG emissions – it serves as a valuable orientation aid. The results deliver a sufficiently accurate quantitative approximation of the GHG impacts of different strategies as an important contribution to decision making.

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