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A Methodology to Price Certified Emission Reduction Certificates from Clean Development Mechanism Projects

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A research report submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfillment of the requirements for the degree of Master of Business Administration

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ABSTRACT

Certified Emission Reduction certificates (CERs) are created by reducing carbon emissions in a Clean Development Mechanism (CDM) project. Very little CER price information is available to the public, as most of the deals are traded over the counter.

The aim of this research is to model the price of CERs from a CDM project. The research methodology comprised of interviews with CDM experts to determine the risk factors influencing CER price and possible valuation methodologies which can be used in pricing CERs from a CDM project.

It became evident that while the risk factors influencing CER price are well known, little is known about the impact these factors have on the final price of CERs. The final model developed was based on a combination of cash flow discounting and hedging using theoretical call options. Using a private equity hurdle rate to indicate project risk, forward selling CERs as EUAs to generate future cash flows, and using implied CDM risk, yields an equation for the price of CER. The model was extremely useful in linking the publicly quoted four tier price category by Point Carbon to a percentage of risk associated with a CDM project.

DECLARATION

I declare that this research project is my own, unaided work. It is submitted in partial fulfillment of the requirements of the degree of Master of Business Administration for the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other university.

………………………………………. Date: ………………………………

Rajesh Purohit

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I would like to thank Tudor Maxwell for his invaluable lessons. During the research, he has been a guiding star for me. I would also like to thank everyone whom I interviewed. I have gained tremendous amount of knowledge in a field close to my heart - Carbon Finance. My colleagues were superb, and aided wherever possible. Lastly, I would like to thank my wife for all the love, support and understanding during the research.

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LIST OF ABBREVIATIONS

AAU Assigned Amount Unit (unit for emissions trading)

Annex 1 The 39 developed countries in Annex 1 of the Kyoto Protocol that have GHG reduction commitments

CDM Clean Development Mechanism

CER Certified Emission Reduction (unit for the CDM)

CO2e Carbon Dioxide equivalent

COP Conference of the Parties

COP/MOP Conference of the Parties and Meetings serving as the meeting of the Parties to the Kyoto Protocol

DOE Designated Operational Entity: an accredited organisation that validates and certifies CDM projects

DNA Designated National Authority

EAU European Amount Unit

EB Executive Board: the highest authority for the CDM under the COP/MOP.

ERU Emission Reduction Unit (unit for JI)

EU European Union

EU ETS European Union Emissions Trading Scheme

GHG Greenhouse gas

IPCC Intergovernmental Panel on Climate Change

IRR Internal Rate of Return

JI Joint Implementation

PCF Prototype Carbon Fund (a WB activity)

PDD Project Design Document

SD Sustainable Development

UNFCCC United Nations Framework Convention on Climate Change

CHAPTER 1: INTRODUCTION TO THE RESEARCH PROBLEM

The purpose of this study is to derive a methodology to price Certified Emissions Reduction certificates (CERs) from a Clean Development Mechanism (CDM) project.

1.1. DESCRIPTION OF THE PROBLEM AND BACKGROUND

The Kyoto Protocol came about as a means to abate the effect of green house gases on climate change (see Appendix A for effect of greenhouse gases). It was adopted at the 3rd session of the Conference of the Parties (COP3) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Kyoto, Japan in December 1997 (Institute for Global Environmental Strategies, 2006).

Through the Kyoto Protocol, developing countries can participate in Clean Development Mechanism (CDM). CDM is one of the project based mechanisms of Kyoto Protocol specifically catering for sustainable development whilst reducing harmful gases affecting the atmosphere (King, 2006). Under the Kyoto Protocol, the sale of certified emissions reduction certificates (CERs), the output of CDM project related to GHG abatement, is permitted to offset project costs, and supplement allowances for the buyer.

CERs are created by projects in developing countries without targets under the Kyoto Protocol (Wilder, Willis, Lake, 2005). Various project and regulatory risks have to be overcome (in an approved CDM project) before any emission reduction certificates are granted by the Executive Board (EB). The Executive Board is appointed by the UNFCCC and is responsible for overseeing the CDM process, approving third party validators/verifiers, approving projects and ultimately issuing carbon credits for CDM projects (Institute for Global Environmental Strategies, 2006).

In order for a project to be considered a CDM project, it must overcome the "additionality" clause which states that all the greenhouse gas emissions reductions claimed as part of a CDM activity must be additional to that which would have occurred in the absence of finance and in the normal course of events (business as usual) , i.e. if the project would have gone ahead without the CER financing, or if the project is required under the laws of the host country, then the project will not qualify for CDM status (Greene, 2006).

This additionality clause implies that the revenue from sale of CERs is needed by the project, to be classified as a CDM project. Thus, a project could enter into a forward sale agreement of CERs at a certain price with future delivery. Further financing could be secured by using the forward sale agreement as collateral. This leads to the question of the price of CERs.

The European Union (EU) has created an emissions trading scheme (ETS) which ties in with the Kyoto Protocol. The EU ETS has already allocated allowances to Member States for the period 2005 to 2007 (known as phase one in the EU ETS). Allowance meaning that each member country has been allocated a limit to emit GHGs per year. At end of each year in the compliance phase, the participating countries have to present allowances to offset the emissions. A penalty is payable if more GHGs are emitted than allowances EU ETS (Article 16, Directive 2003/87/EC). In tying in with the Kyoto Protocol, the EU ETS allows the purchase of CERs to offset emissions. Due to the risk involved in a CDM project and CER registry process, CERs trade at a discount to EU allowance (EUA). This presents an attractive option in that it provides a cheaper alternative to the EU allowance. The risk-reward factors have also drawn the speculators in to the carbon market.

CERs could be bought to meet compliance; or traded in the market as a financial instrument. There is already a secondary market for CERs, where the price is set by market forces. CERs bought from a CDM project could be sold in the secondary market place as high quality (low default and delivery risks) with the seller managing the CER risks (for example by building a diversified portfolio), and profiting from the difference between the initial purchase and the sale of high quality CERs (Byers, 2005). This leaves the question of the price of CERs from a CDM project. Capoor & Ambrosi (2006, p. 42) attest to this:

"Significant volumes of allowances – and virtually all project-based transactions – are traded over the-counter, brokered or made through private bilateral deals. This creates information asymmetry in the market, making reports such as this one necessary. The lack of transparency – and absence of disclosure requirements - is particularly relevant in a young market with high price volatility".

Kyoto Protocol specifies stringent conditions on a project to be classified as a CDM project. In addition to the conventional project risks, the carbon regulatory risks make it very difficult to price the CERs.

The secondary market prices the CERs on a forward pricing mechanism, and is driven by market conditions i.e. demand and supply. However there has not been much research on a fair price of CER from primary source, a CDM project.

1.2. PURPOSE OF STUDY

The purpose of this study was to derive a methodology to price CERs from a CDM project. This was accomplished by determining the project and regulatory risk factors, assessing the impact these factors have on a CDM project and applying current valuation techniques to arrive at a price for project specific emissions reduction certificate.

1.3. STRUCTURE OF THE REPORT

The following section, chapter two contains details about Kyoto Protocol, Clean Development Mechanism, the International Transaction Log, CERs, the risks associated with CERs and valuation techniques. Chapter three and four covers research question and methodology respectively. Chapter five includes the results from the interviews, and pricing model from this research. Discussion of the results follows in the next chapter, and the reports closes off with conclusion in chapter seven.

CHAPTER 2: LITERATURE REVIEW

2.1. KYOTO PROTOCOL AND CLEAN DEVELOPMENT MECHANISM

Kyoto Protocol came about as a result of the need to effect on climate change by restricting the amount of green house gases (GHGs) emitted in the air. It envisages a global system of caps in carbon emissions and setting up of trading system in carbon credits from 2008. Each signatory in Annex 1 (developed countries indicated in Appendix B) has been set an allowance in the period 2008 to 2012. An allowance gives the holder the right to pollute an amount equal to one tonne of carbon dioxide. At the end of the period, each country will have to produce allowances. Any Annex 1 country that fails to meet its Kyoto target will be penalised by having its reduction targets decreased by 30% in the next period (UNFCCC, 2006). Carbon assets recognised in the Kyoto Protocol are all equal to one tonne of carbon dioxide (CO_2) abated or sequestered. Kyoto Protocol allows for participation in CDM projects in Non-Annex 1 countries (developing countries) in return for certified emissions reduction certificates (CERs) (UNFCCC, 2006).

The carbon market helps countries/companies meet their emissions target set by Kyoto Protocol caters by providing mechanism to trade carbon equivalent emissions/allowances (Walker, 2006). Kyoto Protocol provides a means to reduce the effect of green house gases (GHG) on global warming and climate change. Its aim is to lower the global GHG gases by 5% of the base level in 1990.

The Clean Development Mechanism is an outcome of Kyoto Protocol and is one of the flexible mechanisms that allow for emission abatement and creating sustainability in Non-Annex I countries. Developed countries subject to emissions targets are classified as Annex I countries, and those developing countries, that have ratified the protocol, but are not required to limit emissions up to year 2012, are known as Non-Annex I countries.

CDM projects create CERs which can be traded as financial instruments on the various exchanges and over-the-counter. The trading price of CERs is linked to the European Union Allowance (EUA) price, and trades at a discount to the EUAs due to the risks involved in a CDM project. These risks are broadly categories in to conventional project risk and CDM related risk. Project risk covers: technology, human resources, contractor, counterparty, amount of debt (adequate working capital), sovereign and political environment (Spalding-Fecher, 2002). The CDM Risks include the following: whether the project uses approved or new methodology, the project passes environmental impact assessment and sustainability criteria, the project gets go ahead from local Designated National Entity (DNA), is verified by a Designated Operational Entity (DOE), acceptance of project by CDM the Executive Board (EB), and the verification of CERs (the quantity of emissions mentioned in project design document (PDD) versus the actual emissions). The CERs are for future delivery and as a result, the market prices them using forward contracts .

The attraction of CDM credits (CERs) is, in theory, threefold: they are less expensive than the tradable allowance units – European Union Allowance (EUA) and Assigned Amount Unit (AAU); substantial profit can be made from CERs acquired from source; additional finance could be secured on an existing project due to the attractiveness of CERs. (africapractice, 2005). Figure 1, below, demonstrates how the European Union's Trading Scheme is linked to the global Kyoto Market. The diagram below is intended to show the fungibility of CERs and other emission reduction units.

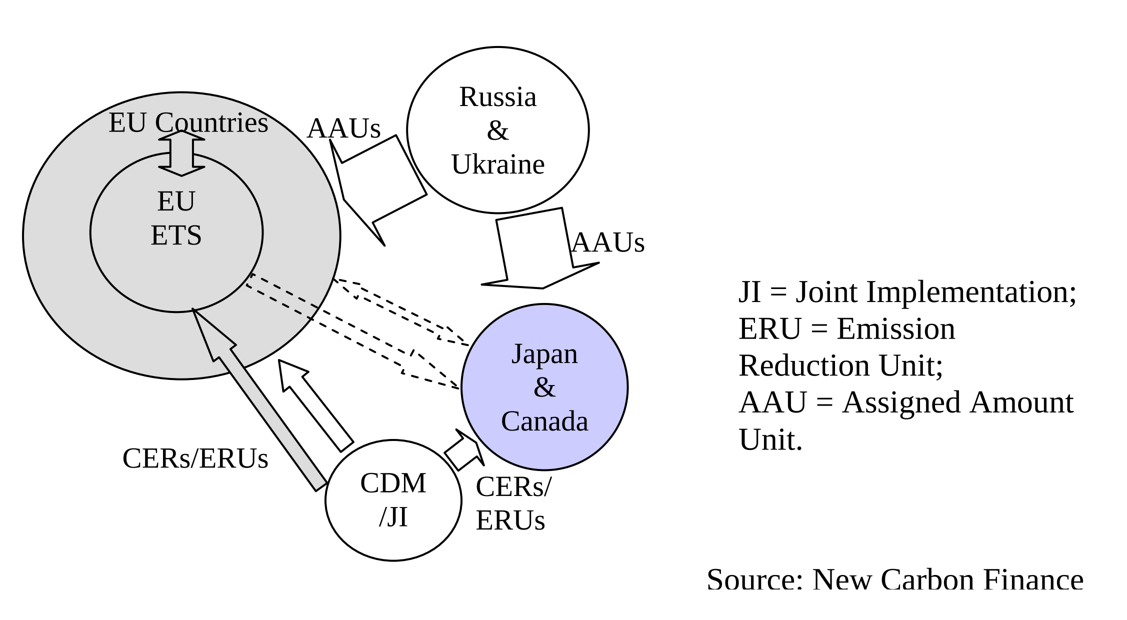


Figure 1: Interaction between the EU ETS and the Global Kyoto Market

In the EU ETS programme, each country is assigned an amount it can pollute. The monitoring period is broken in to two phases. The first phase is from beginning of 2005 to end of 2007, and the second phase matches the one from Kyoto Protocol, 2008 to 2012. In the EU mechanism, the participants will be subject to a penalty of 40 euros in Phase 1 and a penalty of 100 euros in Phase 2 per tonne of extra carbon equivalent emitted over the set allowance EU ETS (Article 16, Directive 2003/87/EC). An entity is free to trade the allowances or acquire them in order to meet its obligations. EU ETS also allows certified emission reduction certificates (CERs) to supplement the allowances of the Member States. As the EU ETS is the most sophisticated carbon market, and due to the ability to use CERs to offset emission, CER prices are linked to EUA prices. In essence, if a CER is guaranteed (i.e. it has the same risks as EUA); it should trade at the same price as EUAs.

2.2. INTERNATIONAL TRANSACTIONAL LOG (ITL)

There has to be a system which validates records and links the different emission reduction systems. Currently, the EU members are linked to the communication hub and EU transaction log via the national registry as shown below in Figure 2.

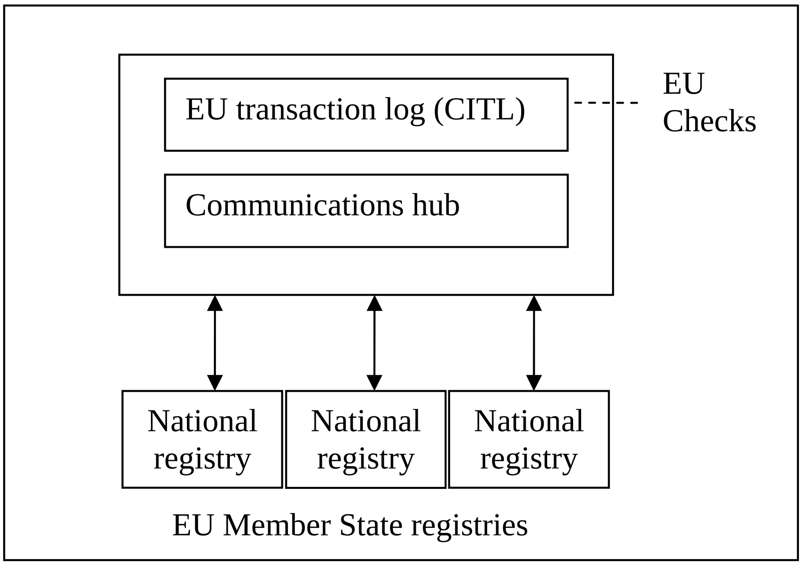


Figure 2: EU ETS Transaction Log

The future Kyoto Protocol communication will look as shown in Figure3. Current CER pricing takes in to account the absence of ITL, and accounts for it by discounting the price of CER by a certain margin. For Kyoto to be successful, the ITL has to be up and running, so ITL risk has to be seen as minimal (close to zero).

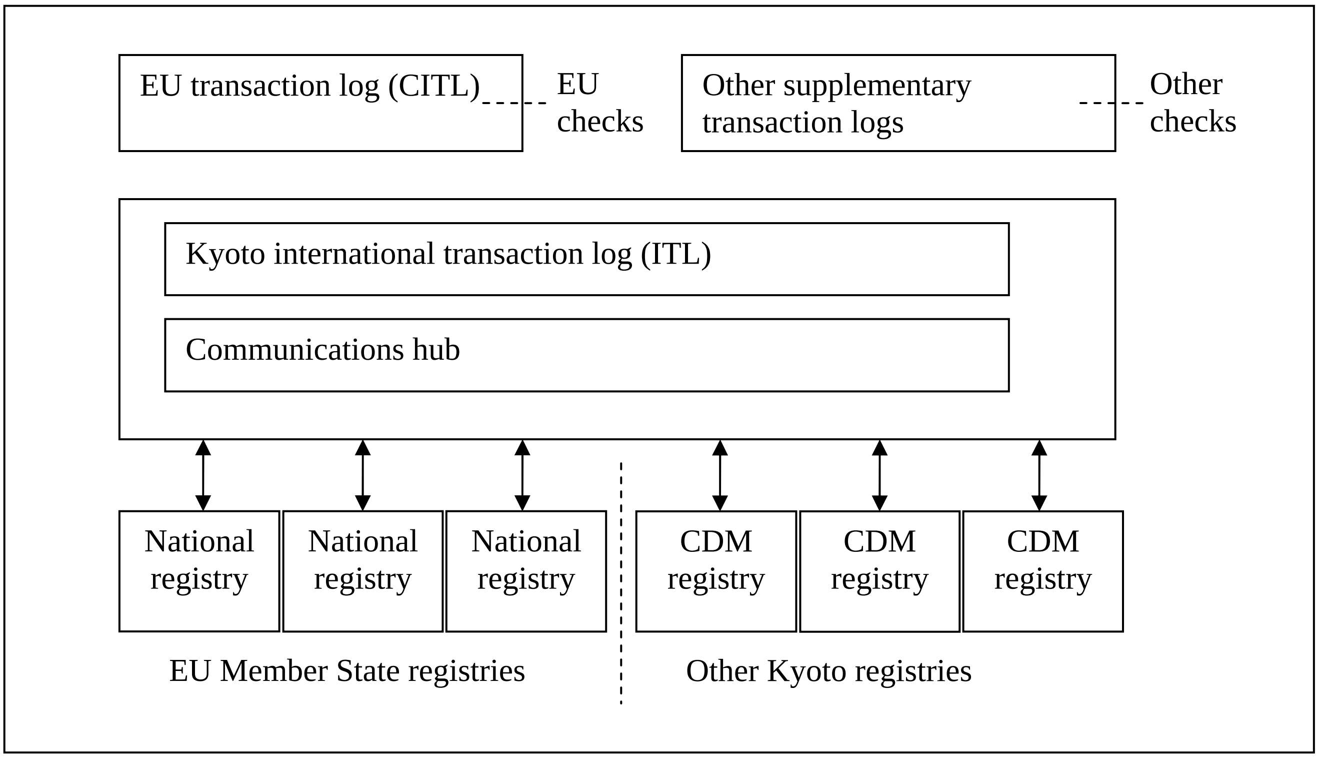


Figure 3: Kyoto (CER) Transaction Log

The ITL validates transactions, feeds EU transactions to the CITL for further checking, builds up records of holdings and transactions which mirror registries, reconciles ITL records with registry records, notifies registries of required transactions, and safeguards integrity Kyoto Protocol accounting. ITL is expected to be completed by November 2006 and registries and CITL to be successfully connected by April 2007 (Howard, 2005).

2.3. CERS

Certified Emission Reduction certificates (CERs) are carbon assets created through CDM projects. A tonne of carbon dioxide equivalent reduction gains one CER. Certified Emission Reduction certificates are generated from a qualified CDM project as shown in Figure 4 below. The risks shown in Figure 4 are referred to as CDM regulatory risks. A project can be financially viable, but may not generate CERs if the regulatory issues are not met. Thus these risks have to be taken in to account in the pricing model. These regulatory risks are reduced with time, as more information becomes available about the project. These regulatory risks can be reduced if the project follows an approved methodology (africapractice, 2005).

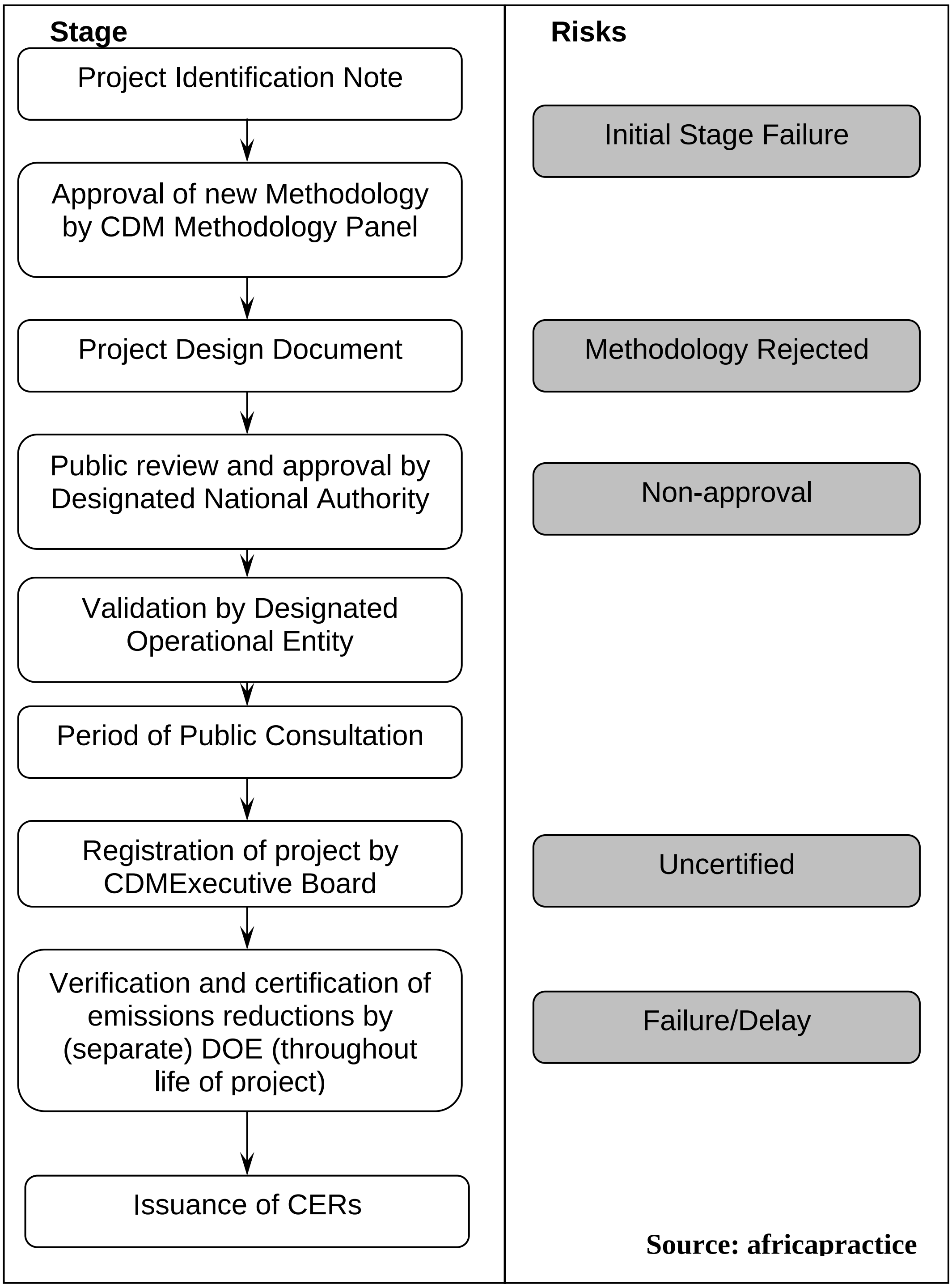


Figure 4: Stages in a CDM Project

The above is not a simple linear process. Each stage has a risk associated with it. Figure 5 illustrates the decision making process and the binary risks (Nahar, 2006) involved in a CDM project. Nahar calls it binary risk, because nonapproval at each step results in CDM project failure. Approval does not guarantee the theoretical CER volume mentioned in project design document will be issued. The issued CERs are based off the monitored emissions, and may be substantially different from the project design document. Fewer CERs may be issued if baseline calculations are changed.

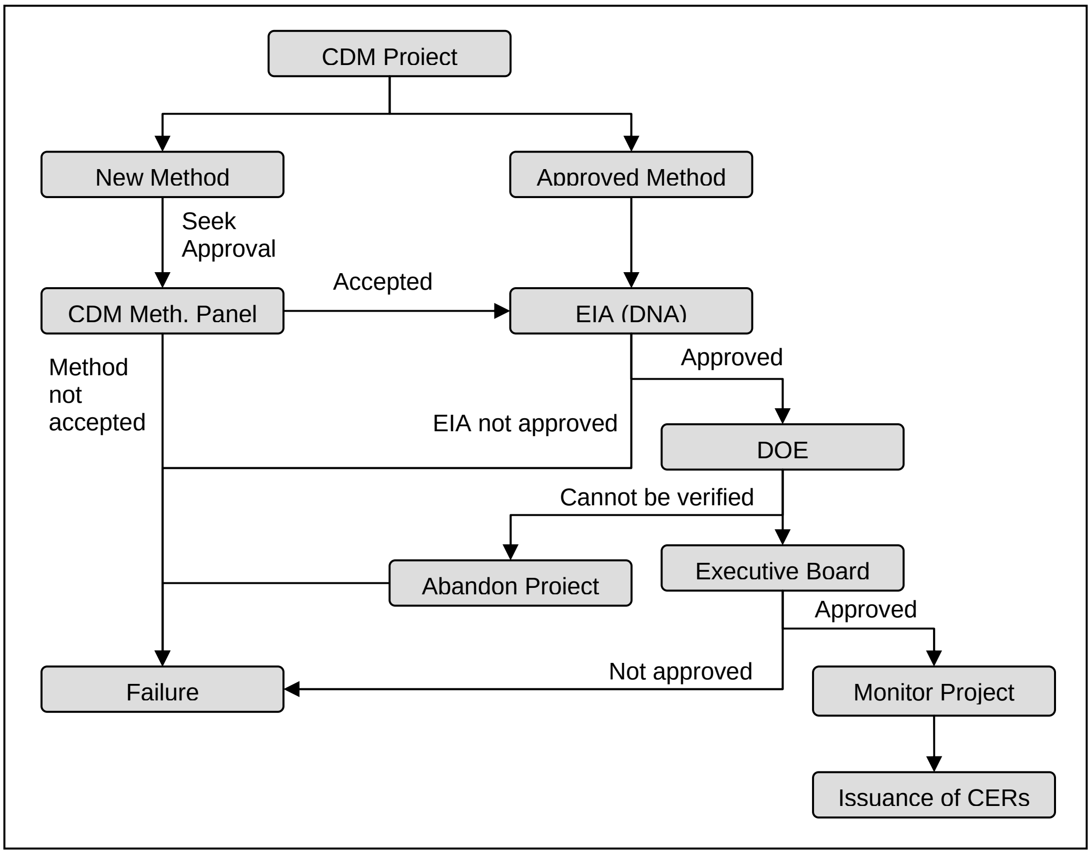


Figure 5: Decision Flow of CDM Project

Interest in CERs come from five general groupings – public buyers (government and multilateral institutions), private funds and project financiers, brokers, private companies and offset purchasers (SouthSouthNorth, 2004). A private company could buy CERs to be within its limits, giving the CER holder the right to pollute or it could be buying for trading purposes (it would have a specific view on the CER price). There is also a direct (equity) investment (Shell Trading, 2006) that could result in a return on investment in addition to CERs.

Price of CER has been grouped in to four major categories (Nordseth, 2006) depending on the types of emission reduction purchase agreement (ERPA). These categories their description is shown below in Table 1.

Table 1: Current CER prices and Point Carbon's price categories

Price/Risk category	Approx. price range (Euro/t CO2e)	Description
1	3-6	Non-firm volume. Buyer buys what seller delivers even if emissions reduction turns out not to qualify as CERs.
2	5-10	Non-firm volume. Contract contains preconditions, e.g. that the underlying project qualifies for the CDM.
3	9-14	Firm volume. Contract contains preconditions (as above). Usually strong *force majeure* clause and high credit rating requirements.
4	12-14	Firm volume. No preconditions. Forward spot trades will in future fit this category. Currently only the JSE Carbon Credit Notes fit under this category.

"These categories are broad, and prices vary within them, according to specific price determinants linked to project market maturity" (Eik, 2006, p. 12).

Point Carbon (CDM & JI Monitor, 2 May 2006) indicate that a rough rule of thumb is to price CERs at half the price of EUAs. From the table above, this can only be applied to category 2 – if the buyer takes the risk.

An emission reduction purchase agreement specifies the details of the purchase. They can vary from fixed volume and exposure to regulatory risk to fixed volume and guaranteed CER delivery (irrespective of project fruition). Due to continuing confusion about regulatory environment, De Witt Wiljnen (2006) considers the quality of current ERPAs to be below par. Wilder (2005, p. 1) echoes similar concerns: "The contracts are perhaps least sophisticated in the one area entailing the greatest risk: where CERs are purchased directly from CDM projects".

Once the project qualifies for the CERs, it goes through monitoring, verification and the final issuance of CERs. The CERs are sold according to the ERPA agreement. The buyer can hold the CERs to offset its emission requirement, or trade in the market. Once up and running, the International Transaction Log (ITL) will allow the transfer of CERs from host nation.

Wilder, Willis and Lake (2005) suggest that CERs may not be able to trade at the market level of EU allowances due to the stringent verification procedures involved in a CDM project.

Hartridge (2006, p. 5) interprets Article 16(3-4) of Directive 2003/87/EC: "Payment of the excess emissions penalty shall not release the operator from the obligation to surrender an amount of allowances equal to those excess emissions when surrendering allowances in relation to the following calendar year." If Hartridge's interpretation is true and emission reductions are in demand, it could imply that the price of CERs could go much higher than the current penalty of 40 Euros in phase one and 100 Euros in phase two.

2.4. RISK ASSOCIATED WITH CERS

There are a numerous risks associated with CDM project, making the pricing of CERs very difficult. Generally, the risks are split in to two categories. Those related to the project i.e. the development risk and those related to CDM/CER, the regulatory risk(Lee, 2004).

According to Spalding-Fecher (2002), the risks faced by a CDM project include: technical risk, policy risks, market risks, liability risks, credit risk, country/political risk, environmental/health/safety risk, qualification risk and force majeure.

Monroy (2006) includes a few more to those mentioned above, namely: post 2012 commitments, lack of homogeneous criteria for methodology approval, excess supply – "hot air" (e.g. Russia is sitting with huge amount of excess allowance units as there has been a economic downturn since 1990).

Capoor and Ambrosi (2006) highlight a further risk, namely, EU Member States may impose supplementarity restrictions and restrict market access of CERs. In that event, CERs may be priced at a discount to EUAs.

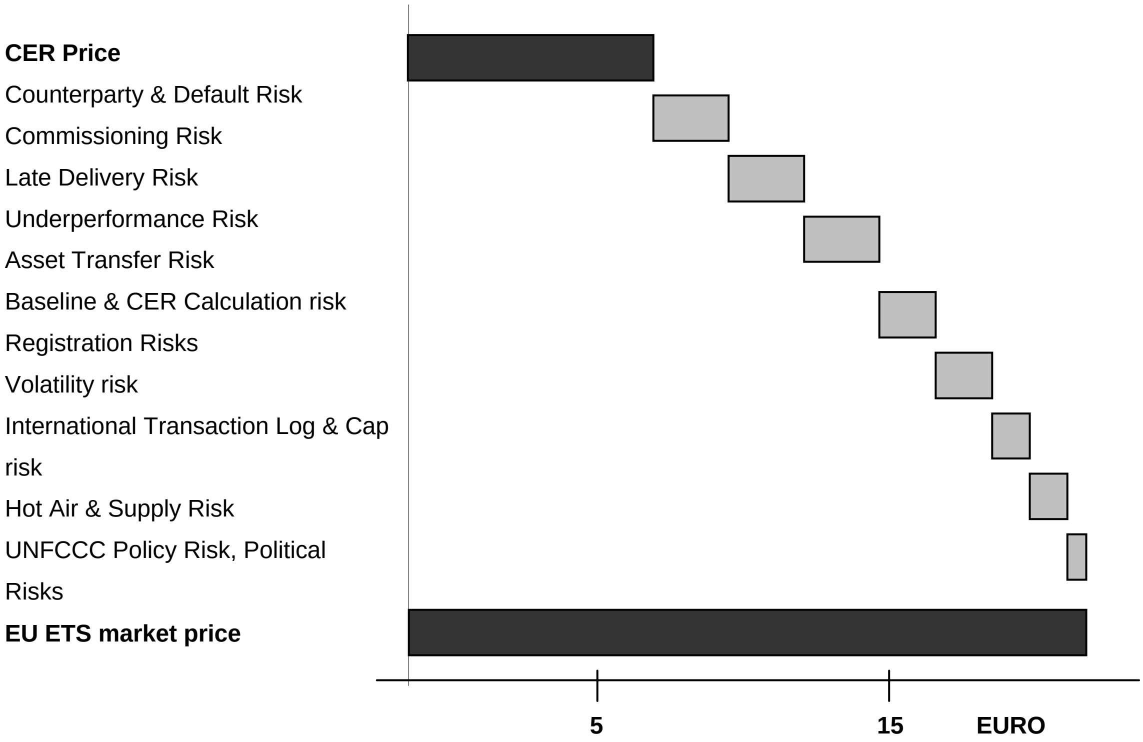
SouthSouthNorth (2004) has a more detailed list of risks relating to CDM projects as shown in Table 2.

Table 2: List of CDM Project Risks

Risks	Description
Construction	The construction risks associated with the project.
Operation and Maintenance	The operational risks – experience of management, employees and contractors,
Validation	The project is validated by the Designated Operational Entity.
Underperformance	The project does not produce the amount of CERs mentioned in the project design document.
Financial	Availability of working capital.
CER Market Uncertainty	The fungibility of CERs is a risk; The absence of post-phase one of Kyoto Protocol is also a risk for CERs outside the 2008 to 2012 period.
Exchange Rate	Foreign exchange risk.
Demand	The demand of CERs
Legislative	Legal risks.
Location	Physical site.
Country	Country risks – investment environment
Any Other?	Other risks.

It is plausible to use the market's forward valuation methodology as the carbon credit market is bound to grow. Cameron and Allen (2005) suggests that companies will lend the carbon credits and earn an interest, thus propagating the use of forward markets.

Figure 6 below indicates pricing determinants and the effect they have on the price of CER based off EUA price.



Source: EcoSecurities

Figure 6: CER Price Structure

The diagram above pictorially illustrates the expected effect of reducing the EUA price to finally arrive at the CER. The exact discount amount for each factor is, unfortunately, absent.

2.5. VALUATIONS

Carbon is gradually being recognised as a factor that needs to be incorporated into all calculations of equity value, credit risk, corporate risk management, capital spending and project viability (Tang, 2005), thus valuation of carbon assets is vital to any organisation.

There is no evidence of a standard methodology to value Certified Emissions Reduction certificates (CERs). Eik (2006) mentions structuring prices of CERs according to consistent criteria based on reality rather than perceptions.

As carbon market is based on compliance, the regulations will determine the interaction of the demand and supply factors, which in turn will determine the price of the carbon assets (reference IEAT, 2006).

Carbon finance is a relatively new area, and as such, there are no detailed models to price CERs. There are a few proprietary models, but they are regarded as providing competitive advantage, so they can only be used as a "black box" for a fee.

SouthSouthNorth (2004) a non-profit organisation, however, does have a web-based spread-sheet model to price CERs. SouthSouthNorth's approach in pricing CERs is to calculate expected future CER price based off the likelihood of occurrence of risk (as shown in Table 1) and its impact on the spot price of CER. The impact is quantified as the percentage change in spot CER price due to each risk factor. The projected CER price is used in project valuation.

Sinclair(2006) calculated the historical average price of CER relative to December 2008 EUA prices to arrive at a ratio price equal to 31% of the EUA price. It was acknowledged that the calculated numbers were considerably lower than the generally accepted CER price in the market due to lack of detailed information needed to derive a pricing model.

"Analysis of all of CDM transaction in the Point Carbon's database indicated CER prices consistently varied according to risk distribution", increasing over time, and increasing with seller risk (Nordseth, 2006, p. 8).

As there is a significant gap between buyers' and sellers' view on risks (Nordseth, 2006), a general valuation methodology based on project risks would help CER buyers/sellers negotiate a reference point. A valuation methodology can also help a project acquire loans from financial institutions (which could be instrumental in determining the success of the project and also provide proof of additionality – necessary to qualify as a CDM project).

There could be numerous methodologies applied to price CERs:

Present value of expected future cash flows of the project (Firer, Ross, Westerfield & Jordan, 2004). The problem with basic discounted cash flow model is the difficulty in obtaining the discount rate. Generally, the average cost of capital (wacc) is used as the discounting rate.

Usually, if cost of capital, which is approximated by wacc, is not know, the rate is derived from a similar proxy company. However, due to the infancy of carbon finance, there are very few proxy companies, and little or no market information about them.

An extension of the discounted cash flow methodology could be used in form of calculating the internal rate of return (IRR). Firer, Ross, Weterfield and Jordan (2004, p. 261) state the IRR rule as follows: "Based on the IRR rule, an investment is acceptable if the IRR exceeds the required return. It should be rejected otherwise." If an investment decision in a CDM project is purely based on profits generated by the purchase of CERs from a project and the subsequent sale of the CERs at market price, calculating the internal rate of return will be possible. A project finance approach generally uses this approach. From a seller's point of view, the minimum price CER should be sold at is the price generated by overcoming the minimum acceptable rate of return for the project to proceed.

Gilbert (2004) suggests using real options (option on an asset) in addition to net present value if two conditions – uncertainty and management flexibility – are considered in the project. CDM projects will be subjected to both, thus following Gilbert's argument Real Options could provide a valuation possibility. Real Options have also been used in capital budgeting (Tompkins). A project could be valued without the carbon component, and the option to register and subsequently delivery of CERs can be seen as management's choice. However, the lack of project risk data may pose valuation difficulties. The management flexibility and the information which will become available in future will allow pricing of CERs from a CDM project using Real Option theory.

Point Carbon (2006, Carbon Price Forecasting) approached the pricing of EUAs using fundamental analysis. They first established the demand and supply as follows:

Gross Carbon Balance = Emissions / (Cap + CERs + NERs)

The numerator, Emissions, is dependent on weather, fuel prices and GDP – the determinants of the emissions produced in the atmosphere, and the denominator is the total of emissions allowances (the cap), emission reduction units and new entrant reserves. The above equation implies that the gross carbon balance is equal to one if the amount of emissions is equal to the sum of the allocated allowances and the other Kyoto Protocol emission reduction units. In essence this equation measures the demand and supply of the emission reduction units.

A number above one for gross carbon balance implies that the emissions are greater than the emission reduction units, and thus a greater demand for the emission units. A number below one indicates the reverse of the argument i.e. more emission reduction units are in the market.

Point Carbon then used scenarios and Monte-Carlo simulations to forecast prices. A possibility could be to use similar model to price CERs.

Spalding-Fecher (2002) proposes an alternate calculation to obtain the current value of CER as follows:

$$CV = \frac{FVxQxP_{sucess}xP_{qualifying}}{(1+r)^n}$$

Where,

CV = current value from sale of CERs

FV = future value of CER (per tonne)

Q = annual quantity of CERs (tonnes)

$P_{success}$ = probability of technical success

$P_{qualifying}$ = probability of credit qualification

r = discount rate

n = the period from now until delivery of CERs (in years)

The unknowns here are the future value and probabilities of success and qualification.

We do know that CERs, can be used to supplement EU allowances, thus, assuming that CERs have the same risks as EUAs, they should be trading at the same price. There is market data available for EUA prices. One could then use the spot EUA prices to arrive at a forward price of EUAs which can be used to assume a certain CER price in the future. A forward price for a particular forward contract is the delivery price that would apply if the contract were entered in to at that time. Hull (2000) provides a generalised formula for a forward price:

$$F_0 = S_0 e^{rT}$$

This equation implies that the forward price is in effect a future value calculation where the current spot price grows at a continuously compounded at rate r (risk free rate) for period T. The risk free rate is used because it assumes that the portfolio is a riskless portfolio.

A binomial valuation approach could also be used to price CERs. Hull's (2000) general formula for price of an option:

$$f = e^{-rT}[pf_u + (1-p)f_d], where$$
$$p = \frac{e^{rT} - d}{u - d}$$

The above formula is the present value of the sum of probability of future upward price and probability of future downward price.

Black-Scholes option pricing (Hull, 2000) which may be used in Real Options pricing (Gilbert, 2004) for call and put options (*c* and *p*) is as follows:

$$c = S_0 N(d_1) - Xe^{-rT} N(d_2), and$$
$$p = Xe^{-rT} N(-d_2) - S_0 N(-d_1), where$$
$$d_1 = \frac{\ln(S_0 / X) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}},$$
$$d_2 = \frac{\ln(S_0 / X) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

where,

c = price of call option

p = price of put option

S_o = Spot price of the underlying

X = Strike price of the option

N(d) = Normal Distribution

r = risk-free rate

T = time to expiry of the option

σ = volatility

Other methodologies may emerge during the interviews with valuation experts.

CHAPTER 3: RESEARCH QUESTION

The aim of this research is to derive a methodology to price Certified Emissions Reduction certificates (CERs) from a Clean Development Mechanism (CDM) project. This implies understanding the risk factors influencing the price of CERs. Thus the basic research question in order to develop a pricing model is: "how do you determine the price of CERs from a Clean Development Project?"

The above question is broken in to two further questions:

(1) What are the risk factors influencing the CER prices?

(2) How can these factors be used to develop a valuation methodology to price the CERs?

This first part involves determining the risk factors involved in a CDM project and how these factors interact to determine the price of CERs. The risk factors in a CDM project are shown in Figure 6 below. From a macro perspective, the CER market price (which is based on the demand and supply of emission reduction units) will also affect the price of CERs purchased from a CDM project.

The diagram below illustrates that CERs originate from a CDM project. The CDM project has two major risk categories associated with it. The sum individual risks under each broad category determines the ability of CDM project to deliver CERs, and thus the final price of CERs.

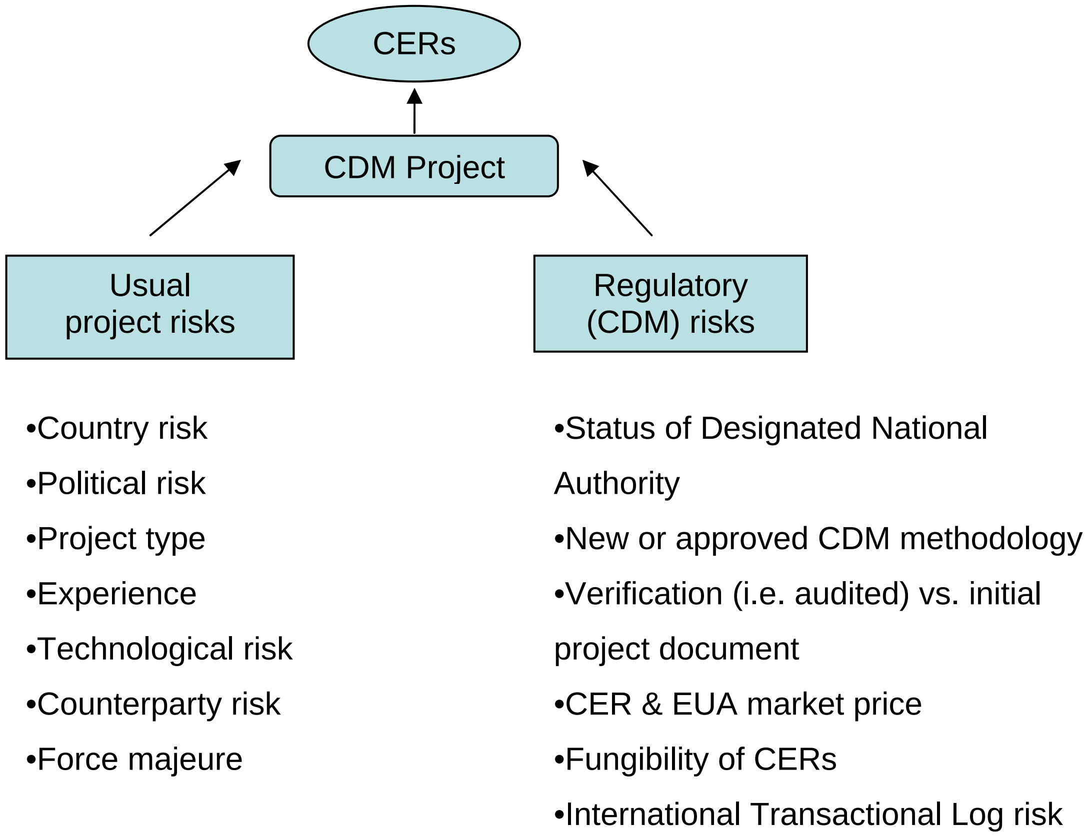


Figure 7: CDM Project Risks

The second part of the research is to determine a method to the price CERs using a method or combination of methods suggested by experts.

CHAPTER 4: RESEARCH METHODOLOGY

The purpose of this research is to build a model to price CERs from a CDM project. The methodology followed is shown below:

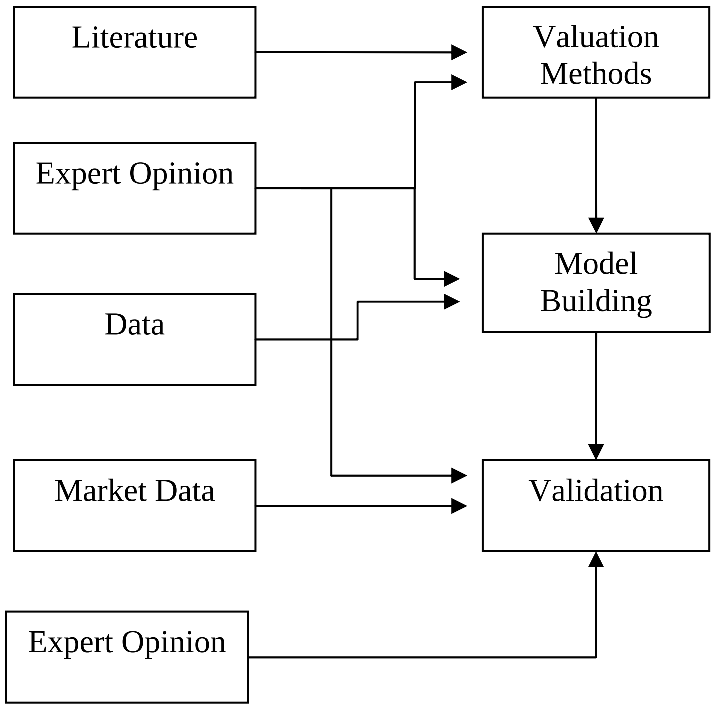


Figure 8: Flow diagram of the research

There are numerous valuation methodologies which can be applied to carbon finance. A combination of the different pricing techniques could also be applied to value CERs. The literature review in Chapter Two covers some of the valuation methodologies in detail.

Due to the infancy of the carbon field, price and contract information is seen to provide competitive advantage, and as a result, very limited information is available to public. Sinclair (2006) voiced similar concerns about the current CER data being inadequate to yield disaggregated information. Due to these restrictions, this research was based on expert opinion as suggested by Welman and Kruger (2001).

The purpose of interviewing CDM experts was two fold: (1) to learn about the risk factors affecting CER prices and how they affect CER price, and (2) determine a suitable method to price CERs.

The interviews consisted of detailed open-ended semi-structured interviews with CDM experts (see Appendix D for list of the experts). The questions asked were as follows:

- What factors/risks influence the price of CERs from a CDM project?
- How are these factors combined / weighted to result in the current market price?
- How can the risks be mitigated?
- What valuation techniques could I use to price CERs from CDM project?

The data and suggestions from CDM experts were used in the final model to derive the CER price for types of projects and different delivery risks. As a benchmark, these calculated prices will be tested against historical prices and current market prices. In later interviews, experts were also asked about the validity of the proposed valuation model.

Population, sampling method and sample

The candidates were chosen using a combination of convenience sample (based in South Africa) and "snowball" effect (Welman and Kruger, 2001). As the method focused on interviewing CDM experts, the population of this research is all CDM experts in South Africa. William Greene (2006) has a list of CDM experts in South Africa. Of the experts mentioned in the book, only thirteen are based in South Africa. Table 3, below, contains the list of CDM experts who were interviewed. Out of the list in Table 3, ten interviewees were from South Africa, two who were in South Africa during the course of the research, and one is based in Denmark.

Table 3: CDM Experts Interviewed

Experts Interviewed	Type of interview
William Greene (Point Carbon, CDM, London)	Personal
Harmke Immink (PriceWaterCoopers, Designated Operational Entity, CDM)	Telephonic
Colin King (Standard Bank, CDM & Project Finance)	Personal
Anton Louis Oliviers (NuPlanet Clean Energy, CDM)	Telephonic
Roon Osman (Shell, CDM, *London*)	Telephonic
Amit Oza (Nedbank, Carbon Finance & Valuations, London)	Personal
Gregor Paterson-Jones (Sterling Waterford, CDM)	Telephonic
Chris Purcell (ITPower, CDM)	Telephonic
Henk Sa (EcoSecurities, CDM)	Personal
Anne-Franziska Sinner (ECON Analysis, *Denmark*)	Email
Randall Spalding-Fecher (ECON South Africa, CDM)	Telephonic
Geoff Stiles (Marbek, CDM)	Personal
Emily Tyler (SouthSouthNorth, CDM)	Personal

Limitations

The lack of detailed publicly available data restricted the ability of the model to disaggregate inherent CDM risks. However, the available information was sufficient to develop a model using assumptions mentioned in the next section. It was acknowledged that due to the scarcity of detailed public data, the model from this research would be built upon when more information is available. Table 4 shows the amount of information necessary to develop a detailed pricing model.

Table 4: Information Necessary to Develop Model Without Assumptions

Factor	Description
Project Type	It influences the technology use, final CERs.
Methodology	Is it approved or new? It is also inked to project type.
Originating Country	The investment environment and CDM status of country.
Credit rating of Seller/Guarantee	Determines the default risk on the seller's side.
Credit rating of Buyer/Guarantee	Determines the default risk on the buyer's side.
Who takes risk?	In conjunction with credit rating, affects price of CER.
Volume of CERs	The amount of CERs at risk. Needed to establish expected cash flows.
Price of CER	Exact price needed (instead of a range).
Type of price	Fixed, floating, cap, etc.
Deal Date	Date the deal was done.
Delivery Date(s)	The date(s) the CERs will be delivered.
Benchmark Instrument	What instrument was the used as the benchmark. At them moment, it is EUAs.
Benchmark Instrument's Price/Rate	The price of the benchmark instrument.
Stage of CDM Process	PDD done? Approved by DNA? Verified by DOE? Approved by EB?

Compare the required data to current publicly available CER market information: price/risk category, deal date, price range, volume traded and delivery period. Only five pieces of data! As a result, the developed model yielded high level information about the CDM project.

Capoor and Ambrosi (2006, p. 44) state that "the volatility in EUA Phase I and price signals for EU forward contracts for 2008 have alternated between contango (future price higher than spot) and backwardation (future price lower than spot) over the past several months. This suggests continued market uncertainty about Phase II allocations. Fundamental demand in the carbon market is created by the cap. While weather and energy prices may add to the mix, it is the level of the constraint that helps establish market prices. The recent market reaction to the generous caps allocated in Phase I may give a fresh impetus to the Phase II caps, if the EU ETS is to be a centrepiece of the EU's plan to meet or exceed Kyoto obligations." This uncertainty makes pricing extremely difficult.

There are many ways to value a project, and the impact of the several regulatory issues associated with CDM project, and limited public availability of data makes pricing CERs extremely difficult. But a model was developed to price CERs with given risk level, or used to imply CDM risk given a price.

CHAPTER 5: RESULTS

5.1. FACTORS AND THEIR INFLUENCE ON PRICE OF CERS

All CDM experts agreed on the general risks associated with a CDM project, but could not indicate the risk weighting in pricing CERs. The general risks are shown below:

Table 5: Project and CDM Risks

Factors Influencing CER Price	Description
Project Risk	
Technology	Risks associated with new technology.
People / HR	Risks linked to work force and human resources issues.
Management	Experience of management.
Political	Investment environment of country.
Counterparty	Creditworthiness.
Financial	Adequate supply of cash/working capital for smooth running of the project.
Project Performance	Project has to perform to be able to generate CERs. However, it may operate, but deliver reduced amount of CERs.
Force Majeure	Force of nature.
CDM Risk	
Approved or new methodology	New methodology could be rejected by the Executive Board. It will also take longer time – thus lost revenue.
Approved by DNA	Project may not meet the sustainability issues, which results in zero CERs.
Verified project	Projects have to be verified by an independent party before accepted by the Executive Board.
CER verification	Once project is granted CDM status, it may not be issued CERs indicated on the PDD, thus the verification (auditing) risk.

Factors Influencing CER Price	Description
CDM Risk	
Country	Acceptance of Kyoto, how it deals with CERs, tax issues on CERs, environmental and sustainability issues.
ITL	International Transaction Log links the Kyoto units to other schemes. Failure will result in little demand for CERs.
Price of EUA	CER price is linked to EUA price, thus changes in EUA price will impact CER prices positively or negatively.
Market Risk	Supply and demand of emission Kyoto emission reduction units
Gold Standard	Indicates high sustainable development factor in project. It has a positive impact on price of CER.

Additional risks not mentioned by all the interviewees:

Hank Sa pointed out that the Executive Board (EB) could change a methodology in the future. An example of a change in baseline methodology demonstrated this risk. It had the effect of reducing the number of CERs to 60% of original amount.

Sa separated CER risk in to four broad categories: CER/EUA market risk (supply and demand of emissions reduction units and its influence on CER prices), performance risk (project performance as well as CER verification), CDM risk (Kyoto risks, change in base methodology, asset transfer), performance (CDM and project performance) and project risk (technology, people, experience, country, project type, foreign currency, force majeure, counterparty). The widely mentioned ITL risk was not seen as a risk.

Interestingly, it was suggested that due to the portability of CERs into different phases, a risk-less CER should be priced higher than EUAs (which cannot be transferred from Phase 1 to Phase 2). One rough method to calculate the premium was to analyse the variability of company's emissions against its allowances, and obtain a minimum level with high degree of certainty to forecast amount of EUAs needed. The varying portion can be hedged using CERs. However, this is beyond the scope of current this research, but a possible research topic for future.

Amit Oza viewed supplementarity risk as minimal, and best illustrated by the following argument: A CER bought by a Japanese entity which will not have to deal with supplementarity, it is a purely EU ETS consideration. Japan can use CERs to comply with Kyoto, and sell the assigned AAUs in to the EU market. In addition, many EU member states (Iberian countries) have already said that they will have 0% caps (even though countries like UK have caps). Therefore the CER can be brought into the EU ETS through Spain for instance and be sold to a company in UK, thereby getting around the UK cap. Once in the system supplementarity doesn't matter.

According to Anton Louis Oliviers, the type of buyer also influences the price paid for CER. There are three different types of buyers: direct buyers, buying to meet compliance, brokers and fund managers. Direct buyers are willing to pay a slightly higher price (with lower CDM risk – as the CERs are needed to meet the

Kyoto obligations). There is brokerage cost involved when dealing with brokers (the brokerage is usually a percentage of notional value, and can influence the CER price). The fund managers will manage the risks, and thus will be inclined to pay a lower price.

Anne-Franziska Sinner stated that the in general, the recent CER price-level is dependent on the EUA price – indicated by the strong price correlations of both price levels. The CER price, in practice, reflects a discounted EUA price (according to its non-delivery risk).

The International Emission Trading market which starts in the next trading period 2008-2012 will increase the demand for CERs – there will be greater number of private and institutional trading participants from different carbon markets. Thus, the price level will be a result of the total demand and supply of these credits. The EU ETS participants will represent only one player in this market, resulting in CER prince becoming independent of the EUA prices. The relation between them two will also alter as strong market determinants such as Russia's supply strategy, the total JI project potential, the total Kyoto Gap etc. becomes known.

Anne-Franziska Sinner agreed with assumption that riskless CERs are equal to EUAs if there is no banking option for EUAs or CERs and the delivery risk for

CER is the same. CERs can be banked, and in theory, they should have a higher price than EUAs if there is no risk attached to them.

Sinner viewed the likelihood of EUAs being bankable into the next (third) ETS period as being low, however, stated that that German draft NAP II allows banking which. The Second National Allocation Plans (NAP II) should help clarify the banking of EUAs in to the next phase.

Sinner mentioned that the ability of CERS to be banked for use in second Kyoto period is uncertain as well. Technically and legally (according to the Kyoto Protocol and the Marrakesh Accords) it would be possible on the international emission trading market, but there is uncertainty about the second Kyoto commitment period. However, the likelihood of ability to bank CER into 2013 is higher than for the EUAs.

5.2. SUGGESTED VALUATION METHODOLOGIES

All the experts indicated that the CDM projects involve numerous factors and their combination makes valuation of CERs extremely difficult, and thus the absence of CER valuation methodology.

William Greene suggested concentrating on a specific category of projects (e.g. landfill methodology which has been approved by the Executive Board). Details of approved projects are available, and could be used to calculate risk distributions which could be used in a pricing model. It was acknowledged that due to lack of data availability and relatively low number of approved methods, this approach is currently unsuitable.

Colin King suggested the use of bond pricing methodology to obtain a yield to discount the future cash flows. A purchaser of a new bond will price the bond by taking in to account the risks associated with the issuer. These risks are quantified as a margin to the relevant benchmark curve. The overall bond yield is the sum of all the risk margins plus the benchmark yield.

Geoff Stiles, preferred empirical evidence. It was suggested that South African companies currently involved in CDM project be surveyed to determine the risk weights used to calculate the CER prices used in the project design document (PDD) or emission reduction purchase agreement (ERPA). It was acknowledged that trying to get data from the few South African who have registered a project design document will be extremely difficult; in addition, there is are not many projects in South Africa, resulting in small sample data.

Emily Tyler suggested the use of Real Options as a means to price CERs. However, cautioned on its use due to limited data. However, its use can still be explored as this research could be built upon in the future. It was also suggested that Capital Asset Pricing Model could be used as there may a beta available for carbon assets.

Amit Oza suggested the use general project valuation techniques in conjunction with a rate of return used by private equity firms to value their investments.
Roon Osman, indicated that there it is very difficult to try to model the price of CERs form CDM project as there are too many variables involved. The methodology used at Shell ties in with the market prices.

Anton Louis Oliviers has been involved with the Durban Landfill CDM project and has practical experience in selling CERs from the project. It was indicated that there can be no pricing model. The price is determined by negotiations between the buyer and the seller. Usually, the seller needs a minimum price for the CERs to proceed with the project, and the buyer is cognisant of the market price and the delivery risks.

5.3. PRICING MODEL

5.3.1. DESCRIPTION OF MODEL

The approach used to calculate the CER price is best illustrated by the diagram below:

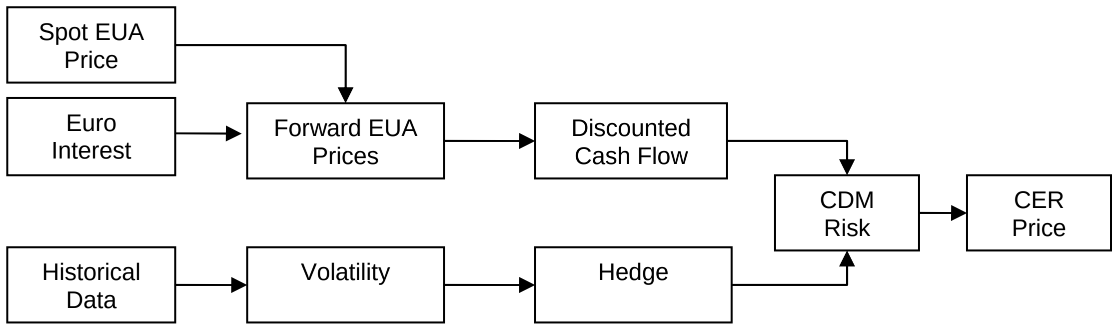


Figure 9: Approach Taken to Price CERs

The approach originated from basic discounted cash flow model (Firer, Ross, Westerfield & Jordan, 2004), and suggestions made by Colin King and Amit Oza. It used a discount rate to price the future cash flows of a CDM project – similar concept to pricing a bond where the discounting rate is based off a benchmark plus a margin for the "riskiness" of the bond.

There was insufficient data to follow the methodology suggested by William Greene, nor was any institution willing to divulge any useful information about its own CER prices to follow Geoff Stiles' recommendation about empirical evidence. Use of Real Options to price CERs was also restricted by the amount of public information on CER prices and deal details.

Hypothetically, CERs bought at fixed price now, can be sold as EUAs. The price differential implies a profit or loss in future. These future cash flows are discounted by the rate which encompasses all the risks. However, the number of CERs delivered depends on the CDM risk. Thus the overall risk was separated in to two: project risk and CDM risk. The present value of the future profit and loss was discounted using only the project discount rate. This present value amount is used to hedge the uncertainty surrounding the CER delivery. The hedge is in the form of theoretical call option priced using Black-Scholes (Hull, 2000).

Due to unavailability of the detailed CER data, the CER pricing model was developed using available public information. Henk Sa and Anne-Franziska Sinner both mentioned that riskless CERs should be trading higher than EUAs because they can be banked in to the next phase. However, due to further complexity in deriving the CER premium over EUA, a conservative approach was taken by assuming that the price of risk-less CER is equal to price of EUA. It has to be noted that the demand and supply factors also influence the CER price, thus a strict supplementarity regulation or excess supply from Russia could drive down the price of CER.

A project would contract to sell a certain quantity of CERs (defined as "q"), and it has a final certified (delivered) amount, "n" out of the q. A risk-less CDM project will deliver the exact amount of CERs mentioned in the contract, i.e. q = n. Assuming that the risk-less CER price is equal to EUA, a potential buyer can agree to buy q CERs from a project at fixed price for the period, assume the delivery risk and immediately sell these CERs (as EUAs) at EUA price on the forward market. The difference between the price of EUA and CER yields a profit or loss. Assuming an arbitrage free transaction, the present value of the future profit or loss (cash flows) has to be equal to zero. Assuming that the project risk rate (i.e. the discounting rate) is know, then, it would be a simple matter of reverse engineering the CER price such that the present value of the future cash flows is zero.

The market does not have all the required EUA prices. Only the 2006, 2007 and 2008 vintages are available. However, forward prices can be calculated using market EUA prices in conjunction with Euro Swap rates (which is a close approximation to the risk-free rate needed in the formula). The basic forward pricing methodology (Hull, 2000) was used to calculate the future EUA prices.

There is still a question as to the number of final CERs received. Assuming a certain percentage of CERs will be delivered, the buyer of the CER will have to hedge the quantity he may not receive (q-n). Since EUA are sold on a forward basis, one way to hedge non-delivery of CER is to buy call options. A call option gives the holder of the option the right to buy the underlying at an agreed price.

A theoretical European call option was priced using historical EUA volatility, the strike price set at the same forward EUA prices mentioned above (thus the zero cash flow at the future date if the call option is exercised), spot EUA prices, and periods matching the delivery date of the CERs. The current annual EUA market volatility of 56% - based off calculations from Hull, (2000) was used to price the call option using Black-Scholes option pricing model. The cost of the call option is an upfront cost, thus the total of all the call options for each year (of delivery) was added to the present value calculated by for the project. The new price of CER was again calculated by goal-seeking the sum of the present value of the profit from sale of EUA and purchase of CERs plus the price of the call options.

The discounting rate is made up of a benchmark rate + margin; where the margin is a spread related to the various risk aspects of conventional project as well as CDM risks.

A typical private equity fund or venture capital investment would want a internal rate of return between 20% to 25% (or more). They have a target hurdle rate which has to be met to invest in the project. Since a CDM project could be operational, but not generate CERs, the project IRR rate should be same as that used to value a project without CERs.

A brief interview was conducted to determine typical IRR rates. Iain Macualay, a project financier at Nedbank, indicated rough range of discounting rates for projects. Typically, for large projects with minimal counterparty risk, the expected rate of return is around 15 percent. However, "green-fields" (a new project), could have a return in excess of 25 percent. Brait and Ethos (both private equity firms) indicated that its hurdle internal rate (IRR) of return is project and sector dependent, but on average they look for IRR of 20 to 25 percent. Amit Oza also indicated a hurdle rate of 20 to 25 percent for venture capital and private equity investments.

According to Belville South Landfill project (Loots, 2005, p. 14), "the private sector range of pre-tax project IRR's expected for the conservative/medium scenarios, is likely to be in the region between 35% to 50% per annum" for green-fields projects

The Mondi Executive Board guidelines has specific requirement of minimum IRR between 17% to 20% IRR in terms of return on investment of project to be approved (Mondi Biomass, 2005).

A rate of 25 percent was used in the model to indicate riskiness of a project.

The model described above take the following form in Excel:

Table 6: Pricing Model in Excel Spread Sheet

Cash Flows							
Pricing date	01-Nov-06						
Vintage	31-Dec-06	31-Dec-07	31-Dec-08	31-Dec-09	31-Dec-10	31-Dec-11	31-Dec-12
Years	0.2	1.2	2.2	3.2	4.2	5.2	6.2
EUA=CER	11.0	11.3	15.8	16.3	16.8	17.4	18.0
Discount Rate	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Fixed CER price	**13.23**	**13.23**	**13.23**	**13.23**	**13.23**	**13.23**	**13.23%**
Negotiated amount	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Delivered %	100%	100%	100%	100%	100%	100%	100%
P/L	-2,230,000	-1,980,000	2,520,000	3,058,373	3,586,386	4,165,171	4,777,338
Present Value	-2,149,683	-1,526,950	1,553,762	1,508,567	1,415,211	1,314,882	1,205,770

Sum of PV	3,321,558
Sum of protection (options)	-3,321,558
Total	**-**

Percentage to Hedge (CALL)	12.64%

Based on the assumption that the deal above was priced with EUA 06-08 price of 11, 11.3 and 15.8 euros respectively and implied theoretical EUA forward price for the remaining period 2009 to 2012, a discount rate of 25% and 100% CER delivery from project, the total "Sum of PV" is equal to +3,321,558 priced at fixed purchase price of 13.23 euros for CERs, and selling them as EUAs at the EUA prices mentioned above.

This present value amount was used to calculate the number of EUAs needed to be hedged using call options. The price of the call options is equal to at -

3,321,558, implying 126, 381 EUA (Table 8 below) have to be hedged for each year of the contract.

The forward EUA prices used in Table 7 were calculated using formula from Hull (2000) – the forward pricing has been covered in the Chapter Two. An example of the forward prices is shown below in Table 7. Since the 2006 to 2008 EUA prices are know, only the 2009 to 2012 prices needed to be calculated.

Table 7: Calculation of Forward EUA prices

Forward Prices of EUA							
Pricing Date	01-Nov-06						
Vintage	Dec-06	Dec-07	Dec-08	Dec-09	Dec-10	Dec-11	Dec-12
CER prices	12.2	12.2	12.2				
Interest Rate (Euro)		3.87%	3.85%	3.77%	3.78%	3.80%	3.82%
Period				1	2	3	4
Borrowing Rate		0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
Last Price				15.75	15.75	15.75	15.75
Interest from sale of CERs		0.08	0.55	0.60	1.22	1.88	2.57
Borrowing Cost		0.01	0.07	0.06	0.16	0.24	0.32
Fwd Price				16.29	16.82	17.40	18.01

Along with the forward-forward interest rate, i.e. the rate for the period 2008 to 2009, and the 2008 EUA price and a borrowing margin of 0.5%, the forward price of 2009 EUA was 16.29 euros. The same method was used to calculate the EUA price for the remainder of the period.

The Black-Scholes option pricing formula (Hull, 2000) mentioned in Chapter Two was used to calculate call option. The variables and the final call option price are shown in Table 8 below. To enable relative comparison between the different CER prices, it was assumed that historical volatility was the same for all the periods.

Table 8: Call Option Pricing

Option Pricing							
Pricing date	01-Nov-06						
Expiry Date	31-Dec-06	31-Dec-07	31-Dec-08	31-Dec-09	31-Dec-10	31-Dec-11	31-Dec-12
Volatility	56.00%	56.00%	56.00%	56.00%	56.00%	56.00%	56.00%
Spot	11.00	11.00	11.00	11.00	11.00	11.00	11.00
Term	0.16	1.16	2.17	3.17	4.17	5.17	6.17
Strike price	11.00	11.25	15.75	16.29	16.82	17.40	18.01
Risk free	8.74%	8.74%	8.74%	8.74%	8.74%	8.74%	8.74%
d1	0.18	0.43	0.21	0.38	0.52	0.63	0.73
d2	-0.05	-0.17	-0.62	-0.61	-0.62	-0.64	-0.66
N(d1)	0.57	0.67	0.58	0.65	0.70	0.74	0.77
N(d2)	0.48	0.43	0.27	0.27	0.27	0.26	0.25
Call Price	1.07	2.95	2.90	3.81	4.57	5.21	5.77
Option Cost							
No. of CERs to be hedged	126,381	126,381	126,381	126,381	126,381	126,381	126,381
Cost of Options	134,919	373,157	366,868	481,420	577,374	658,642	729,179
Total Cost	**- 3,321,558**						

The "Call Price" mentioned in table above is the price of one call option. The total price of the hedge for each period is the cost of each option multiplied by the number of emission reduction units required to be hedged. The over price for the hedge is the sum of the option cost for each period, indicated by "Total Cost" above.

5.3.2. RESULT: IMPLIED CDM PROJECT RISK

As demonstrated above, the usefulness of the model is its ability to imply CDM risk. Using the average of the historical CER price range (see Appendix C for list of historical CER data), the implied CDM risk is as shown in Table 9 below.

The historical data contained a specific risk category and an associated priced range. Table 9 contains the implied CDM risk level attributable to each risk classification using the minimum, maximum and middle of the historical price range.

Table 9: Implied CDM Risk

Volatility	56%	Discount Rate	25%
Risk category	At Risk Price (min)	At Risk Price (max)	At Risk Price (mid)
1	105%	91%	98%
1	106%	91%	98%
1	106%	91%	98%
2	79%	22%	51%
2	72%	16%	44%
2	78%	18%	48%
2	77%	23%	50%
2	76%	29%	52%
2	77%	23%	50%
2	76%	29%	52%
2	78%	38%	58%
2	78%	38%	58%
2	78%	38%	58%
2	90%	37%	64%
2	69%	40%	55%
3	37%	21%	29%
3	47%	33%	40%
4	47%	12%	29%
4	41%	5%	23%
4	36%	1%	19%

The above results can be condensed in the four risk categories shown below in Table 10. This indicates the CDM risk involved in the risk classification used by Point Carbon.

Table 10: Implied CDM Risk Grouping

Risk category	Implied CDM Risk Range	Implied CDM Risk (average)
1	98%	98%
2	44% to 64%	53%
3	29% to 40%	35%
4	18% to 29%	24%

5.3.3. TEST AGAINST HISTORICAL DATA

The implied risk levels were used to test the market prices not used in the section above. Historical EUA volatility for each of the data points was calculated to determine the price of call option. The results of the CER price using (1) CDM risk rate as per category and (2) assumed 60% CDM risk level are shown in Table 11.

Table 11: Calculated Prices for Historical CER Prices

Date	EUA'08 Price	Actual CER Price	CER Price as % of EUA	Risk Category	Volatility	CDM Risk	Calculated Price	Diff in Price
25-Nov-05	19.25	4.00	21%	2	55%	53%	8.00	4.00
16-Dec-05	21.20	5.03	24%	2	54%	53%	9.54	4.51
13-Jan-06	20.80	9.20	44%	2	52%	53%	9.22	0.02
16-Feb-06	27.85	5.70	20%	1	51%	98%	2.98	-2.72
21-Apr-06	31.00	11.90	38%	2	49%	53%	17.94	6.04
24-Aug-06	17.80	6.75	38%	2	55%	53%	10.92	4.17
02-Nov-06	15.75	13.15	83%	4	56%	24%	12.48	-0.67
25-Nov-05	19.25	4.00	21%	2	55%	60%	6.50	2.50
16-Dec-05	21.20	5.03	24%	2	54%	60%	8.02	2.99
13-Jan-06	20.80	9.20	44%	2	52%	60%	7.56	-1.64
16-Feb-06	27.85	5.70	20%	1	51%	98%	3.08	-2.62
21-Apr-06	31.00	11.90	38%	2	49%	60%	16.24	4.34
24-Aug-06	17.80	6.75	38%	2	55%	60%	10.07	3.32
02-Nov-06	15.75	13.15	83%	4	56%	20%	12.73	-0.42

Except the data point on 2-Nov-2006 (which is from a broker), the Historical CER prices in Table 11 came from ACX-Change. It has an average price from each auction, and useful to validate model as it does not have price range (as commonly reported by Point Carbon). The draw back is that there is no indication on the risk taken by the buyer or seller. The implied CDM risk yielded indicated that all, but the 16-Feb-2006 data point, fall within risk category 2. The implied CDM risk category on 16-Feb-2006 was probably a risk category 1 contract.

The CER prices from the model indicated that the CER prices should have been higher than the actual. An explanation of the price differential could be due to differing views on the risks or that the CER prices at the auction are at a good value.

The price on 2-Nov-2006 was known to be a risk category 4, and yielded a close approximation the actual CER price.

The calculated CER prices from this model fell within the current price range for each risk category. Due to lack of detailed CDM data, further statistical analysis could not be performed.

5.3.4. COMPARE AGAINST "RULE OF THUMB"

The current "rule of thumb" for CER price is that the price is 31% of the December 2008 EUA price (Sinclair, 2006). Table 12 below indicates the December 2008 EUA prices, the actual auction price, the price using the 31% rule of thumb and the calculated price (same as in Table 11 above). The difference between the actual and the 31% rule is smaller than the error between the prices from the proposed model and the rule of thumb approach.

Table 12: Comparing Actual Historical to 31% CER Price Rule and Calculated Prices

Date	EUA'08 Price	Actual CER Price	31% of '08 EUA	Calculated Price	Difference: Actual - 31% rule
25-Nov-05	19.25	4.00	5.96	8.00	-1.96
16-Dec-05	21.20	5.03	6.57	9.54	-1.5
13-Jan-06	20.80	9.20	6.44	9.22	2.7
16-Feb-06	27.85	5.70	8.63	2.98	-2.93
21-Apr-06	31.00	11.90	9.61	17.94	2.29
24-Aug-06	17.80	6.75	5.51	10.92	1.23

The above calculations used CDM risk level derived from the mid of the price range for each risk category. The same calculation was repeated using the CDM risk implied by the low end of the CER price range and the results are as shown in Table 13 below.

Table 13: Price Comparison Using Upper Implied CDM Risk Level

Date	Actual CER Price	31% of '08 EUA	Calculated Price	Difference: Calc Price - Actual	Implied CDM risk
25-Nov-05	4.00	5.96	6.03	2.03	77.0%
16-Dec-05	5.03	6.57	6.34	1.31	77.0%
13-Jan-06	9.20	6.44	6.82	-2.38	77.0%
16-Feb-06	5.70	8.63	7.22	1.52	77.0%
21-Apr-06	11.90	9.61	7.96	-3.94	77.0%
24-Aug-06	6.75	5.51	8.32	1.57	77.0%

5.3.5. EXPERTS OPINION OF THE PRICING MODEL

As a means of confirming the validity of the model, and due to the difficulty involved in scheduling interviews again, five interviewees out of the thirteen experts (Table 3) were asked to comment on the developed in this research. Out of the five, three responded, the other two could not comment. Opinion of each of the three experts follows.

Anne-Franziska Sinner agreed that the proposed approach was reasonable if it is assumed that the EU ETS is a major market player in the whole carbon market. The concern was around the assumption that risk-less CERs are equal to EUA prices.

Henk Sa, agreed that the logic behind the modelling was sound, and also indicated that the CER may decouple from EUA prices.

Amit Oza indicated that the basics of the proposed appeared be sound. Oza pointed out that approach taken to price CERs in this research offered a methodology which could be used to obtain insights into the carbon market.

CHAPTER 6: DISCUSSION OF THE RESULTS

6.1. CDM RISKS AND VALUATIONS TECHNIQUES

Most of the risks mentioned by the interviewees were same, adhering to risks mentioned in literature. These risks are covered in Table 5. Some of the interviewees, mentioned extra risks and points which could impact the price of CER. Henk Sa mentioned the risk associated with baseline methodology. Sa also mentioned that that risk-less CERs should be higher than EUA prices due to the fact that CERs can be banked for use in next EU ETS phase, but EUAs cannot be banked.

Amit Oza view that widely publicised supplementarity risk as negligible as some participant countries have stated to allow full hundred percent of CERs to meet compliance.

Anne-Franziska Sinner suggested that the price of CERs may become independent if EU ETS becomes one of many large market players.

None of the interviewees could provide guidance to how the risk factors influenced the price of CERs.

There were some suggestions as to the type of method to be utilised in valuing price of CERs from CDM project. The opinions ranged from using standard discounted cash flow analysis, to probability to derive pricing model, to use of empirical evidence, to real options. But other than discounted cash flow method, none of the methods mentioned could be used due to insufficient publicly available data.

The proposed model in this research consisted of a discounted cash flow approach in conjunction with a hedge in form of call options. The discounted cash flow model addresses conventional project risk and the hedge focuses on CDM regulatory risk.

The objective of the research was fulfilled by developing a pricing model for CERs.

6.2. DESCRIPTION AND VALIDATION OF MODEL

It was acknowledged that in carbon finance, it being a relatively new field, information would not be forthcoming. As a result the research was classified as an exploratory research project with aim of deriving a model to price of CER from CDM project.

Based on the assumption that CERs bought from CDM project are sold at EUA (or even a slightly higher price), a simple cash flow discounting method cannot be used on its own as there is uncertainty on the number of CERs delivered by the project.

A simple demonstration proves the point. Assuming that hundred percent of the CERs are delivered and using the broker price of 84% of 2008 EUA price (for minimal CER risk and high quality counterparty) the implied discount rate is listed in Table 14 below.

Table 14: Implied Discount Rate at CER Price of 84% of EUA

Cash Flows							
Pricing date	02-Nov-06						
	31-Dec-06	**31-Dec-07**	**31-Dec-08**	**31-Dec-09**	**31-Dec-10**	**31-Dec-11**	**31-Dec-12**
Years	0.2	1.2	2.2	3.2	4.2	5.2	6.2
EUA=CER	11.0	11.3	15.8	16.3	16.8	17.4	18.0
Discount Rate	**51.96%**	**51.96%**	**51.96%**	**51.96%**	**51.96%**	**51.96%**	**51.96%**
Fixed CER price	13.23	13.23	13.23	13.23	13.23	13.23	13.23
Amont of CERs	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Delivered %	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
P/L	-2,230,000	-1,980,000	2,520,000	3,058,373	3,586,386	4,165,171	4,777,338
Present Value	-2,084,153	-1,217,760	1,018,757	813,640	627,871	479,864	361,780
Total of Present Value		**0**					

Using low risk market price of CER, Table 14 implies an IRR of almost 52%, highly unrealistic result for low risk transaction – and the IRR is immeasurable for higher risk CER. The problem is that the deliver risk and the cost associated with the purchase at market price and subsequent delivery of CERs (due to forward transaction) is unknown.

A cashflow discount model will work if the unknowns factors mentioned above are known, but they are not, thus leading to the choice of hedging the exposure by purchasing call options in the pricing methodology. The proposed model uses the available market rates/prices to calculate the riskiness of the project and steers clear of the detailed cash flow analysis of each project (due to insufficient data).

The proposed model used historical CER data to impute CDM risk. The Point Carbon price classification was used as a base to calculate the implied CDM risk as most of the historical data used originated from Point Carbon. The imputed CDM risk was used as a known factor when calculating CER.

The usefulness of this model is not only determining CER price at, but also in associating carbon risk to a given CER market price. If the risk level is know, for example, the broad risk category used by Point Carbon, the model can be used to price CERs. Table 15, below, indicates the implied CDM risk for each Point Carbon risk category using the minimum, maximum and middle of the indicated CER price range.

Table 15: Risk Categories and Implied CDM Risk Based

Risk category	Price Range	Risk based off minimum price	Risk based off maximum price	Risk based off middle of range
1	3 – 6	106%	91%	98%
2	5 – 10	77%	29%	53%
3	9 – 14	42%	27%	35%
4	12 – 14	41%	6%	24%

The test run compared the actual values (obtained from ACX-Exchange) to the values from "rule of thumb" approach and calculated prices from the model. The initial results indicated the model's prices varied to a greater degree compared to the values from "rule of thumb" (see Table 12 for the details). However, when the lower price range of the historical data was used to impute the CDM risk, and this risk level was used in the same test case, the prices between the model and "rule of thumb" were comparable. This implies that the auction priced the CDM project at the high risk end of the second risk category used by Point Carbon.

The 31% "rule of thumb" approach has to be closer to the actual prices as it is based on the historical average CER price relative to the December 2008 EUA price. As long as this factor remains the same the 31% rule is applicable. The "rule of thumb" does not take in to account the different risk categories, and falls apart when applied to projects with different CDM risks. Sinclair (2006) mentions that the 31% rule yielded a result below the market norm, further indicating that the auction prices were lower than the general market.

6.3. INSIGHTS

Calculating the price of CERs in the current (non-transparent) market is extremely difficult. All the factors which determine the CER price are known about CDM projects, but as indicated by the interviews with experts, not much is know on how these factors interact to determine the price of CER.

The boundary of CER price is set by determinants of supply and demand factors. The lower limit of CER price is set by the willingness of CDM project owner who sells CERs at a price above the minimum level required to proceed with the project (from discussion with Anton Louis Oliviers). From a buyer's perspective, the maximum price for CER paid by EU member should be based on the cost-benefit analysis of the penalty to be paid (if the member has a shortfall in emissions reduction units) and the replacement cost of acquiring emission reduction unit to cove the shortfall. Thus, there is a certain CER price which meets both the parties needs, and it should be implied in the market prices.

Interestingly enough there is little overlap between the calculated CDM risks when the quoted prices do not overlap. The greater the price transparency, i.e. a fixed price level versus a price range, the higher the possibility in assigning risk value to each of the factors determining the CER price.

The methodology from this research gives a risk associated with CDM project, thus it can be used as the probability of qualifying in the equation used by Spalding-Fecher (2002):

$$CV = \frac{FVxQxP_{sucess}xP_{qualifying}}{(1+r)^n}$$

CV in the above equation is the current value generated from sale of Q tonnes of emissions at a price of FV per tonnes. Psuccess the probability of project success and Pqualifying is the credit qualification.

The price of each tonne of emissions is calculated by dividing CV by Q. If the price of CER (per tonne) is required, CV is divided by Q. In effect, the above equation is reduced to:

$$CER = \frac{FVxP_{sucess}xP_{qualifying}}{(1+r)^n}$$

The above equation could be equated to the 31% rule (as both yield price of current price of CER), but more contract information is needed before establishing the linkages.

The model developed in this research is useful as it determines CDM risk using historical CER data, and this implied CDM risk can be used to forecast CER prices. It should be noted that the discount rate was fixed for all the valuations to derive the relative CDM risk. If the discount rate was increased (assuming higher risk), the present value would yield a low price. In the model, this present value is used to buy the call options, and thus implies that less cash is available to purchase the options, which further implying lower CDM risk. This model is useful when comparing relative CDM risks of similar projects risks.

Table 16 below indicates the readiness and investment environment of countries to implement CDM projects. It also indicates the changes in the CDM rating of the countries in the period December 2004 to December 2005. If additional, detailed information was available, the following CDM country ratings could be used to break down the country specific risks.

Table 16: Point Carbon's CDM Country Rating

	CDM	Dec-05	Dec-04
1	India	A-	(1, BBB)
2	China	BBB	(5, B)
3	Chile	BBB	(2, BBB)
4	Mexico	BB+	(7, B)
5	Brazil	BB+	(3, BB)
6	Korea	B+	(4, BB)
7	Peru	B+	(6, B)
8	Morocco	B	(5, B)
9	South Africa	B	(10, CCC)
10	Argentina	B	(n.a.)
11	Malaysia	B	(n.a.)
12	Vietnam	CCC+	(8, CCC)
13	Egypt	CCC+	(n.a.)
14	Indonesia	CCC+	(11, CCC)
15	Thailand	CCC+	(9, CCC)
		Source:	Point Carbon

The above risk ratings imply a certain risk level associated with sovereign risk and CDM status (the readiness of country) risk. Sovereign risk can be obtained from credit default swap spreads in the market or by using country rating provided by the likes of Standards and Poor, Moodys & Fitch. However, there is not enough data at present to separate the risk levels. Future research could deal with this aspect.

CDM projects risks can be categorised in to conventional project risk and CDM regulatory risk (Lee, 2004). Conventional project risks relate to uncertainties in project performance and in the market of project output while CDM-specific risks refer to uncertainties in the Kyoto process and its implementation as well as the market performance of carbon assets. The results in the proposed model utilised a fixed discount rate, but this can be broken down to a deeper level. Table 17 shows grouped CDM projects from different countries and their IRR with and without CERs. Again, with detailed information, the country risk could be separated to yield specific project type risk.

Table 17: Country and Project Type IRR

Country	Project Type	% IRR (w/out)	% IRR (w/cers)
Romania	Direct heating	10.5%	11.4%
Costa Rica	Wind	9.7%	10.6%
Jamaica	Wind	17.0%	18.0%
Morocco	Wind	12.7%	14.0%
Chile	Hydro	9.2%	10.4%
Costa Rica	Hydro	7.1%	9.7%
Guyana	Bagasse	7.2%	7.7%
Nicaragua	Bagasse	14.6%	18.2%
Brazil	Biomass	8.3%	13.5%
Latvia	Methane	11.4%	18.8%
India	Methane	13.8%	18.7%

Source: Colin King, 2006

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

The aim of this research was to develop a model to price CERs from a CDM project. It soon became apparent, through interviews, that the factors influencing the CER price were well known. However there is very little understanding on the issue between these factors and the price of CER.

The objective of this research was achieved as it produced a pricing model to price CERs, while at the same time quantifying the risk associated with the overall CDM risk. The limited public domain historical data mainly consisted of price range for a set of four risk categories. The calculated CDM risk for each of these risk categories gives an indication of risk associated with the risk category used by Point Carbon as follows:

Table 18: Price Range vs. Implied CDM Risk Range

Price/Risk category	Approx. price range (Euro/tCO2e)	CDM Risk Range – Minimum	CDM Risk Range – Maximum	Description
1	3-6	106%	91%	Non-firm volume. Buyer buys what seller delivers even if emissions reduction turns out not to qualify as CERs.
2	5-10	77%	29%	Non-firm volume. Contract contains preconditions, e.g. that the underlying project qualifies for the CDM.
3	9-14	42%	27%	Firm volume. Contract contains preconditions (as above). Usually strong *force majeure* clause and high credit rating requirements.
4	12-14	41%	6%	Firm volume. No preconditions. Forward spot trades will in future fit this category. Currently only the JSE Carbon Credit Notes fit under this category.

The greater the amount of detailed information available, the higher the ability of model to assign a value to the price influencing factors.

In order to systematically arrive at the price determinants, the risks are grouped in to broad categories and then broken in to manageable components as illustrated below in Figure 9. The CDM risks are based over and above the project risks, as no CERs would be generated if the project fails.

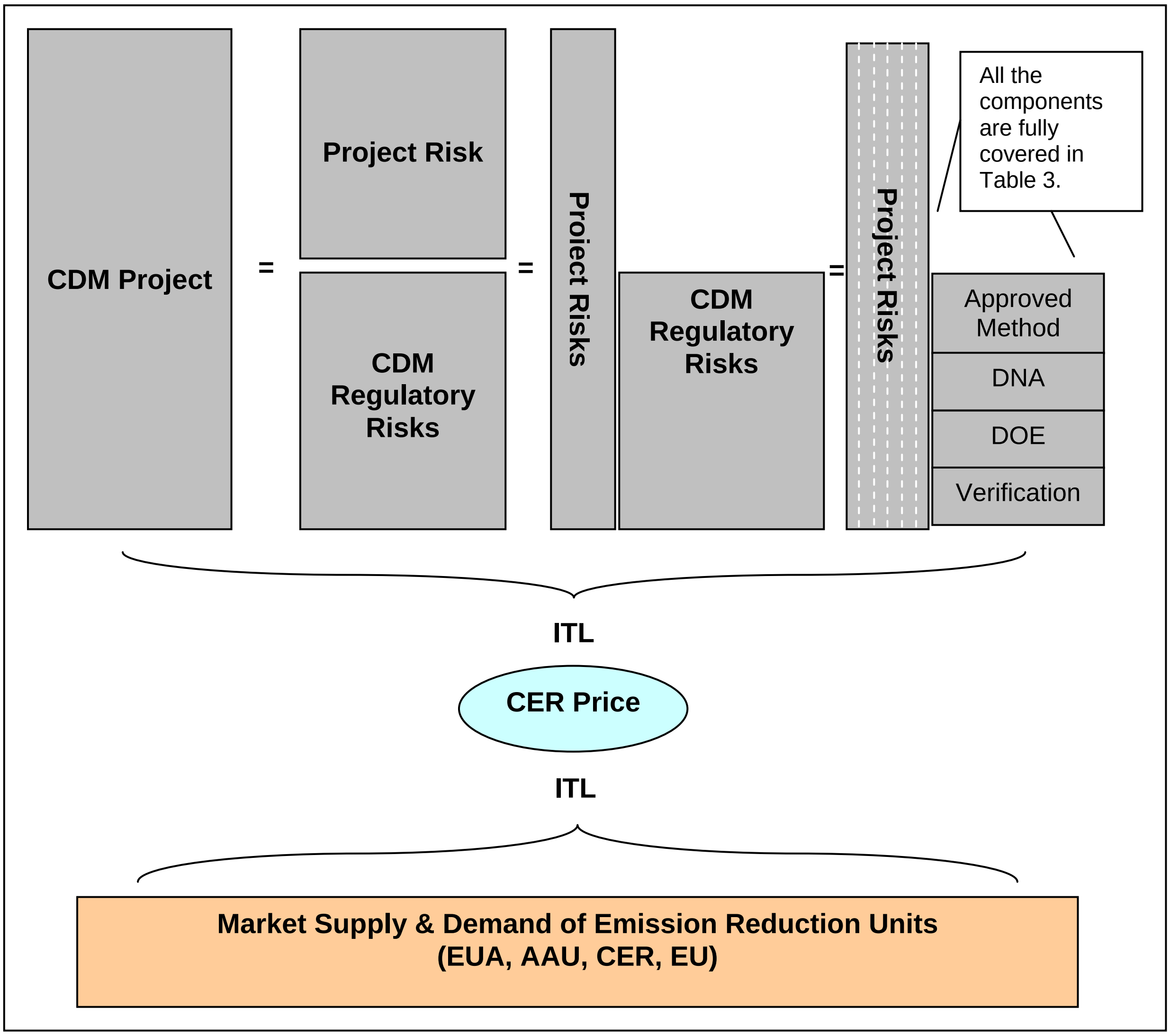


Figure 10: Components of Price Determinants

The diagram above illustrates the two broad price CER determinants: project based factors and market forces. These two broad factors are linked via the International Transactional Log (ITL). ITL is set to be up and running by April 2007 (Howard, 2005). Figure 9 aids in visualising the risk components. It can be used in future to build on the applying similar risk grouping and applying new information to build on the pricing model.

Each different type of approved methodology could be classified in to group of broad categories. Analysis of the differences in the market price will yield the impact of different types of CDM methodologies. It is hoped that detailed information will be available in future to ensure a positive link between CER price determinants and the market price of CER.

Due to the infancy of and resultant lack of transparency, it is recommended that further research be conducted to determine the impact the identified factors have on the price of CERs.

There is lot of uncertainty surrounding CER pricing. This research is a start in reducing the unknowns. Further research is needed to reduce these uncertainties.

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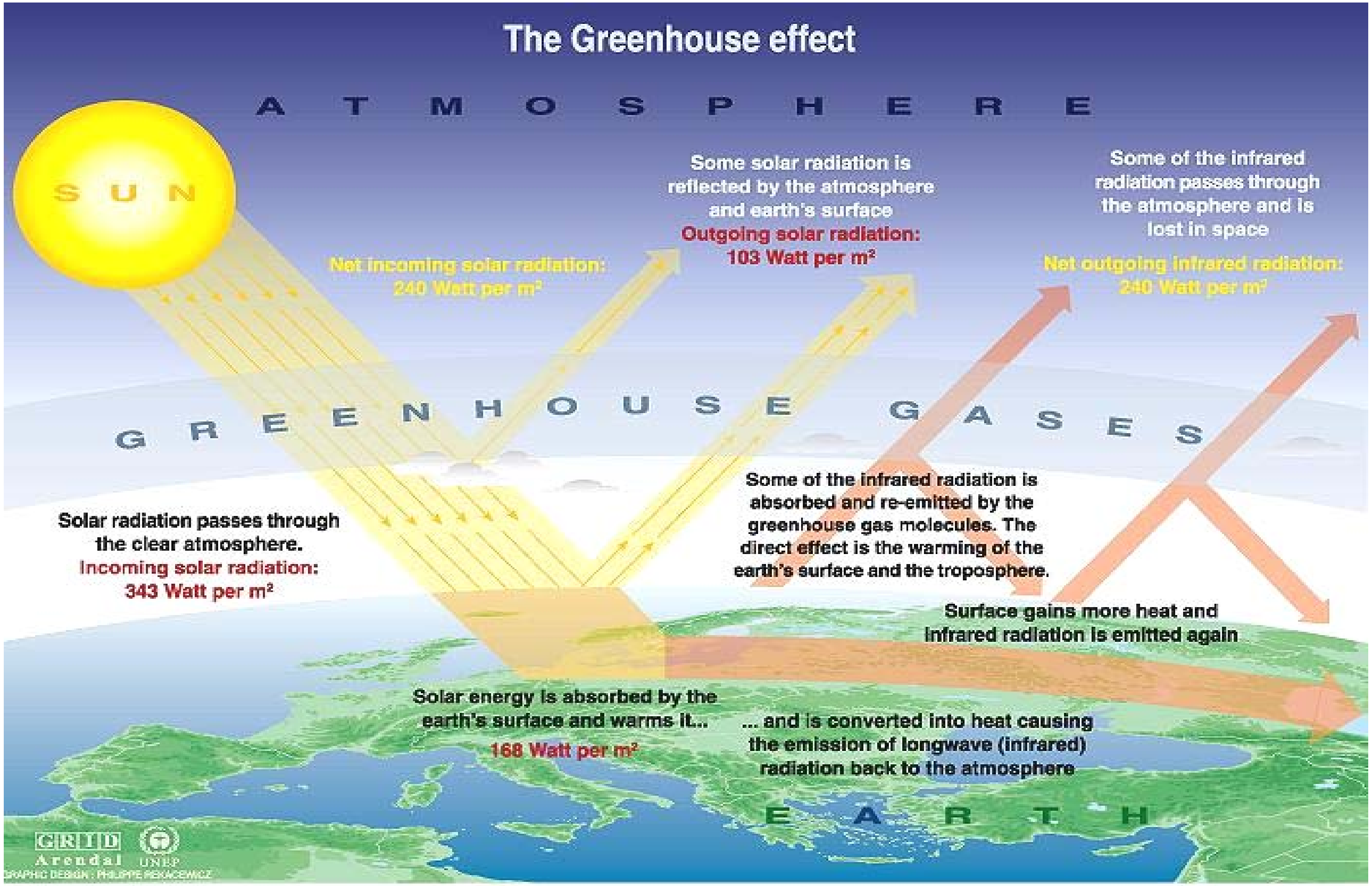
APPENDICES

APPENDIX A: OVERVIEW OF THE GREENHOUSE EFFECT



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

APPENDIX B: ANNEX 1 COUNTRIES AND THEIR EMISSION LEVELS

Country	Emissions reduction target under the Kyoto Protocol (% of 1990 emissions)	Emissions in 2000 (actual levels) MMTCO$_2$e	Emissions in 2000 (% of 1990 emissions)	Projected Emissions in 2010 (% of 1990 emissions)
Australia	+8	501	+18	+16
Austria	-13*	80	+3	+12
Belgium	-7.5*	152	+7	+16
Bulgaria	-8	78	-51	-42
Canada	-6	726	+20	+19
Croatia	-5	22 (1995)	-30	-
Czech Republic	-8	148	-23	-32
Denmark	-21*	69	-1	+15
Estonia	-8	20	-55	-69
Finland	0*	74	-4	+17
France	0*	550	-2	+6
Germany	-21*	991	-19	-32
Greece	+25*	130	+24	+36
Hungary	-6	84	-17	
Iceland	+10	3	+7	-2
Ireland	13*	67	+25	+28
Italy	-6.5*	547	+5	+11
Japan	-6	1386	+11	+7
Latvia	-8	11	-64	
Liechtenstein	-8	0.218 (1999)	0	+2
Lithuania	-8	24 (1998)	-54	
Luxembourg	-28*	5.971	-56	
Monaco	-8	133	+33	
Netherlands	-6*	216.916	+3	+19
New Zealand	0	76.956	+5	+38
Norway	+1	55.263	+6	+22
Poland	-6	386.187	-32	
Portugal	27*	84.700	+30	+54
Romania	-8	164.026 (1994)	-38	-28
Russian Federation	0	1.965.346	-35	-20
Slovakia	-8	49.165	-33	-27
Spain	15*	385.987	+35	+48
Sweden	4*	69.356	-2	+1
Switzerland	-8	52.743	-1	-7.2
Ukraine	0	454.934	-51	
UK	-12.5*	649.106	-13	-15
USA	-7	7.001.225	+14	+16
Total		17.281.439		

Source: emissions data in 2000, HYPERLINK "http://ghg.unfccc.int" http://ghg.unfccc.int; emissions data in 2010, Annex 1 countries Third National Communications, http://unfccc.int.

Note: The numbers in parenthesis show different years. Emissions projections are based on 'with measures' scenario, and reference economic growth.

* *According to burden sharing agreement, average of EU 15 is –8%.*

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APPENDIX C: HISTORICAL CER DATA

Source of Data	Report Date	Date	CDM	Vol (tCO2e)	Delivery	Price Category	Price - Min. (Euros)	Price - Max (Euros)
Point Carbon	18-Oct-06	17-Oct-06	CDM	1,370,000.00	2007-12	2	8	13
Point Carbon	18-Oct-06	12-Oct-06	CDM	7,000,000.00	2007-13	2	8	13
Point Carbon	18-Oct-06	03-Oct-06	CDM	1,000,000.00	2008-13	2	8	13
Point Carbon	18-Oct-06	25-Sep-06	CDM	150,000.00	2007-13	2	8	13
Point Carbon	18-Oct-06	20-Sep-06	CDM	102,000.00	2008-12	2	8	13
Point Carbon	04-Oct-06	25-Sep-06	CDM	150,000.00	2009-13	2	8	13
Point Carbon	04-Oct-06	20-Sep-06	CDM	102,500.00	2007-07	2	8	13
Point Carbon	04-Oct-06	16-Sep-06	CDM	750,000.00	2009-12	2	8	13
Point Carbon	04-Oct-06	14-Sep-06	CDM	1,075,000.00	2009-12	2	8	13
Point Carbon	04-Oct-06	14-Sep-06	CDM	700,000.00	2009-13	2	8	13
ABN Amro	14-Sep-06	29-Aug-06	CDM	11,500.00	2007-07	3	13	15
ABN Amro	14-Sep-06	24-Aug-06	CDM	230,000.00	2009-12	2	6	13
ABN Amro	14-Sep-06	01-Aug-06	CDM	203,152.00	2008-12	2	13	15
ABN Amro	14-Sep-06	18-Jul-06	CDM	14,000,000.00	2006-12	3	13	15
ABN Amro	14-Sep-06	17-Jul-06	CDM	1,200,000.00	2007-12	1	5	7
ABN Amro	14-Sep-06	15-Jul-06	CDM	396,053.00	2007-13	1	5	7
ABN Amro	14-Sep-06	15-Jul-06	CDM	600,000.00	2006-13	1	5	7
Point Carbon	02-May-06	06-Apr-06	CDM	1,000,000.00	2007-12	4	16	26
Point Carbon	02-May-06	29-Mar-06	CDM	25,782.00	2005-07	4	16	26
Point Carbon	02-May-06	15-Mar-06	CDM	2,000,000.00	2007-14	2	7	15
Point Carbon	02-May-06	14-Mar-06	CDM	45,998.00	2008-08	4	16	26

Possible error. The Price Category should be 3.

Data from ACX-Change:

Auction Date	CDM	Volume (tCO2e)	Delivery	Price Category	Average Auction Price. (Euros)
25-Nov-05	CDM	130,000.00	n/a	n/a	4.00
16-Dec-05	CDM	610,000.00	n/a	n/a	5.03
13-Jan-06	CDM	890,000.00	n/a	n/a	9.20
16-Feb-06	CDM	180,000.00	n/a	n/a	5.70
21-Apr-06	CDM	180,000.00	n/a	n/a	11.90
24-Aug-06	CDM	230,000.00	n/a	n/a	6.75