

A quantitative analysis of the cost-effectiveness of project types in the CDM Pipeline

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A quantitative analysis of the cost-effectiveness of project types in the CDM pipeline



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Abstract

The flexibility of the CDM is intended to reduce the cost of compliance for Annex 1 countries and contribute to cost-effective reductions. This paper provides a framework for defining cost-effective payments for CDM carbon reductions. The projects in the CDM pipeline are categorised into project types. The data provided in the Project Design Documents is quantitatively assessed to calculate the median cost and range of costs for producing a CER from the project categories. These are measured against the range of prices in the market in order to estimate the level of cost-effectiveness. Global warming potential and size of the project were shown to be key factors in the cost of producing a CER. The results show that although prices for CERs are difficult to define in the primary CER market, many of the project categories generated CERs at a cost well below the lowest market price. The difference in these two values is defined as a loss in cost-effectiveness. The CDM is shown to be successful at developing the 'lowest hanging fruit' but the mechanism could be improved to fulfil the goal of cost-effectiveness by linking the price per CER to the cost of generating a CER.

Key words: Clean development mechanism, cost-effective, pipeline, Project Design Document, quantitative.

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Abbreviations

BAU -	Business as usual
CDM -	Clean development mechanism
CERs -	Certified emission reductions
CO ₂ e -	CO ₂ equivalent
DNA -	Designated National Authority
DOE -	Designated Operational Entity
EB -	Executive Board
ENR -	Economic no-regret
ENR-NF -	Economic no-regret projects with funding problems
ER -	Economic regret
ERPA -	Emission Reduction Purchase Agreement
ERUs -	Emission Reduction Units
EUA -	European Union Allowances
EU-ETS -	European Union Emissions Trading Scheme
GEF -	Global Environment Facility
GHG -	Greenhouse gas
GWP -	Global Warming Potential
IRR -	Internal rate of return
JI -	Joint Implementation
LoA -	Letter of Approval
MAC -	Marginal abatement costs
MB -	Marginal Benefit
NPV -	Net present value
PDD -	Project design document
PIN -	Project Idea Note
sCER -	Secondary certified emissions reductions
UNFCCC -	United Nations Framework Convention on Climate Change

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1 Introduction

A quantitative analysis of the cost-effectiveness of project types in the CDM pipeline.

Although the Clean Development mechanism (CDM) can be seen as a success in the number of projects initiated and the credits generated, many have questioned if the mechanism has achieved the twin goals of contributing to local sustainable development in the host country and achieving emission reduction targets in a cost-effective manner. Sutter (2003) and Olsen (2007) argue that cost-effectiveness is leading the way for project development whereas Wara (2006) argues that the CDM is less than cost-effective since some projects dominate the market and receive huge economic rent from the sale of credits generated. In 2007 alone approximately €5.4 billion was transacted through primary Clean Development Mechanism for Certified Emissions Reductions (CERs), equivalent to 551 MtCO₂e (World Bank, 2008). Where such mechanisms exist evaluation is crucial in ensuring transparency and accountability as well as learning from experience in order to improve the management of future expenditure. In short, could the emissions reductions generated by the CDM be reached at a lower cost? This is particularly relevant with the impending negotiations on a new climate change agreement to follow on from the Kyoto Protocol.

Although the CDM has a goal of economic effectiveness this paper will argue that the structure of the mechanism has reduced the effectiveness of the resources spent. Furthermore, the paper will attempt to measure the cost of the in-effectiveness through analysing the projects registered under the CDM by measuring their cost of abatement against the price paid for doing the abatement.

This paper will do so by addressing three sub-questions:

1. How can the CDM be defined economically?
2. What are the properties of an effective mechanism?
3. How does the CDM compare to the economically effective mechanism?

To answer these questions the pipeline of CDM projects are bundled into categories and analysed to estimate the cost of reducing one ton of CO₂e. This value is compared against the price paid for the reduction and together the results are used to answer the main question:

How cost effective is the CDM?

1.1 Structure

To answer the main question, the paper will first briefly describe the background and goals of the CDM within the Kyoto Protocol. This will include a summary of its how the credits are generated and the source of the financial data. Chapter 2 will give a description of the projects assessed and the steps taken in selecting and categorising the projects. To complete the analysis two pieces of information is required – the price per CER in the market and the cost of generating a CER. Chapter 3 will formulate a price range for CERs from secondary sources. Chapters 4 and 5 deal with the theory and functional form for analysing the primary data collected. Chapter 6 will present the results of the primary cost data and finally Chapters 7 and 8 will bring together the price and cost data and conclude on their relevance.

1.2 Background to Kyoto and CDM

This Chapter will expand upon the role of the CDM within the Kyoto Protocol flexible mechanisms and the implication of its design on the costs and number of credits generated.

1.2.1 Flexibility through Emission trading

Under the Kyoto Protocol, each of the Annex I countries has agreed to a target for GHG reductions. Regulated companies have three options to reach their emission reduction obligation: reduce production, invest in emission abatement or purchase the right to emit through the three flexible mechanisms defined in the Kyoto Protocol. These are: purchase tradable permits from the market, Emission Reduction Units (ERUs) from Joint Implementation projects or Certified Emission Reduction credits (CERs) from projects eligible under the Clean Development Mechanism.

Greenhouse gases are uniformly mixing pollutants and build up in the atmosphere regardless of who emits them. So, from a global damage perspective, countries are indifferent as to where the reductions are carried out. The Kyoto Protocol mechanisms use a cap and trade scheme for emission credits with the aim of reducing Greenhouse Gas (GHG) emissions. Under the scheme, each participatory Annex I country has agreed a cap on the total emissions, in terms of a 1990 base year. For the majority of countries this will mean a reduction in current GHG emissions levels. Some countries have a surplus of emission allowances and others will demand credits to meet their target. The tradable permits scheme offers a cost-efficient and flexible mechanism for allowing each compliant country to achieve their national target. This is done through allowing countries or industries with high marginal abatement costs (MAC) to purchase credits from those with lower MAC. In effect, MAC are equalized across countries and industries so the total costs associated with achieving the target reductions are minimised¹.

With tradable emissions, the regulatory authority determines the aggregate quantity of emissions and leaves the allocation of the sources of emissions to market forces. In equilibrium, the price will be set where the marginal social cost equals the marginal abatement costs which will produce a market clearing price.

1.2.2 The role and goals of the CDM

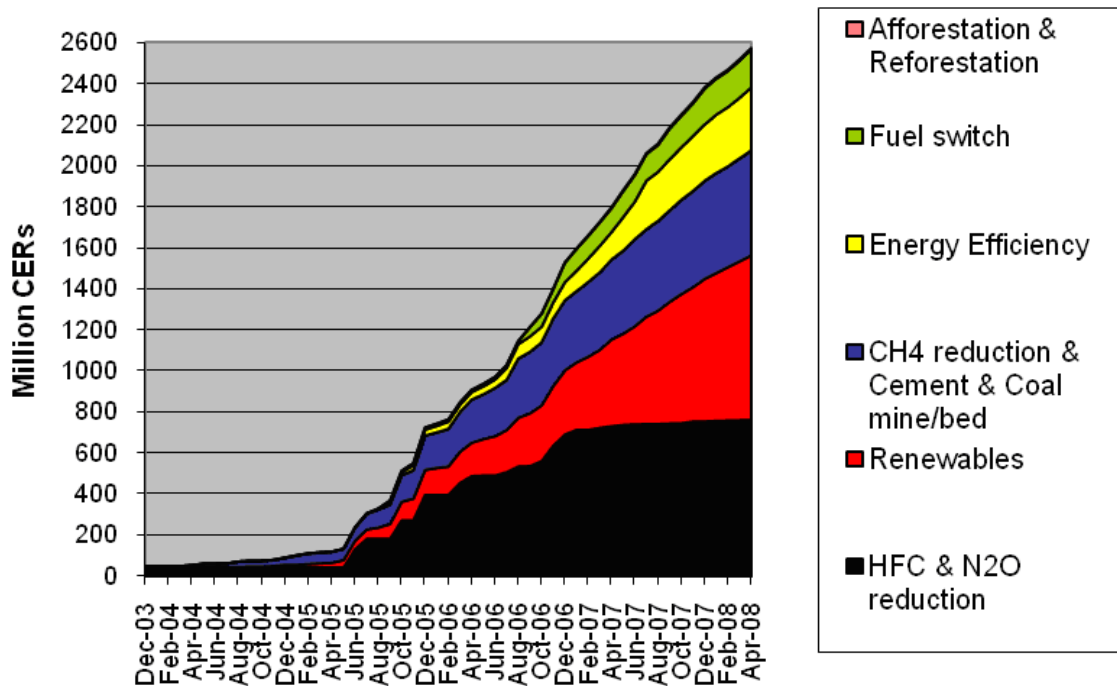
The Kyoto Protocol distinguishes between Annex I parties which are developed countries with assigned national emission reduction targets and Non-Annex I parties which are developing countries with no binding reduction targets. Article 12.2 of the Protocol states that the purpose of the clean development mechanism shall be to *assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention [that being Annex I countries achieving emissions reductions cost-effectively]*.

The CDM is intended to work as a bottom-up approach in that projects in developing countries are paid to reduce GHG emissions that would have otherwise been emitted. This could be through the transfer of cleaner technology and skipping obsolete processes. Figure 1 shows the extent to which

¹ For a more in-depth analysis of Tradable Permits see for example: Boom (2006) and Hanley & Shogren (2006).

CERs are playing an increasing role in reaching the Kyoto Protocol targets as well as the variety of projects involved.

Figure 1: Accumulated CDM credits in the Kyoto Protocol period



Source: UNEP/Risø pipeline, April 08.

The Marrakech Accord assigns the right to the host country to decide if the CDM project assists in achieving sustainable development. As Daly (1996) noted, sustainable development is neither static nor deterministic but an evolutionary process, and so the CDM can be seen as an instrument to assist developing countries towards sustainability. Sutter, C. (2003) and Olsen (2007) have concluded that sustainable development and cost-effectiveness are difficult to obtain in one mechanism since they often involve a trade-off between both goals. The extent to which this trade off exists is important for the effectiveness of the mechanism reaching its goals. The projects analysed in this paper have all received approval from the host country and so shall be considered to have met the minimum sustainable development criteria. This paper will assess whether the projects developed have met the cost-effective goal.

1.3 Additionality and setting a baseline

The additionality criteria are stated in the Protocol as: *reductions in emissions should be additional to any activity that would occur in the absence of the certified project activity* (Article 12.5c). The purpose of the criteria is to ensure that the CDM does not fund projects that would otherwise go ahead or fund projects that cannot measurably demonstrate GHG reductions. All projects must provide details of the project, a calculation for the emission reductions and proof of additionality in a Project Design Document (PDD). This is important for the analysis as it provides the basis for the quality and quantity of the data used.

Stringent regulatory measures ensure the validity of the project but also place a large burden of proof on the project owner. In principle the project activity is equal to the baseline scenario unless this can be disproved and the difference is the estimated reductions. These are used in this paper when calculating the cost per CER. The Marrakesh Accord provides the guidelines for establishing a baseline within the boundary of the project using three approaches:

- 1 The emissions from continuation of present practice
- 2 The emissions from the most economically attractive course of action
- 3 The average emissions of an alternative implemented within the last 5 years.

The boundary should cover all GHGs reductions under the control of the project which can be attributable to the CDM project activity and the estimation of the reductions should be appropriate to the baseline approach selected. The PDD use a methodology that sets the overall guidelines for present and future CDM projects. They are practical tools describing (1) how to estimate a baseline, (2) how to set up project boundaries for a given activity and (3) how to monitor the ongoing project activity as a means to estimate the emissions that would have been generated in the BAU scenario. The UNFCCC and project owners continue to develop methodologies that describe a common practice for the different project types².

² See Appendix I for a list of approved projects activity in the CDM

To ensure the project is additional the project must also demonstrate a barrier to its implementation. The regulatory body, the Executive Board (EB) of the CDM, has developed a consolidated tool for demonstrating and assessing additionality in a project which suggests the following steps:

- Identification of alternatives to the project activity consistent with laws and regulation. All credible alternative scenarios should be described.
- Investment analysis to determine whether the proposed project activity is the most economically or financially attractive option. This may include calculating the internal rate of return (IRR) or net present value (NPV) of the different alternative activities dependent on the analyses method used.
- Barriers analysis where the project demonstrates an investment, technological or prevailing practice barrier that does not apply to the alternative.
- Common practice analysis describing and comparing related activities to prove the credibility of the project.
- Explain the impact of registration on the project on alleviating the barriers previously identified.

The assessment tool is not mandatory in all approved methodologies but a way to address the relevant issues related to additionality and demonstrates how the project owner can take a conservative approach to proving additionality. The PDD may or may not provide financial data dependent on the barrier being overcome. It could therefore be expected that projects that are already financially attractive will give limited financial information but instead argue for additionality using a non-financial barrier. This has implications for the analysis as financially unattractive projects will predominately provide the data used in the analysis. The paper can only measure using the data available and does not attempt to correct for this in any way.

1.4 Financial Additionality

Typically, projects list several barriers to implementation and often include high costs or insufficient returns to investment as one of them. When a project demonstrates financial additionality the PDD can use three options for analysing the costs:

Option 1: Simple cost analysis where the project gains no financial benefits other than from the sale of CERs generated.

Option 2: Comparison analysis where the project is measured against a plausible alternative that is of comparable scale.

Option 3: Benchmark analysis where the project is measured against an identified benchmark value (such as IRR).

Option 1 is the easiest method to use and is mostly used for projects that receive no income from implementing the project apart from the sale of CERs e.g. HFC. The baseline cost for no-income projects is therefore zero compared to the negative cost of implementing the technology.

Choosing a baseline for projects that generate an income as well as CER revenue as a result of the project is more complex as the baseline may be difficult to measure. Option 2 is relatively straightforward since the income stream will tend to be similar and the baseline cost will be the investment and annual costs of the more GHG intensive production. Where no comparable project exists, Option 3 is often used to measure against the expected return in the market for such a project. An example could be a hydro project that does not proceed because it does not achieve the necessary returns on investment and the CER revenue will provide sufficient income to make the project financially possible. This definition of investment additionality is more subjective than the others since the returns required are based on the project owner's perceived risk for the project and country specific market conditions.

The definitions of projects depending on the income stream outside of the CER revenue will be used later when defining a method to calculate the costs. What is clear is that the financial data provided in the PDDs is not consistent and project does not need to provide detailed financial data which reduces the amount of data available for the analysis. Additionally, the PDD values provides an estimates of future costs and does not give the actual costs of production. This is particularly

important for projects that produce electricity since the value of the electricity may change over time and the price expectations demands a substantial degree of foresight as well as being subject to changing government subsidies and taxes. It has been assumed that the PDD values are, at best, estimates of the values.

1.5 The Effect of Global Warming Potential on CERs

As discussed earlier, the project must calculate the amount of GHGs abated as a result of the project. This is influenced by the different residue time and warming potential of GHGs in the atmosphere. The IPCC Second Assessment Report established criteria for comparing GHGs against the same quantity of CO₂. This was approved and adopted as the measurement used in the Kyoto Protocol period. The Global Warming Potential (GWP) is used for 6 major GHGs. Table 1 lists the main gases used measured in CO₂ equivalent (CO₂e) where one CER equals one ton of CO₂e. The multiplication effect of some GHGs can have a large effect on the CERs generated for example, a plant capturing and destroying one ton of HFC-23 generates over 557 times more CERs than a plant capturing and destroying the same quantity of methane. Should both projects cost the same, the HFC-23 plant will generate 557 times more CER for the same investment and therefore be 557 cheaper on a cost per CER basis.

Table 1: Global Warming Potential (GWP) of GHG reductions in CDM projects

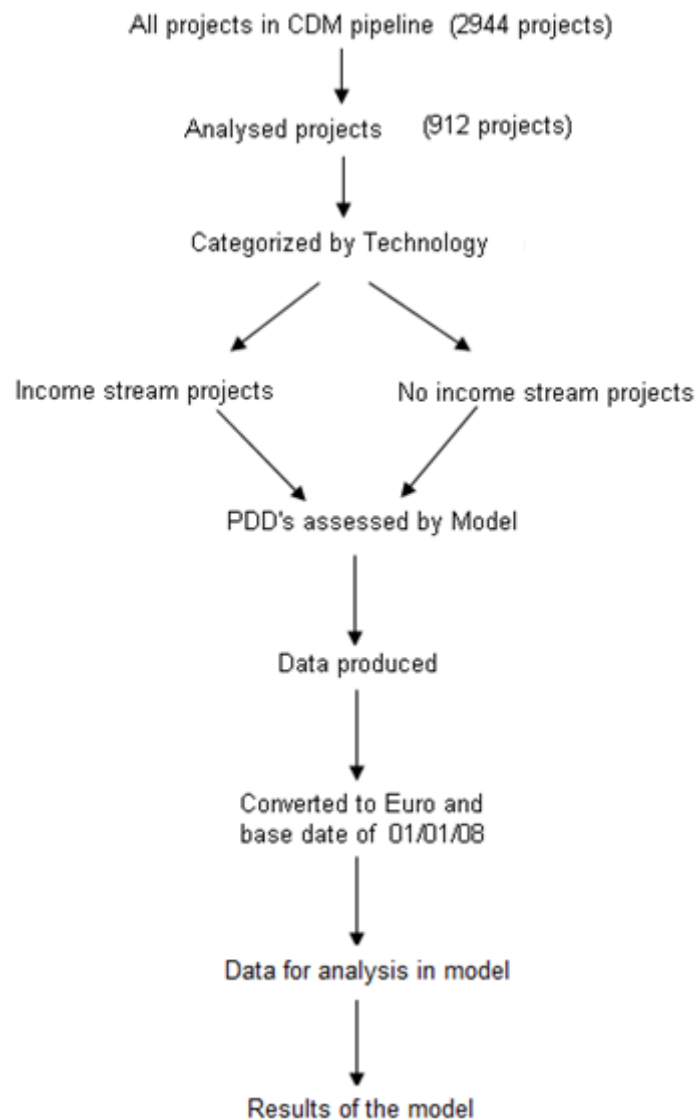
Greenhouse Gas	Source	GWP
Carbon Dioxide (CO ₂)	Burning fossil fuels, land use change and deforestation.	1
Methane (CH ₄)	Created through decomposition of organic waste such as agricultural residues, livestock and landfills. Also a by-product of oil, coal and gas production.	21
Nitrous Oxide (N ₂ O)	Chemical production, animal waste and fertilisers.	310
Hydrofluorocarbons (HFC-23)	Used in refrigeration and air cooling	11,700
Perfluorocarbons (PFCs)	Aluminium and electronic industries.	Up to 9,200
Sulphur hexafluoride (SF ₆)	Electricity transmission lines and magnesium production.	23,900

Source: IPCC 2nd Assessment report, 1995.

2 Method

The prices and contract structures for most CO₂ trades remain confidential which makes the reviewing the CDM markets difficult (World Bank, 2005). The data used in the paper is built on two publicly available databases, the CDM pipeline produced by Jørgen Fenhann at UNEP/Risø and the project data provided in the Project Design Documents (PDD) available from the UNFCCC. Figure 2 provides an overview of the steps taken to select, categorise and assess the data.

Figure 2: Flow chart of method



The UNEP/Risø pipeline provides a record of all the projects that have started the procedure for Executive Board CDM approval. Appendix II provides an overview of the requirements to gain approval from the regulator (the UNFCCC Executive Board). An explanation of the procedure is provided in Chapter 3.3.2. As of 8th January 2008, there were 2944 projects at various stages of development (Appendix II). Out of these, 1095 projects were assessed for validation and subsequently attained the necessary documentation to request registration from the Executive Board. Any projects that were rejected by Executive Board, were under review or correction were not considered as the project is expected to or will be altered. Removing these projects reduced the project number to 935 for analysis which represent the projects that have a PDD, are registered with the Executive Board or are in the process of achieving registration.

The projects were then categorized into the technologies used to achieve emission reductions and then split between those with an income stream outside the CER generated revenue and those without (as defined in Chapter 1.4). The guidelines for categorizing the projects were drafted from the CDM pipeline and a description is given in Table 2.

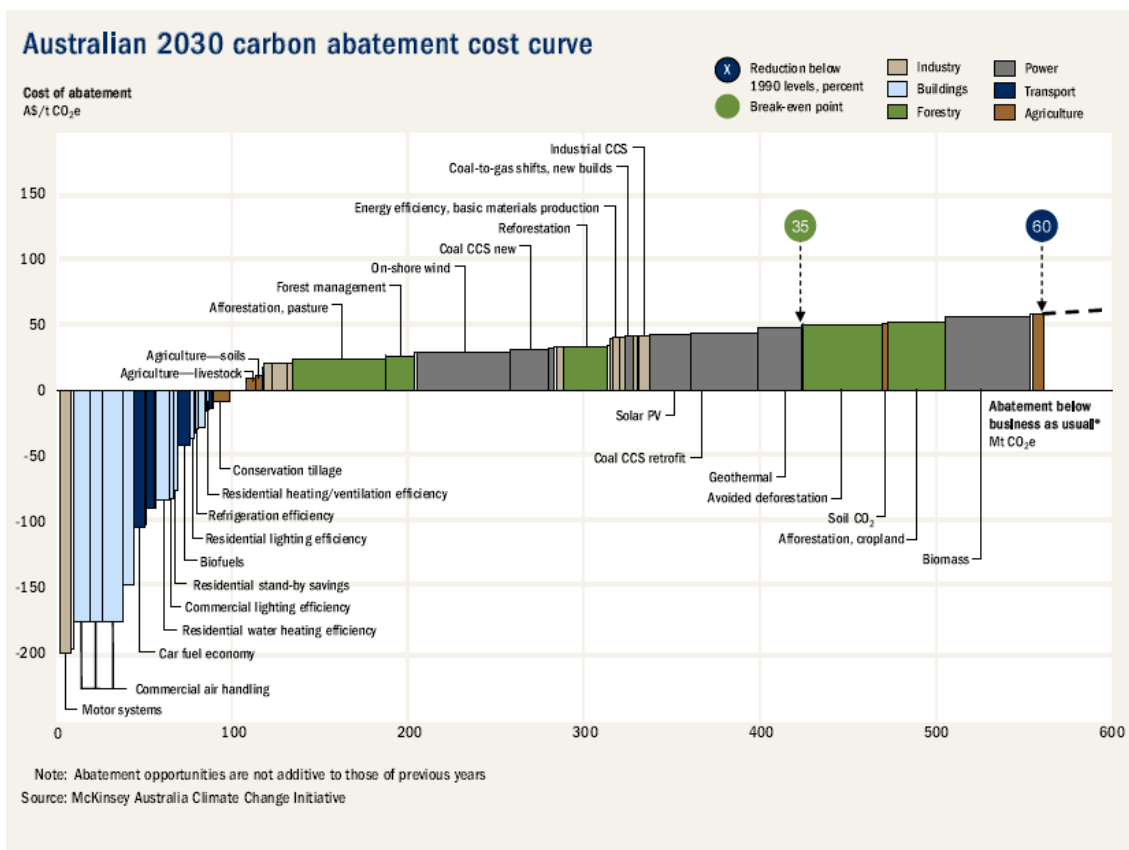
Table 2: Project categories

Agriculture biogas flaring	Projects producing biogas that is flared
Biogas	Projects producing biogas that is used for energy purposes
Biomass energy	New plant using biomass or existing ones changing from fossil to biomass, also biofuels
Coal bed/mine methane	CH ₄ is collected from coal mines or coal beds
Energy efficiency	Improvements in industry, buildings, appliances as well as heat and electricity production
Fossil fuel switch	Switch from one fossil fuel to another fossil fuel (including new natural gas power plants)
Fugitive	Recovery of CH ₄ from oil wells, gas pipeline leaks, charcoal production
Geothermal	Geothermal energy
HFCs	HFC-23 destruction
Hydro	Hydro power: improvements to existing plants or new from run-off river and reservoirs
Landfill gas	Collection of landfill gas, composting, or incinerating of the waste instead of landfill
N ₂ O	Reduction of N ₂ O from production of nitric acid, adipic acid, caprolactam
PFCs	Reduction of emissions of PFCs
Wind	Wind power

Source: UNEP/Risø pipeline (08/01/08)

The classification of projects by technology has also been used by the McKinsey & Co. where they calculate the marginal costs of abatement for the U.S.A and more recently Australia (Figure 3). These reports provide important information on where the cheapest abatement can be made as well as estimating total costs for the economy to meet the reduction targets. The reports were not limited by the mechanisms used to support the technologies and assessed both positive and negative cost technologies. The methodology is similar to this paper in that it used a bottom-up approach although assumptions were made across sectors and technologies rather than on the specific projects. The average net costs were based on technical knowhow and were measured over a year, discounted (using a 7% discount rate) and adjusted to a base year. Again, this is similar to the methodology used in this paper although it is not stated which capital budgeting tool was used.

Figure 3: Carbon cost curve for Australia



Source: McKinsey & Co., 2008

Figure 4 shows the number of projects under each project type used in the analysis split between small scale and large scale methodology. The definitions for small scale in these projects are either; renewable energy with a maximum output capacity equivalent to up to 15 megawatt, energy

efficiency improvement project activities which reduce energy consumption by up to the equivalent of 15 GWh per year or other project activities that both reduce emissions and directly emit less than 15,000t of CO₂ equivalent annually (defined at COP-7, paragraph 6 (c), decision 17). The distribution between small and large scale projects indicates the differences in project sizes across categories. This will be shown later on in the paper to be a possible factor in the cost of generating CERs.

Figure 5 shows the average annual credits generated for the project categories. Although HFC, N₂O and fugitive projects are amongst the lowest in number of projects, they have a disproportionate influence on the CDM pipeline due to the large number of annual credits per project. This is due to the GWP effect discussed in Chapter 1.4. The project categories with lower average annual CERs also have a high proportion of small scale projects.

Figure 4: Number of projects per category

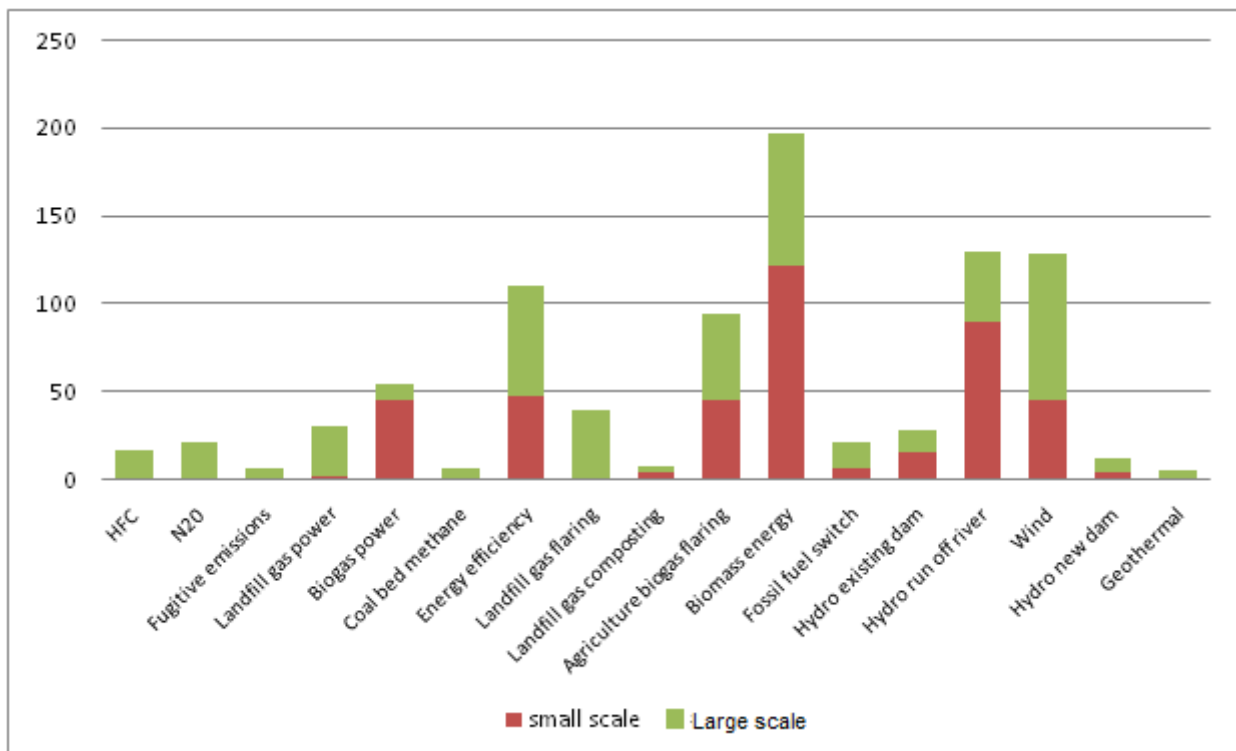
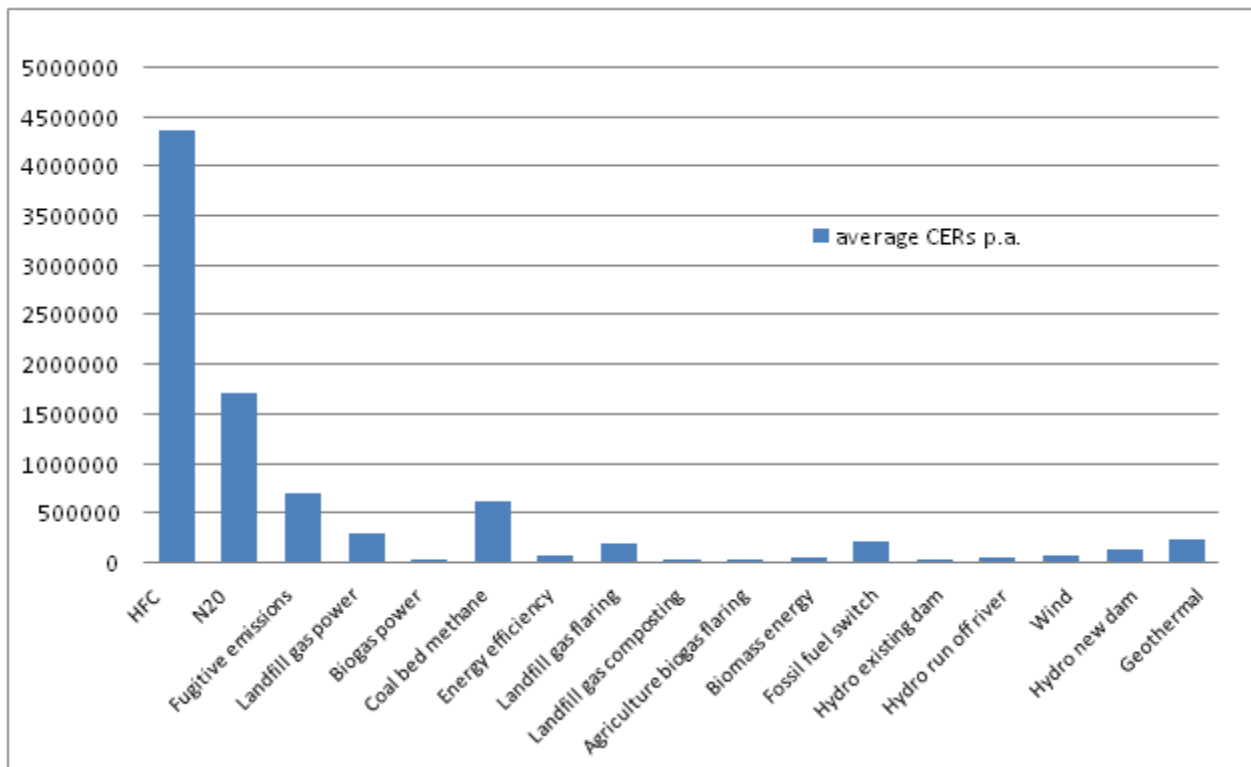


Figure 5: Average annual credits per project category



The PDDs for each project category were assessed with the aim of gathering at least 10 data points. This number was chosen arbitrarily although was framed around the time restrictions in gathering data.

It was not possible to gather 10 data points for some project types because there were not enough projects or the financial data provided was insufficient for the analysis. It will be shown later that the analysis requires conservative and realistic data on the initial investment costs and annual costs as well expected income from the project as a result of the CDM activity. The financial data was often missing for some parts of the investment or given as expected pay-back period or the project costs used non-numerical estimates e.g. high, medium and low used for comparative purposes against the baseline and other possible alternatives.

As a result, six project types did not have any data, these were, cement production, solar energy, reforestation, tidal, energy distribution and transport. They are therefore omitted from the analysis.

This reduced the total project number by 22 (from 935 to 912) and reduced the total annual credits generated by the projects from by less than 0.1% (192,925,389 tCO₂e p.a. to 190,184,436 tCO₂e p.a.). The HFC project data was from both PDD and from non-PDD calculations.

The results were converted to Euro's using the average monthly inter-bank rate and then converted into a base date of 01/01/08 using the monthly Euro Harmonized Consumer Price Index so the data could be compared. The results for each category were then measured against the price received from selling the CERs to measure the cost-effectiveness of the CDM.

3 CER price formation

The following Chapter will formulate the CER price used in the analysis which will be compared with the cost results from the analysis in the later chapters.

There is no single price in the global CO₂ credits market but rather a range of prices depending on the characteristics of the credits such as liquidity, stage of project development and the risks associated with their delivery and use. In the CDM market this fragmented price is further complicated by large volatility - both in price and volume, complexity of the contractual structures, low levels of transparency as well uncertainty in the future of the mechanism itself. The following chapter will discuss the main price drivers for CERs which will allow for the construction of a price range. This will contribute to one side of the cost-effectiveness measurement.

3.1 Buying CERs

The main buyers in the CDM market are European countries with abatement targets under the European Union Emission Trading Scheme (EU-ETS) (Appendix III). The buyers have two markets in which to purchase CER's – the primary and the secondary market.

In the primary market the buyer and seller (i.e. project developer) agree on a price for the expected future credits from a CDM project. The contractual agreement for purchase can take many forms

(discussed in Chapter 3.3.1) and the price per CER is reflected in both the contract terms as well as additional factors such as host country risk, expected delays, project risk, etc.

The secondary CER (sCER) market is used for trading credits which are already delivered or with a guarantee of delivery or compensation if the contract is broken. The seller therefore bears the risk of non delivery. The lower risk for the buyer is reflected in the higher price for credits which can be particularly appealing to buyers with an abatement obligation and a high penalty for non-compliance. The secondary CER market has an observable price as the credits are more standardised than their primary counterparts and the price acts as a ceiling for the primary market.

3.2 Secondary CERs and the EU-ETS

Buyers of CERs that have an obligation to reduce GHG emissions can use a selection of CERs, ERUs and permits to help meet their target. To some extent the credits from the three mechanisms are substitutable (Table 3) since they each represent a ton of CO₂e abated. As the majority of CERs are traded with the EU, the EU-ETS has become the reference price for sCER and primary CER contracts and the price is a major trigger for the development of projects under the CDM. The sCER price has historically been closely linked to the EUA price (European Union allowances used in EU-ETS) as a compliance buyer can use either to comply with their emission reduction obligation. This relationship is however dependent on the regulations that govern their use and the pricing differential within the market reflects the characteristics of the different credits (Table 3).

Table 3: Differences between EUAs and CERs.

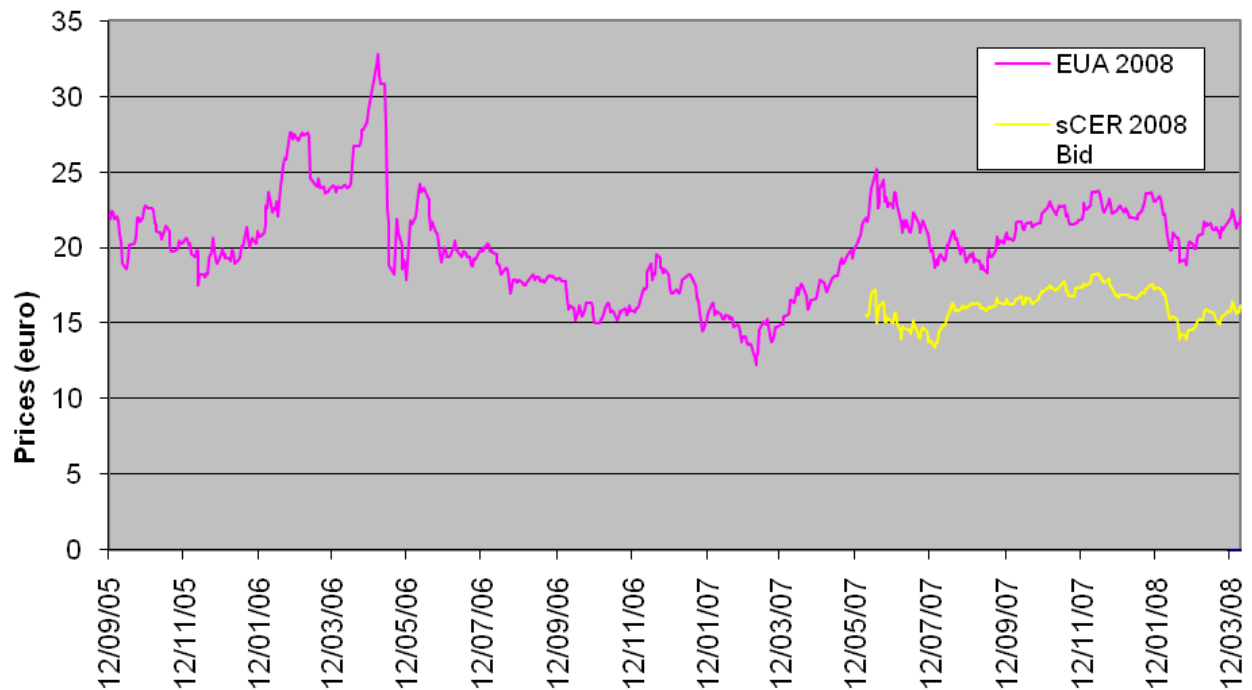
	EUA	CER
Type	Allowance	Offset/Credit
Time of delivery	Immediate settlement and forward	Forward settlement to date, immediate settlement possible in the future
Counterparty risk	None or very limited	Yes
Project risk	No	Yes
Limit on use in EU ETS	None	5–25% of allocations
Banking between EU ETS phases	Not allowed in ETS phase 1 , Allowed from ETS phase 2	Allowed

Source: CD4CDM (2007).

When correlation is strong between the two markets, both prices can be influenced by several factors such as fossil fuel prices, weather, political decisions etc. In mid July 2007 the spread of the December 2008 EUA was priced about 6-7 euro over the December 2008 sCER (The EUA 2008 price is for EU-ETS credits with a 2008 vintage and the sCER 2008 bid is for bids made for 2008 vintage sCER's). This price has since narrowed to around 4 euro (Figure 6). The narrowing of spread may be a reflection of the markets expectation of more certainty in how CERs can be used for compliance in the next commitment phase as well as estimates on the overall supply of CERs. The spread also reflects the price risk while the market waits for the setting up of the link between the EU registries and the International Transaction Log (this would allow transfers of credits between parties) and also on the condition that buyers do not exceed the European Commission import thresholds (Appendix IV). The narrowing trend of the spread may reverse if the supply of credits increases above demand, the market anticipates an overall reduction in price or if future legislation limits the use of CERs for compliance. The CER and EUA prices also influence each other since supply changes in each market affect the attractiveness of both (double causality). An increase in the supply of cheap credits from CDM projects will reduce the demand for EUA's and vice versa.

The correlation between the two prices is often quoted around an 80% spread between sCER and EUA (Figure 6). The EUA price acts as a ceiling on the sCER price since at this price the buyer could equally purchase more useable and less risky EUAs. The price of sCER often mirrors the changes in EUA prices although this may change or decouple from the EUA price depending on future legislation.

Figure 6: EU-ETS and secondary CER prices



Data Source: Point Carbon (April 2008)

3.3 Primary CERs

There is little price transparency in the primary CER market or between project types. The short term volatility in the EUA markets have less impact on the primary CER price since projects take months to negotiate and are mostly specific to the risks associated with the project. These factors also change over time in response to increased certainty in the market and as actors gain experience from “learning by doing”. This has generally led to a trend of increasing prices over time in response to reducing risk and increasing demand. The variables on price, which will now be discussed, should therefore be taken in the context of the underlying dynamics of the price development.

3.3.1 Contracts for primary CERs

For each project, the seller can decide either to sell the rights to future expected CERs or wait until the CERs are generated. Often the buyer and seller of the CERs agree on the transfer of the CERs at

a certain price before the CER are generated. This can be preferential for the buyer as they may use the contractual purchase as collateral for loans and may wish to guard against future changes to the mechanism that reduces the CERs value. The buyer may find these contracts preferable as they can purchase credits now to meet their future commitments and may wish to buy early to get the lowest price or if they anticipate an increase in the market price. Typically these are non-standardised forward contracts and tend to be tailored made to the project. The contracts can be structured in the following forms:

Payment now for future credits:

The buyer invests a lump-sum now and both parties sign an Emissions Reduction Purchase Agreement (ERPA) where the sale of rights to future CERs are contracted. This contract is particularly useful if the investor cannot raise capital easily although the buyer may demand a large risk premium in the form of a low CER price due to the uncertainty in the project delivering.

ERPA signed now for future CERs:

This is by far the most common structure for CDM transactions (IFC, 2008), and is preferable for the buyer since no money is exchanged until the credits are delivered and the seller has an obligation to deliver a certain amount of credits over a certain period. The seller can then use the contract to attract investment and has the security in the price for the credits. The price can be arranged in several ways, such as fixed or indexed to the sCER or EUA price although the majority are fixed for simplicity (IFC, 2008).

Option contract:

The buyer may wish to have an option to purchase credits at a specific price and quantity in the future if they are uncertain of the market developments and their own commitment requirements. The flexibility allows them to hedge against uncertainty and the seller receives income, either upfront or at a later date, as payment for the option. This may not be attractive for the seller as they may have difficulty gaining finance on an options contract and bear the risk for changes that limit the use of CERs. The seller may therefore pay a higher price for the credits that reflects the risks taken by the seller.

3.3.2 Stage of Development

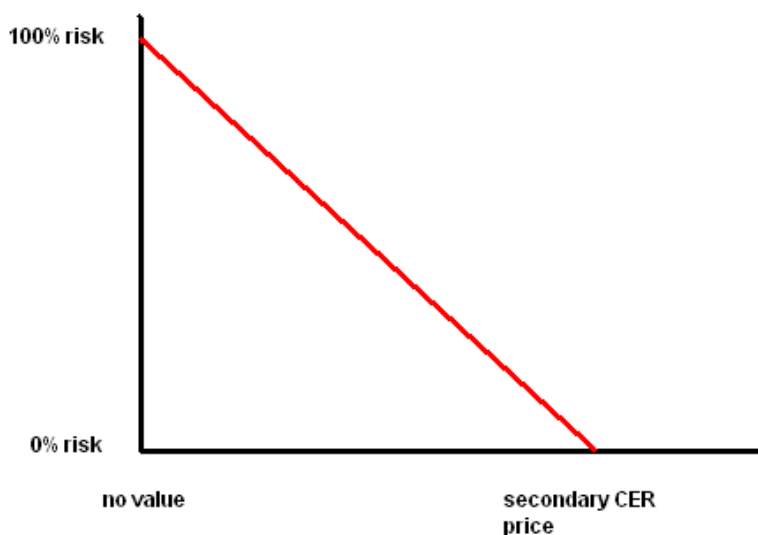
An understanding of the project stages in developing a project is useful for the prices paid for credits and later on for expanding upon the projects assessed for the data set. CDM projects must complete a project cycle from the initial project idea and through approvals by several regulatory authorities before it can produce CER for sale (Appendix II). A CDM project generally involves five stages; Project Idea, Project Design, Validation, Registration and Credit Issuance. A project owner may secure investment in the underlying project at any of these stages by signing a forward contract for expected CERs delivered.

The Project Idea Note (PIN) contains a basic description of the planned project, including expected amount of emission reductions, financial considerations and risks. The level of data at this initial stage can vary considerably from project to project. Signing a contract for sale of future CERs generated at PIN stage poses the greatest risk of non-approval and therefore non-delivery for investors and so the purchaser can expect the largest discount on the price. Each consecutive step taken in the project approval reduces the risk of non-approval and so increases the value of the credits. Often the project owner will seek approval from the host country Designated National Authority (DNA) to confirm in a Letter of Approval (LoA) that the project contributes to sustainable development in the country. If the project has a negative impact on sustainable development, it would not qualify for CDM. In cases where the sustainable development contribution is nil, the project developer may use part of the income from the credit sale to finance other activities that contribute to sustainable development, such as improving the quality of life of the local community. The next stage is to formalise the project design in a Project Design Document (PDD) to be sent to the Designated Operational Entity (DOE). As discussed in Chapter 1.3, the PDD contains more specific details on the project. Once the PDD is completed it is sent to the Designated Operational Entity (DOE) for approval and validation. After successful validation, the project is submitted to the CDM Executive Board for registration. The EB may review the project, reject it or approve it for registration. Only projects registered by the CDM Executive Board may produce CERs for verified reductions. Registration is generally a formality unless the Executive Board doubts the quality of the validation or the projects supporting documentation. Once a project is operational, an ongoing cycle of monitoring, verifying and issuing of CERs is maintained throughout the duration of the CDM project agreement which is initially 7 or 10 years.

3.3.3 Risk in the Primary Market

Since transactions in the primary market are nearly always for CERs not yet generated, projects hold specific risks that the buyer takes into account when making a bid. Some of the risks are the same for all projects such as country risk, political risk, counterparty risk and financial risk whereas others are more specific to the technology and the CDM processes of verification, validation and issuance (for a detailed description of the risks see CD4CDM). The relationship between price for CERs and risk in the primary market and the guaranteed sCER market is shown in Figure 7 below.

Figure 7: Risk and price relationship



The heterogeneous nature of the projects makes it difficult to formulate a price to risk ratio although projects with lower risks will rationally attract higher prices. The effect of the risk on price may depend on the buyer's knowledge of the market as well as their ability to internalise the risk through strategies such as spreading risk across a portfolio of technologies and regions, developing risk valuation tools to help formulate a strategy or include only pay on delivery as part of the ERPA. Under 'pay on delivery' contracts the risk of delay is mostly held by the seller and any delay could mean that the credits are delivered outside the Kyoto Protocol period and possibly at a lower price.

Risk avoidance or spreading strategies can also influence prices by creating a premium for certain technologies or countries where buyers wish diversity in their portfolio. For example, buyers may pay a premium for CERs not from Chinese projects if they are already highly exposed to the risks

from changes in China's position after the Kyoto Protocol period. Additionally, buyers may pay a premium for a project due to their positive environmental characteristics even though the risk is high. The price differentiation across project types and regions can also affect the diversity in supply of credits where higher risk projects increases the returns needed for private investors. Also, risk perceptions are dynamic rather than static and so the effect of some risks on prices will change as the market develops.

3.3.4 Chinese influence on CER prices

The final component of the price range determination is the effect of the Chinese governmental strategy on the minimum CER price. Point carbon estimated that China accounted for 70% of all CERs sold in 2006 (Point Carbon CDM and JI Monitor 4 April 2007). Chinese projects are extremely attractive for buyers, despite some concerns about geographical concentration of such high volumes of carbon (World Bank, 2007) and so any policy by the Chinese government will have an impact on the whole market.

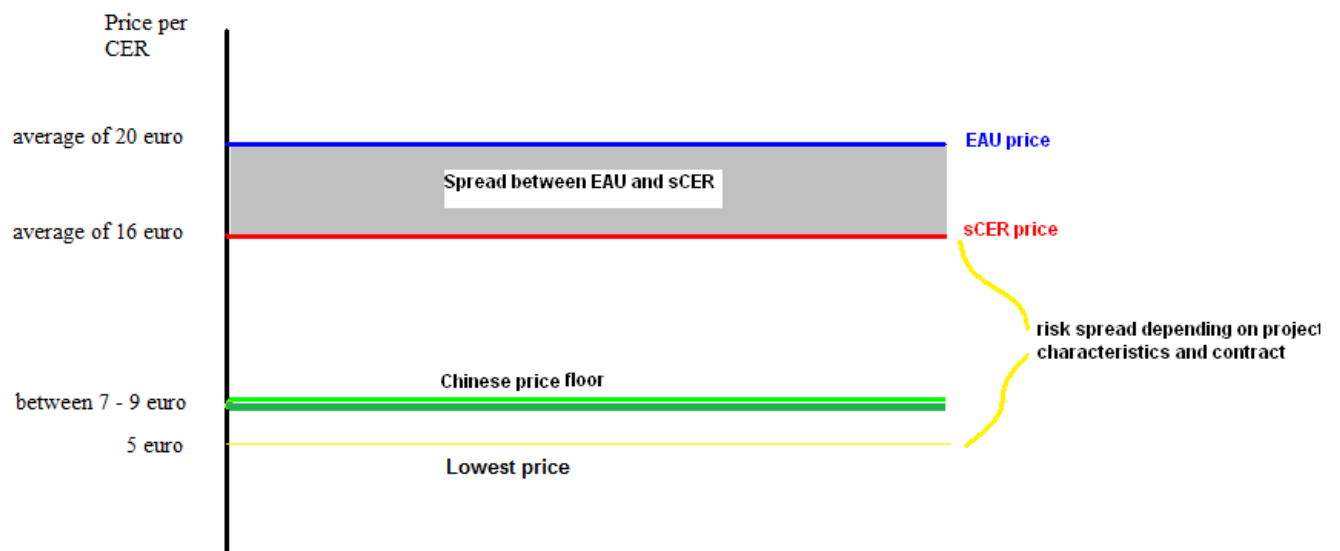
Since 2005, China has operated an informal policy of requiring a minimum price for CERs before providing DNA approval. This has had a strong impact on CER price expectations amongst sellers as they may use this price signal as a basis of negotiation. Since the projects are by definition at an early stage of development, the price acts as a price floor although projects from countries with higher risk may receive a slight discount. It is widely believed that 7 euro was the price floor for most of 2005 and the first half of 2006 and increased to 8 euro in mid 2006 (Point Carbon, CDM and J.I.monitor 4 April 2007). The World Bank estimated the informal price floor at 8 – 9 euro in 2006. Although primary CERs were contracted for less than the Chinese price floor, it had the effect of keeping prices and demand steady (World Bank, 2007).

3.3.5 Defining a range for CER prices

It is clear from this analysis that no single CER price exists but rather a range depending on the many factors discussed. Figure 8 below, provides a range for the prices expected in the market. The EUA (2008) price has varied between 12.25 and 30.25 euro over the period 12/09/05 to 12/03/08 (figure 6, page 24) although for long periods it has been close to the average of 20 euro. Typically

the sCER price has traded at 20% below the EUA price which provides an on average ceiling price of 16 euro per CER. The Chinese minimum price has acted as a price floor but the value has increased over time. The floor will be set as a range of between 7 and 9 euro to allow for the different dates when the contracts were signed. As discussed, some projects, and especially the earlier projects, will have been contracted for lower prices than the price floor. The World Bank (2007) estimated primary CER prices of around 5 euro for 2005 and 7 euro for 2006. The analysis will therefore use 5 euro as the lowest price on the market for the period the projects were contracted.

Figure 8: Range of prices for CERs



4 Theory of an efficient and effective CDM payment

Although private incentives exist to induce changes to the socially desired levels of GHG, the public good characteristics of the benefits and incentive to free-ride necessitate government intervention. The following chapter will discuss the characteristics of an efficient and effective intervention and explain the basis of the analysis in the context of the CDM target market.

4.1 A cost efficiency mechanism for GHG reductions

A truly efficient and hence cost effective climate policy would secure participation by all countries with each country mitigating emissions to the point where the marginal abatement cost (MAC) are equalised across all sources and equal the marginal benefits (MB). This would require targets for all countries, both developed and developing. Efficient intervention can be achieved through tradable permits that equal the marginal benefit of pollution control with the marginal costs of abatement (Baumol and Oates, 1994) or with a Pigovian tax or unit subsidy for abatement where the optimal unit subsidy would equal the marginal cost. Baumol and Oates (1994) showed that the effectiveness and magnitude of the welfare loss in a permit system and unit tax/subsidy differ depending on the slopes of the marginal cost and marginal benefit slopes and that the choice of either system under cost uncertainty will produce different results. With a permits system, the regulator will achieve the required amount of reductions but will be uncertain on the total costs, whereas a tax /subsidy system can be certain of marginal control cost but unsure if the emissions reduction target will be achieved. Taxes are preferred to quantity constraints if the MAC curve is expected to be steeper than the MB and vice versa. For the firm, a tax or unit subsidy is considered equal in that they both have the same effect on the production function. Given any marginal control cost for a firm, the regulator in a competitive market can reach a reduction in emission reductions by setting the unit tax or subsidy equal to the marginal cost of reduction which would be equal to setting the reduction target to the quantity of marketable permits. Wu and Babcock (1999) analytically compared a tax with a cost-share subsidy to achieve environmental objectives assuming full information on the costs of abatement. They concluded that both produce the same result although a tax may induce exit whereas a subsidy may induce entrants. Additionally, a subsidy may produce a net producer surplus (economic rent) which is defined as the difference between the cost of implementing the technology and the payment received for doing so.

Although a tax on the pollution or a payment to induce abatement would be cost-efficient in achieving an emissions reduction target, it may be inappropriate for diverse pollution sources which are difficult to assess and measure at a reasonable cost. Obtaining the necessary information may be difficult in practice so policy makers weigh up the costs of acquiring information and the gains from doing so against a policy that relies on the market to allocate resources to find the most efficient abatement. The perceived difficulties in measuring the MACs has led to the development

of a pricing approach that seeks to achieve a predetermined total emissions cap at least cost by pricing pollution appropriately (Baumol and Oates, 1994).

The Kyoto Protocol uses a pricing approach through a cap and trade trading system to reach the reduction targets but recognises that Non-Annex 1 countries have a role to play in emission reductions. The CDM reduces the costs for meeting Kyoto targets through a one-way cap and trade scheme that opens up the market to low cost reduction possibilities in non-Annex 1 countries. Although committing developing countries to an emissions cap is desirable from a cost-efficiency position, it is not considered so from an equity point of view. This is based on the understanding that developing countries are not responsible for the vast majority of the GHGs in the atmosphere, may not have the means to pay the costs of reducing their GHG emissions, have a lower willingness to pay and should be allowed to develop as other countries have without the burden of emissions reductions (for a comprehensive analysis see Grubb et al. 1999). The UNFCCC has therefore adopted common but differentiated responsibilities and respective capabilities approach. The CDM was included within the Kyoto Protocol as it recognised not only that the cost of reduction may be lower in developing countries but also that developing countries could benefit from the investments and be encouraged to follow a path of low carbon sustainable development without taking on the financial burden for doing so.

The CDM attempts to capture the principle of common but differentiated responsibility, ethical and sustainability criteria as well as economic efficiency that invariably leads to a trade-off between the goals. As Grubb (2000) noted, “The CDM offers a global distribution of the effort to reduce GHG emissions that is more of a political and ethical issue rather than one of economic efficiency”.

4.2 Cost efficiency and cost effectiveness

A policy that achieves the maximum net benefit is said to be efficient and effective. An efficient policy requires that no one is made worse off by the policy change (Pareto) or at least no one will be potentially worse off (Kaldor-Hicks criteria). To measure the CDM in efficiency terms is complicated in that it would require knowledge on dynamic costs, benefits and preferences over time and requires these costs and benefits to be quantified in a monetary terms.

A more appropriate and manageable measure is to consider the cost effectiveness of a policy in the terms of can we achieve the goal at a lower cost or alternatively can we achieve a more ambitious goal using the same resources. Assessing cost-effectiveness of a policy allows for the more stringent requirements of measuring efficiency to be by-passed in that the least cost means of achieving a goal is identified, which may or may not be efficient. Choosing a cost-effective mechanism is important for policy makers whose objective is to maximize the welfare gain from the money spent. In using cost-effectiveness it is important to recognise that the analysis cannot be compared to other policies with different benefits. Additionally, relying on cost-effectiveness as a assessment criteria can lead to identification of a policy that makes no economic sense. The findings of a cost-effective analysis should therefore be taken in context. Nonetheless, showing a policy measure is more effective than another is useful if the results can be incorporated into a future policy agreement that leads to lower costs in reaching the goal.

4.3 A cost effective payment for CDM projects

A way of achieving an emission reduction goal cost-effectively would be to pay the project owner the amount equal to the cost incurred for reducing CO₂ emission. For example, this could be a payment to cover the extra cost for producing electricity from a CO₂ neutral source rather than from fossil fuels. Alternatively, it could be the cost of implementing a change in production to reduce GHG emissions. In both examples, this would be the amount needed to make the project owner indifferent to constructing the emission reduction project and continuing with the lower cost business as usual scenario without abatement. Any payments over the cost for doing so would be captured as economic rent. Rent seeking is an important factor in the markets for attracting investment but comes at a price of reduction in the cost-effectiveness of the policy since the rent may not contribute to the goal of GHG reduction.

Adopting a policy of paying only the cost is based on the assumption that the regulator knows the costs of abatement and pays that amount for each polluter respectively and this is sufficient to induce the change. Although knowledge of abatement costs becomes more apparent as the number of CDM projects increases, the costs of gathering the data needed to implement a strategy of minimum payment could be prohibitive and should be measured against the rents saved by doing so. Additionally, many of the projects have benefits outside the GHG abatement that should be

included when evaluating the cost-effectiveness of a payment, especially when the goals of the policy also include sustainable development. The expansion on the analysis to take into account these benefits is outside the remit of this paper and so will not be considered. This paper will not attempt to measure the total benefits of the CDM but will instead measure and evaluate the payments given through the CDM for reducing GHG emissions compared to the cost-effective policy just defined.

It is significant for the validity of this least-cost approach that it does not require the assumption that the firms are profit maximizers or perfect competitors. All that is necessary is that they minimize costs for the output level they select (Baumol and Oates, 1994). This is important for this analysis where the CER market is dominated by small producers with little information on how their own production can be assessed in the terms of the market for carbon. It will therefore be assumed that the project owner has primary production (e.g. electricity, steel, cement) outside CER generation and a leverage payment is sufficient to induce the change to lower GHG emitting production but will not alter the amount of the primary good produced as a result of the payment. This assumption is reasonable when we consider how unlikely it is that small project owners know their production functions and CER potential sufficiently to adjust their production to maximize income from the credits generated. This is especially the case if the primary production is defined by capacity of the facility and the reduction of CO₂ emissions is second to the production of the primary good.

4.4 The use of incremental costs

Paying incremental costs for abatement has become a key concept in international efforts to protect the global environment. Funding rules based on incremental costs are included in the Convention on Biological Diversity and the Montreal Protocol (Swaminathan, 2000). The U.N. Framework Convention on Climate Change (UNFCCC, 1992) itself states in Article 4.3 that the *developed country Parties (....) shall provide such financial resources (....) needed by the developing country Parties to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of this Article* (i.e. the objectives of the Convention). This approach was adopted by the Global Environment Facility (GEF) which, through addressing global environmental issues including climate change, aims to support sustainable development. The GEF has similar goals to

the CDM but uses a different funding structure in that it gives additional grants to meet the incremental costs of implementing an environmentally improving project over a cheaper, more polluting baseline. As with the CDM, the projects must be defined by a boundary and the environmental benefit must be measured and accounted for. The GEF discounts the costs over time but unlike the CDM, the payments are defined by the project and not the carbon price in the market. This approach is similar to cost-effective functional form used in this paper.

4.5 The effect of transaction costs

In reality, any funding to reduce GHG emissions would incur transaction costs. For CDM projects transaction costs are incurred outside the physically construction of the project through fulfilling the additionality criteria. As discussed, this is where the project must pass stringent approval, monitoring and evaluation procedures. These costs vary across projects and are related to the project size. Fichtner et. al. (2003) estimated CDM transaction of between 6% and 53% of the total project costs, with technical assistance and administration costs being the most significant. These include the measuring, monitoring and baseline modelling needed to prove additionality. Chadwick (2006) estimated costs of \$200,000 for developing a methodology alone for an LPG plant in Ghana which was over 60% of the CER approval transaction costs. Transaction costs are important to estimate when designing a mechanism and they are not specific to the CDM. The GEF projects also face similar costs when using an incremental cost model. The least cost method used in this paper does not include these transaction costs although this may be an interesting to investigate and include in the future.

4.6 Estimating the costs within the CDM target market

By measuring the cost of implementing a project the paper assumes that cost is the main barrier to project development and by paying only the costs the total reductions could be reached at a lower cost. The projects can be split into two categories:

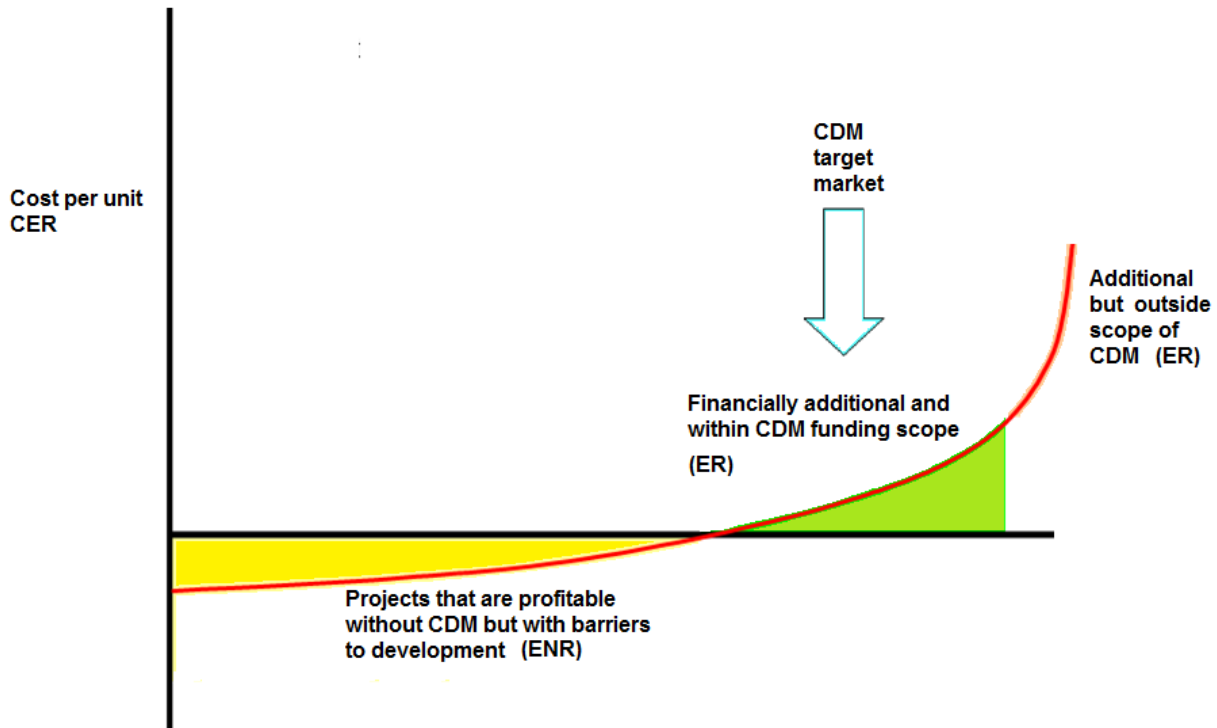
1. Projects which are economically feasible and generate a net economic benefit even without the CDM funding.
2. Projects which are only feasible because of the revenue received from the generated CERs.

Projects in the first category can be referred to as “economical no-regret” (ENR). They are activities that should be carried out because of the improvement in efficiency. Developing these projects would generate a new gain and so the activity is a Pareto improvement. Grubb et al. (1999) argues that these types of projects are non-additional because the activity would have been carried out anyway. The fact that the cheapest projects are the least likely to be financially additional is what Grubb et al. (1999) refers to as the inborn paradox of the CDM. Allowing the ENR projects under the CDM would violate the financial additionality criteria.

Some studies have shown that the ENR projects might not be implemented despite their economic efficiency improvements (Sugiyama & Michaelowa, 2001). The authors argue that the ENR projects can be further divided into two: the projects that have available funding (ENR-F) and projects that have difficulties regarding available funds (ENR-NF). The ENR-NF projects are often public sector related and attractive from a societal point of view but lack public sector funds. These projects often have positive sustainable development benefits beside the pure economic benefits. The main hurdle for the implementation of ENR-NF is the shortage of investment in capital in Non-Annex I countries and their lack of ability to attract foreign direct investments without the CDM. These projects can claim to be additional as they would not have been implemented without the CER funding.

The second category are “economic regret” (ER) projects that would not be feasible without CER revenue e.g. renewable energy technology that raises the cost of energy production. The ER projects are financially additional as the project would not be implemented without the CER revenue. Figure 9 below illustrates the project types described and also those that are too expensive to be within the scope of the CDM. Shresta & Timilsina (2002) suggest a limit based on the assumption that there is less of a cost difference between Annex I and Non-Annex I countries when the investments are in modern state of the art capital. The limit may also be defined as the minimum costs of abatement in the Annex I country and is shown as the projects which are additional but outside the scope of the CDM.

Figure 9: CDM target market



The ENR-NF projects are not violating the additionality criteria but investment may not be an appropriate method for measuring the barrier. The detection and measurement of these types of project are unlikely to be captured in the method used in this analysis since the ENR projects will mostly likely chose a barrier other than investment as proof of additionality. So, by definition, they will not be included in the cost analysis for each project type.

To date, very little work has been done in compiling and comparing costs on CDM projects. The attractiveness of individual projects has been estimated in some studies but they focused mainly on country specific parameters, registration procedures and the number of CERs (Diakoulaki, et al, 2007). Capital budgeting tools such as Net Present Value (NPV) and Internal rate of Return (IRR) have been used in similar analysis to this paper to define the optimum payment in related markets. Kverndokk et al. (2004) defined the optimal output payment in the electricity sector as being equal

to the discounted cost of the technology divided by the price of the good (electricity). Gilau et.al.(2007) also used the definition where the present value of emission reductions were measured against the GHG reductions although the analysis only assessed a few renewable technologies within a village. Wara (2006) used a simple cost estimation for an HFC-23 project by using initial and annual costs but the types of projects assessed were limited. In attempting to classify projects by sustainability Sutter (2003) used IRR as an economic indicator of the effect of CDM revenue compared to the baseline of no CER income. The report was however limited to income generating projects (electricity generation through methane capture and biogas power).

Ellis and Kamel (2007) and Matsushashi et.al. (2004) are amongst the most comprehensive studies to date on the costs per credit for CDM projects. Matsushashi et.al (2004) analysed 42 non-categorised projects using IRR over a 10 year financing period and although the technique assumed a price for CERs it measured the returns based on Monte Carlo simulations. This does not fit well with the method used here. Ellis and Kamel's (2007) approach is the most similar to the method used in this paper in that they measured the initial investment costs associated with 23 CDM project activities against the annual credits. The paper did not categorise the projects and was limited by the lack of publicly available investment cost information. Yet, they were able to conclude that there was no link across different CDM project types for the initial level of investment required and the number of credits generated. For many project types the CER revenue was more likely to be the "icing on the cake" rather than the reason for undertaking the project in the first place. The paper is somewhat lacking in several aspects. The projects were split between income or no-income stream definitions, as in this paper, yet the value of the income was not taken into account. Since the future income streams were not measured and therefore not discounted the measurement was static rather than dynamic with no account for the affect of different income streams over time. The cost of the BAU scenario was not defined and so no account was taken for the purely additional costs of the project and finally, not all project types were measured to allow comparisons of costs. This paper attempts to improve upon the Ellis and Kamel (2007) paper by including for these missing factors and to determine costs for different project categories.

5 Defining an effective payment for a CDM project

The functional form is based on measuring the minimum leverage payment by calculating the cost per unit of reduction for each project type within the CDM pipeline. The analysis therefore requires two pieces of information for each project; 1) the costs of reducing a ton of CO₂e and 2) the number of credits generated.

5.1 The functional form

The profit function for project “j” under the baseline scenario without CER income can be expressed as follows:

$$\pi_j = P(y_j)y_j - C_j(y_j)$$

where;

$$\pi_j = \text{profit for firm } j$$

$$y_j = \text{output levels for firm } j$$

$$P(y_j) = \text{price for the output of firm } j$$

$$C_j(y_j) = \text{costs of producing output for firm } j$$

The implementation of emission abatement is at a cost to the firm and enters the profit function as follows:

$$\pi = P(y_j)y_j - C_j(y_j, a_j) ;$$

where;

$$a_j = \text{the abatement technology for firm } f$$

$$C_j(y_j, a_j) = \text{cost of producing output and abating for firm } f.$$

For the project, “s*” is the baseline CO2e emissions and “s” is the CO2e emission after abatement and payments $g(s^* - s)$ is where $dg/d(s^* - s) > 0$, that is the payments increase by the amount emissions are reduced. It will be assumed that the credit price is constant over time and for each unit of CO2e emission reduction. The payments are $v(s^* - s)$ where v is the CER credit price and so v, s* and s are constants for each project. If we assume that abatement does not alter the production levels, costs of production or prices received for the output, the subsidy level required to make the firm indifferent to investing in the abatement technology is where the profit function including the project is at least equal to the baseline scenario, shown as:

Baseline profit function = CDM project profit function

$$\rightarrow P(y_j)y_j - C_j(y_j) = P(y_j)y_j - C_j(y_j, a_j) + v(s^* - s)$$

$$\rightarrow -C_j(y_j) = -C_j(y_j, a_j) + v(s^* - s)$$

$$\rightarrow = -C_j(a_j) + v(s^* - s)$$

$$\rightarrow C_j(a_j) = v(s^* - s)$$

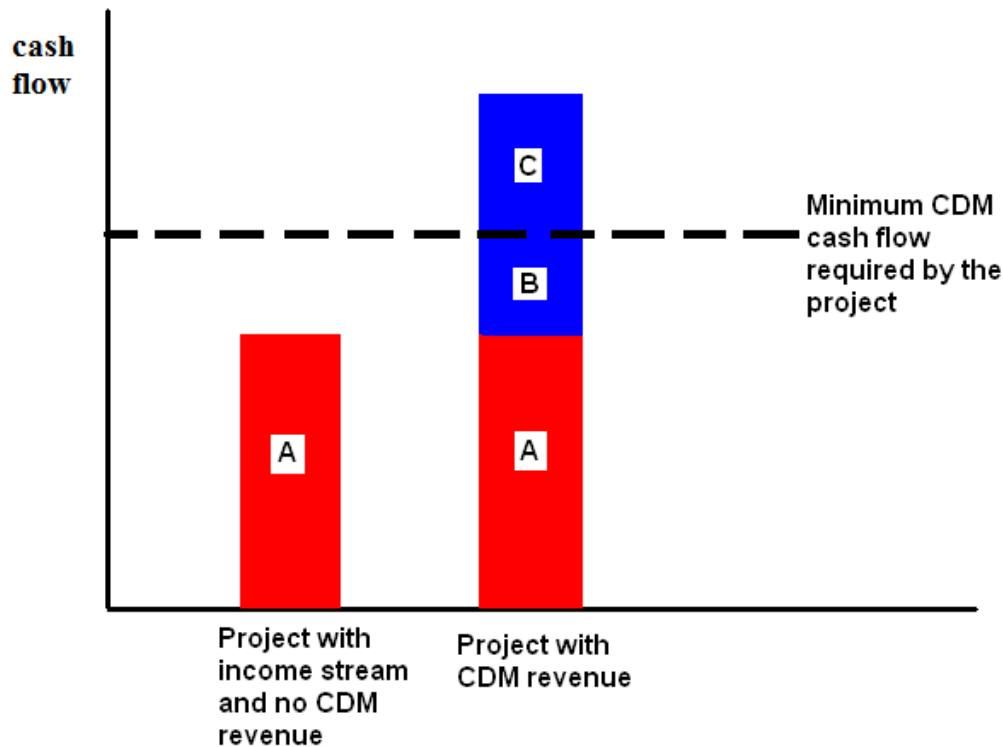
The final equation states that in the costs of abatement in the project should be equal to the payments received for doing the abatement. Since (s*-s) is given in the PDD as the estimate of emissions reductions as a result of the project, solving the equation for ‘v’ will be equal to the minimum payment per credit required to proceed with the project.

5.2 Effect of paying the minimum for each project

The aim of the CDM is to provide a leverage payment to projects to induce adoption of the lower emission technology. Many projects demonstrate that the costs of adopting the project is proof of financial additionality in that the project would not have occurred as a business as usual project without the CDM payments. This is shown in the Figure 10 below where the returns from the project are represented by area A. The CER payment required by the project is area B which raises

the project's income stream to the minimum to induce the adoption of the project. Any payment additional to the minimum, shown as area C, will be captured as economic rent.

Figure 10: The minimum payment for a CDM project

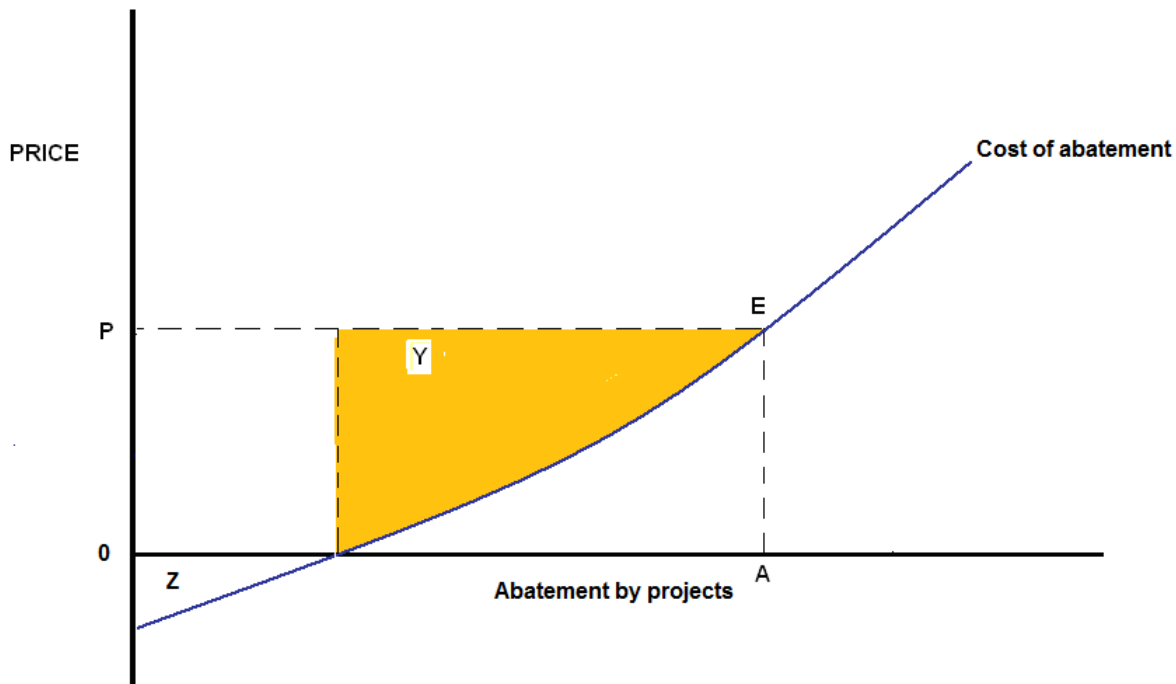


This analysis of one project can be expanded to the whole market for CDM projects where the cost of abatement differs across projects. The price paid for CERs is linked to the Kyoto credit trading market price and not related to the cost of making the reduction. Figure 11 below illustrates the price of CERs and the effectiveness of the monies transferred as leverage for projects to reduce emissions.

The cost of reducing CO₂e for all economic regret projects is represented by the cost of abatement curve. By linking the CERs to the market price for credits, the price of credits P will be sufficient to pay for abatement up until point A. Any projects that receive a credit price greater than the cost of generation will capture economic rent. The total rent for all projects where the cost of abatement per CER is lower than market price is equal to area Y. If the mechanism paid only the cost of abatement

for each project to induce abatement the programme would pay the price per CER equal to the cost of abatement and the result would be a saving of Area Y in excess payments and an increase in cost-effectiveness.

Figure 11: The market price and costs for CDM abatement



5.3 Discounting for different project types

Calculating the price to pay using $Cj(aj) = v(s * -s)$ is not an accurate representation of the project as it does not take into account the time value of future cash flows. This is based on the assumption that money can always earn a positive return over time. Investments can be defined either as static or dynamic depending on whether the time value of money and benefits are considered. Static indicators such as unit investment costs take the ratio between the first year investment costs and the expected environmental effect (such as the data produced by Ellis and Kamel (2006)). This definition of project costs has drawbacks in that it does not take into account the annual operating costs or the differences in the project lifespan. Dynamic indicators, such as Net

Present Value (NPV) and Internal Rate of Return (IRR), avoid these issues by including annual expenditure and the time preference elements of an investment and so will be used in this analysis.

Discounting cash flows allows for the value of alternative use of funds over time to be included in the calculation. The discount rate can be defined as the opportunity cost of the investment. This is often defined as the rate of return which comprises of the real rate of return plus inflation, cost of liquidity and the risk associated with the investment. Several methods exist for the evaluation and comparison of investment decisions although NPV and IRR are the most popular. This chapter will define briefly the connection between both methods and the reasons for choosing both NPV and IRR in this analysis.

The NPV is derived by discounting the cash flows of a project at the opportunity cost of capital by summing up the incremental discounted cash flows over the life of the project and deducting the initial outlay the NPV gives a value in absolute terms (Levy and Sarnat, 1994). If the NPV is positive then the project creates wealth. The IRR is also a time discounted measure and is related to the NPV in that it is the rate of discount which equates the NPV of the cash flow to zero. Typically if the IRR is greater than the discount rate the project creates wealth. The relationship between the two measures is shown more formally below:

NPV

$$NPV = \sum_{t=1}^n \frac{N_t}{(1+r)^t} - I_0$$

IRR

$$NPV = 0 = \sum_{t=1}^n \frac{N_t}{(1+H)^t} - I_0$$

Where:

N_t = net cash at the end of year t

I_0 = initial investment

r = the discount rate

t = the project duration

H = hurdle rate³

If a project's cash flows are calculated with $NPV = 0$, then solving for r , the project will also have the properties of $r = H$. Therefore, when assessing a single independent project, with a fixed cost of capital, certainty in the magnitude and timing of all prices of all assets and returns from the investment, the project owner will be indifferent to using NPV or IRR since they both, by definition, will give the same result.

Now we have an equation that represents the efficient payment ($C_j(a_j) = v(s * -s)$) and two measures for taking into account the opportunity cost of the capital over time, we can now merge them to formulate two equations for assessing CDM projects.

Typically NPV is preferable since the calculation is more straight-forward whereas IRR often requires iterative techniques and so can be more time consuming. When a project submits financial details to prove financial additionality they can choose either method. Typically the use of the method can be split between two categories of projects (as discussed in Chapter 1,3) - those that derive an income outside the CERs as a result of the project's implementation (e.g. renewable energy projects with a positive NPV from electricity sales) and those that have no additional income as a result of reducing the CO₂ emissions (e.g. HFC projects with negative NPV for the abatement technology).

Where there is no additional income outside the CERs sales, the project will usually be submitted with a NPV calculation. This is probably because the project always incurs a net cost to the project owner and so calculating the initial and running costs is a simple way of demonstrating that the project has a negative NPV and so financially additional to the baseline of no action. This method also reduces the need to include a discount rate since even under a zero discount rate the project will still have a negative NPV. For the projects with additional income, most likely through the sale of

³ The hurdle rate is the minimum IRR required by a project to attract investment and is usually determined at project level although some estimates are available for general investments in a sector or country. At project level, the rate is influenced by the project's risk characteristics, country risks and by the cost of money in the host country.

electricity, the NPV calculation is often less useful for a project investor since the number is absolute. The investor will more often prefer to compare it to another parameter, i.e. the opportunity cost of the capital, when making an investment decision. By calculating the IRR, the project owner can more easily demonstrate that even if the project is wealth creating without the CER sales, the returns on investment are insufficient to induce investment. In this respect, the baseline returns from the project is lower than the required returns for such a project type. An example could be a wind project that generates electricity and earns an IRR of 8% over the project life where the minimum return (hurdle rate) is higher, at say 12%. The project is financially additional in that the project would not proceed without the CER income and that the CER income must increase the IRR above the 12% hurdle rate. Ideally, only one way of measurement would be preferred but as the projects are invariably split between the two methods of measurement, this paper will assess them on this basis. The next section will define the formula for both measures based on the efficient subsidy level derived earlier

5.4 No Income stream projects (outside CER revenue)

The initial definition of NPV will be amended slightly so that the initial investment (I) is included within the net cost (N). This is arguably a more accurate definition since the initial investment may extend over many years and so should also be discounted over time to give a present value.

Reducing the equation also conveniently simplifies the equation as follows:

$$NPV = \sum_{t=1}^n \frac{N_t}{(1+r)^t}$$

All of these projects have a negative income stream and so will always have a negative NPV. As shown previously, the minimum subsidy required is where the cost of abatement is equal to the subsidy per unit where the NPV = 0. By substituting this definition into the NPV above, we obtain:

$$NPV = \sum_{t=1}^n \frac{(C_j(a_j) - v(s^* - s))_t}{(1+r)^t} = 0$$

(equation 1)

If the costs, discount rate and emission reductions are known for the project, we can solve for 'v' and calculate the minimum subsidy required for the project, discounted over time, so that the project is no worse off for implementing the abatement. Since the discount rate can vary across projects, sectors and countries, it is difficult to define one discount rate for all projects. Many of the projects did not give a discount rate. For the ones that did, the discount rates provided in the PDD's ranged from 8% to over 16% although the majority were within the 8-12% range. To allow for the projects to be compared one discount rate is required. The GEF uses 10% in its paradigm case analyses. All this is an arbitrary rate it falls within the average rate used in most developing countries. As this rate also falls between the rates often quoted in the PDD and so will be used in this analysis. A selection of discount rates could have been used but this was rejected in favour of simplifying the analysis.

5.5 Projects with an income stream (outside the CER revenue)

As discussed previously, these projects already have an income stream and a positive NPV over the project life e.g. a hydro scheme. The minimum subsidy should therefore take into account the income stream from the project when calculating the additional subsidy required. This is important as paying for the full project costs would be excessive since the project has an income stream to supplement the investment. The subsidy should therefore be where the rate of return equals H, defined as the hurdle rate, or minimum return on investment for the project.

As in equation 1, we can reduce the IRR definition by including the initial investment (I) into the parameter N and substituting N for the minimum subsidy payment; $Cj(a_j) - v(s^* - s)$.

$$NPV = \sum_{t=1}^n \frac{(Cj(a_j) - v(s^* - s))_t}{(1+H)^t} = 0$$

The costs, number of emissions and hurdle rate are provided in the PDD so we can solve for 'v' again which will be the minimum payment required so that the project achieves the minimum required return.

As discussed in Chapter 5.3, by definition the discount rate equals the hurdle rate. For no-income projects the discount rate is 10% yet the hurdle rate in this instance is defined by the project owner. This creates a problem when comparing the values since the rate may be different. A solution would be to compare all the projects using the same method but as discussed, this would not reflect the data given in the PDD's and would reduce the number of project categories and data points significantly. The hurdle rate is important for the project as it reflects the owner's opinion of the return needed to invest. Many of the PDDs used a hurdle rate of around 10% so it is expected that the effect will be limited. For these reasons, it was decided to use the rate given in the PDD. .

5.6 Selecting a project term

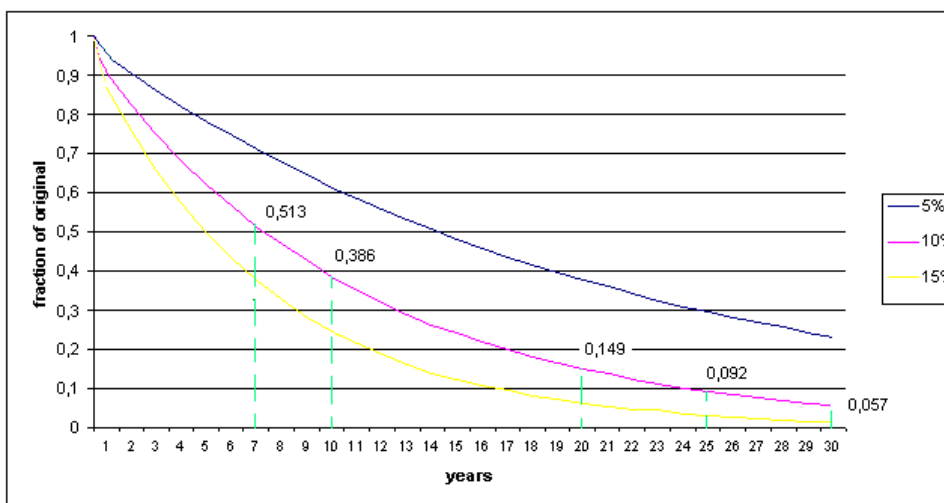
When applying for registration with the Executive Board, all the projects choose either a single 10 CER generation period or an initial 7 year period with the option of renewing twice. The choice between the two options can be influenced by expectations on the future market and if CERs will have a value in any new international agreement. The term applied for may also be influenced by the host DOE on whether they expect a binding target in future and so may wish to save possible future credits for their own use. It is not stated in any of the PDD's as to the reason for selecting one period over another.

Of all the projects in the CDM pipeline as of 1st January 2008, 87% had an initial term of 7 years and 13% chose a 10 year period. The analysis will therefore assume a seven year crediting period for all the projects so they can be compared. Choosing 7 years will produce the most conservative figure since a lower number of CERs will be generated by the project. For the no-income projects, it will be assumed that the project owner will have no further costs for the abatement since they will just stop abatement when there is no payment for doing so.

This assumption is not appropriate for projects with on-going income stream since they will still have positive return after the seven year crediting period. This income should therefore be included in the calculation of reaching the hurdle rate for the project. Using the full term for the projects creates a problem when comparing different projects with different terms. This problem could be solved by selecting one term for all projects although doing so will affect the data by adding an assumption that would not hold for many of the projects. Besides, further assumptions for on-going costs would have been needed due to missing data on some projects. Figure 12 shows the

diminishing importance of cash flows at different discount rates over time. At a 10% discount rate, after 20 years the investment is only worth 14.9% of the initial outlay and decreases to 9.2% after 25 years and 5.7% after 30 years. The CDM projects typically have a project life of between 20 and 30 years. The differences between the values over long periods are small and so will not be corrected in the analysis. Although this is a weakness in the data generated, it should be taken in the context against the alternative of adjusting all the projects for one term or estimating hypothetical costs for some projects where normally the project term would have ended.

Figure 12: Graphical representation of the discounting effect



6 Results for cost per CER across project categories

The following Chapter will now provide the results from all 17 project categories including information on the project types and explanation of any outliers. Histograms and box-plots were used as they can be easily compared and give an indication of the cost ranges for each project type and the distribution of the different costs.

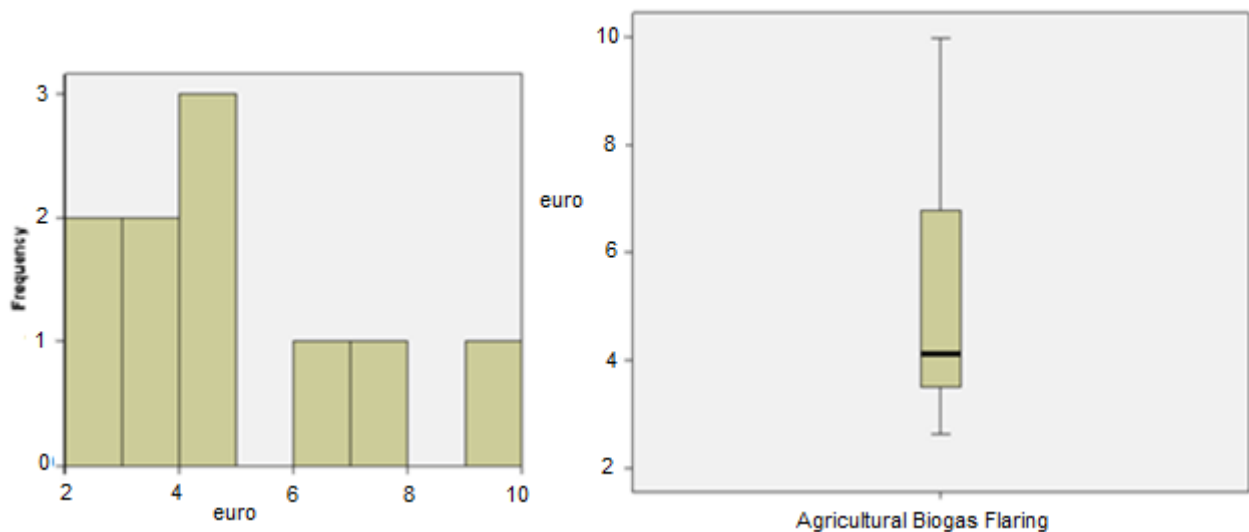
6.1 Agricultural biogas flaring

These projects deal with the flaring of biogas which comprises primarily of methane and carbon dioxide and is the by-product of the fermentation or digestion of biodegradable material. Although the GHGs can be produced from manure in animal husbandry and in the breakdown of wastes in

crop production all the projects analyzed were from animal waste (swine). For these projects the bio-gas generated by the project is flared and so no income stream is generated from electricity production. Some of the projects submitted encompass several farms and locations. The level of technology used has a bearing on the costs of producing a credit. All the projects used in the analysis used an anaerobic digester or alter the collection and storage of the animal waste in order to capture the methane normally emitted.

94 projects were assessed and data was generated for 10 projects. Most of the projects are the transfer from anaerobic lagoons to anaerobic digester technology. The median value was just over 4 euro and three quarters of the projects ranged between 3.3 and 6.7 euro (figure 13). The data is skewed to the lower range. One project had a significantly higher cost of over 9 euro per CER as it used a more sophisticated version of anaerobic digestion called activated sludge which requires higher capital and maintenance costs.

Figure 13: Agricultural biogas flaring histogram and boxplot

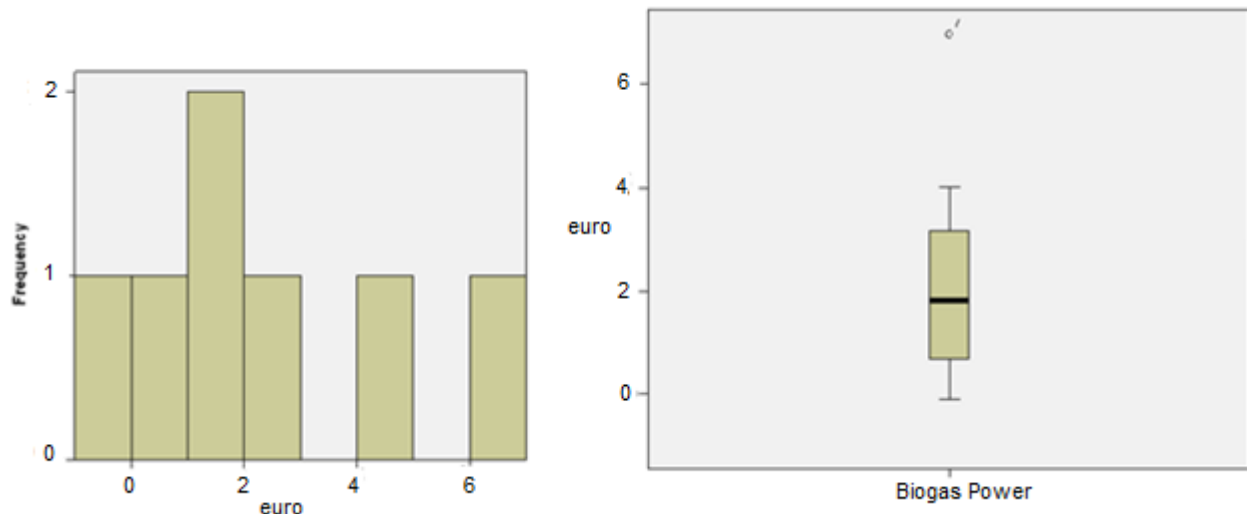


6.2 Biogas power

54 of the projects produce biogas that is used for energy but only 7 data points were able to be collected from the PDDs. These projects are very similar to the biogas flaring projects in that they predominately use an anaerobic digester to capture methane from agricultural waste. Instead of

flaring the methane it is burned to create steam for electricity production or heat. The additional technology requires extra equipment and maintenance costs whilst the energy generated has a value and so provides an income stream to the project.

Figure 14: Biogas power histogram and boxplot



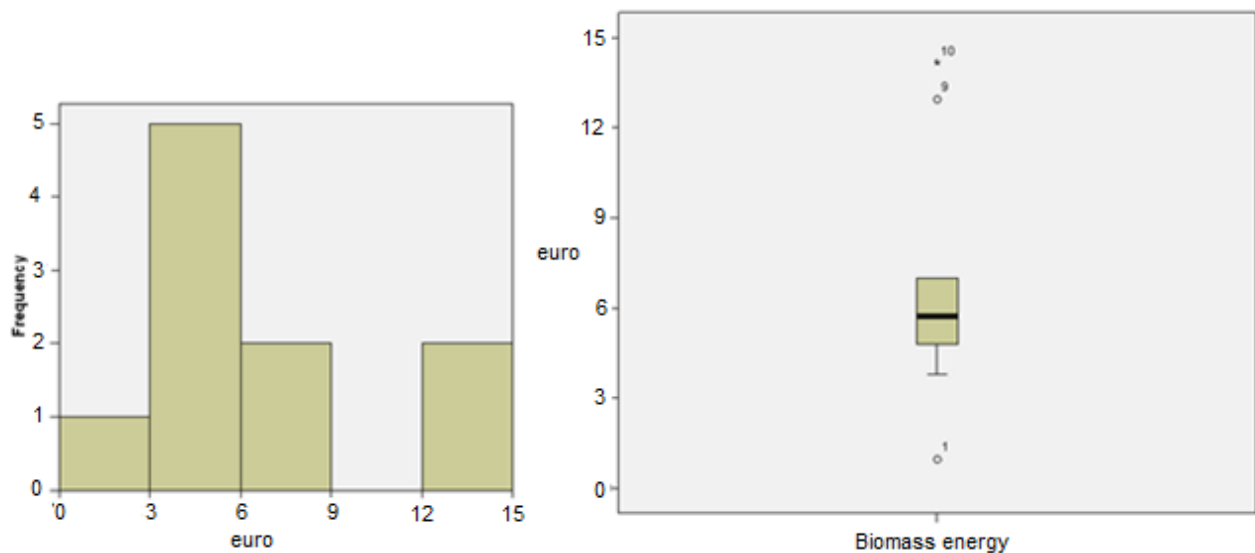
The median value was 1.86 euro and most of the projects ranged between 0.35 and 2.4 euro (figure 14). The project with the highest price of 6.99 euro per CER had the smallest CERs p.a., almost one third of the other projects. Economies of scale may have therefore been a factor in the higher price. All but one project required an additional income stream from CERs to make the project viable. The exception of -0.09 euro is interesting in that the hurdle rate was surpassed for the project without the CER revenue yet the project owner argued that the project involved a substantially higher capital investment than most other probable alternatives, a longer time horizon and greater risk than alternative investments as well as management related barriers. While the project offers an attractive return on investment these barriers were used to argue that the project was still additional.

6.3 Biomass energy

10 data points were collected from the 197 data points. The median value was 5.7 euro and the data points stretched over a large price range from 1 euro to 14 euro although the 7 of the points were between and 3.8 and 7 euro (figure 15).

These projects use agricultural residues such as rice husks, bagasse and palm oil as a fuel for energy production. This can either be through the construction of a new plant or conversion of an existing fossil fuel facility. The baselines are influenced not only by the costs of equipment but also by the carbon intensity and cost of the fuel they are replacing. A plant that replaces a comparatively expensive fuel with biomass will have a lower cost per CER than one where the new fuel is more expensive than the one used in the baseline. The calorific intensity of the fuel is also an important factor in the amount of energy produced by the facility. The large range of values could be explained by the variety of agricultural residues used and the level of technology adopted.

Figure 15: Biomass energy histogram and boxplot



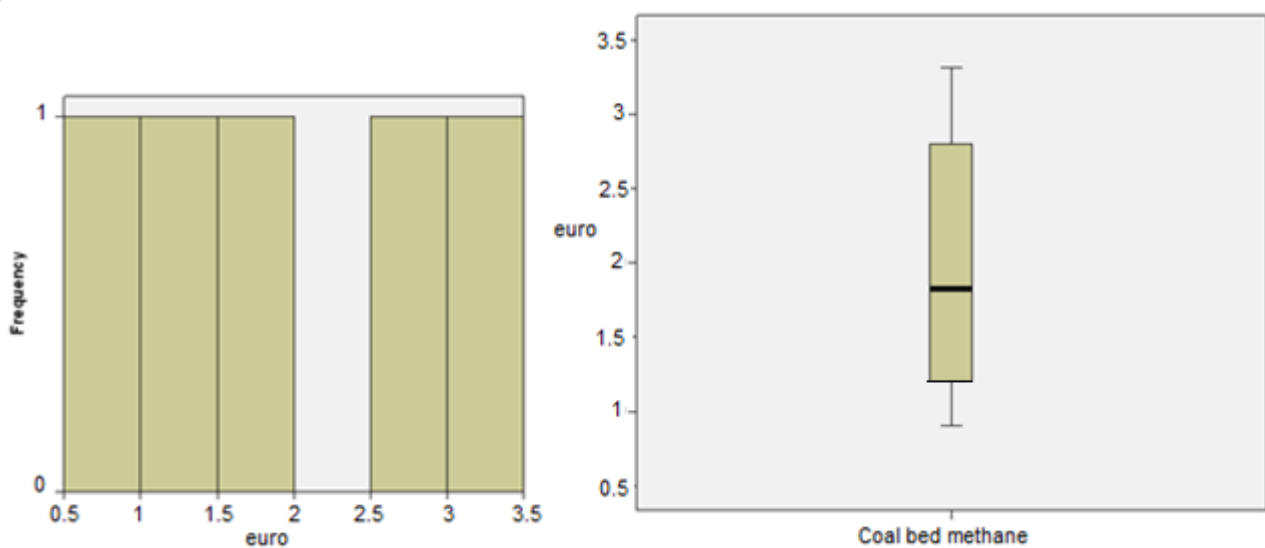
6.4 Coal bed methane

These projects all involve the installation of drainage systems, waste heat recovery units, storage tanks and compressors to capture and use the methane which would otherwise be released into the atmosphere. Once in operation, the methane is used to produce electricity and the captured waste heat is used as thermal energy source, most often as hot water for local residents. Income is received outside the CERs by selling the electricity generated through the grid network or through supplying heat and electricity to local residents. Some of the energy collected is used in the mining operation to off-set those traditionally generated by fossil based fuels.

Of the 7 projects in the pipeline, sufficient financial information was only available for 5. All 7 projects are based in China and so the project share common key parameters such as electricity purchase price and the investment hurdle rate. For all projects, the IRR without the CER revenue was below the hurdle rate, which was for the most 11.8%.

There is little difference in the costs with them ranging from 0.9 to 3.3 euro. The median value was 1.8 euro per CER (figure 16).

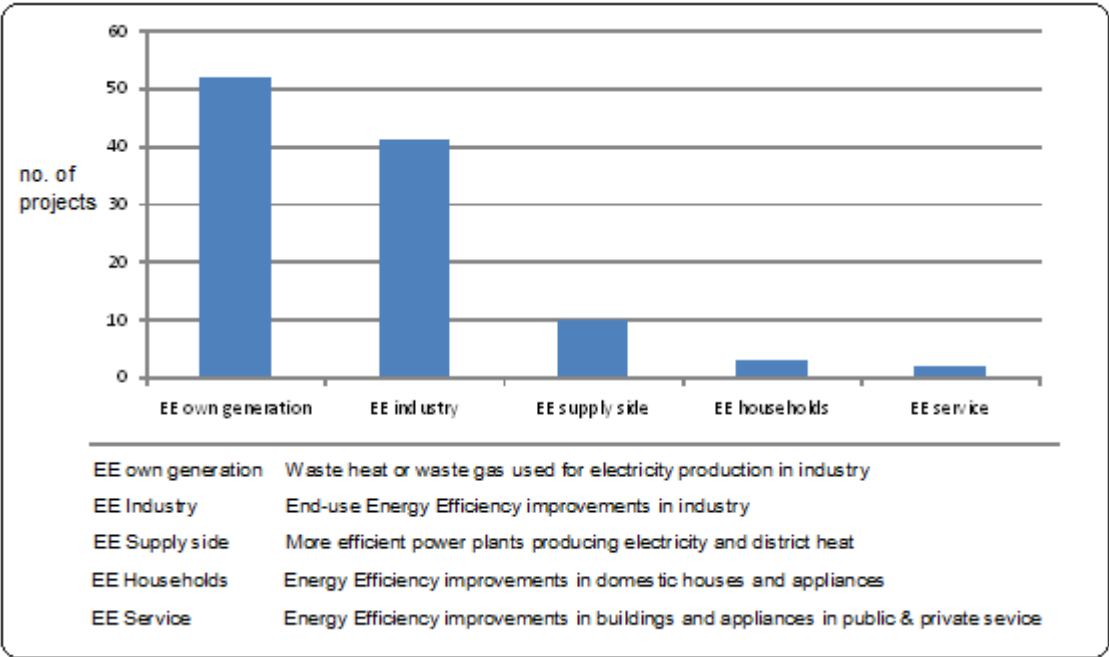
Figure 16: Coal mine methane histogram and boxplot



6.5 Energy efficiency

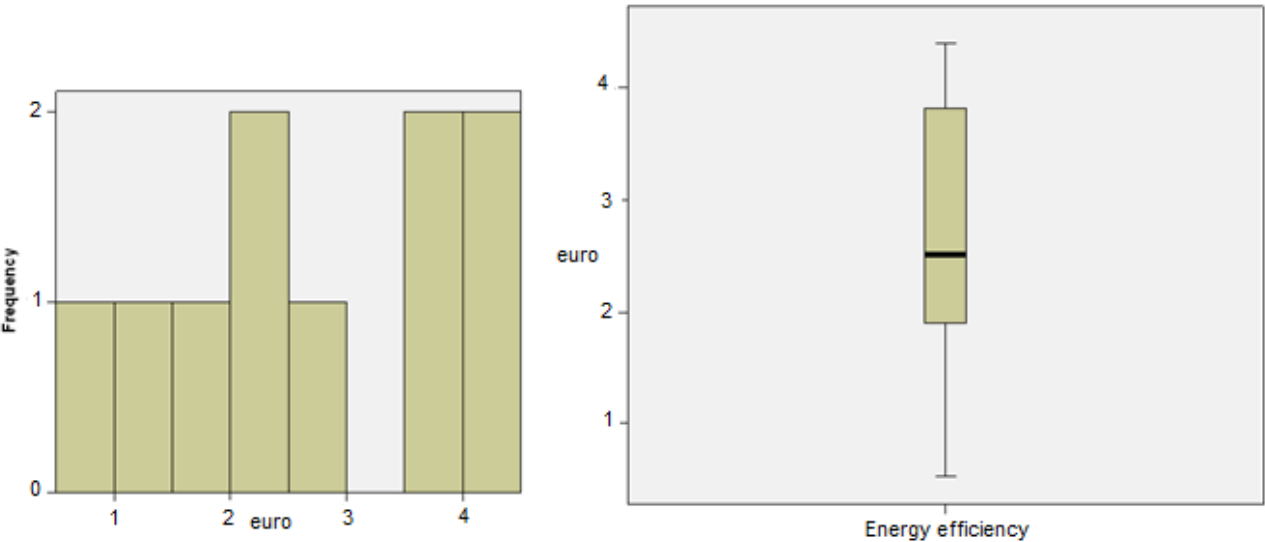
The 110 energy efficiency projects analysed encompass many project types varied across many sectors and technologies (figure 17). Often the projects are in high energy consuming industries where large scale efficiency improvements can be made such as utilising waste heat in production and installing new efficient technology or retro-fitting. Of the 10 projects assessed, 6 are from energy efficiency own generation, 2 are from energy efficiency in industry, one is from supply and one is from service. No data was available for the energy efficiency household project. The data represents the split of project categories quite well and even though the project designs were significantly different, the values were similar ranging from 0.5 euro to 4.4 euro with the majority of the values close to the median of 2.5 euro per CER (figure 18).

Figure 17: Energy Efficiency categories



Source: UNEP/Risø pipeline 08/01/08

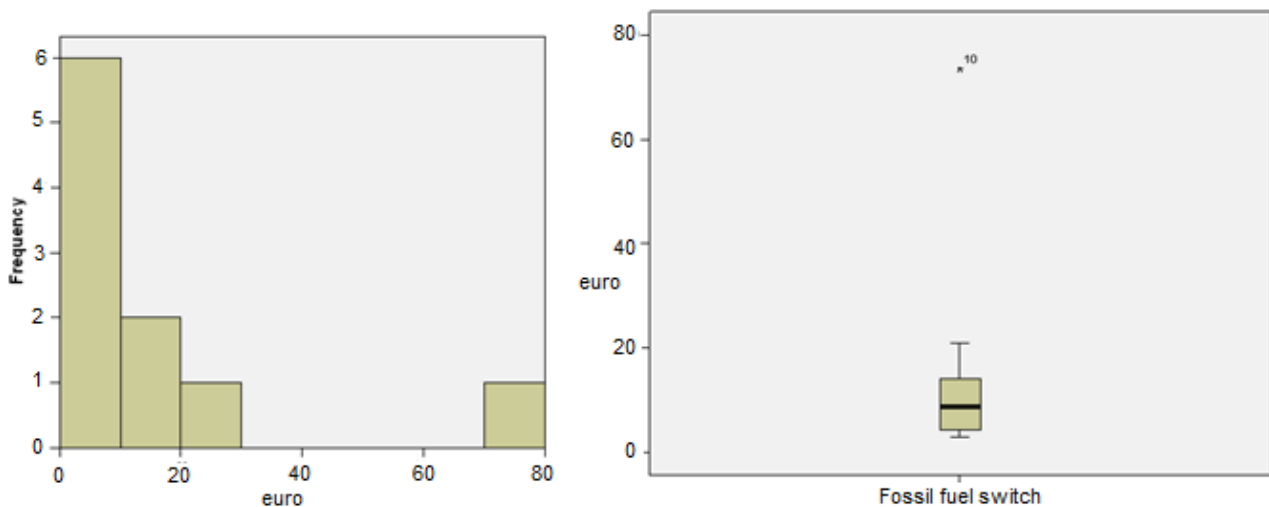
Figure 18: Energy efficiency histogram and boxplot



6.6 Fossil fuel switch

The 22 projects in the portfolio of projects switched from using a fossil fuel to another, less carbon intensive fossil fuel of which 19 switched to natural gas either from fuel oil, coal or naphtha (a form of liquid fuel). The other three projects switched to charcoal, hydrogen and biomass. Converting to the new fuel type generally involved switching the boiler system although some included the building of a new plant. 10 values were collected of which 6 were between 2.8 euro and 9.4 euro and a median of 8.6 euro per CER (figure 19).

Figure 19: Fossil fuel switch histogram and boxplot



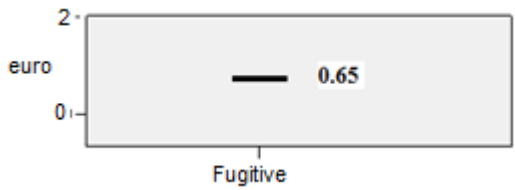
The high values are for projects where the new fuel was more expensive to purchase than the existing fossil fuel which led to very high costs for the project or the project required the installation of a new plant. The lower cost projects generally involved retro-fitting boilers to cope with the new fuel and so had lower upfront costs.

6.7 Fugitive emissions

All these projects deal with the capturing and recovery of gas, five of which are from oil and gas production and the other two smaller projects that reduce methane emissions in timber and charcoal production. The baseline was flaring of the emissions. Recovering the fugitive gas generates an income stream outside that gained through the CERs although this will vary depending on the quality and quantity of the gas recovered. Only 1 project gave estimates for production costs with abatement technology although the data is dependent on gas and electricity prices.

The baseline for the project was 10% IRR although the project mentioned a higher rate of up to 20% as normal for the sector. This has a significant effect on the income needed from CERs sales to achieve the minimum IRR. The project was close to the baseline 10% IRR without the CER revenue and only required 0.65 euro per CER to achieve the hurdle rate (figure 20).

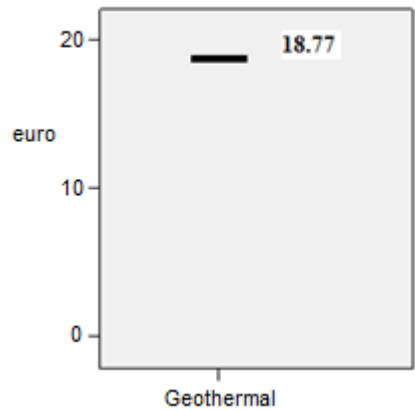
Figure 20: Fugitive boxplot



6.8 Geothermal

There were 6 geothermal projects but only one provided financial data that could be used in the analysis (figure 21). The investment cost of the project is compared to the BAU investment cost of a natural gas plant.

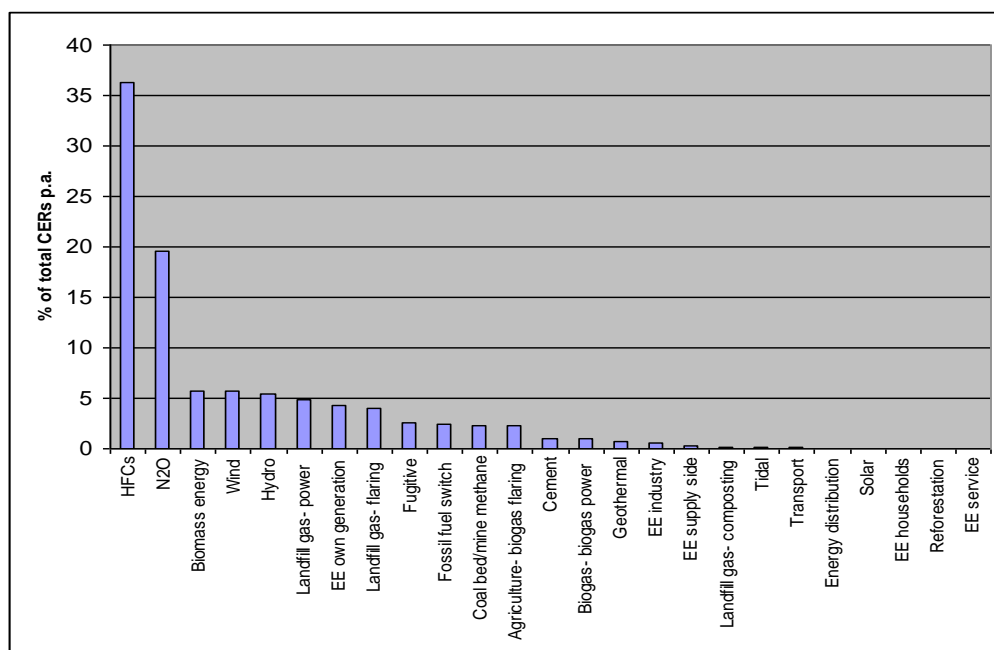
Figure 21: Geothermal boxplot



6.9 HFC

Although only 16 HFC projects were included in the analysis, due to the global warming potential of the GHG, they represent more than 35% of the annual CERs generated by the projects (figure 22).

Figure 22: Percentage of total annual CERs by project type



Source: UNEP/Risø pipeline 08/01/08

HFC's production is regulated under the Montreal Protocol as an ozone depleting gas. Although most countries have subscribed to reducing ozone depletion gases, China, like many developing countries have no mandatory target on HFC23 emissions at present. Usually the HFC-23 gas is released into the directly into the air. Two technologies exist to reduce HFC23 emissions from HCFC22 production - manufacturing process optimization and destruction of HFC23 by thermal oxidation (March Consulting Group 1998). All the CDM projects analysed utilize thermal oxidation technology. The installation of the technology requires a large initial investment as well as on-going costs with no economic benefit (outside CER revenue) for the project owner. As a result, none of the 16 projects in the data set were required to provide installation and O&M costs. Data was collected from various secondary sources (Table 4).

Table 4: Costs for HFC projects

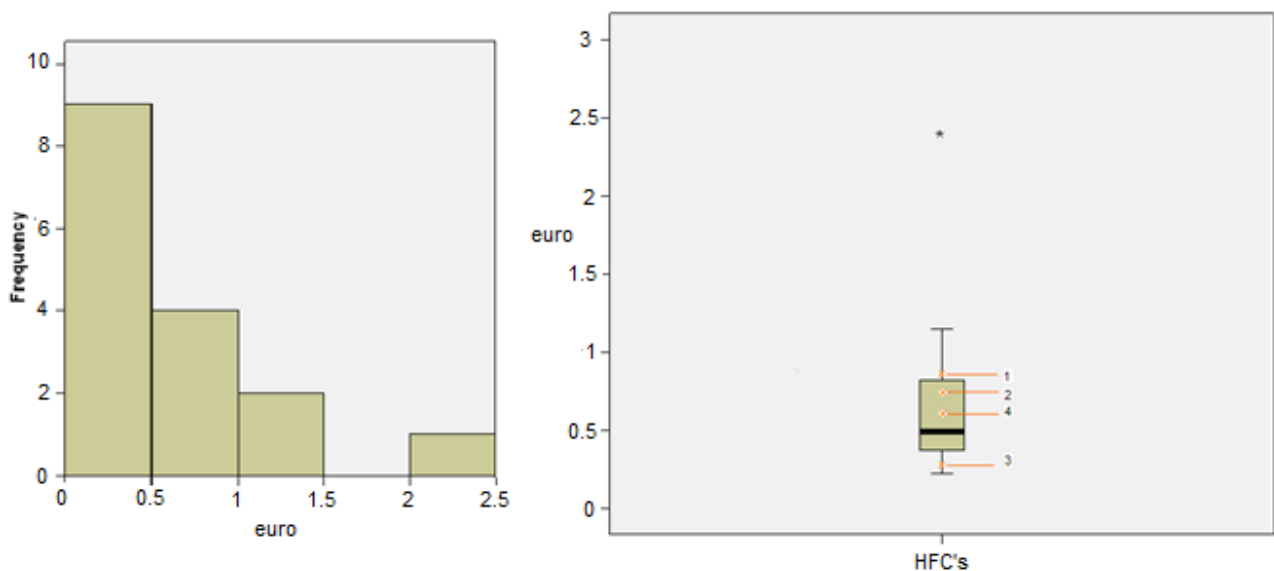
Source	Costs	Notes
US EPA (2001)	US\$7 million initial plus \$200,000 p.a.	For 5.7 MTCO ₂ e. 4% discount rate = \$0.64 per ton, 8% discount rate = \$0.78 per ton.
Wara (2006)	3m euro plus 200,000 euro p.a. (8.5 euro cents per credit).	For 2,3 MTCO ₂ e p.a. Using a 10% discount = 35 euro cents per tCO ₂ e
Schaefer et. al. (2006)	80 US cents per TCO ₂ e.	For 22 MTCO ₂ e
China Green Enterprise Limited, (2005)	\$7.4 million plus \$148,000 p.a.	Annual equipment maintenance costs 2% of installation costs
World Bank (2006)	US\$0.75 - 1.00 per ton CO ₂ e	No details given on calculation

The US EPA (2001) estimated the total installed capital costs for thermal oxidation at approximately \$7 million per plant with annual operational costs of \$200,000 for a plant that converts 5.7 million metric ton of CO₂e. At a 4% discount rate this calculates to 0.64 dollars per ton CO₂e, or 0.78 at 8% discount rate. Wara (2006) noted an initial investment of 3 million euro and 200,000 euro O&M costs for a facility capable of capturing and destroying 200 t HFC-23 per year (equivalent to 2.34 Mt CO₂e p.a.).

The World Bank (2006) figure is from a financial estimate from a project in China. This is particularly relevant as since 9 out of the 16 projects are in China. The costs were stated as \$7.4 million initial costs and \$300,000 working capital for generating almost 10.5 million credits per year. This is the largest project in the CDM pipeline analysed. Although the full cost structure has not been given, a simply analyse of the Figures at 10% discount rate would equate to approximately 16.9 euro cents per credit. This figure is low compared to the other estimates of between 75 US cents and \$1 or Wara's estimate of 35 euro cents. Comparing the figures is difficult for the projects currently in the pipeline since it is unclear if all plants would require the same technology regardless of the credits they produce and that the annual costs would be fixed. A conservative estimate was therefore constructed using the highest fixed cost of \$7.4 million and highest annual costs at 8.5 cents per CER generated.

The projects in the pipeline vary between generating between 0.5 million and 10.4 million credits. The estimate will be more conservative for the lower CER producing projects as the initial investment costs may be substantially lower than for the largest project. Nonetheless, overall the figures provide a conservative estimate for the HFC projects and are similar to the four other estimates given. One project has a comparatively high value over 2.38 euro per CER. This project generated far lower levels of credits than the others (one twentieth of the largest project) and so required a higher credit price to compensate for the costs. The histogram and box plot shows that the majority of the projects cost between 0.4 and 0.7 euro per credit and the median cost of 0.5 euro per CER (figure 23).

Figure 23: HFC Histogram and boxplot



(1=World Bank, 2=US EPA,3= Wara, 4= Schaefer et.al.)

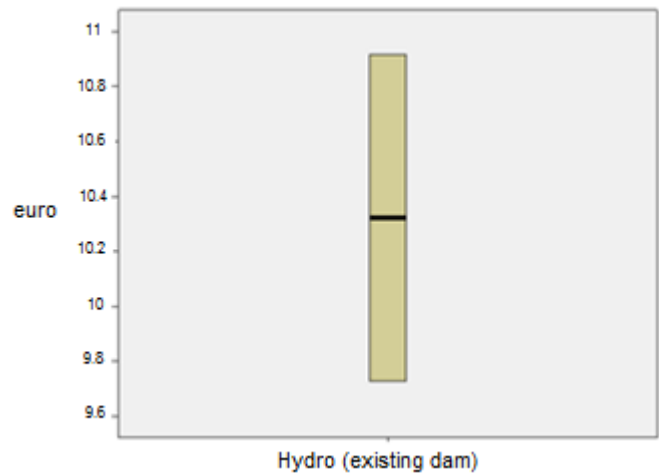
6.10 Hydro

The 170 hydro projects have been divided into three categories as it is expected that the costs will differ. New run-off river projects make up 129 of the project, 28 for upgrades to existing schemes and 13 for new projects. All the projects are dependent on the electricity prices used in the calculations but showed some similarity in the CER price needed to pay for the costs of implementing the project.

6.10.1 Hydro existing dam

These projects involved the upgrading or re-fitting of components in existing dams. Only two data points were available and were calculated as 9.73 euro and 10.92 euro per CER (figure 24).

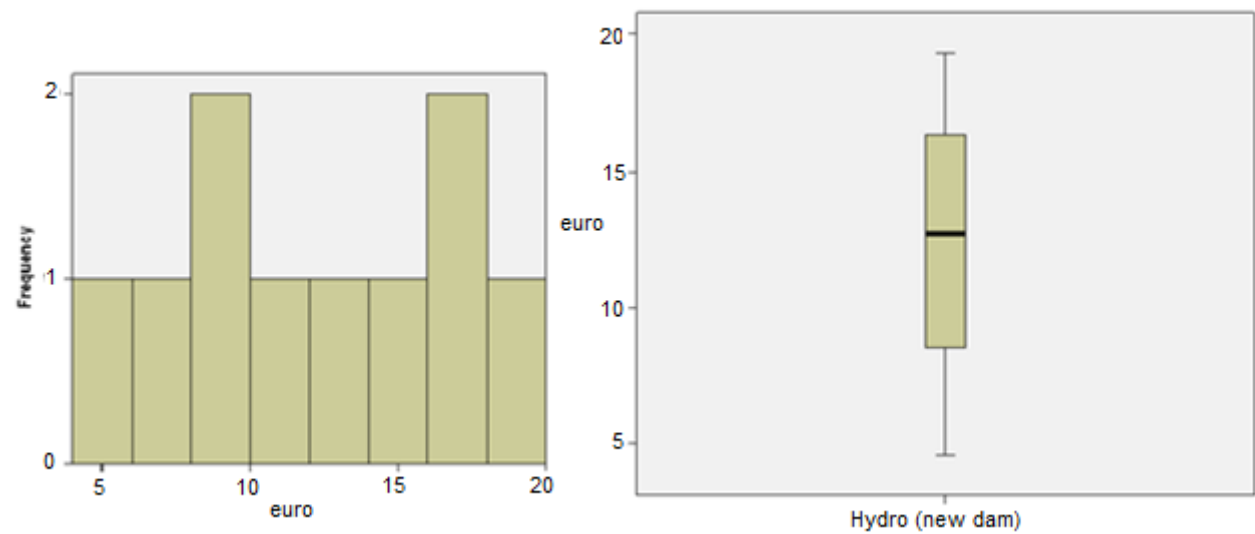
Figure 24: Hydro existing dam boxplot



6.10.2 Hydro new dam

The ten data points showed a large distribution of values with no dominant price range. The median value was 12.79 euro and the projects were between 9 and 16 euro per CER (figure 25).

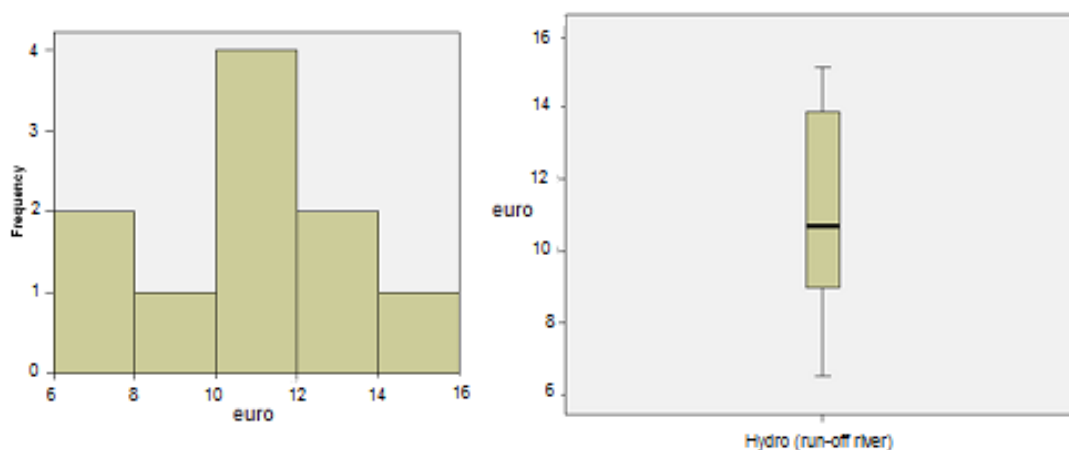
Figure 25: Hydro new dam histogram and boxplot



6.10.3 Hydro run-off river

The 10 new run-off river projects had a median value of 10.7. The most dominant price group was between 10 and 12 euro and the majority of the projects ranged between 9 and just under 14 euro per CER (figure 26).

Figure 26: Hydro run-off river histogram and boxplot



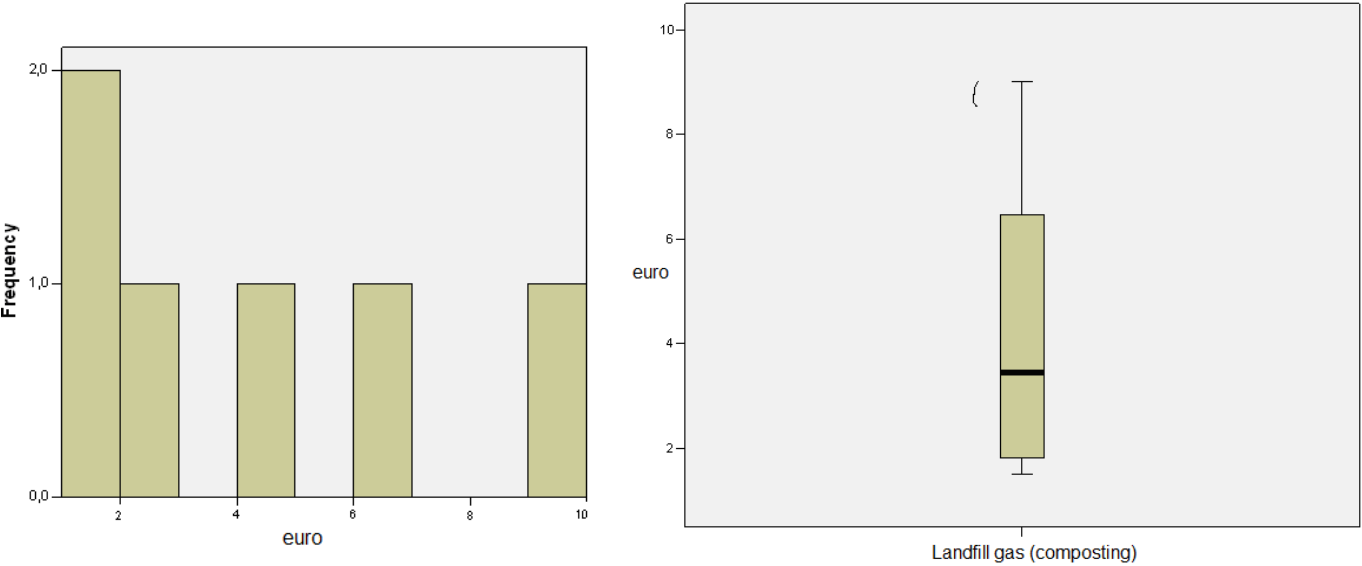
6.11 Landfill gas

The dumping of organic waste in open landfills is a common in non-Annex 1 countries so CDM projects can claim credits through capturing the methane generated from anaerobic digestion using three techniques – composting, flaring and capturing for energy use.

6.11.1 Landfill composting

The composting projects involved controlling the biological decomposition of organic matter through simple techniques such as aerobic co-composting. The technology is often a low level system of stacking and mechanical aeration. The most expensive project used a higher hurdle rate than the other projects which contributed to the higher figure. Of the 6 data points available, no price range dominated and they ranged between 2 and just over 6 euro per CER. The median value was 3.5 euro (figure 27).

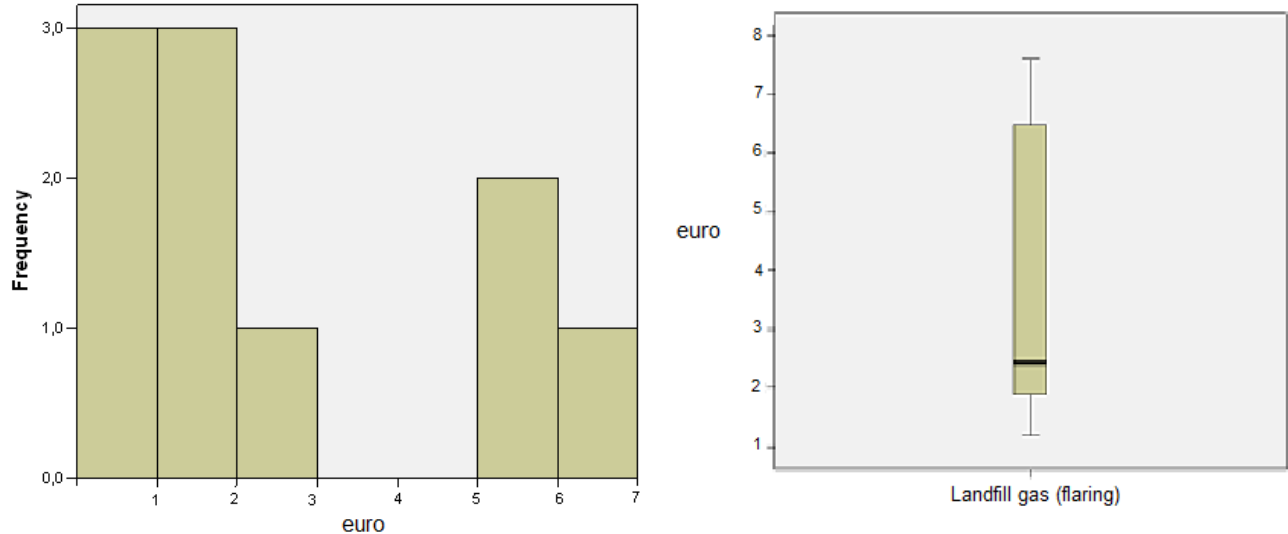
Figure 27: Landfill composting histogram and boxplot



6.11.2 Landfill flaring

The capturing and flaring of landfill gas generated through the decomposition of the organic waste involves investing in a landfill gas collection system and a flare station. The principal components of landfill gas are methane (CH_4) and carbon dioxide (CO_2). Flaring involves methane destruction leading to GHG emissions reductions. 10 data points were produced and the majority were under 3 euro per CER. The median value was 2.42 euro (figure 28).

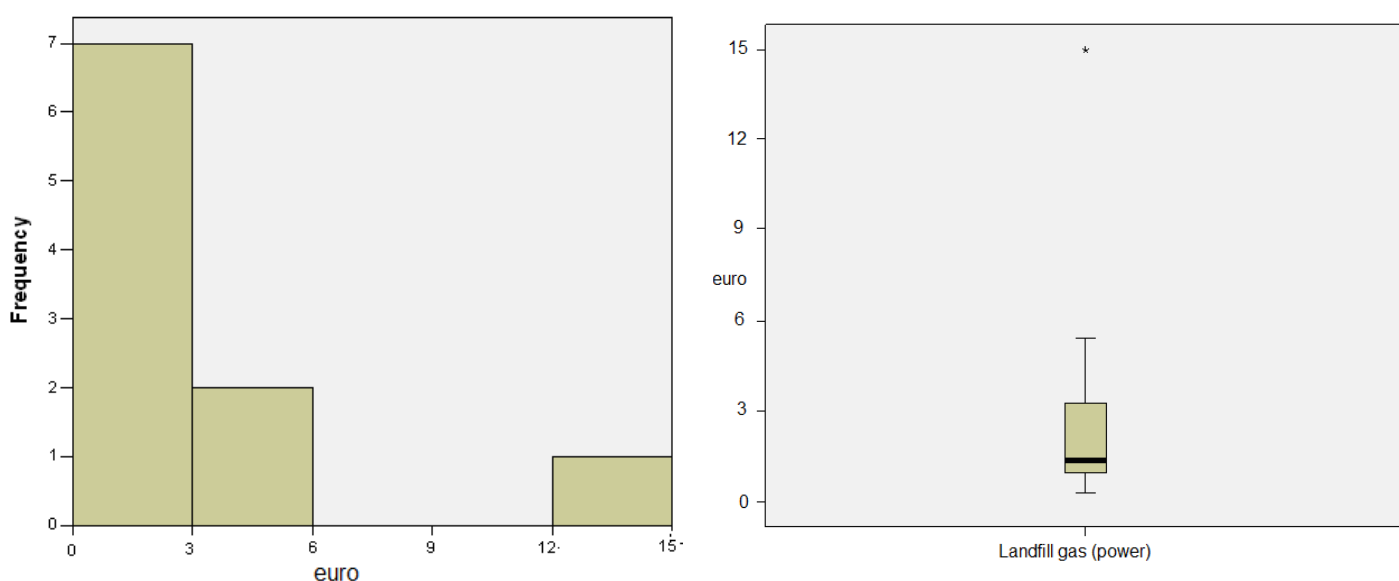
Figure 28: Landfill gas flaring histogram and boxplot



6.11.3 Landfill power

10 points were also collected for landfill gas power which involves the same technology used by landfill flaring except additional technology is needed to store the methane and then utilize the resource for energy production. The extreme Figure of around 15 euro was the result of a high discount rate compared to the other projects as well as high initial costs. The majority if the projects were under 1.6 euro per CER, the range was small and the median value was 1.38 euro (figure 29).

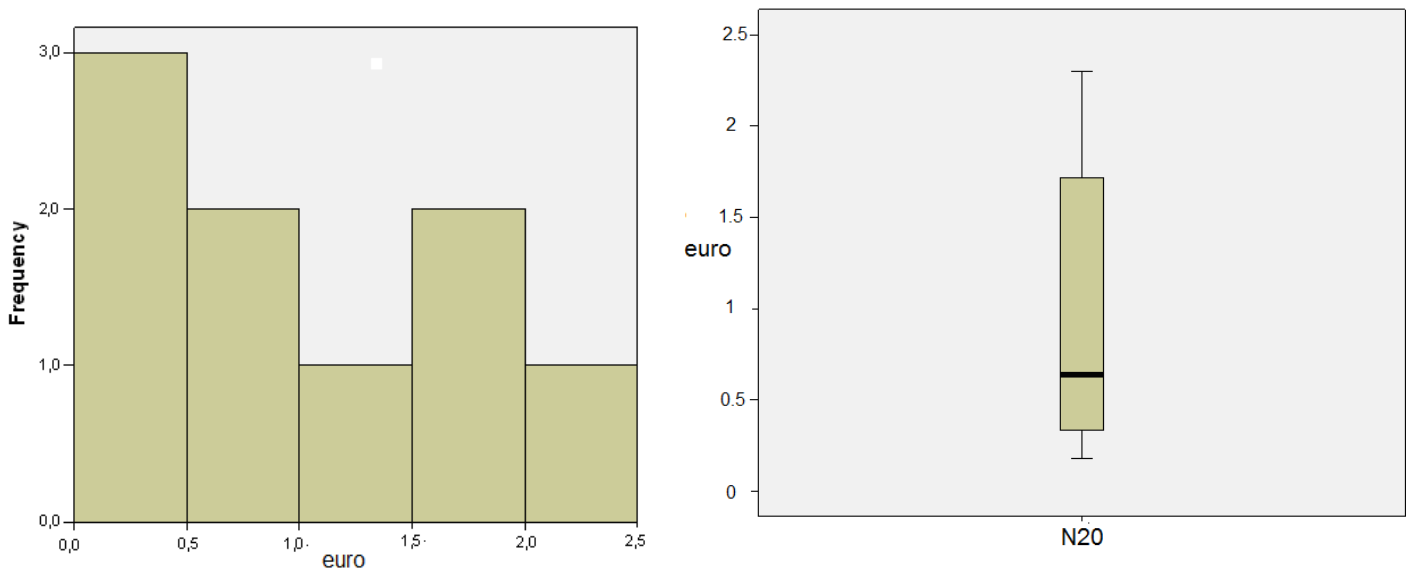
Figure 29: Landfill gas power histogram and boxplot



6.12 N2O

These projects allow for a secondary catalyst to be installed to decompose the N₂O that would otherwise be vented into the atmosphere as the N₂O has no economic value. The world's nitric acid plants represent the single greatest industrial process source of N₂O emissions (corresponding to 125 million t CO₂e p.a). Depending on the technical parameters of the project, the project can either install a catalytic decomposition process or a catalytic reduction process inside the reactor to abate N₂O emissions once it is formed. Of the 22 projects in the pipeline, only 4 are for the removal of adipic acid, the other 18 are for nitric acid. 3 of the 9 projects analysed were for adipic acid which produced slightly lower figures than the 6 nitric acid projects although they were all within a small range. The median value was 0.65 euro per CER and the majority were ranged between 0.3 and 1.8 euro per CER (figure 30).

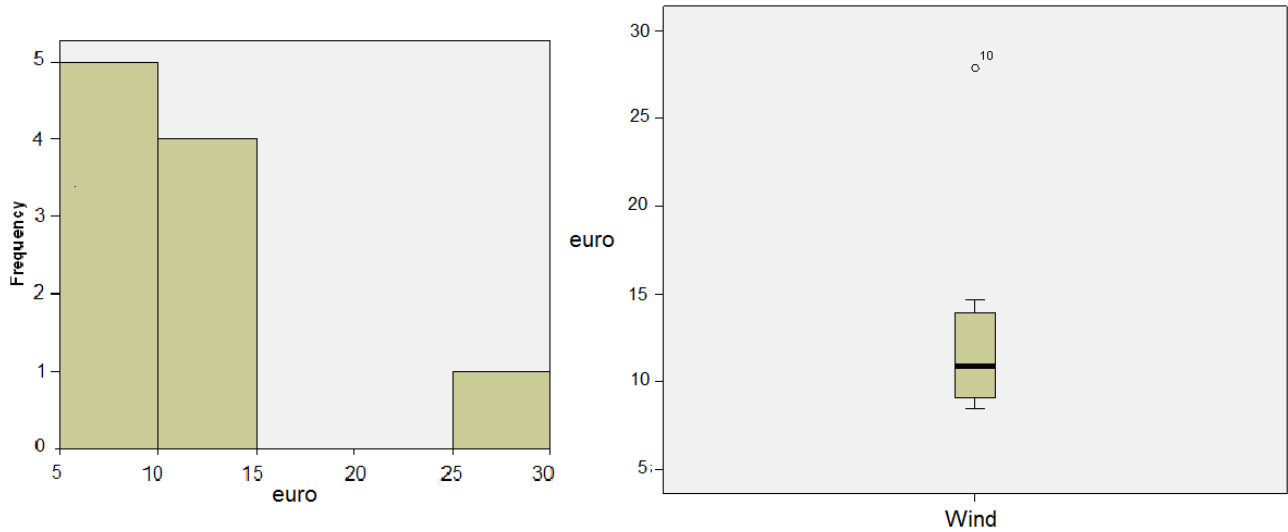
Figure 30: N2O histogram and boxplot



6.13 Wind

From 128 projects, 10 data points gave a median value of 10.9 euro per CER with all but one project within the range of 8.5 and 14.7 euro per CER (figure 31). The outlier project used a very low price for electricity sales and had a high hurdle rate.

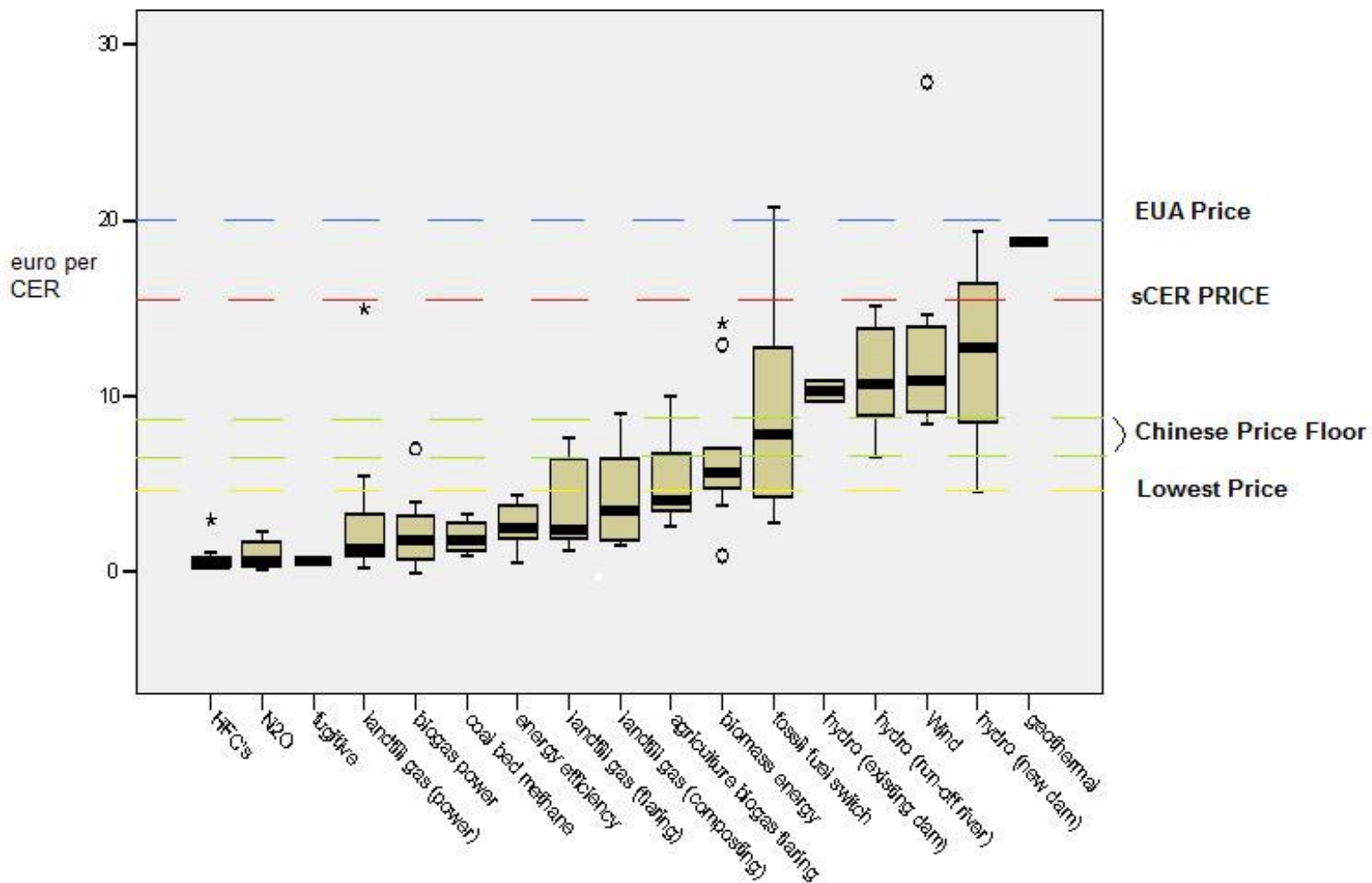
Figure 31: Wind histogram and boxplot



6.14 All project types measured against price per CER

The results for all projects are given in figure 32 which can be measured against the prices defined in the price formulation chapter. This allows for an overview of the costs per CER and the prices received in the market which will now be discussed.

Figure 32: Cost per CER for project categories and the price formulation



7 Discussion

It can be seen in Figure 32 (page 63) that the CDM structure of linking the cost paid for CER reductions to the market is not the most cost-effective way of reducing GHG emissions in non-Annex 1 countries. 10 of the 17 project categories generated CERs at a cost lower than the minimum price of 5 euro per CER. Coupling this data with Figures 4 and 5 (pages 19 and 20) gives an indication of the magnitude of the loss and that projects that dominate the market are also those with the lowest costs per CER. This is particularly in the case of HFC and N₂O projects. The results agree with the findings of Wara (2006) that some GHGs can be abated at a very low cost.

There are however some exceptions such as wind and hydro which are amongst the most expensive (Figure 32) have a comparably large number of projects in the pipeline (Figure 4). Some projects were shown to produce credits even though the cost was actually or potentially higher than the payment for doing so e.g. hydro new dam. These projects are few but highlight the diversity of projects developed under the CDM and shows that CER revenue is not the only factor in project development.

It is clear that GWP and the size of the projects play a role in the cost per CER. This is especially the case for HFC and N₂O projects which are large scale and have a high GWP. Projects that reduce methane (e.g. landfill and biogas) are cheaper than those that displace CO₂ emissions from fossil fuel based electricity generation (e.g. wind, hydro, geothermal). This finding disagrees with Ellis and Kamel (2007) who stated that there was no link across different CDM project types between the level of investment and the number of credits. These findings show that GWP and size of project have an influence on the cost per CER across project categories.

The difference in cost per CER within the project type illustrates that many of the projects can be categorised, but not all. Categorising assumed that project costs were expected to be similar even though they are in different countries, with different lending and construction costs and prices for the energy produced. On the whole, the results supported this assumption with only a few exceptions. The cheaper projects generally had a low range of costs whereas some of the most expensive projects such as fossil fuel switch and hydro new dam had a larger range of costs. These were often the result of high hurdle rates or low levels of credits compared to the up-front costs.

The fossil fuel switch projects were influenced by the price of the replacement fuel compared to the baseline and the hydro new dam projects costs were dependent on the assumed price of future electricity prices as well as economies of scale.

The grouping of projects created issues in collecting sufficient data points for each category since some categories did not have enough projects or the PDD did not have sufficient data. The later reflects the variety of the methods for demonstrating additionality. The low number of data points for some categories influenced the robustness of the results in particular for energy efficiency projects which could have been split into further categories. This was not possible due to the lack of data. It is perhaps not surprising that these projects were amongst the cheapest but the small range on costs perhaps demonstrates that further classification of the projects was not required.

As expected the ENR projects were not measured by this method (Figure 9, page 36) and this will bias the median figure given for the projects with negative cost per CER (e.g. energy efficiency). Including negative cost projects would have lowered the median figure and increased the range. This is a reflection of the design of the method in that projects do not have to choose financial additionality as a barrier and so do not have to provide the data needed for the analysis. This analysis only measures barriers which are related to cost and so the exclusion of these projects is inevitable. The project lifetime, discount rate and hurdle rate will also influence the robustness of the results and these issues were addressed in the paper. Standardising the reporting of financial data in the PDD would increase the robustness of any future analysis.

Measuring cost-effectiveness is complicated because the majority of the prices are confidential and there is no single price for CERs. The price formulation chapter shows that there is little transparency in the primary market. The price range develops over time and reflects the characteristics of the project, the contract and expectations of future prices. The Chinese price floor and secondary CER price has brought some stability to the market in that it sends a price signal to both buyers and sellers. This is important for a well functioning market. The price range shown in Figure 8 (page 29) has implications for the robustness of the analysis since the paper cannot give a single price for each project or project type to measure against the cost. If the price floor had the effect of increasing the price paid for CERs then the mechanism will have been less cost-effective as only 5 of the 17 project categories had a median price above the price floor.

If prices increase in the market due to; the influence of the Chinese price floor, merging of the sCER and EUA price and a general upwards price trend, then more projects will become viable. Some of the least costly projects types are limited in how many can be developed (i.e. the number of eligible HFC installations) and when the supply is exhausted more expensive projects will gradually take a larger share as long as the CER price is high enough. Nevertheless, it is clear from this analysis that the price was high enough for the majority of the projects. This was even the case with the most conservative assumption of years of generating credits and the conservative data requested by the EB when completing the PDD. In this respect, the CDM market defined in Figures 10 and 11 (pages 40 and 41) appears to be a fair description of what was found in the PDDs.

The market mechanism requires investors to implement the projects and economic rent is therefore important for inducing investment and expanding the supply of CERs. The rent has led to the CDM being successful in attracting investors where it was previously lacking, reducing the cost of abatement as well as making large reductions quickly. This is particularly important when we consider the Stern Review's (2007) findings that the benefits of strong, early action considerably outweigh the costs. It is unlikely that a minimum cost basis without any profit would induce the same level of investment. This price is important not only for the development of the primary CER market but also for this analysis where a price per CER is needed to measure against the cost of producing the CERs. Market mechanisms are often appealing if they are performance based, avoid the risk of picking winners and allow the market to choose appropriate alternatives that lower the marginal cost of abatement. The CDM has also been successful in increasing price discovery in the market which is essential for future effective policy formation.

The outcome of allowing the price of the CERs to be determined by the market has meant that the majority of the projects could have been implemented at a lower cost and economic rent is captured from the generation and selling of CERs. Removing the rent has the potential to reduce the overall costs of reaching the same level of emission reductions. This is however dependent on such a mechanism being able to collect the necessary information at a reasonable cost. This has already been shown with the GEF and the PDDs submitted as part of the CDM process could provide the financial data. This, in essence, is the reason for the loss in cost-effectiveness i.e. the price paid for the credit is not linked to the cost for doing so. The economic rent can be seen as the incentive for investment and picking the 'low hanging fruit'.

The CDM is working in that the cheapest options are being developed first since these represent the projects with the largest potential economic gain for the investor. But, the rent does not necessarily contribute to reducing GHG emissions and so the overall cost of the reductions is increased.

Since new information is of value, flexible mechanisms such as the CDM have significant advantages over rigid policy mechanisms as they can adopt a sequential decision making approach that adapts to new information. Evolution of the CDM is likely and perhaps essential in post-Kyoto in order to increase the cost-effectiveness of the CDM. The U.N. has set up an ad-hoc working group to target ways to enhance amongst others the ‘scope, effectiveness and efficiency’ of the project based mechanisms (U.N., 2008). Moving to a mechanism based on abatement costs is probably unlikely due to the large information costs but the prospect becomes more viable as information levels increase. This paper highlights that the mechanism could be altered to reduce some of the rent captured through developing the ‘lowest hanging fruit’ to increase the cost-effectiveness of the CDM. This however may come at a cost to credibility to the market. The private sector needs a credible, long term regulatory framework in order to invest in infrastructure change and any severe changes to the mechanism may reduce investment just when the scale of investment needs to increase. A future with higher CER prices is essential for encouraging the development of projects, especially as the “low hanging fruit” are used up. Faith in a continued high price is needed to encourage investment in the market during the infancy where risks are high and returns therefore should be high and generated quickly. Conversely, a high CER price increases the rent and exacerbates the loss in cost-effectiveness for the cheapest projects. The magnitude of the loss in future will depend on the cost of reductions and the price in the market. Should these merge over time the mechanism will inadvertently become more cost-effective.

8 Conclusion

In order to meet more stringent GHG reduction targets in the future more funding will be required. This can be through a scale up of investment and/or optimising the application of existing funds. The CDM represents a large investment for reducing GHG emissions and so increasing the cost-effectiveness can either reduce the overall cost of reaching the targets or increase the GHG reduced. The optimal cost-effectiveness payment for CDM projects is defined as paying only the cost of abatement for the emissions reductions. Measuring the costs of abatement against the price paid for the CO₂ reduction is somewhat more difficult. This paper offers a framework for doing so and uses it to analyse the whole pipeline quantitatively.

The loss in cost-effectiveness is difficult to measure but the costs can be shown against different prices estimated in the market. This paper uses the information available on costs within the project PDD's and prices in the market to illustrate that the large majority of the projects were developed at a cost below the lowest market price for CERs and the projects can be grouped into the technology used. The high price for CERs has allowed for a range of projects with different costs to be developed quickly and the cheap abatement options have dominated the market. The CDM has therefore been a success at identifying new and cheap ways of reducing CO₂ emissions, attracting foreign investment to developing countries and expanding the supply of credits but pays large rents for doing so which may not contribute to GHG reductions. The CDM could be improved to fulfil the goal of cost-effective GHG reductions by linking the price per CER to the cost of generating a CER.

The CDM has reduced the cost of compliance for Annex-1 countries but the GHG reductions could have been made at a lower cost. The CDM has not met the goal of economic effectiveness as defined in this paper. It is clear from the analysis that the CDM was not designed purely for economic effectiveness and so it should be of little surprise that a complex, ethically loaded mechanism does not achieve the reductions at the lowest cost.

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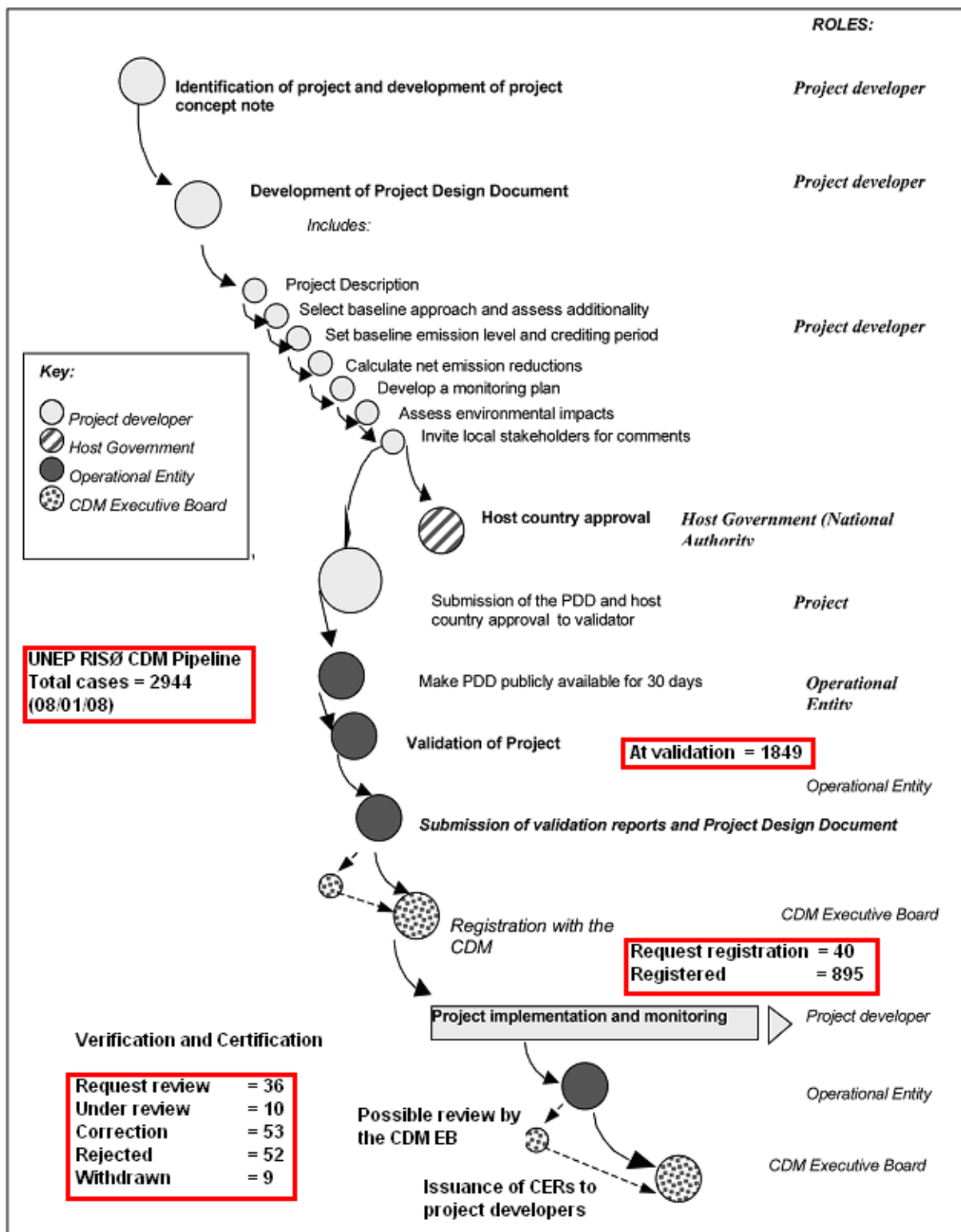
10 Appendixes

10.1.1 Appendix I: Approved methodologies under the CDM

Project activities that result in reducing emissions of one or more of the six GHGs, namely, Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF₆), are eligible for CDM. These project activities may reduce GHGs from energy use and production (fuel combustion and fugitive emissions from fuel), industrial processes, use of solvents and other products, the agriculture sector, and waste management. Projects that sequester (store) carbon in biomass, through afforestation and reforestation activities, are also eligible under CDM. The following types of GHG mitigation or sequestration projects and activities can be eligible for CDM:

- Renewable energy technologies
- Energy efficiency improvements - supply side and/or demand side
- Fuel switching (e.g., coal to natural gas or coal to sustainable biomass)
- Combined heat and power (CHP)
- Capture and destruction of methane emissions (e.g. from landfill sites, oil, gas and coal mining).
- Emissions reduction from such industrial processes as manufacture of cement
- Capture and destruction of GHGs other than methane (N₂O, HFC, PFCs, and SF₆)
- Emission reductions in the transport sector
- Emission reductions in the agricultural sector
- Afforestation and reforestation
- Modernization of existing industrial units/equipment using less GHG intensive practices/technologies (retrofitting)
- Expansion of existing plants using less GHG intensive-practices/technologies (Brownfield projects)
- New construction using less GHG-intensive practices/technologies (Greenfield projects)

10.1.2 Appendix II: Overview of the registration procedure and the projects at each stage



10.1.3 Appendix III: European countries make up the majority of CDM project buyers.

Buyer countries	Number of projects
Austria	40
Belgium	2
Canada	55
Czech Republic	1
Denmark	43
Finland	16
France	46
Germany	117
Greece	0
Hungary	4
Iceland	0
Ireland	4
Italy	98
Japan	298
Latvia	0
Luxembourg	8
Netherlands	286
New Zealand	1
Norway	4
Portugal	1
Spain	79
Sweden	134
Switzerland	131
United K.	864
CDCF	3
WBCF	0
NEFCO	0
IBRD	1
CCAC16	1
n.a.	1337
Total	3574

Note: In some project more than one investor country participates.

Source: UNEP/Risø pipeline 08/01/08

10.1.4 Appendix IV: Overview of EU ETS Import Limitation on CERs

Country	Emission Cap under EU ETS 2008-12 (Mt)	Limitation on CER/ ERUs, %	Limitation on importation of CER/ ERUs 2008-12 (Volume of credits, Mt)	Level of limit
Austria	154	10	15	Installation level
Belgium	293	Flanders: 24 (energy), 7 (industry); Wallonia: 4; Brussels: 8	25	Installation level
Bulgaria*	220	12.6	28	Installation level
Czech Rep.	430	10	43	National level**
Cyprus	28	10	3	N/A
Denmark*	119	19	23	Electricity production sector: 32.5%; Other sectors: 7%.
Estonia	64	0	0	N/A
Finland	188	10	19	Installation level over 5 yrs.
France	664	13.5	90	Installation level
Germany	2266	20	453	Installation level
Greece	346	9	31	Installation level
Hungary	135	10	13	N/A
Ireland	112	10	11	Installation level over 5 yrs.
Italy	979	15	147	Installation level over 5 yrs.
Latvia	17	10	2	installation level
Lithuania	44	20	9	N/A
Luxembourg	14	10	1	Installation level
Malta	11	0	0	N/A
Netherlands	429	10	43	Installation level
Norway*	65	38.2	25	N/A
Poland	1044	10	104	Installation level
Portugal	177	10 (general), 50 (combined cycle plants)	18	Installation level
Romania*	345	10	45	Installation level
Slovakia	155	7	11	National level**
Slovenia	42	15.8	7	National level**
Spain	762	20	152	Installation level
Sweden	114	10	11	National level
United Kingdom	1231	8	98	Installation level. Limit set per year, but banking between years allowed.
Total	10443		1416	

* Point Carbon estimates, given no EC ruling at time of writing

** First come, first served for installations

Source: CD4CDM, A fair price for Carbon.