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An analysis of potentials and barriers within the present methodological framework

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1 Abstract

The exponentially increasing number of projects in the Clean Development Mechanism (CDM) framework shows that the CDM has become a very successful instrument of climate protection in the last years. Despite this success there are still sectors in developing countries offering a large Greenhouse Gas (GHG) reduction potential that remain widely untouched by CDM project activities.

One of these is the sector of municipal solid waste management. The widespread practice of waste disposal on landfills leads to the development of large amounts of methane which in return amplifies the greenhouse effect. Reforms in waste management practices can therefore effectively reduce global greenhouse gas emissions.

However, the small share of CDM projects including waste management activities shows that this potential is not being utilized yet by carbon financing. This work therefore surveys the functional framework of CDM projects in the waste sector, pointing out the main reasons for this lack of activities.

- CDM projects in the waste management sector have to be implemented carefully with full consideration given to all possible external impacts of the project. This is due to the fact that in developing countries, the waste sector often offers the only livelihood to some of the extremely poor people. Any project activity in this sector should therefore incorporate these waste pickers as far as possible.
- A detailed examination of the procedures to establish the baseline pointed out the inherent problems of applying the First Order Decay (FOD) model according to Tier 2. This appliance is a special balancing approach allocating the accomplished emission reductions of a project at the date of the avoided emissions instead of the time of the avoidance activity. Despite financial disincentives, basically contradicting the sustainable development objectives of the CDM, the Tier 2 balancing approach causes a massive decline in investment attractiveness in comparison to other less sustainable project types.
- Guidelines have been produced on how the statistical requirements of the procedures to establish the baseline can be fulfilled. Further it has been shown that significant results could be produced in a considerably less complicated way.
- To determine the potential in terms of GHG reductions the different project forms of AM0025 have been simulated, their practicability has been discussed and the related monitoring procedures have been examined. A comparison to a German eco efficiency analysis showed the extent of the losses in potential caused by the time shifted allocation of baseline emissions according to Tier 2.
- The critical findings are listed and afterwards combined in a draft methodology that should allow for more feasible projects in the waste management sector in future.

This work should deliver incentives for the further development of the CDM framework. Moreover it can be used to develop Voluntary Emission Reduction (VER) methodologies and thus opening up an alternative market for carbon credits from activities in the waste management sector.

2 Municipal Solid Waste Management sector in the framework of climate change – terms and definitions

After long lasting political discussion, the green house effect is now widely accepted as a global problem. The global community is confronted with its consequences to an ever increasing degree and will have to face this problem and solve it through a large coalition of nations.

This work looks into a very particular aspect of this problem-solving process as it examines the generation of so-called "Certified Emission Reductions" (CER). These are created by implementing waste managements projects that reduce the emission of greenhouse gases (GHG) in the Municipal Solid Waste (MSW-) sector, the benefits of which to climate change will be explained further in Chapter 4.

Before describing the subject in detail, some important background information and definitions are given to allow for an easy entrance into this matter.

2.1 The development of the international treaties on combating climate change

In 1992 the United Nations Conference on Environment and Development (UNCED) took place. This conference made history as it represented the biggest international meeting in terms of participating parties that has ever taken place.

At this global event the "United Nations Framework Convention on Climate Change" (UNFCCC) was agreed on. Binding in international law, this framework convention comprehended that definitive measures should be elaborated to stop the anthropogenic climate change:

The participating nations committed themselves to account for and to report their yearly Greenhouse Gas (GHG) emissions. Further it was agreed on that the Conferences of the Parties (COP) should elaborate more definitive treaties to combat climate change with common but differentiated responsibilities.

The UNFCCC came into force on March 21, 1994. It was furthermore eponymous to the UN-Agency founded with the main task to attend to the implementation of the convention resolutions and which will be of further relevance for the subject of this work.

The first conference of the parties (COP-1), 1995 in Berlin was held in order to agree on the implementation of an ad-hoc working group. This working group was mandated to elaborate a treaty on a defined and binding emission threshold.

The treaty known as Kyoto Protocol was presented and agreed on the COP-3 in Kyoto. It includes a GHG emission reduction of an average 5.2 % in comparison to the reference year 1990. This reduction is to be achieved by all countries listed in Annex B of the Kyoto Protocol in the period between 2008 and 2012. These 39 countries are also known as Annex B countries and constitute the industrialized countries (USA, European Union, Russia, Japan etc.).

The European Union committed itself to 8 % GHG emission reduction compared to 1990 GHG emission levels accordant to its historic responsibility. Germany contributes 21 % whereas England aims at 12.5 % and France solely stabilizes its emission to the level of 1990. Emerging market countries like India, China and Brazil do not have to meet any reduction target. This is one of the reasons mentioned by the United States of America to justify their refusal to ratify the Kyoto Protocol.

After further amendments on COP-7, 2001 in Marrakech, a framework was created for the so-called flexible mechanisms to work. These were already provided in the Kyoto Protocol but still lacked regulations and terms. The flexible mechanisms are tools to limit the overall GHG reduction by allowing the generation and the trade of carbon emission allowances. These mechanisms are important for this work and are defined below.

2.2 Market Based Mechanisms to reduce GHG emissions

2.2.1 Emission Trading

The term Emission Trading describes markets for pollution rights of a certain kind, in this case the market for GHG emission rights. To establish an emission trading system at first a cap for the overall emissions within the system's boundary needs to be defined over a defined period of time. The system boundary is geographically tied to a certain area and covers a certain range of participants (e.g. energy suppliers, the cement industry etc.). According to this overall cap, the coordinating entity then distributes specific volumes of GHG emission rights to the market's participants either by auction or allocation. These emission rights allow the owner to emit a certain amount of GHG gases. In case the owner exceeds the allocated or purchased volume, he needs to buy more emission rights. In the case that his emissions fall below the volume he owns, he may sell his contingent.

As any emissions not covered by emission rights will be penalized by the coordinating entity, the carbon emission rights obtain a flexible price on the market. According to the law of supply and demand therefore, the carbon emissions themselves achieve a certain price. If the financial equivalent of the GHG emission rights exceeds the costs of a measure to reduce GHG emissions, the participant will carry out this GHG emission reduction. Afterwards he will be able to sell his GHG emission right contingent or could stop purchasing additional emission rights.

By changing the overall cap, the coordinating entity can subsequently lower the emissions trading period after trading period. The increasing prices for emission allowances then generate an economic interest in lowering the GHG emission reductions for the participants and thus enabling them to conduct more expensive GHG emission reduction.

Such a GHG emission trading system has existed since the beginning of trading period I of the "Emission Trading System" of the European Union (EU ETS) on January 1, 2005. It includes the trade of carbon dioxide emission rights known as "European Union Allowance Units" (EAU). One EUA authorizes the emission of one tonne carbon dioxide (1 tCO_2). At the moment in Phase II of the EU ETS (2008-2012) circa 80 % of the EAU are being allocated. Furthermore, obligatory participation is determined to certain key industries that cover around 50 % of the present CO_2 emissions within the European Union. The further development in the following trading periods shall, step by step, include more industrial sectors and increase the share of auctioned EAU in the same time. With the beginning of Phase II, participants have been able to purchase their EAU not only on the EU ETS market but also by buying emission rights generated by projects taking place in the framework of the "Clean Development Mechanism" (CDM). Thus a second source of emission rights is now available.[1]

Another important Emission Trading system is existent in the framework of the Kyoto Protocol. It contains the bilateral trade of "Assigned Amount Units"(AAU) between Annex B countries which may trade the volume they were allocated to other Annex B countries. (cf. Chapter 2.1)

2.2.2 CDM - Clean Development Mechanism

The main subject of this work is the "Clean Development Mechanism"(CDM) to promote a sustainable development in developing countries. It is part of the "flexible mechanisms" of the Kyoto Protocol and aims

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[1] Also emission rights from Joint Implementation projects can be purchased, part of the flexible mechanisms as well. This mechanism however, is of no further relevance for this work.

at cost effective GHG emission reductions. The leading thought is the irrelevance of the location of GHG emission reductions from a global point of view as it is more decisive that there is an effective GHG emission reduction. Furthermore the CDM shall offer development aid to a certain extent by means of climate protection projects. The possible host countries for CDM projects are those Kyoto Protocol member countries that are not mentioned in Annex B. These are developing countries and emerging market nations which do not have to meet a Kyoto target.

In these countries GHG emission reduction projects can be conducted. After reporting, monitoring and verifying the precise volume of the GHG emissions reduced, the project conductor is then allocated the equivalent in "Certified Emission Reductions" (CER). These CER can be used by participants of the EU ETS to cover up their emissions to a certain extent - 22 % at present in Germany. As in this way the emission reduction of host countries are offset with emission in industrialized countries the CDM is also known as "offsetting mechanism".

GHG reduction projects can be any kind of activity that achieves a measurable GHG emission reduction. The measurement itself needs to be done according to standards defined in methodologies by UNFCCC. Unlike in the EU ETS emission reductions of all gases declared as GHG gases in the Kyoto Protocol may be aimed at in the CDM. These are carbon dioxide (CO_2), methane (CH_4), sulphur hexafluoride (SF6), nitrous oxide (laughing gas, N_2O) and the group of hydro fluorocarbons (HFC).

The most important criteria for the admission of an activity as CDM project is the "additionality" of the activity. A project is considered additional if the activity as such would not have been implemented in the absence of CDM financing and the engagement of the CDM project developer. This is important as any activity that would have put in place anyway would result in the trade of inconsistent CER. These in turn would cause the overall growth in global GHG emissions and corrupt this entire offsetting mechanism. Therefore the proof of additionality is one of the most important and most discussed aspects of the CDM.

Whilst project developers tend to argue about the strict requirements of the proof of additionality, Non-Governmental Organisations often doubt the environmental integrity of CDM-Projects. Studies show that the proof of additionality is very often scant and that the certified examiners frequently tend to neglect the detailed examination of this point. [Schneider et al. 2007]

Generally any approach to reduce on GHG emissions is valid, ranging from wind farms to the large scale substitution of conventional light bulbs by more energy efficient ones.

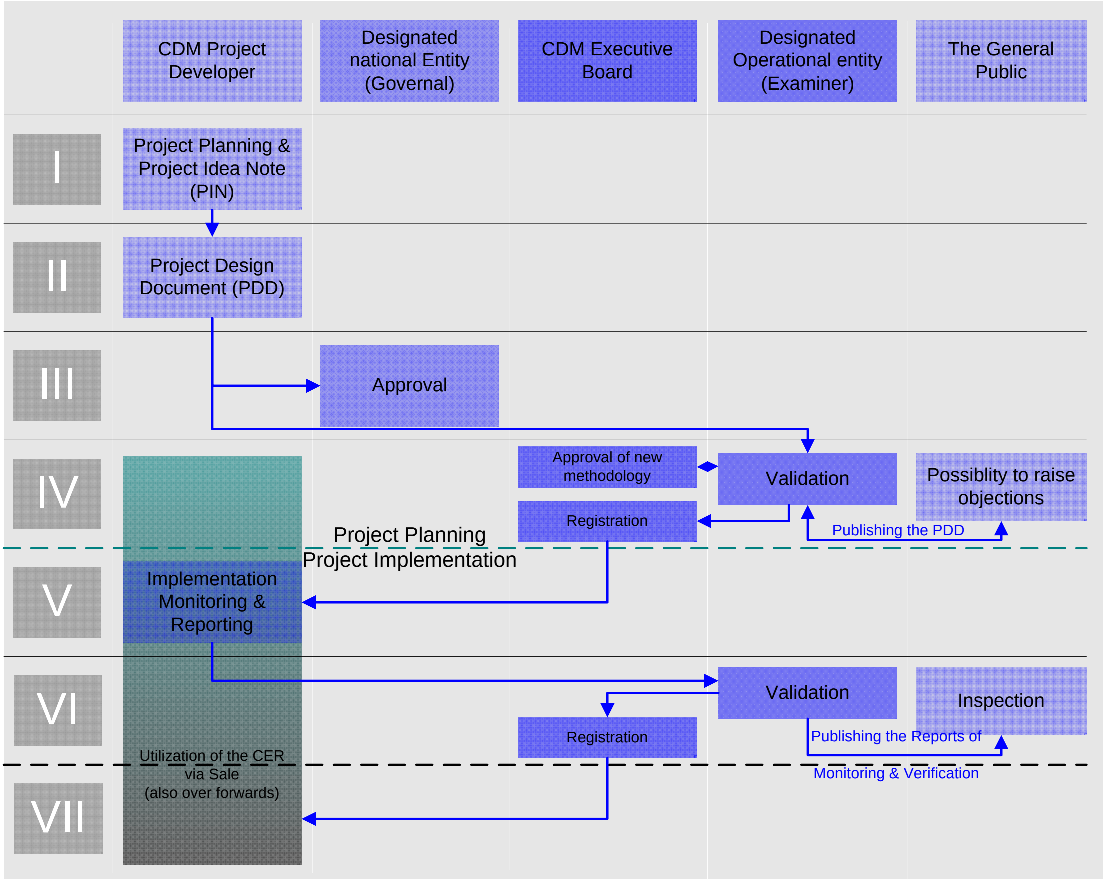

Figure 2-1: UNFCCC Procedures for the implementation of CDM Projects (On the basis of CO2ncept plus)

In Figure 2-1 the formal requirements for implementing a CDM project are illustrated. The precise knowledge of these processes and the policy decisions already made on controversial issues is of great and decisive value to a project developer. Thus a well established industry of CDM consultants has developed in the recent years.

The sale of CER is taxed by the UNFCCC at 2 % of the allocated volume to cover the operational expenses of the UNFCCC secretariat itself and to pay into the "adaptation fund" for adaptation on the consequences of climate change.

2.2.3 PoA – the programmatic CDM

CDM Projects with a similar structure can be bundled as "Programme of Activities"(PoA). Thus transfer costs can be lowered to a considerable extent, which is a great asset for small scale projects. A basic requirement for registration of a PoA is the application of the same methodology to every CDM project activity (CPA).

A typical example for a PoA is the large scale distribution of energy-efficient fridges at a reduced price and the simultaneous acceptance and controlled disposal of the replaced old ones [Umweltbundesamt 2008]. (*Ministry of the Environment*)

2.2.4 VER - Voluntary Emissions Reduction

Besides the discussed mechanism within the UNFCCC framework there is another market for emission certificates. The so called "Voluntary Emissions Reduction"(VER) certificates are not subject to the strict conditions of the UNFCCC secretariat. Though there is no guarantee for the quality of these certificates as they lack a supervising body, they offer an alternative market for emission certificates. This market is often used to label sport events, flights or conferences as carbon neutral. The certificates however, cannot be used within the EU ETS.

To assure standard of quality for this market, some nameable Non-Governmental Organisations (e.g. WWF) have joined forces and founded the "Gold Standard Foundation". GHG emission reduction projects with a "Gold Standard Label" offer a higher environmental integrity and are therefore more valuable than there non-labelled pendants. As the sustainability of CDM projects is also being questioned frequently the Gold Standard Foundation offers a "CDM Gold Standard Label" as well. Another VER Label is offered by the TÜV Süd "Blue Registry". These projects are not restricted to renewable energy as Gold Standard projects are.

2.3 CDM Methodologies

In relation to the "flexible mechanisms" of the Kyoto Protocol the term methodology describes a standardized UNFCCC guideline on how to balance the achievements of activities that reduce emission reductions.

The assessment of such activities has to be undertaken to account for the GHG emission reductions achieved. Therefore the project benefits are compared to a reference scenario, the so called "baseline emissions". These describe the total GHG emissions occurring in absence of the project under continuance of the business as usual practice.

The measuring and the data management necessary to construct such a baseline scenario differ in dependence on the kind of activity applied. By means of two examples these measures shall be illustrated now without further commenting on the methodologies themselves.

Example 1: A Wind Farm

To assess the GHG reduction achievements of wind farms according to ACM0002, it is necessary to account for the CO_2 emissions that would have occurred in the substitute baseline scenario in order to produce the same amount of energy as provided by the wind farm.

Additionally the backup power plants for the wind farms have to be incorporated in the equation. These are activated if, in case of a lull, the wind farms suffer a drop in production.

Thus three key parameters have to be assessed or measured to account for the GHG emission reduction.

Example 2: A Waste Incinerator

This example addresses the main topic of this work and features a far more complex balancing structure. At first the GHG reductions achievable are of a more miscellaneous nature. The combustion of MSW avoids landfill gas emissions on the one hand but on the other hand it produces energy. This energy can be utilized to produce process heat or electrical energy which may substitute conventional energy production.

Secondly, these GHG reduction potentials necessitate the comparison to two different baseline scenarios. The carbon intensity of the business-as- usual energy production is to be assessed as well as the methane production potential of the current waste management system. These baseline emissions then must be compared to the emissions of the activity itself. Therefore the fossil carbon content of the MSW combusted needs to be measured and the emissions from transporting and operation procedures need to be calculated.

Instead of the three key parameters from example 1, in this case five parameters are necessary for establishing the GHG balance. Furthermore the assessment of these parameters is far more complex in practice. Quantifying the avoided methane emissions from landfills may only be done by using the "First Order Decay Model" of the IPCC. According to UNFCCC requirements additionally a very exact measurement of the processed MSW composition is necessary (see Chapter 9).

A detailed balance of a waste incinerator according to the approved methodology AM0025 is available in Chapter 6.4.5.

The outcome of the methodological calculations directly resembles the CER the project may claim.

Methodologies are mostly submitted by project developers in preparation of the planning of a project. After passing examination of the CDM Methodology Panel, which is directly subordinated to the UNFCCC secretariat, a methodology attains the status of an "Approved Methodology" or "Approved Small-Scale Methodology". Afterwards the methodologies are published and may then be used by any project developer who plans a project which is eligible for the respective methodology.

The difference between the two forms of methodology is reasoned by the two existing classes of CDM projects. Dependent on the size of the project it is scaled to the "Large Scale" or "Small Scale" group.

The achievement in GHG emission reducing serves as criteria of differentiation. For projects utilizing renewable energies it adds up to ≤ 15 MW of energy supplied annually whereas energy efficiency projects are being scaled at a reduction in energy use of ≤ 15 GWH/year. Any other emission alleviating activities are separated at a total GHG emission reduction of ≤ 60.000 t CO_2e/year. The efforts necessary for registration and monitoring of small scale projects should be lower in comparison to their larger pendants, which is not always the case (cf. Chapter 6).

The nomenclature of the applied methodologies at the same time illustrates the size of a project. A large scale project requires methodologies of the class AMXXX (Approved Methodology No. xxxx), whereas small scale projects need to use methodologies of the AMSxxxx class (Approved Methodology for Small Scale Projects No. xxxx). A discussion of the methodologies relevant for the theme of this work is available in Chapter 6.

3 The informal sector – current waste disposal in developing countries

This work discusses technical solutions that are intended to solve the challenges of the currently increasing MSW volume worldwide. Before elucidating the issue of how the climatic aspect to this challenge might be handled, it might first be necessary to discuss this subject from a humanitarian point of view.

Municipal solid waste (MSW) is a resource. Whilst this insight needed to redevelop within industrialized countries over the last decades, it has never been lost in the developing world. The sale of the resources which are found in refuse provides a decent living for a number of people who often belong to the poorest of the poor.

Figure 3-1: Waste picker in India and in Morocco (Dieter Schuetz_pixelio.de)

A closer look at the informal sector shows that this economic niche is often occupied by socially disadvantaged groups. In Serbia for instance the largest fraction of waste pickers is formed by the ethnic group of the Roma, whereas in Pakistan, it is Afghan refugees and in Cairo the religious minority of the Copts who all make a living from this illegal business. Being denied access to society, waste picking is often the only source of income for them. Measured against industrialized nations' standards of living, these people share an extraordinary burden in terms of health and environmental aspects.

The waste pickers' field of work, also known as the informal sector, is not governmentally induced but has more or less developed uncontrolled as the masses flooded into the large cities in the last century. These people directly depend on the access to either the waste collection or to the waste disposal sites to sort out the recyclable materials they can resell. Thus any change of the waste management structure has to be done carefully with regard to the large numbers of people fundamentally affected. In Cairo for instance, the number of waste pickers is estimated to amount up to 60.000 people. AVINA and related NGO's, speaking for waste pickers, estimate the total number of waste pickers worldwide at around 60 million people [Tangri et al. 2009].

Materials that illustrate the conditions under which waste pickers live can be found in the photo reportage “Scrap Life” from Greenpeace [Knoth 2009].

In South America and India a number self-organized waste picker associations have been founded to represent and plead the case of the waste pickers to society and the government. Their work also covers the organisation of the waste management itself as these associations reorganise the informal sector. For instance by substituting the middleman in the trading chains, they manage to gain higher revenue for their goods. By rationalizing and centralizing the waste sorting process, these associations might even manage to increase their revenues to such an extent that the waste pickers might be able to afford sending their children to school instead of having them participate in the work.

This process of self organisation stands in direct contrast to foreign investors entering the waste disposal business in these countries. Investors often propagate centralized solutions which are optimized for the high wage level of industrialized countries but lack due consideration of the possibilities of manual recycling. A chronicle of the failure of these commercial solutions is provided by a case study of the waste management sector in Cairo. The recycling quotas of the informal sector detected in that work reach a level of up to 95 % which is astonishing compared to commercial automated solutions. [Drabinski 2009]

This shows that given the low wage standards in developing countries, manual sorting is a predominant and viable alternative to automated waste treatment and waste incinerators. Thus a large share of the recyclables can be recovered and reused, putting men and women to work and offering a sustainable waste management option. At the same time the amount of landfill waste can be reduced whilst a large share of the refuse materials are recovered. This is clearly an environmentally valuable activity in terms of GHG effect and in terms of general pollution prevention. From this perspective it seems reasonable to call this development of self organisation a "clean development" process.

CDM projects are intended to encourage such sustainable and clean developments. Within the current CDM system however, the recycling potential must be considered as having been widely neglected.

Whilst the South American recycling activities still remain excluded from the CDM, there are activities of waste picker associations in India that might fit into the existing system. These associations reorganize MSW collection systems and process the organic fraction in small anaerobic digestion plants. As can be seen below, such activities are already included in the CDM methodologies.

The utilization of CDM finance for these micro activities is difficult because the CDM framework tends to give advantage to large groups of investors and projects. The programmatic CDM might enable incorporation of such small activities into one large PoA.

4 Landfill gas generation as the basis for CDM projects

4.1 Landfill gas and its relevance for the Greenhouse Effect

The sector of Municipal Solid Waste (MSW) management gives rise to emissions that sum up to around 8 -12 % of the total greenhouse gases emitted from developing countries. Therefore reducing these emissions is an attractive field for flexible mechanisms.[2]

These methane emissions are based on a biological process that appears in landfills and known as anaerobic fermentation. Soon after the inclusion of the MSW in the landfill, micro organisms start to consume the deposited degradable organic carbon. Whereas at first the oxygen available enables aerobic bacteria to grow in numbers, their respiration soon exhausts this oxygen. As the small stream of oxygen diffusing through the landfill body is insufficient to keep up the large aerobic population, the anaerobic bacteria can thus prevail. Also in consuming the degradable fraction of the waste, their metabolism produces methane. Under certain conditions hydrogen, an intermediate product of this process, may also be accumulated.

These gases can create an immediate explosion hazard in landfills. After diffusing out of the landfill body, the methane amplifies the green house gas effect 21 times more than carbon dioxide.

Any project that avoids the generation of landfill gases can therefore be considered climate protective. Possible forms of such projects will be discussed in Chapter 6.4.

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[2] This value is extracted from the GTZ Workshop "Waste and Climate", Bonn, August 2008, relating to a preliminary report, Establishing and Proving an Instrument to Balance GHG in the waste sector", IFEU (The IPCC mentions 2.8% instead the difference is presumably due to the integration of the sectors waste and wastewater.)

Besides the forms of environmental pollution mentioned, landfills cause a number of different negative effects in their environment such as health risks, fetidness problems and water pollution. These aspects should be kept in mind when discussing the subject of this work but will not be examined here in further detail.

4.2 Approaches to forecasting the generation of landfill gases

The generation of landfill gases has been subject to several publications in the last decades as the forecasting of the amount of gases to be expected is highly complex. Neither the exact composition, physical framework parameters are known nor is it possible to measure precisely the total amount of gases diffusing out of a landfill body. Therefore the lack of information about the processes going on in a landfill body renders predictions and the provision of evidence about their accuracy highly problematic. Any results of a landfill prognosis model thus has to be considered to be a mere approximation.

The first step of most prognosis models used is to determine the total methane building potential of the MSW over the total degradable organic carbon fraction. So, for example, lignin is not considered to be degradable by the mentioned bacteria as the degradable organic fraction is not equivalent to the total organic fraction. This is the first point for which assumptions have to be made. It is impossible to exactly analyze the MSW deposed of on a landfill site. Therefore assumptions need to be made about the total organic fractions and the degradable proportion. Sampling campaigns have delivered information regarding this topic. They show that the height of the variance of the examined materials is such that not a true but only a statistically affirmed result can be given.

The second step is to describe the process of degradation in the landfill body. This process is dependent on a number of parameters. First of all the humidity and temperature inside the landfill body are important. Whilst the temperature within a landfill can easily be measured, the humidity can vary due to so-called dry nests within the body. Secondly, the matter bacteria settle on influences their activity (e.g. biotoxines). Thirdly, the stream of oxygen diffusing through the body is in direct relation to the proportion between anaerobic and aerobic bacteria activity. Few of these parameters can be measured precisely and sampling procedures to determine the remaining parameters statistically are complex.

Therefore most of these parameters are defined by assumptions, based on singular samplings, instead of empiric data collection.

4.3 The First Order Decay Model in CDM application

The First Order Decay (FOD) model is a quite sophisticated landfill gas prognosis model. It distinguishes between different climes and it is possible to adapt the model to particular waste compositions. The waste fractions are differentiated by means of degradation velocity and the respective degradable organic carbon content.

Originally the FOD model was designed to assess nationwide landfill gas GHG emissions [IPCC 2006]. As part of the IPCC guidelines for Greenhouse Gas Inventories it serves for the UNFCCC member states to report their GHG emissions annually to the IPCC.

Its establishment within the United Nations has led to its obligatory use within CDM methodologies in order to calculate the landfill gas avoided by the treatment of MSW. In this application some modifications were made. In the following chapter this form of appliance in the UNFCCC-"Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" will be examined in detail [UNFCCC 2008].

Table 4-1: The First Order Decay Model as applied in the UNFCCC Baseline tool:

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH_4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot \left(1-e^{-k_j}\right) \qquad (1)$$

$BE_{CH4,SWDS,y}$	= Methane emissions avoided during the year y from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year y (tCO_2e)
φ	= Model correction factor to account for model uncertainties (0.9)
OX	= Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)
f	= Fraction of methane captured at the SWDS and flared, combusted or used in another manner
GWP_{CH4}	= Global Warming Potential (GWP) of methane, valid for the relevant commitment period (Currently set at 21 tCO_2e /t_{CH4})
F	= Fraction of methane in the SWDS gas (volume fraction) (0.5)
DOC_f	= Fraction of degradable organic carbon (DOC) that can decompose
MCF	= Methane correction factor
$W_{j,x}$	= Amount of organic waste type j prevented from disposal in the SWDS in the year x (tons)
DOC_j	= Fraction of degradable organic carbon (by weight) in the waste type j
k_j	= Decay rate for the waste type j
j	= Waste fraction of category (index)
x	= Year during the crediting period: x runs from the first year of the first crediting period (x = 1) to the year y for which avoided emissions are calculated (x = y)
y	= Year for which methane emissions are calculated

The MSW category Wj is allocated to the degradable organic carbon content DOC_j. The resulting carbon content is then multiplied with the exponential function that considers that the methane generation develops over time. This calculation needs to done for every year of the assessment period. It produces the particular amount of methane the certain waste type j generated in the respective year. Summing up the different waste types results produces the amount of methane generated in year y.

The methane generation coefficient k_j is to be selected from diverse given default values. The choice of the coefficient k_j considers the clime on the landfill and the properties of the waste fraction contemplated. It distinguishes between boreal and tropical crimes and sub classifies these in wet and dry climes.

The selectable parameters for the degradable organic carbon DOC_j offer the choice between wet and dry categories. Neither the IPCC guidelines nor the methodologies specify how the differentiation shall be done. It is assumed in this work that the distinguishing procedure given for the k_j values is to be applied for the DOC_j parameter as well (for DOC_j and k_j see Table 4-2). Combined, these two parameters characterize the methane generation rate and the total potential volume of methane (s. Table 4-2).

The factor OX considers that there are substances that oxidise methane if applied as coverage of the landfill. Their efficiency is a matter of controversy within expert circles. The UNFCCC methodology applies an oxidation potential of 10 %.

There might be a landfill gas-capturing facility installed on the landfill which will be substituted through the project activity. Hence the UNFCCC assumes that 50 % of the methane generated is captured by the facility and sets factor F at 0.5. The IPCC however, states in the IPCC guidelines 2006 that the efficiency of these facilities ranges from 10 % to 85 %.

As already mentioned in Chapter 4.2, there are diverse unknown parameters influencing the activity of the bacteria as well as temperature and humidity. Considering these, the factor DOC_f massively influences the methane results calculated. It describes the share of the degradable organic fraction that is actually degraded under the conditions of the landfill. The IPCC does not give a reference value which is why the UNFCCC provided its own, which is set at 50 %. Project developers often argue that this parameter is arbitrarily set as it halves the potential of CDM projects including waste treatment.

The methane correction factor differentiates between several types of landfills. The diverse subclass range is shown below. Their MCCF value considers the different conditions in the respective landfill class for anaerobic processes to develop.

1.0 for anaerobic managed solid waste disposal sites. These must have controlled placement of waste (i.e., waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste;

0.5 for semi-aerobic managed solid waste disposal sites. These must have controlled placement of waste and will include all of the following structures for introducing air to waste layer: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv) gas ventilation system;

0.8 for unmanaged solid waste disposal sites – deep and/or with high water table. This comprises all SWDS which do not meet the criteria of managed SWDS and which have depths of greater than or equal to 5 meters and/or high water table at near ground level. The latter situation corresponds to filling inland water, such as pond, river or wetland, by waste;

0.4 for unmanaged shallow solid waste disposal sites. This comprises all SWDS which do not meet the criteria of managed SWDS and which have depths of less than 5 metres.

The share of methane in the landfill gas, factor F is set at 50 %. This can be determined on the basis of the anaerobic process. The assessment of the masses of methane in the landfill gases is directly deduced from the molar masses over the proportion 16/12.

To make a conservative statement of the methane generated in the baseline of CDM projects the UNFCCC applies a correction factor .

Conservative is a UNFCCC dictum that describes a preferably pessimistic result given the perspective of the project developer. This step is taken to avoid accounting for non existent GHG-emission reductions. Whenever a conservative assumption is made the parameter in question is set in a way that reduces the achievable GHG emission reductions. In the case that the questionable parameter is part of the baseline, it will be set to lower the baseline emissions. In case it is part of the project activity emission calculation, it will heighten them. Fundamental decisions within the UNFCCC are mostly set conservatively to avoid an oversupply with CER and to avert that the entire offsetting approach is watered down by non-existent CER.

As a consequence, the methodologies require that any waste fraction that is not part of those given by UNFCCC shall be conservatively allocated to the next apparent category. As a consequence, ashes from burning refuse derived fuels (RDF) that are disposed of on a landfill might need to be allocated the category wood and thus generate methane.

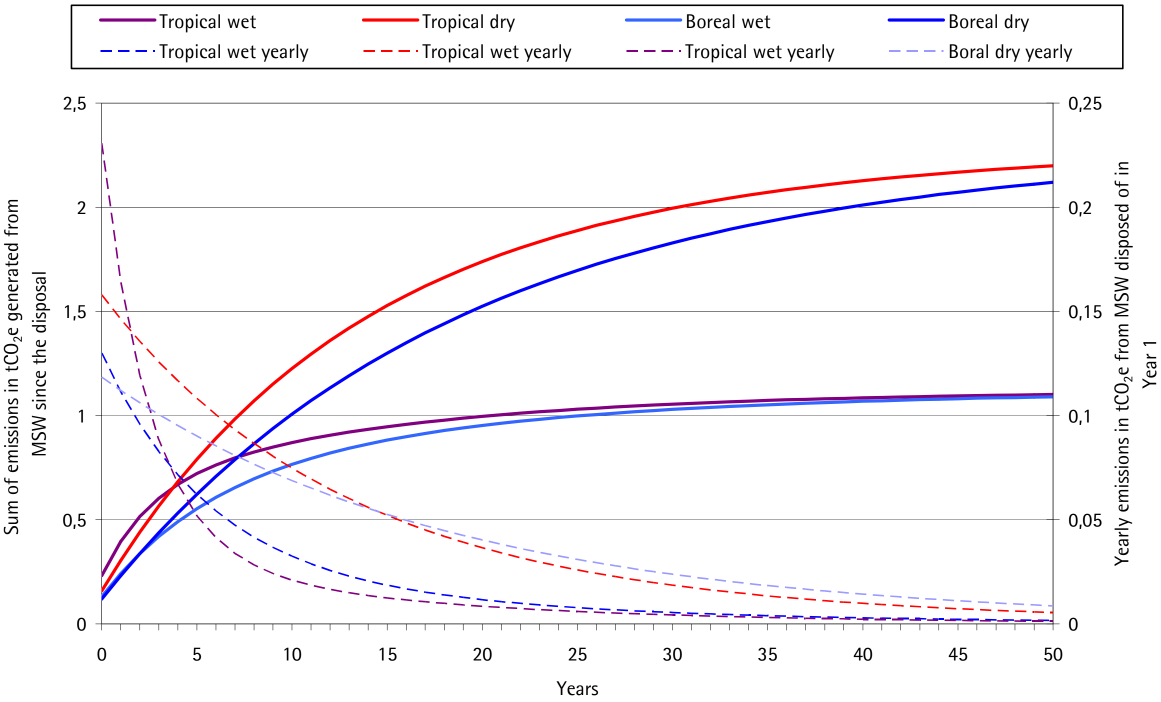


Figure 2: Comparison of the clime categories of the FOD model based on a Tunisian MSW composition

For illustration purposes Figure contains the methane development of one specific MSW composition on the same landfill class in the different clime categories. The dashed lines indicate the methane production in the respective year. Please note that the maximum crediting period is 21 years. At this time the methane generation is far from finished. The project crediting period however, finishes the balancing time frame of emission reductions.

Table 4-2: IPCC Default factors for MSW fractions listed by IPCC MSW categories

MSW components			Categories used by UNFCCC Methodology Tools					Nappies	Rubber and Leather	Plastics	Other *
			Paper/ Cardboard	Textiles	Food Waste	Wood	Garden and Park Waste				
Dry matter content of wet weight in %			90	80	40	85	40	40	84	100	90-100
DOC content in wet waste in %			40	24	15	43	20	24	(39)	-	-
DOC content in wet waste in %			44	30	38	50	49	60	(47)		
Total carbon content in %			46	50	38	50	49	70	67	75	3
Fossil carbon content in %			46	50	38	50	49	70	67	75	0-100
Decay Rate **	Boreal and temperate (MAT<20°C)	Dry (MAP/PET<1)	0.04	0.04	0.06	0.02	0.05	NA	NA	-	-
		Wet (MAP/PET>1)	0.06	0.06	0.185	0.03	0.1	NA	NA	-	-
	Tropical (MAT>20°C)	Dry (MAP<1000 mm)	0.045	0.045	0.085	0.025	0.065	NA	NA	-	-
		Wet (MAP>1000 mm)	0.07	0.07	0.4	0.035	0.17	NA	NA	-	-

* "Other" includes the IPCC categories Glass, Metal and "other inert waste"

** MAT is the Mean Annual Temperature, MAP - Mean Annual Precipitation, PET - Potential Evapo-Transpiration

4.4 Evaluation of the Fist Order Decay Model

The FOD model in its UNFCCC application is a quite sophisticated model as it takes many variable parameters into account.

The subcategories "dry" and "wet" however, include a certain weakness which will be discussed further in Chapter 7.3. The methodologies demand to determine the waste composition with a high confidence interval of 95 % with 20 % maximum uncertainty. This constitutes a severe challenge in terms of the necessary sample size for waste treatment projects. Strategies to solve this problem are discussed in 5.

As some waste fractions are not considered in the methodologies the conservative practice of allocating them to one of the existing waste categories falsifies the prognosis. This especially applies to residuals of the waste treatment process (e.g. MSW composting or MSW digestion residuals).

The most criticized aspect of the FOD model is its application in respect of Tier 2, due to the decisions made during the 23rd executive board meeting. This means that avoided emissions can only be assessed in the year in which they would have occurred. Further, the assessment is limited to the crediting period which means a maximum timeframe of 21 years. As a consequence, waste treatment projects loose a considerable share of their achievement as the emissions avoided occur after the end of the crediting period. Additionally the achievements performed are remunerated later. Both of these points have increased the payback period and reduced the attractiveness of MSW treatment projects for investors considerably. Chapter 7.1 takes a closer look at this topic. Table 4-3 illustrates the consequences of this from of allocation for the first year of the activity. It is important to keep in mind that the assessable share of the avoided emissions shrinks during the following years subsequently as the balancing time frame is reduced.

Table 4-3: Allocated emissions reductions compared

Crediting periods	GHG Reduction assessed for until the end of the crediting period	Share of the assessed reduction
7	0.540	50.7
10	0.660	62.0
14	0.780	73
21	0.900	85
(50)	(1.070)	(100)

5 Establishing the Baseline

The determination of the degradable organic carbon is crucial to assess for the landfill gas avoided within a MSW treatment project. Besides the definition of the landfill class substituted it is therefore necessary for establishing the baseline to detect the composition of the MSW treated (cf. Chapter 4.4).

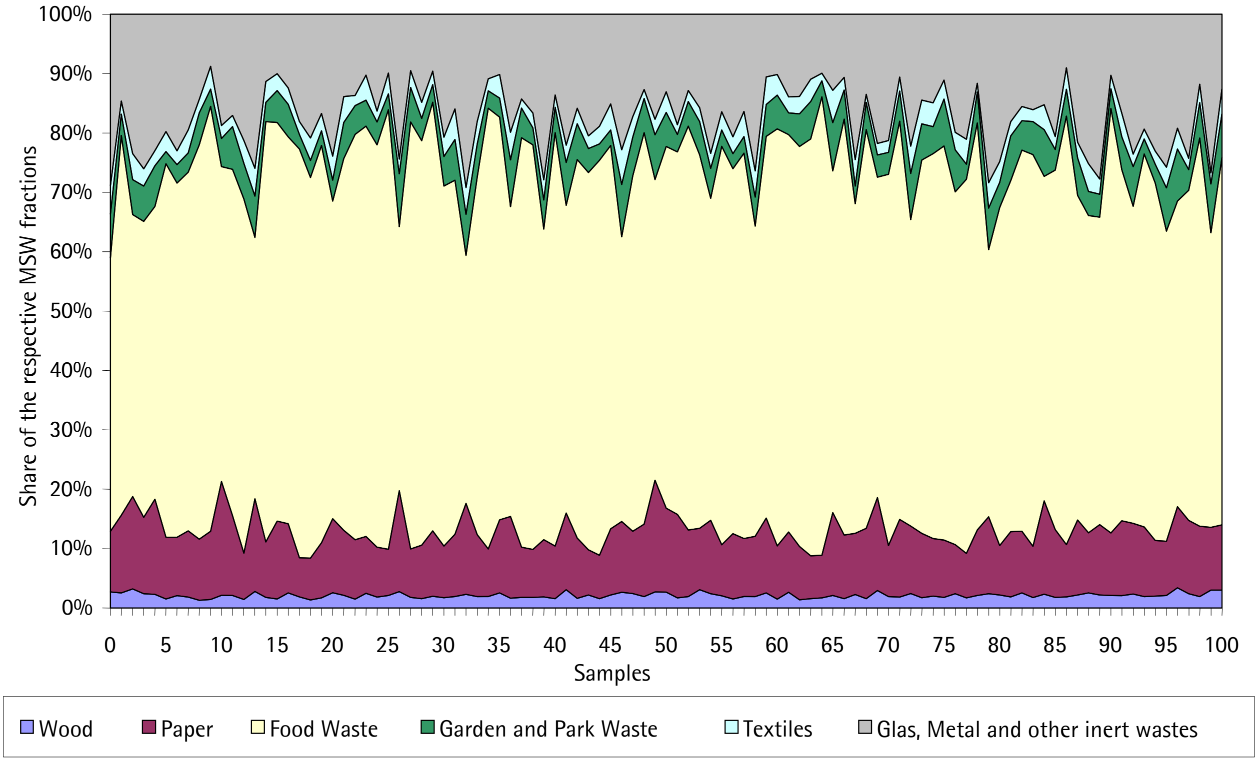


Figure 5-1: Possible degree of oscillation of a Tunisian MSW composition based on German MSW coefficients of variation

Figure 5-1 illustrates the possible degree of variation of the MSW composition. It combines the result of the Tunisian MSW analysis that serves as calculating basis in Chapter 6 and coefficients of variation of a German MSW study [Pohlmann 1994, IPCC 2006]. These coefficients can be found in Figure 5-2.

The fundament of the UNFCCC methodologies to assess for landfill gas avoidance projects within the CDM is the “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site” [UNFCCC 2008]. It is based on the FOD model discussed in Chapter 4.4 [IPCC 2006].

The tool necessitates the precise detection of the MSW composition with a confidence interval of 95 % with 20 % maximum uncertainty. This requirement is set due to the inhomogeneous, heterogeneous and temporally varying character of the MSW composition. Inhomogeneous means in this context that the components of the MSW are located chaotically within the system. Heterogeneous describes the widely differing properties of the different matters contained in it and temporally varying indicates that composition and amounts of the MSW accumulating can differ seasonally, weekly and even daily. The MSW composition and its properties are therefore not elusive on sight and have to be determined empirically.

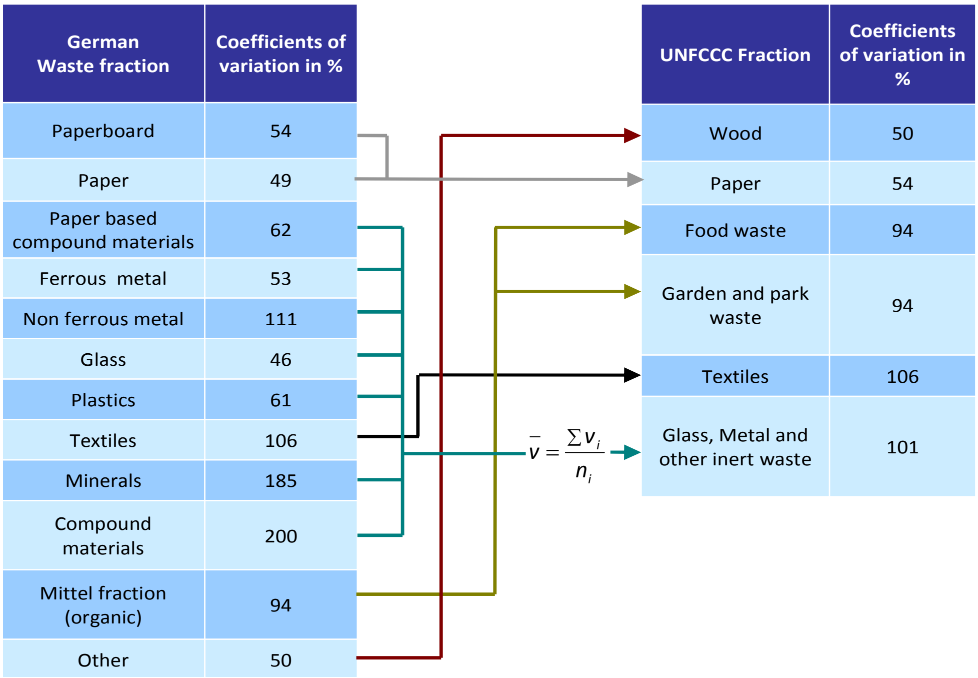
To comply with the statistical requirements the appliance of a systematic sampling plan is necessary. Critical amendments to the statistical requirement can be found in Chapter 7.2 of this work. Ways to achieve it most feasibly are discussed in the following chapters.

5.1 Feasible concepts to fulfil the statistical requirements

It is vital for project developers to estimate the sample size necessary for defining the MSW composition according to UNFCCC procedures in advance. This can be done determining the sample size as a function of the coefficients of variation. For this, these coefficients of MSW sorting analyses already realised need to be transferred to the target region of the project (s. Figure 5-2). The expected waste composition of the target region can be estimated by pilot sampling campaigns or be derived from other sources.

The starting point of the following explanations is the waste composition which has been used for calculation in Figure 5-1. The local waste composition reflects the respective local social and economical framework. Therefore it is locally variable. Data about the local coefficient of variation can be considered to be more reliable for a prognosis than values from waste analysis done elsewhere. In this Tunisian scenario, however, these local values are not available. Instead the coefficients of variation of the German waste study used for Figure 5-1 are used. This nationwide study accumulated the waste sorted in waste categories that are not identical to the UNFCCC waste categories. The study's waste categories and its coefficient of variation therefore need to be converted to fit to the UNFCCC balancing system.

Figure 5-2 illustrates how the transformation of the coefficients of variation might be done. Parts of the allocation of the categories can be done directly using the substantial character of the respective fractions. The aggregation mixed fractions like the biological inert materials or the compound materials however, must be done by building the arithmetic mean over the coefficients of variation of the respective source fraction.



German Waste fraction	Coefficients of variation in %
Paperboard	54
Paper	49
Paper based compound materials	62
Ferrous metal	53
Non ferrous metal	111
Glass	46
Plastics	61
Textiles	106
Minerals	185
Compound materials	200
Mittel fraction (organic)	94
Other	50

$$\bar{v} = \frac{\sum v_i}{n_i}$$

UNFCCC Fraction	Coefficients of variation in %
Wood	50
Paper	54
Food waste	94
Garden and park waste	94
Textiles	106
Glass, Metal and other inert waste	101

Figure 5-2: The transformation of the coefficients of variation to adapt to UNFCCC standard fractions

The determination of the sample size as a function of coefficients of variation based on the normal distribution can be done over the following term [Hartung 1991].

Table 5-1: The procedure to determine the sample size as a function of the coefficients of variation

$n = \left(\frac{1{,}96 * v_i}{\varepsilon_{xrel}} \right)^2 = \left(\frac{1{,}96 * v_i}{0{,}1} \right)^2$	**(2)**
n	= Sample size necessary
1.96	= t-distribution coefficient for a confidence level of 95%, basic population N >> sample size n
v_i	= coefficient of variation of MSW fraction i
$_{xrel}$	= acceptable uncertainty of 20 % (± 10 % deviation)

Assuming the normal distribution for the MSW waste composition is a precondition for this method. The validity of this assumption might not be unconfined, but it can serve as a rough estimate on which the further planning of the sampling procedures can be built. This is due to the sampling efforts forecast worth the planning of the entire facility and the treatment process.

The number of sorting campaigns deduced from the forecast can then be adapted further when the operation has started. As the first sorting campaigns take place, information about the real local coefficients of variation is gathered. This information can be used to estimate the remaining sampling campaigns that still have to be conducted to reach the statistic significance until the end of the year. Relating to this information the operator can then either increase or decrease the planned amount of samples to optimize the cost-value-ratio.

Table 5-2: Results of the Prognosis

Categories		Wood	Paper	Food Waste	Garden and park waste	Tex-tiles	Inert wastes (glass metal and other)
Waste composition of a Tunisian sorting analysis		0.02	0.11	0.61	0.05	0.03	0.18
Coefficient of variation [Pohlmann 1994]		0.5	0.54	0.94	0.94	1.05	1.01
Variance	Minimum	0.015	0.080	0.323	0.027	0.014	0.090
	Maximum	0.025	0.140	0.897	0.074	0.046	0.271
Necessary sample size within a 95 % confidence level with 20 % uncertainty		96	112	339	339	424	391

These results represent a first estimate which is not conclusive. The linking of variation coefficients of German MSW with the Tunisian is a mere assumption. It can serve though to define the dimension of the necessary sample size to be expected as the real Tunisian coefficients of variation will be within the range of the German ones.

The large sample size of this calculation shows that the consideration of the incoming sample size is of advantage for a proper planning of a waste treatment facility. The project developer can design the facility in such a way that the large size of samples necessary can be dealt with smoothly.

For the interpretation of the results from Table 5-2 it is important to bear in mind that the coefficients of variation used here were assessed for in a German MSW sorting analysis at the waste containers of the single households, not at the waste treatment facility. The transport and temporary storage of the MSW will result in an intermixture of the MSW. Therefore it can be assumed that the coefficients of variation resulting from a sorting analysis at the facility will be lower than those applied in the calculation above.

It appears reasonable to estimate a coefficient of variation of around 80% for the design of a facility. The resulting 250 samples should then be distributed over the year. In the case that the coefficient of variation resulting from the sorting analysis is higher, the sample size can still be increased.

5.2 Sampling in practice

The design of a waste treatment facility that has to consider 250 sampling units to be drawn yearly will lead to the implementation of a continuous sampling concept. It offers the highest grade of operational integration and enables employees to concentrate especially on the sorting of the waste.

5.2.1 Sampling plan

The determination of the arithmetic middle of the MSW composition according to the UNFCCC-Tool is to be done for each year ex post. Thus the sampling is subjected to a limited period of time in which enough samples have to be taken to reach the statistic significance required.

In general the sampling frequency should be enforced in the beginning of the year. For example for 250 scheduled samples to be taken in a year, the first 150 should be taken in the first half of the year. In case the variance is higher than expected it can thus be guaranteed by increasing the sample size such that the statistic significance is reached.

In this way it can be assessed early whether or not the samples size prognosis was in range of the reality. In case the sample analysis results in highly dispersive fractions, the frequency and number of samples can be increased and thus the UNFCCC requirements fulfilled until the end of the year. The labour force necessary for intensive sorting campaigns is relatively cheap in developing countries. A manual continuous sorting concept is therefore affordable in contrast to industrialized countries. Thus a very detailed picture can be given through the manual continuous sorting concept:

Different approaches for establishing of the standard sampling procedure are possible. The following concepts are taken from German publications about the subject [Landesumweltamt Brandenburg 1999, Laenderarbeitsgemeinschaft Abfall 2001].

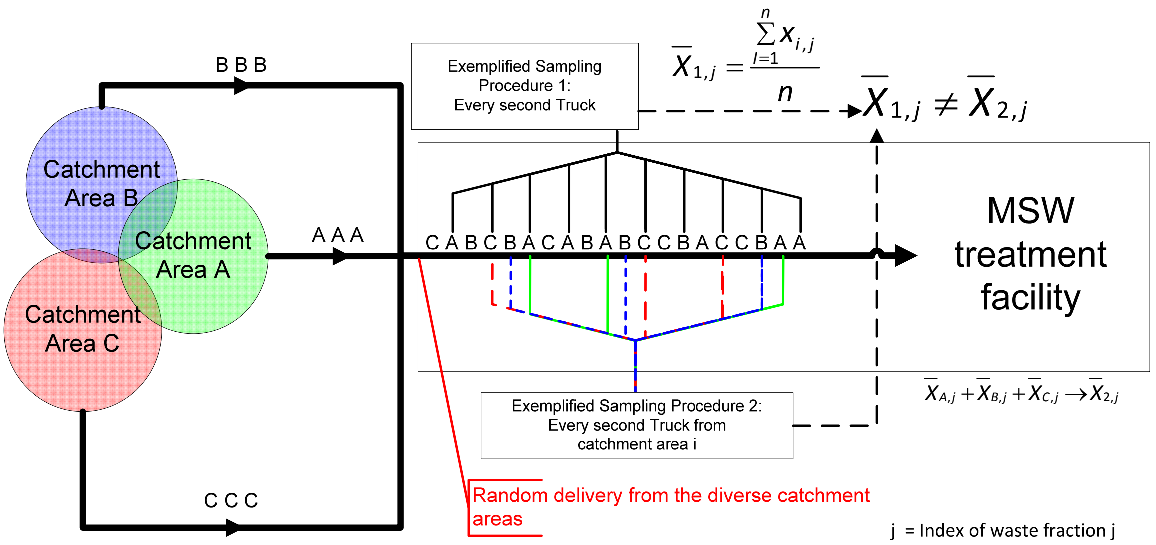


Figure 5-3: Two possible procedures of sampling plans

Figure 5-3 illustrates two examples of how the sampling subject and the sampling moment could be appointed.

Sampling Variant 1 exemplifies the continuous sampling of every second incoming truck. This number is to be chosen with regard to the number of samples to be drawn in total. This variant neglects the origin of the waste. In case the waste composition of the different catchment areas A, B and C differ considerably, the undifferentiated waste composition analysis will result in a high variation. This in return will cause a larger amount of samples to be necessary in order to accomplish the statistic significance required. In the case that these areas do not differ much then differentiated sampling will be an unnecessary effort.

Variant 2 shows a possible form of the discussed differentiated waste composition analysis. In this case the sampling is done continuously and with regard to the catchment area. The results of the different areas can thus be determined precisely and extrapolated to suggest the subpopulation. These results can then simply be added to receive the result of the basic population. Therefore a result for the total amount of waste is produced which is differentiated in several waste fractions.

In practice from an economical point of view a smaller total sample size is to be preferred. Otherwise the sampling efforts could strain the logistical and economical clearance by the operator. In the analysis results in a constant waste composition a reduction of the sampling size is to be considered.

To what extent a differentiated waste analysis is possible in the respective location will have to be decided from case to case in developing countries to find the locally optimal solution.

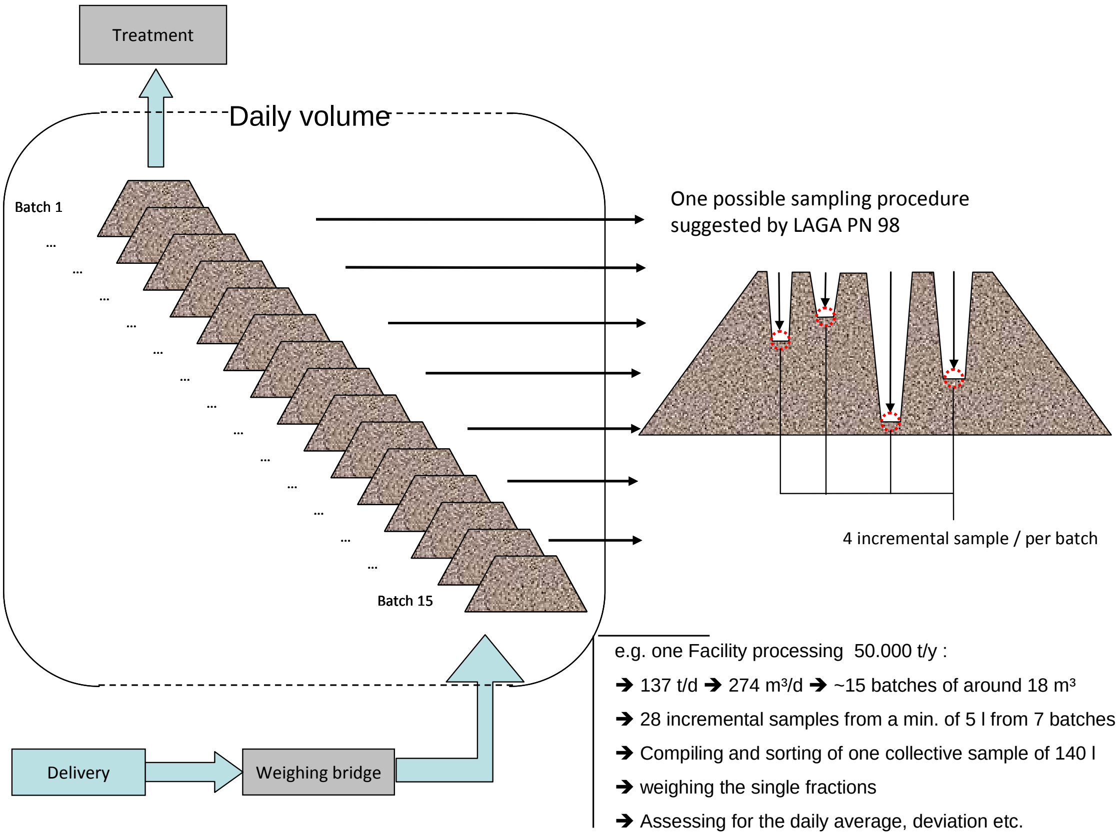
The mathematic application of the data derived from the sorting campaigns will be explained in Chapter 5.2.3.

5.2.2 Sampling modalities

The modalities of the sampling are to be determined from case to case. The samples should be drawn at points in the process where there is a good mixture of the waste fractions. This means for instance drawing a sample from the pile dumped by a truck at the facility instead of drawing the sample before the dumping. Drawing the sample in the truck before the dumping would incorporate effects of decomposition in the analysis (e.g. descent of the heavy materials). The perfect mixture of the MSW will not be found at any point in the process. The consideration of effects of decomposition in the choice of the sampling point however, can reduce the range of variation.

The following approaches of sampling are designed for two different variants of waste treatment processes. A precondition for both processes is that the weighting of the incoming wastes is undertaken beforehand.

Sampling of the MSW after the delivery



e.g. one Facility processing 50.000 t/y :
➔ 137 t/d ➔ 274 m³/d ➔ ~15 batches of around 18 m³
➔ 28 incremental samples from a min. of 5 l from 7 batches
➔ Compiling and sorting of one collective sample of 140 l
➔ weighing the single fractions
➔ Assessing for the daily average, deviation etc.

Figure 5-4: Sampling from single batches according to LAGA PN 98

Figure 5-4 illustrates the sampling approach for a facility processing the entire waste in one stream (e.g. waste incinerator). The suggested sampling variant selects particular delivery batches for analysis according to the sampling plan. After the dumping of the MSW delivery LAGA PN 98, a German guideline for waste sorting analysis, suggests drawing individual samples from different places within the batch.

One viable variant for implementation of such a sampling procedure is illustrated in Figure 5-4. Its dimensions are chosen with regard to the facilities discussed in detail in Chapter 6.4.

The sampling can be done by using a digger, shovels, claws or special drills. It is very important to draw the different individual samples in different depths of the batch.

The volume of the individual samples for particle sizes between > 50 mm to ≤ 120 mm should amount to 5 l at least. The number of samples necessary is dependent on the total volume of MSW processed. This can be estimated by assuming the density of the MSW (0.5 m³/t MSW). In the example the result requires 28 individual samples.

The guideline LAGA PN 98 further envisages gathering the individual samples to several pooled samples for further scientific examination. As the UNFCCC-Tool requires a mere sorting analysis for determining the properties of the waste, the individual samples are to be gathered in one collective sample. One collective sample moreover represents one sample of the overall sampling size calculated in 5.1.

Sampling of a the MSW stream at the belt

According to LAGA PN 98 the sampling from a belt is to be preferred in comparison to the sampling of a bulk batch. It should hereby be kept in mind though to:

Always cut the entire mass flow during the sampling

Carry out the sampling after reaching a stationary state of the process

Draw the samples at a stable frequency

As the dimension of the well known example facility is used again, the same amount of individual samples is required. The required 28 individual samples are to be extracted in the same periods of time. In a continuous process this seems possible without question. Therefore the continuous undifferentiated sampling as mentioned in Chapter 5.2.1 can be applied.

Conducting differentiated sampling is difficult though as the different batches might decompose and interpenetrate each other.

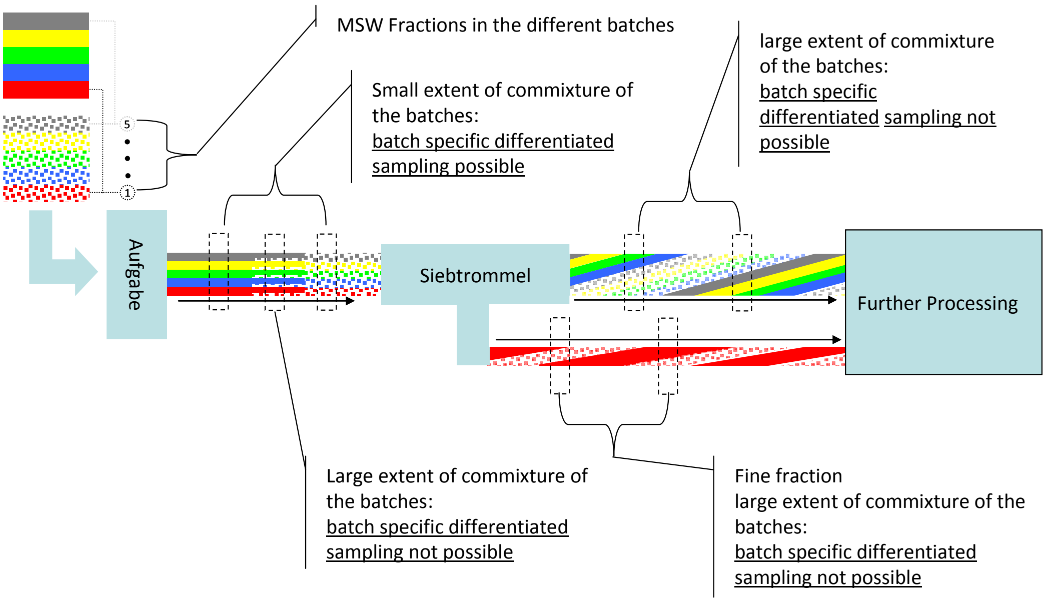


Figure 5-5: Possible overlapping effects in the MSW treatment process disturbing differentiated sampling plan

A schematic and idealised illustration of a MSW treatment facility dividing the mass flow shows this issue by means of the sieve drum in Figure 5-5. The differently coloured fractions leave the sieve drum with different velocities and interpenetrate with the following batch. If a batch is stretched wide enough on the belt to ensure only this batch is being sampled, the differentiated sampling might be possible. Due to effects of decomposition in the process, the risk of capturing several batches with one sample must be considered too high to rely on differentiated sampling procedures. Therefore a simple continuous sampling procedure seems more recommendable.

Reducing the sample size by dividing the mass flow and manual sorting

The following concept of a MSW treatment facility shall serve to exemplify this. It will be registered as CDM project in the autumn 2009 in the framework of methodology AM0025 (cf. Chapter 6.3) and implemented to supply the Pakistan cement industry with refuse derived fuels (RDF).

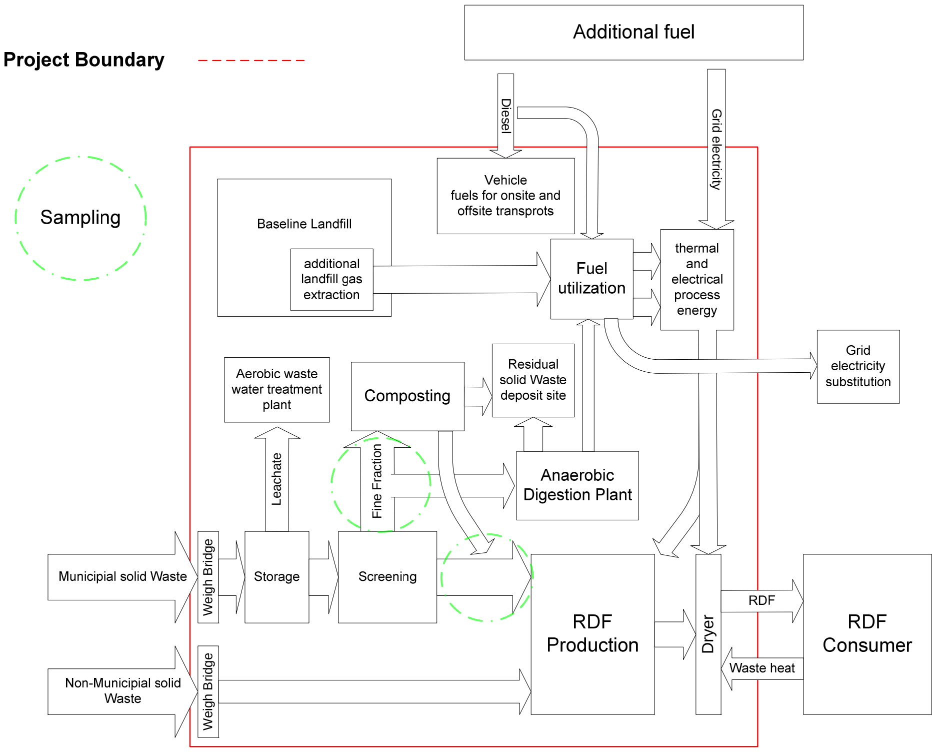


Figure 5-6: Flow chart of MSW treatment facility in the framework of AM0025

In Figure 5-6 the flow chart is illustrated as it will be documented in the "Project Design Document" (PDD). By continuous manual sorting the UNFCCC categories are allocated in the RDF production process. Thus samples will have to be drawn from only two points in the process there. In the first point before the composting plant the whole partial mass flow has to be examined. In the second point the sampling can be done at the end of the RDF production line to identify the sorting residuals composition. For the sampling, special collecting bins can be used at the transition point between two belts.

The total sample size necessary will be altered completely in this process type as the amount of undefined matter is reduced by the manual sorting line.

In conclusion it must be amended that it is vital for reliable results of any kind of sampling procedure to have a standardized detailed sampling and sorting procedure. As far as possible also the operators entrusted with this task should remain the same. Thus the impact of random variation can be reduced.

5.2.3 Sampling evaluation

The conducting of a sorting analysis can be done according to multiple guidelines and standards (e.g. Brandenburg guideline). The sorting of the collective sample into the UNFCCC categories is done by collecting them in different containers. By weighing the different containers the mass fraction of the collective sample is identified. The results of the sorting are recorded and statistically evaluated.

Table 5-3: Formulas for the mathematic evaluation of samples

Arithmetic middle of the sample $\bar{p}_{j,x}$:

$$\bar{p}_{j,x} = \frac{\sum_{n=1}^{z} p_{n,j,x}}{z} \tag{3}$$

$\bar{p}_{j,x}$ = Arithmetic middle of the mass fraction of waste category j in year x

$p_{n,j,x}$ = Mass fraction j in collective sample n in year x

z = Number of collective samples drawn in year x

Standard Deviation s_p and Variation $s_p{}^2$:

$$s_p = \sqrt{s_p{}^2} = \sqrt{\frac{\sum_{n=1}^{z} \left(p_{n,j,x} - \bar{p}_{j,x}\right)^2}{z-1}} \tag{4}$$

Confidence level:

$$\left(\bar{p}_{j,x} - 1{,}96 \cdot s_p\right) < \bar{P}_{j,x} < \left(\bar{p}_{j,x} + 1{,}96 \cdot s_p\right) \tag{5}$$

1,96 = Factor of the t-distribution

Maximum deviation $e_{p,rel}$:

$$e_{p,rel} = \frac{s_p}{\bar{p}_{j,x}} \tag{6}$$

Coefficient of variation **v**:

$$v_j = \frac{s_p}{\bar{p}_{j,x}} \tag{7}$$

The procedure to determine the sample size as a function of the coefficient of variation has been explained in Chapter 5.1. By combining it with the determined coefficients of variation it can be used at this point to assess the overall sample size necessary to fulfil the UNFCCC requirements. The prognosis based on this procedure allows increase of the overall sample size in order to adjust to the forecasted amounts. Lowering the sample size is critical even if the prognosis is promising. In case the prognosis fails due to changes in the variation of the MSW, this could cause a failure resulting in the loss of CER for the current year.

As soon as $e_{p,rel}$ is reduced below 0.1, the UNFCCC requirements are fulfilled. Now the sampling can be stopped and its result can be used to assess the total waste processed.

Table 5-4: Extrapolation procedure according to the base line tool

Extrapolation of the total volume of MSW processed in the case of continuous sampling:	
$W_{j,x} = W_x \frac{\sum_{n=1}^{z} p_{n,j,x}}{z}$ (8)	
$W_{j,x}$	= treated amount of waste category j in year x
W_x	= total treated amount of MSW in year x
Extrapolation of the total volume of MSW processed in the case of continuous, differentiated sampling:	
$W_{j,x} = \sum_{m=A}^{z} W_{m,x} \frac{\sum_{n=1}^{z} p_{m,n,j,x}}{z_m}$ (9)	
$W_{j,x}$	= treated amount of waste category j in year x
$W_{m,x}$	= total treated amount of MSW in year x of catchment area m
$p_{m,n,j,x}$	= MSW mass fraction j from sample n of catchment area m from year x
z_m	= Number of samples drawn for catchment area m in year x

The establishment of the base line according to the UNFCCC base line tool is thereby completed.

Table 5-5: Results of a sampling evaluation for 10 collective samples

Category		Wood	Paper	Food waste	Garden and park waste	Textiles	Glass, metal and other inert waste
Results of Analysis	1	0.03	0.13	0.64	0.04	0.02	0.15
	2	0.03	0.16	0.47	0.06	0.04	0.23
	3	0.015	0.080	0.323	0.027	0.014	0.090
	4	0.025	0.140	0.897	0.074	0.046	0.271
	5	0.02	0.10	0.63	0.02	0.03	0.20
	6	0.02	0.10	0.60	0.03	0.02	0.23
	7	0.02	0.11	0.60	0.03	0.04	0.19
	8	0.01	0.10	0.66	0.05	0.02	0.14
	9	0.01	0.11	0.72	0.03	0.04	0.09
	10	0.02	0.19	0.53	0.05	0.02	0.19
Arithmetic middle		0,02	0.13	0.58	0.04	0.03	0.19
Standard deviation		0,01	0.03	0.08	0.02	0.01	0.05
Variation		3,E-05	9.E-04	7.E-03	3.E-04	7.E-05	3.E-03
Coefficient of Variation		0.53	0.49	0.37	0.61	0.53	0.52
Level of confidence		0.03	0.19	0.74	0.08	0.05	0.29
Deviation		0.28	0.24	0.14	0.37	0.28	0.27
Amount of samples still to be done		56	47	28	72	55	54
$W_{j,x}$ in [t]		1.034	6.485	29.230	2.191	1.495	9.566

6 Analysis of the UNFCCC methodologies in the waste treatment sector

In the CDM framework there are multiple methodologies applicable in the waste sector. Those that serve to assess for landfill gas avoidance projects are discussed and analysed in detail in the following chapters.

Beside these there are other methodologies available for CDM projects in the waste sector. Their subject is the treatment and utilization of landfill gas on Solid Waste Disposal Sites (SWDS). This type of CDM project is very successful and more frequent because of the low investment costs. Epitomizing a classical "end-of-pipe" technology the focus lies in reducing the emissions already generated by capturing the landfill gas retroactively. Thereby only a fraction of the methane produced can be captured and eliminated as large shares of the gas tend to diffuse out of the landfill body. Hence this is not a sustainable answer to the rising amounts of MSW in developing countries.

In contrast to these successful and cheap projects the more sophisticated waste treatment technologies offer a larger potential of environmental benefits. Instead of eliminating just a share of the landfill gas, these technologies can avoid the gas generation in the first place. Nevertheless these technologies underachieve largely in the CDM. The reasons for this lack of success are to be discussed for methodologies that balance the following technologies.

- Composting
- Anaerobic digestion
- RDF Production
- Waste incineration

With reference to the publicly available methodologies it is resigned from the illustration of the respective balancing equations from methodology AMS III E, AMS III F, AM0025 V10 and AM0025 V11.

6.1 AMS III E

The small scale methodology AMS III E serves to balance the emission reduction of projects ranging up to 60.000 tCO_2e per year. If limited to the methane avoidance potential from treatment of MSW accords to facilities that process around 40.000 to 80.000 tonnes of MSW per year, depending on the quality of the waste and the climatic conditions of the project's location. Another influencing parameter is the crediting period as the delayed assessment of the avoided emissions causes an aggregation of emission reduction in the last years of the project.

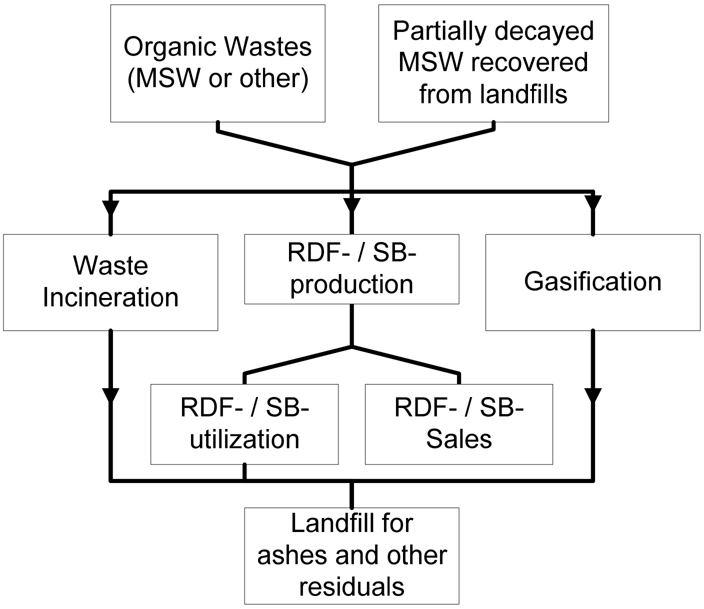


Figure 6-1: Macrostructure of the small scale methodology AMS III E

Designated for the treatment are organic wastes or recovered partially decayed wastes from deconstruction of landfills. Their methane generation potential is reduced via gasification or combustion of the wastes. AMS III E therefore represents the path of thermal treatment of organic wastes.

To balance the projects emissions, the avoided methane emissions are compared to the emissions caused by the thermal treatment of the waste and other emissions of the project activity (in tCO_2e). In particular these are:

- Increased transportation
- Methane emissions from anaerobic treatment of waste water
- Combustion of fossil carbon, including primary fuels and the fossil carbon content of the wastes combusted
- Consumption of electricity and fuels on the project site
- Emissions from residuals of the treatment process on the landfill

Possible climatic benefits due to production of electricity and recycling of MSW fractions remain unconsidered.

Contrary to its large scale pendant AM0025, the AMS III E requires consideration of the occasional burning of landfills as a lessening factor of the methane generation in the baseline tool. As it is a common practice amongst waste pickers that landfill site is ignited in order to gain access to hidden resources, this in principle is a factor to be considered. But for establishing a proper baseline neither the methodology nor the IPCC guidelines nor the baseline tool contain any guidance on how this effect should be considered. Developing an individual method for this is risky for project developers as the designated operational entity (DOE) might not agree with it.

Furthermore, the methodology requires evidence of produced refuse derived fuels (RDF) or stabilized biomass (SB). Therefore a monitoring system must be established to guarantee that no methane emissions result from the further storage and utilization of the RDF. It requires the project operator to monitor that the RDF are not subject to anaerobic digestion processes and are always in conditions that do not permit the absorption of water. This second condition can be considered superfluous as absorption of water is one of many factors causing anaerobic digestion.

Moreover in case of RDF/SB sale the price for which RDF/SB will be sold is not valid evidence for the methodology such that it could be used accordingly. This seems irrational as one may think that the purchase of fuels would necessarily result in an incentive for the client to use them properly. Thus any emission reduction from sold RDF/SB for energetic utilization is cut down by 5 %.

AMS III E requires that the methane generation of any residuals from treatment processes is to be balanced according to the baseline tool. Again there is no guidance given on how this should be done. The balancing systems lacks values for the degradable organic carbon content DOC_j and the degradation coefficient k_j.

The AMS III E contains guidance on how the treatment of recovered materials from dismantled landfill shall be assessed. It requires the keeping of records for the dismantled landfill to calculate the organic carbon remaining in the treated matter. These data are simply non-existent in most developing countries, which is why this path of the methodology has to be considered as largely unconvertible.

After its first publication on 1st November 2002 the AMS III E has been used in 3 projects. Two of these projects were validated but have not yet been certified and no CER have been allocated to these projects (cf. Figure 2-1). The only successful project using AMS III E is situated in Lagos and uses wood wastes to produce RDF. Therefore it must be concluded that AMS III E is of no relevance for CDM projects operating in the sector of municipal solid waste.

6.2 AMS III F

This methodology, available since February 24, 2006, can be used to assess methane avoidance by digestion or composting of MSW. Like AMS III E it is a small scale methodology that is valid for projects where GHG emission reductions are less than or equal to 60.000 tCO_2e annually. The balancing concept of AMS III F considers the following emissions from:

- Increased transportation
- Methane leakage from digestion plants
- Methane emissions from composting
- Methane emissions from anaerobic treatment of waste water
- Consumption of electricity and fuels on the project site
- Emissions from residuals of the treatment process on the landfill

Just as in AMS III E, the recycling of MSW is not considered in the balancing system. The methodology includes requirements for fertilizer monitoring but does not consider the environmentally friendly substitution of industrial fertilizers.

A special feature of AMS III F is that evidence has to be given yearly about the validity of the baseline. This is a considerable additional effort for project developers and project operators. In other methodologies the baseline is usually valid over the entire crediting period as it has been defined in the project design document of the CDM project. The fundament of the CDM project is therefore called into question yearly in AMS III F projects.

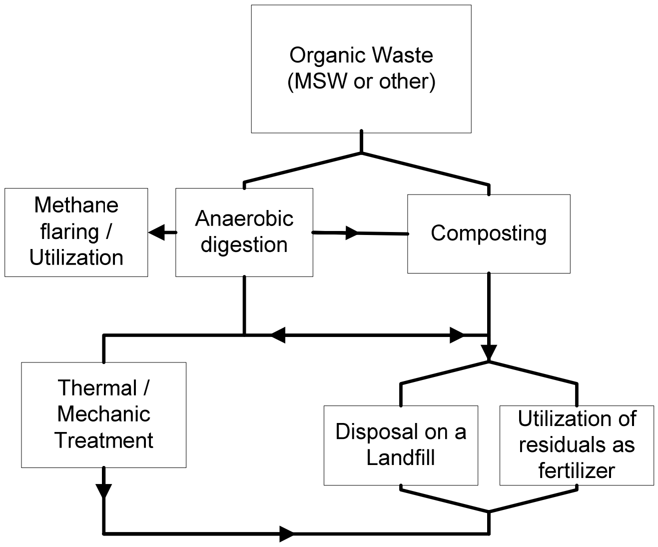


Figure 6-2: Macrostructure of small scale methodology AMS III F

For the establishment of the baseline AMS III F replenishes the baseline tool by an additional requirement. It contains the consideration of local governmental requirements of the host country which prescribe the elimination of emissions. The share which is to be eliminated by law has to be deducted from the baseline emissions.

This is one of several contradictions to the Marrakesh accords of the COP that can be found by examining methodologies. These dictate that local laws and regulations passed after November 11, 2001 which prescribe a GHG elimination of any kind do not have to be considered in baseline calculations. The CDM Executive Board confirmed this decision in its 16th meeting. This was decided in order to avoid incentives for passivity regarding the fight against climate change in developing countries to allow more profitable baselines. The CDM Methodology Panel that published this methodology therefore directly contradicts its superordinated bodies within UNFCCC.

AMS III F requires the monitoring of the use of sold composting fertilizers. By means of random sampling, evidence must be given as to whether or not the fertilizers are subject to conditions that might allow anaerobic digestion effects. Providing this evidence can be very complex, especially in developing countries.

There are 20 registered projects at the moment. Although the forecasts stated otherwise, none of these projects have yet been able to claim any CER.

6.3 AM0025

The large scale methodology AM0025 is the focus of this work. This is due to its convenience in respect of the dimensions necessary for cost efficiency while realising waste treatment facilities in the CDM. This is due to the fact that small scale projects are proportionally heavier loaded by the certification process costs than large scale ones.

AM0025 allegorizes effectively the fusion of AMS III E and AMS III F as it covers both areas and more. As in contrast to the methodologies discussed above, the GHG reduction potential of substituting primary resources by RDF utilization can be assessed by AM0025.

All treatment variants mentioned above are included in this methodology. Therefore it is possible to link a MSW composting facility with RDF production from the high calorific fraction. The methodology assesses the following forms of emissions from project activities:

- Increased transportation
- Methane leakage from digestion plants
- Methane emissions and nitrous oxide emissions from composting
- Methane emissions from anaerobic treatment of waste water
- Consumption of electricity and fuels on the project site
- Emissions from combusting of fossil carbon, including primary fuels and the fossil carbon content of the wastes combusted (CO_2, CH_4, N_2O).
- Emissions from residuals of the treatment process on the landfill

AM0025 has recently been updated. This eleventh, currently the last amendment published in January 12 2009 contains a number of changes especially regarding waste incinerators which will be addressed in the following. It is valid retroactively for every project registered after December 5, 2009.

With reference to the methodology text and to Figure 6-3 the balancing equations are not outlined in this work.

Furthermore, Chapter 7.5 lists points that may complicate project activities and which therefore require special attention.

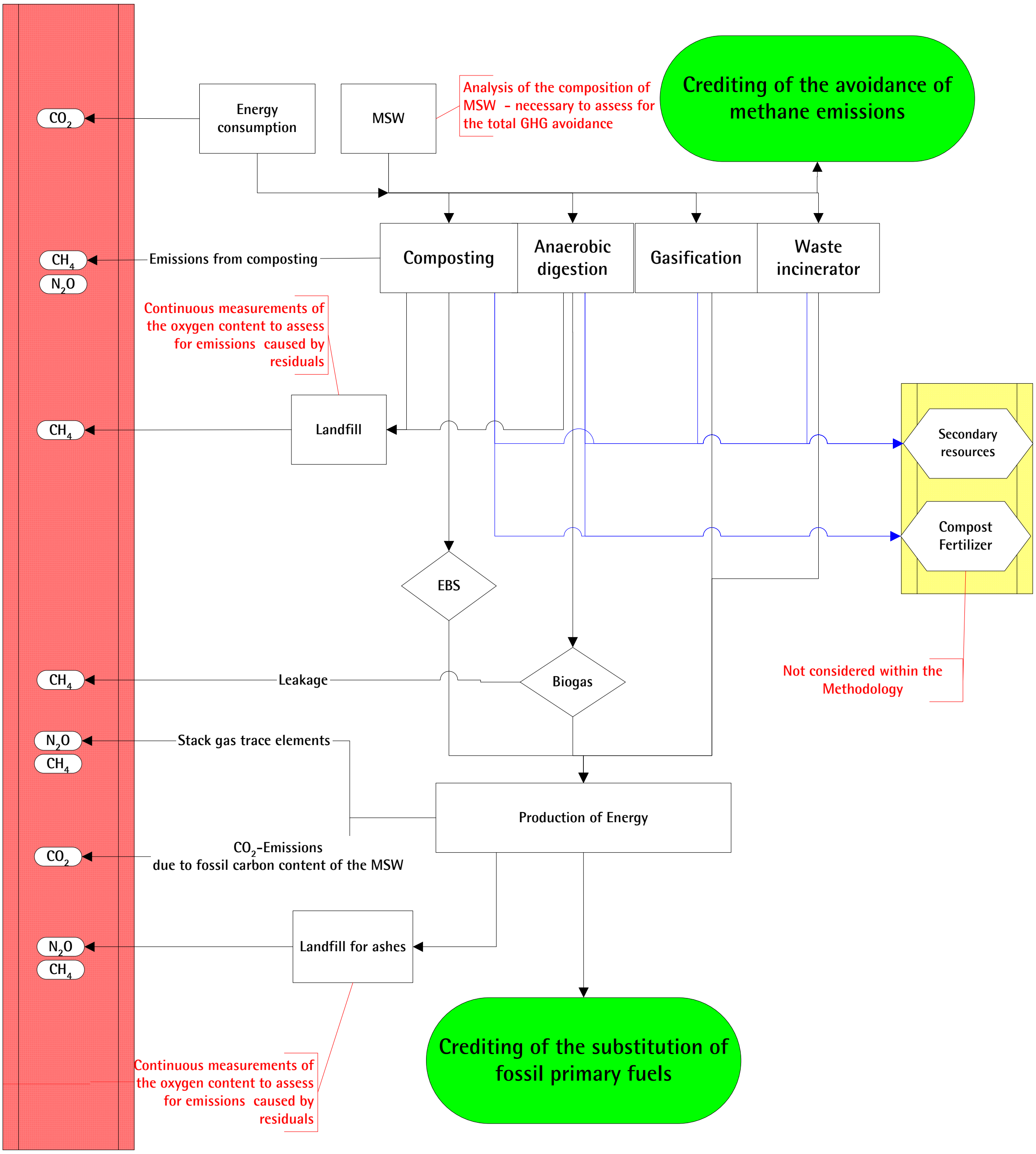


Figure 6-3: Treatment technologies included in AM0025

6.4 Comparing the GHG reduction potential of the MSW treatment technologies applicable in the CDM

The different variants for treating MSW will now be compared by balancing them according to AM0025. Thus the impact of key parameters can be examined, such as changes in the carbon intensity of the electricity grid or the impact of the different climes in which a project can be situated. The gasification of MSW is not balanced because of a lack of parameters to simulate it and since the gasification allegorizes only a niche application.

The balancing is concentrated on large scale projects only. Certain aspects of the small scale methodologies are taken up in Chapter 8.

6.4.1 Definition of the starting point - Scenario Tunisia

For a comparison of the different treatment variants a common basis is necessary. Firstly therefore, the project preconditions are determined.

The processed matter of the treatment facilities adds up 50.000 t MSW per year. The projects are situated in Tunisia. A country that evinced its interest in CDM projects in COP14 in Posznán. The waste composition must be assumed as no sorting analysis from Tunisia is available. Therefore the IPCC default values for North Africa are used [IPCC 2006].

The clime is determined by choosing the climatic parameters of Tunis. This clime complies with the climatic category "boreal dry" from the baseline tool. Therefore the parameters DOC_j and k_j are fixed and the baseline can be established.

Combusting activities necessitate data about the fossil carbon fraction (FCF_j) of the MSW processed. The fossil share of the carbon dioxide emission is deducted from the emission reduction achieved. The fossil carbon fraction listed by waste fraction can be extracted from the IPCC National GHG Inventories Volume 5.

6.4.2 Other collective parameters

On managed landfills, energy is consumed during the emplacement of the waste and the monitoring. Therefore this source of GHG must be incorporated to assess emissions caused by land filling. The data necessary is provided by a report of bifa environmental institute [bifa 2003].

These values are derived from German landfills. Especially the Tunisian electrical energy consumption can be considered lower than the German since post-treatment activities on German landfills are more intense due to the legal requirements (e.g. landfill gas extraction is not legally prescribed in Tunisia). Nevertheless, these German parameters are used in the balances as the supplier of conservative results.

Moreover, part of every model is the landfill for ashes. Composting and digestion residuals are disposed of on regular landfills. Also for landfill residuals the consumption of energy has to be assessed for. The required parameter can be found in the mentioned bifa report and can also be considered conservative.

Any additional transports are trivialized to add up to 50 km. It is assumed that only vehicles are in use that have a capacity of 28 tonnes and a consumption of 25 l/100 km. To assess the resulting emission reduction the methodology AM0025 is used. Where necessary, differences between Version 10 and Version 11 will be outlined to show the changes impacting on project developers.

The calculation of emissions due to electric energy consumption is a necessary part of the balance. For Tunisia it is done by acquiring the carbon intensity of the Tunisian grid from a grid factor of a "CDM Project Design Document" (CDM-PDD) that was situated there. As this is a relatively low value, for comparison reasons another value is defined to appoint the impact of the grid factor on the total balance. Therefore grid factors from China are used that feature relatively high carbon intensity [China Electrical Power Press 2207, UNFCCC 2004].

Table 6-1: Collective parameters applied for every model

Parameter	Value applied	Comment
EG_{SWDS}	= 25.92 kWh/MSW landfill	Consumption-SWDS
$F_{Diesel,SWDS}$	12,620 MJ Diesel/t SWDS	Consumption-SWDS
$CEF_{elec\ low}$	= 627 kg CO_2e/MWh	Tunisian grid factor
$CEF_{elec\ high}$	= 950 kg CO_2e/MWh	Chinese grid factor
$F_{Diesel,Ashes\ DS}$	= 3,075 MJ Diesel/t Ashes	Consumption - ashes deposit site
$EG_{Ashes\ DS}$	= 2.3 kWh/t Ashes	Consumption - ashes deposit site
$DT_{i,y}$	= 50 km	Additional transports per station
$F_{cons,LKW\ class\ 5}$	= 25 l Diesel/100 km	Vehicle fuel consumption
$CAP_{cons,LKW\ class\ 5}$	= 28 t /LKW	Vehicle capacity

Finally, to account for the possible energy production from combustion, the calorific values of the different matters are necessary. Therefore data from the Bavarian Environment Agency (BEA) is used [BEA 2003].

Table 6-2: Waste composition and their respective parameters necessary for accounting

Categories	$W_{j,x}$ in %	DOC_j in % (IPCC)	FCF in % (IPCC)	NCV in MJ/kg (BEA)
Wood	2	43	-	15
Paper	11	40	1	10.5
Food waste	61	15	-	5.5
Textiles	3	24	20	16
Garden and Park waste	5	20	-	10
Compound material	6	0	100	3
Nappies	7	24	100	29.5
Leather	1	39	60	18
Glass, metal and other	1	0	10	7

inert matter				
Plastics	1,5	0	20	24
Rubber	1,5	0	20	24

6.4.3 Mechanical Biological Treatment with composting

The following simulation of a mechanical biological treatment (MBT) facility according to AM0025 is based on models from bifa eco-balancing tools developed according to DIN EN ISO 14040 [bifa 2003].

The eco balances are needed for the electrical energy use and the fuel consumption of the facility. The usage of the same data base will allow for a direct comparison of the methodologies outcome in contrast to the results from bifa in Chapter 6.4.7.

The model applied is a mere pre-treatment facility. After shredding the wastes, these will be aerobically digested on the composting site. In contrast to the methane developed under anaerobic conditions, now mainly carbon dioxide is emitted. Thus the aspired emission reduction is achieved.

According to the bifa model the treatment process causes a weight loss of 25 % of the input mass flow. The fuel consumption of the bifa model is adopted whilst the electrical energy consumption is assumed to be zero. This can be done as the facility of the bifa model features an automated sorting process which is not part of the composting plant developed in this chapter. The waste water caused by the facility is assumed to be treated aerobically. As methane could be built up during composting, AM0025 prescribes frequent measurements of the oxygen content of the compost heap. Hence, for the simulation an assumption is needed as to what percentage of the compost heaps is subject to anaerobic conditions (i.e. oxygen content below 10 %). The percentage of anaerobic measurements is allocated to the total amount of MSW composted. It is assumed, that 5 % of the samples feature oxygen content below 10 %. This means that according to AM0025, 5 % of the composted waste is subject to anaerobic conditions. For this the FOD model is used which calculates that 5 % of the first year total emission of a landfill is emitted from the composting pile.

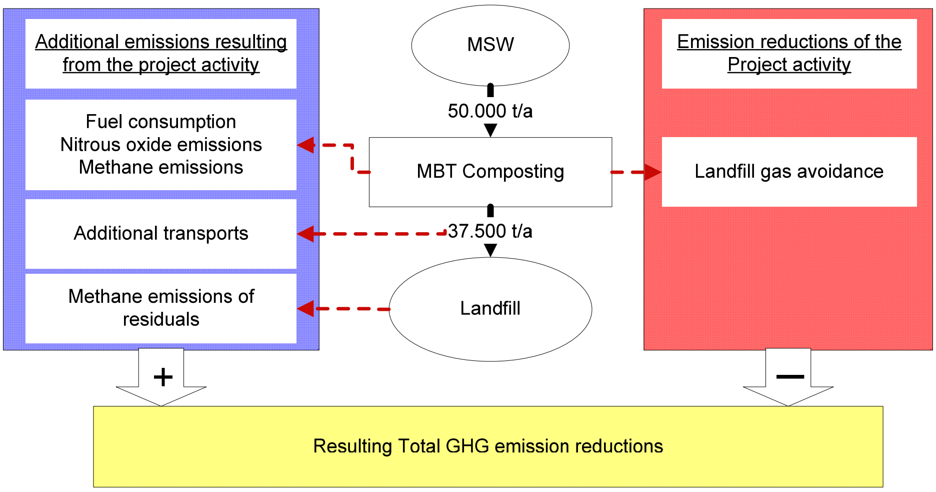


Figure 6-4: Macrostructure of the GHG Balance MBT Composting

An additional transporting station is now necessary for transporting the composting residuals to the SWDS. Here in addition to the collective parameters given above for the modelling the following parameters were needed:

Table 6-3: Specific additional modelling parameters for a composting plant

Parameter	Value applied	Comment
F_{diesel}	= 0.4 l / t MSW	Fuel consumption of the facility
W_{ges}	= 50.000 t / Year	Amounts of MSW treated
$m_{compost}$	= 0.75 t / t MSW	Composting residuals per unit MSW
$DT_{i,y}$	= 50 km	Additional transports (s. Figure 6-4)
$S_{a,y}$	= 0.05	Share of anaerobic-composted MSW
$DOC_{Compost}$	= 0.2	Residual degradable organic carbon content
$k_{Compost}$	= 0.02	Degradation coefficient of the residuals
Calculated characteristics:		
$M_{compost,y}$	= 37,500 t/year	Total landfill amount of compost
DT_{Ges}	= 67,000 km/year	Total distance of transports

There is no recovery of resources in the model. The stabilized waste is directly landfilled after treatment. The bifa model contains the assumption that the disposed residual waste stability is conform to the German Waste Disposal decree (AbfAblV, 2006) and mostly inert. Instead, the UNFCCC methodology demands the calculation of emissions from degradation of residual carbon by the FOD model (s. Chapter 7.4).

As the parameters necessary for this are not purported by UNFCCC it is estimated that the residual carbon is equal to 20 % and the degradation coefficient of wood is chosen. There is no guideline available on how these values should be determined except for the instruction to choose these values conservatively. This can cause conflicts with the examining designated national entities during execution of the project that might result in the failure of the CDM project because of formal requirements. Whenever possible these values should therefore be emphasized by measurements. A standard measurement procedure however, is not available.[UNFCCC 2008]

Figure 6-5 illustrates two clime extremes of the FOD model (cf. 4). The category “boreal dry” is presented in contrast to “tropical wet”. These two categories differ in two aspects. First, the boreal / tropical categories influence the degradation velocity. Second, wet / dry contain information about the waster content of the wastes which affects the total carbon content and therefore the methane generation potential.

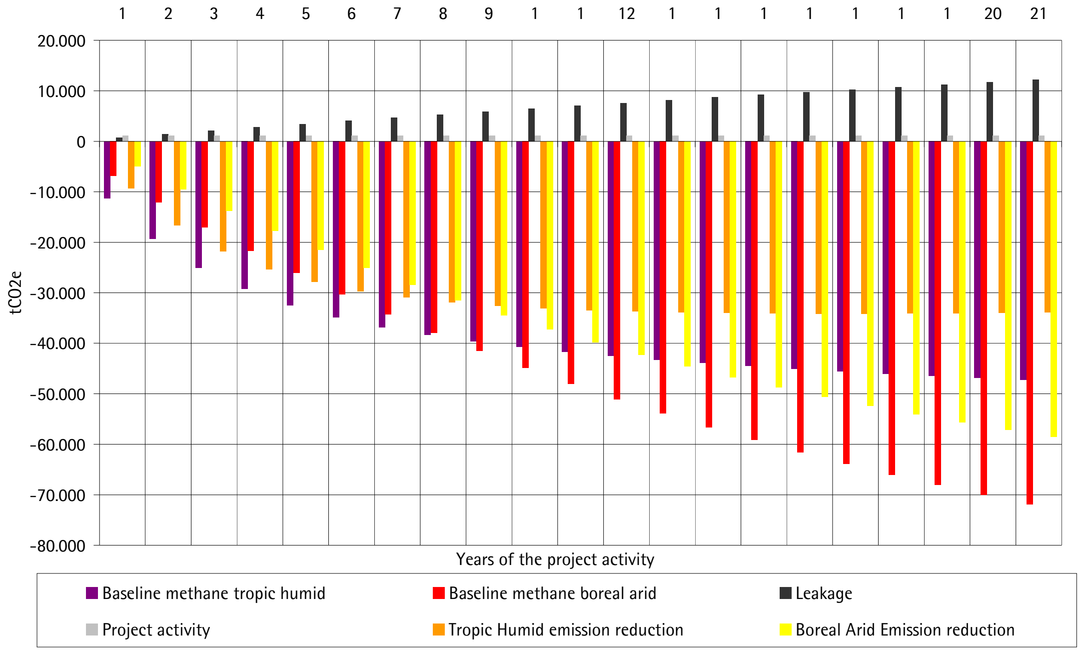


Figure 6-5: MBT Composting – comparison between two climes

Figure 6-5 illustrates the GHG Balance according to AM0025 standards. This scheme of illustration will be of further use in other treatment simulations.

The categories displayed are a result of the AM0025 balancing structure. Categories only displayed once are valid for both of the scenarios embedded in the graph.

The first two, red and ruby coloured columns, represent the FOR models result for the two different climes. They display the course of the methane emissions until the end of the maximum crediting period, 21 years. They are marked negative as these emissions are being avoided by the project.

The third column in dark grey contains leakage emissions that are caused by the project. This means transporting emissions as well as residual emissions on the landfill.

The fourth column in light grey covers the emissions of the project activity on the project site during the treatment process. It contains nitrogenous oxide trace element emissions and methane emissions from the composting process as well as any form of energy use and fuel use in the project.

The resulting emission reductions of the two clime variants are displayed in orange and yellow. Figure 6-5 and Table 6-4 indicate the difference in emission reductions of two identical facilities in different climes. As a consequence also the revenue from CER of the project is changed considerably.

As already mentioned in Chapter 4.4, the allocation of emissions avoided has to be done in the year of the avoided emission and not in the year of the avoidance itself. To get an impression of the amount of emissions that have been avoided by treatment in the respective year the emission reduction of the year 21 can be consulted. This column contains the sum of emissions that have been avoided from year 1 to year 21 which would have been emitted in year 21. As a consequence the baseline emission from year 21 equals the sum of emissions avoided in year 1, emitted until year 21. Comparing this column of year 21 to the one of the first year illustrates that only 7.8% of the emissions avoided in year 1 are allocated in year 1. The resulting consequences will be elaborated further in Chapter 7.1.

Noticeable in addition is that considerably lower emissions are the result in a humid clime although these emissions occur earlier. Furthermore, in a humid clime, the residual emission from landfills adds up, which causes the total emission reductions to sink after year 12. This will also be commented on further in Chapter 7.1.

Table 6-4: Emission reductions of a composting plant by crediting periods and clime categories

Project activity	Boreal dry in tCO_2e	Tropical wet in tCO_2e	Difference in € (15 € per CER)
Years 1 - 7	-120.836	-189.021	1.022.765
Years 1 - 10	-224.064	-259.089	525.376
Years 1 - 14	-397.466	-394.115	50.272
Years 1 - 21	-774.574	-632.399	2.132.622

Another striking point is how low the emissions from project activities are. This is one of the greatest assets to a MBT as it enables it to equal other more sophisticated solutions in terms of CER potential. No combustion takes places and in practice a lot of valuable resources can be reclaimed from the waste stream. Combined with the low initial investment cost and low operational costs, the composting facility is a comparatively attractive treatment technology.

6.4.4 Mechanical biological treatment with RDF production

In the framework of AM0025 the production and utilization of “refuse derived fuels“(RDF) in substitution of fossil fuels is assessable only with an embedded utilization. The sale of RDF cannot generate CER revenue as it is outside the project boundary. Therefore a project developer should extend the project boundary to the utilisation facility, if possible. These emission reductions can thus be assessed accordingly.

RDF Scenario 1: Electrical power generation from RDF

This section of the work examines a facility that separates the different fractions over a sieve drum. The low calorific fractions are composted and landfilled whilst the high calorific fraction is used to fuel an electrical energy plant. System-dependent data like energy consumption and the resulting amounts of compost and ashes can be seen in the bifa analysis.

Emissions from combustion of the fossil carbon fraction of the MSW have to be deducted from emissions avoided by the project activity. A guideline on how the fossil carbon fraction of the stack gases should be measured is now available in version 11 of AM0025 published in January 12 2009 (cf. Chapter 7.5.5). Therefore a path has been opened for a feasible balancing of RDF utilization for project developers.

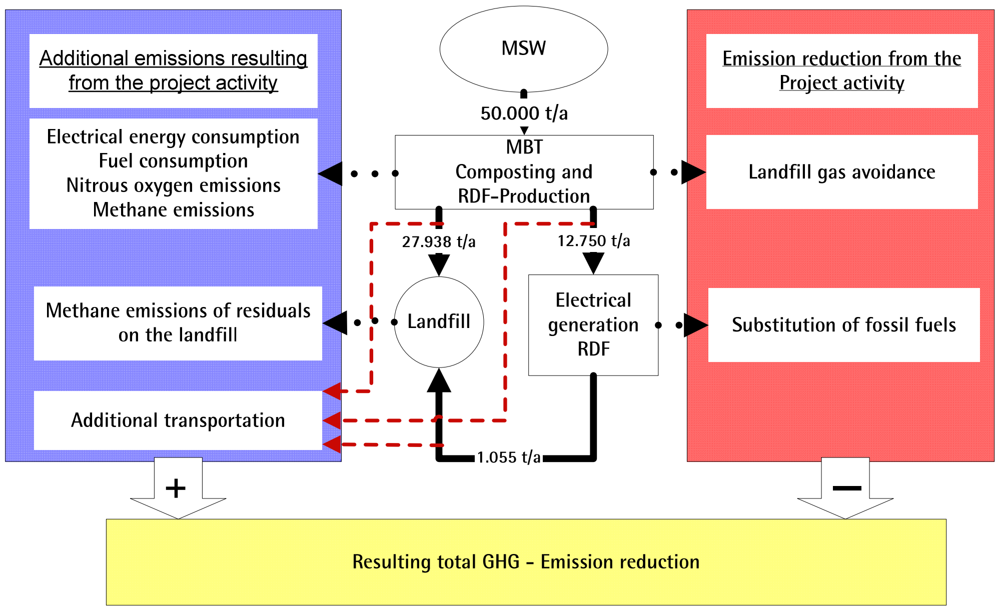


Figure 6-6: Macrostructure of a MBT with composting and production of electricity from RDF

In most tropical and subtropical developing countries it seems hard to find enough demand for thermal energy supply. This is why no thermal energy utilisation is dealt with in this chapter. The activity therefore focuses on electrical energy only, serving to gain a clear view of the impact of changes in the grid factor

The high calorific fractions which are separated entirely from the waste stream include leather, rubber, nappies, paper, compound material and plastics. About 50 % of the textiles and the wood in the MSW are also sorted. The resulting calorific value is assessed using data published by the BEA, listed in Table 6-2 [BEA 2003].

The aggregated calorific value results in 17.922 MJ / kg and can be considered relatively high. German sources mention calorific values of an average 13.4 MJ / kg. These high values could result from a calorific value determination on a dry basis whilst the MSW of this scenario is calculated on a wet basis [Wallmann et al. 2008]. Nevertheless, since this would emphasize the intended comparison the higher value is used.

The fossil fuel consumption for the start up of the process of the plant is taken from a bifa examination of a German waste incinerator.

Due to the reconditioning of the RDF it is estimated that a complete combustion takes place and that the RDF residual ashes cause no emissions on the landfill site.

Table 6-5: Specific additional modelling parameters Scenario 1

Parameter	Value applied	Comment
$\eta_{electric}$	= 0.15	Efficiency of electrical energy production of RDF utilization
F_{Gas}	= 8.5 m³/t Input	Consumption of natural gas for co-firing
EF_{Gas}	= 74,100 kgCO_2e/TJ	Emission factor of natural gas [IPCC 2006]
$F_{light\ heating\ oil}$	= 2 kg/t Input	Consumption of heating oil

Parameter	Value applied	Comment
$DT_{i,y}$	= 150 km	Additional transports (s. Figure 6-6)
$EG_{PJ,FF}$	= 46 kWh /t MSW	Electrical energy consumption of the MBT
$A_{ci,RDF/WRDF}$	= 82.8 kg Ashes/t RDF	Ashes resulting from RDF combustion
Calculated characteristics		
$M_{compost,y}$	= 27,938 t/year	Amount of compost landfill
M_{RDF}	= 12,750 t/year	Resulting amount of RDF produced
M_{Ashes}	= 1,055 t/year	Ashes caused by RDF combustion
$H_{u\ EBS}$	= 17,922 MJ/kg	Calculated RDF calorific value
DT_{Ges}	= 74,600 km/year	Total transports

The substituted fossil fuels would have caused emissions which can be added to the avoided landfill gas emissions. In Figure 6-7 these emissions are indicated in ruby red and pink.

Figure 6-7 shows that for the first year, emission reduction is in the positive range. This means more emissions have actually been caused than reduced in the first year. This result can occur in several forms of waste treatment facilities in the framework of AM0025 regardless of the quality of operation procedures. These are owed to the postponed allocation of the landfill gas emission reductions discussed in Chapter 4.4.

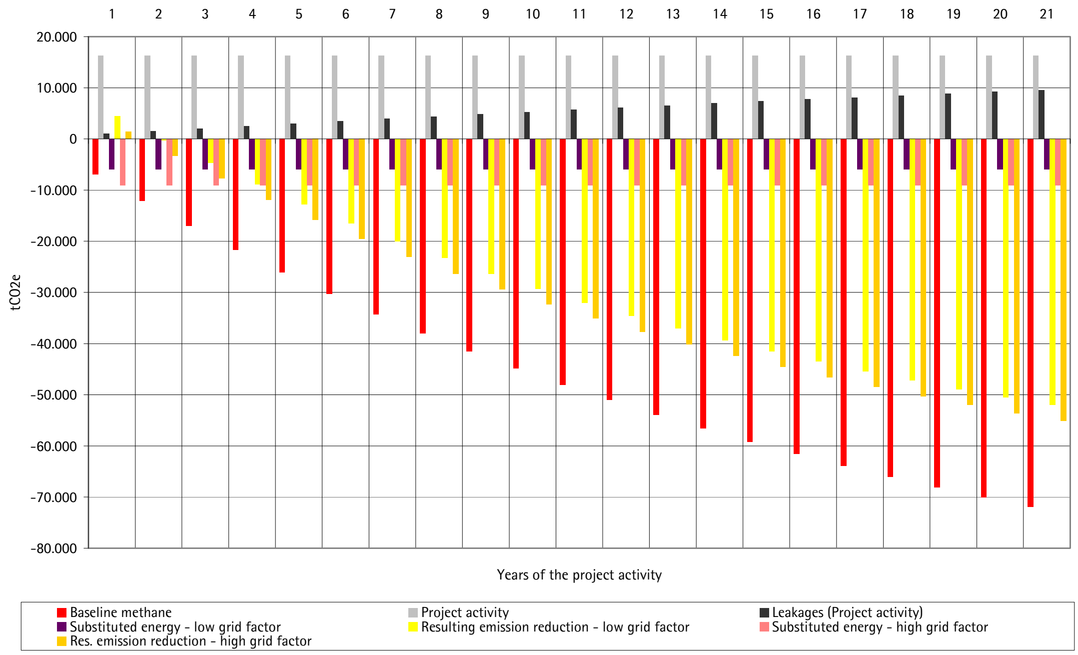


Figure 6-7: MBT producing electricity from RDF – A comparison of the impact of differing grid factors

The standard procedure for such cases of more emissions has been defined in the eleventh update of AM0025. The project has to compensate all the emissions that are caused by it, either in the same year or in the following years. After all the additional emissions the project caused have been compensated, the remaining emissions reductions achieved so far can be claimed as CER.

Figure 6-7 shows that the higher the grid factor, the higher the emission reductions will be and the lower, the debts of emissions. Calculated over 21 years a difference of 64,580 tCO_2e CER emerges.

Conspicuous is the amount of emissions arising from project activity that derive from the fossil carbon content of the RDF fired in the plant. Their height is also caused by the relatively low efficiency of the plant. This causes the CER sum claimable to fall considerably and rendering the RDF MBT less attractive than the MBT with simple composting. In case the RDF sale of electricity revenues can't compensate, the composting plant variant of the MBT prevails financially.

RDF Scenario 2: Utilisation of the RDF in a Combined Heat and Power Plant substituting a fossil fired cogeneration plant

For balancing a baseline of combined heat and power (CHP) plant, AM0025 prescribes the use of equation (27) of the methodology. This equation includes an error which reduces the energy produced by the project activity by the factor 1000^{-1} (cf. Chapter 7.5.7). To show the impact of this error the improbable assumption is made that there is a CDM project in Tunisia which substitutes a CHP plant.

Thermal energy use can change the circumstances described above. It is assumed now that the plant meets a demand for thermal energy supply in the area and can thus produce and sell its heat. The data describing the efficiency of the plant is taken from technical literature [Wallmann et al. 2008].

Instead the grid factor in this variant AM0025 prescribes assessment of the substituted cogeneration plant. Electrical and fossil energy used are incorporated in the calculation. It is assumed that this Tunisian CHP plant is fuelled with natural gas.

Table 6-6: Specific additional modelling parameters for Scenario 2

Parameter	Value applied	Comment
$\eta_{elektric}$	= 0.10	Efficiency of electrical energy production of RDF utilization
$\eta_{thermal}$	= 0.45	Efficiency of thermal energy production of RDF utilization
η_{Cogen}	= 0.90	Efficiency of the substituted CHP plant

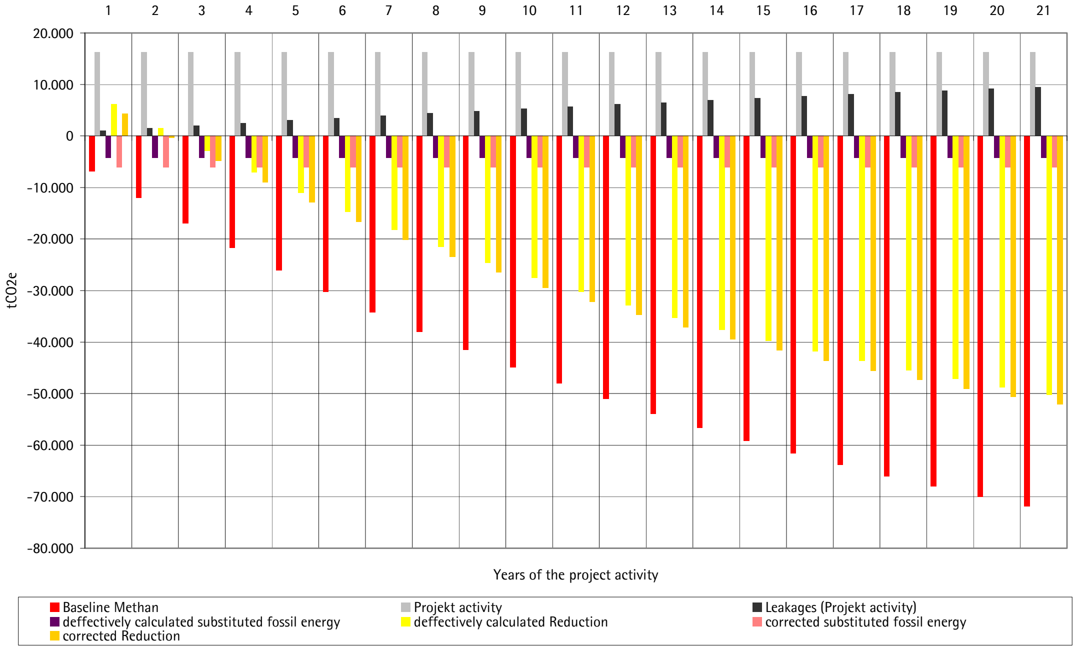


Figure 6-8: Illustration of the defective Equation (27) of AM0025

The comparison of the ruby red and the pink column in Figure 6-8 shows the impact of the error. It lowers the reduction balance by 7 % for this scenario. In case the electrical efficiency reaches 15 % the error adds up to 10 %.

The methodology sets a default value of 90 % efficiency of CHP plants which is a very good value. In practice this value should be lower and cause the emission reduction generated from substituting it to rise. Furthermore it is very unlikely to find a cogeneration plant in Tunisia or other developing countries that would reasonably need to be substituted. The CDM activities should therefore concentrate on substituting old fashioned ways of energy production.

RDF Scenario 3: RDF Utilization delivering thermal and electrical energy with substitution of separated electrical and thermal sources.

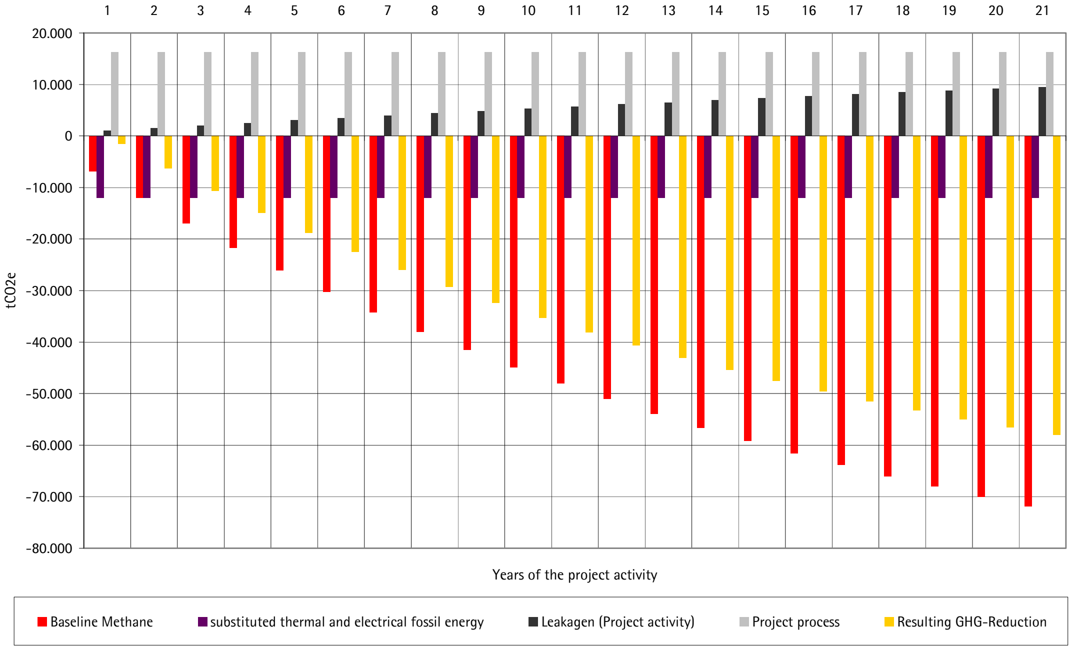


Figure 6-9: MBT with RDF utilization to substitute thermal and electrical fossil energy

Figure 6-9 contains a more probable scenario. The facility now is substituting Tunisian electricity off the grid and natural gas fired boilers.

Table 6-7: Specific additional modelling parameters for Scenario 3

Parameter	Value applied	Comment
boiler	= 0.9	Efficiency of the gas boiler

In contrast to avoided landfill emissions, substituting gas boilers and electricity is directly assessed for in the respective year. The additional emissions from combustion are now fully compensated and CER can be claimed for the first year. Therefore the RDF utilization can prove successful in the CDM. For outrunning the composting facility however, it needs a very high efficiency level. In addition, both technologies differ greatly in terms of investment costs. It is therefore very important for CDM project developers to identify a facility in the area that can utilize the RDF thus avoiding building a new one.

RDF Scenario 4: Utilisation of RDF in the Cement Industry

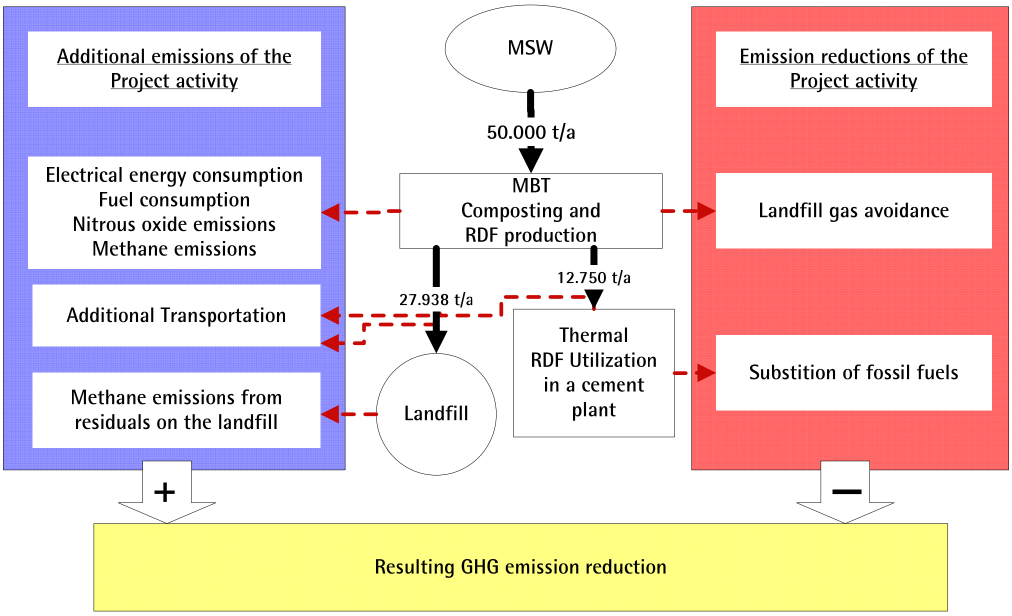


Figure 6-10: Macrostructure of an MBT with RDF Utilization in a Cement plant

Amongst the possible purchasers of RDF another area of utilization is available. To demonstrate this variant of treatment the simulation is now rearranged again. The RDF produced is now utilized in a cement plant. The efficiency achievable is conservatively set at 85 %. In addition the 1,900 km of transporting of ashes is superfluous as these are now compounded in the cement. Figure 6-11 illustrates that these changes have their impact on the GHG balance.

Table 6-8: Specific additional modelling parameters for Scenario 4

Parameter	Value applied	Comment
$\eta_{Zementwerk}$	= 0.85	Efficiency of RDF Utilization in the cement plant

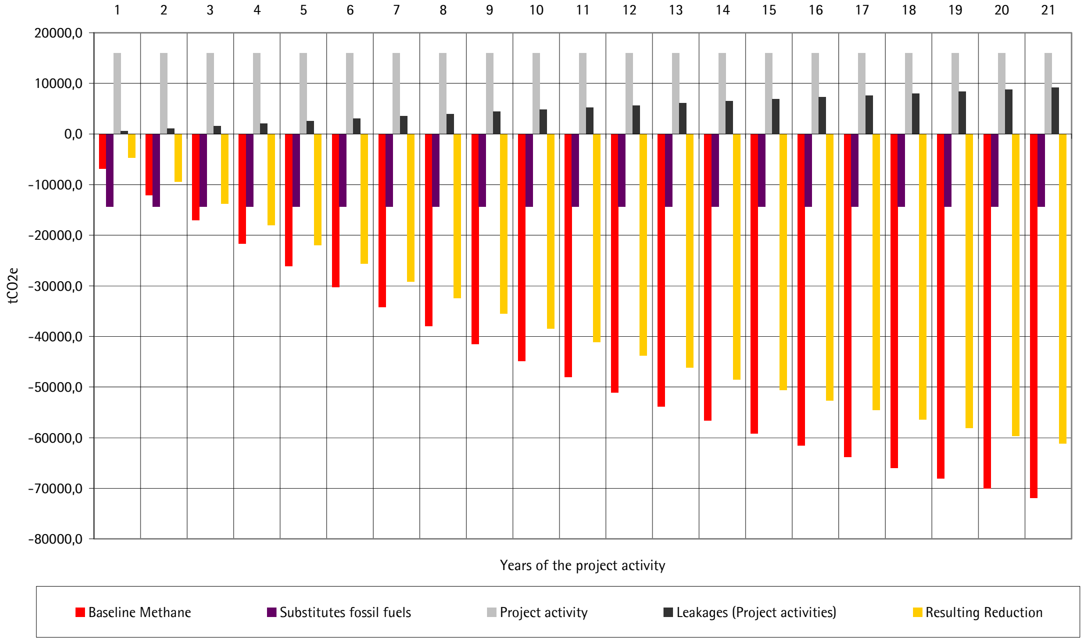


Figure 6-11: MBT with RDF utilization in a cement plant

Figure 6-12 shows a comparison between the diverse MBT variants within the framework of the longest crediting period (3 times 7 years).

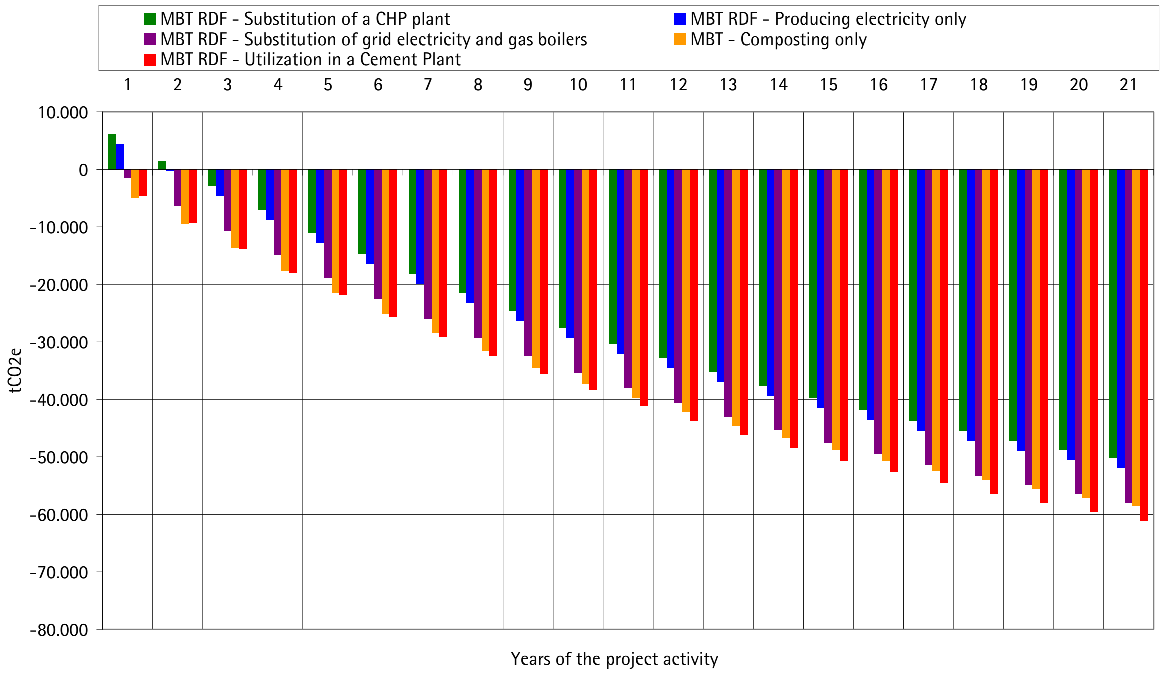


Figure 6-12: Comparison between the diverse MBT treatment variants

The utilization of MSW as alternate fuel according to AM0025 is attractive only in the case of a high degree of efficiency when the fossil carbon contents emissions are compensated by the fossil fuels substitutions. This is dependent on the way of power generation and the substituted primary fuel. Suboptimal choices of the forms of energy generation or the usage of an inconvenient baseline scenario can reduce the amounts of CER that might be claimed by the project.

Therefore a composting MBT can stand comparison as it lacks any emissions from combustion and offers lower investment cost and low operational costs that are accompanied by a large amount of CER in terms of CER/$ investment. These benefits do not consider additional assets which composting plants could offer through recycling.

6.4.5 Waste incinerators without preconditioning

Scenario 1: The classical waste incinerator

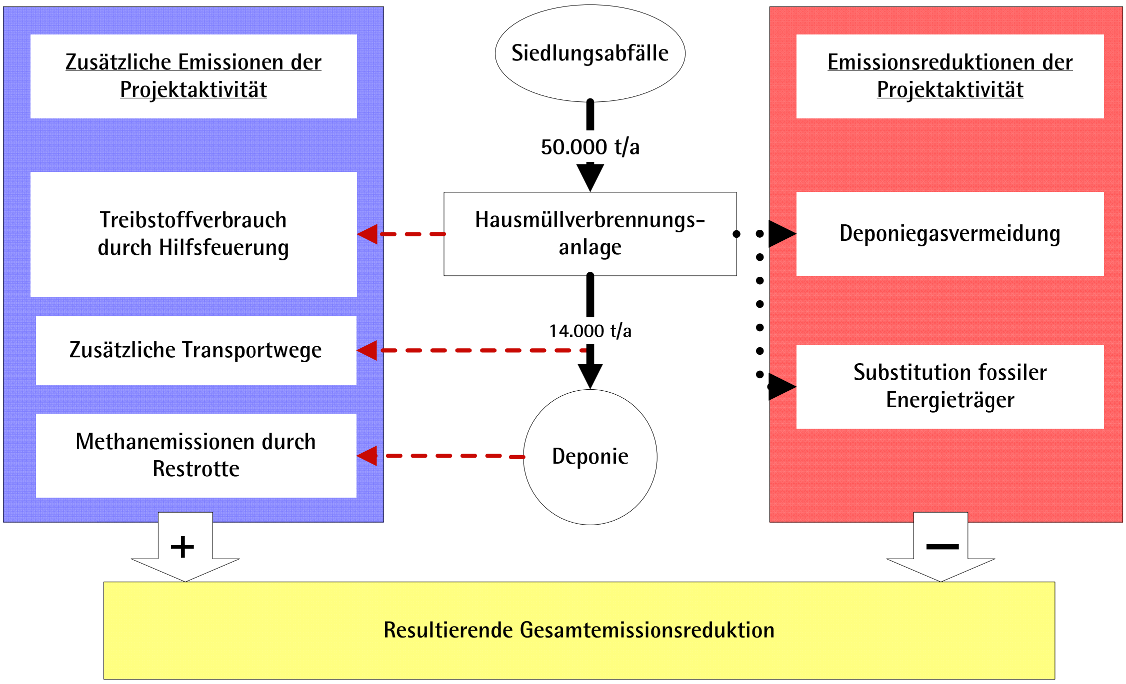


Figure 6-13: Macrostructure of the balancing scheme for waste incinerators according to AM0025

The waste incinerator is another variant of the MSW treatment technologies included in AM0025. The direct transportation of the MSW in the combustion facility reduces the transportation distances considerably. In addition the combustion process enables production of heat and electricity.

The preconditions of thermal energy supply have been discussed in the preceding chapter. A thermal energy purchaser nearby is essential to supply the thermal energy produced. As this is improbable in developing countries, this balance will be restricted to electrical energy production only. Furthermore, the result of incorporating the thermal energy resembles the result of the next example of direct utilization of MSW in the cement plant, although it could not provide the same efficiency.

As before, the modelling of the waste incinerator is based on parameters taken from the already mentioned bifa report [bifa 2003].

As well as the parameters listed below, in order to create a reference case, the values used are those of paragraphc 6.4.1.

Table 6-9: Specific additional modelling parameters for waste incinerator scenario 1

Parameter	Value applied	Comment
$\eta_{electric}$	= 0.1	Efficiency of electrical energy production
F_{Gas}	= 8.5 m^3/t Input	Consumption of natural gas for co-firing
EF_{Gas}	= 74.100 $kgCO_2e/TJ$	Emission factor of natural gas [IPCC 2006]
$F_{light\ heating\ oil}$	= 2 kg/t Input	Consumption of heating oil
$DT_{i,y}$	= 50 km	Additional transports (s. Figure 6-13)
$a_{residual}$	= 0,28 t Ashes/t MSW	Ashes resulting from MSW-combustion
$F_{residual}$	= 65 kg C/t Asche	Residual carbon content of the ash
$DOC_{HMV\text{-}Ashes}$	= $DOC_{Textiles}$ = 0.3	Assumed degradable organic content for AM0025 V10
$k_{HMV\text{-}Ashes}$	= $k_{Textiles}$ = 0,04	Assumed degradation velocity for AM0025 V10
Calculated characteristics		
$M_{compost,y}$	= 27,938 t/year	Amount of landfill compost
M_{RDF}	= 12,750 t/year	Resulting amount of RDF produced
M_{Ashes}	= 14,000 t ashes/year	Ashes caused by RDF combustion
$H_{u\ MSW}$	= 8,996 MJ/kg	Calculated MSW calorific value
DT_{Ges}	= 12,525 km/year	Total transports

With the eleventh update of AM0025, published in January 12 2009, a mechanism was introduced that penalizes the inefficient operation of waste incinerators.

Version 10 of AM0025 prescribed that to determine the combustion efficiency, every single MSW fraction is to be combusted separately. Version 11 now accommodates the fact that, first, the combustion efficiency is a parameter characterizing a facility, second that combustion efficiency of specific materials is not defined as such and third that the IPCC default parameters AM0025 in Version 10 did not exist. Instead the IPCC gives default parameters for the combustion efficiency of waste incinerator that amounts to almost 100 % [IPCC 2006].

Further, Version 10 demanded assessment of methane generation from residuals of the waste incineration whereas, again, DOC_j and k_j values were not given for the combustion ashes.

The amended chapter in Version 11 alleviates this circumstance in the following way:

The FOD model is no longer necessary for the assessment. Instead, up to a "residual carbon content" of 5 % in the ashes, this carbon will directly be transformed stoichiometrically to carbon dioxide. These hypothetical emissions are part of the project activities emissions and are intended to deliver an easy conservative assumption. The penalty comes into effect as soon as the total residual carbon content exceeds

5 % total carbon share. The share above 5 % has to be transformed stoichiometrically in methane, straining the balance 21 times greater.

Though it is generally reasonable to demand an effective treatment of the waste there is nevertheless a hitch to the "residual carbon" content of the ashes as demanded in AM0025. This definition includes biologically inert carbonates that even absorb carbon dioxide from the atmosphere to a measurable extent.

The combustion efficiency of average German waste incinerators usually leaves about 1-2 % non-oxidized organic carbons in the ashes. As by definition carbonates and charred matter also have to be incorporated in this balance, this results in a total carbon content of 3-6 %. This parameter can be expected to frequently exceed the threshold of 5 % in developing countries (cf. Chapter 7.5.6).

As this parameter is demanded in the methodology it has to be demanded by the certifier before any CER can be allocated. Assumptions on why this requirement was implemented in the methodology in its recent form are desisted from. The resulting consequences shall nevertheless be displayed.

The parameters lacking in the calculation of version 10 are chosen conservatively and thus alleviate the gap between the two versions. In absolute numbers, Version 11 causes a loss in CER in comparison to Version 10 of about 64,000 tCO_2e accordant to a proportional loss of CER of around 22 %.

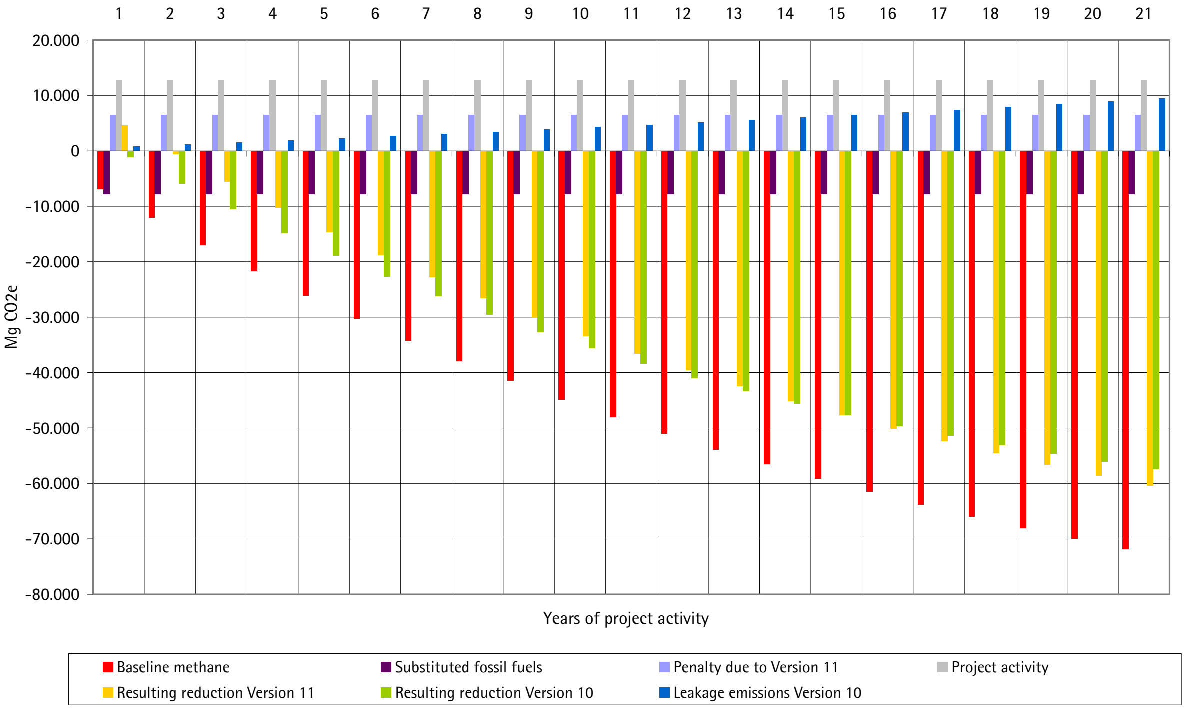


Figure 6-14: Balance of a waste incinerator according to AM0025 Version 10 and Version 11

Figure 6-14 displays the impacts of this new regulation. A total residual carbon content of 6 % was used. Though displaying an extreme case by German means, it might well be that in the first years after the implementation in developing countries, a lack of process guidance results in such values or even higher ones.

The direct comparison shows that Version 11 causes emissions from the project activity which cannot be compensated in the first two years by the emission reductions. The waste incinerator which is very expensive anyway, is thus even less attractive for investors.

Scenario 2: Co-firing of unconditioned MSW in a cement plant

The last combustion alternative remaining is the utilization of raw MSW in a cement plant. This variant has the benefit of being untouched by most barriers of AM0025, like the problem of the ashes. The rotary furnace of cement plants even allows for the addition of unbruised tires. Thus the partial adding of non-preconditioned MSW can be considered viable. Because of chemical limitations to the production process it is not possible to feed this process entirely or mainly with MSW. Therefore also in several cement plants it might not be possible to dispose of the full balanced volume of 50.000t/year entirely. Nevertheless, for comparison reasons to the other treatment technologies, this volume is calculated in full.

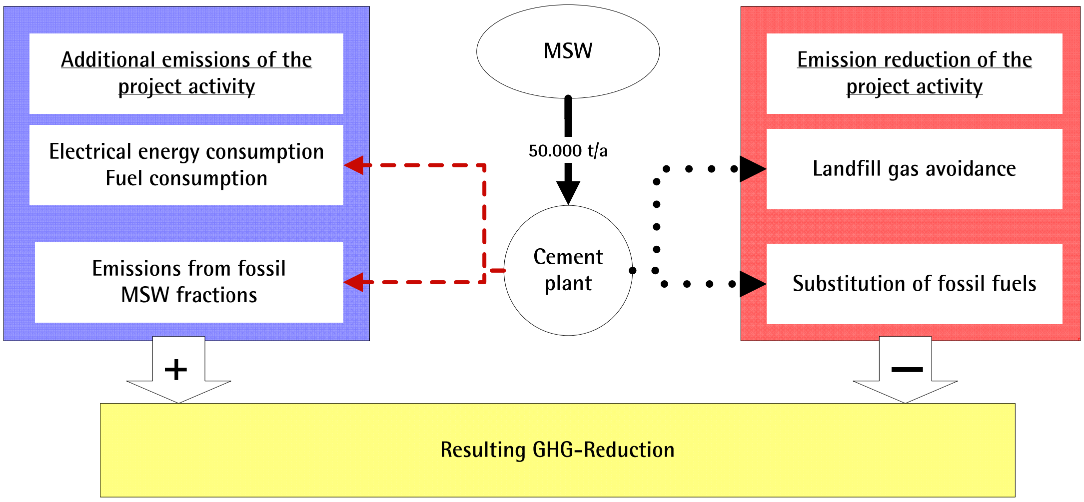


Figure 6-15: Macrostructure of the balance of MSW utilization in a cement plant

A certain additional effort will be necessary to dispose of the greatest contradictions. The electricity and fuel consumption of the RDF production are used for this to allow for a conservative and easy calculation. Their share of the total emissions of the project is below 1 % though and can thus be considered negligible.

There are no additional transports necessary. The efficiency of MSW utilization is appointed to 70 %, which is a rather conservative assumption.

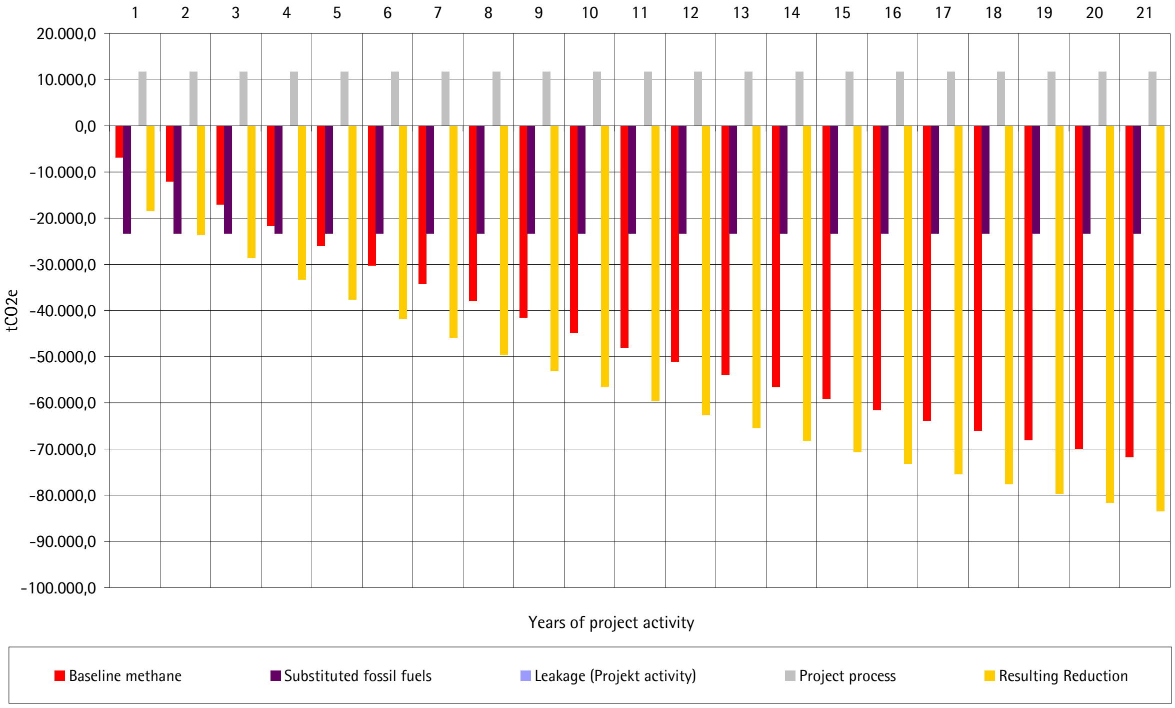


Figure 6-16: Co-firing of MSW in a cement plant

The co-firing of MSW in a cement plant is numerically a very effective way of achieving GHG reductions as the MSW is used very efficiently. In this way the impact of the incinerated biomass can fully come into effect. This results in a large GHG emission reduction, illustrated in Figure 6-16 and Figure 6-19. The use of MSW in cement plants is limited, though. A certain calorific value must be met and high concentrations of chloride – MSW is rich in chloride - can reduce the quality of the cement considerably.

Unlimited amounts of MSW can therefore not be disposed of in this way, but it offers a highly profitable niche option for disposal.

6.4.6 Anaerobic digestion of MSW

There are several variants of anaerobic digestion processes viable for treating MSW. Wet digestion, dry digestion and a hybrid form: co-digestion can all be conducted. All these variants are assessable by AM0025,

The following balancing model examines a co-digestion plant only. The necessary modelling assumptions render the differentiation in the several variants questionable due to the high uncertainties in the calculation.

For the balancing of co-digestion facility, individual parameters have to be defined in terms of methane generation and methane leakages. There is an expert discussion going on at the moment about these parameters. Therefore the Federal Ministry of the Environment, Natural Preservation and Nuclear Safety has initiated a research project to determine the methane slip of these plants.

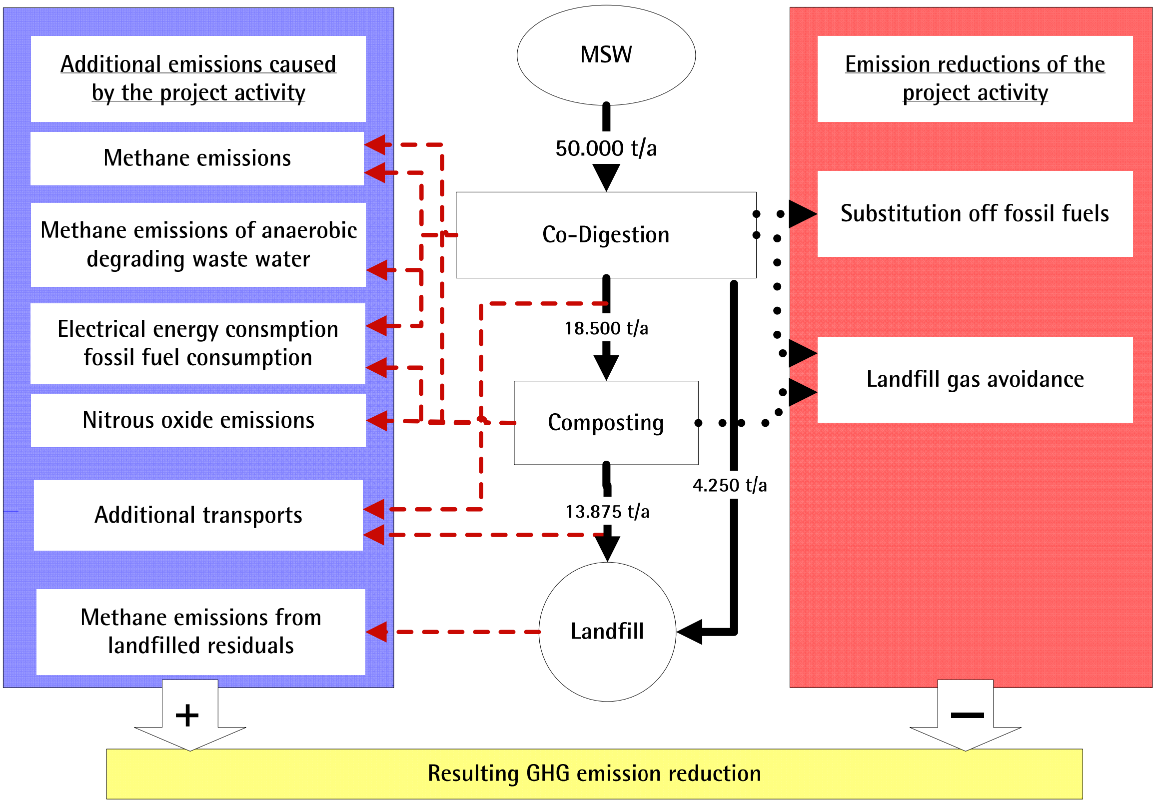


Figure 6-17: Macrostructure of the Co-Digestion

AM0025 demands proof of the absence of methane leakages in MSW digestion plants. How such proof could be provided is not further explained. The ongoing expert discussion as mentioned argues this point specifically. Therefore the IPCC default leakage factor for digestion plants of 2 kg CH_4/t MSW is applied [IPCC 2006].

Figure 6-17 shows the structure of the co-digestion plant modelled in this chapter. After the anaerobic digestion the residuals are composted. A partial flow of contraries is separated before the digestion process and is landfilled together with the composting residuals.

Information about the mass flow balance in the facility is provided by a bifa report from 2000 which includes a detailed examination of a pilot co-digestion plant [bifa 2000].

The waste waster generated in the process is assessed by usage of this information. The proportion of waste waster in relation to the waste processed in the plant is transferred into the model. The measured COD parameter can also be extracted from the report. The highest measured value is applied to enable a conservative balancing. To support this conservative approach the highest methane correction factor (MCF) from IPCC is applied. This factor describes the potential methane generation of waste water pouring in different water bodies.

The calculation of the amount of bio gas produced is necessary to calculate the carbon neutrally provided energy from biogas in dependence to the MSW fed into the plant. Therefore the DOC_j values from IPCC for the different waste fractions are used to identify the organic dry fraction of the MSW (cf. Table 4-2). A simplified version of the model of Tabasaran is used to assess the total amount of biogas potentially generated in m^3 [Tabasaran 1976].

The degree of oxidation of the educt in the model determines the proportion of carbon dioxide to methane generated in the facility. In simple terms, it is assumed that the organic matter is on hand in the form of glucose, the cellulose monomer. By assessing carbon dioxide and methane as ideal gases a volume proportion of 50:50 results for the biogas composition.

Thus 1,868 m³ of biogas per kilogram carbon input result stoichiometrically. Using the standard density of methane the mass of the methane produced can be determined. This amount is cut down by 50% following the estimate that only half of the potentially usable carbon can be digested by the bacteria in the limited timeframe. Another 50% is cut down on the assumption that 50% of the biomass cannot be digested at all by the bacteria. In sum a correction parameter of 0.25 results. The resulting amounts of biogas fit to the rules of thumb in use in industrial practice.

The modelling of the composting element is done analogical to the one discussed in Chapter 6.4.3.

Table 6-10: Specific additional modelling parameters for the anaerobic digestion

Parameter	Value applied	Comment
W_{ges}	= 50,000 t/Year	Processed amount of MSW
F_{diesel}	= 0.4 l/t MSW	Fuel consumption
$m_{compost}$	= 0.75 t/t Input	Resulting compost per tonne input
$DT_{i,y}$	= 50 km	Additional transports
$S_{a,y}$	= 0.05	Share of composting piles under anaerobic conditions
$DOC_{Compost}$	= 0.2	Residual organics in the compost
$k_{Compost}$	= 0.02	Coefficient of degradation velocity
$P_{COD,yhigh}$	= 1570 mg/l	Chemical oxygen demand
$q_{COD,y}$	= 0.470 m³/t MSW	Specific amount of waste water
B_0	= 0.265 t_{CH4}/tCOD	Methane generation coefficient of the waste water
$MCF_{deep\ Lagoon}$	= 0.8	Methane correction factor of the water body the waste water pours into
Calculated characteristics		
$M_{compost,y}$	= 18,500 t/year	Amount of compost landfilled
$Q_{COD,y}$	= 23,500 m³	Produced excess water
$M_{Contraries,y}$	= 4,250 t/year	Contraries to be landfilled annually
DT_{Ges}	= 65,450 km/year	Total transports

The calorific value of the methane enables now to assess the amount of energy substituted per treated tonne of MSW. Hence the calculating term is the following.

Table 6-11: The assessment of the energy produced from biogas

$$EG_{d,i} = \eta_{BHKW} \cdot 3{,}6 \cdot 10^{-3} \cdot NCV_{CH4} \cdot 0{,}25 \cdot \rho_{CH4} \cdot \upsilon_{CH4} \cdot 1{,}868 \cdot TOC \qquad (10)$$

Parameter	Value applied	Comment
$EG_{d,i}$	= electricity produced by the project activity (MWh/t MSW)	
$_{CHP}$	= 0.36	Efficiency of the electrical energy plant
$_{CH4}$	= 0.5	Volume share of methane
NCV_{CH4}	= 50.4 MJ/kg	Calorific value of methane
TOC	= 336.7 kg C/t MSW	Dry share of organic carbon in the MSW

This model produces thereby for the scenario Tunisia 650.2 MWh/t MSW carbon neutral energy. The grid factor already used for the Tunisian electricity grid can thus deliver the amount of carbon dioxide emissions avoided.

The model conveys an impression of how much biogas can be produced in dependence to the composition of the MSW processed. It includes rough estimates though and should therefore not be used unquestioned. In addition there has to be a reliable monitoring procedure for the methane leakage of the facility. In case there is none, a leakage factor of 15% has to be used according to AM0025. Under such conditions none of the emission reductions of Figure 6-18 would have occurred as the methane leakage would fully compensate them.

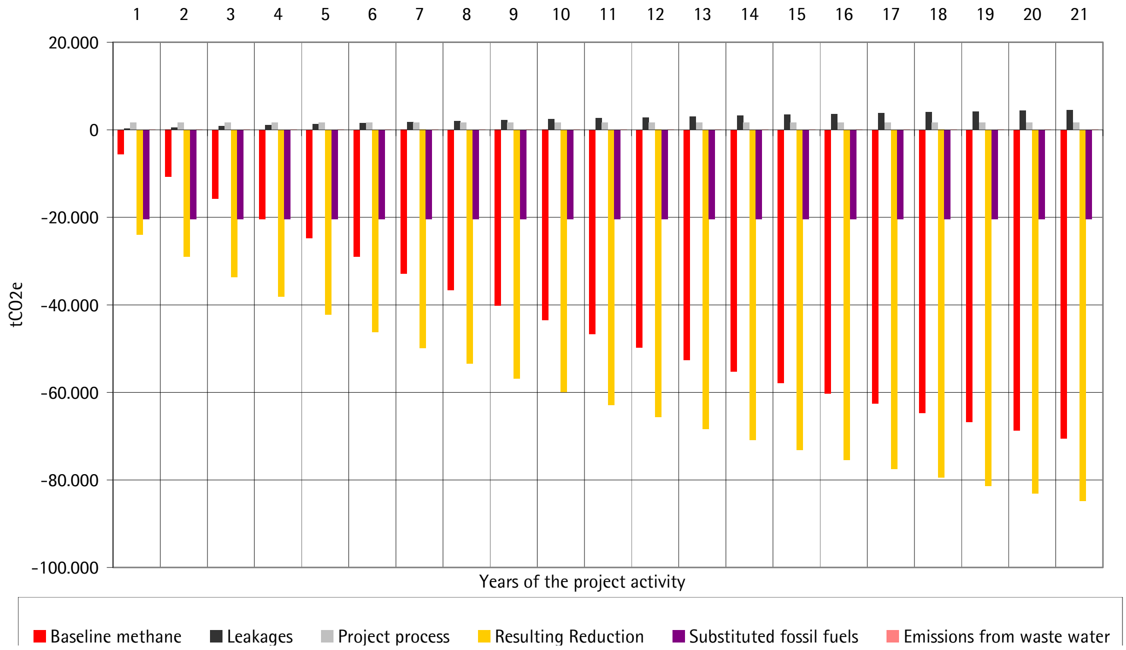


Figure 6-18: The balance of a co-digestion facility according to AM0025

The result shown in this model Figure 6-18 is nevertheless impressive. Though including a number of assumptions, this model shows that digestion plants compared to other types of treatment technologies can play their part well within AM0025 (cf. Figure 6-19). This is mainly due to their potential to supply large amounts of energy without causing any fossil carbon emission.

6.4.7 Conclusive comparison of treatment variants and balancing systems

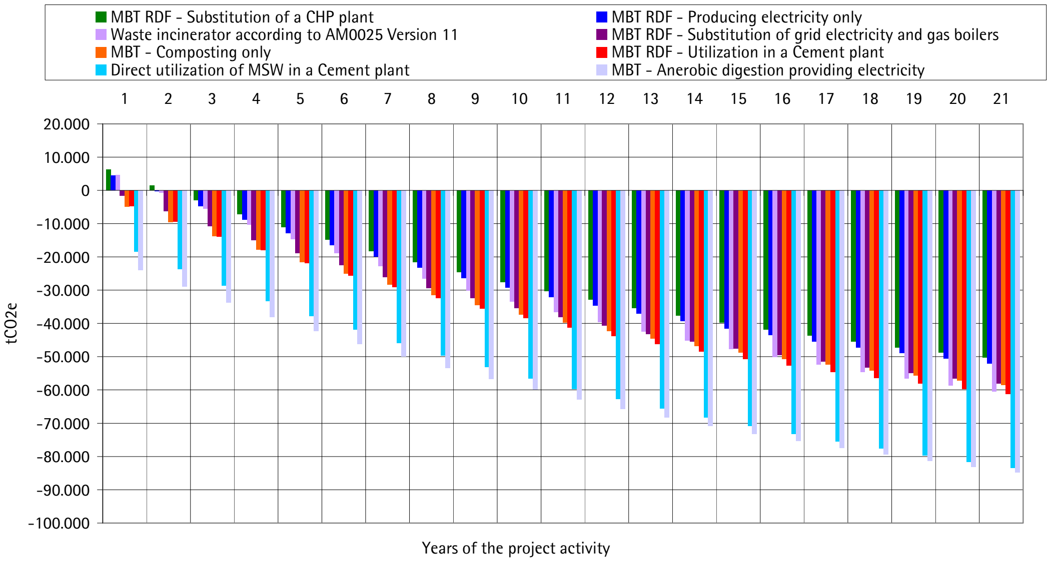


Figure 6-19: Comparison of the different treatment options within AM0025

Figure 6-19 shows that highly sophisticated technical solutions do not necessarily make for higher GHG emission reductions. In fact only a careful consideration of the diverse treatment options in the respective context of application can deliver the optimal solution. The variant MBT – Composting delivers the best cost-performance ratio as the technological expenses are minimal in this scenario. Nevertheless the eligibility of the different variants definitely depends on the respective framework in local infrastructural terms (e.g. Cement plant or plants with co-firing options etc.).

bifa environmental institute fabricated an eco efficiency analysis of the different MSW disposal options for Tunisia according DIN EN ISO 14040. The balancing procedures differ considerably from those of UNFCCC methodologies.

On the one hand the landfill gas prognosis is not done on the basis of the FOD model but by means of the model of Tabasaran and Rettenberger balanced over 50 years. On the other hand the emission reductions are assessed at the moment of the avoidance activity. Furthermore potential emissions from treatment residuals are neglected. Where these are identified, other differences will be indicated [Tabasaran et al. 1987].

Figure 6-20 displays the results of the eco efficiency analysis of bifa environmental institute. The several variants follow a different nomenclature than those discussed above. Analogical to the baseline of UNFCCC the model compares the disposal options to the worst reference scenario, a managed landfill without landfill gas capturing. In addition to the disposal options already discussed a landfill managed according to German standards is included (i.e. Landfill gas capturing). Further, three variants of MBT facilities are included.

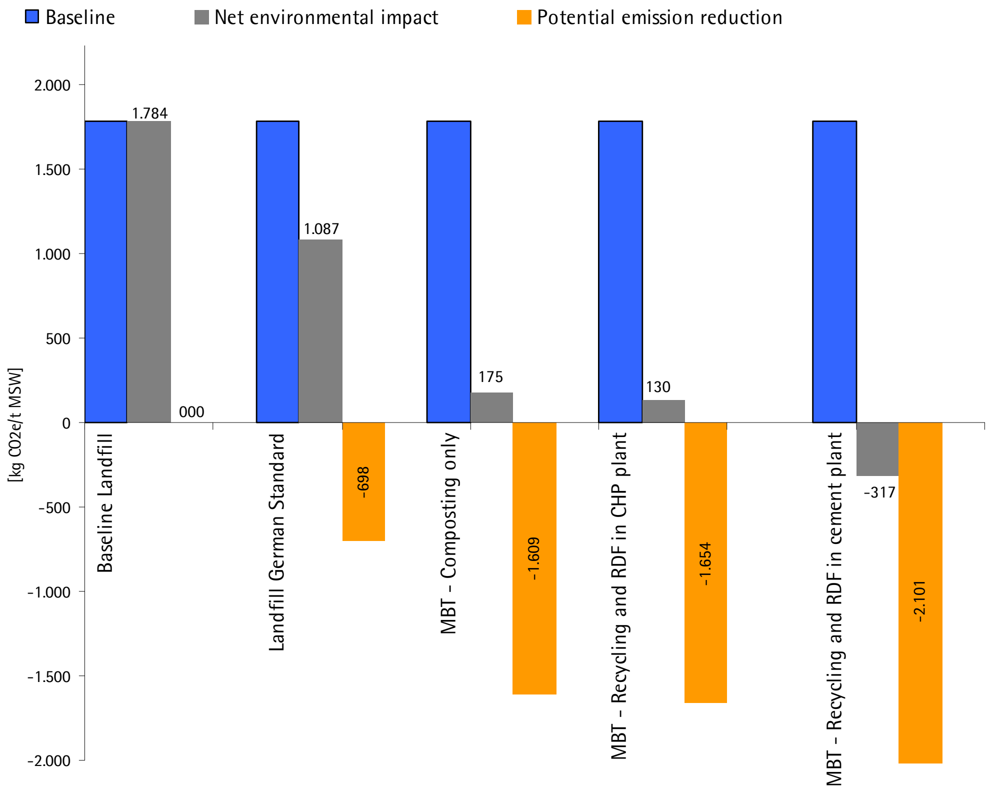


Figure 6-20: *Eco efficiency analysis results of different disposal options according to DIN EN ISO 14040 and bifa standards*

The "MBT" represents a simple composting plant. The other two MBT variants both include the recovery of metals and the extraction of the high calorific fraction of the MSW. The RDF is utilized in a CHP plant or in a cement plant. Project emissions are indicated in grey, the resulting difference to the blue baseline is the GHG reduction is displayed in yellow. These columns represent absolute numbers without dependences over time.

To compare the UNFCCC methodology balances to the bifa balancing model, comparison values now need to be defined. As the balances established so far all feature a strong dependence over time, these have to be dissolved to compare properly.

A crediting period is restricted to the maximum of 21 years - 3 times 7 years – and the FOD model can only be applied to years of the crediting period by UNFCCC standards. When summed up, the emissions that derived from one particular tonne disposed of in one particular year differ a lot during the respective years chosen. This is due to the balancing period which shrinks during progress towards the end of the crediting period. Thus the tonne disposed of in the first year obtains the greatest baseline emissions and the greatest GHG reduction potential. The GHG reduction potential of the 21st year add up to only 7.8 % of the GHG reduction potential from year one whilst the baseline emissions remaining for waste disposed of in the tenth year amount to 66.2 %.[3]

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[3] These numbers are based on the Tunisian waste composition and the clime category "boreal dry". The total GHG emission potential the FOD model calculates for this scenario amounts to 2.1 tCO_2e.

The arithmetic middle assessable as emission reduction potential over 21 years averages to 0.871 tCO_2e per tonne MSW disposed of. This amounts to only 50 % of the GHG reduction potential accounted for in the bifa model. These deliberations show that a comparison between the two balancing models is not entirely valid. Figure 6-21 and Figure 6-22 show such comparisons now for two isolated cases. The baseline emissions in Figure 6-21 are calculated for the first year whereas Figure 6-22 contains the baseline emissions assessable for MSW disposed of in the tenth year of a 21 year crediting period.

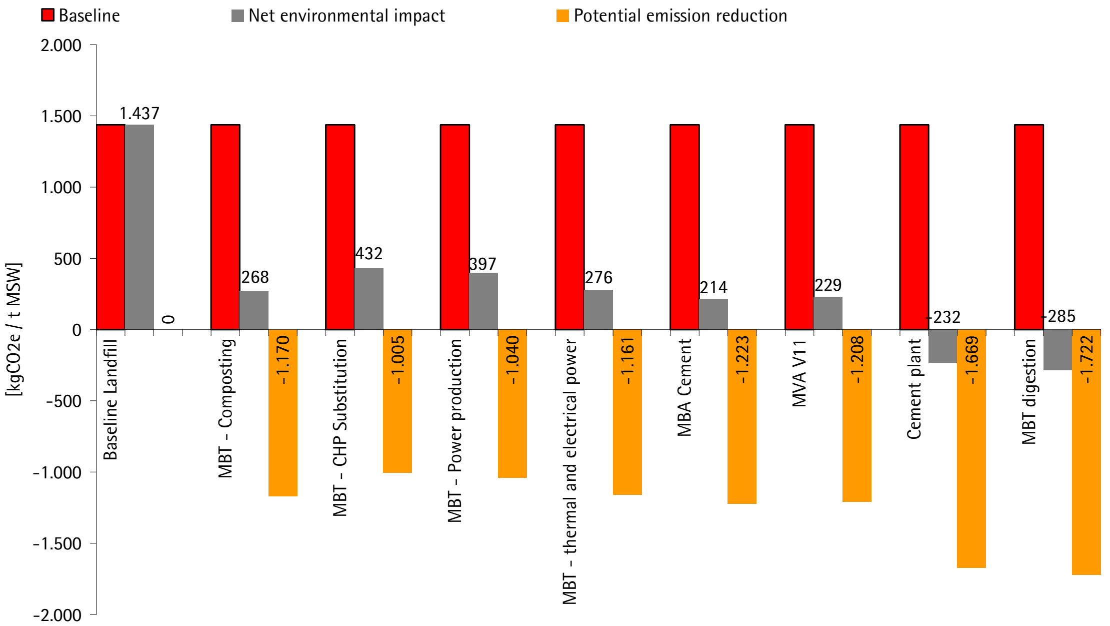

Figure 6-21: Emission reduction potential balanced for the first year of 21 years according to AM0025

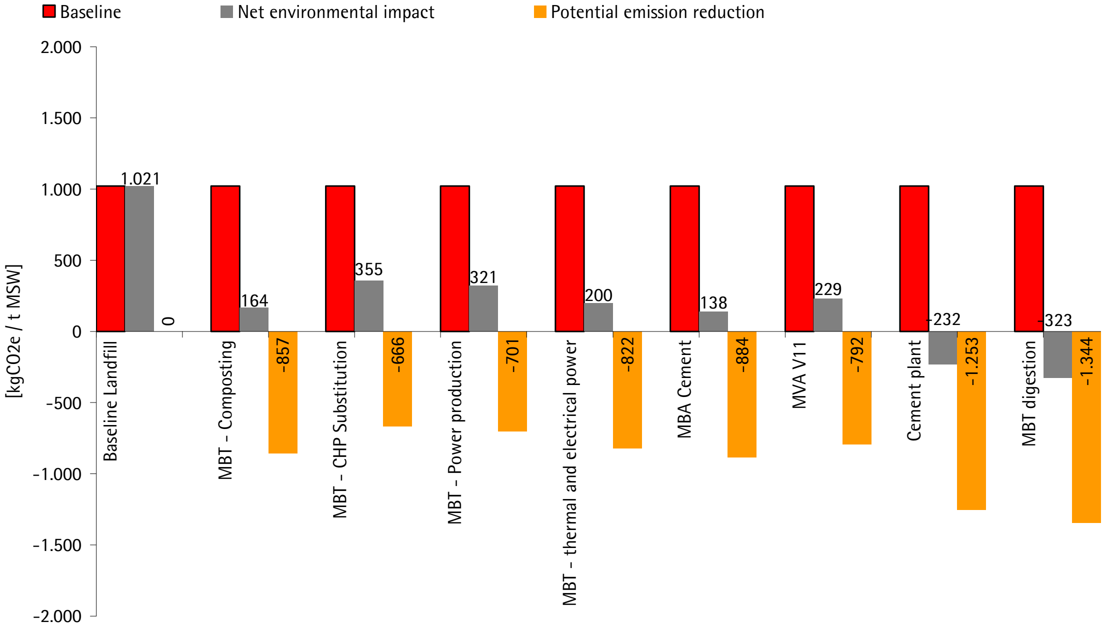

Figure 6-22: Emission reduction potential balanced for the tenth year of 21 years according to AM0025

Figure 6-21 therefore contains the balance of the most profitable year of the entire crediting period. The emissions caused by the waste disposed of in year one have been summed up for the baseline as well as for the project and the leakage emissions. All treatment options discussed are included. This balance must not be confused with the total reduction balance of a project as discussed in the chapter before, but it gives an impression about the consequences of the postponed emission assessment. Figure 6-22 shows the same graph not for the first but for the tenth year of the crediting period. The trend is clearly visible. Year after year the merits from treating the MSW shrink further. The illustration of year 21 is desisted from as the information already delivered enables us to imagine the marginal remaining reduction potential according to this balancing scheme.

The differences between Figure 6-20, the bifa graph, and Figure 6-21, according to AM0025, are caused by several circumstances. Firstly the prognosis models differ and secondly the bifa model considers the emission reduction potential of recycling activities. Moreover, different default values are used and other assumptions are made in the two balancing schemes (e.g. organic carbon content of MSW, emission factors from composting etc.).

The comparison shows the possible range of such virtual balancing schemes and the related uncertainties.

The consequences of abandoning the usual practice in eco efficiency analysis for balancing CDM projects are shown in Chapter 6.4.7.

7 Hindrance, disincentives and improvement potential of the UNFCCC balancing schemes

The examination of the methodologies available for waste treatment within the CDM allows a conclusive evaluation of these now. During the virtual balancing according to these methodologies a number of hindrances emerged that might cause considerable efforts for project developers.

These are discussed in the following chapter. Solutions are offered where available and systemic deficits are highlighted. Chapter 8 contains a draft for a new methodology which considers these points.

7.1 Financial disincentives due to the postponed allocation of Certified Emission Reductions

It has been indicated several times in this work that the postponed allocation of emission reductions achieved causes problems for project developers. This chapter now shows the chances which result from it.

It has been discussed in detail in Chapter 4.4 and Chapter 6.4.7 how the postponed allocation causes only a small share of the total avoided GHG to be allocated in the respective first year. Further it was demonstrated that the overall emissions assessable within the crediting period represent only a share of those emissions that would result from the MSW in total (cf. 4.4)

Dependent on the respective baseline according to the FOD model between 60 % and 90 % of the total emissions resulting from the waste of the first year have been emitted after 21 years. The share of emissions assessed shrinks with the advancing project age. In year ten only 50 % to 60 % remain and in year 21, the last year of the crediting period, the assessable share of emission reductions amounts to only 7 % to 20 % of the total potential.

In any given case the emission reduction achieved is only partially remunerated, thus further lowering the attractiveness of these very sustainable technologies.

To discuss this balancing approach a long term evaluation is undertaken now according to the following considerations from the perspective of a project operator:

It is obvious that the activities of the project are remunerated only sparely in the last years of the project. In the case that the activities of the first years are over and their achievements are allocated towards the approaching end of the crediting period, is it worth continuing the treatment in the last years of the project? Or should it rather be taken out of service in order to save the operational expenditures from which no financial benefits are derived? Which year of the project would then be the optimal shut down time and how large would be the amount of expenditure saved?

The CDM Executive Board has so far not given any note or comment on such a case. Of course a project operator could not claim emission reductions he did not avoid in the first place. Still, if the project achieved GHG avoidances in the past which are to be allocated in the future, shutting down the facility should not logically impact on the allocation of these. Therefore an examination of the questions given above is now undertaken.

For such considerations the primarily eligible treatment options is the MBT composting plant as all of its GHG reduction potential assessable is landfill gas avoidance. Thus most emission reductions are allocated in the years after the avoidance itself. Any other project form which substitutes fossil fuels as well would not be affected as much by this effect as a share of its avoidance activities is allocated instantly.

Table 7-1: Economical key parameters of a composting plant with a capacity of 50.000 t/year

Parameters	Values
Investment expenditure:	
Mechanical treatment	€ 492,000
Biological treatment	€ 830,000
Overall	€ 1,322,000
Variable costs (wages, maintenance, energy consumption)	
Mechanical treatment	€ 100,000
Biological treatment	€ 180,000
Overall	€ 280,000
Other	
Capital return	6 %
Additional revenues per tonne MSW (Gate fee, also of metals or other)	€ 3-5/t MSW
Estimated CER Price	€ 15/ tCO_2e

A combination of the GHG reduction balance from Chapter 6.4.3 and the economical parameters given above is now used to examine the economics of a MBT composting plant. The economical parameters are extracted from a guideline to construct a MBT in developing countries [Santen et al. 2007].

The investment costs are amortized over the entire crediting period on the same lines. Combined with the interest rates € 66,550 per year is spent over 21 years for paying off the plant.

CER prices were highly volatile in the past and will remain so due to their dependence on political decisions. This circumstance will be ignored as the balancing structure is to be examined in isolation. Therefore the price of the CER is set at €15/tCO_2e.

The largest possible crediting period of 21 years is chosen to amplify the effect.

It can be assumed that either the sale of recycled resources, gate fees or some other sort of financial subsidies contribute their share to finance the project. Without further questioning it is therefore assumed that the project obtains subsidies independent from the CDM. Several earnings per tonne are simulated.

Looked at upside down the critical point is reached at € 4 per tonne MSW on subsidies. Underneath this border the shutdown of the facility starts being profitable in year 20. Hereby the total revenues in year 21 add up to € 1,800 more than under continuous operation.

In Figure 7-1 subsidies of € 3 per tonne MSW are given. Here the largest additional revenues already amount to € 58,800 in year 20. In case of absence of subsidies a shut down in year 18 would produce additional € 345,000 on income.

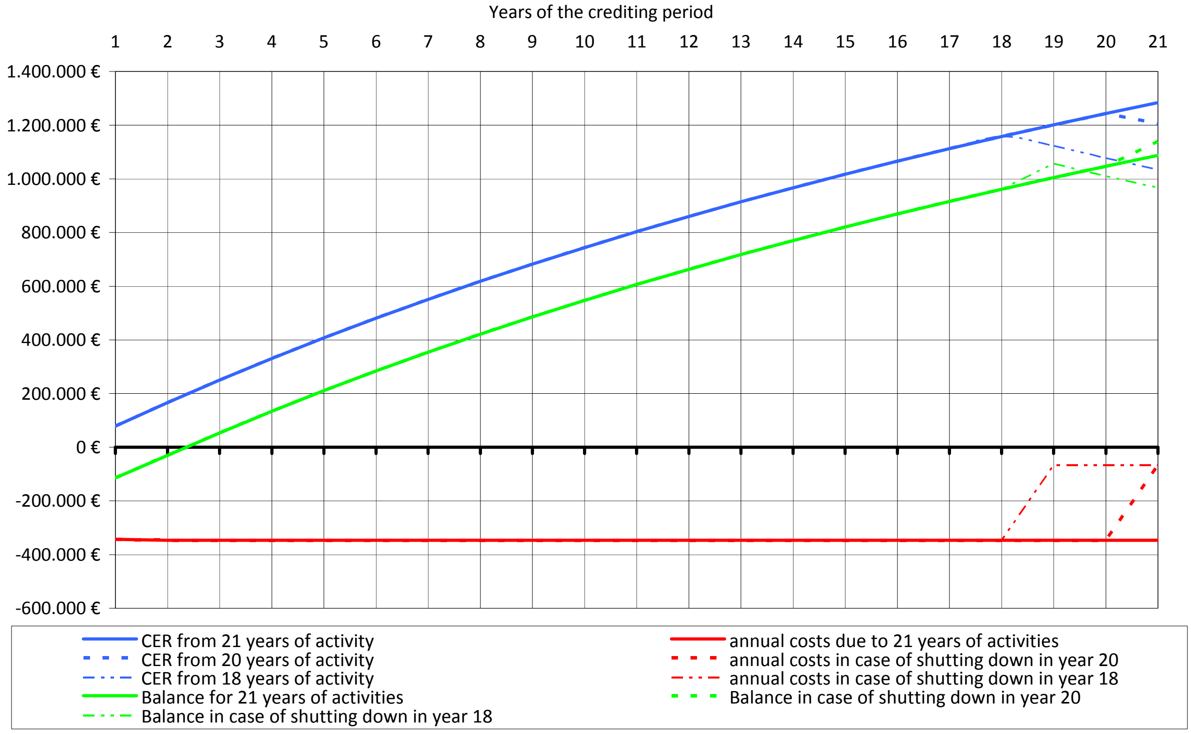

Figure 7-1: Financial balance of a CDM project lasting 21 years and the related impact of a preterm shutdown

These considerations are not intended as guideline for operators. They should instead animate reconsideration of the balancing scheme itself as these incentives are anything but sustainable.

7.2 The impact of the least important waste fraction on the sample size

Chapter 5 demonstrated the efforts necessary to apply to the UNFCCC statistical requirements. A precise determination of the baseline emissions is doubtlessly worthwhile. Table 5-2 on page 18 showed however, that the large sample size tends to be dependent on the smallest fractions in the waste as these vary the most. This is a frequently found phenomenon in MSW sampling as these small fractions are less often found which automatically produces variation coefficients of more than 120 %.

As much as their variation has an impact on the sample size necessary, just as weak is their influence on the methane generation potential of the waste or the results of the FOD model. Their impact is shown in a calculative example. In this calculation two cases have been considered to assess for the total methane generation potential of the waste. The first includes the smallest and most varying fraction; the second excludes it from the assessment. The result is impressive as can be seen in Figure 7-2.

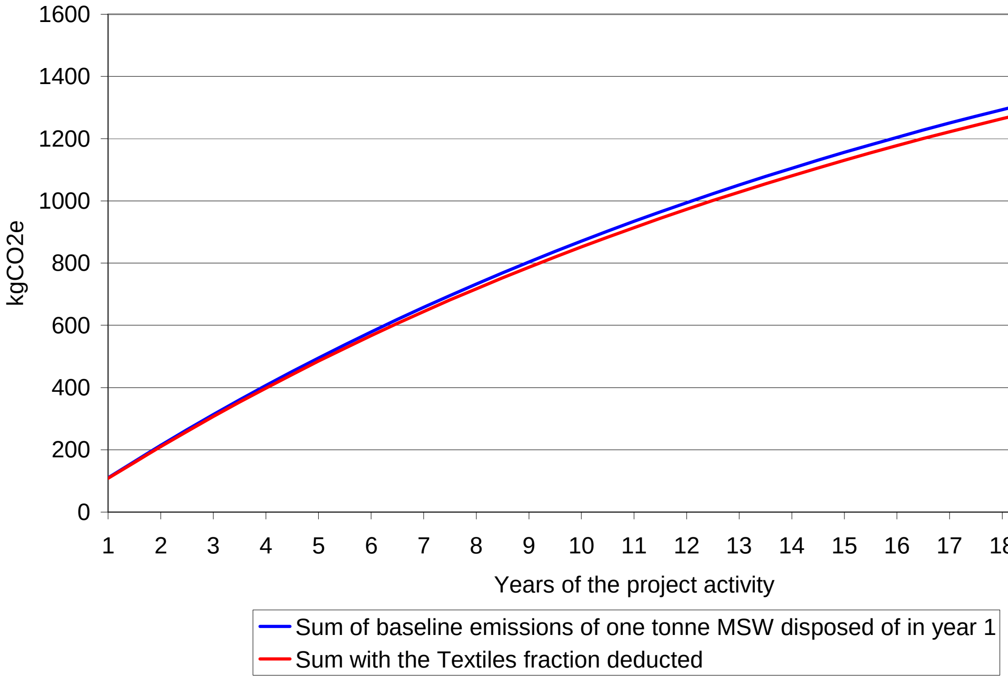

Figure 7-2: Impact of the most varying fraction on the assessed baseline emissions for one tonne MSW disposed of in year 1

Over 21 years the difference amounts to 1 %.

A simple pragmatic solution for this problem seems to be to restrict the high statistical requirements (95 % confidence level, 20 % max. uncertainty) to those fractions which deliver the biggest methane potential. These would be the categories "paper and cardboard", "garden and park wastes" and "kitchen and food waste".

A second approach is to limit these restrictions to fractions with a share larger than 5 % on the overall MSW mass.

7.3 The problem of the organic content categories in the FOD model

The baseline tool demands the categorization of the MSW in fractions to allocate these to the respective default values of the degradable organic carbon (DOC_j). The categories are divided into subclasses named "Dry" and "Wet". It is not further specified where the differentiation should be made (cf. Chapter 4.3).

A procedure on how this should be done is available though for the degradation coefficient parameter k_j. This parameter also separates into "Dry and "Wet" and further differentiates in different clime categories as it models the conditions on a landfill.

It could be assumed therefore that this scheme should be transferred to the DOC_j parameters. DOC_j assesses the degradable carbon content in the MSW disposed of and therefore massively influences the assessable methane generation potential. Additional to the clime in practice this factor is subject to a number of influencing factors (e.g. MSW collection and storage). A solely clime dependent assessment thus seems inadequate. In rain-laden regions MSW can be collected dry by storing it in tons. Whether considered wet or dry influences the assessable methane generation potential by up to 50 %. This effect is especially strong in regions with a heavy monsoon season as the categorizations are done annually. Thus it can occur that a region slips into the wet category due to one or two months of heavy precipitation.

By being balanced as wet the MSW is calculated to be rich in water and accordingly less rich in carbon and less methane-generating. In both described cases the monsoon region and the weatherproof waste collection considerably large cut downs in methane generation potential have to be accepted due to methodological requirements.

This shows that the FOD model from the IPCC GHG Inventory Guidelines has not been consequently modified to the practical demands of CDM projects.

A solution for monsoon projects could be to allow the categorization of the clime on a monthly basis. For dry collection systems allowing the proof of dry collection might solve the problem. A third way to avoid generalizations would be to develop a standardized measuring system for determination of the dry degradable carbon content.

7.4 Absent values

For any kind of residuals from treatment processes DOC_j and k_j values are demanded by the methodologies without indicating how such values should be determined or where they are received from. Determining these individually includes the risk of non-acceptance from the DoE. The guiding sentence mentioned occasionally namely, of choosing the next conservative value is not of great help either as it equalizes the individual determination. Choosing a too conservative value will lessen the revenue of a project. Default values or a standardized procedure would help on this point.

7.5 Potential of improvement in AM0025

7.5.1 The compliance rate as perverse incentive

The compliance rate of the environmental regulations during the crediting period must be monitored. It could mean for instance the requirement to install landfill gas extraction facilities on landfills. As soon as the compliance with the MSW rules exceeds 50 %, the project activity receives no further credit, since the assumption that the policy is not enforced is no longer tenable according to UNFCCC.

This implies the risk for project developers that the baseline could be nullified year after year.

In general such rules do not lack ratio as an improper baseline could result in allocation of emission reductions that have not been conducted. It delivers a disincentive though for host countries not to enforce their environmental politics as if the country does enforce its environmental policies it alienates investors from financing projects. In the UNFCCC language such circumstances are known as perverse incentives. These should be avoided wherever possible as they unintentionally generate counterproductive forces. Therefore the COP constituted in the Marrakesh accords that any legislation giving advantages to less emission intensive technologies does not have to be considered for establishing baselines. This is valid as long as the respective law has been enacted after November, 11 2001. The CDM executive board has confirmed this decision [UNFCCC 2001, UNFCCC 1004].

Therefore there is a direct contradiction between the methodology and the fundamental decisions of its authors. As a consequence DoE tend to demand the application of the methodology's demands as a DoE has no interest in conflicts with the CDM EB board.

7.5.2 Balancing problem of mass losses due to evaporation

AM0025 demands that mass losses are considered landfilled. This neglects that large losses of water through evaporation can occur in a MBT. This strains the GHG emission balance inadequately. The problem can be solved though by careful monitoring of the waste streams in the treatment facility including the water losses per section.

7.5.3 Assessment of additional transportation

It is required by the methodology to balance the emissions from additional transportation as leakage emissions. This necessitates the monitoring of the vehicle classes, their respective fuel consumption and their driven distances. There is no standard procedure prescibed for this.

In developing countries the waste collection and delivery can happen in numerous ways from oxcart to truck. To asses the fuel consumption for every single vehicle or vehicle type seems therefore inadequately complex. Instead, vehicle type categories may help. This however, needs to be agreed with the DoE in advance.

The additional transportation distance necessary for the project activity has been assessed by taking the distance between landfill and treatment facility in some PDDs.

7.5.4 Monitoring of the oxygen content in the compost heap

The lack of a quality assurance standard means that monitoring of the oxygen content of composting piles can be easily manipulated. No requirements exist as to how the sampling should be carried out. Nevertheless, a large sample size is necessary to reach the required statistical significance (95 % confidence interval, 20 % uncertainty).

As these samples can be taken arbitrarily, the results are more or less meaningless. It is hard to observe if the operator of the facility draws samples systematically at different places in the piles. He can in theory draw samples at places where the oxygen content is high, and thus intentionally showing the balance in better light.

7.5.5 The assessment for the fossil carbon content

AM0025 necessitates the determination of the fossil carbon content of MSW or RDF combusted in order to calculate the emission from fossil sources caused by the combustion process (FCF_{MSW}).

For this purpose, the eleventh update of AM0025 introduced the monitoring standard D6866 and D7459 of the "American Society for Testing and Materials"(ASTM). According to AM0025, all MSW fractions should be present in the sample in equal proportions as in the MSW. Possible sampling points for this procedure are before and after the combustion. [ASTM 2009]

The monitoring of the stack gas is far simpler than drawing samples from the inhomogeneous, heterogeneous waste stream. Therefore the first variant is to be preferred.

7.5.6 Combustion efficiency

The history of the combustion efficiency has been described in Chapter 6.4.5. The numerous amendments regarding waste incinerators indicate that the focus was laid on this treatment variant.

It must be considered highly questionable, whether detailed instructions on how possible residual GHG emissions should be measured are stated but in fact these totally neglect the toxic emissions that can derive from waste incinerators.

7.5.7 The defective equation for baselines with cogeneration plants

In case a CHP plant is included in the baseline and will be substituted by the project activity, equation (27) of AM0025 is to be applied. A detailed examination of this equation however, shows that it contains an error regarding the SI-units. This error results in cutting down the electrical energy produced by the project by the factor 1000^{-1}. The consequences of this circumstance have been explained in Chapter 6.4.4.

7.5.8 Other improvement potential

- There is a copy and paste error in the baseline tool on page 4. The factor F does not represent the share of organic carbon non-degradable under anaerobic conditions. The Factor DOC_f which lacks description is directly below Factor F and can be considered as the one originally addressed.
- AM0025 contains a wrong reference to source information on page 26: The MCF_p– factor for balancing emissions from waste water in different water bodies. The data addressed can be found in IPCC GHG Inventory Guidelines Volume 5, not Volume 4.
- The factors MC_{N2O} and MC_{CH4} mentioned on page 34 are incomplete in their description. "Incineration or RDF/stabilized biomass combustion" is the correct term to complete their descriptions.
- According to AM0025, page 30, the total amount of methane produced annually in waste digestion plants shall be recorded as "tCO_2/year".

7.5.9 Conclusion

AM0025 is a special kind of methodology in several aspects. In contrary to other methodologies it has not been designed by project developers but by the CDM Methodology Panel.

Bundling all relevant waste treatment options is therefore of high relevance for the waste sector in the CDM. In its present form however, there are still several deficiencies. This insight is taken up in the following draft of alternating procedures to establish a practical GHG emission balance.

8 Basic suggestions for a simplified methodology for waste treatment activities avoiding methane emissions

The basis of methane emissions forecasting following UNFCCC standards has been discussed in the foregone chapters. The methodologies available for methane avoidance activities have been examined. Hindrances and improvement potential have been listed. The potential of the different treatment options of AM0025 have been shown. Combined with the findings that can be extracted from the IGES Database, showing that most registered methane avoidance projects have not yet been allocated any CER, the situation needs to be considered as improvable [IGES 2009].

Especially AM0025 has been updated numerous times, not always improving the situation for these projects. For instance the CDM Executive Board decided in February 2006 to henceforth allocate time-shifted CER [UNFCCC 2006].

Therefore the conduction of waste treatment projects in the framework of the CDM has been considerably aggravated. At the same time, however, the claim to emission rights should be possible for such activities in the appropriate context. This chapter will list simplified procedures to enable a significant but nevertheless practicable balancing of methane avoidance projects.

It might serve to complement the CDM or - further elaborated – to deliver a methodology for the VER market (cf. Chapter 2.2.4). Like AM0025 this draft is modularized. Every module obtains definite boundaries to avoid double-counting.

The time shifted allocation approach according to Tier 2 of the FOD model is abandoned in favour of the older Tier 1 approach. The methane avoidance is thereby assessable in the year of the avoidance – the year of the arising expenses which is analogical to common practice of eco efficiency analysis procedures. It should reduce the payback period of the waste treatment options considerably. Monitoring procedures of AM0025 are adopted where applicable. Solutions from common industrial practice or simplified conservative procedures are also suggested.

The modules included are the following:

- Sorting of MSW
- Recycling of MSW
- Combustion of MSW including energy utilization
- RDF Production and utilization
- Composting of MSW
- Anaerobic digestion of MSW
- Production of fertilizers

These modules are further expounded in the following chapters:

8.1 Establishing the baseline

The UNFCCC baseline tool for forecasting methane emissions is applied here [UNFCCC 2008] in slightly modified form (cf. Chapter 4.4).

- The FOD Model is used according to Tier 1.
- The correction factor φ is reduced from 0.9 to 0.85 to compensate uncertainties from simplifying assumptions in the case of IPCC waste composition data used instead of waste sorting analysis.
- The absent DOC_j values are no longer needed for residuals of waste treatment activities as residuals emissions are assessed by generalizing deductions of the emission reductions achieved. Therefore the FOD model is not needed here.
- The unspecific categorization "wet" and "dry" to determine the DOC_j – the degradable organic carbon content - is abandoned. Instead if he proves that there is no humidification, the project developer may apply the category "dry". Furthermore it is allowed to balance on a monthly basis and to sum up these results at the end of the year. The degradation coefficients remain untouched by this modification. These would have been rendered irrelevant anyway as Tier 1 is now applied.
- The demanded statistical significance (95 % confidence interval, 20 % uncertainty) to assess the composition of the MSW can be restricted to the fractions generating the most methane. The sorting should be assisted by a guideline (cf. Chapter 5) [Landesumweltamt Brandenburg 1999].

Compared to the present UNFCCC requirements, these modifications should allow for an easier establishment of the baseline.

8.1.1 Determining the grid factor of the electricity grid

Balancing the electricity consumption and the production of electricity of a project activity necessitates a grid factor (tCO_2/MWh).

AM0025 demands the use of the UNFCCC Tool to calculate the emission factor for an electricity system. Therefore it is necessary to monitor the detailed operations of all plants supplying energy to the grid, and this down to every hour of the year. [UNFCCC 2007]

This can prove to be very difficult and therefore alternative ways are now proposed:

- National authorities that publish such factors might be used as source
- International databases (e.g. IGES, IEA and UNDP) offering country specific values might be used
- Project design documents of validated CDM projects are a valid source
- As conservative alternative the relatively low emission factor for middle Europe can be applied.[Eco Invent Centre 2008]

8.1.2 Additionality

Projects that shall serve to protect the climate should most appropriately improve the status quo in the respective area in the same time. For VER projects the demonstration of additionality is therefore deemed that it can be shown that there is still unprocessed MSW disposed of on landfills in the region of the projects.

In case of CDM appliance, the baseline tool for demonstration and assessment of additionality should be used [UNFCCC 2008].

8.2 RDF Production

The activity conducted within the boundary of this module eliminates the methane building potential of the processed waste as this is converted to a valuable fuel. The methane avoidance is valid only if thermal utilization of the RDF is afterwards ensured by either selling the RDF to customers or by using these in an own facility.

Any emission due to electrical energy and fuel consumption is to be deducted from the avoided baseline emissions.

In contrast to AM0025, the confirmation of utilization can be provided by sales documents, given a sale at a fair market value since the disposal of the bought RDF on a landfill would be irrational for customers.

The monitoring necessary on the grounds of AM0025 is thus made obsolete as it could be difficult to carry this out in developing countries. Without incorporating a utilizing facility within the project boundary, the project can therefore at least claim methane avoidance.

Utilization of RDF within the project boundary must be balanced in the module RDF utilization. Possible recyclables extracted can be balanced in the module "Recycling".

8.3 RDF Utilization

The module RDF utilization shall serve to compare the substituted emissions of the primary fuel to the fossil based emissions of the combusted RDF.

Any emission due to electrical energy and fuel consumption is to be deducted from the avoided baseline emissions.

In contrast to AM0025 the determination of the fossil carbon content of the waste may be done by various procedures.

The following procedures are eligible:

- A manual sorting analysis used for determining the waste composition might be amended to assess the Fossil Carbon Content by allocating the IPCC Fossil Carbon Content factors to the respective fractions [IPCC 2006]
- A standardized radiocarbon analysis such as required by AM0025 Version 11.
- Other methods that are agreed with the DoE

Furthermore, to assess the substitution potential of the RDF precisely there should be random sampling in combination with the determination of the calorific value.

8.4 Anaerobic digestion of MSW

This module is structured analogically to AM0025. It can only assess for methane avoidance.

In case of a VER appliance of this draft, any gas delivered from the digestion plants should not be assessed for in the VER framework. Instead the output of the facility can be considered a 100 % carbon neutral fuel. As the CER are more valuable the utilization could therefore be balanced in the CDM framework using methodology AMS II D, AMS II E or AMS II F

Any emission due to electrical energy and fuel consumption is to be deducted from the avoided baseline emissions.

Any partial mass streams extracted from the waste before feeding the facility can be excepted from the balance in case this eases the project balancing.

The monitoring of the emergency flares required from AM0025 is not included in this draft. There is a considerable economic interest for the operator in running a facility without losses.

In order to avoid elaborate monitoring procedures regarding methane leakages, a default value of 10 % shall be deducted from the achieved emission Waste incinerators

Any emission due to electrical energy and fuel consumption is to be deducted from the avoided baseline emissions. Further the fossil based CO_2 emissions (e.g. from plastics) are assessed as project emissions.

The fossil carbon content in the MSW may be determined by the following options:

- A manual sorting analysis used for determining the waste composition might be amended to assess the Fossil Carbon Content by allocating the IPCC fossil carbon content factors to the respective fractions. [IPCC 2006]
- A standardized radiocarbon analysis as required by AM0025 Version 11.
- Other methods that are agreed on with the DoE

In case of VER appliance of this draft, this module assesses methane avoidance only. Generated electricity could be accounted for in the framework of AMS II B.

To consider eventual emissions from residual organics in the combustion ash as a result of inefficient combustion, the GHG emission reduction is reduced by 5 %. The analysis of the total carbon content of the ashes as demanded by AM0025 is thus not needed.

8.5 Transports

Additional transports and related emissions are difficult to assess in the waste sector. A large number of collectors with different routes and different vehicles deliver the collected MSW.

AM0025 demands the determination of these emissions by recording the distances travelled, the vehicle capacity and the fuel consumption per 100 km for each individual vehicle. No guidance is given on how this information can easily be gathered.

Validated PDD however, shows that DoE accept the assessment for additional transportation distances by using the distance between landfill and treatment facility as the conservative value for the MSW delivery.

Following transport distances in the treatment and disposal chain are easy to identify as starting point and destination as well as the vehicles in use which are known.

In case of RDF, fertilizer or recyclable sales, a substitution of primary materials is conducted therefore no additional transportation emissions are hereby generated.

Only those elements of the treatment chain that are part of the disposal path should be assessed as additional transportation. One hypothetical additional transportation path would thus be the distance from the substituted landfill to the sorting facility to the composting facility finally to landfill of the handling residuals. The vehicles in use would have to be identified and the masses transported assessed by weighing.

The MSW collection is the most complex element regarding the identification of the used vehicles. Instead of detailed testing, a viable means would be the use of approximate categories for fuel consumption.

8.6 Production of fertilizers

In developing countries it is usual practice of local farmers to use the organic material bound in landfills as fertilizers. This hygienically and environmentally questionable practice could be substituted by offering professionally produced compost derived from MSW. Contraries could be taken out in the treatment process. In case the organic matter itself is sufficiently aerobically digested its emissions would be mostly eliminated. An important element of a circular economy would be established and even industrial fertilizers could be substituted by such practice.

AM0025 contains no balancing methods for the substitution potential of fertilizer produced from composting. AMS III F even requires keeping track of compost provided in order to give evidence that it is not subject to anaerobic conditions and thus producing methane (c.f. Chapter 6.2).

The incorporation of industrial fertilizer substitution would in fact provide a valuable incentive for the vitalization of a circular economy. The assessment would be possible by comparing the emissions from production of compost with emissions from industrial fertilizer production. The result should then be halved to provide a conservative assumption as compost matters can indeed cause considerable residual emissions. The carbon intensity of industrial fertilizers could be obtained using European eco efficiency analysis databases like the one from [Eco Invent Centre 2008].

8.7 Recycling

Although establishing a circular economy with minimal resource consumption is a long-term environmental objective, there are no methodologies available for recycling activities in the CDM framework.

Due to a lack of data on transportation distances and production process on the international resource market, such balancing can only be considered as including too many uncertainties. Nevertheless the potential of carbon crediting to user support in a circular economy should not be discounted.

Resources like glass, metal, recyclable plastics and paper should be incorporated in this drafted balancing system. The Eco-Invent database may serve to develop these models. The emission intensity of the secondary resources would need to be monitored whilst the primary resource production emissions could be appointed by data of European production factors. These are reasonably energy efficient and thus conservative. Both production chains would need to be balanced to the point where both processes equal each other.

For example, secondary aluminium production substitutes the extraction of bauxite, the transportation of the raw material, the synthesis of aluminium oxide, the transport of the aluminium oxide and the fused-salt electrolysis by melting down aluminium scrap. All relevant values of these processes are available in the [Eco Invent Centre 2008].

Additional transportation challenges every pragmatic balancing approach as the primary as well as the secondary transportation chain has to be defined. It can be seen from the AM0025 balances, that transportation is one of the smallest emission sources. Therefore it is proposed to generalize this aspect. Both balancing sides include a large part of unknown transportation sequences. Additionally the primary transportation chain is considerably longer. Therefore a 5 % abatement of the emission reduction achieved by the secondary resource production process compared to the primary one – transportation excluded - seems adequate.

8.8 Further development of the draft

This draft is firstly intended as suggestion for further elaboration of AM0025. The approaches described are based on AM0025 and focus on an improvement of the situation for waste treatment projects. Further, elements have been implemented that remained unconsidered in AM0025 such as recycling.

Alternatively this further elaborated draft could be applied as VER methodology. The VER Gold Standard Foundation allows only projects that produce electricity on a purely renewable basis. Landfill gas avoidance therefore cannot be accounted for in this framework. Therefore another VER registry will have to be chosen. TÜV Süd, one of the leading CDM DoE, offers an alternative platform for VER certificates, the Blue Registry.

9 Conclusion and outlook

9.1 Subsumption of the results

The results derived from this study now allow for a conclusive valuation of CDM projects' feasibility in the waste management sector.

In Chapter 4 the landfill gas forecasting tool used by UNFCCC, the FOD model has been discussed and the consequences of its time-shifted application have been addressed.

The concept pointed out in Chapter 5 demonstrated how the statistical significance can be handled in respect of UNFCCC demands for the waste composition analysis. Further Chapter 7.2 demonstrated that reasonable results could also be obtained with less effort.

Chapter 6 compares the emission reduction potentials obtained by the diverse treatment options in the framework of AM0025. A considerable emission reduction potential is at hand in the calculation scheme of AM0025. Although there remains a large gap between the AM0025 potential and the results of assessment by DIN EN ISO 14040 eco efficiency analysis standards due to the time shifted allocation of CER. From variant to variant these potentials differ widely and it has to be carefully decided what kind of technology should be applied in the respective situation to receive optimal results.

The aspects of the time-shifted allocation of CER according to Tier 2 of the FOD model have been examined in Chapter 7.1 in detail. The financial incentives identified contradict the main idea of the CDM, the clean development, as it is more profitable to shut down the treatment facilities during the crediting period in order to optimize the project revenues. This is not in line with sustainable development.

Other elements hindering project developers to implement waste treatment projects have been identified in the following subchapters of Section 7. Despite several amendments and updates, many obstacles still remain for waste management projects.

Chapter 8 used these findings for drafting a concept for a simplified balancing procedure. It may either be used to feed the further elaboration of the existent methodologies or to create an alternating balancing scheme in the framework of VER projects.

These results should indicate the unexploited potential in the waste sector for combating climate change. They show the lack of feasibility of CDM projects in the waste management sector and provide suggestions for alternatives.

9.2 Future developments of the carbon market

Despite its success, in various respects the CDM remains subject of fundamental criticism. Opposing opinions label it a modern "sale of indulgences" with which polluting industries can officially carry out their business. The situation is considerably more complex.

The deficits in implementing CDM projects smoothly in their respective social environments remain. CDM-financed dams flood entire valleys and waste treatment projects can take away the livelihood of the waste pickers.

In practice, the environmental impact study necessary for CDM projects is often conducted insufficiently. For combustion activities especially in the waste sector there remains a large monitoring gap regarding non GHG pollutant emissions which should definitively be closed.

Furthermore the CDM creates incentives at times to maintain the operation of antiquated technologies by delivering vital financing no longer provided by the product sales; for instance by implementing flue gas cleaning systems (N_2O elimination) or utilizing wasted thermal energy.[WDR 2009]

In terms of its aim of a clean development the CDM still lacks a sufficient legal fundament that bans the big and quick hits that dominate the present CER generation (HKW elimination, landfill gas elimination and N_2O elimination). The reason for their dominance is their low proportion of €/ tCO_2e avoidance costs. Sustainable technologies like waste treatment or wind energy cannot provide such low costs. Thus the largest share of CER generated is generated by large and cheap end-of-pipe projects. In return these cheap measures lower the CER price which renders more sustainable and expensive project types from less attractive to unprofitable.

In 2005 there were 134 CDM projects that will claim around 265 million CER until 2012. 40 million CER of these are allotted to two HFC-23 avoidance projects and another 70 million CER to one single N_2O Project in South Korea. The CER-allocated two of these three projects therefore made up for 42 % of the total sum of CER at that time – flooding the market with cheap CER. The revenues from these CER most likely exceed the revenues from product sales in these factories. This is an effective incentive for investors to build more of these plants. Therefore it seems more appropriate internationally to agree on banning these large punctual GHG sources by law [CDM Watch 2005].

Besides these isolated considerations of the CDM from a more general point of view it is to be amended that the coverage of the global GHG emissions sources by carbon trading systems remains incomplete.

On the part of the industrialized countries it is evident that just a fraction of their economy's GHG emissions is being capped by trading systems and their emission targets range far in excess of the necessary reduction targets. On the other hand, emerging markets and developing countries do not have to meet emission thresholds at all.

Therefore it seems necessary to expand the system from both sides. The sector coverage of the emissions trading systems should be expanded to all emission sectors possible. Also all industrialized nations should start participating in emissions trading schemes or start establishing their own ones. When the United States recently started the development of an own emission trading scheme, a strong signal was sent out to the carbon market and other countries for other countries [Ulken 2009].

As far as developing countries are concerned, measures should be found to upgrade the present mechanism from a mere offsetting mechanism to a framework which enables effective climate protection. The concepts like the sector crediting approach might deliver the tools necessary. These concepts envisage trading just a fraction of the GHG emission reductions achieved. This could allow for a massive expansion of climate protective activities without flooding the carbon markets and at the same time effectively reducing global GHG emissions [bifa 2009].

Given an appropriate incorporation of forest protection mechanisms like REED (Reducing Emissions from Deforestation and Degradation) the instruments for an effective fight against global warming are available. All it needs beyond that is the political will to use them.

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