Reasons for the Underperformance of Clean Development Mechanism Project Activities in the Animal Waste Management Sector

- An Analysis of Swine Manure treating Facilities in Latin America

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To my grandmother, Hildegard Klier.

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SUMMARY

INTRODUCTION

The Clean Development Mechanism (CDM) is one of the flexible, project based mechanisms of the Kyoto protocol, which came into force in 2005. The projects participating in this mechanism estimate the potential emission reductions ex-ante by following specific guidance of the Executive Board (EB) of the United Nations Framework Convention on Climate Change. The amounts of emission reductions estimated and the amounts of emission reductions monitored ex-post differ. In some sectors projects reduce more emissions than forecasted (e.g. industrial gases sector) in other sectors less (e.g. landfill sector). The performance of project activities undertaken in the animal waste management sector is particular low (45 %). These projects aim at avoiding greenhouse gas emissions by capturing and flaring methane emitted from open lagoons in which swine manure is disposed. The reasons for the overestimation of potential emission reductions are subject to this doctoral thesis. In order to investigate whether inaccurate ex-ante assumptions are to be held responsible, it is analyzed if the ex-ante assessment of descriptive statistical parameters (hypothesis I) or if the use of default values issued by the Intergovernmental Panel on Climate Change (IPCC) (hypothesis II) causes the gap between forecasted and measured emission reductions.

MATERIAL AND METHODS

A sample of projects is identified, showing comparable characteristics. Relevant documentation regarding each project is consulted including project design documents, validation reports, monitoring reports, verification reports and others.

As assessment factor the baseline emission forecast success is introduced. It is analyzed for each project of the sample. The hypotheses are further elaborated by assessing each applicable parameter and developing assumptions on its impact. It is investigated, if the suggested assumptions and introduced alternative approaches influence the baseline emission forecast success. Corresponding correction factors are derived. The quality of the monitoring is assessed by reviewing the monitoring reports and related documentation in order to receive information on mistakes and failures occurring during the monitoring of the projects.

The results for all parameters applicable to each hypothesis are combined in order to test the hypothesis. Finally, all quantifiable measures are combined and applied to determine the overall impact of the parameters on the baseline emission forecast success.

RESULTS

Initially the projects of the sample estimated the baseline emissions with a forecast success of 25 %, meaning that only 25 % of the forecasted baseline emissions were monitored ex-post. Analysing the descriptive statistical parameters (hypothesis I) results in heterogeneous correction factors between 0.95 (population) and 1.14 (start date). The assessment of the influence of default values (hypothesis II) shows that all default values lead to an overestimation and range from 1.16 (volatile solids not weight adjusted) to 1.64 (methane conversion factor). Using the alternative default values introduced in this study for the methane conversion factor and the volatile solids and adjusting the latter by animal weight have the strongest impact on the baseline emission forecast success.

If all resulting correction factors of the analysed parameters are combined the baseline emission forecast success is improved by a factor of approximately 3.13. The resulting forecast success is about 79 %.

The impact of the monitoring could not be quantified. On the one hand mistakes of the management personnel and monitoring equipment are found on and on the other, monitoring procedures, such as the indirect determination of the methane content of the biogas on a quarterly basis lead to inaccuracies. However, these effects may influence the forecast success both in a positive and in a negative way.

Although the introduced corrections increase the baseline emission forecast success significantly, the improved performance of the projects is still heterogeneous. This shows that not all issues are covered by the corrections. The remaining discrepancies between forecasted and measured data could be due to monitoring issues. Another reason could be the fact that nearly no project specific data was available to test the default values. Therefore, default values were replaced by new and adjusted default values developed in this study.

CONCLUSION

Although the default factors have been proven to be inaccurate, the institutions advising to use them cannot be held solely responsible for the low performance of the projects. The UNFCCC methodology along with the IPCC guidelines inform the project developer about risks and uncertainties related to the default values and suggest more accurate measures. Nevertheless, it has been shown that the IPCC defaults are not substantiated enough and are based on only few references or estimates. Therefore, project developers have to use the default values with caution and obtain data from on-site measurements whenever possible.

In addition, it has to be considered that the perspectives of the IPCC and the UNFCCC are different when estimating emissions. Both aim at conservative estimates. However, from the point of view of the IPCC, emissions should be rather overestimated than underestimated in order to assess the greenhouse gas inventories conservatively. The opposite is the case for CDM projects were the overestimation should be prevented through conservative approaches. Therefore, adjusting the IPCC defaults by a well substantiated conservatism factor when obtaining them for CDM projects should be considered.

Summing up, it can be concluded that forecasting the biological process of biodigestion is complex and not thoroughly understood yet. More research has to be undertaken, especially on the methane conversion factor, in order to have default values allowing accurate and conservative forecasts.

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ABBREVIATIONS

AD	anaerobic digester
AL	anaerobic lagoon
AM	approved methodology
AMS	approved small scale methodology
AWM	animal waste management
AWMS	animal waste management system
B	methane yield
B_0	maximum methane potential
BE	baseline emissions
CAFO	confined animal feeding operations
CDM	Clean Development Mechanism
CER	certified emission reduction
CH_4	methane
CO_2	carbon dioxide
d	days
D NA	desgnated national entity
DOE	designated operational entity
e.g.	exempli gratia
EB	executive board
EF	emission factor
ER	emission reduction
GHG	greenhouse gases
GWP	global warming potential
HFC	hydrofluorocarbon
HRT	hydraulic retention time
IPCC	Intergovernmental Panel on Climate Change
L	leakage
LoA	Letter of Approval
LU	livestock unit (500 kg)
MCF	methane conversion factor
mio.	million
MS%j	fraction of animal manure handled in system j
na	not applicable
N_2O	nitrous oxide
n_m	number of days in a month
No.	number
P	pressure
PDD	project design document
PE	project emissions
PFC	perfluorocarbon
PP	project participant
SF_6	sulphur hexafluoride
SM	swine manure
T	temperature
tCO_2e	tonne of carbon dioxide equivalent
TS	total solids
UN	United Nations
UNEP	United Nations EnvironmentProgramme
UNFCCC	United Nations Framework Convention on Climate Change
VS	volatile solids excreted
€	Euro

1 INTRODUCTION

1.1 General Description of the Clean Development Mechanism (CDM)

The clean development mechanism (CDM) is a young mechanism that came into force in line with the Kyoto protocol in February 2005. It was established as one of three project based flexible mechanisms of the Kyoto Protocol and aims at several goals, one being to enable industrialized countries to implement emission reduction measures in developing countries, which allows them to save abatement costs. Reducing greenhouse gases (GHG) emissions often requires high investments when undertaken in developed countries. On the other hand, emission reductions can often be accomplished at lower prices in developing countries. In addition, the CDM promotes technology transfer and sustainable development, as implementing project activities in developing countries usually requires the import of technology and know-how (Glachant et al. 2007).
Six key gases[1] are eligible under the Kyoto Protocol. As carbon dioxide is the principal GHG among these, all GHG emissions reduced are transformed into CO_2 equivalents. Each certified emission reduction (CER) is valued one tonne of CO_2. CERs are issued by the United Nations Framework Convention on Climate Change (UNFCCC). After the issuance, CERs can be sold to industrialized countries which have emission reduction targets (UNFCCC 2008; UN 1998).

Up to October 2009 over 1,800 CDM projects have been registered at the United Nations Framework Convention on Climate Change (UNFCCC). Various project types are eligible under the CDM. Some projects reduce emissions by implementing renewable energy sources (e.g. geothermal-, wind- and hydropower) or by capturing potential GHG (e.g. methane, nitrous oxide, hydrofluorocarbons etc.). Many of these projects are operational and have received CERs. The traded CERs form a significant part of the revenues of these projects. (UNFCCC 2009)

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[1] Carbon dioxide ($C0_2$), Methane (CH_4), Nitrous oxide (N_20), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6)

1.2 The CDM Project Cycle

Before receiving CERs, a CDM project has to pass a complex process, which is presented in the following. This CDM project cycle aims at ensuring that real, measurable and verifiable emission reductions are generated by the projects. These emission reductions have to be additional to what would have occurred without the implementation of the CDM project (UNFCCC 2008).

To understand this process, the five main steps that have to be completed before a project receives CERs are explained below.

Step 1: Validation

The project developer describes the planned project in detail in a project design document (PDD) following an approved methodology[2] and general UNFCCC guidance. The validating designated operational entity (DOE) checks the correctness of the PDD. If the project is in line with all applicable UNFCCC requirements and has received a Letter of Approval (LoA) from the host country's designated national authority (DNA), the project is submitted for registration to the UNFCCC Executive Board (EB).

Step 2: Registration

The EB with support of assigned experts makes the final judgment on whether the project activity is suitable under the CDM. Unless three members of the EB request a review of the project, it is registered as CDM project activity.

Step 3: Monitoring

After the project is implemented and operating, the emission reductions have to be monitored by the project developer. They have to be documented according to a monitoring plan described in the PDD. The project proponent is flexible in dividing the entire crediting period in monitoring periods. At the end of each period, the emission reductions are presented in a monitoring report. This report is submitted to a DOE for verification.

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[2] If no approved methodology is applicable to the project, a new methodology may be developed which has to be approved by the Executive Board.

Step 4: Verification

Before CERs can be issued, a DOE verifies that the implementation, operation and monitoring of the project activity were in accordance with the registered monitoring plan. In the verification and certification reports the DOE certifies the reduced amount of emissions.

Step 5: Issuance of CERs

After the verification, a request for issuance of CERs is submitted along with the monitoring report and the verification/certification report to the EB. In case of compliance with the UNFCCC requirements, the verified/certified amount of CERs is issued (UNFCCC 2008).

At the stage of validation (step 1), the amount of CERs to be generated by the project activity is estimated. The number of potential carbon credits is forecasted based on the methodology. However, it is only after step 6 that the project owner will know how many CERs were actually generated. Recent analyses point to a big gap between the ex-ante estimated and the ex-post issued CER amounts in many cases.

1.3 Animal Waste Management Projects under the CDM

Animal waste management projects form one project type, eligible under the CDM. These projects aim at reducing emissions by changing the animal waste management practice of farms. Many livestock producing farms store and dispose wastewater in uncovered pits or lagoons. This situation on site is called baseline scenario. In these treatment systems manure decays anaerobically through bacteria, which produce biogas. Biogas is composed of methane and carbon dioxide with small fractions of water, sulphuric acid, nitrogen, oxygen and hydrogen (Table 1). The exact composition of biogas depends mainly on the type of substrate and the content of dry matter (Schattauer 2004; Gray 2004).

In line with a CDM project open lagoons are replaced by new covered lagoons. Methane is captured and destroyed through flaring. Flaring methane results in carbon dioxide and water, and, since methane has a global warming potential (GWP) of 21, GHG are reduced. The new situation on farm is called project scenario. It is assumed that the amount of methane produced in the baseline scenario and in the project scenario is equal. A project may consist of more than one farm. Often farms are bundled, hence a group of lagoons form one project. The covered lagoons are referred to as anaerobic digesters or biodigesters. However, these digesters are neither mixed nor heated. Hence, they differ greatly from the European understanding of anaerobic digesters, which are usually operated at a certain temperature with specific mixing equipment and controlled feeding etc.

Component	Proportion [vol. %]
Methane (CH_4)	50-75
Carbon Dioxide (CO_2)	25-45
Water (H_2O)	2-7
Sulphuric acid (H_2S)	20-20,000 ppm
Nitrogen (N_2)	<2
Oxygen (O_2)	<2
Hydrogen (H_2)	<1

Table 1: Composition of Biogas (Kaltschmitt et al. 2001; Gray 2004)

In case of animal waste managing CDM projects, the basis of every CER is the actual amount of methane generated, captured and destroyed. CERs are measured in tons of carbon dioxide equivalent (tCO_2e). Therefore, methane emissions are converted as per Equation 1.

$$CO_{2e\ methane} = \frac{CH_{4\ annual} * \mathrm{GWP}_{\mathrm{CH_4}}}{1{,}000}$$

Equation 1: Carbon Dioxide Equivalent of Methane

Where

$CO_{2e\ methane}$	Carbon dioxide equivalent emission in [t]
$CH_{4\ annual}$	Annual methane production in [kg]
GWP_{CH_4}	Global warming potential of methane in [-]

1.4 Issuance Success of Animal Waste Management CDM Projects

Several steps have to be completed by a CDM project before it receives CERs. The performance of a CDM project can be ascertained by comparing the amount of emission reductions estimated in the PDD and the number of CERs issued after verification (chapter 1.2). The resulting percentage serves as evaluation criterion and is called **issuance success**.

Table 2 (UNEP Risoe 2009) gives an overview over the issuance success of different project categories. It can be observed that the performance of the projects varies among types. Projects reducing N_2O, HFCs and fugitive emission deliver more CERs than expected. They achieve issuance successes from over 100 %. In contrast, geothermal, landfill, coal bed /mine methane and agriculture projects deliver less than 50 % of the forecasted CERs amounts. Animal waste managing projects rank among agriculture projects, as agricultural projects are in this context defined as "projects producing biogas that is flared" (UNEP Risoe 2009). On average they only receive 45 % of the ex-ante estimated CERs (UNEP Risoe 2009).

CDM project type	**Issuance success** [%]
Geothermal	29
Landfill gas	37
Coal bed/mine methane	41
Agriculture	**45**
Transport	51
Energy efficiency service	63
Energy efficiency industry	74
Cement	76
Wind	77
Fossil fuel switch	86
Biomass energy	87
Energy efficiency supply side	93
Hydro power	95
Energy efficiency, own generation	97
Hydrofluorocarbons	103
Fugitive	112
Nitrous oxide	123
Total	**97**

Table 2: Issuance Success of CDM Project Types

Agricultural projects were supposed to deliver approximately 8.2 mio. CERs by Januar 2009, but only 3.7 mio. CERs were issued. Thus, companies that invested in these projects received 4.5 mio. CERs less than estimated. Assuming a CER price of 17 €[3] (Think Carbon, New Carbon Finance 2009) the expected CER-revenue is reduced by 76 mio. € so far. This loss in revenue has severe consequences for the investors. Mainly one company, AG Cert Ltd., which developed most of the low performing projects, has been affected.

[3] Average CER price 2008 (Think Carbon, New Carbon Finance 2009)

1.5 Purpose of the Study

The above described low issuance success of animal waste managing projects is even more interesting, considering that the animal waste management sector has been seen as low hanging fruit among potential CDM project activities in the beginning of the CDM. The strong underperformance of these projects has been noted many times (e.g. Castro 2008; Point Carbon 2007; Castro et al. 2007). However, in contrast to landfill gas projects no assessment of the causes has been undertaken so far regarding manure treating project activities.

Therefore, this thesis focuses on this project type, in order to assess the reasons for the unexpected low performance in this sector. In respect to this the estimation of methane emissions is assessed in detail. As basic assessment criterion of the performance the baseline emission forecast success is developed and used (chapter 2.1). Hypotheses are advanced and assumptions elaborated (chapter 2.2). Afterwards hypotheses and related assumptions are tested following the approach described in chapter 3 and their influence on the project performance is evaluated (chapter 4).

2 ASSESSMENT OF PROJECT PERFORMANCE PARAMETERS

In order to address the reasons for the underperformance of animal waste treating CDM project activities the baseline emission forecast success is derived as assessment criterion for the over-all project performance in this chapter. Furthermore, based on the emission reduction formulae and main steps in the project management hypotheses are advanced and assumptions put forward regarding applicable parameters.

2.1 Baseline Emission Forecast Success

The baseline emission forecast success describes the relation between the estimated and the ex-post monitored amount of baseline emissions. To asses this factor, it has to be further elaborated how the success of animal waste management CDM projects is measured.
The emission reductions (ER) are defined as baseline emissions (BE) minus project emissions (PE) and leakage (L), as presented in Equation 2 (UNFCCC 2004; UNFCCC 2004).

$$ER_{net} = BE - PE - L$$

Equation 2: Emission Reductions

Where

ER_{net}	Net emission reduction due to the project activity in [tCO_2e]
BE	Total baseline emissions in [tCO_2e]
PE	Total project emissions in [tCO_2e]
L	Leakage losses in [tCO_2e]

The baseline emissions are those that would have been emitted in the absence of the project. The project emissions occur in addition to the baseline emissions in line with the CDM project (e.g. electricity consumption of the equipment for pumping). Leakage has to be accounted for increased GHG emissions outside the project boundaries that are caused by the project (UNFCCC 2004; UNFCCC 2004).

In case of animal waste management CDM projects nitrous oxide emissions are negligible. Approximately the same amount of nitrous oxide which is reduced by the project is emitted through leakage. Hence, only the methane emissions are assessed in line with this research. Furthermore, animal waste managing projects show nearly stable relations between ER, BE, PE and L. The emission reductions are about 87 % of the baseline emissions, the project emissions and leakage together amount to about 13 % of the baseline emissions.
Therefore, the baseline emissions are brought into focus, as they form the main part of the emission reductions. The approximate project emissions and leakage can be derived from the baseline emissions. In consequence, not the success of estimating issued CERs, but the success of estimating the baseline emissions - the *baseline emission forecast success* - is considered as reference parameter in this study (Equation 4).

The BE estimated ex-ante are calculated as presented in Equation 3. Equation 4 shows the formula to determine the *baseline emission forecast success*. This value serves as criterion for the issuance success in this research. The more accurate the baseline emissions are estimated ex-ante, the higher the baseline emission forecast success and the higher the issuance success.

$$BE = \frac{Population * MS\%j * B_0 * VS * MCF * D_{CH_4} * n_m * GWP_{CH_4}}{1{,}000}$$

Equation 3: Baseline Emissions (BE)

Where

BE	Baseline emissions in [tCO_2e]
$Population_{month}$	Number of head of a defined population in that month in [head]
$MS\%j$	Fraction of animal manure handled in a system j in [-]
VS	Volatile solids (VS) excreted in [kg $head^{-1}d^{-1}$]
n_m	Number of days in that month in [d]
B_0	Maximum methane potential of VS in [m^3 kg^{-1}]
D_{CH_4}	Methane density in [kg m^{-3}]
GWP_{CH_4}	Global warming potential of methane in [-]
MCF_{month}	Methane conversion factor for the month in [-]

$$BE\ forecast\ success = \frac{BE_{ex-ante\ estimated}}{BE_{measured\ ex-post}}$$

Equation 4: BE Forecast Success

Where

$BE_{ex-ante\ estimated}$	BE estimated initially in [tCO_2e]
$BE_{measured\ ex-post}$	BE measured ex-post in [tCO_2e]
$BE\ forecast\ success$	Extent to which the estimated amount of BE is monitored ex-post in [-]

2.2 Advancing Hypotheses

The formulae used by project developers in order to estimate baseline emission are given in the UNFCCC approved methodologies. In this case mainly the approved methodology 0016 (AM0016) version 02 is applicable. The baseline emissions are the CO_2 equivalent of the annual methane production. The estimation of the annual methane production is based on Equation 5. It is determined by three parameters as demonstrated below.

$$CH_{4\ annual} = \sum_{mj} EF_{month} * \ Population_{month} * MS\%j$$

Equation 5: Annual Methane Production

Where

$CH_{4\ annual}$	Amount of methane produced in [kg]
$Population_{month}$	number of head of a defined population in that month in [head]
EF_{month}	Emission factor, monthly methane production per animal in [kg $head^{-1}$]
$MS\%j$	fraction of animal manure handled in a system j in [-]

As presented in Equation 5, the number of animals has to be assessed as well as the fraction of manure that is handled in the waste management system and the emission factor. The EF is defined by Equation 6.

$$EF_{month} = n_m * B_0 * VS * MCF_{month} * D_{CH_4}$$

Equation 6: Emission Factor

Where

EF_{month}	Emission factor, monthly methane production per animal in [kg $head^{-1}$]
VS	Volatile solids (VS) excreted daily per animal in [kg d^{-1} $head^{-1}$]
n_m	Days in that month in [d]
B_0	Maximum methane potential of VS in [m^3 kg^{-1}]
D_{CH_4}	Methane density in [kg m^{-3}]
MCF_{month}	Methane conversion factor for the month in [-]

Summing up, the parameters needed in order to calculate the baseline emissions are: Population, fraction of manure handled in system j (MS%j), volatile solids excreted (VS), number of days in a month (n_m), maximum methane potential (B_0), methane density (D_{CH4}) and methane conversion factor (MCF).

The listed parameters can be subdivided into two groups considering the way they are determined ex-ante[4]. The first group consists of parameters that are evaluated based on **descriptive statistical data** related directly to the project activities. This applies to the parameters population, start date, fraction of manure handled in system j (MS%j). The second group summarizes parameters that are based on **default values** (e.g. B_0, VS, MCF, D_{CH_4}).

However, an assessment of these parameters only, does not include management aspects, such as the in-time-implementation (correct estimation of the start date) of the projects or the

[4] The parameter number of days in a month (nm) is not analyzed specifically, as it is indisputable. In calculations the exact number of days of a month is used if the data is allocated to a certain month, elsewise the average number of 30.44 days in a month is used. The same applies to the methane density.The methane amount is measured and converted into dry standard cubic meters by most measurement devices. Therefore, it is concluded that the standard density of methane can be used in order to convert the gas amount form volume into mass units.

correct estimation of participating farms. Furthermore, the adequate monitoring[5] of the project performance is not included. As these aspects are directly project related they are allocated to group I (Table 3).

Basis for Hypotheses		**Parameter**
Parameter source I	descriptive statistical data	▪ Number of farms ▪ Start date ▪ Population ▪ Fraction of manure handled in system j (MS%j) ▪ Monitoring
Parameter source II	default values	▪ Volatile solids excreted (VS) ▪ Maximum methane potential (B_0) ▪ Methane conversion factor (MCF)

Table 3: Grouping of relevant Parameters

It is assumed that mistakes are made when appraising the values of the parameters ex-ante, which leads to an inaccurate baseline emission forecast and is therefore responsible for the underperformance. In order to assess this in detail, two hypotheses are advanced based on the manner of determining the parameters ex-ante (using descriptive statistical or default values) as described above.

Hypothesis I: *The ex-ante assessment of **descriptive statistical data** leads to a wrong estimation of baseline emissions.*

Hypothesis II: *The use of **default values** leads to a wrong estimation of baseline emissions.*

These two hypotheses are analysed by assessing each related parameter in detail and testing its impact on the project performance. The parameters and the approaches followed are described in the following.

[5] Monitoring is supervising the performance of a project by assuring adequate operation and maintenance procedures, keeping data records, and measuring, calculating and estimating all relevant parameters in accordance with the approved monitoring plan.

2.2.1 Hypothesis I: Descriptive Statistical Data

In the following it will be described how each parameter relevant to hypothesis I, is assessed.

2.2.1.1 Number of Farms

Animal waste management projects often consist of more than one farm. Each farm or production site keeps a certain number of animals, which produce manure and therewith the basis of baseline emissions. If not all of the farms designated to participate in a project take part, less baseline emissions are generated. Therefore, it is suggested that: *The number of farms participating in a project was overestimated, which leads to an overestimation of baseline emissions* **(*assumption 1*).**

2.2.1.2 Start Date

It has been shown for other project types (e.g. landfills) that projects are implemented behind schedule and start reporting emission reductions later than expected (Castro et al. 2007). This could be the case for agricultural projects as well. Hence, the following assumption is made: *The starting date of the monitoring on the farms was estimated too optimistically, which leads to an overestimation of baseline emissions (**assumption 2**).*

2.2.1.3 Population

The population is one of the three main parameters determining the amount of emission reductions (see Equation 5). Manure is the basis for biogas production. Since the number of animals kept on a farm correlates directly with the amount of manure excreted, it is indispensable to have accurate estimations about the number of manure producing animals in a project activity, as a first step to forecast the baseline emissions potentially generated.

As per methodology the project participant has to divide the animals into sub categories and to determine the monthly population. The data should be obtained from detailed farm records, or by calculating the difference between ‘animals in’ and ‘animals out’. No time period is defined over which record have to be obtained. (UNFCCC 2004)

Therewith, project participants are flexible in their decision on the length of the period they assess. Thus, it is not guaranteed that the chosen time period is representative. The pork industry underlies great fluctuations, due to several reasons. Owners of pork production facilities react very flexible to market conditions (Hanau 1956; Deecke 2005). In conclusion, the **third assumption** is made: *The amount of animals was forecasted to optimistically leading to an overestimation of baseline emissions.*

2.2.1.4 Fraction of Manure handled in System j

The portion of manure that is handled in the baseline system influences the quantity of methane produced as shown in Equation 5. This impact is described in this chapter.

The type of animal waste management system (AWMS) influences the production of methane. Therefore, it is important to assess if the entire amount of manure is processed in a certain system. If more than one treatment facility is available, it has to be assessed how much manure is treated in which system. This is described by the parameter MS%j.

No explicit guidance is given on how to forecast and measure this parameter. It can be assumed that not the entire amount of manure reaches the anaerobic digester, because other treatment facilities exist or manure is disposed without passing the digester. This suggests that: *The fraction of animal manure handled in system j has been overestimated, which leads to an overestimation of baseline emissions **(assumption 4)**.*

2.2.1.5 Monitoring

Project developers have to develop a detailed monitoring plan describing the way the GHG are measured and the assessed data is processed. The monitoring of emissions is complex and challenging and the time period between planning, implementation and the actual monitoring of a project is quite long. Therefore, it is assumed that due to mistakes in monitoring emission reductions generated are lost, which leads to **assumption 5**: *The monitoring is not undertaken adequately, which leads to an overestimation of baseline emissions.*

2.2.2 Hypothesis II: Default Values

In order to analyse the parameters related to hypothesis II default values have to be assessed. The methodologies ask the project developers to obtain default values from the IPCC guidelines, if no project or country specific data is available. In case of the sample IPCC 1996 default values were used for the parameters B_0, VS and MCF.

As a first step the parameters are described. Secondly the data sources (IPCC 1996) from which the default value was derived are assessed. As a third step the IPCC default values are compared to values found in literature. The average of the literature values is calculated. Finally, this average serves as alternative default value and indicates whether the IPCC default values used by the project developers are consistent or rather too high or too low.

2.2.2.1 Maximum Methane Potential

Parameter Description

B_0 is defined as **the maximum amount of methane that can be produced per kilogram of VS** of a certain substrate. It is given in cubic meters methane per kilogram VS [m^3 kg^{-1}]. B_0 for swine manure depends on animal type and diet, but is independent from all other factors (Safley et al. 1992). It is one of the factors determining the EF (Equation 6). Therefore, it is important to have an exact value to forecast the emission reductions.

Sources of Default Value

IPCC 1996 default values are used by project developers in order to estimate the methane potential of the manure. The references on which the IPCC 1996 default value for B_0 is based on are evaluated in line with this research. Additionally, more recent studies have been consulted to compare the B_0 values in order to assess whether this value changed since 1996.

The IPCC 1996 guidelines obtain the B_0 value from a study undertaken by Safley et al. (1992). Safley et al. did a literature review resulting in values presented in Table 4. They concluded that the correct B_0 value in the U.S. for breeding swine equals 0.36 m^3 kg^{-1} as published by Summers et al. (1980) and for market swine 0.47 m^3 kg^{-1} following the results of Chen (1983). These values were adopted further and led to the over-all default value of 0.45

$m^3\ kg^{-1}$ for swine manure in developed countries[6]. This value can be calculated building the average of the literature values presented by Safley et al. (1992) excluding the highest and the lowest value (Table 4).

Reference	B_0 [$m^3\ kg^{-1}$]
Summers et al. 1980	0.36
Hashimoto 1984	0.48
Hill 1984	0.32
Kroeker et al. 1984.	0.52
Stevens et al. 1977	0.48
Chen 1983	0.47
Iannotti et al. 1979	0.44
Fischer et al. 1975	0.45
Average[7]	**0.45**

Table 4: B_0 Values as presented by Safley et al. (1992)

A thorough assessment of the references consulted by Safley et al. (1992) and additional literature shows that inconsistencies in the determination of the maximum methane potential of swine manure exist, since the determination of B_o is not standardized. Thus, comparing B_0 values from different sources is difficult. Studies differ in definition of B_0, test design and reference values obtained. The **definition of B_0** is important. Since, many studies refer to the maximum methane yield achieved (B) in line with their test as B_0, even though B might have been higher, if the test was conducted under different conditions. A clear description, similar to the one given by Verein Deutscher Ingenieure (2006), where B_0 is reached if the gas yield does not increase by more than 1 % of the total gas amount produced up to that point is lacking. In addition, the information given on the **test designs** varies in

- Retention time (e.g. 90 days (Steed et al. 1994), 272 days (Massé et al. 2003))
- Use of inoculums
- Mixing frequency (once a day (Llabrés-Luengo et al. 1987; Hashimoto 1983) continuously (Summers et al. 1980))
- Feeding frequencies (every five minutes (Summers et al. 1980), once a day (Hashimoto 1984))
- VS loading rates
- Temperature

[6] Although the CDM focuses on developing countries, the values for developed countries are relevant here. It is assumed by the UNFCCC that the condition under which pork is produced at large scales in developing countries is similar to developed countries. A self test is presented in AM0016 for project developers to check if developing country conditions apply to their project.

[7] average of the data excluding highest and lowest value

- Type of digester
- Laboratory equipment (e.g. vessel (Summers et al. 1980), bottle (Steed et al. 1994))

Typical **reference values** used are total solids (TS), VS, fresh matter or organic matter. In other cases the maximum methane yield has to be derived from the maximum biogas yield which is sometimes presented without analyzing the composition of the biogas.

Since the IPCC 1996 guidelines have been published, different attempts have been made to solve this problem of lacking standardization. In 2003 a test to determine B_0 of substrates for biogas production was developed by the University of Hohenheim, which shows reproducible results (Helffrich et al. 2003). Furthermore, in 2006 a guideline by the Association of German Engineers on the fermentation of organic materials was published (Verein Deutscher Ingenieure 2006). However, these attempts to standardize the determination of B_0 are the result of quite recent activities.

Therefore, literature is used with caution when **evaluating the IPCC 1996 default** value on the maximum methane potential of swine manure. It has to be mentioned that the IPCC does not specify B_0 values for each sub-category of swine[8], even though B_0 is per definition dependent on diet and animal type (IPCC 1996). The diet for each swine category has to meet specific needs, which differ significantly (Granz 1982). Hence, the excreted manure is composed differently leading to different B_0 values. Therefore, it can already be concluded that the over-all consideration of all swine categories without further specification is most likely a source of mistake.

Comparison of Default Value with Literature Data

Additional studies are assessed, in order to evaluate the IPCC 1996 default value of 0.45 m^3 kg^{-1}. Table 5 shows different references with the corresponding B_0 values. A broad range of values can be observed. Rodrigez Andara et al. (1999) published the lowest values of 0.17 and 0.18 m^3 kg^{-1} whereas Pos et al. (1985) determined the maximum methane production potential of swine manure at 0.58 m^3 kg^{-1}. The IPCC 1996 default value lies in the middle range of these values although it is higher than the average of 0.41 m^3 kg^{-1}.

[8] Swine can be subdivided into mature swine (e.g. sows in gestation, sows which have farrowed and are nursing young, boars) and growing swine (e.g. nursers, finisher, gilts, growing boars). (IPCC 2006, table 10.1, p. 10.11)

Reference	B_0 [m^3 kg^{-1}]
Rodrigez Andara et al. 1999	0.17
Rodrigez Andara et al. 1999	0.18
Hill 1984	0.32
van Velsen 1981	0.32
Zeeman 1994	0.32
Moller H. et al. 2004.	0.35
Summers et al. 1980	0.41
Iannotti et al. 1979	0.44
Fischer et al. 1975	0.45
Hashimoto 1983	0.46
Chen Y.R. 1983.	0.47
Hashimoto 1984	0.48
Stevens et al. 1979	0.48
IPCC 2006	0.48
Hashimoto 1983	0.49
Hashimoto 1983	0.50
Kroeker et al. 1984	0.52
Pos et al. 1985	0.58
Average	**0.41**
IPCC 1996	**0.45**

Table 5: Results of B_0 Literature Review

In conclusion of the above, it can be stated that the determination of IPCC B_0 default value has been conducted based on only few studies which show significant inconsistencies in defining and determining B_0 (Table 4). Hence, using this default value to forecast the emission reductions can lead to mistakes. This can be further specified, as the default value (0.45 m^3 kg^{-1}) is higher than the average B_0 calculated from the results of various studies (0.41 m^3 kg^{-1}) (Table 5). Therewith, it is assumed that: *Using the IPCC 1996 default value for B_0 to estimate the baseline emissions leads to an overestimation of baseline emissions* ***(assumption 6)***. In addition, the alternative value of 0.41 m^3 kg^{-1} for this parameter is introduced.

2.2.2.2 Volatile Solids

Parameter Description

Volatile solids (VS) are defined as "**degradable organic material in livestock manure**" (IPCC, 1996) given in [kg]. The content of VS in manure depends on feed intake, composition and digestibility. As VS is one of the five parameters defining the emission factor, an exact estimate contributes to reliable ER forecasts.

Sources of Default Value

The IPCC (1996) issue a VS default value of 0.5 kg head^{-1}d^{-1}. This value is given for swine having 82 kg live mass, which are grown in developed countries (IPCC 1996). This over-all default value is not further specified for different swine categories (e.g. breeding swine, market swine etc.), although animal groups of one breed require distinct diets and digest differently (see also chapter 2.2.2.1). This lacking specification of the default value might be a source for mistakes when using it to forecast emission reductions.

Comparison of Default Value with Literature Data

In the following a **literature review on VS excretion rates** is undertaken. The default value is compared to VS values found in the literature, in order to evaluate its plausibility.

Only few references present clear VS excretion rates per animal. The majority of the studies either provide

1. the total amount of daily excrements (urin and faeces) per animal or
2. the amount of VS dropped daily related to one livestock unit at 500 kg mass (LU).

Therefore, the available data is difficult to compare. In the first case, the entire amount of manure is given consisting of water, total solids (TS), VS, ashes etc. Thus, the VS excretion can only be derived by making additional assumptions. The content of VS in pig manure is mostly given as percentage of TS [%TS]. Therefore, not only information about the average VS content has to be assessed. In addition, the TS fraction of the manure has to be determined, in order to derive the parameter. Data regarding these parameters is researched and compared as presented in Table 6. In order to assure comparability with the IPCC default, the values refer to average swine of approximately 82 kg (0.164 LUs) (Statistisches Bundesamt 2009).

A broad range of values can be obtained regarding the quantity and quality of swine manure. The TS content varies between 3.86 % (Institut für Umweltforschung 1986) and 10 % (Krieg 1994; KTBL 1993) leading to an average of about 6.45 %. Minimum values for the VS fraction in TS around 62 % are published by Pande et al. (1988), whereas others (KTBL 2008; Kuhn 1993; TBW undated b) present values around 81 % TS, resulting in an average VS fraction of 72 % TS. These averages derived from the presented values were used to calculate the daily VS excretion per head as presented below, if no specific value was given.

Reference	**TS** [%]	**VS** [% TS]
Baader et al. 1978	8.50	na
Bayrische Landesanstalt für Landwirtschaft 2009	7.50	na
Braun 1982	3.80	na
Braun 1982	6.40	na
Hobson et al. 1979	na	70.00
Höhne 2006	6.00	na
Institut für Umweltforschung 1986	4.17	na
Institut für Umweltforschung 1986	5.40	na
Institut für Umweltforschung 1986	3.98	na
Kloss 1981	7.50	na
Krieg 1994	10.00	76.50
KTBL 2008	7.00	80.50
KTBL 2008	7.50	na
KTBL 2004	7.50	na
KTBL 1993	6.00	77.00
KTBL 1993	10.00	na
Kuhn 1993	7.00	80.50
Llabrés-Luengo et al. 1987	3.40	na
LUFA Nord-West 2007	6.00	na
Pande et al. 1988	5.04	61.74
Pande et al. 1988	7.70	61.40
Pande et al. 1988	8.29	62.81
Perwanger et al. 1984	6.28	71.01
Perwanger et al. 1984	6.55	71.10
Rüprich 1980	7.50	na
Schulz et al. 1990	5.38	na
Schwab 2005	4.70	na
Schwab 2005	6.00	na
TBW undated b	5.00	81.00
TBW undated c	7.00	na
TBW undated a	8.50	na
Wellinger et al. 1988	4.30	na
Wong 1990	7.50	na
Wulf et al. 2003	5.60	na
Average	**6.45**	**72.14**

Table 6: Comparison of TS and VS Values

In order to determine the daily VS excretion per animal, the total amount of manure dropped per head is multiplied by the corresponding VS and TS values.

The comparison of data shows that different approaches can be followed to define the daily manure excretion rate. Galler (1989) states that pig excrete about 6 % of their live weight per day which is in line with Taiganides et al. (1996) (6.17 %). Daily excretion rates between 3.4 % and 11.1 % of the live weight are presented by Braun (1982). Other references give clear faeces and urine amounts per animal per day resulting in the VS values presented in Table 8.

In the second case mentioned above, the VS excretion per LU (livestock unit, 500 kg live mass) is presented. It is assumed, the average swine being 0.164 LUs (82 kg) (IPCC 1996). Hence, multiplying the daily VS excretion of a 500 kg swine by 0.164, results in the daily VS excretion per head of an 82 kg swine. Dürr (1983) and Hayes et al. (1979) give a daily VS excretion per LU of 2.41 kg and 2.70 kg respectively, leading to a daily VS excretion per animal of 0.39 and 0.44 kg (Table 7). Safley et al. (1992) present 8.5 kg VS per 1,000 kg mass resulting in 0.70 kg head^{-1}d^{-1} VS excretion.

Reference	**VS** [kg head^{-1}d^{-1}]
Taiganides et al. 1996	0.33
Braun 1982	0.34
Galler 1989	0.36
TBW undated a	0.39
Dürr 1983	0.39
Baader et al. 1978	0.39
Kloss 1981	0.39
Krieg 1994	0.42
Hayes et al. 1979	0.44
Chesshire 1984	0.46
Höhne 2006	0.61
Safley et al. 1992	0.70
Average	**0.43**
IPCC 1996	**0.50**

Table 7: Comparison of VS Excretion Rates

Thus, the VS excretion of an average 82 kg swine varies from 0.33 kg d^{-1} (Taiganides et al. 1996) up to 0.70 kg d^{-1} (Safley et al. 1992) with an average of 0.43 kg head^{-1}d^{-1}. In addition, Table 7 shows that the IPCC 1996 default value for VS lies over the average of 0.43 kg head^{-1}d^{-1}. Indeed, only the values published by Safley et al. (1992) and Höhne (2006) are higher than the IPCC default, all other values derived from literature are lower.

Table 8 demonstrates that the VS excretion also depends on the animal type. This is on one hand due to the different weights, as nurseries with a live weight of 19 kg certainly excrete less VS than a boar reaching 200 kg. On the other hand it is a result of specific feeding meeting distinct breeding/growing requirements, as described above.

Summing up, it can be concluded that the daily VS excretion clearly depends on the animal weight and type. In addition, it has been shown through the literature review resulting in a VS value of 0.43 kg head^{-1}d^{-1} that the VS value provided by the IPCC 1996 (0.50 kg head^{-1}d^{-1}) is too high. An alternative value of 0.43 kg head^{-1}d^{-1} is derived.

Reference	Type of Animal	VS [kg head^{-1}d^{-1}]
KTBL 2008	finisher	0.25
KTBL 2004	finisher	0.33
Rodrigez Andara et al. 1999	finisher + nurser	0.44
Rodrigez Andara et al. 1999	finisher + nurser	0.24
KTBL 2008	farrow (up to 28 kg incl. Sow)	0.53
KTBL 2004	farrows (up to 25kg incl. sow)	0.83
KTBL 2004	nurser	0.08
KTBL 2008	gilt	0.24
KTBL 2008	boars	0.32
Galler 1989	swine 40 kg	0.16
Galler 1989	swine 60 kg	0.19
Galler 1989	swine 90 kg	0.21
Braun 1982	swine 15 kg	0.05
Braun 1982	swine 70 kg	0.21
Braun 1982	swine 125 kg	0.19
Braun 1982	swine 170 kg	0.69
Maramba et al. 1979	swine 18-36 kg	0.12
Maramba et al. 1979	swine 36-55 kg	0.24
Maramba et al. 1979	swine 55-73 kg	0.31
Maramba et al. 1979	swine 73-91kg	0.37
Chesshire 1984	swine 50 kg	0.25

Table 8: VS Excretion of different Swine Categories

Thus, it is firstly suggested that: *Using the IPCC 1996 default value for VS excretion leads to an overestimation of baseline emission **(assumption 7)***. Secondly it is assumed that: *Not adjusting a VS default value by animal weight leads to an overestimation of baseline emissions **(assumption 8)***.

2.2.2.3 Methane Conversion Factor

The Methane Conversion Factor (MCF) is an especially complex factor defining the EF in line with the previously discussed parameters. In this chapter the MCF and the parameters influencing it are described. In addition, MCF published by the IPCC is evaluated. The analysis is limited to the MCF of anaerobic lagoons, as this is the only relevant AWMS in the context of this research.

Parameter Description

The MCF is defined as **portion of Bo that is actually converted into methane and emitted to the atmosphere** (Safley et al. 1992). It depends on the wastewater treatment system, the composition of the wastewater, the temperature and the retention time (UNFCCC 2004).

It can be derived as follows:

The MCF equals the annual methane production divided by the product of B_o and annual VS production as shown in Equation 7 (Maningo et al. 2002; UNFCCC 2004).

$$MCF = \frac{CH_{4generated}}{(VS_{generated} * B_0)}$$

Equation 7: Methane Conversion Factor

Where

MCF	Methane conversion factor in a given time period in [-]
$CH_{4generated}$	Amount of methane generated in a given time period in [m^3]
$VS_{generated}$	Total amount of VS excreted in a given time period in [kg]
B_0	Maximum methane potential of the manure in [m^3 kg^{-1}]

Parameters influencing MCF

Many parameters influence the methane generation. IPCC states that it is influenced by

- Climate
- Timing of storage
- Length of storage
- Manure characteristics
- Determination of manure left in the facility
- Time and temperature distribution between indoor and outdoor storage
- Daily temperature fluctuation
- Seasonal temperature fluctuation
  (IPCC 1996; UNFCCC 2004).

These factors are further discussed below when elaborating the hypothesis on MCF.

AM0016 instructs the project participants to either calculate MCF as per Equation 7 using site specific data or to obtain IPCC default values (UNFCCC 2004).

Figure 1 visualizes the complexity of parameters determining MCF. The three main parameters influencing the EF are presented along with the factors impacting them. VS and B_0 are mainly dependent on animal type, diet, and the resulting composition of the manure (see chapter 2.2.2.1 and 2.2.2.2), whereas the MCF is determined by farm management and composition of the manure. These parameters along with the lagoon design influence the loading rate and content of inhibitors. The resulting hydraulic retention time (HRT), the mixing and the climate, especially the temperature, impact the MCF as well. All relevant parameters and their impacts on the MCF are discussed in the following, in order to evaluate if the IPCC default value of 90 % is reasonable.

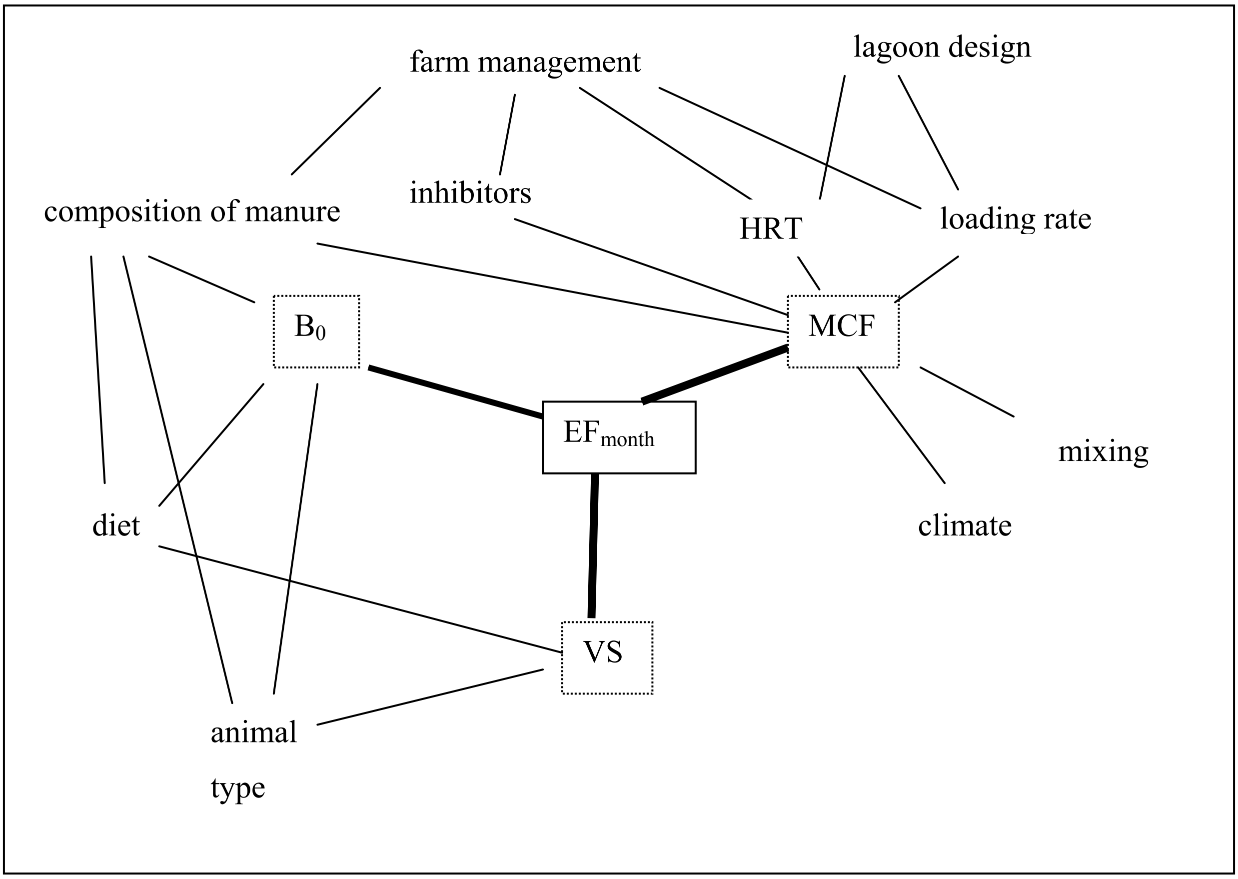

Figure 1: Factors influencing the EF

The **design of anaerobic lagoons** can be very different and impacts the conversion of organic material to biogas. The **surface/depth** impacts the methane production of an anaerobic lagoon. To ensure anaerobic conditions a lagoon should be more than 2 meters deep. Close to the surface oxygen transfer through the air-water interface occurs which is undesirable as too much oxygen may hinder the growth of anaerobic bacteria. The surface to volume ratio should be small in order to keep reaeration limited. If the oxygen fraction in the manure remains small, the facultative anaerobic microorganisms consume the oxygen and create anaerobic conditions enabling the anaerobic bacteria to grow (Bischofsberger et al. 2005; Gray 2004).

The **method of adding the substrate** is important as well, as anaerobic lagoons perform best if the inlet pipe is near the bottom of the lagoon and the effluent exit is located at the opposite end of the lagoon close to the scum. This allows the bacterial flocs to settle out of suspension and permits the active sludge to remain at the bottom. In addition, the fresh manure is mixed with the microbial solids in the active anaerobic sludge layer (Gray 2004).

As anaerobic lagoons are not mixed, stratification within the digester occurs. Hence, the sludge is only digested partially. In anaerobic lagoons three different layers can be identified as shown in Figure 2 (Gray 2004). The **scum area** consists of grease and floating debris and forms the surface of the lagoon. This layer insulates the lagoon, suppresses odours and maintains anaerobic conditions by eliminating oxygen transfer through the air-water interface. In the case of pork industry wastewaters this layer is not easily formed due to the low fibre and grease content. Therefore, the top 100-150mm of the manure is considered aerobic. This reduces the methane production. The next layer, the **supernant** consists of about 0.1 % VS, whereas 3-4% VS can be found in the bottom layer, the **sludge layer.** The sludge builds up within several months before maximum biological activity is reached (Gray 2004).

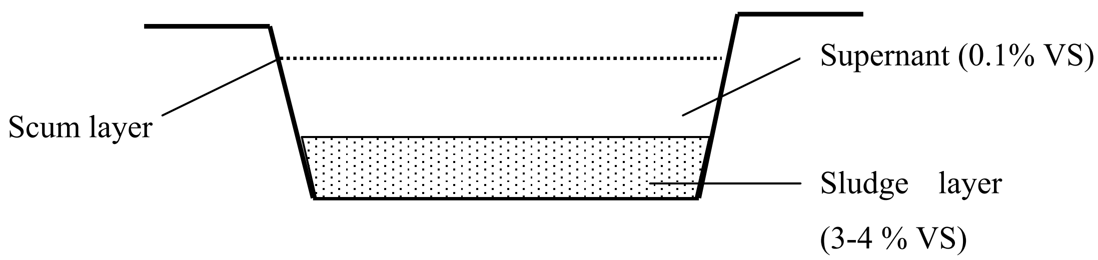

Figure 2: Layers in an anaerobic Lagoon (Gray 2004)

Some sludge particles remain in suspension with the wastewater even if no mechanic mixing is installed. This results from the flow pattern of the liquid and the constant release of methane and carbon dioxide from the sludge layer. Through this “natural mixing” the decomposition of organic matter is also performed in the supernant. Therefore, mixing is crucial for a good performance of the biodigestion process (Winterhalder 1985; Gray 2004).

In anaerobic lagoons all phases of the biogas process occur in parallel. The microorganisms, which are active during biogas production, have different specific needs in regard to ambient conditions. Methanogenic bacteria grow slowly and are highly sensitive to disturbances of ambient conditions. The other microorganisms involved in the production of biogas tolerate sub-optimal conditions to a certain extend (Schattauer 2004; Edelmann 2001).

As mentioned above, the **size** of a system is important as it influences the retention time. Is a lagoon large in relation to the amount of manure treated, the wastewater is stored for a longer period of time. Hence, more organic material is decomposed and only small fractions leave the lagoon undigested. Thus, more biogas is produced. The **HRT** describes the residence time of the substrate in the lagoon. Long retention times from 6-12 months are necessary for ambient temperature digesters (5-25°C), as the bacteria activity during winter can decrease to zero, whereas the digestion rate will be much higher in summer (Gray 2004).

In addition, the **temperature** impacts the methane production significantly. Methanogenic bacteria are mostly mesophilic and much more sensitive in terms of temperature than the fermentative bacteria. They achieve the highest growth and conversion rates at temperatures between 30 and 40 °C (Kroiss et al. 2005).

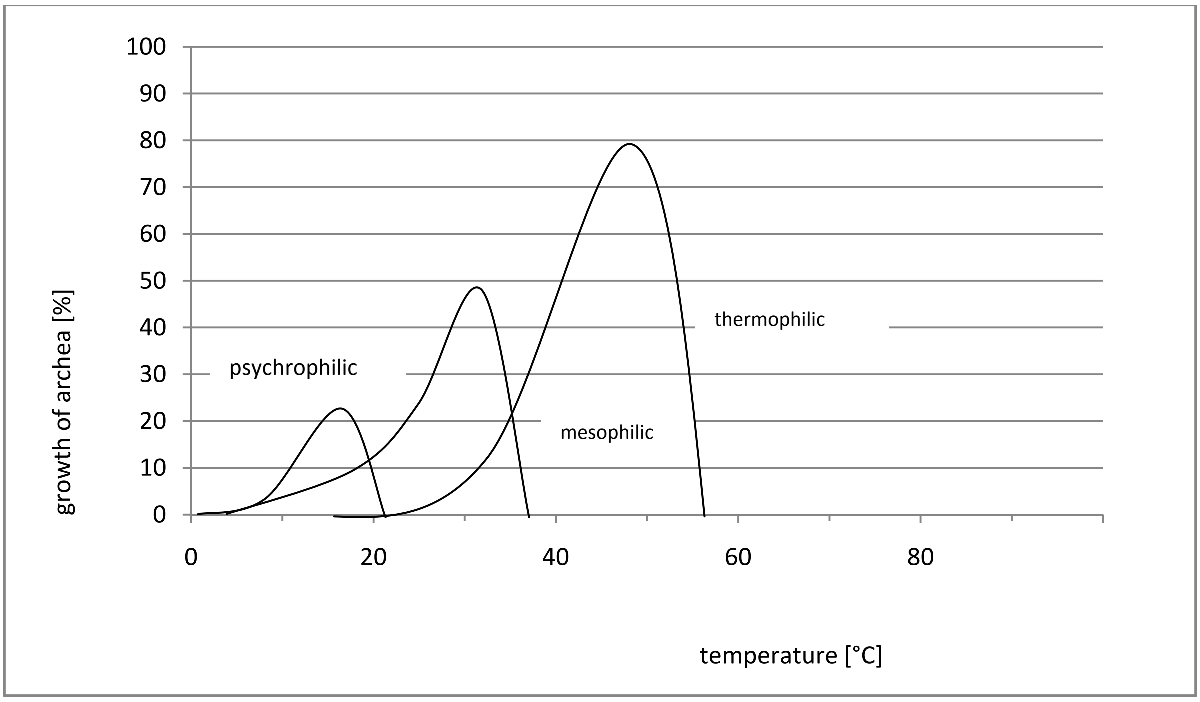

Figure 3: Growth of methanogenic Bacteria in Relation to Temperature (Batstone et al. 2002)

Biogas producing bacteria can be divided into three groups. In literature different temperature optima are given for these bacteria types. In case of psychrophilic bacteria the span varies between 5-25 °C (Gray 2004) temperatures up to 25 °C (Schattauer 2004) and temperatures under 20°C (Weide et al. 1979). Mesophilic conditions are defined differently as well, ranging from 25 - 38 °C (Gray 2004), 20 - 40 °C (Weide et al. 1979) to 32 - 42°C (Edelmann 2001). Figure 3 gives an overview about the different temperature ranges the bacteria prefer (Bischofsberger et al. 2005).

The **farm management** is another important parameter. If animals are grown in other than slatted floor systems, possible bedding materials form part of the manure and change its composition. In cases where the excrements are manually taken out of the barns (without flushing), the manure is dryer and more condensed. In tropical and subtropical countries it is common practice to grow pig on concrete floors and flush the barns. The flushing frequency varies from season to season. During winter barns and animals are usually cleaned every two to three days, whereas in summer they are washed up to three times a day (Vanotti et al. 1999; Deecke 2005). The amount of water used for the cleaning also enters the AWMS. This has a significant impact on the composition and the retention time of the manure in the system. The more water is added, the shorter the retention time, the more wastewater leaves the system un-decomposed.

These conditions determine the type, the amount and the performance of anaerobic bacteria in the waste water and therefore the biogas production.

As the microorganisms require certain substances for successful development the **composition of the manure** is also an important factor. Components in the manure such as lipids, cellulose and proteins are present as solids in suspension. The manure components are either converted into microbial biomass and gas or not metabolised at all (e.g. lignin) (Gray 2004). The content of **dry matter** also impacts the biogas production. Indeed, dry matter contents from over about 10 % to 12 % can inhibit the biogas production. In addition, if methanogenic bacteria are inhibited for some reason or the digester is **overloaded** which leads to an accumulation of volatile acids, the buffering capacity of the ammonium bicarbonate may be exceeded. This results in a rapid decrease of pH under 6.0 and causes the gas production to decline. The redox potential of the substrate controls the CH_4/CO_2 ratio. Therefore, instable relation between CH_4 and CO_2 in the biogas can be a sign for instable pH conditions (Pind et al. 2003; Gray 2004; Bischofsberger et al. 2005).

Other **inhibitors** to the biogas production process can be substances poisonous for the bacteria such as, antibiotics, desinfectants etc. The content of inhibitors in the substrate has different impacts on the type of bacteria involved in the process. In general, a rather high tolerance against inhibitors can be observed amongst the broad range of hydrolytic and acid

forming bacteria. In contrast, the methanogenesis is only performed by a few sensitive species of methanogenic microorganisms. Furthermore, the former are constantly renewed as they form part of the undigested manure. Instead the archea population is self-sustaining and needs a long time to restore if destroyed or significantly affected by inhibitors (Gray 2004; Edelmann 2001). Therefore, if manure is used as substrate, a bypass should be installed to avoid high concentrations of antibiotics and disinfectants in the digester in case an intense medical treatment of the animals has been undertaken on the farm (Deecke 2005).
Out of all the presented information, it can be concluded that the MCF is sensitive to many factors. Given that a stable anaerobic conditions are maintained in an anaerobic lagoon, without any significant disturbances to the biodigestion process a typical MCF progression as presented in Figure 4 results.

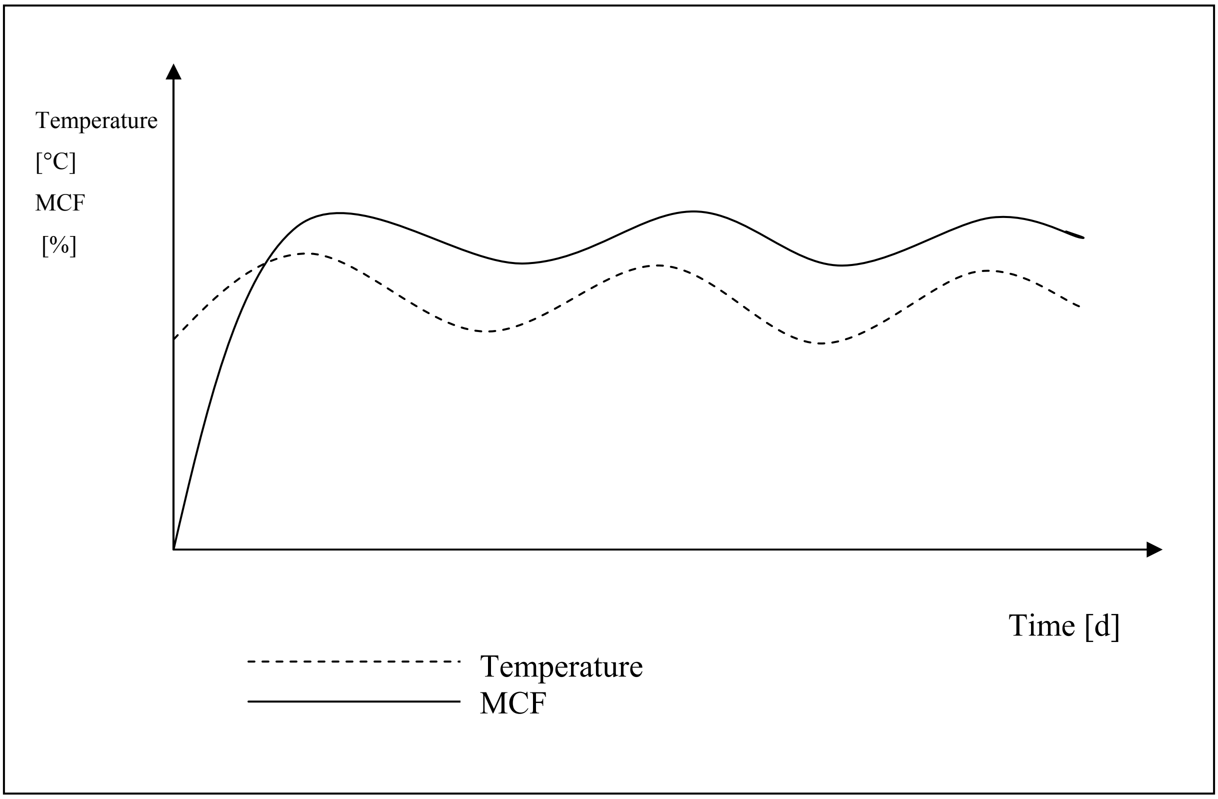

Figure 4: Typical MCF Curve

At the beginning when only fresh manure is in the lagoon, the MCF is very low because no stable anaerobic conditions have been established yet. It increases steadily up to a certain level. After reaching this value, it increases when the temperature increases and decreases respectively.

Sources of Default Value

The MCF default value for anaerobic lagoons can be identified in the IPCC tables by choosing the AWMS and climate. In IPCC 2000 MCF values for anaerobic lagoons are given as 0 – 100 % for cool, temperate and warm climates. As one distinct value is needed to forecast the methane production, project developers have to resort back to the IPCC 1996 default value of 90 % for all climates (IPCC 1996; IPCC 2000).

At the time when the project activity forecasts the emission reductions, the annual methane production is not available. Although anaerobic lagoons produce methane, it is usually not measured. In fact, at that stage the MCF is actually needed to calculate the annual methane production. Therefore, Equation 7 cannot be obtained to determine a site specific MCF by the project developers. Thus, the IPCC default values are used. Therefore, only the IPCC default values for the MCF are evaluated here.

The MCF 90 % value presented in IPCC 1996 guidelines is taken from Safley et al. (1992). Anaerobic lagoons, according to Safley et al. (1992), provide good anaerobical storage conditions. They assume that 90 % of B_0 is realized. They do not base this value on data gained from experiments, measurements or other references. They estimated the MCF. To capture the uncertainty they assume further that it can be 100 % as "high case" and remains 90 % as "low case". These values are valid for all climates according to Safley et al. (1992). Estimates cannot be considered strong scientific evidence. In addition, the manner of presenting the MCF default values for swine manure in the guidelines indicates that they are only AWMS and temperature dependent. Users have to choose the climate in which the lagoon is located and obtain the corresponding MCF, even though it is mentioned that the MCF depends on many other factors. Furthermore, the unspecific MCF values published by the IPCC in 2000 show how broad the range of values can be and that no reliable and specific MCF default values are available. This gives a hint that the IPCC 1996 default value could be responsible for wrong emission reduction estimates.

Therefore, definitions of anaerobic lagoons that have been published in line with the default value by Safley et al. (1992), UNFCCC (2004) and IPCC (1996 and 2000) are presented below. They show different levels of accuracy/specification.

Out of all the factors presented above, only the retention time is defined by AM0016. The range which is given for the HRT is very broad. As explained above, it influences the MCF greatly if the manure remains 30 days in a system or more than 200 days.

Length and width of an anaerobic lagoon are not specified by the IPCC. Only Safley et al. (1992) require a minimum depth of 1.83 meters (6 ft). The volume of the lagoon in relation to the amount of wastewater treated is indirectly described by the retention time. The higher the amount of wastewater and the smaller the lagoon volume, the shorter is the retention time. IPCC state that wastewater stays up to one year or longer in an anaerobic lagoon whereas AM0016 and Safley et al. (1992) give a period of 30 to 200 days or more as retention time.

Therefore, an assumed over-all default value of 90 % for MCF for anaerobic lagoons without further specification or restrictions seems to be not specific enough and too high. Hence, it is considered as potential source of mistake in the estimation of emission reductions. Due to the lack of data in literature no comparison with other data is possible here, which also applies to the development of an alternative MCF default value. This issue is addressed further in chapters 3.3.9 and 4.9. However, considering the above it can be assumed that: *Applying the IPCC default value for MCF of 90 % leads to an overestimation of baseline emissions* ***(assumption 9)***.

2.2.3 Summary of Hypotheses and Assumptions

For all relevant descriptive statistical parameters (hypotheses I) an assumption has been suggested. For each parameter applicable to hypothesis II a literature review was undertaken and alternative values were calculated which serve to test the assumptions made in this respect.

Table 9 shows the summary of all assumptions that are analysed in the following chapters.

Hypothesis	**Assumption**		
	No.	**Parameter**	**Content**
I	1	No. of farms	The number of farms participating in a project was overestimated, which leads to an overestimation of baseline emissions.
	2	Start date	The starting date of the monitoring on the farms was estimated too optimistically, which leads to an overestimation of baseline emissions.
	3	Population	The amount of animals was forecasted to optimistically leading to an overestimation of baseline emissions.
	4	MS%j	The fraction of animal manure handled in system j has been overestimated, which leads to an overestimation of baseline emissions.
	5	Monitoring	The monitoring is not undertaken adequately, which leads to an overestimation of baseline emissions.
II	6	B_0	Using the IPCC 1996 default value for B_0 to estimate the baseline emissions leads to an overestimation of baseline emissions.
	7	VS	Using the IPCC 1996 default value for VS excretion leads to an overestimation of baseline emissions.
	8	VS	Not adjusting a VS default value by animal weight leads to an overestimation of baseline emissions.
	9	MCF	Applying the IPCC default value for MCF of 90 % leads to an overestimation of baseline emissions.

Table 9: Summary of Hypotheses and Assumptions

3 MATERIALS AND METHODS

3.1 Assessed Documents

Relevant scientific literature has been assessed in order to advance the hypotheses. In order to test them, project specific documents are thoroughly analyzed. Every CDM project activity has to follow an approved methodology. These methodologies are available on the UNFCCC webpage.

The CDM is designed as a transparent mechanism. Thus, project data regarding the baseline of the project activities has to be publicly available on the UNFCCC web site. In the course of each CDM project the following documents are published (the entity writing the document is given in brackets):

- project design document (Project participant (PP))
- validation report (DOE)
- validation protocol (DOE)
- monitoring report (PP)
- verification report (DOE)
- verification protocol (DOE)
- certification report (DOE)
- if applicable: requests through the EB and corresponding responses by PP and DOE

The PDD contains detailed information on the data building the basis for the calculation of baseline emissions (e.g. number of animals). The monitoring report includes relevant data recorded during each monitoring period (e.g. temperature, animal counts, biogas amounts). The documents issued by the DOE contain information about the findings during validation and verification. Depending on how detailed and transparent the assessment of the project is presented, indications on mistakes occurring during planning and especially monitoring can be assessed. If the EB questions the assessment of the validating or verifying DOE it issues different types of requests (request for clarifications, request for review etc.). These requests and the corresponding answers were assessed as well.

Although transparent and detailed information has to be provided to the DOEs, the data presented in the monitoring reports is sometimes not very specific. Therefore, some information has to be assessed indirectly, which is described further below when applicable.

3.2 Identification of the Sample

In Table 10 (UNEP Risoe 2009) a detailed overview over the issuance success levels among animal waste management CDM project activities that received CERs by January 2009 is given. The UNFCCC reference numbers are listed together with the expected and issued CER amount. In addition, the resulting issuance success of each project, the applied methodology, the host country, and the baseline scenario and project are presented (UNEP Risoe 2009).

UNFCCC Reference no.[9]	Methodology	Baseline Scenario	Project Scenario	Host country	Issuance Success
31	AM6	AL, SM	AD + activated sludge, SM	Chile	111%
32	AM6	AL, SM	AD + activated sludge, SM	Chile	100%
33	AM6	AL, SM	AD + activated sludge, SM	Chile	95%
104	AM16	AL, SM	AD, SM	Mexico	2%
105	AM16	AL, SM	AD, SM	Mexico	31%
108	AM16	AL, SM	AD, SM	Brazil	29%
120	AM16	AL, SM	AD, SM	Mexico	20%
150	AM16	AL, SM	AD, SM	Mexico	29%
161	AM16	AL, SM	AD, SM	Mexico	42%
162	AM16	AL, SM	AD, SM	Mexico	22%
163	AM16	AL, SM	AD, SM	Mexico	47%
196	AM16	AL, SM	AD, SM	Mexico	29%
197	AM16	AL, SM	AD, SM	Mexico	10%
204	AM16	AL, SM	AD, SM	Mexico	21%
225	AM16	AL, SM	AD, SM	Mexico	33%
240	AM16	AL, SM	AD, SM	Mexico	42%
257	AM16	AL, SM	AD, SM	Mexico	19%
324	AM16	AL, SM	AD, SM	Mexico	23%
335	AM16	AL, SM	AD, SM	Brazil	31%
336	AM16	AL, SM	AD, SM	Brazil	29%
337	AM16	AL, SM	AD, SM	Brazil	36%
364	AM16	AL, SM	AD, SM	Brazil	26%
365	AM16	AL, SM	AD, SM	Brazil	19%
409	AM16	AL, SM	AD, SM	Brazil	15%
411	AM16	AL, SM	AD, SM	Brazil	21%
412	AM16	AL, SM	AD, SM	Brazil	33%
413	AM16	AL, SM	AD, SM	Mexico	84%
417	AM16	AL, SM	AD, SM	Brazil	19%
418	AM16	AL, SM	AD, SM	Brazil	20%
419	AM16	AL, SM	AD, SM	Brazil	38%
420	AM16	AL, SM	AD, SM	Brazil	36%
421	AM16	AL, SM	AD, SM	Brazil	24%
422	AM16	AL, SM	AD, SM	Brazil	29%
458	AM6	AL, SM	aerobic treatment, SM	Chile	75%
459	AM6	AL, SM	deep bedding, SM	Ecuador	61%
460	AM6	AL, SM	deep bedding, SM	Ecuador	70%
461	AM6	AL, SM	deep bedding, SM	Ecuador	79%
472	AM16	AL, SM	AD, SM	Brazil	75%
542	AMS-III.D.	AL, SM	AD, SM	Mexico	39%

Table 10: List of Animal Waste Management CDM Project Activities having CERs issued by January 2009 (UNEP Risoe 2009)

[9] Hereafter: Project number

On average the projects achieve an issuance success of 45 %. The broad range is interesting. The project performing worst (No. 104) reaches 2 % of the forecasted amount of emission reductions, whereas the best performing project (No. 31) achieves 111 %.

The distribution of the issuance success among this project type is presented in Figure 5. It can be observed that 28 (72 %) of the 39 project activities that received CERs by January 2009 have an issuance success below 50. Only two projects have been issued more CERs than expected and just seven projects reach 51 % to 100 %.

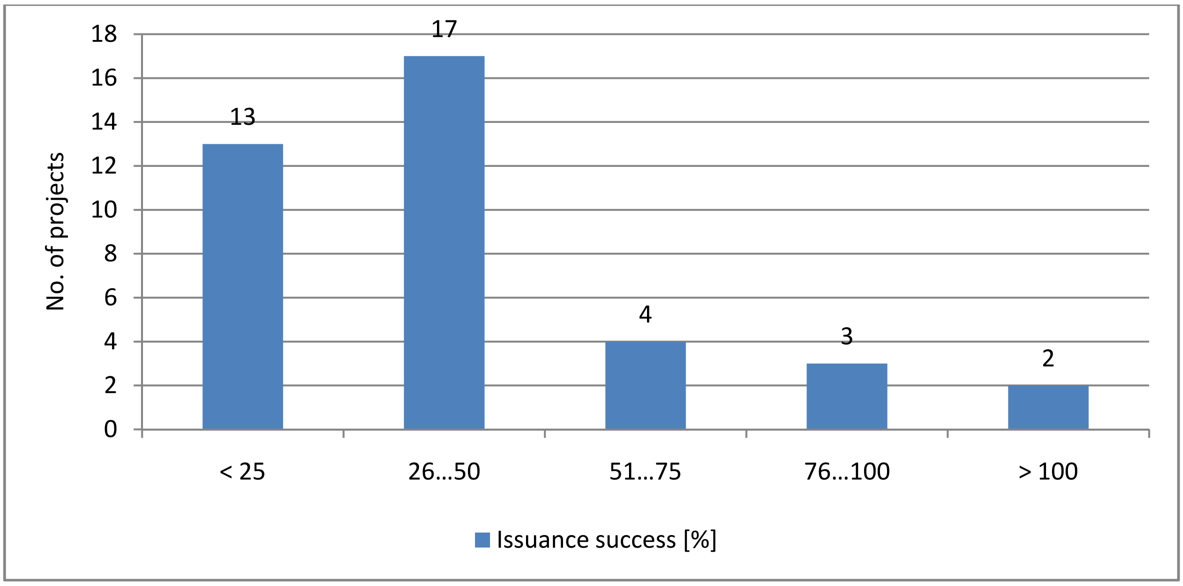

Figure 5: Distribution of Issuance Success

The majority of the projects are located in Mexico and Brazil, apply AM0016 and treat swine manure in anaerobic lagoons in the baseline scenario. In the project scenario ambient temperature anaerobic digesters[10] are operated. To identify the sample, projects with other baseline or project scenarios (No. 459, 460, 458, 461, 33, 32) were excluded as well as projects applying different methodologies. This provides comparability among the projects of the sample. In addition, projects number 104, 413 and 472 are excluded, as the calculation of the baseline emissions could not be retraced. The remaining projects (projects not highlighted grey) built the sample.

[10] Anaerobic digesters here: covered anaerobic lagoons (unheated, unmixed etc.)

The ex-ante estimated BE and those that are measured ex-post of each project forming part of the sample are presented in Table 11. The 28 projects belonging to the sample were expected to generate 6 mio. tCO_2e as baseline emissions. Only 1.6 mio. tCO_2e were measured during the monitoring periods. This leads to a baseline emission forecast success of 25 % on average.

Project no.	BE $_{ex-ante}$ [tCO_2e]	BE $_{ex-post}$ [tCO_2e]	BE forecast success [%]
105	322,434	87,524	27
108	23,379	5,171	22
120	370,476	66,354	18
150	353,957	91,192	26
161	143,780	57,955	40
162	262,221	60,804	23
163	62,922	28,609	45
196	97,584	32,834	34
197	46,976	4,235	9
204	143,690	26,988	19
225	83,288	25,023	30
240	194,074	74,403	38
257	155,131	26,776	17
324	173,245	34,202	20
335	204,668	54,622	27
336	705,034	176,829	25
337	523,928	145,884	28
364	537,754	126,046	23
365	135,700	24,455	18
409	17,815	2,262	13
411	307,821	63,376	21
412	263,023	82,219	31
417	242,547	53,764	22
418	163,392	29,648	18
419	276,261	92,540	33
420	109,332	35,076	32
421	107,178	22,870	21
422	231,867	59,449	26
Total	**6,259,476**	**1,591,110**	**25**

Table 11: BE Forecast Success of the Sample

3.3 Methods

Scientific literature and the above described documents are thoroughly assessed in order to evaluate which reasons are responsible for the low baseline emission forecast success. The hypotheses advanced in chapter 2.2 are tested based on the project data and information available. It is analyzed if the actual monitored situation confirms or refutes the hypotheses and related assumptions. For all quantifiable parameters the alternative values are used and a correction factor is derived. Hypotheses and related assumptions are declared confirmed, if the over-all correction factor resulting from an introduced measure is higher than 1.00 and falsified if the factor is equal or below 1.00.

Finally, it is attempted to evaluate and quantify the impact each reason had on the underperformance by comparing the correction factor.

3.3.1 Number of Farms

To assess this parameter, the number of farms designated to participate in each project is taken from the PDDs. The information about which farms did not report any data in a monitoring period is obtained from the monitoring reports. Information on the start date of monitoring is given there. Where no monitoring took place it is stated: “not applicable”. For each project it is analyzed how many farms did not participate over the entire assessed number of monitoring periods.

The next step is assessing and summing the number of animals that would have been on each farm not reporting data. With the population data the BE that were lost due to the opting out of these farms are calculated. The subtraction of this value from the ex-ante estimated BE results in the amount of BE that would have been forecasted, if the number of farms taking part was correctly determined ex-ante, as shown in Equation 1. By putting the BE that would have been estimated if the number of farms was forecasted correctly in relation to the BE that were forecasted expecting all farms to participate as planned a correction factor for the parameter no. of farms is derived (Equation 9).

$$BE_{no.\ of\ farms} = BE_{ex-ante} - BE_{lost\ due\ to\ opted\ out\ farms}$$

Equation 8: BE correct Number of Farms

$$CF_{no.of\ farms} = \left(\frac{BE_{correct\ no.of\ farms}}{BE_{ex-ante}}\right)^{-1}$$

Equation 9: Correction Factor resulting when considering actual Number of Farms

Where (Equation 8, Equation 9)

$BE_{no.of\ farms}$	BE that would have been estimated ex-ante if the no. of farms was forecasted correctly in [tCO_2e]
$BE_{ex-ante}$	BE estimated ex-ante in the PDDs in [tCO_2e]
$BE_{lost\ due\ to\ opted\ out\ farms}$	BE that were supposed to be generated by the opted out farms in [tCO_2e]
$CF_{no.of\ farms}$	Correction factor showing the impact of the correct estimation of no. number of farms on the BE forecast success in [-]

3.3.2 Start Date

As described above, forecasting the BE correctly requires estimating emission accurately and operating the project in line with the plan. Two approaches can be followed in order to assess the impact of the forecasted starting date. It can either be stated that a better coordination of the implementation would have led to a punctual beginning of the monitoring and therewith in higher ex-post measured BEs or it can be stated that a better planning would have resulted in envisaging later starting days, which would have reduced the expected amount of BE and led to a higher BE forecast success. In this case the latter approach is chosen. Hence, it is assessed if an accurate planning would have reduced the expected amount of baseline emissions on the level of the ex-post measured BE.

The ex-ante BE calculations are undertaken based on the population data. This is the only parameter known on a monthly basis specific to each farm.

The forecast quality of the starting dates is assessed individually, in order to separate their effect from the "drop out effect" of farms. It is tested by obtaining the dates on which each farm started the monitoring. This information is used to calculate how many animals were supposed to be on-site during the missed out period. Based on this the BE are calculated. The result includes the BE lost due to farms not participating at all (see assumption 1). Therefore, the BE missed due to farms opting out are subtracted, resulting in the BE lost due to delays or rather inaccurate starting date assessment ex-ante. This amount is subtracted from the BE estimated ex-ante, as shown in Equation 10. In addition, the correction factor resulting from this measure is calculated as shown below.

$$BE_{start\ date} = BE_{ex-ante} - BE_{lost\ due\ to\ delays}$$

Equation 10: BE correct Monitoring Start Dates

$$CF_{start\ date} = \left(\frac{BE_{start\ date}}{BE_{ex-ante}}\right)^{-1}$$

Equation 11: Correction Factor resulting from the Use of the correct Start Date (monitored ex-post)

Where (Equation 10, Equation 11)

$BE_{start\ date}$	BE that would have been estimated ex-ante if the starting date of monitoring was forecasted correctly in [tCO_2e]
$BE_{ex-ante}$	BE estimated ex-ante in the PDDs in [tCO_2e]
$BE_{lost\ due\ to\ delays}$	BE that were supposed to be generated between the planned and the actual starting date in [tCO_2e]
$CF_{start\ date}$	Correction factor, impact of the inaccurate forecast of the starting date on the forecast quality in [-]

3.3.3 Population

Farm records were taken from the PDDs which served as forecast for the population during the monitoring periods of the project. In the PDD the expected animal counts are given per farm per animal type and month[11]. The initial BE is forecasted assuming that the population given in the PDD is producing manure and biogas from a certain start date of monitoring onwards. A simple comparison of the ex-ante and the ex-post measured population would lead to wrong results. Potential losses have to be considered. Therefore, the ex-ante population estimates from the PDD, which imply that all farms participate and no delays occur, are adjusted by the results taken from chapter 4.1. In addition the BE and the BE forecast success are adjusted accordingly.

The adjusted population forecasts are summed up and compared to the number of animals counted during each monitoring period. Both the adjusted ex-ante estimated population and the ex-post amount counted are compared resulting in a correction factor (Equation 12). The ex-post data can be obtained for each project on a monthly basis divided into animal types from monitoring reports. In contrast to the ex-ante data, the ex-post population is not specified on farm level.

$$CF_{population} = \left(\frac{Population_{ex-post}}{Population_{ex-ante\ corrected}}\right)^{-1}$$

Equation 12: Correction Factor resulting from the Use of the correct, ex-post monitored Population

Where

$CF_{population}$	Correction factor for population, impact of the population estimation on the forecast quality in [-]
$Population_{ex-post}$	Ex-post monitored animal counts in [head]
$Population_{ex-ante\ corrected}$	Animal counts forecasted under consideration of delays and opting out of farms in [head]

[11] Mortalities and days unpopulated are presented in some PDDs. It is assumed that animals died on the 15th of each month, as no specification is given. It is observed that in some cases the total animal counts already consider these losses, in others not. In order to assess the approach followed by the project developer, the BE are calculated based on the animal counts. Mortalities and animals lost due to unpopulated days are subtracted from the total population, whenever it leads to BE amounts that closer match with the BE presented in the PDDs.

3.3.4 Fraction of Manure handled in System j

Data in the monitoring reports and verification reports is obtained and compared to the information given on MS%j in the PDDs, in order to assess if the values of this parameter measured ex-post are different from those estimated ex-ante. A correction factor is calculated as resulting from this approach as shown below.

$$CF_{MS\%j} = \left(\frac{MS\%j_{ex-post}}{MS\%j_{ex-ante}}\right)^{-1}$$

Equation 13: Correction Factor resulting from the Use of the ex-post monitored MS%j Value

Where

$CF_{MS\%j}$	Correction factor for MS%j, impact on the forecast quality in [-]
$MS\%j_{ex-post}$	Ex-post monitored MS%j in [-]
$MS\%j_{ex-ante}$	Ex-ante estimated MS%j in [-]

3.3.5 Monitoring

The assumption in respect to the monitoring is tested by assessing the monitoring and verification reports and the verification protocols. Findings that reveal weaknesses and failures in monitoring are assessed and described. In addition, it is assessed if the number of farms belonging to each project correlates with the BE forecast success, as a correlation would be an indicator for monitoring management problems when assuming that the more farms have been managed the more management mistakes occur.

3.3.6 Maximum Methane Potential

The assumption regarding the **maximum methane production potential** is tested as follows. The IPCC default value as used in the PDDs is put in relation to the new B_0 value, 0.41 m^3/kg. A correction factor results, as demonstrated in Equation 14.

$$CF_{B_0} = \left(\frac{B_{0_{new\ default}}}{B_{0_{IPCC}}}\right)^{-1}$$

Equation 14: Correction Factor resulting from the Use of the alternative B_0 Default Value

Where

CF_{B_0}	Correction factor, impact of the change in B_0 on the forecast quality in [-]
$B_{0_{new\ default}}$	New default value 0.41 in [m^3 kg^{-1}]
$B_{0_{IPCC}}$	IPCC default value for B_0 in [m^3 kg^{-1}]

3.3.7 Volatile Solids

The first assumption on the parameter volatile solids is tested by comparing the newly developed VS default value of 0.43 kg head-1d-1 and the IPCC default value, resulting in a correction factor for this value.

$$CF_{VS} = \left(\frac{VS_{new\ VS\ default}}{VS_{IPCC}}\right)^{-1}$$

Equation 15: Correction Factor resulting from the Use of the alternative VS Default Value

Where

CF_{VS}	Correction factor, impact of this change in VS on the forecast quality in [-]
$VS_{new\ VS\ default}$	New default value in [kg d^{-1} $head^{-1}$]
VS_{IPCC}	IPCC default value for VS in [kg d^{-1} $head^{-1}$]

3.3.8 Volatile Solids (weight adjusted)

The second assumption regarding the VS is tested by adjusting the IPCC default value for VS of 0.5 kg/head/d by animal weight, in order to assess if the resulting adjusted VS value is different from the default value. Therefore, the population data presented in the PDDs is assessed. The animal counts are subdivided into animal categories, but only the estimated number of head is given, not the weight. However, the verification reports state that the project developer started to use standard North American animal class weights (Sows 181 kg, gilts 181 kg, boars 204 kg, finishers 56 kg, weaners 13 kg) to adjust the VS when calculating the BE ex-post. These default values on animal weight are used to adjust the VS. The formula which is obtained to calculate weight corrected VS values is described in Equation 16. Based on this data, the adjusted VS value is compared to the originally used IPCC default value, resulting in a correction factor (Equation 17).

$$VS_{weight\ adjusted} = \left(\frac{W_{site}}{W_{IPCC\ default}}\right) VS_{default}$$

Equation 16: Adjustment of VS by Animal Weight

Where

$VS_{weight\ adjusted}$	VS excretion adjusted to average site-specific animal weights in [kg d-1 head-1]
W_{site}	average weight of animals on site in [kg]
W_{IPCC}	IPCC average swine weight in [kg]
$VS_{default}$	VS excretion default value in [kg d-1 head-1]

$$CF_{IPCC\ VS\ default\ weight\ adjusted} = \left(\frac{VS_{IPCC\ weight\ adjusted}}{VS_{IPCC}}\right)^{-1}$$

Equation 17: Correction Factor resulting from the Use of the alternative VS Default Value

Where

$CF_{VS\ IPCC\ weight\ adjusted}$	Correction factor, impact of this change in VS on the forecast quality in [-]
$VS_{IPCC\ weight\ adjusted}$	IPCC default value adjusted by animal weight in [kg d^{-1} $head^{-1}$]
VS_{IPCC}	IPCC default value for VS in [kg d^{-1} $head^{-1}$]

In a third step the new VS default value of 0.43 kg/head/d is weight-adjusted as described above. The resulting values are compared with the ex-ante used IPCC default value, in order to determine the correction factor

$$CF_{new\ VS\ default\ weight\ adjusted} = \left(\frac{VS_{new\ default\ weight\ adjusted}}{VS_{IPCC}}\right)^{-1}$$

Equation 18: Correction Factor resulting from the Use of the alternative Weight adjusted VS Default Value

Where

$CF_{new\ VS\ default\ weight\ adjusted}$	Correction factor, impact of the change in VS on the forecast quality in [-]
$VS_{new\ default\ weight\ adjusted}$	New VS default value in [kg $head^{-1}$ d^{-1}]
VS_{IPCC}	IPCC default value for VS in [kg $head^{-1}$ d^{-1}]

3.3.9 Methane Conversion Factor

The suggested statement on the **methane conversion factor** is tested as described below. We have learned that the MCF is a complex factor influenced by many parameters. Unlike for VS and B_0, no alternative MCF default value for anaerobic lagoons could be obtained through a literature review. The only possibility to approach MCF based on the present information is to calculate it considering the measured methane emissions presented in the monitoring reports as basis value. Therefore, in a first step Equation 5 and Equation 6 are combined, broken down for the time period of a month and solved for MCF resulting in:

$$MCF = \frac{CH_{4\,month}}{Population_{month} * MS\%j_{month} * VS * B_0 * D_{CH_4} * n_m}$$

Equation 19: MCF

Where

MCF	Methane conversion factor during the monitoring period in [-]
$CH_{4\,month}$	Amount of methane generated during the monitoring period in [kg]
$Population_{month}$	Number of animals kept during the monitoring period in [head]
$MS\%j_{month}$	Percentage of manure handled in a treatment system j during the monitoring period in [-]
VS	Volatile solids excreted in [kg $head^{-1}$ d^{-1}]
n_m	Number of days in a month in [d]
B_0	Maximum methane potential in [m^3 kg^{-1}]
D_{CH_4}	Methane density in [kg m^{-3}]

With this equation the MCF values are calculated for the sample. The ex-post population is presented in the monitoring reports and the methane production [m^3] is obtained by dividing the measured baseline emissions [tCO_2e] by the global warming potential of methane (21) multiplied by 1,000. All other parameters are left as in the PDD. Afterwards, an average on the resulting monthly MCF value for each project is calculated. The distribution of the MCF values is also assessed.

As a second step, the MCF is calculated a second time, using the results obtained from chapters 4.1 to 4.8, to account for potentially inaccurate parameters that were chosen at the PDD stage. The resulting value for MCF is used as alternative value. The effect of the new MCF default value on the BE forecast success is shown through the relation between the

IPCC MCF default value and the new MCF. Through this assessment a correction factor can be derived as demonstrated below:

$$CF_{MCF} = \left(\frac{MCF_{new}}{MCF_{IPCC}}\right)^{-1}$$

Equation 20: Correction Factor resulting when using alternative MCF Default Value

Where

CF_{MCF}	Correction factor, impact on the forecast quality when using new MCF in [-]
MCF_{new}	New MCF default value in [-]
MCF_{IPCC}	IPCC default value for MCF in [-]

As a final step in the MCF assessment, the progression of the MCF curve in relation to temperature of each project is assessed, in order to evaluate if the MCF curve can be considered typical (Figure 4). If it shows a typical progression it can be concluded that stable anaerobic conditions exist in the digester.

3.3.10 Combination of all Measures

In the last step, all quantifiable results from the above described analyses are combined. The over-all correction factor is assessed by multiplying all individual correction factors as shown in Equation 21.

$$CF_{total} = CF_{no.of\ farms} * CF_{starting\ date} * CF_{population} * CF_{MS\%j} * CF_{B_0} * CF_{new\ VS\ default\ weight\ adjusted} * CF_{MCF}$$

Equation 21: Total Correction Factor

Where

CF_{total}	Over-all correction factor when combining all measures analyzed in [-]
$CF_{no.of\ farms}$	Correction factor, impact of the correct estimation of no. number of farms on the result in [-]
$CF_{starting\ date}$	Correction factor, impact of the delays on the forecast quality in [-]
$CF_{population}$	Correction factor for population, impact of the population estimation on the forecast quality in [-]
$CF_{MS\%j}$	Correction factor for MS%j, impact on the forecast quality in [-]
CF_{B_0}	Correction factor, impact of the change in B_0 on the forecast quality in [-]
$CF_{new\ VS\ default\ weight\ adjusted}$	Correction factor, impact of the change in VS on the forecast quality in [-]
CF_{MCF}	Correction factor, impact on the forecast quality when using new MCF in [-]

The multiplication of the total correction factor by the initial BE forecast success leads to the BE forecast success that would have been achieved if all assessed measures were applied when estimating the BE ex-ante (Equation 22).

$$BE\ forecast\ success_{total} = BE\ forecast\ succes_{original} * \ CF_{total}$$

Equation 22: Total BE Forecast Success

Where

$BE\ forecast\ success_{total}$	BE forecast success resulting when combining all measures analyzed in [-]
$BE\ forecast\ succes_{original}$	Actual BE forecast success of the projects in [-]
CF_{total}	Over-all correction factor when combining all measures analyzed in [-]

In order to cross-check the achieved results from the above described measures, a second approach is used to analyze the impact of the introduced measures. First, the BE are calculated for each quantifiable assumption individually. All parameters are left constant; only the value of the applicable parameter is changed into the alternative value. The resulting BE forecast success is compared to the forecast success resulting from the multiplication with the correction factor (Equation 23). Next, all individual deviation factors are multiplied in order to determine the over-all deviation. Finally, both results are averaged.

$$Deviation\ factor = \frac{BE\ forecast\ success_{project\ data}}{BE\ forecast\ success_{CF}}$$

Equation 23: Deviation Factor BE Forecast Success Determination

Where

$Deviation\ factor$	The resulting deviation between the results of both approaches in [-]
$BE\ forecast\ success_{project\ data}$	BE forecast success resulting from calculating the BE based on project data and changing the parameters applicable for each assumption individually in [-]
$BE\ forecast\ success_{CF}$	BE forecast success resulting from multiplying the original BE forecast success by the correction factor determined for each individual parameter in [-]

4 RESULTS

The results of the assessment of the assumptions are presented in the chapters below. After demonstrating the outcome of the analysis of each parameter the result for the related assumption is shown.

4.1 Number of Farms

Assumption 1: *The number of farms participating in a project was overestimated, which leads to an overestimation of baseline emissions.*

Table 12 shows the number of farms that were designated to participate in each project in the second column. In addition, the number of farms not reporting any data during each monitoring period (roman numbers) is listed. The empty cells highlighted grey indicate that a monitoring period has not been conducted yet (e.g. project number 120 had five monitoring periods, project number 196 only two). It can be observed that only in 7 projects all farms during all monitoring periods participated (project number, 108, 163, 240, 335, 365, 409). In all the other projects some farms did not report monitoring data during the periods. Furthermore, the number of farms not reporting data decreases over the monitoring periods (e.g. 105, 120, 422), whereas in some cases the number of farms not reporting remains at a certain level after the first monitoring periods (e.g. 120, 324, 417, 418, 422).

Project no.	Monitoring period / No. of planned farms	No. of farms not reporting data [12]				
		I	II	III	IV	V
105	**20**	5	0	0	0	0
108	**1**	0	0	0		
120	**16**	10	2	2	2	2
150	**17**	6	1	1		
161	**22**	0	0	0		
162	**27**	10	10			
163	**6**	0				
196	**13**	4	4			
197	**4**	1				
204	**8**	2	2	2		
225	**13**	2	2			
240	**19**	0	0	0		
257	**18**	2	2			
324	**15**	6	5	5		
335	**8**	0	0	0		
336	**33**	6	4	4		
337	**35**	6	1	0	0	
364	**15**	1	0	0	0	
365	**13**	0	0	0		
409	**5**	0				
411	**25**	3	3	3		
412	**18**	1	1	1		
417	**24**	4	4	4		
418	**11**	4	4	4		
419	**37**	4	1	1		
420	**10**	1	1			
421	**15**	1	1			
422	**20**	5	2	2		
Average	**17**	**3**	**2**	**2**	**1**	**1**

Table 12: Overview over the Number of Farms per Monitoring Period supposed to take part in the Projects and to report Data and the Number of Farms not reporting Data

It can be concluded from the decreasing number of farms not reporting data, that not all of the farms opted out completely. The farms that started monitoring in later monitoring periods did not opt out, but had delays in implementation. In the following, only the farms which did not report during all monitoring periods are considered as farms not participating (Table 13).

[12] The empty cells highlighted grey stand for monitoring periods that have not taken place yet (e.g. project no. 163 conducted only one monitoring period by January 2009).

Project no.	BE $_{ex\text{-}ante\ estimated}$ [tCO_2e]	BE $_{opted\ out\ farms}$ [tCO_2e]	BE $_{correct\ no.\ of\ farms}$ [tCO_2e]	Correction factor no. of farms	BE forecast success no. of farms [%]
105	322,434	0	322,434	1.00	27
108	23,379	0	23,379	1.00	22
120	370,476	44,652	326,556	1.13	20
150	353,957	2,063	346,752	1.02	26
161	143,780	0	143,682	1.00	40
162	262,221	64,806	197,298	1.33	31
163	62,922	0	62,922	1.00	45
196	97,584	15,868	81,535	1.20	40
197	46,976	6,497	40,437	1.16	10
204	143,690	26,377	117,282	1.23	23
225	83,288	5,912	74,711	1.11	33
240	194,074	0	194,074	1.00	38
257	155,131	13,920	141,270	1.10	19
324	173,245	40,374	133,196	1.30	26
335	204,668	0	204,668	1.00	27
336	705,034	50,508	630,126	1.12	28
337	523,928	5,577	506,795	1.03	29
364	537,754	0	537,754	1.00	23
365	135,700	0	135,700	1.00	18
409	17,815	0	17,815	1.00	13
411	307,821	9,767	336,869	0.91	19
412	263,023	16,431	279,911	0.94	29
417	242,547	40,259	237,482	1.02	23
418	163,392	68,749	95,932	1.70	31
419	276,261	5,920	270,130	1.02	34
420	109,332	5,600	103,655	1.05	34
421	107,178	3,159	104,567	1.02	22
422	231,867	18,228	213,146	1.09	28
Total	**6,259,476**	**444,665**	**5,881,410**	**1.06**	**27**

Table 13: BE initially estimated ex-ante, BE lost due to Farms not participating, BE with correct Number of Farms actually participating, corresponding Correction Factor and BE Forecast Success

This shows that 9 out of 28 projects did not lose any baseline emissions due to the drop out of farms, thus the correction factor equals 1.00. In case of project number 418 the highest effect can be observed resulting in a correction factor of 1.70. On average a correction factor of 1.06 is determined. The BE forecast success reaches 27 % if the correct number of farms would have been estimated in advance. It is higher than the initial forecast success of 25 % (chapter 3.2).

In conclusion, the correct forecast of participating farms would have resulted in a more accurate estimation of baseline emissions. **Thus, assumption 1 is correct.**

4.2 Start Date

Assumption 2: *The starting date of the monitoring on farms was estimated too optimistically, which leads to an overestimation of baseline emissions.*

In the following the impact of the inaccurate forecasting of the monitoring start is analyzed. Table 12 has shown that some farms started the reporting of monitoring data late. Thus, assumption 2 was suggested. The assessment of the delays results in a loss of BE (Table 14).

Project no.	BE ex-ante estimated [tCO_2e]	BE lost due to delays [tCO_2e]	BE start date [tCO_2e]	Correction factor start date	BE forecast success start date [%]
105	322,434	94,225	228,209	1.41	38
108	23,379	0	23,379	1.00	22
120	370,476	37,159	333,316	1.11	20
150	353,957	40,348	313,609	1.13	29
161	143,780	0	143,780	1.00	40
162	262,221	9,217	253,004	1.04	24
163	62,922	2,241	60,681	1.04	47
196	97,584	1,479	96,105	1.02	34
197	46,976	7,897	39,079	1.20	11
204	143,690	1,029	142,661	1.01	19
225	83,288	0	83,288	1.00	30
240	194,074	0	194,074	1.00	38
257	155,131	14,402	140,729	1.10	19
324	173,245	9,746	163,499	1.06	21
335	204,668	21,422	183,246	1.12	30
336	705,034	184,016	521,017	1.35	34
337	523,928	103,312	420,616	1.25	35
364	537,754	62,206	475,547	1.13	27
365	135,700	19,264	116,436	1.17	21
409	17,815	3,033	14,782	1.21	15
411	307,821	59,130	248,691	1.24	25
412	263,023	26,367	236,657	1.11	35
417	242,547	22,955	219,592	1.10	24
418	163,392	14,428	148,964	1.10	20
419	276,261	20,831	255,430	1.08	36
420	109,332	3,449	105,883	1.03	33
421	107,178	4,328	102,850	1.04	22
422	231,867	20,421	211,446	1.10	28
Total	**6,259,476**	**784,953**	**5,474,523**	**1.14**	**29**

Table 14: BE initially estimated ex-ante, Losses due to inaccurate Start Date Forecast BE with correct Start Date, Corresponding Correction Factor and BE Forecast Success

The table above demonstrates that in four cases no delays occurred (e.g. projects number 108, 161, 225, 240) whereas in all others they have an impact resulting in correction factors up to 1.41 (e.g. project number 105). It can be observed that nearly all projects lost BE due to delays. A correct ex-ante determination of the starting dates of the project would have led to a

BE forecast success of 29 %. Over-all a correction factor of 1.14 results, showing that **assumption 2 is true**; the date of the monitoring start was estimated too optimistically.

4.3 Population

Assumption 3: *The amount of animals was forecasted to optimistically leading to an overestimation of baseline emissions.*

In this chapter the comparison between the ex-ante estimated amount of animals and the ex-post monitored population is shown.

In Table 15 the left column presents the number of animals expected to be on site during the first monitoring periods of each project. This value is corrected by the animal counts lost due to opting out of farms and delays. The correction factor is derived along with the BE forecast success.

Project no.	Population ex-ante [head]	Population ex-post [head]	Correction factor population	BE forecast success population [%]
105	2,631,297	2,636,887	1.00	27
108	245,972	191,232	1.29	28
120	3,328,358	2,167,390	1.54	28
150	3,592,189	3,294,823	1.09	28
161	1,657,807	1,997,434	0.83	33
162	2,169,957	2,649,490	0.82	19
163	699,663	606,960	1.15	52
196	925,146	1,285,141	0.72	24
197	375,671	320,099	1.17	11
204	1,340,782	1,221,405	1.10	21
225	892,156	695,638	1.28	39
240	2,237,706	2,091,204	1.07	41
257	1,462,134	1,436,678	1.02	18
324	1,419,656	1,001,768	1.42	28
335	2,112,858	2,886,685	0.73	20
336	5,425,063	6,560,381	0.83	21
337	4,785,476	5,090,882	0.94	26
364	5,483,148	5,294,011	1.04	24
365	1,342,529	1,209,164	1.11	20
409	170,442	186,676	0.91	12
411	2,754,838	4,161,173	0.66	14
412	2,539,246	2,908,452	0.87	27
417	2,067,738	2,033,824	1.02	23
418	924,888	1,166,112	0.79	14
419	2,876,891	2,999,650	0.96	32
420	1,156,287	1,501,549	0.77	25
421	1,149,458	1,126,570	1.02	22
422	2,227,837	2,351,450	0.95	24
Total	**57,995,193**	**61,072,728**	**0.95**	**24**

Table 15: Population ex-ante and ex-post, corresponding Correction Factor and BE Forecast Success

Three different groups can be identified:

Correction factor >1.00

Population has been overestimated. Fewer animals have been kept than expected.

Example: In the case of project 324, the project developer expected to keep a population of about 1,420,000 animals during the periods that have been monitored so far. The ex-post measured number of animals equals 1,002,000.

a) **Correction factor 1.00**

Population estimates were accurate. As many animals as expected have been kept.

Example: In the case of project 105, about 2,631,000 animals were expected to produce manure and nearly the same population of 2,637,000 was monitored ex-post.

b) Correction factor < 1.00

Population was underestimated. More than the forecasted number of animals participated in the project activity.

Example: This is the case for project number 335, in which a population of 2,113,000 animals was estimated, whereas the ex-post counted number of heads was 2,887,000 during the three monitoring periods.

Table 15 shows the results of the comparison of the population ex-ante estimated and ex-post measured. A broad range can be observed. The highest correction factor is 1.54 of project number 120; the lowest factor is 0.66 of project number 411. The over-all comparison reveals that the population was forecasted quite accurately. In total the resulting correction factor is 0.95, showing a slight underestimation, in contrast to the expected overestimation in this assumption. Therefore, it can be concluded that **the suggested statement regarding the population forecast is false**.

4.4 Fraction of Animal Manure handled in System j

Assumption 4: *The fraction of animal manure handled in system j has been overestimated, which leads to an overestimation of baseline emissions.*

It has been assumed in chapter 2.2.1.4 that the ex-ante estimation of the parameter **fraction of manure handled in system j (MS%j)** is a reason for overestimation of BE.

All analyzed project activities have anaerobic lagoons as validated baseline scenario. It is described in the PDDs that 100 % of the manure handled on each farm are disposed in this type of AWMS. Therefore, MS%j ex-ante equals 100 % for all projects analyzed. In the ex-post situation described in the monitoring reports MS%j is 100% on all farms as well. The situation in the project scenario is the same situation as predicted, therefore the correction factor equals 1.00 (Table 16). In conclusion, no mistakes have been made while assessing the fraction of manure handled in the AWMS. **The assumption is incorrect.**

Project no.	**MS%j** $_{ex-ante}$ [%]	**MS%j** $_{ex-post}$ [%]	**Correction factor** $_{MS\%j}$	**BE forecast success** $_{MS\%j}$ [%]
105	100	100	1.00	27
108	100	100	1.00	22
120	100	100	1.00	18
150	100	100	1.00	26
161	100	100	1.00	40
162	100	100	1.00	23
163	100	100	1.00	45
196	100	100	1.00	34
197	100	100	1.00	9
204	100	100	1.00	19
225	100	100	1.00	30
240	100	100	1.00	38
257	100	100	1.00	17
324	100	100	1.00	20
335	100	100	1.00	27
336	100	100	1.00	25
337	100	100	1.00	28
364	100	100	1.00	23
365	100	100	1.00	18
409	100	100	1.00	13
411	100	100	1.00	21
412	100	100	1.00	31
417	100	100	1.00	22
418	100	100	1.00	18
419	100	100	1.00	33
420	100	100	1.00	32
421	100	100	1.00	21
422	100	100	1.00	26
Total	**100**	**100**	**1.00**	**25**

Table 16: Ex-ante and ex-post MS%j, corresponding Correction Factor and BE Forecast Success

4.5 Monitoring

Assumption 5: *The monitoring is not undertaken adequately, which leads to an overestimation of baseline emissions.*

The monitoring reports and the verification reports have been assessed in order to reveal mistakes in monitoring. The following issues were found:

- 22 of the 28 projects (see below) operated flow meters using inappropriate oil during the first one or two monitoring periods. According to the monitoring reports, the higher viscosity of the oil led to too low biogas measurements.
    - Projects using wrong oil in monitoring period I:

    162, 196, 204, 257, 324, 365, 409, 411, 412, 417, 418, 419, 422

    - Projects using wrong oil in monitoring period I+II:

    150, 161, 163, 335, 336, 337, 364
- Project 197 implemented an inappropriate biogas meter having a tendency to measure lower gas amounts than in fact generated according to the verification report.
- In case of project number 108 an unsuitable biogas meter was installed, which stopped operating and was not operational nor replaced during seven months. Thus, the correct measurements were lost and average biogas values measured during the previous months were taken as baseline emissions.
- In some cases malfunctioning of the equipment was documented.
- According to the verification reports no leaks in the digester cover were observed during the on-site visits, but the leakage-checks undertaken by the project operators were not documented. Thus, no judgment on methane lost through leaks in the covering layer of the digester can be made.

It was assumed that the higher the number of farms in a project the higher the amount of BE lost due to difficulties in monitoring coordination and project management. It was examined if a relation between the number of farms belonging to a project and the baseline forecast success exist. Figure 6 shows that such a relation does not exist.

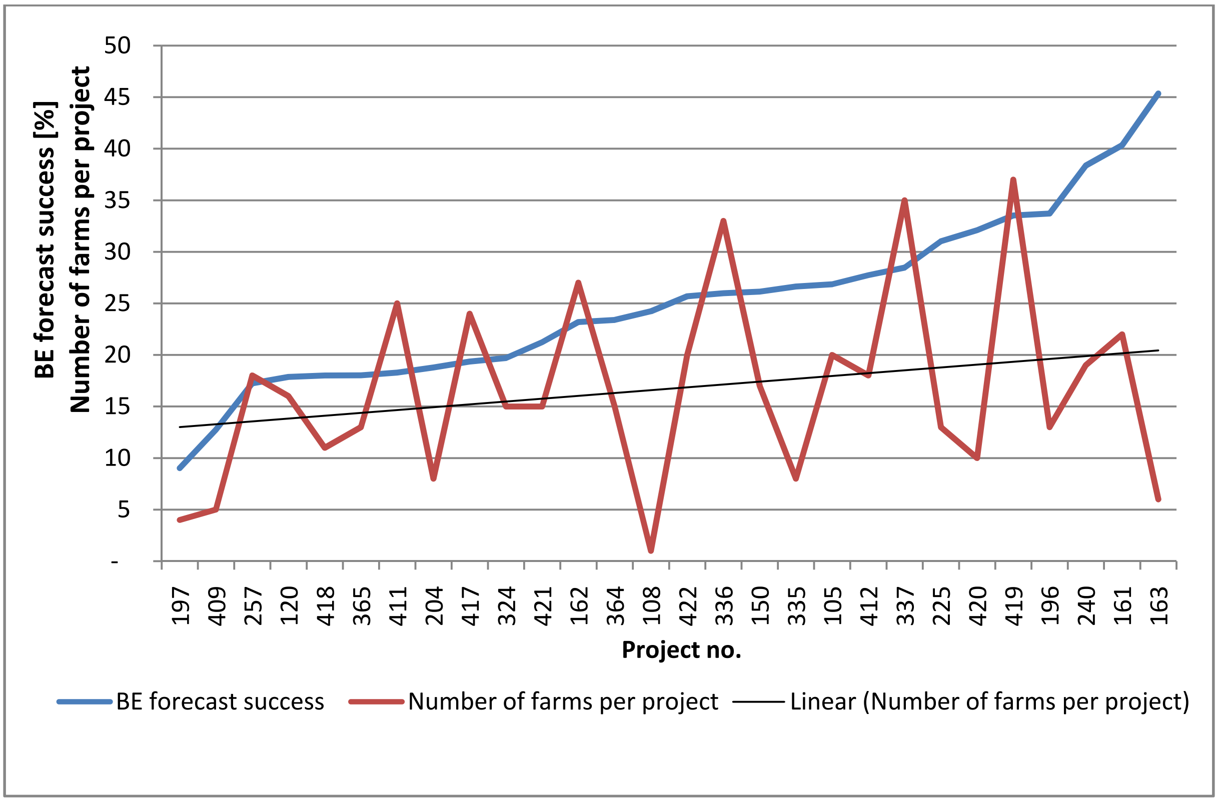

Figure 6: Relation between Number of Farms in a Project and initial BE Forecast Success (sorted by BE Forecast Success)

In conclusion, it can be stated that especially in the beginning of the monitoring mistakes occurred, leading to lower baseline emissions measured than in fact generated. The amount of baseline emissions lost through failures of monitoring cannot be quantified. However, it can be stated that:

The assumption that mistakes in monitoring led to a loss of baseline emissions is true.

4.6 Maximum Methane Potential

Assumption 6: *Using the IPCC 1996 default value for B_0 to estimate the baseline emissions leads to an overestimation of baseline emissions.*

In chapter 2.2.2.1 it was hypothesized that changing the B_0 value from 0.45 $m^3\ kg^{-1}$ (IPCC 1996) to 0.41 $m^3\ kg^{-1}$ would lead to a more accurate forecast in emission reductions. The baseline emissions were calculated with the IPCC default value and the new B_0 value and compared with the ex-post measured amount of emission reductions. The results of this analysis are presented in Table 17. It can be observed that the baseline emissions calculated with the alternative value of B_0 are below the baseline emission estimated based on the IPCC default value. The total resulting BE forecast success is 28 %.

Project no.	$B_{0\ IPCC\ default}$ [$m^3\ kg^{-1}$]	$B_{0\ new\ default}$ [$m^3\ kg^{-1}$]	Correction factor B_0	BE forecast success B_0 [%]
105	0.45	0.41	1.10	30
108	0.45	0.41	1.10	24
120	0.45	0.41	1.10	20
150	0.45	0.41	1.10	28
161	0.45	0.41	1.10	44
162	0.45	0.41	1.10	25
163	0.45	0.41	1.10	50
196	0.45	0.41	1.10	37
197	0.45	0.41	1.10	10
204	0.45	0.41	1.10	21
225	0.45	0.41	1.10	33
240	0.45	0.41	1.10	42
257	0.45	0.41	1.10	19
324	0.45	0.41	1.10	22
335	0.45	0.41	1.10	29
336	0.45	0.41	1.10	28
337	0.45	0.41	1.10	31
364	0.45	0.41	1.10	26
365	0.45	0.41	1.10	20
409	0.45	0.41	1.10	14
411	0.45	0.41	1.10	23
412	0.45	0.41	1.10	34
417	0.45	0.41	1.10	24
418	0.45	0.41	1.10	20
419	0.45	0.41	1.10	37
420	0.45	0.41	1.10	35
421	0.45	0.41	1.10	23
422	0.45	0.41	1.10	28
Total	**0.45**	**0.41**	**1.10**	**28**

Table 17: IPCC and alternative B_0 Default Value, corresponding Correction Factor and BE Forecast Success

Therefore, the use of the new B_0 leads to an increase of the over-all BE forecast success by the factor 1.10. Hence, it can be concluded that forecasting the BE by obtaining the IPCC default value for B_0, as required by the methodology, leads to an overestimation of BE. **Thus, assumption 6 is true**.

4.7 Volatile Solids

Assumption 7: *Using the IPCC 1996 default value for VS excretion leads to an overestimation of baseline emissions.*

In the following assumption 7 is assessed, before the impact of a weight adjustment of the IPCC default value and the new default value on VS is tested, as described in chapter 3.3.7.

Project no.	$VS_{IPCC\ default}$ [kg head^{-1}d^{-1}]	$VS_{new\ default}$ [kg head^{-1}d^{-1}]	Correction factor new VS	BE forecast success new VS [%]
105	0.50	0.43	1.16	32
108	0.50	0.43	1.16	26
120	0.50	0.43	1.16	21
150	0.50	0.43	1.16	30
161	0.50	0.43	1.16	47
162	0.50	0.43	1.16	27
163	0.50	0.43	1.16	53
196	0.50	0.43	1.16	39
197	0.50	0.43	1.16	10
204	0.50	0.43	1.16	22
225	0.50	0.43	1.16	35
240	0.50	0.43	1.16	45
257	0.50	0.43	1.16	20
324	0.50	0.43	1.16	23
335	0.50	0.43	1.16	31
336	0.50	0.43	1.16	29
337	0.50	0.43	1.16	32
364	0.50	0.43	1.16	27
365	0.50	0.43	1.16	21
409	0.50	0.43	1.16	15
411	0.50	0.43	1.16	24
412	0.50	0.43	1.16	36
417	0.50	0.43	1.16	26
418	0.50	0.43	1.16	21
419	0.50	0.43	1.16	39
420	0.50	0.43	1.16	37
421	0.50	0.43	1.16	25
422	0.50	0.43	1.16	30
Total	**0.50**	**0.43**	**1.16**	**30**

Table 18: Alternative VS Default Value, corresponding Correction Factor and BE Forecast Success

Table 18 demonstrates the results of the testing. The effect of applying the new VS value of 0.43 kg head^{-1}d^{-1} to forecast the baseline emissions, instead of the IPCC default value, is shown. This measure leads to an increase of the BE forecast success by the factor 1.16. If the new VS default value is used to forecast the baseline emissions, the success is 30 % instead of 25 %.

Thus, statement 7 is true. Using the IPCC default value of 0.50 kg $head^{-1}$ d^{-1} to calculate emissions ex-ante leads to an overestimation of baseline emissions.

4.8 Volatile Solids (weight adjusted)

Assumption 8: *Not adjusting a VS default value by animal weight, leads to an overestimation of baseline emissions.*

The effect of adjusting the default values given for 82 kg swine by average weight of animal classes is shown. **Adjusting the IPCC default of 0.5 kg $head^{-1}$ d^{-1}** value by animal weight leads to different project specific VS values depending on the animal categories kept on site. The average VS values in each project resulting from the adjustment of the VS of each farm by animal types are presented in Table 19. In addition, the corresponding correction factor and the resulting BE forecast success are shown.

Project no.	$VS_{IPCC\ default}$ [kg $head^{-1}d^{-1}$]	$VS_{IPCC\ default\ weight\ adjusted}$ [kg $head^{-1}d^{-1}$]	Correction factor $_{VS\ IPCC\ default\ weight\ adjusted}$	BE forecast success $VS_{IPCC\ default\ weight\ adjusted}$ [%]
105	0.5	0.37	1.35	37
108	0.5	0.43	1.17	26
120	0.5	0.36	1.39	25
150	0.5	0.34	1.46	38
161	0.5	0.46	1.08	44
162	0.5	0.44	1.13	26
163	0.5	0.37	1.35	61
196	0.5	0.41	1.23	41
197	0.5	0.25	2.01	18
204	0.5	0.34	1.45	27
225	0.5	0.39	1.28	38
240	0.5	0.31	1.61	62
257	0.5	0.38	1.31	23
324	0.5	0.34	1.45	29
335	0.5	0.47	1.07	28
336	0.5	0.36	1.38	35
337	0.5	0.34	1.46	41
364	0.5	0.92	0.54	13
365	0.5	0.28	1.76	32

Project no.	VS $_{IPCC\ default}$ [kg head^{-1}d^{-1}]	VS $_{IPCC\ default\ weight\ adjusted}$ [kg head^{-1}d^{-1}]	Correction factor $_{VS\ IPCC\ default\ weight\ adjusted}$	BE forecast success VS $_{IPCC\ default\ weight\ adjusted}$ [%]
409	0.5	0.36	1.41	18
411	0.5	0.43	1.17	24
412	0.5	0.35	1.42	44
417	0.5	0.31	1.62	36
418	0.5	0.37	1.37	25
419	0.5	0.36	1.38	46
420	0.5	0.36	1.40	45
421	0.5	0.40	1.25	27
422	0.5	0.34	1.46	37
Total	**0.50**	**0.39**	**1.29**	**33**

Table 19: Weight Adjustment of IPCC VS Default Value, corresponding Correction Factor and BE Forecast Success

It can be observed that in all cases except project number 364, the weight adjusted VS value lies below the IPCC default. The weight adjustment of the IPCC default value leads to an over-all correction of 1.29. The resulting total BE forecast success is 33 %. Thus, the BE calculated with the corrected default value result in a more accurate BE forecast. Therefore, it can be stated that **assumption 8 is true**: Not adjusting the VS default value by animal weight leads to an overestimation of BE.

In the next step, the **alternative VS default value of 0.43 kg head^{-1}d^{-1}** is **weight adjusted**. Table 20 shows the adjusted VS values and the corresponding correction factor of 1.50 in total. In the right column, the new BE forecast success is presented resulting from the adjustment. With 38 % it is 13 percent points higher than the original BE forecast success of 25 %.

This corroborates assumption 8 also for the alternative value. Not adjusting the VS default by animal weight leads to too high baseline emission estimates, adjusting it results in more accurate forecasts.

As the last tested measure (adjusting the alternative VS value) leads to the highest effect and combines the results from the assessment of assumption 6 and 7, this approach is used when combining all measures in chapter 4.10.

Project no.	VS $_{IPCC\ defaul}$ [kg head^{-1}d^{-1}]	VS $_{new\ default\ weight\ adjusted}$ [kg head^{-1}d^{-1}]	Correction factor $_{new\ VS\ default\ weight\ adjusted}$	BE forecast success $_{new\ VS\ default\ weight\ adjusted}$ [%]
105	0.5	0.32	1.57	43
108	0.5	0.37	1.36	30
120	0.5	0.31	1.62	29
150	0.5	0.30	1.69	44
161	0.5	0.40	1.26	51
162	0.5	0.38	1.32	31
163	0.5	0.32	1.56	71
196	0.5	0.35	1.43	48
197	0.5	0.21	2.34	21
204	0.5	0.30	1.69	32
225	0.5	0.34	1.49	45
240	0.5	0.27	1.88	72
257	0.5	0.33	1.52	26
324	0.5	0.30	1.69	33
335	0.5	0.40	1.24	33
336	0.5	0.31	1.60	40
337	0.5	0.29	1.70	47
364	0.5	0.79	0.63	15
365	0.5	0.24	2.04	37
409	0.5	0.31	1.64	21
411	0.5	0.37	1.36	28
412	0.5	0.30	1.65	52
417	0.5	0.27	1.88	42
418	0.5	0.31	1.59	29
419	0.5	0.31	1.61	54
420	0.5	0.31	1.63	52
421	0.5	0.34	1.46	31
422	0.5	0.29	1.70	43
Total	**0.50**	**0.33**	**1.50**	**38**

Table 20: Alternative Weight Adjusted VS Default Values, corresponding Correction Factor and BE Forecast Success

4.9 Methane Conversion Factor

Assumption 9: *Applying the IPCC default value for MCF of 90 % leads to an overestimation of baseline emissions.*

4.9.1 Methane Conversion Factor calculated with IPCC Default Values

Table 21 presents the MCF values calculated for each reported monitoring period of every analyzed project activity.

Project no.	**MCF [%]** (parameters chosen as per PDD)				
Monitoring period	**I**	**II**	**III**	**IV**	**V**
105	22	35	36	36	
108	24	27	36		
120	21	32	31	35	30
150	14	26	34	27	
161	34	30	29		
162	9	31			
163	32	54	53	48	
196	23	28			
197	14				
204	15	25	27		
225	32	41			
240	39	39	32		
257	11	22			
324	27	43	35		
335	15	21	25		
336	21	26	32	30	
337	20	22	34	36	
364	20	20	27	32	
365	12	26	25		
409	13				
411	13	15	21		
412	27	31	30		
417	19	31	28		
418	17	24	34		
419	20	36	38		
420	22	29			
421	19	24			
422	18	27	29		
Average	**20**	**29**	**32**	**35**	**30**
Minimum	9	15	21	27	30
Maximum	39	54	53	48	30
Over-all average	**27**				

Table 21: MCF reached by Projects calculated with IPCC Default Values for VS and B_0

All monitoring periods show different MCF values on average. During the first period the average MCF was about 20 % and increased during the following three monitoring periods up to 35 %. As few projects had already undertaken the fourth and fifth monitoring period by the time the data was assessed, only the first three periods were considered, when concluding that the MCF increases over time. The same is true for the minimum and maximum levels.
Furthermore, it can be stated that a broad range of values is resulting. The overall minimum value is 9 %, whereas the maximum MCF lays at 54 %. The overall average amounts to 27 %.

Figure 7 shows the distribution of the MCF values in the monitoring periods of the sample. Out of the 87 MCF values building the set of data (31 projects, 2.8 monitoring periods on average), 28 times projects performed with a MCF value from below 24 % in a monitoring period. MCFs between 24 % and 39 % were reached 53 times and 6 project activities had a MCF of more than 39 %.

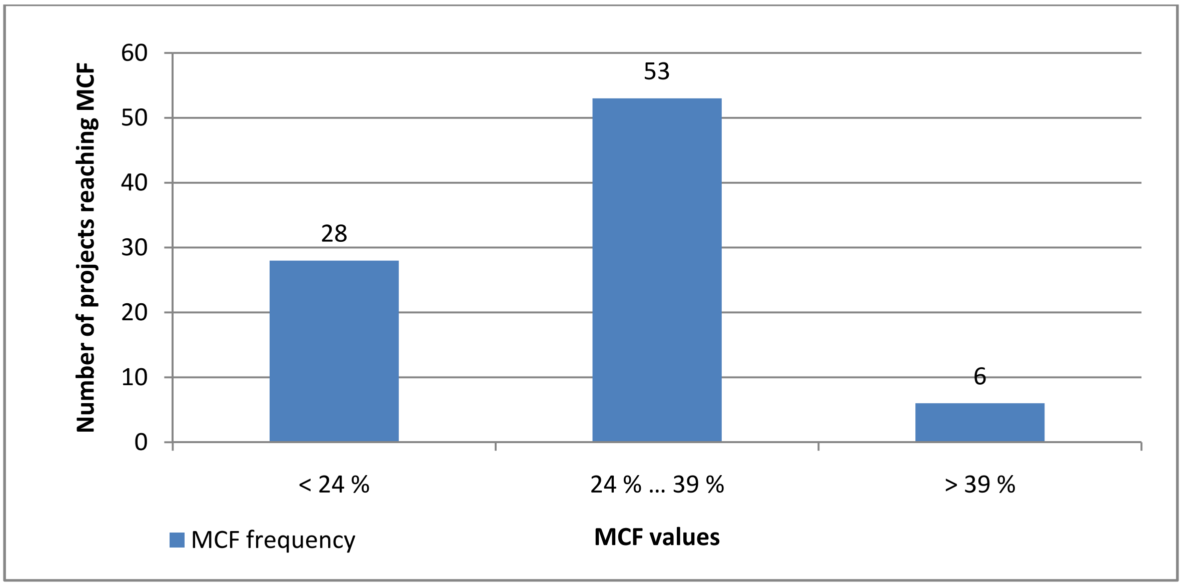

Figure 7: MCF Frequency Distribution

4.9.2 Methane Conversion Factor calculated with intermediate Results

The consideration of the intermediate results from chapters 4.1 to 4.7 resulted in the values presented in Table 22.

Project no.	MCF [%] (VS = 0.43 kg head^{-1}d^{-1} weight adjusted, B_0 = 0.41 m^3 kg^{-1}, ex-post population)				
Monitoring period	**I**	**II**	**III**	**IV**	**V**
105	42	69	71	71	
108	37	41	55		
120	60	90	89	100	85
150	26	48	64	50	
161	67	58	57		
162	18	58			
163	54	92	90	82	
196	46	55			
197	33				
204	26	44	47		
225	61	79			
240	70	70	57		
257	23	43			
324	44	69	56		
335	34	48	58		
336	67	80	101	94	
337	41	46	69	75	
364	38	39	52	61	
365	34	73	71		
409	25				
411	24	28	40		
412	46	52	50		
417	36	61	56		
418	29	40	56		
419	35	63	68		
420	44	60			
421	32	40			
422	30	44	49		
Average	**40**	**57**	**63**	**76**	**85**
Minimum	18	28	40	50	85
Maximum	70	92	101	100	85
Over-all average	**55**				

Table 22: MCF calculated with Results from Chapters 4.1-4.7

The trend of MCF increasing over the first monitoring periods is the same as in Table 21. However, the over-all values are higher with an average of about 55 %. The maximum MCF of 101 % is reached by project number 336 in the third monitoring period the lowest (18 %) with project 162 in the first monitoring period.

The MCF of 55 % is used in the following instead of 27 %, as it is adjusted by the results already achieved.

Project no.	MCF $_{IPCC}$ [%]	MCF $_{new}$ [%]	Correction factor $_{MCF}$	BE forecast success $_{MCF}$ [%]
105	90	55	1.64	44
108	90	55	1.64	36
120	90	55	1.64	29
150	90	55	1.64	42
161	90	55	1.64	66
162	90	55	1.64	38
163	90	55	1.64	74
196	90	55	1.64	55
197	90	55	1.64	15
204	90	55	1.64	31
225	90	55	1.64	49
240	90	55	1.64	63
257	90	55	1.64	28
324	90	55	1.64	32
335	90	55	1.64	44
336	90	55	1.64	41
337	90	55	1.64	46
364	90	55	1.64	38
365	90	55	1.64	29
409	90	55	1.64	21
411	90	55	1.64	34
412	90	55	1.64	51
417	90	55	1.64	36
418	90	55	1.64	30
419	90	55	1.64	55
420	90	55	1.64	52
421	90	55	1.64	35
422	90	55	1.64	42
Total	**90**	**55**	**1.64**	**42**

Table 23: Alternative MCF, corresponding Correction Factor and BE Forecast Success

Table 23 shows the effect of using the new lower MCF value of 55 % when forecasting the baseline emissions. The over-all BE forecast success equals 42 %, and the resulting correction factor is 1.64, demonstrating that assumption 8 is true; using the IPCC MCF default value of 90 % leads to an overestimation of BE.

4.9.3 Assessment of the typical MCF Curve

Only seven projects (120, 163, 204, 240, 324, 409, 412 and 419) show a MCF-temperature relation that can be considered "typical" with restrictions, compared to Figure 4. Figure 8 - Figure 11 demonstrate a progression considered typical as examples. Figure 12 shows a MCF-temperature relation that is considered untypical observed in ten of the cases. In the remaining projects a correlation can be realized, but the fluctuations are too high for considering it typical.

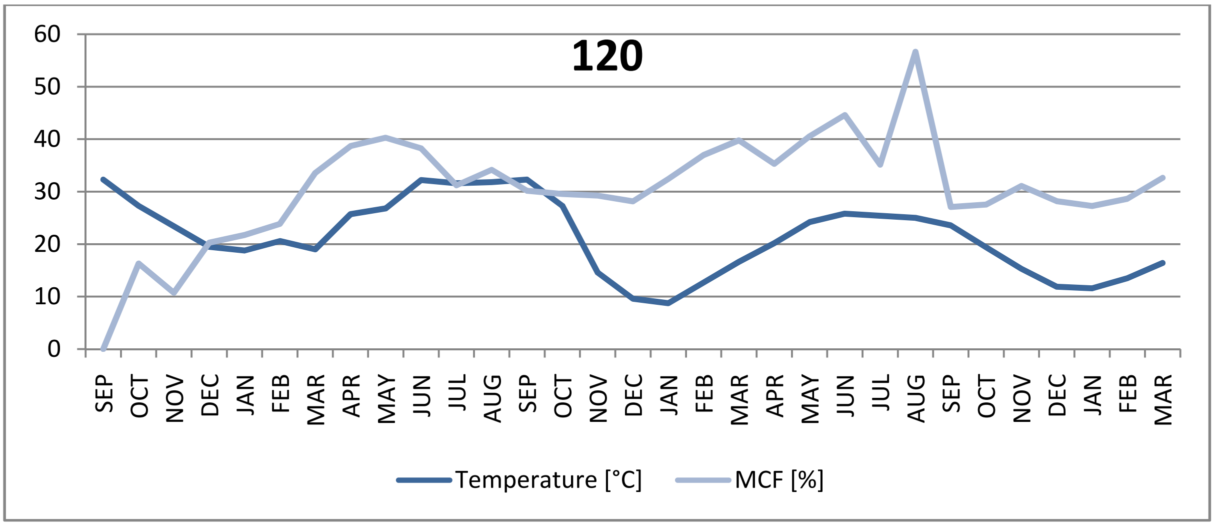

Figure 8: MCF Curve Project Number 120

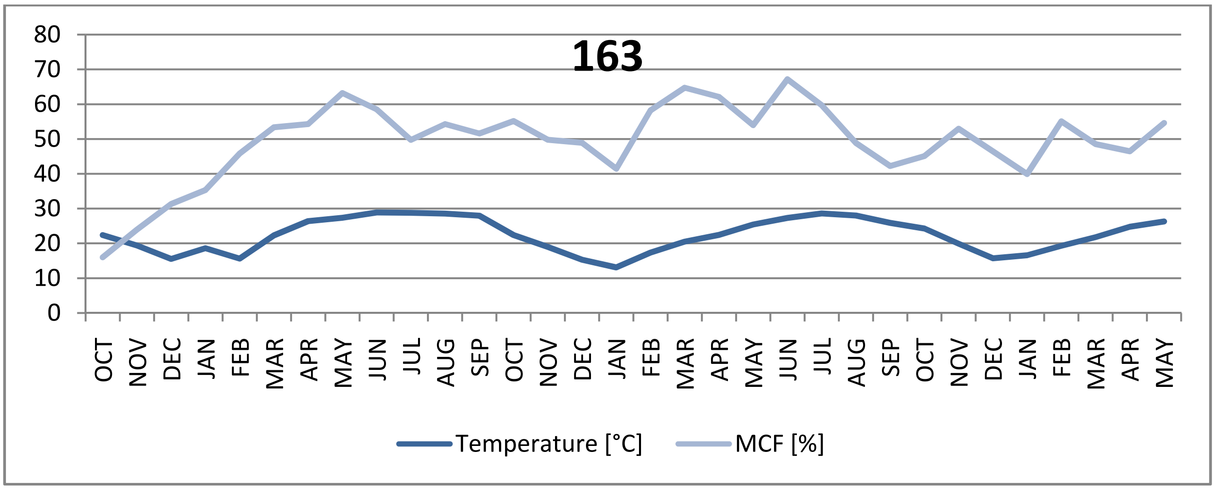

Figure 9: MCF Curve Project Number 163

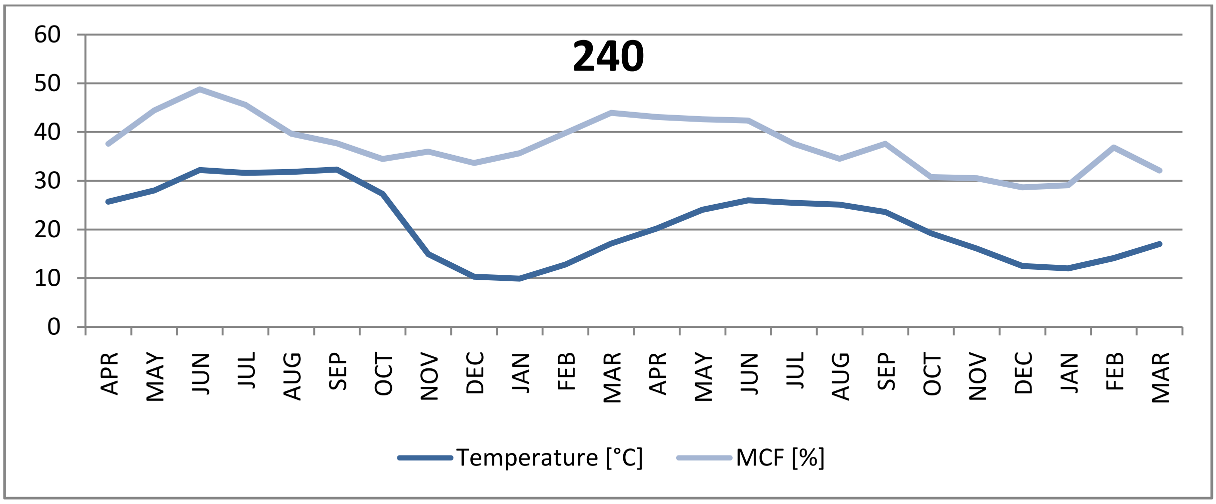

Figure 10: MCF Curve Project Number 240

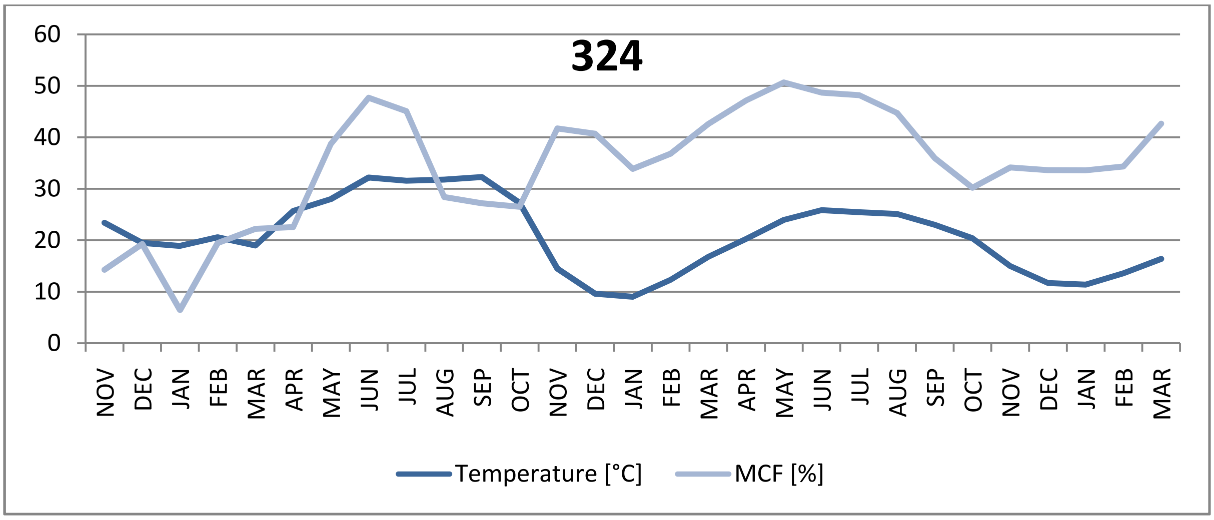

Figure 11: MCF Curve Project Number 324

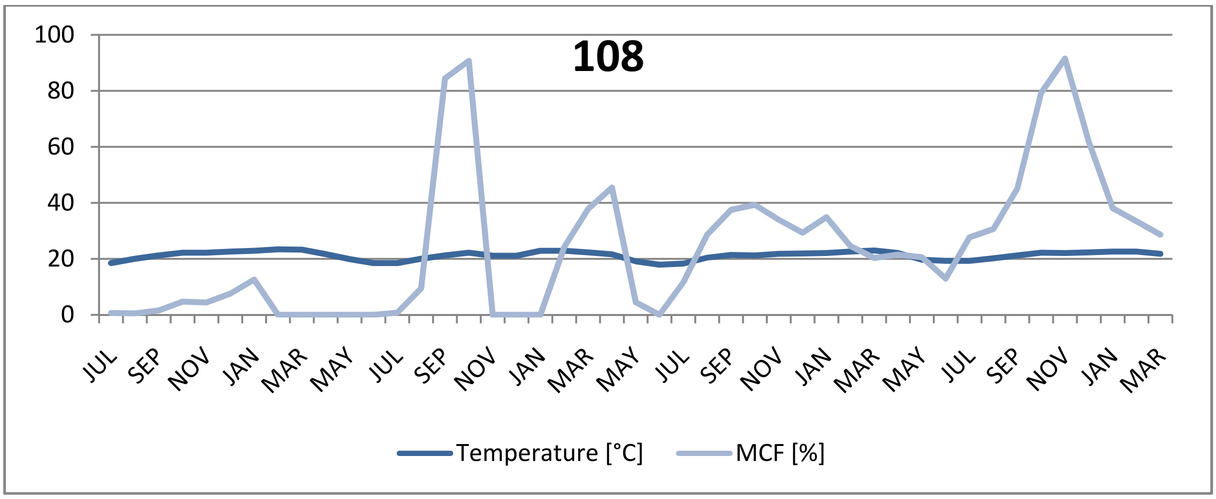

Figure 12: MCF Curve Project Number 108

4.10 Combined Effect of introduced Measures

In this chapter the results from applying all tested measures in line with the two hypotheses and all together are presented.

Figure 13 shows the distribution of BE forecast successes among the sample, after applying all tested alternatives. Ten out of 28 projects have a BE forecast success of below 75 %. The majority (16) of the sample reaches a success between 75 % and 125 % and two projects have a BE forecast success of more than 125 % after applying all measures. Considering that initially the highest individual BE forecast success was 45 % reached by project number 163, it is obvious that the measures undertaken lead to an improvement of forecast accuracy.

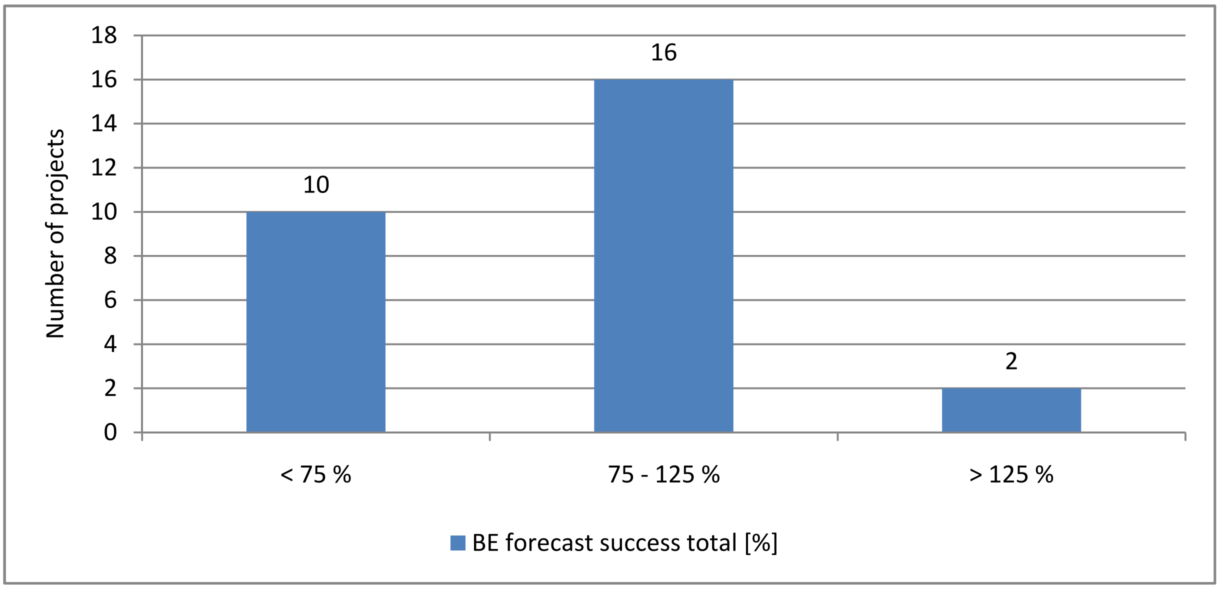

Figure 13: Distribution of total BE Forecast Success among Projects

Table 24 presents the total correction factors resulting for each project and the corresponding BE forecast success. The total correction factor is higher than 1.00 in all cases. Thus, the BE forecast success of all analyzed projects is higher when the introduced measures are applied jointly.

Furthermore, it can be seen that the range of total correction factors is very broad. The lowest factor (1.33) is resulting in case of project number 364. The highest factor is shown by project number 197 (6.83). The BE forecast success varies between projects as well. After applying all measures project number 411 reaches a BE forecast success of 33 %, whereas project number 163 shows a particular high success of 154 %. The total correction factor of all measures combined is 3.13, which leads to an improved BE forecast success of 79 %, instead of the initially achieved forecast success of 25 %. In Annex 1 all individual correction factors are shown along with the total correction factor, being the product of all individual correction factors. The impact of all individual measures as well as the combined effect is shown in Annex 2.

Project no.	Correction factor $_{total}$	BE forecast success initial [%]	BE forecast success $_{total}$ after corrections [%]
105	3.99	27	108
108	3.15	22	85
120	5.64	18	102
150	3.82	26	101
161	1.88	40	76
162	2.67	23	62
163	3.35	45	154
196	2.24	34	76
197	6.88	9	62
204	4.10	19	78
225	3.82	30	121
240	3.61	38	139
257	3.37	17	58
324	5.92	20	118
335	1.82	27	49
336	3.60	25	96
337	3.69	28	106
364	1.32	23	31
365	4.75	18	87
409	3.25	13	42
411	1.82	21	33
412	2.71	31	75
417	3.87	22	72
418	4.24	18	81
419	3.06	33	97
420	2.46	32	100
421	2.86	21	54
422	3.44	26	87
Total	**3.13**	**25**	**79**

Table 24: Total Correction Factor and resulting BE Forecast Success

The other approach to test the effect of the elaborated alternatives is calculating the BE using the new values for each parameter at the same time, which leads to a total BE forecast success of 75 %. This is lower than a BE forecast success of 79 % when correcting the initial forecast success by the total correction factor. The average is 77 %. The deviation is analyzed and presented in Annex 3. Assessing the impact of one parameter at time by using the correction factor or calculating the BE based on the alternative value, leads to negligible differences, if any, between the two BE amounts resulting. This is due to rounding errors. When on the one hand combining all correction factors (3.13) and applying all alternative values at once for the other the effect increases. Two different BE values and therewith two different BE forecast successes (79 % and 75 %) emerge.

It can be concluded that the new over-all BE forecast success lays around 77 % and is higher than the initial BE forecast success of 25 %. The measures introduced in this study lead to an improvement of the estimation of baseline emission.

4.11 Summary of Results

Table 25 gives an overview of all tested assumptions and the results of applying the measures as described in chapter 3.3. It can be concluded that, with the exception of assumption 3 and 4, all statements were supported by the results. However, although each tested parameter has an impact on the baseline emissions, neither one of them accounts alone for the overestimation of baseline emissions. The statements can be grouped by their impact on the BE forecast success:

- **Negative impact:** The project developer underestimated the population. If they estimated the number of animals correctly, the BE estimates would have been increased and the BE forecast success decreased.
- **No impact:** The estimates on the fraction of manure handled in the system are accurate. Therefore the correction factor is 1.00 and the BE forecast remains 25 %.
- **Minor positive impact:** The corrections undertaken in line with assumption 1, 2, 6, 7 and 10 led to a small increase of BE forecast success. The correction factors lay between 1.01 and 1.16 leading to improved BE forecast successes in the range of 26 % up to 30 %.
- **Major positive impact:** The measures regarding assumption 8 and 9 show a high impact. The measures individually undertaken lead to correction factors of 1.29 when adjusting the IPCC VS default value; 1.50 if the new VS default value is corrected by animal weight and 1.64 if the reduced MCF value is obtained. The resulting BE forecast successes are 33 %, 38 % and 42 % respectively.

Looking at the individual measures that improve the total BE forecast success, the original BE forecast success of 25 % is increased to 27 % if the number of participating farms is forecasted correctly. The effect of estimating of the starting dates of monitoring correctly is 1.14 leading to a BE forecast success of 29 %. A similar impact on the BE success have the use of the alternative B_0 and VS default values. If the new VS default value is adjusted to the weight of animal classes on-site the BE success reaches 38 %. The use of an MCF value of 55 % leads to the highest BE forecast success among the individual measures with 42 %. All measures combined result in a correction factor of 3.13 and a BE forecast success of about 79 %, which is higher than the originally reached success of 25 %.

Hypothesis	Assumption				
	No.	Parameter	Content	Conclusion: true/false	
				CF	BE forecast success
I	1	**No. of farms**	The number of farms participating in a project was overestimated, which leads to an overestimation of baseline emissions.	true	
		Tested correction	Using the ex-post measured number of farms.	1.06	27 %
	2	**Start date**	The starting date of the monitoring on the farms was estimated too optimistically, which leads to an overestimation of baseline emissions.	true	
		Tested correction	Using the ex-post determined starting date.	1.14	29 %
	3	**Population**	The amount of animals was forecasted to optimistically leading to an overestimation of baseline emissions.	false	
		Tested correction	Using the ex-post measured population.	0.95	24 %
	4	**MS%j**	The fraction of animal manure handled in system j has been overestimated, which leads to an overestimation of baseline emissions.	false	
		Tested correction	Using the ex-post monitored value for MS%j.	1.00	25 %
	5	**Monitoring**	The monitoring is not undertaken adequately, which leads to an overestimation of baseline emissions.	true	
		Tested correction	na	na	na
	Total Hypothesis I			**1.16**	**29 %**
II	6	**B_0**	Using the IPCC 1996 default value for B_0 to estimate the baseline emissions leads to an overestimation of baseline emissions.	true	
		Tested correction	Using the newly developed default value of 0.41 m^3 kg^{-1}.	1.10	28 %
	7	**VS**	Using the IPCC 1996 default value for VS excretion leads to an overestimation of baseline emissions.	true	
		Tested correction	Using the newly developed default value of 0.43 kg $head^{-1}d^{-1}$.	1.16	30 %
	8	**VS**	Not adjusting a VS default value by animal weight leads to an overestimation of baseline emissions.	true	
		Tested correction	Adjusting the IPCC default value of 0.5 kg $head^{-1}d^{-1}$ by animal weight.	1.29	33 %
		Tested correction	Adjusting the newly developed default value of 0.43 kg $head^{-1}d^{-1}$ by animal weight.	1.50	38 %
	9	**MCF**	Applying the IPCC default value for MCF of 90 % leads to an overestimation of baseline emissions.	true	
		Tested correction	Using the newly developed default value of 55 %.	1.64	42 %
	Total Hypothesis II			**2.71**	**66 %**
Total				**3.13**	**79 %**

Table 25: Summary of tested Hypotheses and Assumptions

The assumptions tested under **hypothesis I** (assumption 1-5) show heterogeneous results. The estimation of the number of farms and the start date led to an overestimation, whereas the population was underestimated. The fraction of manure was assessed correctly. In case of the assessment of the monitoring, mistakes could be observed, but quantifying the impact was not possible. Multiplying the correction factors of the parameters analysed in line with the first hypothesis leads to a factor of 1.16 and a BE forecast success of 29 %. Therewith, it can be stated that over-all hypothesis I is true.

In case of **hypothesis II** all assumptions are shown to be correct. The use of all default values led to an overestimation of baseline emissions. The multiplication of all correction factors under hypothesis II leads to a factor of 2.71 resulting in an improved BE forecast success of 66 %. Comparing this result with 1.16 it can be concluded that the default values have a higher impact on the success of the analyzed project than the ex-ante assessment of descriptive statistical data.

5 DISCUSSION

The results achieved in line with this research will be discussed considering relevant literature as well as statements made by interviewed experts during the Carbon Expo 2009 in Barcelona. These interviews were undertaken, in order to evaluate the perception of this problem in the carbon business. Opinions of relevant persons on the causes for the underperformance were obtained. A set of suitable persons involved in animal waste managing projects was identified in advance to the survey. It was intended to interview representatives of all relevant stakeholder groups involved in a CDM project activity. Except questioning an EB member, this was fulfilled. Three representatives of DOEs being involved in animal waste management projects were interviewed as well as five project developers, one CDM analyst and one independent country expert who also works for the Brazilian DNA. The interviewees were asked to name the three main reasons for the underperformance of animal waste project activities.

Summarizing the answers, three main reasons were assumed to be causative for the underperformance of the project activities.

1. The **number of farms** participating in the projects was overestimated.
2. The **methodology** is responsible for the low issuance success. The guidance on estimating the emission reductions leads to an overestimation of emission reductions.
3. The **monitoring** has not been undertaken adequately. Hence, emission reductions are lost.

5.1 Hypothesis I

It has been demonstrated that the descriptive statistical data is more accurately assessed ex-ante than expected. The comparison of the ex-ante assumed values and the ex-post monitored data, leads to the conclusion that project specific data assessment is only a minor source of mistake when estimating emission reductions. This is discussed for each parameter individually in the following.

5.1.1 Number of Farms

Regarding the **number of participating farms** it has been shown in chapter 4.1 that avoiding the inaccurate forecast of this parameter has a positive impact on the BE forecast success. In only 9 out of 28 projects all farms participated as planned, the remaining projects consist of fewer farms than planned. The reasons for the opting out of farms could not be found in detail. According to interviewees in some cases production sites were not built at all or pork producers went bankrupt (Anonym I 2009). The latter is the case according to the interviewee for project number 108. In other cases farmers withdrew their agreement to participate for unknown reasons. However, no scientific evidence on these opinions could be found.

The questioned experts ranked this parameter as one of the main reasons for overestimation of baseline emissions. This is not supported by the results. The effect of opting out of farms is not very strong (1.06). It ranks among the parameters having only a minor impact. Nevertheless, anticipating the opting out of a certain number of farms when planning a CDM project, would lead to more accurate and conservative estimates.

5.1.2 Start Date

The inaccurate forecast of the **start date** of monitoring has a slightly higher impact on the BE forecast success than the opting out of farms. Delayed project start is not a specific problem to animal waste management projects. Castro et al. (2007) concluded that delays due to many reasons defer the start of CDM projects of many types. This study shows that in case of animal waste management projects this is also true. Forecasting the correct project start would have led to an increase of BE forecast success up to 29 % over-all. Specific reasons for the delays are not available. In general, inexperience in technology, lacking knowledge of country specific procedures and the CDM process are possibilities. These are also mentioned by Castro et al. (2007). Similar to the anticipation of opting out of farms, a conservative realistic time planning is advantageous in order to reach a better BE forecast success.

5.1.3 Population

The **population** in the projects has been underestimated ex-ante, if looking at the total of all projects. An accurate estimating would have reduced the BE forecast success by 0.95 down to 24 %. However, the effect on the individual project is very heterogeneous; some overestimated the animal counts and some underestimated the population significantly. It is shown that a general exaggeration of population data by the farm owners, as stated by one interviewee (Anonym I 2009) is not the case. It has to be considered that forecasting annual animal counts is particularly difficult in the swine market as it is subject to the pork cycle (Hanau 1956). On the one hand, these heavy market fluctuations impede the forecast of the population. On the other hand, the quite short monitoring time does not give representative data. A final conclusion on the accuracy of the population forecasts can only be made after a long-term assessment of the animal counts in a couple of years.

The methodology does not give guidance on how to assess the population. Especially the time period for which farm records shall be obtained is left open. However, over-all project developer handled this parameter with caution and tended to make conservative assumptions. Thus, the methodological guidance can be considered appropriate. Nevertheless, the possibility of fluctuations in population due to market instabilities should be factored in advance.

5.1.4 Fraction of Manure Handled in System j

The parameter **MS%j** is the only parameter estimated accurately in all projects. Nevertheless, an interviewee stated that solid separators have been seen on site (Anonym II, 2009). Separation of solids is common practice in developing countries. The solid fraction is often used for feeding ruminants and the liquid portion for land irrigation. 50 % of the assessed pork producing farms in a study undertaken in Mexico by Deecke (2005) used solid separators (Taiganides et al. 1996; Deecke 2005). Separating the manure leads to a reduction of emissions in the baseline and the project scenario. Therefore, it is unlikely that the separators are used to segregate the undigested manure after the project is implemented, provided that the personnel on site are aware of this fact. However, solid separators are not explicitly listed as animal waste management treatment system in the methodology and are therefore not considered. In addition, their use has neither been documented by the project owners, nor observed by the verifying and validating DOEs. Therefore, obtaining 100 % in both scenarios has to be accepted although therewith, the projects form an exception from the common practice at least in Mexico.

5.1.5 Monitoring

The outcome of the analysis of the **monitoring** leads to the conclusion that mistakes in monitoring occurred and most likely resulted in a reduction of baseline emissions. They also show inexperience in the implementation and monitoring of CDM projects, especially regarding the technology and its maintenance requirements. This is substantiated by statements resulting from the interviews during the Carbon Expo 2009 (Anonym II 2009; Anonym III 2009; Anonym V 2009). The information given on monitoring quality in the reports is only limited. Although monitoring and verification reports do not document leaks in the cover of the digesters some interviewed persons referred to leaks observed on site (Anonym IV 2009).

Some issues related to the monitoring have to be discussed in respect to the methodological guidance in general. Firstly, the indirect determination of the methane content of the biogas can lead to an overrating of methane. If air enters the system the gas volume increases whereas the content of carbon dioxide decreases. As the methane content is defined by the methodology to be the remaining fraction of the measured gas amount it would be determined higher than it is in reality. In addition, the concentration of CO_2 in the biogas is measured on a quarterly basis. Fluctuations in the composition of the biogas occur during the biodigestion (Kaltschmitt et al. 2001). These changes in composition of the biogas are not adequately considered by this method. If the CO_2 concentration is particular high on the day of measurement, the amount of methane is low and vice versa. As the result of the quarterly indirect methane determination is applied for the entire period of three months it can falsify the methane amount documented. Therefore, a direct methane measurement conducted with a higher frequency is recommended in order to obtain correct, reliable methane production data.

These issues on monitoring may lead to an under- or overrating of methane. This lesson was partly learned and applied when designing the consecutive methodology ACM0010. The biogas measurements have to be undertaken on a weekly basis according to the revised methodology. Nevertheless, the frequency of measuring the methane concentration may still be decided by the project developer (ACM0010).

Therefore, more detailed observation of monitoring practices on site might lead to more specific conclusions. However, it is to be expected that the quality of monitoring varies among projects depending on the experience of the project developer as well in terms of the design of the monitoring plan as in the implementation of the project and its monitoring. In addition, the knowledge, experience and reliability of the project owner and people working on site are important to ensure high quality monitoring.

5.2 Hypothesis II

The use of default values has a high impact on the baseline emission forecast success of the analyzed project activities. When ranking the results regarding hypothesis II it has to be considered that all projects overestimated the BE amount and that the equations to calculate BE (Equation 5, Equation 6) are products. A decent reduction of any of the parameters leads to a higher forecast success. Thus, the resulting increase of BE forecast success when using the new lower default values is not necessarily evidencing their accuracy. The uncertainties related to the assessment of each alternative default value are further discussed for each parameter below.

5.2.1 Maximum Methane Potential

It has been shown that a lower **maximum methane potential** default value of 0.41 m^3 kg^{-1} leads to more accurate BE forecasts of 28 % in comparison to 25 % of the initially achieved success. It has certainly to be considered that the methods of obtaining B_0 were not standardized and vary significantly among the references. In addition, it has to be mentioned that the new B_0 is not specific to swine categories. Although these inaccuracies exist, the new B_0 default value is supported by the 2006 IPCC default values. The IPCC issued different values in 2006 for market and breeding swine assuming 0.55-0.41 m^3 kg^{-1} for North America and 0.52-0.38 m^3 kg^{-1} (IPCC 2006) for Europe. This confirms that a range of possible B_0 values exists and that the new default value is in line with the lower and conservative values published by the IPCC in 2006. Additional research is necessary on this parameter. Due to numerous impacts influencing B_0 and lacking standardization of determining it, no final conclusion on one explicit B_0 default value can be made. It can however, be stated that a lower B_0 leads to more conservative estimations. In order to determine reliable B_0 default values for all swine categories, more research following standardized methods is necessary.

5.2.2 Volatile Solids (with and without weight adjustment)

It has been observed that using the new **VS** default value of 0.43 kg $head^{-1}d^{-1}$ obtained through a comparison of values found in the literature increases the BE forecast success by 1.16. The same relation between a reduction of the parameter and the corresponding increase of BE forecast success as described in chapter 5.2.1 applies to VS and the other parameters analyzed. However, the lower VS default value is supported by the change in published IPCC default values in 2006. The IPCC 2006 guidelines differentiate between two swine categories and issue over-all lower values as in 1996. One category is market swine weighing from 46 kg to 50 kg with a VS excretion of 0.27 to 0.30 kg $head^{-1}d^{-1}$. The second category is breeding swine with an average weight of around 198 kg and an amount of 0.46 to 0.50 kg VS excreted daily per animal (IPCC 2006). These values lead to three conclusions: Firstly, the value of 0.50 kg for a 82 kg swine published in 1996 is too high. Secondly, it demonstrates that market and breeding swine excrete substrates of different biogas potential. Thirdly, it shows that a weight adjustment is necessary when aiming to forecast excretion rates accurately. This supports the findings in chapter 4.7. and 4.8. The adjustment of the default value by individual weight of swine categories has one of the highest impacts on the BE forecast among the tested measures. Combining the lower VS default value with its weight adjustment improves the estimates by the factor 1.50 leading to a BE forecast success of 38 %. The adjustment in this study is undertaken by obtaining standard North American animal class weights. The accuracy would be improved further if the particular weight of the swine groups on-site would be assessed when planning a CDM project. In addition, laboratory analyses of VS content of the manure could lead to an improvement.

This finding is furthermore supported by the analyses of projects number 31, 32 and 33. These projects apply AM0006, which in contrast to AM0016, requires an adjustment of the IPCC default value by site-specific swine weights. Projects number 31, 32 and 33 calculate VS using site specific feed intake and digestibility data and adjust the VS excretion rate by weight (UNFCCC 2004). The resulting values on one hand support the IPCC 1996 VS default value as the VS excretion rate assessed in this case equals the IPCC 1996 value of 0.5 kg $head^{-1}d^{-1}$. This is in contrast to the outcome of chapters 3.3.7 and 4.7 and the values published by the IPCC 2006. On the other hand it substantiates that a weight adjustment is necessary. In the case of these projects not adjusting the VS value would have led to an overestimation of methane emissions on four out of five farms and to an underestimation at one.

However, even though the guidance of AM0006 has to be considered stricter and more accurate, the overestimation of VS values is only partly due to the methodology. AM0016 suggests the weight adjustment as one possibility. In addition, it informs the project developer in line with the IPCC 1996 guidance about the uncertainty related to the use of the default values.

5.2.3 Methane Conversion Factor

It has been shown that the **MCF** is one of the most complex factors assessed in line with this research. Using the MCF of 55 %, which was derived in this study based on monitoring data and intermediate results, led to the highest improvement of BE forecast success among the tested measures.

The assessment of MCF is difficult. One possibility to approach this parameter for the projects analyzed based on the limited data available was to calculate it using the amount of methane monitored ex-post and the parameters obtained at PDD stage. The resulting MCF of 27 % is very low compared to the IPCC default value of 90 %. By determining the MCF as described, the resulting value balances all kind of mistakes during monitoring and inaccurate estimates. Therefore, a second approach was followed. The impact of inaccurate estimates of the population, starting dates, numbers of farms, B_0, and VS was reduced by calculating the MCF another time using the adjusted, more accurate values resulting from the assessment in chapters 4.1- 4.8. The resulting value of 55 % is considered more realistic, yet still, balances mistakes occurring during monitoring, since the ex-post documented methane amount might not be the same as produced in the digester. Several incidences falsifying the MCF value are possible. In cases where methane escaped through leaks in the digester cover (Anonym IV 2009), more methane was produced than measured. If meters failed, methane might have been produced, but was not measured. The determination of the methane content was undertaken indirectly by measuring the CO_2 content. If air entered the system the CO_2 content of the biogas would have been reduced, in conclusion the calculated methane amount would be higher than in reality. In addition, the gas analyses occurred quarterly. Fluctuations in digester performance result in fluctuations in gas composition. The CO_2 content assessed on a day with a particular high CO_2 content would reduce the methane amounts documented in the monitoring report for three months and vice versa. These incidences might have led to falsification of the MCF of 55 %.

It can nevertheless be concluded that the MCF of 55 % is more realistic than the 1996 IPCC default value. This IPCC default value of 90 % is based on an estimate made by Safley et al. (1992). Furthermore, the IPCC revised the MCF default values over the last couple of years. In 1996 the value of 90 % and in 2000 the range of 0-100% was given for all climates. In 2006 different temperature-dependent values were published. These values were lower than 90 %, ranging from 66 % for 10 °C average temperature up to 80 % at 28 °C (IPCC 1996; IPCC 2000; IPCC 2006). The analyzed projects in this study operated at an average temperature of 21 °C; according to IPCC 2006 an MCF of 78 % would have been applicable. Although this value is lower than 90 % it is still higher than 55 %. The IPCC 2006 default value is based on a study of Maningo et al. (2002), which develops MCF values for anaerobic lagoons. A factor is introduced, which is determined by the Van't Hoff-Arrhenius equation. Van't Hoff and Arrhenius assessed thermodynamics of chemical equilibrium reactions (Flörke et al. 1985). Applying these theorems to complex biological and biochemical reactions is questionable.

The relationship between temperature and methane generation, especially the steady progression of the MCF curve in dependence of the temperature suggested by Maningo et al. (2002) and the IPCC 2006 has to be questioned for two additional reasons. Firstly, the psychrophilic anaerobic bacteria active at these temperatures perform best at around 19 °C. The activity of these bacteria decreases at temperatures near 30 °C. Mesophilic bacteria take over when the temperature rises beyond approximately 26 °C. The mesophilic bateria will only reach a performance more or less equal with the maximum performance of the psychrophilic bacteria under ambient temperature conditions. If it is considered that the MCF is exclusively temperature dependent, the MCF would have a maximum value around 20 °C, decrease slowly at higher temperatures up to 26° C and starts increasing again from 26 °C onwards reaching the maximum level again at a temperature of approximately 30 °C. This shows that even if the MCF would only be influenced by the temperature a steady progression could not be expected.

Secondly, this study has shown that an exclusive temperature dependency of the MCF is not given in practice. The analysis of the MCF curves of the projects demonstrates that only in some cases the progression could be considered typical in dependency of the temperature and this only with restrictions. In most cases (e.g. project 108) the MCF criss-crossed heavily without showing a close temperature relation. As a restriction to the afore-mentioned, it has to be stated that the temperature data presented in the monitoring reports is an average over all participating farms. The temperatures are taken from internet sources. Neither the temperature of the manure in the digesters is assessed nor the ambient temperature on-site. Therefore, in order to obtain reliable results of the relationship between temperature and methane production, the temperature of the wastewater in the digester and the corresponding methane production needs to be assessed; however, such data is not available at present.

This leads to the conclusion that the conditions under which the methane production takes place differs significantly from the conditions under which a typical MCF can be reached. In fact, many other factors than the temperature are influencing the MCF. This is not surprising, as no detailed definition of the treatment facility "anaerobic lagoon" is given by any of the MCF determining authors. The requirements of the lagoon design (depth > 2 m, retention time 30 - 200 d) are very limited and not specific enough, especially on the retention time. It is unrealistic to assume that the same portion of B_0 is converted into methane if the manure remains 30 days or 200 days in a lagoon. Hence, many different types of manure holding facilities are advised to be classified as anaerobic lagoon. Therewith, they are allowed to apply the corresponding default values, even though adequate anaerobic conditions, sufficient retention times, passive mixing and appropriate loading rates may not be given. The U.S. Environmental Protection Agency states that most of the treatment systems classified as anaerobic lagoons are in fact organically overloaded holding ponds in which no anaerobic digestion occurs (U.S. Environmental Protection Agency 2009). Similar situations have been observed on large pork production facilities in Mexico. Manure is disposed in natural ponds that would also be allowed to be classified as anaerobic lagoon according to the definition of the UNFCCC (Deecke 2005).

The MCF value would be better forecasted if the existing lagoon definition would be improved requiring a distinct

- Retention time of the manure in the digester through defined volume-manure relation
- Maximum VS loading rate
- Passive mixing through an opposite inlet-outlet position
- Cleaning frequency of the digester
- A bypass for manure polluted with inhibitors to the digestion process.

Another possibility would be to publish different MCF values related to certain retention times, loading rates etc. This approach would allow the project developers to adjust the estimates to the seasonal fluctuation in waste water quantity and composition. This is necessary due to the inconstant water use on the farms. Barns are usually flushed in order to clean them and to cool the animals if necessary. Therefore, the wastewater is highly depleted during summer when barns are flushed several times per day. In winter when flushing is undertaken approximately every third day, the volume of waste water decreases along with the water content (Anonym I 2009; Deecke 2005).

In summary, more research on this complex factor has to be conducted in order to be able to estimate the extent to which the maximum biogas potential of a substrate is converted into methane, especially given the fact that forecasting methane yields from organic material in general implies many uncertainties. Stable relations between methane produced under laboratory conditions and methane generated in anaerobic digesters from the same substrate cannot be observed in many cases (Fritz 2008).

Therefore, it can be concluded that the default value of 55 % is more realistic than the IPCC default values provided over the years, although the manner of its determination (chapter 4.9) is not thoroughly in line with the common understanding of the parameter. The MCF value developed in this study can be seen as “extended MCF” as it potentially reflects additional impacts (e.g. leaks in digester cover, monitoring problems). However, despite these additional influences it is based on actual project data and not derived theoretically.

5.3 Summary of the Discussion

Interviewees stated that the quality of the methodologies is to be considered responsible for the underperformance which summarizes the quality on the methodological guidance for determining nearly all analyzed parameters. According to the statements, lacking expert knowledge especially regarding biological and technical issues resulted in misleading guidance.

However, although AM0016 refers to default factors, which have been proven inaccurate, it cannot be held solely responsible for the low performance of the projects. The methodology along with the IPCC guidelines inform the project developer about risks and uncertainties related to the default values and suggest more accurate measures. Thus, it is also in the responsibility of the project developer to use the default values with caution and obtain data from on-site measurements if possible. Nevertheless, it has been shown that the IPCC defaults are not substantiated enough and based on only few references or were estimated.

In addition, it has to be considered that the perspectives of the IPCC and the UNFCCC are different when forecasting emissions. Both aim at conservative estimates. However, from the point of view of the IPCC, emissions should be rather overestimated than underestimated in order to assess the greenhouse gas inventories conservatively. The opposite is the case for CDM projects where the overestimation should be prevented through conservative approaches (UNFCCC 2009; IPCC 1996). A first attempt has been made to take these different perspectives into account. In ACM0010 the consecutive methodology of AM0016 and AM0006, a conservatism factor of 0.94 for the IPCC 2006 default values on the MCF is introduced. However, this factor still leads to an MCF (73 %), which is proven to be too high by this study.

Summing up, the careful ex-ante assessment of descriptive statistical parameters and moreover adjusting all IPCC defaults by well researched and substantiated conservatism factors when obtaining them for CDM projects should be considered if no project specific values are available.

6 CONCLUSION

The study identified reasons for the underperformance of project activities in the animal waste sector. Descriptive statistical parameters (hypothesis I) are less responsible for the underperformance of the projects than the inaccuracies related to the use of default values (hypothesis II). The identified reasons differ especially in their rank from those given by interviewed experts, who assume that inaccuracy of descriptive parameters cause underperformance.

In fact, the main reason is the use of default values. Especially the IPCC 1996 default value of 90 % for the MCF and using the IPCC 1996 VS default without adjusting it by animal weight are responsible for the overestimation. The default value chosen for B_0 leads to exaggerated forecasts in line with the inaccurate assessment of the starting dates of the projects and the number of participating farms, which was overestimated. Not responsible is the ex-ante determination of the fraction of manure handled in the system and the population forecasts, if looking at the entire sample. Yet, it has also to be mentioned that the extent to which each parameter is responsible varies among the projects. Nevertheless, the BE forecast success of each project would have been higher when applying the tested measures and alternative default values jointly. Over-all the combination of the proposed corrections lead to an increase of forecast success by a factor of approximately 3.13 resulting in a BE forecast success of about 79 %.

However, even though the introduced corrections improve the baseline emission forecast success significantly, the performance of the projects is still heterogeneous. This shows that not all issues are covered by the corrections. The remaining discrepancies between forecasted and measured data could be due to monitoring issues or other reasons not assessed. Another aspect has to be considered as well: the fact that nearly no project specific data was available and default values were replaced by new and adjusted default values.

The results of this study show furthermore, that accurate conservative forecasts are essential for operating a successful CDM project activity in the animal waste sector. Using on-site data whenever possible is important. If such data cannot be obtained this study provides alternative more accurate and conservative default values. In addition, it is crucial to plan and conduct the monitoring of the projects carefully. Lessons can be learned from the experiences made by the first CDM projects in this sector. Therefore, CDM projects in the animal waste management sector remain promising business opportunities, when undertaken by experienced managers. This project type is not only valuable due its contribution to prevent global warming. Many other positive side effects, such as reduction of odors, sanitation of the manure, increasing the fertilizer value of the manure and reduction of soil and fresh water pollution contribute to sustainable development.

More profound research is necessary, not only in order to plan, manage and operate CDM projects in the animal waste management sector successfully. This is equally important for the assessment of GHG inventories, as the same default values are used for this purpose. Therefore, the role of the animal production sector as source of GHG emissions can only be defined fairly and precisely if the default values published and used are correct and well substantiated. This would enable the animal production sector to do justice to its actual contribution to climate change.

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LIST OF INTERVIEWS

Anonym I, project developer, interviewed on 27. – 29. May 2009 in Barcelona

Anonym II, DOE representative, interviewed on 27. - 29. May 2009 in Barcelona

Anonym III, project developer, interviewed on 27. - 29. May 2009 in Barcelona

Anonym IV, project developer, interviewed on 27. - 29. May 2009 in Barcelona

Anonym V, DOE representative, interviewed on 27. - 29. May 2009 in Barcelona

Anonym VI, DOE representative, interviewed on 27. - 29. May 2009 in Barcelona

Anonym VII, country expert, Brazil, interviewed on 27. - 29. May 2009 in Barcelona

Anonym VIII, analyst, interviewed on 27. - 29. May 2009 in Barcelona

Anonym IX, project developer, interviewed on 27. - 29. May 2009 in Barcelona

Michael Lehmann, Det Norske Veritas, DOE representative, interviewed on 27. - 29. May 2009 in Barcelona

ANNEX 1: TOTAL CORRECTION FACTOR[13]

Project no.	No. of farms	Start date	Population	MS%j	B_0	new VS	IPCC VS default weight adjusted	new VS default weight adjusted	MCF	Total
105	1.00	1.41	1.00	1.00	1.10	1.16	1.35	1.57	1.64	**3.99**
108	1.00	1.10	1.29	1.00	1.10	1.16	1.17	1.36	1.64	**3.15**
120	1.13	1.11	1.54	1.00	1.10	1.16	1.39	1.62	1.64	**5.64**
150	1.02	1.13	1.09	1.00	1.10	1.16	1.46	1.69	1.64	**3.82**
161	1.00	1.00	0.83	1.00	1.10	1.16	1.08	1.26	1.64	**1.88**
162	1.33	1.04	0.82	1.00	1.10	1.16	1.13	1.32	1.64	**2.67**
163	1.00	1.04	1.15	1.00	1.10	1.16	1.35	1.56	1.64	**3.35**
196	1.20	1.02	0.72	1.00	1.10	1.16	1.23	1.43	1.64	**2.24**
197	1.16	1.20	1.17	1.00	1.10	1.16	2.01	2.34	1.64	**6.88**
204	1.23	1.01	1.10	1.00	1.10	1.16	1.45	1.69	1.64	**4.10**
225	1.11	1.00	1.28	1.00	1.10	1.16	1.28	1.49	1.64	**3.82**
240	1.00	1.00	1.07	1.00	1.10	1.16	1.61	1.88	1.64	**3.61**
257	1.10	1.10	1.02	1.00	1.10	1.16	1.31	1.52	1.64	**3.37**
324	1.30	1.06	1.42	1.00	1.10	1.16	1.45	1.69	1.64	**5.92**
335	1.00	1.12	0.73	1.00	1.10	1.16	1.07	1.24	1.64	**1.82**
336	1.12	1.35	0.83	1.00	1.10	1.16	1.38	1.60	1.64	**3.60**
337	1.03	1.25	0.94	1.00	1.10	1.16	1.46	1.70	1.64	**3.69**
364	1.00	1.13	1.04	1.00	1.10	1.16	0.54	0.63	1.64	**1.32**
365	1.00	1.17	1.11	1.00	1.10	1.16	1.76	2.04	1.64	**4.75**
409	1.00	1.21	0.91	1.00	1.10	1.16	1.41	1.64	1.64	**3.25**
411	0.91	1.24	0.66	1.00	1.10	1.16	1.17	1.36	1.64	**1.82**
412	0.94	1.11	0.87	1.00	1.10	1.16	1.42	1.65	1.64	**2.71**
417	1.02	1.10	1.02	1.00	1.10	1.16	1.62	1.88	1.64	**3.87**
418	1.70	1.10	0.79	1.00	1.10	1.16	1.37	1.59	1.64	**4.24**
419	1.02	1.08	0.96	1.00	1.10	1.16	1.38	1.61	1.64	**3.06**
420	1.05	1.03	0.77	1.00	1.10	1.16	1.40	1.63	1.64	**2.46**
421	1.02	1.04	1.02	1.00	1.10	1.16	1.25	1.46	1.64	**2.86**
422	1.09	1.10	0.95	1.00	1.10	1.16	1.46	1.70	1.64	**3.44**
Total	**1.06**	**1.14**	**0.95**	**1.00**	**1.10**	**1.16**	**1.29**	**1.50**	**1.64**	**3.13**

[13] Total correction factor calculated based on Equation 21

ANNEX 2: INDIVIDUAL AND COMBINED IMPACT OF INTRODUCED MEASURES ON BE

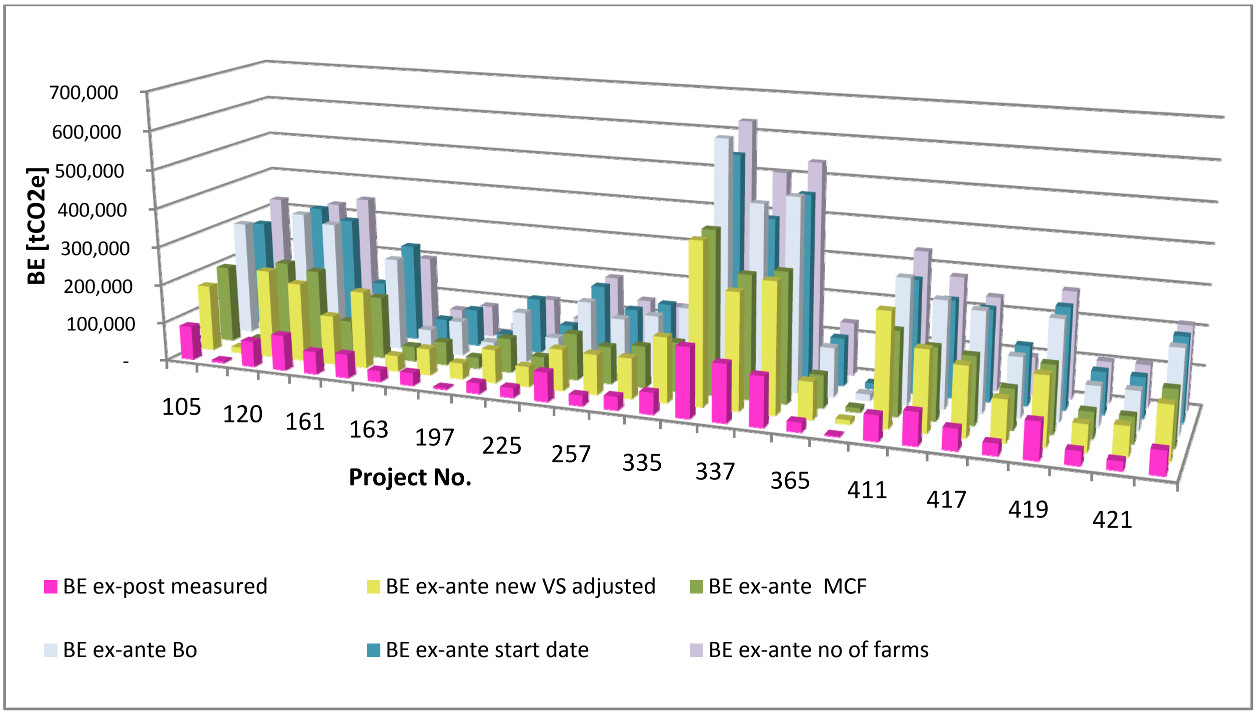

Figure 14: Individual Impact of the Parameters in Comparison to ex-post measured BE

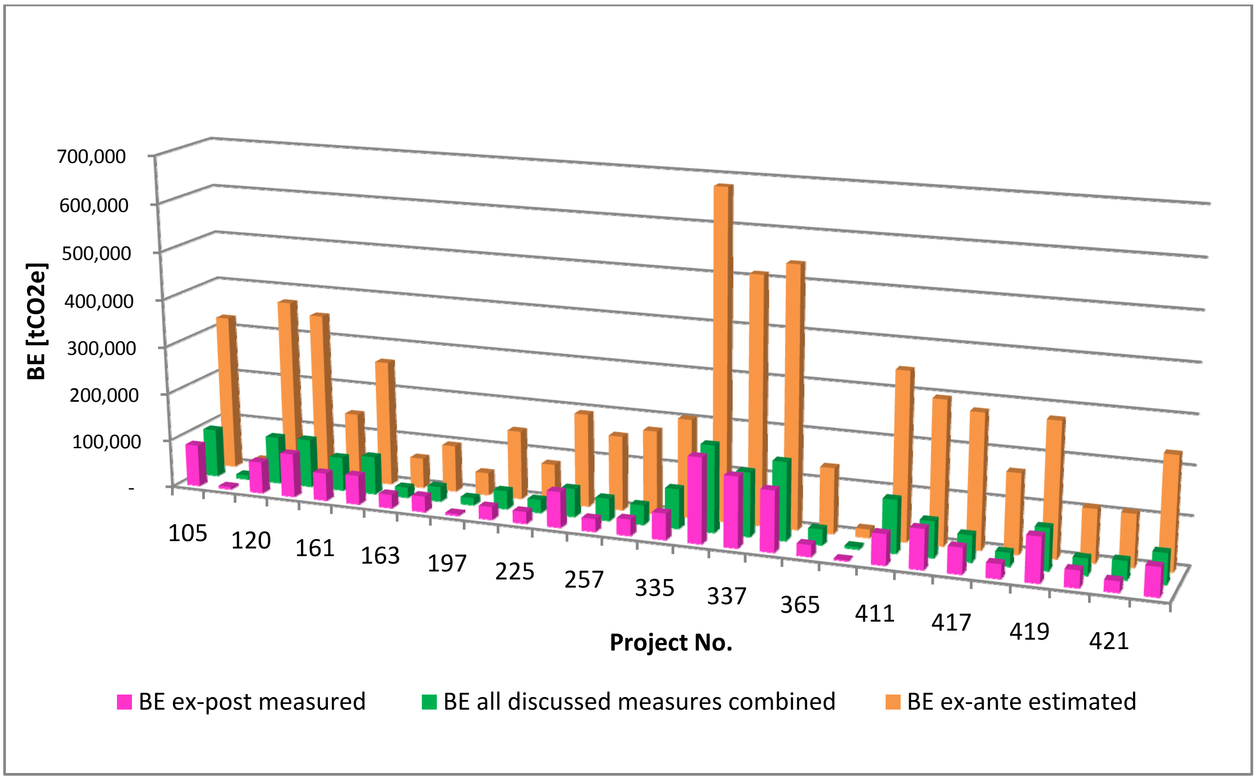

Figure 15: Combined effect of all introduced Measures in Comparison to BE ex-ante estimated and ex-post measured

ANNEX 3: ERROR ANALYSIS

Parameter	BE after correction									
	No. of farms		Delays		Population		MS%j		B_0	
Calculated based on	project data	correction factor	project data	correction factor	project data	correction factor	project data	factor	project data	factor
Project no.										
105	322,434.01	322,434.01	228,209.49	228,209.49	228,694.27	228,694.27	322,434.01	322,434.01	293,773.21	293,773.21
108	23,378.75	23,378.75	23,378.75	23,378.75	16,585.34	16,585.34	23,378.75	23,378.75	21,300.64	21,300.64
120	326,555.99	326,555.99	333,316.37	333,316.37	187,975.32	187,975.32	370,475.69	370,475.69	337,544.52	337,544.52
150	346,752.20	346,752.20	313,609.30	313,609.30	285,756.33	285,756.33	353,956.85	353,956.85	322,494.02	322,494.02
161	143,681.69	143,681.69	143,779.76	143,779.76	173,235.23	173,235.23	143,779.76	143,779.76	130,999.33	130,999.33
162	197,297.92	197,297.92	253,003.81	253,003.81	229,787.32	229,787.32	262,221.23	262,221.23	238,912.67	238,912.67
163	63,078.77	63,078.77	60,681.01	60,681.01	52,640.97	52,640.97	62,921.69	62,921.69	57,328.65	57,328.65
196	81,534.99	81,534.99	96,104.59	96,104.59	111,458.85	111,458.85	97,583.99	97,583.99	88,909.86	88,909.86
197	40,436.53	40,436.53	39,078.95	39,078.95	27,761.83	27,761.83	46,976.31	46,976.31	42,800.64	42,800.64
204	117,282.10	117,282.10	142,661.08	142,661.08	105,931.10	105,931.10	143,689.82	143,689.82	130,917.39	130,917.39
225	74,710.75	74,710.75	83,287.74	83,287.74	60,331.91	60,331.91	83,287.74	83,287.74	75,884.38	75,884.38
240	193,880.79	193,880.79	194,073.75	194,073.75	181,367.80	181,367.80	194,073.75	194,073.75	176,822.75	176,822.75
257	141,269.95	141,269.95	140,728.88	140,728.88	124,601.48	124,601.48	155,131.13	155,131.13	141,341.70	141,341.70
324	133,195.71	133,195.71	163,498.69	163,498.69	86,882.22	86,882.22	173,244.78	173,244.78	157,845.25	157,845.25
335	205,066.40	205,066.40	183,245.82	183,245.82	250,358.98	250,358.98	204,668.03	204,668.03	186,475.32	186,475.32
336	630,126.42	630,126.42	521,017.29	521,017.29	568,974.54	568,974.54	705,033.58	705,033.58	642,363.93	642,363.93
337	506,795.40	506,795.40	420,616.16	420,616.16	441,526.53	441,526.53	523,928.40	523,928.40	477,356.98	477,356.98
364	538,796.37	538,796.37	475,547.32	475,547.32	459,143.68	459,143.68	537,753.78	537,753.78	489,953.44	489,953.44
365	135,702.09	135,702.09	116,436.06	116,436.06	104,869.45	104,869.45	135,700.35	135,700.35	123,638.10	123,638.10
409	17,741.33	17,741.33	14,782.22	14,782.22	16,190.20	16,190.20	17,815.15	17,815.15	16,231.58	16,231.58
411	336,869.09	336,869.09	248,690.67	248,690.67	360,893.90	360,893.90	307,820.83	307,820.83	280,458.98	280,458.98
412	279,910.93	279,910.93	236,656.90	236,656.90	252,246.80	252,246.80	263,023.41	263,023.41	239,643.55	239,643.55
417	237,481.56	237,481.56	219,591.96	219,591.96	176,391.29	176,391.29	242,546.61	242,546.61	220,986.91	220,986.91
418	95,931.80	95,931.80	148,964.00	148,964.00	101,135.60	101,135.60	163,391.89	163,391.89	148,868.17	148,868.17
419	270,129.69	270,129.69	255,429.59	255,429.59	260,156.31	260,156.31	276,260.74	276,260.74	251,704.23	251,704.23
420	103,655.48	103,655.48	105,882.99	105,882.99	130,227.67	130,227.67	109,332.43	109,332.43	99,613.99	99,613.99
421	104,566.83	104,566.83	102,850.40	102,850.40	97,706.16	97,706.16	107,178.17	107,178.17	97,651.22	97,651.22
422	213,146.19	213,146.19	211,445.55	211,445.55	203,938.64	203,938.64	231,866.90	231,866.90	211,256.51	211,256.51
Total	**5,881,409.73**	**5,881,409.73**	**5,476,569.08**	**5,476,569.08**	**5,296,769.73**	**5,296,769.73**	**6,259,475.76**	**6,259,475.76**	**5,703,077.91**	**5,703,077.91**
Deviation		**1.0000**		**1.0000**		**1.0000**		**1.0000**		**1.0000**

Error Analysis **Part II**

Parameter	BE after correction						BE forcast success [%]	
	VS		MCF		all combined		all combined	
Calculated based on	project data	correction factor	project data	correction factor	project data	correction factor	project data	correction factor
Project no.								
105	204,769.30	204,769.30	197,043.00	197,043.00	80,866.90	80,866.90	108.23	108.23
108	17,144.69	17,144.69	14,287.01	14,287.01	6,772.11	7,421.59	76.36	69.68
120	228,450.53	228,450.53	226,401.81	226,401.81	64,539.38	65,687.93	102.81	101.01
150	209,018.28	209,018.28	216,306.96	216,306.96	93,955.31	92,652.31	97.06	98.42
161	114,248.08	114,248.08	87,865.41	87,865.41	76,644.13	76,591.86	75.62	75.67
162	199,136.26	199,136.26	160,246.31	160,246.31	97,162.81	98,280.38	62.58	61.87
163	40,206.26	40,206.26	38,452.15	38,452.15	18,728.74	18,775.50	152.75	152.37
196	68,302.49	68,302.49	59,634.66	59,634.66	43,437.42	43,471.00	75.59	75.53
197	20,102.85	20,102.85	28,707.75	28,707.75	6,614.82	6,829.44	64.02	62.01
204	85,248.69	85,248.69	87,810.44	87,810.44	34,992.64	35,040.15	77.12	77.02
225	55,915.01	55,915.01	50,898.06	50,898.06	22,552.04	21,775.32	110.96	114.91
240	103,458.02	103,458.02	118,600.63	118,600.63	53,833.06	53,779.53	138.21	138.35
257	101,933.97	101,933.97	94,802.36	94,802.36	45,586.34	46,069.97	58.74	58.12
324	102,707.63	102,707.63	105,871.81	105,871.81	28,679.07	29,279.42	119.26	116.81
335	164,962.34	164,962.34	125,074.91	125,074.91	112,354.24	112,572.93	48.62	48.52
336	440,541.29	440,541.29	430,853.85	430,853.85	197,952.58	195,912.71	89.33	90.26
337	308,975.47	308,975.47	320,178.46	320,178.46	144,977.43	142,120.98	100.63	102.65
364	854,318.12	854,318.12	328,627.31	328,627.31	406,140.48	406,927.90	31.04	30.98
365	66,420.14	66,420.14	82,927.99	82,927.99	28,579.81	28,580.18	85.57	85.57
409	10,887.16	10,887.16	10,887.03	10,887.03	5,508.95	5,486.12	41.06	41.23
411	226,954.74	226,954.74	188,112.73	188,112.73	148,153.64	168,762.15	42.78	37.55
412	159,100.63	159,100.63	160,736.53	160,736.53	84,956.12	97,156.25	96.78	84.63
417	129,005.67	129,005.67	148,222.93	148,222.93	52,237.48	62,628.80	102.92	85.85
418	102,612.66	102,612.66	99,850.60	99,850.60	35,364.38	38,559.05	83.84	76.89
419	171,925.27	171,925.27	168,826.01	168,826.01	90,145.99	90,236.78	102.66	102.55
420	67,061.46	67,061.46	66,814.26	66,814.26	44,475.30	44,520.39	78.87	78.79
421	73,456.78	73,456.78	65,497.77	65,497.77	37,285.42	37,529.76	61.34	60.94
422	136,694.93	136,694.93	141,696.44	141,696.44	66,942.92	67,343.37	88.81	88.28
Total	**4,463,558.71**	**4,463,558.71**	**3,825,235.19**	**3,825,235.19**	**2,129,439.55**	**2,002,530.05**	**74.72**	**79.45**
Deviation		**1.0000**		**1.0000**		**0.9404**		**1.0643**

ANNEX 4: GLOSSARY

Approved Methodology (AM)
An AM determines how a project activity's baseline and the related emissions have to be forecasted. It furthermore defines how additionality has to be evidenced and how the emission reductions have to be monitored and documented after the project is implemented and starts operation.

Baseline Scenario
The baseline scenario is the situation that demonstrates the GHG emission that would occur in the absence of the project (e.g. methane emissions through manure storage and disposal in uncovered anaerobic lagoons).

Certification
A DOE certifies that a project activity achieved GHG reductions as verified through a specific time period.

Certified Emission Reductions (CERs)
A certified emission reduction (CER) is the unit for a certified and issued amount of emission reductions. It equals one metric tonne of carbon dioxide equivalent.

Clean Development Mechanism (CDM)
Article 12 of the Kyoto Protocol defines the clean development mechanism. "The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under article 3".

Crediting Period
The crediting period is the period, for which reductions from the baseline scenario are verified and certified by a DOE for the purpose of issuance of CERs.

Designated National Authority (DNA)
A DNA is the legal entity of a host country, which is responsible for the approval or disapproval of a CDM project.

Designated Operational Entity (DOE)
A DOE is an entity accredited by the COP/MOP through the UNFCCC. A DOE validates CDM projects and verifies and certifies CERs.

Host Country

A host country is the country on which territory the CDM project is implemented.

Issuance of Certified Emission Reductions

The EB instructs the CDM registry administrator to issue a specified quantity of CERs for a project activity into the pending account of the EB in the CDM registry. The CERs are then forwarded to the registry accounts of project participants involved.

Leakage
Net changes of GHG occurring outside the project boundary that are measurable and attributable to the CDM project activity are called leakage.

Letter of Approval (LoA)

The host country of each CDM project has to approve a planned CDM project by issuing a LoA.

Monitoring of a CDM Project Activity
Collecting and archiving of all relevant data that is necessary to determine the baseline, measuring GHG within the project boundary and leakage.

Monitoring/Verification Period
The crediting period can be divided into time periods for which verifications take place. The project developer/owner is flexible in determining the length of a monitoring period. The maximum length is equal to the crediting period.

Project Activity
The Kyoto Protocol and the CDM modalities and procedures differentiate between "project activity" and "project". A measure, operation or an action aiming to reduce GHG emission is called a "project activity"
A project activity could be identical with or a component of a project. However, in the context of this thesis all project activities are projects.

Project Design Document (PDD)

A PDD describes the project's baseline, additionality and monitoring plan following an approved methodology and general UNFCCC guidance.

Project Developer
A project developer is the person or entity responsible for the conceptual design of the CDM project and the preparation of all relevant documentation regarding the CDM. The project

developer can be identical with the project owner or an external consultant employed by the owner of the project.

Transparent and Conservative
Baselines have to be established in a transparent and conservative manner. Assumptions and choices are made explicitly and are substantiated. "In case of uncertainty regarding values of variables and parameters, the establishment of a baseline is considered conservative if the resulting projection of the baseline does not lead to an overestimation of emission reductions attributable to a CDM project activity (that is, in the case of doubt, values that generate a lower baseline projection shall be used)."

UNFCCC Executive Board (EB)

The EB issues guidance on how to undertake CDM projects and takes the final decision on the registration of CDM projects and the issuance of CERs.

Validation

The evaluation of a project activity by a DOE against the CDM requirements is called validation.

Verification
Monitored reductions in GHG that have occurred as a result of a registered CDM project activity during the verification period are verified by a DOE.

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