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The Clean Development Mechanism: An opportunity to finance decentralised sanitation?

Diploma Thesis

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Abbreviations

BUWAL	Swiss Agency for the Environment, Forests and Landscape
CDCF	World Bank's Community Development Carbon Fund
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
CO_2e/a	Carbon Dioxide equivalent per annum
CoP	Conference of Parties
DNA	Designated National Authority
DOE	Designated Operational Entity
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
EB	CDM Executive Board
ETH	Swiss Federal Institute of Technology Zurich
ETS	Emissions Trading System
EU	European Union
FDI	Foreign Direct Investment
GEF	Global Environment Facility
GHG	Greenhouse Gases
GWh	Giga Watt Hours
KP	Kyoto Protocol
kt	Kilo Tons
MOP	Meeting of the Parties to the Kyoto Protocol
MW	Mega Watts
NGO	Non-government organisation
ODA	Overseas Development Assistance
PDD	Project Design Document
PIN	Project Idea Note
SANDEC	Department of Water and Sanitation in Developing Countries
SSC	Small-scale (as in SSC methodologies)
SwissFlex	Swiss Secretariat for the implementation of the flexible mechanisms of the Kyoto Protocol
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
WWF	World Wildlife Fund

Abstract

The Clean Development Mechanism (CDM) aims at meeting two objectives: Reduction of greenhouse gas emissions at lowest cost and sustainable development of countries hosting CDM projects. The latter objective is easily met by decentralised approaches involving communities, creating jobs and channelling CDM money into wages rather than machinery produced in industrialised countries. The transaction costs and risks associated with the CDM have, however, shown to favour large centralised projects. Though many decentralised projects contribute significantly to increasing sustainable development, they cannot compete with large centralised projects on emission reductions at lowest cost.

Research assumptions have revealed that the CDM promotes the development of large, centralised projects rather than small, decentralised activities. This hypothesis is corroborated by the fact that decentralised projects are disadvantaged by their higher transaction costs although important efforts are made to improve the feasibility of small-scale projects, such as the small-scale baseline methodologies and option to join small-scale projects together.

The study assesses the viability of selected case studies and suggests approaches to enhance decentralised CDM projects. Three case studies of potential, decentralised CDM projects are compared to a case study of an existing large, centralised CDM project. The following case studies were compared:

- An existing methane-flaring project in Santa Cruz, Bolivia was used as reference. The landfill receives the waste of about one million people.
- A decentralised composting project in Dhaka or Khulna, Bangladesh. According to the baseline scenario, the waste is dumped in a landfill where it emits more methane than in the composting process. The plant processes the organic waste of about 5,000 people.
- Collection and use of methane from public toilet installations in India. According to the baseline scenario, the biogas produced in the septic tanks of the public toilets is directly emitted into the atmosphere. Each toilet complex is used by about 1,000 slum dwellers.
- Use of polyethylene bag digesters filled with cow manure to produce biogas and replace fuel wood as a source of energy for cooking purposes. The fuel wood is a carbon source, as the wood cut in the given region does not grow back and is therefore considered unsustainable. The biogas produced per digester is sufficient to cover the cooking requirements of one household.

The landfill gas flaring project ranks highest among all the other case studies regarding the criteria used to compare the case studies: The project has the lowest risks, lowest transaction costs, lowest investment costs per unit carbon dioxide equivalent reduced, and the simplest organisational setup. Decentralised composting achieves a medium score for each criterion used, while the polyethylene bag digester project scores badly on all accounts. With leakage of more than 20% biogas from the polyethylene bag digester system, the project is at risk of turning into a greenhouse gas source rather than a reduction. The use of methane from the public toilets project achieves a medium score, however, its institutional setup is considered extremely challenging.

To improve decentralised project viability, the contribution to sustainable development made by these projects either requires the establishment of a market value or the institutional setup should lower the hurdles for small and decentralised projects. Simple ways are suggested to convince buyers of the contribution made by Certified Emission Reductions in the field of social sustainability. The "voluntary market" is shown to include buyers that are willing to pay more for emission reductions achieved through highly sustainable projects. Networking is, however, needed to inform project developers of such opportunities. Changes in the institutional setup are suggested and include a lowering of the registration costs and monitoring requirements for small and decentralised projects.

1 Introduction

1.1 Potentials of decentralised approaches

Decentralised projects such as composting or building and maintaining public toilets have proven very beneficial for poor communities on a pilot scale. These “islands of success” (Bhatia 2004) need to be scaled up in order to improve the lives of the poor majority living in developing countries.

> **“About 2.4 billion people or 40% of the world’s population, in developing countries still lack adequate excreta disposal systems, despite the professed commitment of governments and the international community to tackle the problem. The result is a continuing horrifying toll in death and disease that is widely recognized as one of the greatest failures of the last decades. Despite all the ideas and ‘pilot’ projects, approaches have not proved to be replicable, sanitation policies are absent or not put into practice, investment remains mainly external and limited, and local subsidies have not been sustainable. In the words of Kofi Annan, the Secretary General of the United Nations: ‘There is a tragic disparity between its human importance and its political priority.’ ”** (Bhatia 2004)

Using the example of composting, decentralised projects have the following advantages compared to centralised approaches:

- **Flexibility** is achieved through rapid adoption to user needs and allowing for continuous quality surveillance by the user. (Zurbruegg and Vermeul 1999)
- **Community strengthening** is achieved by a decreased dependency on municipal services, enhanced responsibility, raised environmental awareness, and increased employment possibilities. (Zurbruegg and Vermeul 1999)
- **Transport costs are reduced** because the waste is composted near its source. (Zurbruegg and Vermeul 1999)
- **The use of appropriate technology** such as small-scale and labour intensive composting is far more adapted to the socio-economic situation. (Zurbruegg and Vermeul 1999)
- **Less initial capital** is required because a decentralised approach allows sequential implementation.

Bearing in mind the advantages of decentralised projects and the tremendous need for improved sanitation services for the urban poor, the question arises as to whether or not the Clean Development Mechanism (CDM) will be able to channel much-needed investments into the waste and wastewater sectors in developing countries. The next section formulates the hypothesis of this study and describes the specific tasks.

1.2 Objectives and research question

1.2.1 Hypothesis

The CDM fosters the tendency to develop large, centralised rather than small, decentralised projects.

The diploma thesis aims to lay out why the above mentioned hypothesis should be accepted or rejected.

1.2.2 Tasks

- Explain the CDM together with a short history of how its concept has changed over time. Elaborate on the current international debate concerning the CDM.
- Describe the typical factors of small-scale and large-scale projects using selected case studies. This involves an analysis and comparison of their typical economic, institutional and organisational setting. Elaborate on the difference in resulting transaction costs for CDM eligibility of small-scale versus large-scale projects.
- Compare alternative options and funding sources for greenhouse gas abating projects within as well as outside the CDM.
- Discuss the usefulness of the alternative methodologies and funds for improving the attractiveness and eligibility of small-scale projects. Suggestions on ways to further alleviate the disadvantages that small-scale projects face compared to large-scale projects should be laid out.
- Areas where this study has not been able to reach a final answer should be pointed out and topics for further research should be suggested.

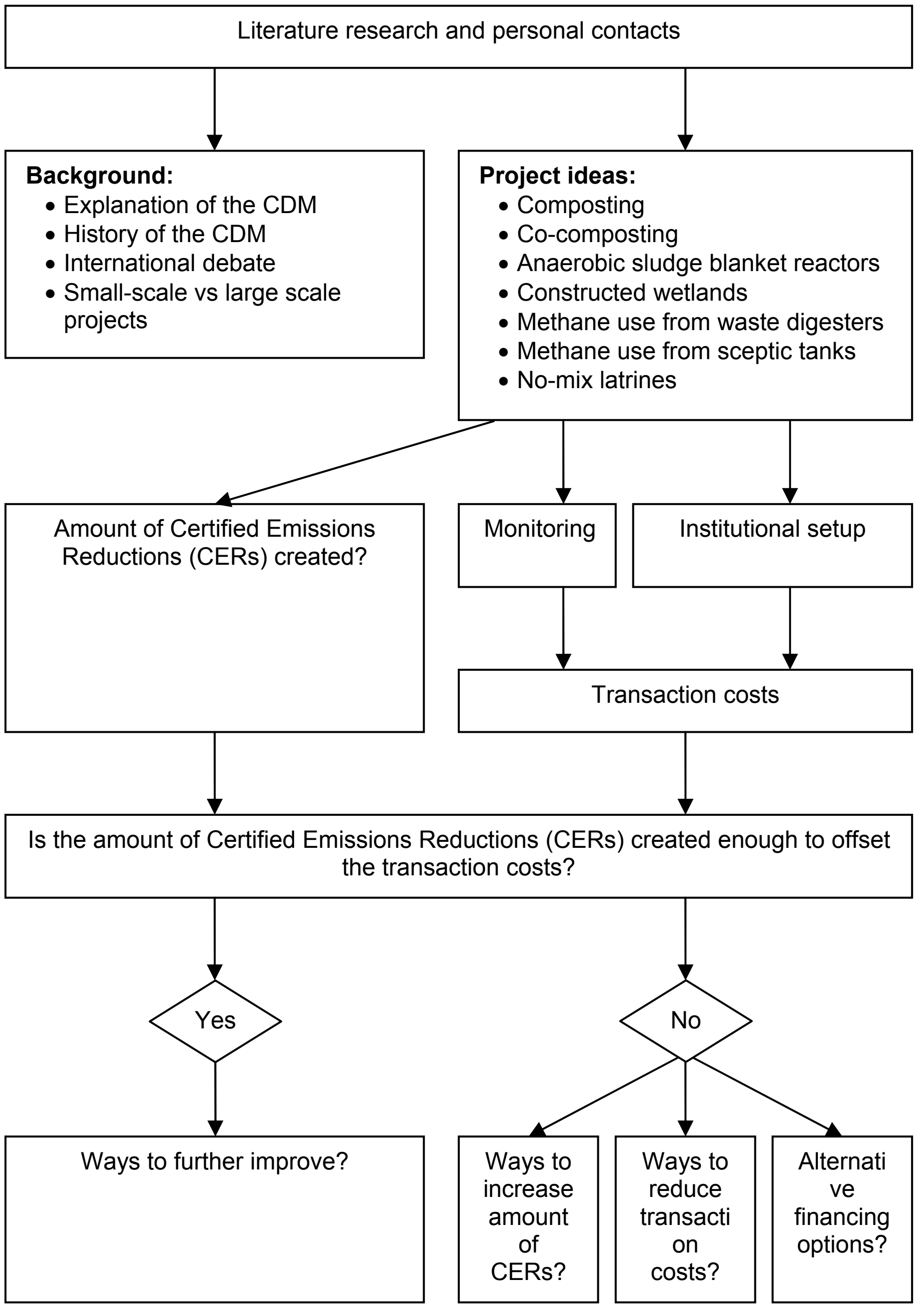
1.3 Methodology

Literature research and personal contacts are used to describe the CDM procedures and factors used to assess decentralised project ideas. From several different project ideas in the field of water and sanitation three are selected as case studies and are compared to an existing waste management project approved by the CDM. For each project idea the amount of certified emission reductions created are estimated as far as possible. Monitoring requirements and the institutional setup are looked at in order to assess transaction costs. Secondary data from empirical research is also used to assess the transaction costs for projects of different scales.

The transaction costs are then compared to the potential revenues from the sales of the emission reductions at the current price of 5€ per ton of carbon dioxide equivalent reduced. If the transaction costs are below the revenues then ways to further improve the profitability of projects are assessed. Figure 1 one below shows the methodology used to assess project ideas. In cases where the transaction costs are larger than potential CDM revenues the up-scaling of the projects is looked at as well as reducing the transaction costs and other ways to improve the feasibility of decentralised projects.

Figure 1 Methodology overview

Rectangular boxes represent processes such as brainstorming sessions, analysis or literature research. Rhomboid forms represent decisions. Flashes indicate the order in which processes and decisions are undergone. (Many of the project ideas noted below are discarded because of lack of project and / or baseline data.)



1.4 Background

The US Environmental Protection Agency (EPA 2000) states that since the beginning of the industrial revolution,

- atmospheric concentrations of carbon dioxide have increased nearly 30%,
- methane concentrations have more than doubled,
- and nitrous oxide concentrations have risen by about 15%.

The US Environmental Protection Agency further explains that these increases have enhanced the heat-trapping capability of the earth’s atmosphere. It adds that the 20th century's 10 warmest years all occurred in the last 15 years of the century and concludes that increasing concentrations of greenhouse gases are likely to accelerate the rate of climate change.

As evidence of human impact on the climate is becoming stronger and stronger, the international community has started to realise its need to combat climate change. This has resulted in the an endeavour to internationally formulate actions to reduce GHG emissions, i.e. the Kyoto Protocol. The following section explains the content of the Kyoto Protocol.

1.4.1 The Kyoto Protocol

The Kyoto Protocol is an international agreement to reduce greenhouse gas emissions. At the heart of the Kyoto Protocol are the legally binding emissions targets for so-called Annex B Parties. These countries have a high per capita emission of greenhouse gases and are therefore required to reduce their emissions during the first commitment period, while Non-Annex B Parties will follow later. The first commitment period is the time between 2008 and 2012. For the Protocol to enter into force it needs to fulfil certain criteria as described below:

> **„The Protocol is subject to ratification by Parties to the Convention. It shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55 % of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession.”** (UNFCCC 1997)

Appendix 6.1 explains some of the main terms used in CDM specific language, such as the “Annex B” and “Annex I” countries mentioned above.

The Kyoto Protocol was adopted in 1997 and entered into force in February 2005. Please refer to appendix 6.2 for a more detailed description of the history of the Kyoto Protocol and, in particular, the Clean Development Mechanism.

The international debate about the future climate regime is dominated by the discussion of how anthropogenic impact on the climate can be reduced without hampering economic growth. Developing countries and the US are more explicit about their preference of economic growth over mitigating climate change while others, such as the EU, make strong statements but show weak actions about combating climate change. Nevertheless, there is a common denominator that anthropogenic climate change is a problem and that something needs to be done about it.

Appendix 6.3 explains the positions of the EU, the US, Japan, China, India, Brazil, Ghana and several Non Government Organisations (NGOs) on climate change. Each country's current efforts to reduce greenhouse gas emissions as well as their current ideas about a climate regime beyond 2012, i.e. beyond the first commitment period of the Kyoto Protocol, are discussed.

1.4.2 The CDM in a nutshell

The basic idea of the CDM is to reduce greenhouse gas emissions in a more cost efficient way than in a scenario in which the entire greenhouse gas emissions reductions as agreed in the Kyoto Protocol are achieved in the Annex I countries themselves. While Non-Annex I countries (mostly developing countries) are not required to reduce their greenhouse gas emissions under the Kyoto Protocol, they may still be able to offer cost effective opportunities to reduce greenhouse gas emissions. The CDM allows Annex I countries to benefit from such opportunities while fostering investments and sustainable development in Non-Annex I countries.

In theory an investor from an industrialised country, or an industrialised country government, can invest in, or provide finance for, a project in a developing country that reduces greenhouse gas emissions so that they are lower than they would have been without the extra investment – i.e. in comparison to what would have happened under a business as usual outcome without the CDM project. The credits – carbon credits – that the investor then gets for the reductions can be used to meet their Kyoto target. If the CDM works perfectly then it will simply change the location in which some of the greenhouse gas emissions reductions will happen, but will not result in more or less reductions than were agreed under the Kyoto Protocol.(CDM_Watch 2003)

An example: a Swiss company needs to reduce its emissions as part of its contribution to meeting Switzerland's emission reduction target under the Kyoto Protocol. Instead of reducing emissions from its own activities in Switzerland, the company provides funding for the construction of a new composting plant in Vietnam that would not have been able to go ahead without this investment. This, they argue, prevents the dumping of organic waste on landfill sites in Vietnam thus reducing future CH_4 emissions in Vietnam. The Swiss investor gets carbon credits for those reductions and can use them to help meet their greenhouse gas reduction target in Switzerland. The incentive for the Swiss company to invest into the composting plant is that the greenhouse gas emission reduction in Vietnam is more cost efficient than the reduction of its own greenhouse gas emissions in Switzerland.

In practise such a neat case is unlikely. CDM Watch (CDM_Watch 2003) states the following differences to the theory explained above:

- Estimating what would have happened if the Swiss-funded composting plant didn't go ahead requires predicting something inherently uncertain. There may be more than one possible scenario and we will never know if our prediction was correct.
- In many cases the actual pattern of CDM investment and crediting is more complex than the above example portrays. Intermediaries such as the World Bank or other carbon credit procurement agencies investing money on behalf of industrialised country governments and corporations are often involved. Developers may also be self-financing CDM projects and then seeking a buyer for the emissions reductions.

CDM Watch however concludes that the fundamental principle remains the same:

> **„Industrialised country governments and companies provide the finance to make possible a project that results in fewer emissions than would have happened otherwise. The credit for reducing those emissions is claimed by the industrialised country investor, and can be used to meet their own reduction target."** (CDM_Watch 2003)

The next section explains the process by which individual projects are developed and approved.

1.4.3 The CDM project approval and monitoring process

SwissFlex, the national Secretariat for the implementation of the flexible mechanisms of the Kyoto Protocol, provides information about the CDM approval and monitoring process. Its website provides an overview over the CDM project cycle. The following **main players** are specified:

- The **Designated National Authority** (DNA) is responsible to pre-screen project idea notes. The DNAs of involved countries (e.g. SwissFlex plus the DNA of the host country) decide whether or not they approve the Project Design Document. Each member state is responsible to appoint its own DNA, such as SwissFlex in Switzerland. (BUWAL 2004)
- A **Project Developer** may be any natural and legal entity, for they are all allowed to participate in the CDM (Governments, private sector companies, financial institutions, NGOs, legal persons). (BUWAL 2004)
- A **Designated Operational Entity** (DOE) under the CDM is either a domestic legal entity of the home or host country or an international organisation accredited and designated by the Executive Board and confirmed by the Conference of the Parties. It has two key functions:
  - validate a proposed CDM project activity
  - verify emission reduction of a registered CDM project activity

- The CDM **Executive Board** supervises the CDM under the authority and guidance of the Conference of the Parties. The executive board is made up by ten members from Parties to the Kyoto Protocol (one from each of the five United Nations regional groups; two other Annex I; two other Non-Annex I; one representative of the small island developing States) and elected by the Conference of the Parties. (BUWAL 2004)

SwissFlex further describes the CDM project cycle in seven steps (BUWAL 2004):

1 A **Project Idea** is filled in a Project Idea Note (PIN). The PIN is then sent to SwissFlex, which pre-screens the project idea with regard to the eligibility of the project.

2 A **Project Design Document** (PDD) is prepared by the project developer. The PDD is done according to an existing approved methodology. A new methodology may be suggested, but will have to be authorised and registered by the Executive Board. The PDD contains
- a description of the baseline and monitoring plan,
- an analysis of environmental impacts,
- comments received from local stakeholders,
- a description of additional environmental benefits.

The PDD must be approved by the Designated National Authorities of involved countries (e.g. SwissFlex plus the DNA of the host country), The Designated National Authority of the host country also needs to confirm that the project fosters sustainable development.

3 **Validation** is the process of independent evaluation of a project activity by a designated operational entity against the requirements of the CDM. The Project Design Document is validated by an appropriate Designated Operational Entity selected by the project developer. The Designated Operational Entity will
- make the Project Design Document publicly available,
- receive public comments,
- decide whether the project should be validated,
- submit a registration request to the executive board.

4 The **Registration** is done by the executive board. A project participant or at least three executive board members may successfully request a review of the project. After registration the project is ready to be implemented.

5 **Monitoring** of the project's emissions is done regularly throughout its lifetime. Project developers will
- prepare a monitoring report as outlined in the Project Design Document
- include an estimate of Certified Emission Reductions generated by the project
- once the monitoring report is completed submit it to a Designated Operational Entity for verification and certification.

6 **Verification** is the periodic independent review by the Designated Operational Entity of the monitored emissions reductions that have occurred as a result of a CDM project. **Certification** is the written assurance by the DOE that, during a specified time period, a project achieved the reductions in emissions as verified.

7 **Issuance of Certified Emission Reductions**
The certification report constitutes a request for issuance to the executive board of Certified Emission Reductions. Unless a project participant or three executive board members request a review within 15 days, the executive board will issue the CERs.

A CDM project can be funded by the project developer, by an investor or by a fund acting in behalf of several investors. In the case of a unilateral project the project developers carries the risk of not finding a CER buyer. Most unilateral projects are transformed in the early project stages into a multilateral project in which the project developer has found an investor or fund that is either interested in the CERs themselves or in selling the CERs on the carbon market. Once a project is registered as unilateral it cannot be changed into a multilateral project even after the project developer has found an investor willing to buy the CERs created by the project.

Table 1-1 The CDM project cycle

Steps	SwissFlex	Project Developer	Designated Operational Entity	CDM Executive Board
1		Project Idea		
	Pre-screening			
2		Project Design		
	Approval	Approval		
3			Validation	
4				Registration
5		Monitoring		
6			Verification Certification	
7				Issuance of CERs

source: Swiss Flex (BUWAL 2004) CERs are “Certified Emission Reductions”

1.4.4 Options to foster decentralised projects within the CDM

Decentralised projects are often small in scale and make a large contribution to sustainable development This section describes the small-scale methodologies and the Gold Standard that are designed to improve the odds of either small projects or projects with high sustainable development benefits.

The CDM Executive Board has specified **simplified modalities and procedures for small-scale CDM project activities**. Project participants may propose changes to existing methodologies as well as propose the baseline determination and monitoring methodologies for additional project categories. (UNFCCC 2003)

Projects that fall under the following **three categories are eligible** for using the small-scale rules (UNFCCC 2003):

a) Renewable energy projects which have a maximum capacity of 15 MW

b) Energy efficiency projects with a reduction in energy consumption by up to 15 GWh/a

c) Other greenhouse gas reducing projects that directly emit less than 15 kt of CO_2e/a

The **Gold Standard** is an independently audited best practice benchmark for emission reduction projects. It has been developed by the WWF in collaboration with governments, NGOs and corporations around the world. The Gold Standard is designed to exceed the environmental standards demanded by the market regulator and governments. The Gold Standard ensures purchasers of Gold Standard credits that their assets have value and are sourced from projects which make a genuine contribution to sustainable development. (Gold_Standard 2003) As decentralised projects often have large sustainable benefits they may benefit from higher revenues when selling their emission reductions under the Gold Standard.

1.4.5 Options to finance greenhouse gas abating projects outside the CDM

The CDM is not the only option to fund greenhouse gas abating projects. This section describes some options outside the CDM that can be used to attract investment into climate change mitigating projects of any scale.

The **Global Environment Facility** (GEF) is a financial mechanism structured as a trust fund that operates in collaboration and partnership with three implementing agencies (UNDP, UNEP, and the World Bank) for the purpose of achieving global benefits for the environment.

The second largest group of GEF-funded projects are projects addressing climate change. The GEF is the financial mechanism for the United Nations Framework Convention on Climate Change (UNFCCC). It therefore receives guidance from the Conference of Parties on policy, program priorities, and eligibility criteria related to the Convention. GEF climate change projects fall under four areas (UNDP 2005):

1) removing barriers to energy efficiency and energy conservation;
2) promoting the adoption of renewable energy by removing barriers and reducing implementation costs;
3) reducing the long-term costs of low greenhouse gas emitting energy technologies; and
4) supporting the development of sustainable transport.

From 1991 to 2004, GEF allocated $1.74 billion to climate change projects and related activities. (GEF 2005)

The **Chicago Climate Exchange** provides a vessel for companies to make a voluntary, legally binding commitment to reduce their emissions of greenhouse gases by four percent below the average of their 1998-2001 baseline by 2006. Emission sources and offset projects have been done in the United States, Canada, Brazil and Mexico. Chicago Climate Exchange reduction commitments and trading will apply for a pilot phase from 2003 until 2006. (Convery et al. 2005) For a new greenhouse gas mitigating project, generating emissions reductions after 2006, the specifications for the next commitment phase need to be awaited.

Myclimate offers climate protection projects to compensate for CO2 emissions, namely in air travel. 500ppm, a German society for emissions trading, invests in greenhouse gas mitigating projects to generate emission reductions. 500ppm is constantly looking for JI and CDM projects and also for small projects for which the transaction costs associated with CDM registration are too high but still can comply with the Gold Standard. The emission reductions are then offered to clients via myclimate or through co-operation partners. (myclimate 2005)

1.4.6 Institutional design options

The institutional design option chosen for a CDM project influences the way investments are channelled into CDM projects as well as the responsibilities and the extent of involvement of the participants. The most common design options are the bilateral, multilateral and unilateral design options. (Krey 2004)

In **bilateral** project architecture the project development, project financing and sharing of costs and credits are negotiated and decided by the project suppliers and the investors on a project-specific basis. Governments or companies from Annex B countries directly participate in the project and are direct investors. (Krey 2004)

Single investors in the **multilateral** project design option do not directly invest in a CDM project themselves but deposit their money in an independent multilateral fund, which then invests in a portfolio of projects on behalf of the depositors. Potential project suppliers that design projects compete for the fund’s resources. The investors receive Certified Emission Reductions in proportion to their share in the fund. (Krey 2004)

The slow implementation of incentives for industrialised country companies to embark on CDM projects and low carbon prices led to a preference of just buying Certified Emission Reductions instead of investing in projects. Thus a third option has gained prominence – the **unilateral** option where the project development is planned and financed within the host country. (Jahn et al. 2004)

Under unilateral design, the project supplier's own resources are used to finance the project. The project supplier is therefore also the project owner responsible for the design and implementation of the project. All associated risks are taken on by the project supplier, such as the risk to find a buyer of the Certified Emission Reductions generated by the project. (Krey 2004)

2 Project Assessment Criteria

The criteria used to assess the feasibility of the case studies are risks, transaction costs, investment costs and the institutional setup. In the following chapters the transaction costs and risks are explained.

2.1 Transaction costs

This section about transaction costs is divided into a section about transaction costs of CDM projects of any scale and a section about transaction costs of small-scale CDM projects.

2.1.1 Transaction costs of CDM projects of any scale

It is the aim of this section to outline the different components making up the transaction costs of a CDM project. "Transaction costs" are defined as all the costs that would not arise if the project were implemented without the CDM. If CDM revenues are higher than the transaction costs defined above, then the CDM implementation is viable.

Error! Not a valid result for table. below outlines the various cost components a project developer faces when implementing a CDM project and the different factors on which these costs depend.

Table 2-1 Dependence of cost components on various factors

Cost component	Description	Dependence on
Search costs	• Finding interested transaction partners (e.g. fee for brokers) • Communication (e.g. telephone calls, sales representatives' salaries) • Obtaining price information and quality control (e.g. fees for agents)	• the institutional project design • the number of partners involved • the maturity of the market • the size of the market • the level of standardisation of the market
Negotiation costs	Reaching an agreement (e.g. time, travel costs, drafting of contract, fee for specialised legal or financial consultants)	• the institutional project design (bi- and multilateral projects create higher costs than unilateral projects, because more detailed specifications need to be made) • the maturity of the market
Documentation costs	• Project Idea Note • Project Design Document, including:	
	○ Baseline determination and documentation	• Project complexity • Baseline assumptions • Choice of the crediting period[1]
	○ Monitoring plan	• Methodology • Project complexity
	○ Sustainability assessment	• Host country (each host country is responsible to set up its own sustainability criteria)
	○ Environmental impact documentation	• Host country procedures • Project type (determining the emission level of local pollutants) • Project's physical size (visual impact or land use impact)
	○ Stakeholder consultation	• Project size, negative externalities
	○ Calculation of greenhouse gas emissions	• Project complexity
Approval costs	Receiving host country approval (e.g. meetings and presentations at the Designated National Authority)	Costs can be assumed to depend on the host country as they are sensitive to the length of the approval process, transparent rules and procedures as well as clear approval criteria.
Validation costs	Paying the validator for checking if the project meets the validation requirements (usually a fee paid to the validator)	• the project complexity • baseline assumptions (e.g. costs depend on the number of variables that determine the baseline)
Registration costs	Payment to the Executive Board for registration of the project (The fee is charged based on the anticipated emission reduction as given in the Project Design Document. The fee is deducted in form of Certified Emission Reductions upon issuance.)	The anticipated emission reduction For Information regarding the registration costs for different amounts of emission reductions please refer to appendix 6.4.

[1] e.g. a period of 7 years can be renewed two times but the continuing validity of the baseline needs to be shown or the baseline needs to be adjusted

Cost component	Description	Dependence on
Monitoring costs	• the implementation of the monitoring plan • the periodic monitoring activities • the periodic submission of the monitoring report	• The project complexity • The CDM methodology, outlining the frequency with which monitoring is undertaken • The crediting period (The longer the period the more costs)
Verification and certification costs	Payment to the verifier (These costs are considered as a single transaction cost component because the project developer usually pays a single fee to the verifier for both verification and certification.)	• The project complexity • The CDM methodology, outlining the frequency with which verification and certification is undertaken
The adaptation fee	Transferral of 2% of the Certified Emission Reductions to the adaptation fund. The idea is to help the highly vulnerable countries adapt to climate change.	• the total quantity of CERs at the time of issuance • the value of the CERs at the time of issuance • the host country, because projects in least developed countries are exempted from the fee

Adapted after (Krey 2004)

Table 2-2 Overview of dependence of costs on various factors

	Search costs	Negotiation costs	Documentation costs	Approval costs	Validation costs	Registration costs	Monitoring costs	Verification and certification costs	The adaptation fee
Project type / complexity			X		X		X	X	
Project size (physical size)			X						
Total emission reduction						X			X
Host country			X	X					X
Project design	X	X							
Frequency of monitoring							X	X	
Price of CERs									X
Costs lower with small-scale projects			X			X		X	X

Adapted after (Krey 2004)

The following section explains the major amendments that have been made to the CDM rules in order to reduce transaction costs of small-scale projects and which cost components can be assumed to be lower for projects that are eligible under small-scale rules.

2.1.2 Transaction costs of small-scale projects

A significant cost degression with rising emission reductions is observed for all cost components apart from the adaptation fee (Krey 2004). It has been argued that small-scale projects will not be attractive under the CDM due to the large transaction cost burden (Michaelowa and Stronzik 2002). The Executive Board has adopted the simplified CDM rules for small-scale CDM projects as a response. For the small-scale eligibility criteria see chapter 1.4.4.

The costs that are lower for small-scale projects are listed in Table 2-3 below. These costs are cheaper in absolutes but may still be more costly relative to the project size. Any cost component not listed is equally expensive for any project size.

Table 2-3 Cost components that are lower for small-scale projects

Cost component	Reason(s) for lower costs:

Documentation costs	The following steps in writing a Project Design Document are less costly for small-scale projects (Krey 2004):
	• **Baseline determination and documentation** is estimated to be less expensive for small-scale projects for the following reasons:
	  o Automatical qualification for standardised baseline methodologies already defined by the Executive Board according to their project category[2]
	  o No need for external consultants if the existing baselines and the included recommendations should prove self-explanatory
	• **Monitoring plan** costs can be estimated to be lower because simplified monitoring methodologies are included in the small-scale rules. They provide recommendations on which type of data should be monitored and included in the monitoring plan
	• **Environmental impact documentation** costs are likely to be lower because under the small-scale rules a documentation and analysis of the environmental impacts is only required if requested by the host country. The costs therefore strongly depend on the individual host country.

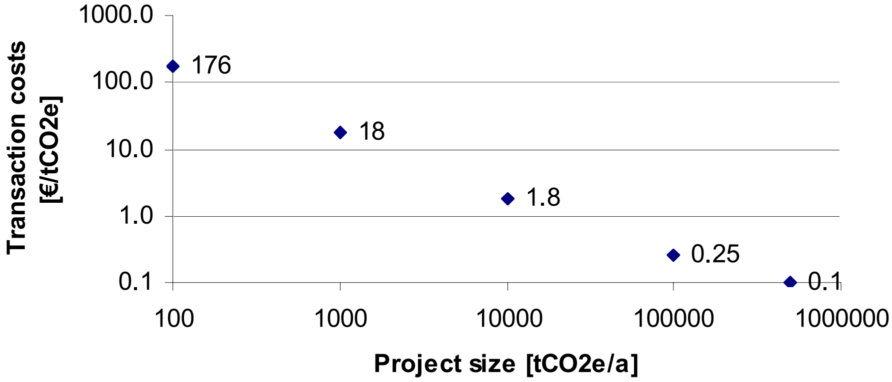
Registration costs	The costs depend on the anticipated emission reduction.
Verification and certification costs	The costs can be estimated to be lower for small-scale projects because the same Designated Operational Entity that validates the project is also allowed to verify and certify the project. As the Designated Operational Entity already knows the project well it will be able to be more efficient and save costs in verification and certification. (Krey 2004)
The adaptation fee	The costs are lower simply because small-scale projects have smaller emission reductions than larger projects.

Adapted after (Krey 2004)

It should be noted that the registration costs and the adaptation fee are not affected by the small-scale methodologies. These components are lower for small-scale projects simply because the projects will have smaller emission reductions than larger projects. Validation and monitoring costs are not affected by the small-scale rules (Krey 2004) either.

[2] If no existing methodology is suitable a new small-scale methodology needs to be submitted to the Executive Board for approval

Figure 2 Transaction costs depending on the scale of the project



The logarithmic scales show that transaction costs per ton of CO2 equivalent reduced are highly dependent on the size of the total emission reductions achieved by the project. After (Krey 2004)

2.2 Risks

The following section aims to identify the risks inherent in CDM projects and to describe the consequences of the risk transfer between seller and buyer of Certified Emission Reductions. The risks are described, risk sharing between seller and buyer is discussed and its implication on the price of CERs is shown. Depending on the risk sharing agreement some of the risks may be moved from the seller to the buyer or vice versa.

Table 2-4 Risk assessment

Risk component	Description of risk
Credit worthiness risk	The risk that the seller, having promised to pay compensation, will not be able to afford to do so in the case he does not deliver.
Enforcement risk	If the seller owes money: How much will it cost to make him pay? Will it be possible to enforce the contract at all? (in some countries)
Legal uncertainties	Who owns the project? Does the seller have the rights to sell the Certified Emission Reductions?
Engineering risk	The risk that the machinery fails.
Operations risk	The risk that the project is commercially unviable and does not run, and therefore does not generate Certified Emission Reductions.
Finance risk	The risk that the project cannot be financed and is not built.
CDM approval risk	The risk that the project will not be approved, that there will be inconsistencies and delays in registration.
Host country approval risk	The risk that time will be wasted in additional bureaucracy or that the host country will not approve of the project at all.
National policy risk	The risk that new regulations make emission reductions mandatory for reasons other than climate change. This leads to investor uncertainty because the additionality of the project might be hampered.

Risk component	Description of risk
CDM Executive Board risk	The risk that the CDM Executive Board might be overwhelmed and delays will occur.
Transaction costs risk	The risk that transaction costs will be higher than expected

source: (Drummond 2005)

Many sellers on the primary market do not have an excellent credit rating. Due diligence is very crucial. Approaches used by the buyer to mitigate risks include (Drummond 2005):

- Detailed financial assessment of the seller
- Parent company guarantee
- Bank guarantee
- Insurance products
- Escrow arrangements, i.e. agreements between two people or organizations in which money or property is kept by a third person or organization until a particular condition is completed.

The value of "make good" clauses depends very much on the credit risk of the seller. (See "credit worthiness risk" in Table 2-4.) The primary tool for risk mitigation is payment after delivery. As this does not eliminate risks, but simply refer them to the seller the next section explores options of sharing the risk between the seller and the buyer.

2.2.1 Options to share the risk between seller and buyer

On the demand side the CER market is fragmented into the following markets (Drummond 2005):

- The primary market made up by forward[3] purchases by governments, funds and corporations.
- The secondary market made up by purchases on the same terms as European Allowances[4].
- A spot[5] market, where the price is based on the market price at the time of delivery, will be operational as soon as CERs exist.

Sharing the risk is relevant only for the primary market, because in the secondary and spot markets the CDM projects have already been successfully completed and the CERs have been issued.

On the **secondary market** local sellers in developed countries have to deliver a fixed volume of European Union Certified Emission Reductions at an agreed price on an agreed delivery

[3] The price of a forward purchase is fixed long before the delivery. Markose, D. S. (2004). "The role of securities in the optimal allocation of risk bearing (Arrow 1964)." University of Essex.
[4] European Allowances are a limited stock of certificates that allow major EU companies to emit a specific amount of carbon dioxide equivalents.
[5] The price of spot market utility is based on the market price at the time of delivery (Markose, 2004)

date. The payment is made upon delivery of the CERs. There is no specific underlying project and the registration risk stays with the seller. The consequence of non-delivery is that the seller must make good or pay compensation that allows the buyer to purchase the same amount of CERs on the market. (Drummond 2005)

On the **primary market** some buy Verified Emission Reductions[6] and some buy Certified Emission Reductions. Those buyers who purchase Verified Emission Reductions take on the project registration risk, while those who buy Cerified Emissions Reductions leave the registration of the project and the associated risk to the seller. Some buy fixed volumes while others buy the actual output from a specific project. The payment is typically made upon delivery of the Certified Emission Reductions, though some pay a portion up-front. The up-front payment is often used to assist with the documentation requirements of the CDM Executive Board. (Drummond 2005)

On the primary market typical consequences of non-delivery are (Drummond 2005):

- requirement to the seller to make good the loss
- allowing the seller to catch-up in later years
- allowing the seller to terminate the contract (e.g. the contract is cancelled if the project is not registered despite best efforts of the seller)

2.2.2 CER pricing

Generally speaking it can be said that the more risks the buyer has to carry, the lower the price he is willing to pay for the deal. Therefore the prices increase as risk is transferred to the seller.

In Europe if a project fails to deliver sufficient Certified Emission Reductions for reasons other than CDM Executive Board decisions, then the seller must make good[7] or pay liquidated damages[8]. In Japan the delivery conditions are often more flexible. The project developer thus carries more risk in Europe than in Japan because the consequences of non-delivery are more severe in Europe than in Japan. Not surprisingly the prices offered by Japanese companies are lower than those offered by European companies.

The pricing used by funds and governments is not very transparent and terms vary. The ratio between risk and reward is therefore hard to know from the outside. It can however be assumed that the more risks a fund or government has to carry, the lower the price it is willing to pay per emission reduction unit. (Drummond 2005)

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[6] Verified Emission Reductions are verified by independent verifiers, but are not (yet) certified by a regulatory authority for use as a compliance instrument Co2e. (2002). "Market Overview."
[7] To “make good” means to put the wronged party into the position it would have been without the contract.
[8] “When the parties to a contract agree to the payment of a certain sum as a fixed and agreed upon satisfaction for not doing certain things particularly mentioned in the agreement, the sum is called liquidated damages.” Library, L. L. (2005). "The Lectric Law Library's Lexicon On Liquidated Damages."

Table 2-5 Certified Emission Reduction pricing spectrum

Primary market buyers	**Price (per tCO_2e)**
funds / government	€ 5.00+
commercial, Japan	$ 6.50 (€ 5.00)
commercial, Europe	€ 6.00+
secondary market	in line with long-term European Allowance prices
spot	equal to the European Allowance price on one day

source: (Drummond 2005)

New supply as well as new demand is anticipated. Therefore it is difficult to make a statement about whether the price for Certified Emission Reductions will decrease or increase. As demand and supply heavily depend on political decisions, the future CER price development is very opaque. For a more detailed assessment of factors affecting the future pricing of Certified Emission Reductions please refer to appendix 6.5.

3 Case Studies

The following case studies showcase project ideas of different scales and types. The scales range from a landfill depositing waste from about one million people to manure digesters on household level. Chapter 3.1 describes an existing project case (a landfill project) that has already been registered by the CDM Executive Board. It is used as a reference to which other project ideas described in subsequent chapters can be compared to.

The fact that the global warming potential of methane is 21 times higher than the global warming potential of carbon dioxide is relevant to all case studies. In the landfill gas project and in the biogas from public toilets project methane that is **emitted anyway** is **collected and combusted**. In the combustion process the methane is turned into carbon dioxide thus achieving an emission reduction in terms of carbon dioxide equivalent emissions. In the decentralised composting project the methane production is **avoided** by composting organic waste instead of dumping it on a landfill. In the manure digesters methane is **produced on purpose** in order to generate a fuel source which can be used to replace other fuels.

In assessing the transaction costs each project idea is first looked at using one single project only. All project ideas except for the landfill project are then assessed on the basis of bundling individual projects together in order to achieve a total emission reduction equal to the landfill project.

The description of case studies is based on public documents and some information therefore remains unavailable. From all risk factors inherent in CDM projects only few have been assessed. The description of risks focuses on CDM approval risks, engineering risks, operations risks and national policy risks. For a more comprehensive list of CDM risks please refer to Table 2-4.

3.1 Landfill gas flaring

The Santa Cruz Landfill Gas Combustion Project was registered as a CDM project activity on June 3, 2005. As the project is the smaller out of only two waste management or wastewater treatment projects that have been registered by the Executive Board by mid June 2005 it is chosen as a case study in this thesis.

The main objective is to capture methane and to flare it at a municipal waste landfill site in Bolivia. Methane is produced during the decomposition of organic waste under anaerobic conditions.

The Project Design Document of the Santa Cruz Landfill Gas Combustion Project mentions a total emission reduction of about 1’700’000 tCO2e over a crediting period of 21 years (UNFCCC 2005c). Per year this results in 80’000 tCO2e, a value that is used to compare the project with the other project ideas. Other project ideas are assessed by bundling individual projects together until they achieve the same reduction of greenhouse gas.

Table 3-1 Key data for the landfill gas flaring project

Indicator	units	value
Total number of people served		1'000’000
Total emission reduction	tCO2e/a	80000
Depreciated investment costs	€/unit/a	78000
Specific depreciated investment costs	€/tCO2e	1

For more information about the financial appraisal of case studies please refer to appendix 6.10.

3.1.1 Organisational setup

The landfill is owned by the municipality of Santa Cruz. The construction of the next compartment of the landfill has been awarded to SUMA, a Bolivian company. The project developers are SUMA, the operator of the landfill, and Grontmij Climate & Energy, a Dutch engineering consultancy. (UNFCCC 2005c)

3.1.2 CDM transaction costs

Information about transaction costs of the Santa Cruz Landfill Gas Combustion Project has not been available for this study. Empirical research has shown that the transaction costs for a project reducing about 80’000 tCO2e per year are around 0.3€ per tCO2e reduced[9] (Krey 2004). These figures are however based on India and provide only a rough estimate.

3.1.3 Risks

Some risk components such as the host country approval risk are not relevant any more because the project has already been registered by the CDM Executive Board.

The **CDM approval risk** is low because landfill gas projects have already been developed and approved. Therefore methodologies are already designed and ready to be used. The combusted gas, being a point source, is simple to monitor compared to a distributed

[9] Based on 1 € equals 1.2 $US.

source.

The **engineering risk** is expected to be small because landfill gas combustion is a well-known technology. As the project does not include an electricity generator, the risks associated with running the generator and selling the electricity are eliminated.

The **operations risk** is low because the financial viability of the project depends only on CDM financing and on the continuing operation of the landfill site. Waste production is more likely to increase than decrease thus enabling the continuing operation of the landfill site.

The **national policy risk** may provide a problem because it is possible that Bolivian legislation may require the flaring of landfill gas and thus change the baseline assumptions. As the baseline has to be reassessed every 7 years there is some danger in that regard.

3.2 Decentralised composting

This project idea is based on the composting activities undertaken by a non-governmental organisation called Waste Concern. Decentralised composting plants operated by Waste Concern are located in Dhaka and other cities in Bangladesh.

The emission reductions are based on a baseline scenario where the waste goes to landfill. On the landfill the waste is degraded under mainly anaerobic conditions producing biogas made up by about equal amounts of methane and carbon dioxide. The carbon emissions from the composting process are based on data about the mass flux and carbon content of the incoming waste and of the outgoing compost. The difference in carbon mass is released into the atmosphere as carbon dioxide. Only a small portion of carbon is expected to be turned into methane in tiny areas with anaerobic conditions. The emission reductions that a plant accepting 3 tons of waste per day can produce are estimated at about 1500 tCO2e per year. A detailed description of the calculation of the emission reductions can be found in appendix 6.6.

Table 3-2 Key data for the decentralised composting project

Indicator	units	value
Number of people served per unit		5'000
Emission reduction achieved per unit	tCO2e/unit/a	1500
Number of units needed to produce 80'000 tCO2e/a (same effect as the landfill project)		50
Depreciated investment costs Khulna[10]	€/unit/a	4000
Depreciated investment costs Dhaka	€/unit/a	20000
Specific depreciated investment costs Khulna	€/tCO2e	3
Specific depreciated investment costs Dhaka	€/tCO2e	14

After (Rytz 2001) Number of people served is based on estimate of 7 people per household. For more information about the financial appraisal of case studies please refer to appendix 6.10.

3.2.1 Organisational setup

A large composting project is currently being implemented by Waste Concern and World Wide Recycling as a CDM project. Waste Concern is a Bangladeshi non-governmental organisation and is operating the composting plant. World Wide Recycling is a Dutch investor and operator in waste treatment. As they are currently gaining experience in CDM project development through their joint-implementation of a CDM project they would be potential developers for a decentralised composting project as well. A decentralised approach would however require more plant managers. The organisational setup would therefore be more complex for a decentralised project.

[10] Land costs in Dhaka are much higher than in Khulna. Appendix 6.10 contains details about the financial appraisal of the decentralised composting case study.

3.2.2 CDM transaction costs

CDM transaction costs are first assessed for one single composting plant only. CDM transaction costs for projects reducing as little as 1500 tCO_2e per year are estimated at about 15€ per tCO_2e reduced (see Figure 2).

The decentralised composting project idea is now assessed on the basis of bundling individual composting plants together in order to achieve a total emission reduction equal to the landfill project. Dividing the 80’000 tCO_2e annual emission reduction achieved by the landfill project through the 1500 tCO_2e reduced by the decentralised composting plant per year results in about 50 decentralised composting plants needed to achieve the same effect on the atmosphere as the landfill project.

3.2.3 Risks

The **CDM approval risk** may be considerable. The management of a complex bundled structure with for example 50 decentralised composting plants makes the operation and monitoring of the project activity more difficult. This may provide a risk that the emission reductions are either not achieved as expected or that the emission reductions achieved by the project are not properly monitored and thus not accepted as CDM credits.

The **engineering risk** is rather small because even if there is considerable methane production (e.g. 10% of the carbon emitted as CH_4) it will always be less methane than what would have been produced in the baseline case. The labour intensive low-tech approach used in decentralised composting plants is very appropriate for a developing country setting. Spare parts for such simple designs should not be problematic to find, which also lowers the engineering risk.

The **operations risk** is mainly the risk that the compost might not find buyers. This may provide a financial risk because the project might become unviable as a result.

Depending on the crediting period used there is also a **national policy risk** because it is possible that Bangladeshi legislation may require the flaring of landfill gas and thus change the baseline assumptions. If a baseline of 10 years is chosen then this risk can be eliminated because in that case the baseline does not have to be reassessed once the project has been registered as a CDM project activity.

3.3 Methane use from public toilets

This project idea is based the operation of about 6'000 so-called "community toilet complexes" in Indian slums by an Indian non-governmental organisation called Sulabh. Beneath each toilet complex there is a sceptic tank where carbon is degraded under anaerobic conditions before it is pumped out, treated and disposed of. Only about 100 of these toilet complexes are equipped with a generator, using the biogas to generate electricity.

The emission reductions are based on a baseline scenario where all the biogas emits directly into the atmosphere. The biogas production from the community toilet complexes are based on the assumption that 1'000 people using each toilet complex per day. This criterion is fulfilled by many but not all Sulabh-operated community toilet complexes. The emission reduction that a generator installed at a toilet complex can achieve is estimated at about 85 tCO2e per year. A detailed description of the calculation of the emission reductions can be found in appendix 6.7. (Bhatia 2004)

Table 3-3 Key data for the methane from public toilets project

Indicator	units	value
Number of people served per unit		1'000
Emission reduction achieved per unit	tCO2e/unit/a	85
Number of units needed to produce 80'000 tCO2e/a (same effect as the landfill project)		1000
Depreciated investment costs	€/unit/a	2000
Specific depreciated investment costs	€/tCO2e	25

For more information about the financial appraisal of case studies please refer to appendix 6.10.

3.3.1 Organisational setup

The land and funds for construction of public toilet complexes are provided by the municipal authorities or donors such as multinational companies. Sulabh constructs and maintains the toilet complexes for public use. Sulabh charges Re 1 per use from the adult male users only while women and children are allowed free use of the facilities. Sulabh can only accept grants and donations and cannot raise loans from banks or financial intermediaries such as the Indian Renewable Energy Agency. The management capabilities of Sulabh are mentioned to be a constraint to installing biogas plants in existing community toilet complexes (Bhatia 2004).

3.3.2 CDM transaction costs

CDM transaction costs are first assessed for one generator at one toilet complex. CDM transaction costs for projects reducing as little as 85 tCO2e per year are estimated at over 180€ per tCO2e reduced (see figure 2).

The biogas use at public toilets idea is now assessed on the basis of bundling individual projects together in order to achieve a total emission reduction equal to the landfill project. Dividing the 80'000 tCO2e annual emission reduction achieved by the landfill project through the 85 tCO2e reduced by an electricity generator per year results in about 1’000 generators that would need to be installed to toilet complexes in order to achieve the same effect on the atmosphere as the landfill project. It is difficult to assess the CDM transaction cost components for such a project. The management of such a complex project structure is certainly challenging. The monitoring could be done by metering the energy produced, which should be rather simple.

3.3.3 Risks

The **CDM approval risk** is made up by different factors on the basis of which the project might not be approved. Such factors include the uncertainties in the monitoring requirements and potential hassles in regard to the bundling of small projects into one large project.

The **engineering risk** is split up in the risk that the generator will not run and the risk that not all methane is combusted. The former is lowered by the fact that Sulabh already has experience in running generators. The latter is small because even if there is considerable leakage of methane (e.g. 10% of the biogas not combusted) there will always be less methane emitted with a functioning generator than without a generator.

The **operations risk** is mainly made up by the risk that the toilet complexes cannot be operated any more because they cannot collect enough revenues and the risk that the non-CDM funding for the generators cannot be raised. The Government of India currently provides a subsidy of Rs 400’000 on a nightsoil-based biogas plant of the capacity used in this study. The discontinuation of this subsidy is part of the operations risk.

The **national policy risk** is negligible because it is very unlikely that the installation of biogas generators at slum toilets will become a legal requirement in India. The need for sanitation is so huge that it is unlikely that the government would want to create any legal barriers.

As the land is owned by the municipalities and the toilet complexes are operated by Sulabh there might be some **legal uncertainties** as to who owns the project. Sulabh or any other project developer may end up not having the right to sell the emission reductions resulting from the project.

3.4 Polyethylene bag digesters

Fuel wood is only a greenhouse gas source because it is taken from forests that do not regrow, i.e. from unsustainable forestry. In many developing countries fuel wood is used in such an unsustainable way. This section explores the idea of replacing unsustainable fuel wood as an energy source for cooking purposes by biogas from digesters fed with cow manure. Methane is more efficient than fuel wood and therefore for the same energy production the combusted methane emits less carbon dioxide than fuel wood.

A NGO called Baobab Trust in Kenya promotes the use of a biogas digester made of a polyethylene bag. About one cow and a calf are needed to have enough manure to feed the bag digester. The digester produces enough biogas for a household to cook during one hour (Baobab_Trust 2004). The emission reductions are based on a baseline scenario where the energy required for cooking is supplied through unsustainable fuel wood and where cow manure is left to degrade under aerobic conditions. In the project case the fuel wood stays in the forest and the cow manure is digested under anaerobic conditions. The biogas is used to replace fuel wood. The project emissions are carbon dioxide produced in the digester (40% of the biogas produced), carbon dioxide emissions from the combusted methane, carbon dioxide and methane emissions from leakage of uncombusted biogas. The emission reduction that one polyethylene bag digester can produce is estimated at about 0.1 tCO2e per year. As the improved energy efficiency of gas stoves compared to wood stoves is not taken into account the emission reduction estimate is conservative. A detailed description of the calculation of the emission reductions can be found under appendix 6.8. (Baobab_Trust 2004)

Table 3-4 Key data for polyethylene bag digester project

Indicator	units	value
Number of people served per unit		one household
Emission reduction achieved per unit	tCO2e/unit/a	0.1
Number of units needed to produce 80’000 tCO2e/a (same effect as the landfill project)		1'000’000
Depreciated investment costs	€/unit/a	270
Specific depreciated investment costs	€/tCO2e	2700

For more information about the financial appraisal of case studies please refer to appendix 6.10.

3.4.1 Organisational setup

As this project operates on the household level it is at the extreme end of decentralisation. Baobab Trust is currently promoting the use of digesters in Kenya. A similar project has been developed by the Netherlands Development Organisation (SNV) in Nepal. This non-governmental organisation has already installed over 100’000 biogas plants in the sizes 4 to 10 m^3. The NGO has been granted continuing support from the Dutch Government. The project sponsors of the CDM project include the Government of Nepal, the Kreditanstalt fuer Wiederaufbau (KfW), the renewable energy support office (Repso) and the Biogas Support Programme Nepal (BSP N) (SNV 2003). A similar organisational setup could be used in Kenya where a non-governmental organisation promotes the use of biogas digesters and is supported by the Kenyan government and others.

3.4.2 CDM transaction costs

CDM transaction costs for one single polyethylene bag digester reducing as little as 0.1 tCO2e per year are highly hypothetical and do not need to be assessed.

The polyethylene bag digester idea is now assessed on the basis of bundling individual projects together in order to achieve a total emission reduction equal to the landfill project. Dividing the 80'000 tCO2e annual emission reduction achieved by the landfill project through the 0.1 tCO2e reduced by a digester per year results in about 1'000'000 digesters that would need to be operated in order to achieve the same effect on the atmosphere as the landfill project. It is difficult to assess the CDM transaction cost components for such a project. The management of such a complex project structure is certainly challenging. Methane leakage is very crucial because it has the potential of turning the project into a greenhouse gas source rather than reduction. The monitoring would be very demanding because leakage can occur at many points in the system and because of the large number of digesters.

3.4.3 Risks

The **CDM approval risk** is still largely unknown but will become clear once the “Biogas Support Programme Nepal” has failed or passed the first CDM project hurdles.

The **engineering risk** is split up in the risk that the system does not work and produce any methane at all and the risk that the system does produce methane but emits it directly into the atmosphere through leaks. The latter is very high because if there is little more than 20% leakage of methane from the digester system there will be more carbon dioxide equivalent emissions from the digester system than from the fuel wood baseline case. The project is therefore at risk of becoming a greenhouse gas source rather than reduction.

The **operations risk** is mainly made up by the risk that not enough digesters can be sold and therefore not enough emission reduction can be achieved. The operations risk depends on the availability of subsidies from development aid, from the government of Kenya and on the economic development of Kenya. All these factors will decide about how many plants can be sold and whether a total emission reduction large enough to cover CDM transaction costs can be achieved.

The **national policy risk** is inexistent because even if the collection of fuel wood would be prohibited it could not be controlled.

4 Synthesis

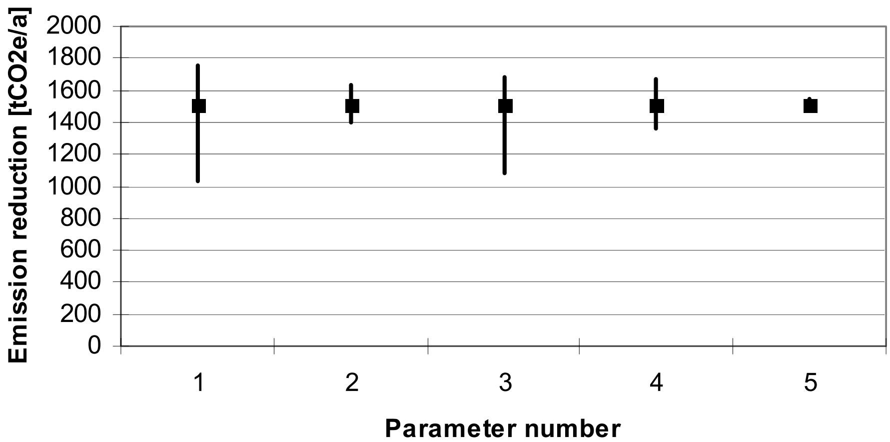
This section is organised as follows: Firstly, uncertainties in source data and their effects on calculation of emission reductions are assessed. Secondly, the case studies are compared to each other in terms of risks, investment costs, additionality, and institutional setup. Thirdly, suggestions on improving the odds of decentralised projects and fourthly, topics for further research are proposed.

4.1 Evaluation of source data

This section assesses the uncertainties in emission reduction estimates for the described case studies. The emission reduction data for the landfill gas flaring project have simply been taken from the Project Design Document of the Santa Cruz Landfill Project. As calculation of emission reduction for the landfill gas flaring project does not form part of this study, the uncertainties are not discussed either. The uncertainties in the other three case studies have been assessed on the basis of estimates from literature or own assumptions. Major uncertainties were found in the polyethylene bag digester case study, followed by the methane production from public toilets. The emission reduction estimate of the decentralised composting case study reveals the lowest uncertainties of the three case studies besides the landfill gas project.

As regards the **decentralised composting** project, uncertainties in the data source regarding methane production in the composting process and in the landfill have the strongest influence on the emission reduction calculation. Under real project conditions, methane production from the composting project would therefore have to be monitored. The uncertainties in baseline emissions (methane production in the landfill) remain even after project implementation. Figure 3 illustrates the variation in emission reductions calculated with different parameter estimates for the decentralised composting project. Parameters 1 and 3 in Figure 3 show the strongest variation in emission reductions calculated for lower and higher estimates. These parameters designate the methane production in the composting process and in the landfill. A comprehensive knowledge of these two parameters is required to obtain a more accurate estimate of emission reductions of the decentralised composting project. On a real scale, methane production in the composting process will have to be somehow monitored to determine the real emission reductions compared to the calculated reductions. Since methane production on the landfill is avoided by the project, it cannot be measured. The uncertainties in the model estimates regarding methane production in the landfill therefore remain even after project implementation.

Figure 3 Variation of emission reduction for decentralised composting



Black boxes show emission reductions calculated for the best estimate values. Black lines show emission reductions calculated for the variation of one parameter using a lowest and highest estimate while all other parameters stay on the best estimate position. The parameters are described as follows:

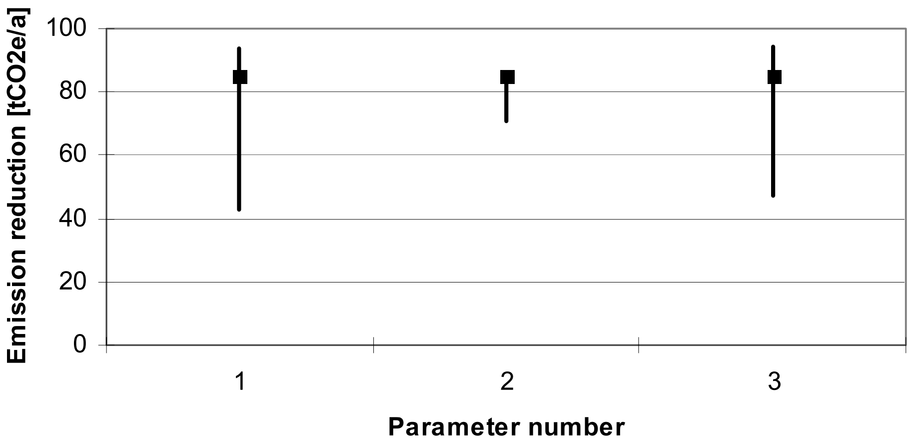
Parameter number	Description	Range
1	Mass of carbon turned into methane per mass of carbon released during the composting process ($t_{CH4\text{-}C}$/ t_C)	0 - 0.07
2	Mass flux of organic waste (t/a)	1000 - 1200
	Mass flux of compost (t/a)	182 - 218
3	Methane production on the landfill ($t_{CH4,landfill}$/ t_{waste})	0.08 - 0.11
	Carbon dioxide production on the landfill ($t_{CO2,Landfill}$/ t_{waste})	0.32 - 0.2
4	Carbon content of waste entering the composting process (t_{carbon}/t_{waste})	0.33 - 0.27
5	Carbon content of final product (t_{carbon}/$t_{compost}$)	0.22 - 0.15

For the source of estimates see appendix 6.9. For best estimate values see appendix 6.6.

Methane emission reductions **from public toilets** are greatly dependent on variations in annual biogas volume produced per toilet complex, and on the amount of biogas captured. Due to the fixed capacity of the generator, changes in biogas production have a negative impact as soon as production drops below the available generator capacity. This may for example occur after emptying the septic tank below the toilet complex.

Figure 4 illustrates the variation in emission reductions calculated with different parameter estimates for the methane produced by public toilets. Figure 4 illustrates the greatest variation in emission reductions calculated for lower and higher estimates of parameters 1 and 3. These parameters designate the variation in annual biogas volume produced per toilet complex, and the amount of biogas captured. A more comprehensive knowledge of these two parameters is required to obtain a more accurate estimate of methane emission reductions of the public toilets project. The annual biogas volume per unit and the ratio of biogas captured basically determine the amount of combustible biogas. On a real scale, the annual biogas volume per unit and the ratio of biogas captured therefore do not have to be measured as monitoring of the combusted biogas alone will allow obtaining accurate information on real emission reductions.[11]

Figure 4 Variation of emission reduction for methane from public toilets



Black boxes show emission reductions calculated for the best estimate values. Black lines show emission reductions calculated for the variation of one parameter using a lowest and highest estimate while all other parameters stay on the best estimate position. The parameters are described as follows:

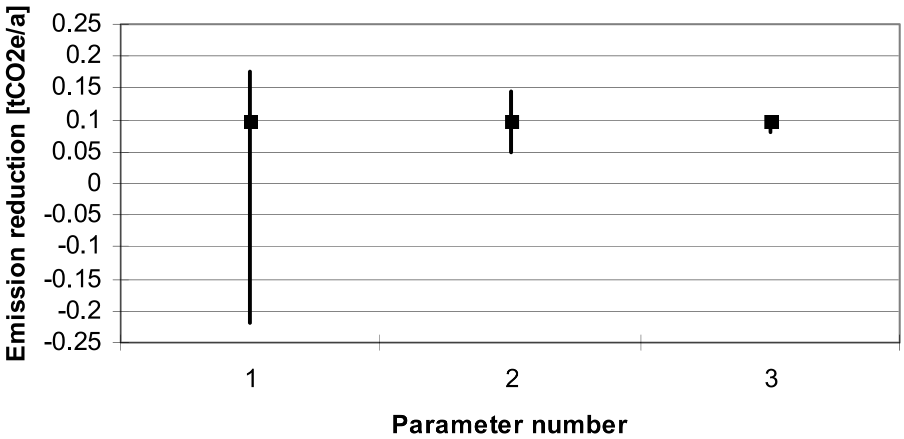
Parameter number	**Description**	**Range**
1	Volume of biogas per unit per year (m^3/(unit*a))	6000 - 13200
2	Methane content of biogas m^3_{CH4}/ m^3_{biogas}	0.5 - 0.6
3	Ratio of biogas captured (i.e. capacity of the generator) to total biogas production ($m^3_{CH4,captured}$/ $m^3_{CH4,produced}$)	0.5 - 1

For the source of estimates see appendix 6.9. For best estimate values see appendix 6.7.

[11] The monitoring of the biogas produced per unit per year may however still be necessary in order to know whether or not the project is eligible for the small-scale methodologies. (Direct project emissions, which include the emission of non-combusted biogas, are a criterion for small-scale eligibility)

The emission reductions from the **polyethylene bag digesters** are extremely sensitive to biogas leakage from the digester system. As no methane is emitted in the baseline scenario, the methane emitted from the project can even cause the project to have a worse effect on the climate than the baseline scenario. The sensitivity is such that a leakage of 10% (i.e. the best estimate value for parameter 1 in Figure 5) causes an almost 50% lower emission reduction than without leakage. Figure 5 illustrates the variation in emission reductions calculated with different parameter estimates for the polyethylene bag digester. As the emission reductions calculated for lower and higher estimates of parameter 1 (leakage) in Figure 5 reveal the strongest variation, additional information on this parameter is required to obtain a more accurate estimate of the emission reductions of the polyethylene bag digester project. On a real scale, leakage will have to be monitored somehow to compare the real emission reductions to the calculated ones.

Figure 5 Variation of emission reduction for polyethylene bag digester



Black boxes show emission reductions calculated for the best estimate values. Black lines show emission reductions calculated for the variation of one parameter using a lowest and highest estimate while all other parameters stay on the best estimate position. The parameters are described as follows:

Parameter number	**Description**	**Range**
1	Leakage coefficient ($m^3_{combusted}$/ m^3_{biogas})	0 - 0.5
2	Volume of biogas produced per polyethylene bag digester per year (m^3/a)	50 - 150
3	Methane content of biogas (m^3_{CH4}/ m^3_{biogas})	0.5 - 0.6

For the source of estimates see appendix 6.9. For best estimate values see appendix 6.8.

4.2 Evaluation of case studies

This section evaluates decentralised project ideas as a function of the CDM requirements and compared to the landfill project. Risks, investment costs, additionality, and institutional setup are discussed. For lack of data availability, transaction and operating costs are not estimated for the case studies. The institutional setup can be used as an indicator for transaction costs. Monitoring is for example expected to be more costly under a highly complex institutional setup. For a detailed analysis of risks, investment costs and institutional setup, refer to the chapters describing the aforementioned case studies. Table 4-2 summarises the results for all case studies.

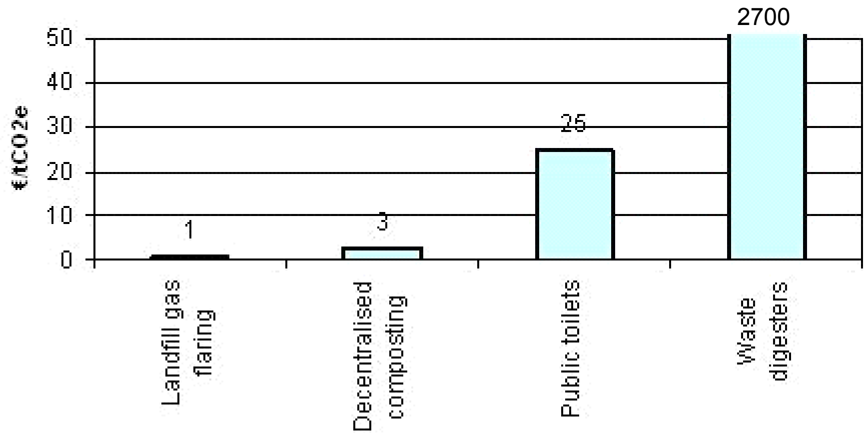
The main **risks** assessed in the case studies include the CDM approval risks, engineering risks, operational risks, and national policy risks. The landfill gas flaring project exhibits the lowest risks. Its only risk is a change in national policy, which could possibly result in altering the baseline assumptions for future crediting periods. The case studies on decentralised composting and public toilets have very similar and mainly medium risk profiles while the composting project has lower engineering risks (due to its simple technology). The public toilets project has no national policy risk (no risk for generators to become a legal requirement at public toilets in India). The highest risks are found in the case study of polyethylene bag digesters where the risks of failed engineering, financing and the CDM (non-)approval risks are particularly daunting. Failed engineering is a high risk as minor leakages have a detrimental effect on the atmosphere and on project viability. Financing is at risk because CDM revenues cover only about 0.5% of the investment costs. CDM approval is at risk, as financial additionality is not apparent with CDM revenues covering as little as 0.5% of the investment costs.

Table 4-1 Evaluation of risks

Case study	CDM approval risks	Engineering risks	Operations risks	National policy risks
Landfill gas flaring	low	low	low	medium
Decentralised composting	medium	low	medium	medium
Public toilets	medium	medium	medium	none
Polyethylene bag digesters	high	high	high	none

Investment costs are estimated for each case study except for the landfill gas flaring project, where cost data was not available. The cost estimate for the landfill gas flaring project is based on the costs per unit emission reduction calculated for a different landfill gas project (DANCEE 2003) in the Project Design Document. The investment costs per unit emission reduction are clearly related to the level of decentralisation. The lowest costs are obtained for the landfill gas project, and the highest for the polyethylene bag digesters project.

Figure 6 Investment costs per ton CO2e reduced



Operating costs, CDM transaction costs and additional non-CDM revenues are not considered. At the current primary market price of about 5€ per ton CO2e reduced CDM revenues for the waste digester project are negligible. CDM revenues may contribute considerably to the viability of the decentralised composting and the public toilets projects as long as CDM transaction costs do not come close to or exceed CDM revenues.

Financial additionality is assessed by comparing investment costs, calculated in units of Euro per ton of carbon dioxide equivalent reduction, to the current CDM revenues in the same units. Additionality is a CDM term indicating that a given project would not be undertaken in the absence of the CDM. Financial additionality means that the CDM revenues are necessary to make the project feasible. If CDM revenues per unit emission reduction are negligible compared to investment costs per unit emission reduction, financial additionality is therefore questionable, since it is difficult to argue that the project requires CDM revenues to be financially viable. This problem occurs in the case study of the polyethylene bag digesters, since even the highest possible revenues of €15 per ton of reduced CO2e could only cover about 0.5% of the investment costs. This estimate does not even consider CDM transaction and operating costs of the digester systems. For this project the financial additionality is clearly not given. To prove financial additionality of the project, barriers other than a lack of finances will have to be found to prove that the project cannot be implemented without the CDM. Such barriers could be a lack of training facilities in the host country for appropriate operation of the polyethylene bag digester system.

The **institutional setup** is crucial as regards project manageability. The complexity of the institutional setup and the resulting transaction costs grow with the level of decentralisation. The landfill gas project has a very simple structure while the polyethylene bag study is extremely difficult to manage. The experience of project developers with the implementation of CDM projects is another important factor when assessing the institutional setup. In this context, the decentralised composting case study scores much better than, for example, the public toilets study. The unclear ownership structure adds to the challenges inherent in the public toilets case study. Since the non-governmental organisation operating the toilet complexes does not own the land, it is not clear who will actually own the emission reductions achieved by the installation of biogas generators.

Table 4-2 shows an overview of the different factors by which the case studies have been assessed. With the level of decentralisation the risks grow, the investment costs rise up to a point where the financial additionality gets lost and the institutional setup becomes more challenging. The effect of reduced costs with increased scale is generally known as “economies of scale” and it is also the reason why under the CDM centralised projects are more attractive than decentralised projects. Among the three case studies using decentralised approaches the decentralised composting project is the only one that can safely be mentioned to be viable. Bundling a number of small composting plants together as one CDM project does certainly provide some challenges but is still possible. The complex and even more decentralised institutional setup makes the public toilets project daunting while the polyethylene bag digester project scores badly on all accounts.

In the waste management sector, under the current situation, landfill gas combustion is favoured over composting due to the high potential of carbon emission reduction that can be achieved on the landfill at the lowest cost. The baseline for composting projects is a landfill without gas capturing and combustion, emitting huge amounts of methane. If the baseline is changed to a landfill with gas collection and combustion, the advantage of composting is not given any more. If all the landfills in a given city combust landfill gas then combusted landfill gas would be the baseline for any waste treatment CDM project. Therefore the baseline for a composting CDM project disappears as soon as the landfill gas is combusted, because only a landfill without landfill gas use can be used as an attractive baseline scenario for composting. The current situation thus not only fosters large centralised projects but also destroys opportunities for the implementation of projects that make a larger contribution to sustainable development.

Table 4-2 Evaluation of case studies (overview)

Case study	Risks	Investment costs	Additionality	Institutional setup
Landfill gas flaring	low	low	OK	simple
Decentralised composting	medium	medium	OK	challenging
Public toilets	medium	medium	OK	very challenging
Polyethylene bag digesters	high	high	questionable	very challenging

Darker shades indicate more problematic areas.

4.3 Conclusion for decentralised projects

This chapter firstly evaluates the potential of decentralised projects under the CDM and then assesses ways to finance greenhouse gas abating, decentralised projects outside the CDM.

The case studies have shown that decentralised approaches are capable of reducing emissions. Therefore they are potential CDM projects. The potential can however only be realised if CDM transaction costs stay far below CDM revenues otherwise it is not worth participating in the CDM. In order to lower transaction costs many projects of the same type need to be implemented as one CDM project. Even with such up-scaling efforts centralised approaches are more attractive to CDM project developers because the management of a simple structure is much easier and less costly than the management of a decentralised structure.

The costs of implementing a decentralised project can be lowered by using appropriate **small-scale methodologies** that facilitate the baseline assumptions and monitoring of the project activity. All of the decentralised projects used as case studies make a large contribution to sustainable development of the host country. Decentralised approaches compared to centralised approaches tend to have more social benefits. This is because they tend to involve the communities more in the operation of the projects resulting in more jobs created. The low-tech labour-intensive technologies used in many decentralised setups channel the cash flows towards salaries of unskilled workers. The high-tech systems often used in centralised approaches however tend to spend a lot of money on equipment that has to be imported from industrialised countries, minimising the positive externalities for the host country. As decentralised projects often make a large contribution to sustainable development of the host country but are not very attractive in terms of transaction costs they need to **put a monetary value on their contribution to sustainable development**. For suggestions on how to convince buyers about the sustainability benefits a project has see chapter 4.4 below.

Three different options to finance decentralised projects outside the CDM are assessed. The Global Environment Facility is described to be looking for the lowest incremental costs to achieve greenhouse gas reductions unless other factors such as equity considerations speak for a different project. For example in waste management it is hard for decentralised approaches to compete with large landfill gas flaring projects on terms of lowest incremental costs. The Chicago Climate Exchange is hard to assess but does not look very promising at the moment. Myclimate is the most attractive option for decentralised projects.

The **Global Environment Facility** selects projects according to focal area strategies. Among alternative measures meeting the climate protection objective the measure with the lowest incremental cost is preferred if other criteria are equal. The other factors include (GEF 2005):

- the program’s priority for projects of that type
- national goals

- equity considerations
- the likelihood of success
- the environmental and social acceptability of the project

If incremental costs of one project type, e.g. the installation and use of methane digesters at public toilets, are higher than other renewable energy sources, e.g. landfill gas collection for energy generation, the project proponent has to argue that one or more of the other factors described above are favourable for the former project. In the case of methane digesters at public toilets in slum areas there are benefits for the poorest people and equity considerations may therefore provide an incentive to favour the project over another project type.

The **Chicago Climate Exchange** has not yet made specifications for the next commitment phase beyond 2006. It also remains open whether or not it will be linked to the EU Emission Trading System in the future. As many questions remain open it is difficult to assess the potential that the Chicago Climate Exchange offers for decentralised waste management and wastewater treatment projects. In the past carbon prices have been so low that the revenues from selling emission reductions from decentralised projects would probably not even have covered the transaction costs.

Myclimate is currently looking for carbon credits achieved by projects that make a large contribution to sustainable development. By selling climate neutral flight tickets myclimate currently raises about 25€ per ton of carbon dioxide equivalent. The project developers selling their emission reductions to myclimate can benefit from the following advantages:

- If the project is too small to cover CDM transaction costs it is possible to lower the transaction costs by verifying the credits without having to go through the CDM process. In that case a board of independent experts validate the baseline assumptions, the monitoring methodology and register the project's emission reductions as non-CDM "Verified Emission Reductions".
- Projects reducing as little as 10'000 tons of carbon dioxide equivalents over 10 years are already looked at.
- The price paid per ton of carbon dioxide equivalent reduced may be as high as 15€ for projects that make a large contribution to sustainable development.

4.4 Suggestions

This section is split into two parts: It first makes suggestions on ways to foster decentralised CDM projects and then suggests improvements to the implementation of decentralised greenhouse gas abating projects outside the CDM.

Under the CDM decentralised projects are currently hampered by the low carbon price and by repulsive monitoring methodologies that cause horrendous transaction costs. The situation could be improved by an increased awareness about the fact that the CDM attracts the development of large centralised projects that contribute little to sustainable development. (See chapter 1.1 for information about the contribution to sustainable development of decentralised projects compared to centralised projects.) If the general public becomes aware of the failure of the CDM to channel investment into projects that really contribute to sustainability then more companies might want to buy "sustainable" CDM credits and there might be political pressure to change the institutional design of the CDM system. The members of the Conference of the Parties that have ratified the Kyoto Protocol and the members of the CDM Executive Board could then design an institution that allows the full potential of decentralised projects to be developed. The institutional design of a CDM that fosters decentralised projects could look as follows:

- The contribution that a project makes to sustainable development and the conservativeness of the methodologies used for monitoring are weighed against each other. Highly sustainable projects are allowed the use of **simple monitoring methodologies that are cheaper to fulfil** while large centralised projects with little sustainability effects are treated very strictly in terms of monitoring methodologies and their interpretation. The existing simplified small-scale methodologies already are one step into this direction.
- The registration fee for small and decentralised projects could be lowered, removed or even turned into a **registration grant** while the registration fee for large centralised projects could be increased.

The odds of decentralised projects also depend on the ability of project developers to **sell their projects' contribution to sustainable development**. Rather than trying to fulfil the "perfect" requirements of the Gold Standard[12] simple values such as the number of jobs created and the money spent on workers' salaries compared to the money spent on machinery imported from developed countries could be used to prove social sustainability. Such figures should be calculated per unit of carbon dioxide equivalent reduced in order to insure the comparability among different project types and sizes. See Table 4-3 below for an example of indicators assessing the sustainability of the landfill gas flaring project and of the decentralised composting project. The landfill gas flaring project spends more money on machinery produced in developed countries than it spends on jobs while the decentralised composting project creates a large number of jobs

[12] The Gold Standard demands very conservative monitoring which causes very high transaction costs for decentralised projects.

but needs no machinery produced in developed countries. With such simple indicators it can be clearly shown that the composting project, per ton of carbon dioxide equivalent reduced, makes a much larger contribution to the sustainable development. The indicators may help the developers of decentralised projects to get higher CDM revenues.

Positive externalities other than job creation include decreased landfill volume in the composting case or less time spent on collection of fire wood for the polyethylene digester case. Different indicator values may be developed based on that.

Table 4-3 Indicators of social sustainability

Indicator	Landfill gas flaring project	Decentralised composting project
Jobs created per 100’000tCO2e	2.5	600
Job expenditures (€/100’000tCO2e)	3’600	440’000
Expenditures on machinery produced in developed countries (€/100’000tCO2e)	50’000	0

For source data refer to appendix 6.11

Outside the CDM the voluntary market provides opportunities sell emission reductions. At the example of Myclimate it has been shown that on the voluntary market it is possible to get higher revenues for carbon credits achieved by highly sustainable projects and to lower transaction costs. The problem is that currently there is little information in the developing world about voluntary market players such as Myclimate. The situation may be improved by **increased publicity of voluntary market players** in potential host countries.

4.5 Topics for further research

All the estimates of emission reductions for the three decentralised case studies used have large uncertainties. It would be interesting to work out more precise values as well as to know more about:

- Ways to improve the institutional design of the CDM in order to choose the best trade-off between fostering decentralised projects making a large contribution to sustainability and the conservativeness of the methodologies used to monitor such projects.
- The use of standard values for monitoring the N2O emissions from the composting process and for assessing the N2O emissions reduced by the replacement of artificial fertiliser by compost
- The use of reed beds replacing anaerobic ponds to lower CH4 emissions
- The use of latrine technologies with reduced CH4 emissions when compared to standard pit latrines (such as no-mix latrines where the faeces dry out rather than being anaerobically decomposed)

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6 Appendices

6.1 CDM Vocabulary

Additionality	An emission reduction that fulfils the additionality criterion would not have happened without the implementation of a CDM project.
Annex B Country	A country listed in Annex B of the Kyoto Protocol. These countries have committed themselves to a specified emissions reduction.
Annex I Country	The Annex I of the United Nations Framework Convention on Climate Change (UNFCCC) is a list of developed countries and countries that are undergoing the process of transition to a market economy. These countries have committed themselves to specific actions such as the adoption of national policies on the mitigation of climate change.
Annex II Country	Developed countries that have signed the UNFCCC are listed in its Annex II. These countries have committed themselves to supporting the developing countries in their efforts to mitigate climate change.
Assigned Amount Units	Countries that are subject to a greenhouse gas reduction target are allowed to emit a certain amount of Carbon Dioxide equivalents, measured in Assigned Amount Units.
Baseline	The scenario that would have happened without the implementation of a CDM project.
Certified Emission Reduction	A greenhouse gas reduction that has been registered by the
Clean Development Mechanism	One of the flexible mechanisms of the Kyoto Protocol. It can be used by an industrialised country to achieve its greenhouse gas reduction target at lower costs by implementing a greenhouse gas mitigating project in a developing country.
Commitment period	The period in which a certain greenhouse gas reduction target needs to be achieved.
Emissions Trading System	The platform on which companies can trade their greenhouse gas allowances.
Executive Board	The ten people responsible for the registration of a CDM project and for the issuance of Certified Emissions Reductions.
Global Warming Potential	The Global Warming Potential of a specific greenhouse gas is a factor describing how many tons of carbon dioxide equals the global warming effect of 1 ton of that specific greenhouse gas.
Joint Implementation	One of the flexible mechanisms of the Kyoto Protocol. It can be used by two annex B parties that decide to implement a greenhouse gas abating project together.
Meth Panel	The group of people working for the Executive Board that check new methodologies. They suggest to the Executive Board whether or not a new methodology should be approved.
Sequestration	The removal of carbon from the atmosphere.
Small-scale Working Group	The group of people being part of and / or working for the Executive Board that make suggestions about specific methodological issues concerning small-scale projects.

6.2 History of the CDM

The history of the CDM is at the same time the history of international efforts to combat climate change:

1983 The United Nations appointed an international commission to propose strategies for “sustainable development” – ways to improve human well-being in the short term without threatening the local and global environment in the long term. (Brundtland_Network 2005)

1987 The UN commission to propose strategies for “sustainable development” chaired by Norwegian Prime-Minister Gro Harlem Brundtland published its report “Our Common Future” widely known as “The Brundtland Report”. This landmark report helped trigger a wide range of actions such as the Rio Earth Summit in 1992. (Brundtland_Network 2005)

> **“Over the course of the 20th century the relationship between the human world and the planet that sustains it has undergone a profound change ... major, unintended changes are occurring in the atmosphere, in soils, in waters, among plants and animals, and in the relationships among all of these. The rate of change is outstripping the ability of scientific disciplines and our current capabilities to assess and advise. It is frustrating the attempts of political and economic institutions, which evolved in a different, more fragmented world, to adapt and cope ... To keep options open for future generations, the present generation must begin now, and begin together, nationally and internationally.”** (Brundtland 1987)

1994 166 countries ratified the UN Framework Convention on Climate Change (UNFCCC). Parties to the Convention agreed to a non-binding commitment to reduce greenhouse gas emissions in the Earth’s atmosphere by returning to 1990 greenhouse gas emissions levels. (Pembina_Institute 2003)

1997 The adoption of the Kyoto Protocol at the 3rd Conference of the Parties: Industrialized countries (defined as Annex B countries in the Protocol) are committed to attain legally binding greenhouse gas reduction targets during the period between 2008 and 2012. (Pembina_Institute 2003)

2001 Most of the final rules for the CDM were agreed at the 7th Conference of the Parties. The Marrakech Accords provided enough certainty for CDM projects to begin in earnest. (CDM_Watch 2003)

2003 The Swiss government ratified the Kyoto Protocol. By doing so, it has committed Switzerland to reduce its emissions of greenhouse gases to 8% below the 1990 level. (BUWAL 2003)

2004 The Russian Federation ratified the Kyoto Protocol. By doing so, the criteria for the Protocol to enter into force were met. Russia’s ratification was crucial because it was the world’s second largest emitter of greenhouse gases in 1990. (UNFCCC 2005a)

2005 The Kyoto Protocol entered into force on 16 February 2005. Few countries that have signed the Protocol still have not ratified it, such as the United States of America and Australia. Few others, such as Turkey and Belarus, have not even signed it yet. (UNFCCC 2005b)

2005 As of 6 April 2005, 148 states and regional economic integration organizations have ratified the Kyoto Protocol. The total percentage of Annex I Parties emissions is 61.6%. . (UNFCCC 2005a)

6.3 The current international debate about the CDM

The positions of the EU, the US, Japan, China, India, Brazil, Ghana and several Non Government Organisations (NGOs) on climate change are described in the following text. Each country's current efforts to reduce greenhouse gas emissions as well as their current ideas about a climate regime beyond 2012, i.e. beyond the first commitment period of the Kyoto Protocol, are discussed. The final section is a brief conclusion about the international debate. Information about the EU, US; Japan, India and Brazil is based on "Kyoto Protocol: Beyond 2012" (Pelangi 2004).

The **European Union** has been consistently pressing for a strong climate policy on the international level over the last 15 years. The EU has been crucial to the adoption of the Kyoto Protocol with its lobbying for strict absolute emissions targets as well as with its political pressure on Russia to ratify the Kyoto Protocol. With its domestic emission trading system for large sources, the EU has surprised the Anglo-Saxon world with its willingness to overcome deep-seated preferences for command and control instruments. The "linking directive", allowing the use of CDM credits in the EU emissions trading system, is the first large-scale incentive for private companies to participate in CDM projects. The EU has however given very generous allocations of emissions to big companies which don't require them to make significant reductions and lowers the demand for CDM credits. Nevertheless, the EU has become the largest provider of CDM capacity building funds and the largest buyer of CDM credits. The EU has been relatively successful in reducing its greenhouse gas emissions since 1990 compared to other OECD countries. However, the UK and Germany will soon have exhausted cheap opportunities to reduce greenhouse gas emissions (such as energy efficiency improvements), which may reverse the trend.

The EU is seriously preparing the negotiations on post-2012 climate policy. A 30 percent greenhouse gas reduction target has been proposed by both Germany and the Netherlands. Such a target looks somewhat less ambitious when the EU's "banked" emissions remaining in the new member states are considered. In the east emissions keep declining despite strong economic growth. Over the first commitment period the "banked" emissions amount to 2.5 billion t of C02, which equals 2.5 times the current gap between the actual emissions and the Kyoto target emissions during the first commitment period (Michaelowa 2004). If untouched until 2012 it could allow a target strengthening by 7.5 percentage points for a 28-member state EU.

The unwillingness of the **United States** to ratify the Kyoto protocol is relieved somewhat by regional actions in California and the Northeast states. California is moving forward in requiring car producers to cut emissions of CO2 by 29.2% by 2015 (Pelangi 2004). The Northeast states in the US are designing their own regional emissions trading program. On the other hand Bush's climate change plan is an almost trivial improvement: It contains the nonbinding pledge to see an 18% reduction of carbon emissions per unit of gross national output by 2012. (The US would expect a 14% improvement over this same period under a business-as-usual scenario.)

Purvis (Pelangi 2004) mentions that the US Congress tends to be very sceptical about actions taken in the UN as they relate to environment and that the US are not a party to many treaties that are universally accepted otherwise such as the Law of the Sea Convention and the Convention on Biological Diversity. The Kyoto approach thus may not be the best approach for the US. *Purvis* concludes that a better way to achieve the goals of emission mitigation and adaptation would be to look at approaches that borrow little from Kyoto. An incremental approach that proposed a step-by-step effort would be easier for the US to accept. The Bush administration is far more likely to agree to new domestic climate legislation than it is to negotiate a climate treaty with mandatory emission limits. The US' allies in Japan, Europe and elsewhere are required to be mindful of US domestic realities. *Purvis* encourages Japan and others to keep an open mind about non-Kyoto alternatives. According to this perspective the US thus offers little support for the Kyoto process including the CDM.

According to the UK Environment Minister, *Elliot Morley*, the UK government will use its presidency of the EU in the latter half of 2005 to look into the possibility of linking the EU emissions trading scheme with new greenhouse gas markets in the US (such as the Chicago Climate Exchange[13] and the Regional Greenhouse Gas Initiative[14]). As the linkage between the EU ETS and US state-level trading schemes is not possible under current legislation, the Linking Directive would need to be rewritten. In 2006, when the European Commission undertakes its review of the EU ETS, such a rewrite could take place. However the Bush Administration is expected to continue challenging state-level regulation on carbon dioxide in the courts, as it has done with the first steps that California has made towards carbon constraints. (Convery et al. 2005)

Japan experienced extraordinary weather in 2004. Cherry blossoms started 10 days earlier than the average over the last 30 years. In summer Tokyo counted a historical record with 40 consecutive days with daily maximum temperature exceeding 30°C. In October an extraordinary powerful typhoon hit Japan.

[13] See chapter 1.4.5 about alternative options outside the CDM

[14] The Regional Greenhouse Gas Initiative is a cooperative effort by eleven eastern states in the US to reduce carbon dioxide emissions including the implementation of a multi-state cap-and-trade programme with a market based emissions trading system. (Convery et al. 2005)

Typhoons hitting the Japanese archipelago are considered to occur more often than usual. The Japanese people are becoming aware that the climate is actually changing and their awareness may produce the political pressure that catalyses future change.

Japanese stakeholders however feel it is unfair that

- the US are not participating in the Kyoto Protocol, as they are the largest emitter of greenhouse gases,
- Japan is making a greater effort than the EU industry, as most of the emissions reductions in the UK and Germany were achieved not only for climate-related reasons[15],
- Japan's target of 6% in relation to the EU's target of 8% is too high. The Japanese industry was very efficient in 1990 already and thus a 6% reduction in Japan requires much more effort than an 8% reduction in the EU.

Kameyama (Kameyama 2004) explains that there is a huge disparity between the different ministries in the Japanese government on the KP. The Ministry of Environment and the Ministry of Economics, Trade and Industry both deal with the same topic, but their positions are very different. The former considers environmental issues to be central, and equity among countries to be important (i.e. developing countries may "catch up" to reach a per capita greenhouse gas emission level as high as the level to which industrialised countries are able and willing to come down to). The latter considers technological solution to be central and participation of major emitters, including developing countries, to be necessary in the post 2012 regime (i.e. at a point in time when developing countries' emissions are most probably still far below developed countries' emissions).

India emits only about one fifth of the global average per capita. Even though the Indian economy is currently growing at 8% per year, per capita emissions will be only a fraction of that of the industrialized countries for the foreseeable future. Motivated by energy security, economics and local environmental issues, efforts at moderating emission intensive growth have successfully been implemented. Such efforts include

- improving energy efficiency
- promoting renewable energy[16]
- encouraging clean coal technologies as well as the collection and use of coal bed methane

As a result of such initiatives in the past emissions were significantly lower than trend emissions predicted. In sum, India has contributed to global efforts to mitigate climate change. India will continue to do so in the future on a voluntary basis, but is not willing to co-operate in attempts to impose binding greenhouse gas reduction commitments on developing countries.

The official stand is that unless the much promised financial and technological resources are forthcoming, the expectation that

[15] Other reasons include energy efficiency improvements and the collapse of GHG intensive industry in eastern Germany.
[16] India's efforts to promote renewable energy are supported by the fact that India has one of the largest renewable energy programs in the world with over 3.5 percent of grid capacity based on renewables. Bhandari, P. (2004). "India, climate change, and sustainable development." Kyoto Protocol: Beyond 2012, Pelangi Indonesia, 11-15.

developing countries should contribute significantly to mitigation efforts is unjustified. India is very active in promoting CDM projects and aims at capturing 10 or more percent of the global CDM market. While other sources of investment and income are clearly of greater volume, CDM funds are considered significant.[17] India also supports unilateral[18] CDM projects due to the following advantages:

- Domestic projects could serve as the pilot phase for future CDM activities
- Domestic projects may entail relatively lower transaction costs, given that project developers would not need to engage in negotiations with buyers of Verified Emission Reductions in the early project stages. Project developers may sell Certified Emission Reductions after their issuance, entailing negotiations only on quantity of carbon and price per tonne.
- Domestically-financed carbon-reduction projects could be used to exhaust the "low hanging fruits", allowing the owner to bank the carbon credits, and sell them at a later date or for use in meeting India's own commitments, should such commitments be agreed to in the future.

In **Brazil** the emission level depends strongly on the Amazon forest deforestation dynamics. Brazil has the world's highest use of renewable biofuels and 92% of the electricity generation comes from hydropower.

The Brazilian climate policy proposal emphasizes the principle of historical responsibility. Brazilian negotiators in the UNFCCC have argued that historical emissions cannot be left out of future target negotiations, since they are more representative of national climate change responsibility than only current levels of emissions. The Brazilian proposal to the UNFCCC calculates that if historical emissions were taken into account, non-Annex I countries' responsibility (in terms of contribution to global average temperature increase) would take longer – about 6 decades – to reach that of Annex I countries, who should therefore continue to lead the efforts of reducing GHG emissions, even beyond 2012. CDM implementation has been quite successful in Brazil due to institutional expertise in the form of a mature Designated National Authority, the high potential of mitigation activities and the existence of a number of experts able to develop CDM projects.

Ghana, as many developing countries, is particularly vulnerable to the negative impacts of climate change due to the lack of capacity to undertake adaptive measures to address environmental problems and due to the socio-economic costs of climate change. Negative impacts of climate change include

- climate change associated health problems
- climate induced disruption of agricultural systems

[17] While Indian sources consider the CDM to be „not insignificant", the Chinese view is somewhat different: China, aiming at capturing 50 % of the global CDM market, considers the CDM to "essentially have no significant effect on GDP growth". World_Bank. (2004). "Clean Development Mechanism in China - Taking a proactive and sustainable approach." World Bank, Ministry of Science and Technology PR China, GTZ, SECO.

[18] For more information on unilateral CDM please refer to chapter 1.4.6 about institutional design options.

- flooding of coastal areas
- low operating water level of the only hydropower generating dam in the country as a result of reduced precipitation[19]

Global Environment Facility's climate change technology needs assessment report reveals what Ghana expects from the developed countries Parties of the UNFCCC: "Developed countries Parties should provide Ghana with technical and financial resources to ensure the effective implementation and transfer of prioritised technologies in a timely manner. Additionally, developed country Parties that own these technologies must show the commitment to transfer them." (GEF 2003)

Non-Government Organisations (NGOs) such as Greenpeace, CDM Watch, WWF, Climate Action Network are concerned about one or more of the following issues related to the CDM:

- The opportunity to reduce greenhouse gas emissions in developing countries is seen as a cheap way out of the obligation to reduce greenhouse gas emissions at home.
- The inclusion of sinks (e.g. reforestation measures as CO2 abatement) is opposed due to the uncertainty about the future re-emission of the captured carbon.
- The link of the EU Emissions Trading System with the CDM is either entirely opposed or the number of CDM credits used in the European Emissions Trading System should at least be limited.
- The only hydroelectric projects to be allowed should be from small, low-impact projects.
- Overseas Development Assistance should not be used to create CDM credits. (Sideridou 2003)
- Since the CDM is a market-based mechanism, projects will go to countries with high GHG reduction potential and with good pre-existing foreign direct investment relations with Annex I countries[20]. Africa scores badly on both accounts and will therefore be largely excluded from a market-driven CDM. (Humphreys et al. 1998)

Finally, Climate Action Network also mentions a positive development: The CDM methodology review process is seen as a welcome restatement of the need for additionality testing, which means that GHG emissions reductions need to be additional to what would have happened in a credible baseline scenario. This provides a strong signal that the approvals process will not be a rubber stamp. Climate Action Network expects this process to strengthen submissions and lead to projects with real benefits to host countries and the environment

Concluding form the countries' sections above it is evident that in many cases economic growth comes first. It is often, especially in developing countries, the Ministries that are in charge of economic development that are the most influential and the Ministries in charge of the environmental issues that are the weakest. Any

[19] The Volta Dam produces 80% of Ghana's national electricity supply. GEF. (2003). "Ghana's climate change technology needs and needs assessment report." Global Environment Facility (GEF), Ghana.
[20] Only 3% of global FDI in 1997 went to Africa

international negotiations on the environment will be examined through the “development first” filter – on how they might affect development and on how they can be used to foster development. Pelangi, an Indonesian NGO, makes the following statement about the importance of re-thinking the “development first approach”:

> **„Climate change is however a development issue and should be seen per say. A new report by major humanitarian institutions shows that climate change will have a major impact on developing economies, and could even overwhelm expensive investments in (economic) development. This fact needs to hit home in developing countries.”** (Pelangi 2004)

6.4 Registration Fee

Table 6-1 Registration Fee for CDM projects

Anticipated emission reduction in t CO_2e/a over the crediting period	$ US
≤ 15,000	5,000
> 15,000 and ≤ 50,000	10,000
> 50,000 and ≤ 100,000	15,000
> 100,000 and ≤ 200,000	20,000
> 200,000	30,000

source: (UNFCCC 2004)

6.5 Longer term dynamics of demand and supply of CERs

From 2008 onwards, the carbon market will change considerably (Drummond 2005):

- New supply:
  - Much greater volumes of Certified Emission Reductions from the CDM will have entered the market
  - (Non-CDM) Emission Reduction Units become available from the former USSR and (some) projects in Europe, Japan and Canada
  - Superfluous emission reduction allowances principally from Russia and the Ukraine
- New demand:
  - Government demand in Europe, Canada (and Japan?)
  - Increased corporate demand in Europe, Canada (and Japan?)
  - Corporate demand in the Eastern US states (Regional Greenhouse Gas Initiative) and in California

6.6 Calculations for decentralised composting

$$E_{Baseline} = \left(\frac{M_{OrganicWaste}}{t} + \frac{M_{AnorganicWaste}}{t} \right) * \left(\frac{M_{CH4,Landfill}}{M_{Waste}} * \frac{M_{CO2e}}{M_{CH4}} + \frac{M_{CO2,Landfill}}{M_{Waste}} \right)$$

$$E_{Project} = \left(\frac{M_{OrganicWaste}}{t} * \frac{M_C}{M_{OrganicWaste}} - \frac{M_{Compost}}{t} * \frac{M_C}{M_{Compost}} \right) * \left[(1-\alpha) * \frac{M_{CO2}}{M_C} + \alpha * \frac{M_{CH4}}{M_C} * \frac{M_{CO2e}}{M_{CH4}} \right]$$

$$E_{Reduction} = E_{Baseline} - E_{Project}$$

Table 6-2 Symbols and values used in the description of "decentralised composting"

Symbol	Description	Value	Units	Source
E	Emissions		t_{CO2e}/a	
M	Mass		t (tons)	
t	Time		a (years)	
α	Mass of carbon turned into methane per mass of carbon released during the composting process	0.03	t_{CH4-C}/ t_C	(Vogt et al. 2002)
$\frac{M_{OrganicWaste}}{t}$	Mass flux of organic waste	1100	t_{waste}/a	(Rytz 2001)
$\frac{M_{AnorganicWaste}}{t}$	Mass flux of inorganic waste going to landfill even in the composting case (metal, glass, stones, bricks pieces, plastic, rubber...)	100	t_{waste}/a	(Shekdar 1997)
$\frac{M_{Compost}}{t}$	Mass flux of compost	200	$t_{compost}/a$	(Rytz 2001)
$\frac{M_{CH4,Landfill}}{M_{Waste}}$	Methane production on the landfill	0.1	$t_{CH4,Landfill}/ t_{waste}$	(Shekdar 1997)
$\frac{M_{CO2,Landfill}}{M_{Waste}}$	Carbon dioxide production on the landfill (based on 50% CO2 and 50% CH4 content of landfill gas)	0.27	$t_{CO2,Landfill}/ t_{waste}$	after (Shekdar 1997)
$\frac{M_{CO2e}}{M_{CH4}}$	Global warming potential of methane (compared to the effect of CO2 over 100 years)	21	t_{CO2e}/ t_{CH4}	UNFCCC
$\frac{M_C}{M_{OrganicWaste}}$	Carbon content of waste entering the composting process	0.3	t_{Carbon}/t_{waste}	(Rytz 2001)
$\frac{M_C}{M_{Compost}}$	Carbon content of final product	0.18	$t_{Carbon}/t_{Compost}$	(Rytz 2001)

$\frac{M_{CO2}}{M_C}$	Mass of carbon dioxide produced per unit mass of carbon, i.e. $\frac{44\frac{g_{CO2}}{mol}}{12\frac{g_C}{mol}}$	3.7	t_{CO2}/ t_C	own
$\frac{M_{CH4}}{M_C}$	Mass of carbon dioxide produced per unit mass of carbon, i.e. $\frac{16\frac{g_{CH4}}{mol}}{12\frac{g_C}{mol}}$	1.3	t_{CH4}/ t_C	own

6.7 Calculations for methane use from public toilets

$$E_{Baseline} = \frac{V_{Biogas}}{u*t} * \left[\frac{V_{CH4}}{V_{Biogas}} * \frac{M_{CH4}}{V_{CH4}} * \frac{M_{CO2e}}{M_{CH4}} + \left(1 - \frac{V_{CH4}}{V_{Biogas}}\right) * \frac{M_{CO2}}{V_{CO2}} \right]$$

$$E_{Project,uncombusted} = \frac{V_{Biogas}}{u*t} * \left(1 - \frac{V_{captured}}{V_{Biogas}}\right) * \left[\frac{V_{CH4}}{V_{Biogas}} * \frac{M_{CH4}}{V_{CH4}} * \frac{M_{CO2e}}{M_{CH4}} + \left(1 - \frac{V_{CH4}}{V_{Biogas}}\right) * \frac{M_{CO2}}{V_{CO2}} \right]$$

$$E_{Project,combusted} = \frac{V_{Biogas}}{u*t} * \frac{V_{captured}}{V_{Biogas}} * \left[\frac{V_{CH4}}{V_{Biogas}} * \frac{M_{CH4}}{V_{CH4}} * \frac{M_{CO2}}{M_{CH4}} + \left(1 - \frac{V_{CH4}}{V_{Biogas}}\right) * \frac{M_{CO2}}{V_{CO2}} \right]$$

$$E_{Project} = E_{Project,uncombusted} + E_{Project,combusted}$$

$$E_{Reduction} = E_{Baseline} - E_{Project}$$

Table 6-3 Symbols and values used in the description of "methane use from public toilets"

Symbol	Description	Value	Units	Source
E	Emissions		t_{CO2e}/a	
M	Mass		t (tons)	
t	Time		a (years)	
u	Unit		-	
V	Volume (all volumes are at norm pressure and norm temperature)		m^3	

Symbol	Description	Value	Units	Source
$\frac{V_{Biogas}}{u*t}$	Volume of biogas per unit per year (for a toilet complex used by 1000 people per day)	12000	$m^3/(unit*a)$	after (Bhatia 2004)
$\frac{V_{CH4}}{V_{Biogas}}$	Methane content of biogas	0.5	m^3_{CH4}/ m^3_{Biogas}	(Bhatia 2004)
$\frac{M_{CO2}}{V_{CO2}}$	Density of carbon dioxide	0.00098	t_{Co2}/ m^3_{Co2}	standard value at norm conditions
$\frac{M_{CH4}}{V_{CH4}}$	Density of methane	0.00072	t_{CH4}/ m^3_{CH4}	standard value at norm conditions
$\frac{M_{CO2e}}{M_{CH4}}$	Global warming potential of methane (compared to the effect of CO2 over 100 years)	21	t_{CO2e}/ t_{CH4}	UNFCCC
$\frac{V_{captured}}{V_{Biogas}}$	Ratio of biogas captured (i.e. capacity of the generator) to total biogas production	0.9	$m^3_{CH4,captured}/ m^3_{CH4,produced}$	own assumption
$\frac{M_{CO2}}{M_{CH4}}$	Mass of carbon dioxide produced per unit mass of methane combusted, i.e. $\frac{44\frac{g_{CO2}}{mol}}{16\frac{g_{CH4}}{mol}}$	2.75	t_{CO2}/ t_{CH4}	own

6.8 Calculations for polyethylene bag digesters

$$E_{Baseline,FireWood} = \frac{V_{Biogas}}{t} * \frac{V_{CH4}}{V_{Biogas}} * \frac{M_{CH4}}{V_{CH4}} * \frac{M_{CH4-C}}{M_{CH4}} * \left(\frac{\frac{J}{M_{CH4-C}}}{\frac{J}{M_{FW-C}}} \right) * \frac{M_{CO2}}{M_{FW-C}}$$

$$E_{Baseline,manre} = \frac{V_{Biogas}}{t} * \frac{M_{CO2}}{V_{CO2}}$$

$$E_{Baseline} = E_{Baseline,FireWood} + E_{Baseline,manure}$$

$$E_{Project,uncombusted} = \alpha * \frac{V_{Biogas}}{t} * \left[\frac{V_{CH4}}{V_{Biogas}} * \frac{M_{CH4}}{V_{CH4}} * \frac{M_{CO2e}}{M_{CH4}} + \left(1 - \frac{V_{CH4}}{V_{Biogas}}\right) * \frac{M_{CO2}}{V_{CO2}} \right]$$

$$E_{Project,combusted} = (1-\alpha) * \frac{V_{Biogas}}{t} * \left[\frac{V_{CH4}}{V_{Biogas}} * \frac{M_{CH4}}{V_{CH4}} * \frac{M_{CO2}}{M_{CH4,combusted}} + \left(1 - \frac{V_{CH4}}{V_{Biogas}}\right) * \frac{M_{CO2}}{V_{CO2}} \right]$$

$$E_{Project} = E_{Project,uncombusted} + E_{Project,combusted}$$

$$E_{Reduction} = E_{Baseline} - E_{Project}$$

Table 6-4 Symbols and values used in the description of "Baobab trust biogas digesters"

Symbol	Description	Value	Units	Source
E	Emissions		t_{CO2e}/a	
M	Mass		t (tons)	
t	Time		a (years)	
J	Energy		TJ (tera joules)	
V	Volume (all volumes are at norm pressure and norm temperature)		m^3	
α	Leakage coefficient	0.1	$m^3_{combusted}/ m^3_{Biogas}$	own assumption
$\frac{V_{Biogas}}{t}$	Volume of biogas produced per polyethylene bag digester per year	100	$m^3/(a)$	after (Baobab_Trust 2004)
$\frac{V_{CH4}}{V_{Biogas}}$	Methane content of biogas	0.6	m^3_{CH4}/ m^3_{Biogas}	(Baobab_Trust 2004)
$\frac{M_{CO2}}{V_{CO2}}$	Density of carbon dioxide	0.00098	t_{Co2}/ m^3_{Co2}	standard value at norm conditions

Symbol	Description	Value	Units	Source
$\frac{M_{CH4}}{V_{CH4}}$	Density of methane	0.00072	t_{CH4}/ m^3_{CH4}	standard value at norm conditions
$\frac{M_{CO2e}}{M_{CH4}}$	Global warming potential of methane (compared to the effect of CO2 over 100 years)	21	t_{CO2e}/ t_{CH4}	UNFCCC
$\frac{M_{CH4-C}}{M_{CH4}}$	Carbon content of methane, i.e. $\frac{12\frac{g_C}{mol}}{16\frac{g_{CH4}}{mol}}$	0.75	$t_{CH4\text{-}C}/ t_C$	own
$\frac{J}{M_{CH4-C}}$	Energy content of methane	0.0065	$TJ/t_{CH4\text{-}C}$	after IPCC
$\frac{J}{M_{FW-C}}$	Energy content of firewood (FW)	0.0033	$TJ/t_{FW\text{-}C}$	after IPCC
$\frac{M_{CO2}}{M_{FW-C}}$	Mass of carbon dioxide produced per unit mass of firewood-carbon combusted, i.e. $\frac{44\frac{g_{CO2}}{mol}}{12\frac{g_C}{mol}}$	3.7	$t_{CO2}/ t_{FW\text{-}C}$	own
$\frac{M_{CO2}}{M_{CH4,combusted}}$	Mass of carbon dioxide produced per unit mass of methane combusted, i.e. $\frac{44\frac{g_{CO2}}{mol}}{16\frac{g_{CH4}}{mol}}$	2.75	t_{CO2}/ t_{CH4}	own

6.9 Lowest and highest estimates for sensitivity analyses

The “best estimate” values are found in the appendices F, G and H. The lowest and highest estimates used for Figure 3, Figure 4 and Figure 5 in chapter 4.1 are shown in Table 6-5, Table 6-6 and Table 6-7.

Table 6-5 Lowest and highest estimates for decentralised composting

Parameter number	Description	Lowest estimate	Highest estimate	Source for lowest estimate	Source for highest estimate
1	Mass of carbon turned into methane per mass of carbon released during the composting process	0	0.07	Physical boundary	Own assumption
2	Mass flux of organic waste (t/a)	1000	1200	Variations based on (Rytz 2001)	
	Mass flux of compost (t/a)	182	218	Proportional to variations of organic waste flux.	

Parameter number	Description	Lowest estimate	Highest estimate	Source for lowest estimate	Source for highest estimate
3	Methane production on the landfill ($t_{CH4,Landfill}$/ t_{waste})	0.08	0.11	(Ngnikam et al. 2002)	After(EPA 2005)
	Carbon dioxide production on the landfill ($t_{CO2,Landfill}$/ t_{waste})	0.32	0.2	Adapted after the methane production on the landfill.	
4	Carbon content of waste entering the composting process (t_{Carbon}/t_{waste})	0.33	0.27	Variations based on (Rytz 2001)	
5	Carbon content of final product (t_{Carbon}/$t_{Compost}$)	0.22	0.15	Variations based on (Rytz 2001)	

Table 6-6 Lowest and highest estimates for methane from public toilets

Parameter number	Description	Lowest estimate	Highest estimate	Source for lowest estimate	Source for highest estimate
1	Volume of biogas per unit per year (m^3/(unit*a))	6000	13200	Own assumption	Maximum capacity of the generator
2	Methane content of biogas m^3_{CH4}/ m^3_{Biogas}	0.5	0.6	Own assumption	Own assumption
3	Ratio of biogas captured (i.e. capacity of the generator) to total biogas production ($m^3_{CH4,captured}$/ $m^3_{CH4,produced}$)	0.5	1	Own assumption	Own assumption (physical boundary)

Table 6-7 Lowest and highest estimates for polyethylene bag digesters

Parameter number	Description	Lowest estimate	Highest estimate	Source for lowest estimate	Source for highest estimate
1	Leakage coefficient ($m^3_{combusted}$/ m^3_{Biogas})	0	0.5	Own assumption	Own assumption
2	Volume of biogas produced per polyethylene bag digester per year (m^3/a)	50	150	Own assumption	Own assumption
3	Methane content of biogas (m^3_{CH4}/ m^3_{Biogas})	0.5	0.6	Own assumption	Own assumption

6.10 Economic appraisal of case studies

Table 6-8 Economic appraisal of case studies

Case study	tCO2e/a	€/unit/a	€/tCO2e/a
Landfill gas flaring	80000	77695	1
Composting Khulna	1500	4199	3
Composting Dhaka	1500	20301	14
Public toilets	85	2112	25
Waste digesters	0.1	273	2733

Due to lack of data for the Santa Cruz Landfill data (1€/tCO2e/a) was taken from the Danetsk Landfill CDM Project Design Document (DANCEE 2003). The costs for decentralised composting are shown in Table 6-10 below. The costs for public toilets are based on (Bhatia 2004). The costs for the polyethylene bag digesters are based on e-mail correspondence with Baobab Trust. In order to calculate depreciated investment the following formula was used:

$$DC = C * \frac{i}{1 - \frac{1}{(1+i)^n}}$$

Source: (Rytz 2001)

Where DC=depreciated costs, C=investment and land costs, i=interest rate of 15%, n=number of years (10 years)

Table 6-9 Investment costs for a decentralised composting plant

Cost component	€	€/a	€/m^2
Investment costs	6887		
Depreciated investment costs		1372	
Land price Khulna			37
Land price Dhaka			250
Land costs Khulna	14187		
Depreciated land costs Khulna		2827	
Land costs Dhaka	95000		
Depreciated land costs Dhaka		18929	
Total Khulna (depreciated investment)		4199	
Total Dhaka (depreciated investment)		20301	

Depreciated costs are calculated using the following formula:
DC=depreciated costs, C=investment and land costs,
i=interest rate of 15%, n=number of years (10 years)

$$DC = C * \frac{i}{1 - \frac{1}{(1+i)^n}}$$

Area needed for the plant is 380m^2
Source: (Rytz 2001)

6.11 Source data for the calculation of indicators

Table 6-10 Source data for the calculation of indicators

Indicator	Landfill gas flaring project Value	Landfill gas flaring project Source	Decentralised composting project Value	Decentralised composting project Source
Emission reduction per unit per year (tCO2e/a)	80’000		1’500	own
Jobs created per unit	2	(UNFCCC 2005c) after (DANCEE 2003)	9	(Rytz 2001)
Job expenditures (€/person/a)	1’460	Job costs in Bolivia assumed twice the costs in Bangladesh	730	(Rytz 2001)
Jobs created per 100’000tCO2e	2.5		600	
Job expenditures (€/a)	3’000		6’500	
Job expenditures (€/100’000tCO2e)	3’600		440’000	
Expenditures on machinery produced in developed countries (€/unit)	40’000		0	
Expenditures on machinery produced in developed countries (€/100’000tCO2e)	50’000		0	