IMPACT OF CARBON TRADING ON UTILITIES

A Thesis submitted in partial fulfilment for the requirement of degree in Master of Science in Energy Systems and the Environment

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DEDICATION

With love and gratitude to my mother of blessed memory, ***Lady Callista Ngozi Opara****, this thesis is dedicated.*

ABSTRACT

Global concerns for greenhouse gas emission from various sources, have led to the adoption of Emission Trading, one of various Kyoto Mechanisms. Emission trading is thus the key policy instrument for dealing with increasing greenhouse gas emission levels, particularly carbon dioxide emission. Environmentalists have long argued that the impact of resource depletion and pollution should be subtracted from calculations of a country's gross domestic product (GDP). Carbon trading, in essence, puts price tags on the release of greenhouse gases so that they can be included in economic decisions.

Various installations are usually included in a typical Emission Trading Scheme as in the case of the EU Emission Trading Scheme.

Emphasis is however laid on the Power Sector in this thesis. For the purpose of clarity, this thesis is broken into six chapters.

The first chapter gives a general introduction of the thesis, with much emphasis on the reasons and purpose of the study.

The definition, origin of emission trading and how it relates with other mechanisms as contained in the Kyoto Mechanisms are broadly examined in Chapter 2. The Chapter also sheds light on how carbon market functions.

In Chapter 3, The EU Emission Trading Scheme and how the burden of curbing greenhouse carbon dioxide and other greenhouse gas emissions across the EU is broadly examined.

A Spreadsheet Model is used to assess how power generators can invest in emission reduction in a carbon constrained economy in Chapter 4, for the purpose of creating certified emission reduction (CERs).

Chapter 5 analyses the likely impact of the EU Emissions Trading Scheme on energy utilities. The introduction of emission allowance will change operating costs in the power generation sector, and as such, there is need for power generators to structure their generation and business in a carbon constrained economy.

In Chapter 6 suggestions and policy implications as regards the effect on carbon trading on energy utilities are given.

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INTRODUCTION

1.1 Overview

Combating climate change caused by human activities is one of the most daunting tasks faced by the world today. This is because greenhouse gases are now widely recognized as being responsible for giving rise to climate change.
The United Nations Framework Convention on Climate Change (UNFCC) sets an overall framework for countries within its umbrella to tackle the challenge posed by climate change. Towards this end, policy makers have the onerous task of minimizing the economic and social consequences of changing the production and consumption patterns of energy.
Emission trading was thus introduced in the Kyoto Protocol to tackle greenhouse gas emission from various activities. The European Union (EU) has started implementing emission trading for which CO_2 will take centre stage in the first phase (2005-2007), and a second phase to run from 2008-2012 to coincide with the first Kyoto commitment period.

1.1 Reasons for Study

Reports from the World Energy Outlook (WEO) 2002 Reference scenario which takes cognizance of government policies and measures on climate change and energy security that has been adopted mid-2002, suggest that CO_2 emission will increase by 1.8 per cent per year from 2000 to 2030.
The power generation sector is thus the primary target for emission trading as agreed to by climate change agreements. The reasons being:

- Electricity takes the bulk share of energy utilization
- In the case of the power generation, curtailing emission through carbon abatement technologies, deployment of renewable energy and nuclear power and other means, are better achieved than in other energy conversion process
- Emissions from power generation are concentrated in one place – the power station – where it is easier to control
- Electricity is more susceptible to project mechanisms that allow for reduction through emission trading and other flexible mechanisms.

The table as provided by IEA displays the global growing importance of carbon emission from power generation

Table 1.1 Electricity contributions to CO_2 emissions

	1971	1977	2010	2020
Global CO_2 emissions (Mt) from fossil fuels	14753	22984	30083	36680
Emission from Power Generation (Mt)	3885	7663	10761	13479
Electricity/Global	26.3	33.3	35.8	36.8

Source IEA – WEO

1.2 Purpose of Study

The purpose of this study is to address the following:

(1) To explore how installations involved in emission trading can invest in a greenhouse gas emission reduction projects and thus create Certified Emission Reduction (CER). A quantitative spreadsheet model is employed for this purpose to compare emission from a typical power plant with the emission under a typical baseline scenario. The baseline in this case reflects the 'business-as-usual'. The results obtained from the model should not be viewed as a projection, but rather as tool to explore the potential impact of carbon trading.

(2) To assess the impact of carbon trading on power generators and make useful suggestion and recommendation.

Chapter 2

BACKGROUND STUDY

2.1 Carbon Trading

Carbon trading or more generically, Emission Trading is the term applied to the trading of certificates representing various ways in which carbon-related emissions reduction targets might be met.

Emission trading is a seen as a market based system that provides companies with the flexibility to meet their environmental goals at lowest cost and encourages innovation and development of low-cost techniques to reduce emission (Greenhouse Gas Market Overview).

Under the Kyoto Protocol portfolio, emission trading, one of several flexible mechanisms is an important part of the solution necessary to enable countries to meet their emissions reduction target.

Participants engaged in carbon trading buy and sell contractual commitments or certificates that represent specified amounts of carbon-related emissions that either:

- are allowed to be emitted;
- comprise reductions in emissions (new technology, energy efficiency, renewables);
- comprise offsets against emissions, such as carbon sequestration (capture of carbon in biomass).

People engage themselves in emission trading because it is the most economical means of achieving an overall reduction in the level of emission, on the proviso that transaction costs involved in the market involvement are kept at reasonable levels. It is cost effective because the entities that have achieved their own reduction emission target easily will be able to create emission reduction certificates surplus to their own requirements. These entities can sell other surpluses to other entities that would incur very high costs by seeking to achieve their emission reduction requirements with their own business.

Under an emission trading regime, to avoid a penalty, a participant must possess allowances commensurate its total emission of the regulated pollutant for each compliance period. Allowances are usually retired to offset actual emissions. Emission allowances are created either by the regulating body (e.g. a sovereign government) or through emissions reducing activity or both. Emission allowances created by the regulating entity are generally distributed to emitters by grant, auction or a combination of the two.

Regulated sources are usually free to buy or sell allowances among each other – and even to sell onto non-regulated entities, with the condition that each regulated source must have sufficient allowances in its account at the end of each compliance period to cover its emission during that period.

Once initially allocated or created, emission allowances can be bought, sold, traded or (sometimes) banked for future use. They may be even retired (without necessarily balancing physical emission) to create an additional environmental benefit.

2.2 Policy Background

2.2.1 The United Nations Framework Convention on Climate Change (UNFCCC)

The Convention on Climate Change sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other heat-trapping gases. (The United Nations Framework Convention on Climate Change**)**

Under the Convention governments:

- gather and share information on greenhouse gas emissions, national policies and best practices
- launch national strategies for addressing greenhouse emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries

- cooperate in preparing for adaptation to the impacts of climate change

The UNFCC was negotiated between 1990 and 1992, against the backdrop of preparations for the UN Conference on Environment and Development (UNCED). UNCED was convened in Rio de Janeiro to promote the integration and environmental protection of in economic and social development.
Nearly all the commitments set out in the UNFCCC are differentiated: more detailed commitments have been taken on by a total of 41 developed countries that are listed in Annex 1 of the Convention and hence known as Annex 1 parties (Farhana Yamin, 2005). The Annex 1 parties, comprising industrialized nations are charged in terms of mitigating commitments, to champion the cause for long-term GHG emission trends by enacting policies and measures. The Convention also includes a quantified aim for Annex1 Parties: to stabilize their CO_2 emission and other GHGs at 1990 levels by the year 2000. To monitor progress, Annex 1 Parties have to submit annual GHG inventories and implementation reports, called national communications, usually every three years, to the UNFCC supreme body called Conference of the Parties (COP).

Non –Annex 1 Parties refers to the developing countries that negotiate as a bloc called G-77. Other countries such as Mexico, Korea, China, and countries from Central Asia, such as Kazakhstan are included in G-77.

The Convention also contains financial, technological and adaptation measures that give rise to the flow of resources from the wealthier Annex I that are included in the Annex II of the Convention in favour of developing countries. Annex II comprising the OECD countries, excluding Turkey and Korea and other planned economic countries, have commitments to providing developing countries with financial and technological assistance to meet the full cost of preparing GHG inventories/national communications and the incremental costs of implementing their other Convention commitments. (UNFCC, Article 4.3) Annex II parties are also charged with the responsibility of assisting countries that are vulnerable to climate change meet the cost of adaptation.

The Convention establishes institutional machinery to oversee the implementation of these commitments and to ensure that further action is taken by Parties to respond to the latest scientific and technical information, including the negotiation of new commitments adopted in the form of amendments and protocols to the Convention. The main convention institutions are as follows:

- Conference of the Parties (COP);
- Secretariat;
- Subsidiary Body for Implementation (SBI);
- Subsidiary Body for Scientific and Technological Advice (SBSTA); and
- Financial Mechanism operated by the Global Environment Facility (GEF)

Under the UNFCCC umbrella, the COP is the main policy-making body. It meets annually and provides the principal forum for international discussions premised on climate change.

The Intergovernmental Party on Climate Change (IPCC) is an independent scientific network with a separate legal existence.

2.2.2 Kyoto Protocol

The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty on global warming. It also reaffirms sections of the UNFCCC. Countries which ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. The maximum amount of emissions (measured as the equivalent in carbon dioxide) that a Party may emit over the commitment period in order to comply with its emissions target is known as a Party's *assigned amount*. The Protocol includes provisions for the review of its commitments, so that these can be strengthened over time.

The targets cover emissions of the six main greenhouse gases, namely:
- Carbon dioxide (CO2);
- Methane (CH4);
- Nitrous oxide (N2O);
- Hydrofluorocarbons (HFCs);
- Per fluorocarbons (PFCs); and
- Sulphur hexafluoride (SF6)

The formal name of the agreement, which reaffirms sections of the UNFCCC, is the Kyoto Protocol to the United Nations Framework Convention on Climate Change (http://www.cnn.com/SPECIALS/1997/global.warming/stories/treaty/). It is an agreement negotiated as an amendment to the United Nations Framework Convention on Climate Change (UNFCCC, which was adopted at the Earth Summit in Rio de Janeiro in 1992). All parties to the UNFCCC can sign or ratify the Kyoto Protocol, while non-parties to the UNFCCC cannot.

Adopted by consensus at the third session of the Conference of the Parties (COP3) in December 1997 to the UNFCCC in 1997 in Kyoto, Japan, it contains legally binding emissions targets for Annex I (developed) countries for the post-2000 period.

All Parties agreed that the Protocol's focus should be advancing the implementation of existing commitments of developing countries. The Protocol shares objectives and guiding principles, and deploys with some legal modifications, its institutional machinery. The modifications thus create a legally distinct institutional body for the Protocol: referred to as the Conference of the Parties serving as the meeting of the Parties to the Protocol (COP/MOP). The remaining modifications ensure that only parties to the Protocol can make decisions relating to the Protocol.

The main essence for the negotiation of the Protocol was to strengthen the mitigation of commitments of Annex 1 Parties. This is achieved through the establishment of the legally binding targets for Annex I Parties (COP, 6th *Session*, Part 2*).* These targets which cover a basket of six GHGs from defined sources and sectors are differentiated in the form of absolute national emission caps to be achieved from 2008 to 2012 with a specific requirement on Annex I Parties to have made progress by 2005. (COP, 6th *Session*, Part 2*).* The Protocol also establishes a collective target for Annex 1 Parties amounting to 5 per cent below 1990 levels in the commitment period 2008-2012. Table 2.1 gives breakdown of Kyoto targets for various countries.

Table 2.1 Kyoto targets, 1990 emissions, 2010 anticipated emissions (including the effects of policies in place as of 2002) and the difference between 2010 and target

(*in million tones* (*metric) of carbon)*	Kyoto limit	1990	2010	Difference
USA	1536	1652	2191	655
JAPAN	332	353	418	86
EU	1080	1174	1313	233
Other OECD	406	430	546	140
FSU	1385	1413	1064	-321
CEE	429	429	345	-84
Annex B without US	3632	3799	3704	72
All Annex B	5168	5451	5895	72

Source: Reilly (2002)

2.2.3 Kyoto Mechanisms

The Protocol also establishes three innovative "mechanisms" known as *joint implementation*, the *clean development mechanism* and *emissions trading*. These are designed to help Annex I Parties cut the cost of meeting their emissions targets by taking advantage of opportunities to reduce emissions, or increase greenhouse gas removals, that cost less in other countries than at home. To participate in the mechanisms, Annex I Parties must meet the following eligibility requirements:

- They must have ratified the Kyoto Protocol.
- They must have calculated their assigned amount, as referred to in Articles 3.7 and 3.8 and Annex B of the Protocol in terms of tonnes of CO2-equivalent emissions.
- They must have in place a national system for estimating emissions and removals of greenhouse gases within their territory.
- They must have in place a national registry to record and track the creation and movement of ERUs, CERs, AAUs and RMUs and must annually report such information to the secretariat.
- They must annually report information on emissions and removals to the secretariat.

The eligibility of each Annex I Party is initially to be determined through submitting a report on the above information to the secretariat, at the latest by 1 January 2007 (or a year after becoming a Party to the Protocol, whichever is later). This report will be reviewed, and any questions arising will be dealt with by the Enforcement Branch of the Compliance Committee within 16 months of submission through a set of expedited procedures. Should a Party subsequently be found to not meet the eligibility requirements, it may seek reinstatement of eligibility through a further expedited procedure. For further information, see the pages on Articles 5, 7 and 8, assigned amount accounting, and the Compliance Committee.

The Marrakesh Accords provide for businesses, non-governmental organizations and other entities to participate in the three mechanisms, under the authority and responsibility of governments.
Any Annex I Party that has ratified the Protocol may use the mechanisms to help meet its emissions target, provided that it is complying with its methodological and reporting obligations under the Protocol. However, Parties must provide evidence that their use of the mechanisms is "supplemental to domestic action", which must constitute "a significant element" of their efforts in meeting their commitments. (http://unfccc.int/kyoto_mechanisms/items/1673.php)
Businesses, environmental NGOs and other legal entities may participate in the mechanisms, albeit under the responsibility of their governments.

The term "joint implementation" sources its origin from the Convention, which refers to the joint implementation of policies. Under the Kyoto Protocol, Joint Implementation provides for Annex I Parties to implement projects that reduce emissions, or remove carbon from the atmosphere, in other Annex I Parties, in return for emission reduction units (ERUs). The ERUs generated by JI projects can be used by Annex I Parties towards meeting their emissions targets under the Protocol. A typical example of JI is replacement of coal-fired power plant with energy efficient Combined Heat and Power (cogeneration) Plant. Under the JI, Annex I Parties are to refrain from using ERUs generated from nuclear facilities to meet their targets.

The Marrakesh Accords provide two procedures for carrying out a JI project.

Under the first procedure, popularly known as track one, the Annex I Party hosting the project fully meets all the eligibility requirements to participate in the mechanisms. In this scenario, the host Party may apply its own national rules and procedures to the selection of JI projects and the estimation of emission reductions from them. The host Party is thus allowed to self-regulate and JI projects and also issue ERUs and transfer them to project participants.

Under track two, the Article 6 Supervisory Committee accredits "independent entities" to ensure, on the basis of project design documents that appropriate baseline and emissions monitoring are in place on which the emission reductions or removals for each project may be accurately calculated. (The Kyoto Mechanisms**)** Once a project is implemented, the participants are to monitor the project and submit the results to an independent entity. This independent entity will determine the reductions in emissions or increases in removals that may be issued by the host Party as ERUs (subject to the host Party having met the necessary eligibility requirements to make such issuance). A host Party which is eligible to carry out JI projects under track one may nevertheless choose to carry them out under track two if it so wishes as this might be seen to make the projects more credible.

The clean development mechanism (CDM) as defined in Article 12 of Kyoto commitments, provides for Annex I Parties to implement project activities that reduce emissions in non-Annex I Parties, in return for sustainable development and certified emission reductions (CERs). The CERs generated by such project activities can be used by Annex I Parties to help meet their emissions targets under the Kyoto Protocol. Article 12 also emphasizes that such projects are to assist the developing country host Parties in achieving sustainable development and in contributing to the ultimate objective of the Convention.

The principal focus of the CDM is on activities that focus on emission reduction. A typical example of the CDM is the installation of more energy efficient boilers. The CDM does not permit Annex I Parties to use CERs generated through nuclear facilities to meet their emission targets.

The Kyoto mechanisms, in general, give the power-generating sector opportunities to invest in projects aimed at curbing emission since ERUs and CERs are funded with permits issued as 'Assigned Amounts' that can subsequently be monetized through emission trading (Hisham Khatib, 2003)

Emission trading provides for an inventory-based system of transfers and acquisitions that are only open to Annex I Parties with Article 3 commitments. Article 17 of the Kyoto Protocol provides for Annex I Parties to acquire units from other Annex I Parties and use them towards meeting their emissions targets under the Kyoto Protocol. This enables Parties to make use of lower cost opportunities to reduce emissions, irrespective of the Party in which Party those opportunities exist, in order to lower the overall cost of reducing emissions.

Only Annex I Parties to the Kyoto Protocol with emission limitation and reduction commitments inscribed in Annex B to the Protocol may participate in such trading. Such Parties may therefore be prepared to transfer units when they do not require them for compliance with their own emission targets.

The units which may be transferred under Article 17 emissions trading each equal to one metric tonne of emissions (in CO_2-equivalent terms), and may be in the form of:

- An assigned amount unit (AAU) issued by an Annex I Party on the basis of its assigned amount pursuant to Articles 3.7 and 3.8 of the Protocol.
- A removal unit (RMU) issued by an Annex I Party on the basis of land use, land-use change and forestry (LULUCF) activities under Articles 3.3 and 3.4 of the Kyoto Protocol.
- An emission reduction unit (ERU) generated by a joint implementation project under Article 6 of the Kyoto Protocol.
- A certified emission reduction (CER) generated from a clean development mechanism project activity under Article 12 of the Kyoto Protocol.

Transfers and acquisitions of these units are to be tracked and recorded through the registry systems under the Kyoto Protocol. These include a national registry to be established and maintained by each Annex I Party.
Emission trading thus allows Parties to acquire and transfer full Kyoto units. The environmental integrity of emission trading is particularly critical to the entire Protocol and is underpinned by requiring all Annex I Parties to review conditions as well as the requirement to comply with strict reporting and review conditions as well as the requirements to maintain a commitment period to limit overselling.

Compliance to these requirements is overseen by the Compliance Committee established pursuant to the Protocol.

Table 2.2 gives an overview of Kyoto Mechanisms

Project Related Mechanism			Non-project mechanism
Name	Joint Implementation	Clean Development Mechanism	Emission Trading
Parties subject to participation/eligibility criteria	Annex I-Annex I	Non-Annex I-Annex I	Annex I- Annex I
Authorized legal entities (dependent on Party eligibility criteria)	Yes	Yes	Yes
Kyoto unit	Emission reduction units (ERUs)	Certified emission reductions (CERS) Temporary CER (tCER) and long-term CER (ICER) from afforestation and reforestation projects	Assigned amount units (AAUs)
Unit fungibility	Yes	Yes	Yes
Unit use restriction	Refrain from using ERUs from nuclear facilities	CERs from afforestation and deforestation not to exceed 1% of Party's assigned amount Annex I are to refrain from using CERs from nuclear facilities	No restrictions

Unit carry over	Yes – 2.5 % of a Party's assigned amount	Yes – 2.5 % of a Party's assigned amount	Yes – without restriction
Unit availability	From 2008 to 2012	From 2000	From 2008 to 2012
Coverage of activities	All Kyoto eligible sources and LULUCF activities	All Kyoto eligible sources with priority to small scale	Not applicable
Responsible institutions	Accredited Independent Entities, Article 6 Supervisory Committee, COP/MOP	Designated operational entities (DOEs), Executive Board, COP and COP/MOP	National Registries, Transaction Log, COP/MOP
Administrative Support	Secretariat	Secretariat	Secretariat
Administrative costs	To be borne by Participants	To be borne by Project Participants and DOEs	No specific Provision

Source: Wollansky and Freidrich (2003)

2.3 Approaches to Emission Trading

There are two principal approaches to emission trading, namely baseline-and-credit, and cap-and-trade regimes.

The baseline-and-credit regimes as regards emission trading do not set a fixed absolute cap on the emissions from the sectors covered by the regime, much as the regulator concerned usually has a complete target in mind when setting the relative target. The relative target is usually placed through defining a baseline, which is expressed in the emission efficiency in relation to the activity of the source, measured in weight per unit of input, output or activity. (Jurgen Lefevere, 2005). The same baseline used can be applied to a wide range of similar installations.

Under the baseline-and-credit regime, installations that can reduce their emissions lower than the market price of allowances, are permitted to obtain allowances which can be traded. Conversely, installations whose emissions are more expensive than the market value can maintain or increase their emission by buying additional allowance from the market.
The baseline-and-credit regimes allocate allowances when a source or installation demonstrates its capabilities to perform better than its baseline.
All baseline-and-credit regimes to a large extent can be described as voluntary approaches to environmental regulations. This is because credits are issued to all firms which achieve emission reductions below a set amount, such as the level that would prevail under a regulatory system (Nick Johnstone). Involvement is such a regime is voluntary. Low cost carbon emitters are not obliged to create carbon credits, and high cost carbon emitters are not compelled to purchase carbon credits. In essence, the efficiency gains created by the tradable permit systems provide the necessary incentives for voluntary participation by firms/installations.

In a cap-and-trade scheme, the situation differs from that as described by the baseline-and-credit regime. The cap-and-trade regimes set a total quantity of emissions measured over a specified time frame, on all emissions covered by the regime. This total emission is usually allocated free or by auction in the form of tradable allowances, to the installations within this regime.

Like in the case of the baseline-and-credit schemes, sources involved in the Cap-and-trade scheme may choose to increase or maintain their emission by buying allowances from the market. Sources, whose emissions are below the emission as predetermined by the market, may elect to obtain allowances which can be traded in the market. In the case where allowances are auctioned, no firm would be likely to participate in the scheme in the absence of a regulatory threat. The table below gives succinct details of a typical trading scheme.

Table 2.3 Allowance and Credit schemes

Cap-and-trade	**Rate-based trading**	**Project-based credit**
Applies to all emissions	Applies to all emissions vis-à-vis some defined standard (e.g., emissions per unit of output)	Applies to emission reductions below defined baseline
All emissions must be traded	Emissions above or below the standard can be traded	Only emission reductions can be traded
Allowance are allocated by the regulatory authority	Credits are generated when a source reduces its emission below the standards	Credits are generated when a source reduces its emission below an agreed baseline
Trading must be built into the regulatory structure from the beginning	May develop incrementally as a means of introducing flexibility into existing regulatory structure	May develop incrementally. Does not require a regulatory structure by itself but rests on the existence elsewhere of a regulatory structure creating demand
Participants can buy or sell or both	Participants can buy or sell or both	Project hosts can only sell
Participation in the programme is mandatory- the overall emission cap still applies even if sources do not trade.	Participation in the programme is usually mandatory – sources must meet existing standards	Participation in the programme is voluntary

Source: US EPA, 2003

2.4 Coverage

In emission trading, coverage refers to the sources or categories of emitters that are involved in the emission trading scheme as well as the gases covered. Listed in Annex A of the Kyoto Protocol are six greenhouse gases from a wide range of sources.

The choice of the coverage of gases by a trading regime usually depends on the coverage of the sources and the measurability of the emissions of gases by those sources, which is determined by the diffuse nature of the sources of the emissions and the uncertainty related to the estimation or measurability of the quantities of those emissions (Jurgen Lefevere). This is because some greenhouse gases are only

emitted in small quantities by the source covered by the regime, while some greenhouse gas emissions from specific sources also have a considerable degree of uncertainty in relation to the measurement of their emission. There are also different political motivations for covering certain sectors (Baron and Bygrave).
The EU Emission Trading Directive, for example, for the aforementioned reasons, limits the coverage of gases to CO_2 only. On the other hand, the UK trading scheme leaves the choice to source to include only CO_2 emissions, or to include their emissions from all six greenhouse gases. The inclusion of all six greenhouse gases is, however, subject to the source being ale to demonstrate that it can actually monitor the emissions in a sufficiently accurate manner (DEFRA)

2.5 Carbon Market

The simplest carbon market can be defined as one which involves an entity preparing a contractual agreement that describes and specifies the kind of activity undertaken to reduce or offset carbon emission.
An offset in principle, is created when someone takes action to reduce emission below the accepted level, and gets reduction in emissions documented in an appropriate manner.

An offset is distinct from a typical emission allowance, which is usually seen as the amount of emission an entity is allowed to emit under government regulation.
Under the Kyoto Protocol, an AAU is an allowance, but entities may elect to use ERUs (emission offsets from Annex B countries approved by governments under the Joint Implementation (JI) and CERs (emission offsets from non-Annex B countries certified by the CDM Executive Board under the Clean Development Mechanism (CDM) to supplement AAUs in complying with their obligations. (Carbon Market Overview)

The following markets are typical with globally sourced emission offset.

- Kyoto compliance instruments (CERs and ERUs) for sale to corporations in Canada and Japan
- Kyoto compliance instruments (CERs and ERUs) for sale to government and multilateral agencies

- Kyoto compliance instruments (CERs and ERUs) eligible for use within the European Emission Trading Scheme, for sale to corporations in Europe
- Voluntary markets for emissions reductions that are not compliant with the Kyoto Protocol, for sale to entities who elect to offset their emissions for non regulatory purposes.

Pricing in carbon market depends on the characteristics of individual markets which include the following:

- International and domestic policy
- Recognition of monitoring and verification protocols
- Recognition of early credit
- Expected versus actual allocation of carbon emission
- Project, financial and operational risk
- Sustainability issues and social impact of underlying project

High prices and relatively low volumes -5,000 to 50,000tCO_2eq are typical with the voluntary market involved in carbon trading. In general, buyers are willing to pay higher prices for projects characterized with high sustainability and social impact.

Transactions involving emission reduction vary from spot purchases and sales to structured options and direct investment.

Spot transaction involves delivery and payment within specified time limit after all necessary contractual agreements have been met.
Under forward settlement, the delivery of reductions and payments are deferred to a future date as specified at the time of trade.
Options are defined as contracts that the buyer or seller the freedom, but not the obligation, to enter into a specified transaction on or before a certain date.
Project investment gives the buyer the choice to invest directly in projects that will produce an acceptable rate of return along with emission reductions.

At the moment, projects concerned with renewable energy and electricity generation have gained prominence the carbon market and have been most successful in their submission to the CDM Methodology panel

In general emission reduction can generally be classified under the following categories

- Energy generation and use: this covers activities that involve building efficiency, commercial/industrial efficiency, fuel switching, renewable energy, transportation, etc
- Carbon capture/recovery/utilization: this covers biomass methane recovery, coal bed methane, waste CO_2 recovery, landfill/capture, etc
- Process changes such as modification of manufacturing processes
- Sequestration: this covers forest sequestration, land conservation, soil conservation and land use.

2.6 Allocation of Allowances.

The total amount of emission allowed in a trading scheme is shared in the form of rights, allowances or permits (as the case may be) through allocation.
In a trading scheme, allocation methods are usually classified as free allocation and auctioning.
An allocation termed free is usually based on historic emissions – 'grandfathering'- or on a baseline related to current activity as in baseline-and-credit scheme. In the case of grandfathering, the distribution of allowances is free of charge and is based on the past emissions levels. The base period or historical emissions principle starts from emissions in a chosen period, either one reference year or the average over several years. While this might be termed "pure" grandfathering, the term 'grandfathering' also refers to distributions using benchmarks, for instance regarding emissions per unit of output, but again on an historical basis.

Auctioning on the other hand, stands for the auctioning of the allowances to the sources covered under the regime, where the amount allocated to a source depends on the price it is willing to pay for the allowances. In the case of auctions, participants in the trading system have to purchase the allowances from the government to cover their expected emissions. The returns of the auction could then be recycled back into the economy, for example by means of reducing other taxes. One of the advantages of auctioning allowances is that it avoids the difficult negotiation of source-by-source allocations. Instead, each source decides how many allowances it needs to buy to cover its projected emissions, and bid for these allowances on the marketplace.

Chapter 3

THE EU EMISSION ALLOWANCE TRADING SCHEME

The EU Emission Trading Scheme (ETS) is one of the policies across Europe, intended to handle carbon dioxide emission and other greenhouse gases and combat the serious threat of climate change (DEFRA). It covers emissions of greenhouse gases from a number of industries, which are specified in the EU Emissions Trading Directive.

The EU ETS came into existence on 1 January 2005, with the first phase running from 2005-2007 and the second phase will run from 2008-2012 to coincide with the Kyoto Commitment. The scheme is based on Directive 2003/87/EC, which entered into force on 25 October 2003.

Under the EU ETS, further five-year periods are subsequently expected. Figure provides more details on the countdown to the operation of EU ETS.

The EU ETS focuses initially on carbon dioxide (CO_2) emission trading and as such, requires allowances to be located to sectors, companies or plants.
Allocations under the EU ETS are made on the basis of the share of emission in a historical base year or the expected share of emissions under a business as usual scenario projection of emissions in a future period (Trevor Sikorski)

A plant registered under the ETS can for example emit less than the level of its allocations. In this scenario, such a plant can sell the additional permits to others that may have emitted more. Conversely, it the plant emits more, it may need to purchase additional permits or pay a penalty associated with the commitment period.

All installations within the umbrella of the EU ETS are allocated allowances for the particular commitment period in question. The numbers of allowances allocated to each installation are set down in a document called the National Allocation Plan. Table 1 provides a summary of the key elements of the Directive on the EU ETS as agreed in July 2003

• A cap is set on the total emissions of all participants in the scheme by allocating a certain amount of emission allowances, which is fixed ex ante for a certain period. These allowances can be freely traded among the participants.

• Participants are obliged to surrender a quantity of allowances equal to their emissions over a certain period. A surplus of allowances can be sold (or banked for the next period), while a deficit has to be covered by purchasing additional allowances (or paying a penalty).

• The obligation to surrender allowances is imposed on fossil fuel *users*.

• Emissions of electricity and off-site heat are attributed directly to power and heat *producers*

Table 3.1 *Key elements of the EU Emissions Trading Scheme (EU ETS), as agreed by the European Parliament, the Council and the Commission in July 2003*

Type of System	**Downstream cap & trade system covering direct emission**
Timing	Phase 1: 2005-2007 Phase 2: 2008-2012 (i.e. first commitment period of the Kyoto Protocol).
Coverage of activities (sectors and/or installations	All combustion plants exceeding 20MW thermal input, including power generators. Oil refineries, coke ovens, ferrous metals, cement clinker, pulp from timber, glass & ceramics Based on the Integrated Pollution Prevention Control (IPPC) Directive, but several IPPC sectors are excluded (e.g. chemicals, food and drink, non-ferous metals, waste incineration). Member states may apply to the commission for installations to be temporarily excluded until 31 December 2007, at the latest (opt-out-clause) Member states may voluntarily extend the scheme to other installations, starting from phase 2 (opt-in-provision)
Coverage of Greenhouse gases	Only CO_2 in phase 1 Other gates may be included in Phase2, provided adequate monitoring and reporting systems are available and provided there is no damage environmentally integrity of the scheme.
Size of market	10,000-15,000 installations About 50% of EU carbon dioxide emissions (CO_2e).
Allocation	Free during Phase 1 with National Allocation Plan based on Annex III criteria and Commission guidelines Member states have the option to auction 5% of allowances in Phase 1 and up to 10% in Phase 2 The Commission has the right to veto over national allocation plans.

Operational rules	On April 30 each year, participants have to surrender a quantity of allowances equal to their emissions in the preceding calendar year. Participants are allowed to trade allowances among each other. Participants are allowed to form an emission pool by nominating a trustee who takes on the responsibility for surrendering and trading allowances on behalf of all members of the pool.
Banking	Banking across years within each compliance period Member states can determine banking from first compliance period (2005-2007) to first Kyoto Protocol period (2008-2012)
Links with Kyoto mechanisms1	Participants may convert emission credits from JI and CDM projects into EU allowances in order to fulfil their obligations under the EU ETS. All types of JI/CDM credits are allowed for conversion, except credits from nuclear facilities and carbon sink enhancement projects. As soon as credits amounting to 6% initially allocated EU allowances have been converted, the Commission must undertake a review and decide whether a quantitative limit could be introduced
Links with other schemes	Agreement with third parties listed in Annex B of the Kyoto Protocol may provide for the mutual recognition of allowances between the EU ETS and other schemes
Monitoring Reporting Verification	Common monitoring, verification and reporting obligations to be elaborated Verification through third party or government authority
Allowance tracking	Linked/harmonized national registries with independent transaction log. To be based on Kyoto Guidelines and US Acid Rain Programme.
Compliance	Non-complying participants have to pay a penalty of €40 per tonne CO_2 during Phase 1 and €100/tCO_2 in Phase 2.

Source: Joe Sijm

3.1 EU Burden Sharing Agreement.

The strength of character for the implementation of the EU commitment to Kyoto Protocol and EU climate change target for the years 2008-2012 is known as the EU's burden sharing agreement. This burden sharing agreement as defined by the EU divides up the EU overall emission target 8 percent of 1990 emissions between 2008 and 2012 by setting individual emission targets, in percentage of 1990 emissions, for each of the Member States that jointly ratified the Kyoto Protocol in May 2002. This target is shared among the 15 Member States under a legally binding burden-sharing agreement under Community law though its inclusion in Annex II to the

Council Decision concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments therein, adopted on 25 April, 2005 (Council Decision 2002/358/EC of 25 April 2002).

The original burden-sharing agreement of the EU set specific emission intention for the year 2010, as a fraction of the emissions of 1990, for all the Member States.

The finalizing of the EU burden-sharing agreement in line with the negotiations at COP-3 in Kyoto significantly strengthened the EU's negotiation and set the precedent for other developed countries to come up with proposals for targets.

Table 3.2 gives the breakdown of Member States under the initial EU burden-sharing agreement.

Table 3.2 Member States under the initial EU burden-sharing agreement (before the finalization of the Kyoto negotiations)

Austria	-25%
Belgium	-10%
Denmark	-25%
Finland	0%
France	0%
Germany	-25%
Greece	+30%
Ireland	+15%
Italy	-7%
Luxembourg	-30%
The Netherlands	-10%
Portugal	+40%
Spain	+17%
Sweden	+5%
United Kingdom	-10%

Source: Jurgen Lefevere

The final outcome of the Kyoto negotiation differed significantly with the assumptions of the EU based on the first burden-sharing agreement. This was largely due to the expansion of the three gases originally proposed by the Community to six gases. The target of emission reduction that was finally agreed upon was 8 per cent over the period 2008-2012 as against 15 per cent by 2010. The Community had to resort to the initial agreement of 23 March 1997 in line with the Kyoto negotiation, to allow for the use of its burden-sharing agreement. Member Sates finally came to a final agreement on 16 and 17 June 1998 to share the 8 per cent emission reduction for the European Community as a whole over the Member States as indicated below

Table 3.3 Member States target under the final EU burden-sharing agreement

Austria	-25%
Belgium	-10%
Denmark	-25%
Finland	0%
France	0%
Germany	-25%
Greece	+30%
Ireland	+15%
Italy	-7%
Luxembourg	-30%
The Netherlands	-10%
Portugal	+40%
Spain	+17%
Sweden	+5%
United Kingdom	-10%

Source: Jurgen Lefevere

3.2 Permits and Allowances

A clear distinction is made under the EU ETS as regards greenhouse gas permits and allowances. The permits are defined as the requirement framework for installations registered under the EU ETS to participate in the trading regime as they set out conditions for the monitoring and reporting of installation emissions.
The tradable units associated with such emissions are known as allowances.

Article 4 of the EU Emission Trading Directive mandates Member States to ensure that from January 1 2005, no installations undertake any activity listed in Annex 1 of the Directive unless it holds a greenhouse gas emission permit (Jurgen Lefevere). All information that needs to be included in the application for permit is contained in Article 5. Included in Article 5 is the description of the installation, the raw and auxiliary materials used that are likely to lead to greenhouse gas emission, the sources of greenhouse gas emission and the planned monitoring and reporting measures.
Contained in Article 6 of the EU ET Directive are the conditions for and the contents of the greenhouse gas emissions permit.
Permits may be issued if the installations concerned are capable of monitoring and reporting greenhouse gas emissions.
The permit must include monitoring requirements, specifying monitoring methodology and frequency, reporting requirements and, importantly, the obligation to surrender allowances equal to the total emissions of the installation in each calendar year. (Jurgen Lefevere)

In general, the procedure for granting the permit is based on the IPPC standard. Article 8 of the ET Directive requires that the permitting procedure to be coordinated with the granting of the IPPC permit and allows Member States to fully integrate the two permitting processes.

Allowance as defined by Article 3(a) of the ET Directive, means the right to emit one tonne of carbon dioxide (tCO_2) equivalent during a specified timeframe, which shall be valid only for the purpose of meeting the requirements of this directive and shall be transferable in accordance with the provisions of this Directive.
The limit or cap placed on allowances gives rise to scarcity needed for the emergence of an emission trading market.
Under such markets, installations or firms that are able to keep their emission below the accepted level, have options to sell their excess allowance at a price determined by the market forces of demand and supply.
Installations that are unable to keep with the accepted level of emission have options to invest in buying allowances from the market, or investing in low carbon intensity technology, or the combination of the aforementioned options, whichever is cheapest.
Companies or installations covered under the EU ETS are allocated allowances free of charge – at least 95% during the first stage and at least 90% during the second stage that runs from 2008-2012.
In general, allowances are initially allocated to the operators of installations covered by the Directive, but can be transferred between natural and legal entities within the Community and between entities within the Community and entities in third countries if a bilateral agreement under Article 25 of the ET Directive exists with those countries.
The table in the next page shows emission allocations and number of installations covered by the EU emissions trading scheme per Member State

Table 3.4 EU Emission Allowance Scheme

EU Member State	CO_2 allowance in million tones	Installations covered	Kyoto target
Austria	99.01	205	-13 %(*)
Belgium	188.8	363	-7.5 %(*)
Czech Republic	National allocation plan yet to be assessed		-8.0
Cyprus	16.98	13	-
Denmark	100.5	362	-21 %(*)
Estonia	56.85	43	-8.0 %(*)
Finland	136.5	535	0 %(*)
France	469.53	1172	0 %(*)
Germany	1497.0	2419	-21 %(*)
Greece	National allocation plan yet to be assessed		+25 %(*)
Hungary	93.8	261	-6%
Ireland	67.0	143	+13 %(*)
Italy	National allocation plan yet to be assessed		6.5 %(*)
Latvia	13.7	95	-8%
Lithuania	36.8	93	-8%
Luxembourg	10.07	19	-28 %(*)
Malta	8.83	2	-
Netherlands	285.9	333	-6%
Poland	National allocation plan yet to be assessed		-6%
Portugal	114.5	239	+27 %(*)
Slovak Republic	91.5	209	-8%
Slovenia	26.3	98	-8.0%
Spain(**)	523.7	927	+15%
Sweden	58.7	499	+4 %(*)
United Kingdom	736.0	1078	-12.5 %(*)
Total so far	**4641.97(**)**	**9089(**)**	
Approximate percentage of estimated overall total.	**ca.70%**	**ca.70%**	

(*) Under the Kyoto Protocol, the EU-15 (until 30 April 2004 the EU had 15 Member States) has to reduce its greenhouse gas emissions
by 8 % below 1990 levels during 2008–12. This target is shared among the 15 Member States under a legally binding burden-sharing agreement (Council Decision 2002/358/EC of 25 April 2002). The 10 Member States that joined the EU on 1 May 2004 have individual targets under the Kyoto Protocol with the exception of Cyprus and Malta, which as yet have no targets.
(**) Figures do not include some Spanish installations for which allocations are in preparation.

Source: EU Emission Trading.

3.3 National Allocation Plan

National allocation plans given an indication of how many CO_2 emission allowances Member States plan to allocate for the 2005-2007 trading period, and how many each plant or installation will receive. Member States' national allocation plans (NAPs) have to be based on objective and transparent criteria, including a set of common rules that are laid down in the legislative framework establishing the ETS. The most important of these rules are as follows:

- An allocation plan has to reflect a Member State's Kyoto target as well as its actual and projected progress towards meeting it. The total quantity of allowances allocated is fundamental in this regard. Allocating too many allowances would mean that greater efforts to cut emissions would have to be taken in economic sectors not covered by the scheme, in potentially less cost-effective ways than trading.

- Allocations to installations must take account of their potential for reducing emissions from each of their activities, and must not be higher than the installations are likely to need.

- Where Member States intend to use JI and CDM credits — thereby giving their companies more scope to emit — to help them reach their national emission target, these plans must be substantiated, for example through budgetary provisions.

Chapter 4

MODELLING METHODOLOGY

The aim of this chapter is to make provision for the estimation of Certified Emission Reduction (CERs) from power plants that contribute to electricity grid, in keeping with the Clean Development Mechanism (CDM). CERs are quantified by comparing emission of power plant projects with that of a typical baseline scenario.
Specific guidance is provided on the selection of estimation methodologies, data collection, and documentation.
Description of methodological and data collection options are described so as to match the details of emission inventories of users.
This guidance, along with its companion Excel worksheet tool, may be used by companies for internal or public reporting needs, or to participate in a GHG programme.

4.1 Procedure for Calculating Emission Reduction.

The following guidelines as outlined below are used in this thesis for the purpose of quantifying emission reduction from

Step 1. Determine the expected annual power output from typical electricity project

Annual Plant Output = Installed Plant Capacity (MW) x Plant Capacity Factor (%) x Hours/year (**Equation 1**)

where;
Plant Capacity Factor = measurement of how much electricity is generated compared with the amount of electricity a plant is capable of producing;
Hours/year= 8760 (24x365) hours/year

Step 2. Estimating CO_2 Emission Factor.

Emission factor, in general, relates the mass of gas emitted to the quantity of fuel burned. It is defined as coefficient that relates the activity data to the amount of chemical compound which is the source of later emission.
Emission factors are usually based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of

operating conditions. It is measured in units of CO_2/unit of activity. For the case of electricity projects, the emission factor is expressed in kg (tonnes)/kWh.

The CO_2 emission factors for fossil fuel are calculated by dividing the carbon content in weight percent as a fraction by the caloric heating value.

The formula below gives details of how to calculate CO_2 emission factor for electricity based project, when it is not provided.

$$\underset{(\text{tonnes } CO_2\text{kWh})}{\text{Emission factor}} = \frac{\text{volume consumed}}{\text{MWh output}} \times \frac{\text{kgC}}{\text{TJ}} \times \frac{\text{TJ}}{\text{volume unit of fuel}} \times \frac{\text{I tonne C}}{\text{1 kg C}} \times \frac{44\text{g/moleC}0_2}{12\text{g/mole C}} \quad (\textbf{Equation 2})$$

Power output (MWh) is based on plant data;

kg/TJ is carbon emission factor per fuel type as prescribed by IPPC;

TJ/volume unit of fuel= net calorific value, country specific, per fuel type as provided by IPPC

Step 3. Determine the expected CO_2 emission from project

$$\underset{(\text{tonnes } CO_2)}{\text{Project Emission}} = \underset{(\text{MWh/year})}{\text{Annual plant output}} \times \underset{(\text{tonnes } CO_2\text{/MWh})}{\text{Emission factor}} \quad (\textbf{Equation 3})$$

where:

Annual plant output = value obtained from Equation 1;

Emission factor is computed using Equation 2 when it is not given.

Step 4. Baseline Determination

Baselines can be standardised or specific to projects. For the case of the former, the same baseline is used for an entire class of projects.

There are several options employed for the quantification of emission factor for grids with different sources of power supply:

(i) the approximate operating margin and the build margin

where:

- the approximate margin is defined as the weighted average emission of power plants supplying the grid, excluding hydro, geothermal, wind, low-cost bio-mass, nuclear and solar generation;

- the build margin is defined weighted average emission of recent capacity addition to the system. In this case.

(ii) the weighted average emission factor (in $kgCO_2/kWh$) of the current generation mix.

Step 5. Computation of weighted emission factor.

The second option known as the weighted average emission factor in Step 4 is considered for baseline determination in this thesis.

Weighted Emission Factor=∑Emission factor per plant x Generation Mix (**Equation 4**)
(kgCO$_2$/kWh) (kgCO$_2$/kWh) (%)

where:

Generation Mix= Percentage contribution to grid by power plants.

Step 6. Computation of Baseline Emission

Baseline Emission= Annual Plant Output x Weighted Emission Factor (**Equation 5**)
(MWh/year) (kgCO$_2$/year)

Step 7. Quantifying Emission Reduction

Emission reduction is defined as the difference between baseline emission and project emission.

$E_{reduction} = E_{baseline} - E_{project}$
tCO_2 (tCO_2) (tCO_2)

where;

$E_{reduction}$= Emission reduction

$E_{baseline}$= baseline emission specific to power plant as defined by Equation 5.

$E_{project}$= project emission specific to power plant as defined by Equation 3.

The flow chart below gives steps in computing for emission reduction.

4.2 The Spreadsheet Model

The database used for the computation of emission reduction was created using the Microsoft Excel package. This package was selected because it is user friendly and is part of Microsoft Office. The program allows for graphical data and can be exported into other programs.

4.2.1 Sources of Data

Emission factors for fuel associated with power generation were selected from the data provided by Carbon Trust. The package is however flexible and allows for the input of emission factors from other regions apart from the one used for the validity of this package.

4.2.2 Estimation Approaches

The program developed with the aid of Microsoft Excel can be used for the quantification of emission reduction associated with electricity grid that sources its supply from various fossil fuel based power plant, hydro and renewables. Table 4.1 gives details of approaches used and the data required.

Table 4.1 Estimation Approach

Estimation Approach	Data Required
Annual plant (diesel, hydro, coal, natural gas, renewables, etc) power output	Installed plant capacity, plant capacity factor
Emission by power plant (diesel, hydro, coal, natural gas, renewables, etc	Annual power plant power output, power output, emission factor.
Baseline emission by power plant (coal, diesel, natural gas, hydro, renewables, etc	Annual power plant output, percentage grid contribution, weighted emission factor
Emission reduction	Project emission, baseline emission specific to power plant

4.2.3 Using the Spreadsheet Model

The Spreadsheet utilizes data provided from a Grid that benefits from various sources of power supply. Supply from Nuclear plant was not considered in the development of the model. This is because the Kyoto Mechanisms such as CDM, JI and Emission Trading do not generating CERs through nuclear facilities to meet emission targets. The inputs required are as follows;

- installed plant capacity
- plant capacity factor
- emission factor

Emissions based on power plant re calculated using the procedure described in section.

In general, there are losses associated with power generation such as transmission and distribution losses. The model, however, works on the assumption that there is no loss associated with the supply of power to the grid.

Scenario

A hypothetical UK based Electricity Grid derives supply of Power

Fuel type	Installed Plant Capacity MWh	Plant Capacity Factor %
Diesel	28	45
Hydro	35	65
Coal	38	58
Natural Gas	40	68
Renewables	24	40

Fuel type	Emission factor $kgCO_2/kWh$
Diesel	0.69
Hydro	0
Coal	0.83
Natural Gas	0.19
Renewables	0

4.3 Emission reduction by power plant.

The spreadsheet quantifies emission reduction from different power plants associated with the grid.

For a particular power plant selected from the Part 2 of the model, the emission reduction associated with the use of such power plant is calculated in Part 3 and subsequently displayed in graphics.

If the data associated with the grid mix, such as Installed Plant Capacity, Plant Capacity Factor, Emission Factor are entered in the database of Part 1, the spreadsheet automatically quantifies the Annual Plant Power Output, Percentage Grid Contribution, Weighted Emission Factor, and Project Emission (see screenshot below)

1 Power Generation Mix

Plant type	Installed plant capacity MW	Plant capacity factor %	Annual plant type power output (MWh)	Percentage Contribution to Grid	Emission factor kgCO2/kWh	Weighted Emission Factor kgCO2/kWh	Baseline Emission tCO2	Project emission tCO2
Diesel	28	45%	110376	13.38%	0.69	0.092302792	37680.88	76159.44
Hydro	35	65%	199290	24.15%	0	0	68034.93	0
Coal	38	58%	193070.4	23.40%	0.83	0.194215946	65911.64	160248.4
Natural Gas	40	68%	238272	28.88%	0.19	0.05486782	81342.86	45271.68
Renewables	24	40%	84096	10.19%	0	0	28709.24	0
		Total Power Output	825104.4					
			Total Percentage Contribution	100%				
					Total weighted emission factor	*0.341386559*		

For each power plant selected in part 2, the spreadsheet computes its project emission. The screen shot below shows the results obtained when the renewable power plant is selected.

2 Project Specification

Plant type	Installed plant capacity MW	Plant capacity factor %	Annual plant type power output MWh	Emission factor kgCO2/kWh	Project emission tCO2
Renewables	24	40%	84096	0	0

Part 3 of the spreadsheet quantifies emission reduction for each power plant selected from Part 2. (See screenshot below)

3 Calculating Project Emission Reduction

Plant type	Annual plant type power output MWh	Weighted Emission Factor kgCO2/kWh	Baseline Emission tCO2	Emission reduction tCO2
Renewables	84096	0.341386559	28709.24407	28709.24407

The following screenshot and graphs on the next page are for the power plant option using a coal fired power station linked to the grid.

1 Power Generation Mix

Plant type	Installed plant capacity MW	Plant capacity factor %	Annual plant type power output (MWh)	Percentage Contribution to Grid	Emission factor kgCO2/kWh	Weighted Emission Factor kgCO2/kWh	Baseline Emission tCO2	Project emission tCO2
Diesel	28	45%	110376	13.38%	0.69	0.092302792	37680.88	76159.44
Hydro	35	65%	199290	24.15%	0	0	68034.93	0
Coal	38	58%	193070.4	23.40%	0.83	0.194215946	65911.64	160248.4
Natural Gas	40	68%	238272	28.88%	0.19	0.05486782	81342.86	45271.68
Renewables	24	40%	84096	10.19%	0	0	28709.24	0
		Total Power Output	825104.4					
			Total Percentage Contribution	100%				
					Total weighted emission factor	*0.341386559*		

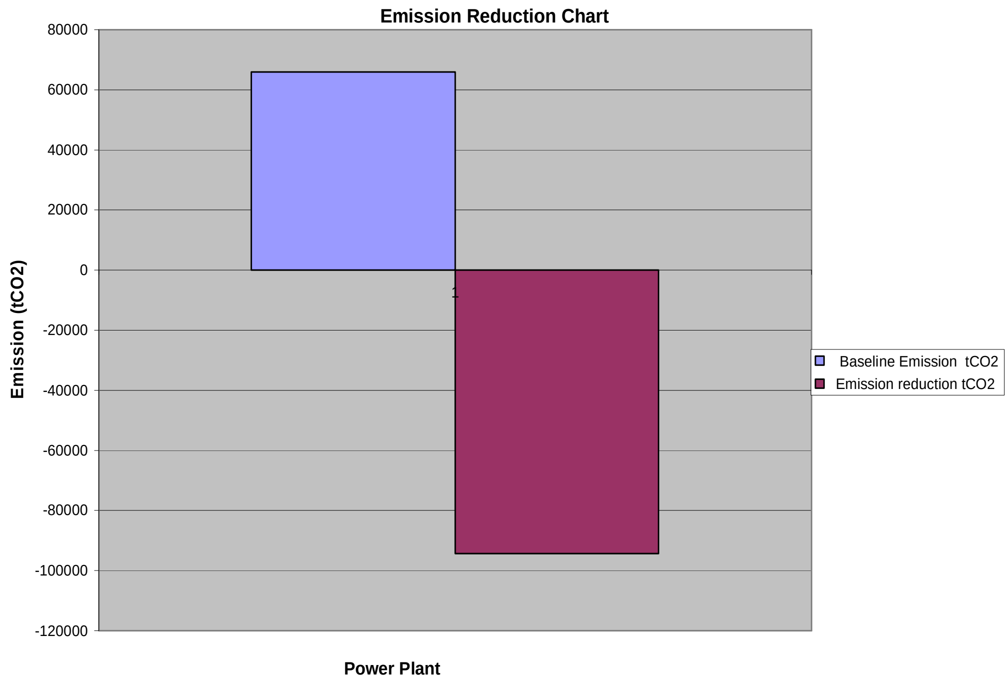
2 Project Specification

Plant type	Installed plant capacity MW	Plant capacity factor %	Annual plant type power output MWh	Emission factor kgCO2/kWh	Project emission tCO2
Coal	38	58%	193070.4	0.83	160248.432

3 Quantifying Project Emission Reduction

Plant type	Annual plant type power output MWh	Weighted Emission Factor kgCO2/kWh	Baseline Emission tCO2	Emission reduction tCO2
Coal	193070.4	0.341386559	65911.63952	-94336.79248

Fig 4.1 Emission Reduction Chart for Coal fired plant



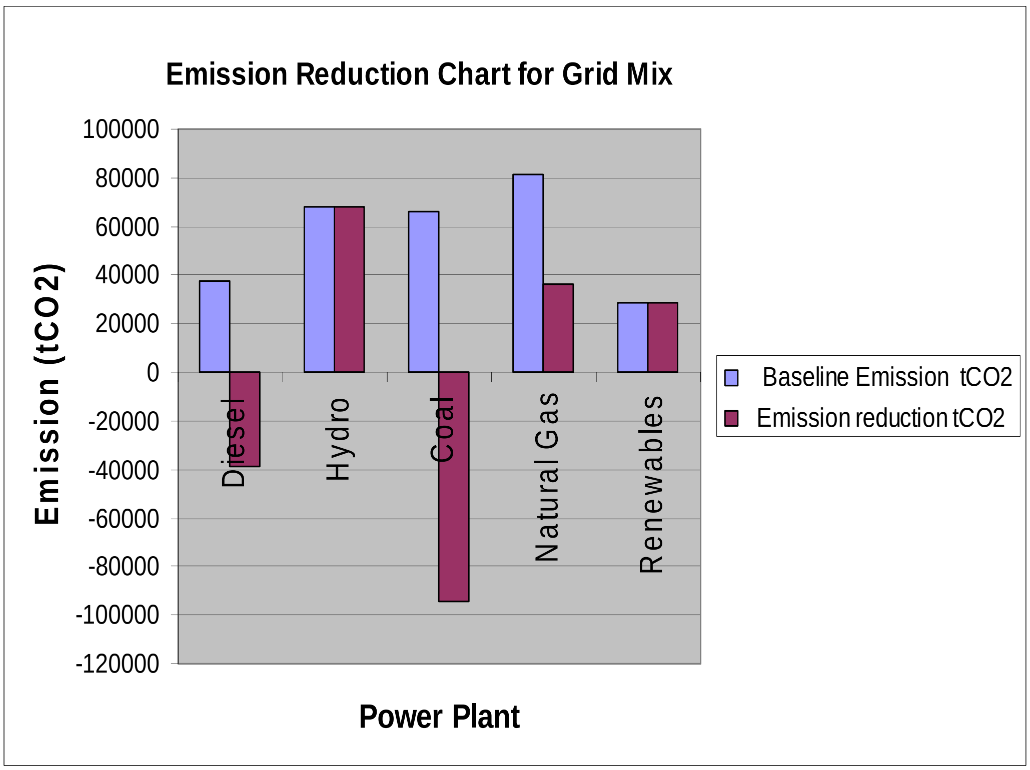


Figure 4.2 Emission Reduction Chart for Grid Mix

4.4 Analysis of Sample Output

With the aid of the spreadsheet model, analysis based on different scenarios, are presented as follows;

Scenario 1: Fossil fuel

From the chart showing emission reduction for gird fuel, the coal and diesel fired generators show significant increase in the project emission when compared with their baseline emission. The gas fired plant shows the least project emission for the grid mix.

According to equation 3,

Project Emission = Annual plant output x Emission factor

($tonnes\ CO_2$) (MWh/year) ($tonnes\ CO_2$/MWh)

For the purpose of emission reduction the coal fired and diesel fired generators as demonstrated by the spreadsheet model, may opt for the following

- to invest in reducing the emission factors of the power plants when an emission cap is implemented,
- to lower the power output of the generators,
- or combine both options.

In the event of high CO_2 prices, the generators may opt to retire the plants or consider carbon abatement options such as co-firing with biomass and improving the ability of the plants to supply power on peak capacity. The coal fired generator may choose to maintain its power output by buying emission allowance from the carbon market From the graphical display of the spreadsheet, the gas fired plants is most suitable for the purpose of emission reduction. The prospect of it assuming a larger share in a typical grid mix will be greatly enhanced in the case of carbon trading and ratification of global environmental agreements.

Scenario 2: Renewables /Hydro

There is no carbon emission associated with the use of renewable and hydro generator. This therefore implies that both generators provide useful options for reduction of carbon emission. Since producing renewable energy decreases total emission, converting tradable renewable certificate into carbon emission allowance could be done if a conversion factor is accepted by the government where such schemes could be linked.

In terms of working out the right grid mix as demonstrated by the spreadsheet, a lot would depend on the existing stock of power plants, the regional fuel endowment, capital and human resources and availability and cost of alternative resources.

Chapter 5

IMPACT OF CARBON TRADING ON POWER UTILITIES

The emergence of the EU ET Scheme will definitely affect the way power generators handle their existing generation capacity and portfolio. As such, the regulatory change posed by emission trading should therefore be viewed in the perspective of the electrical value chain. This entails that the manner which utilities buy energy commodities and manage their exposure to wholesale energy market will reflect the international nature of emission trading. The likely impact of the EU ET Scheme on power utilities are discussed in the following sub-headings.

5.1 Price Implication

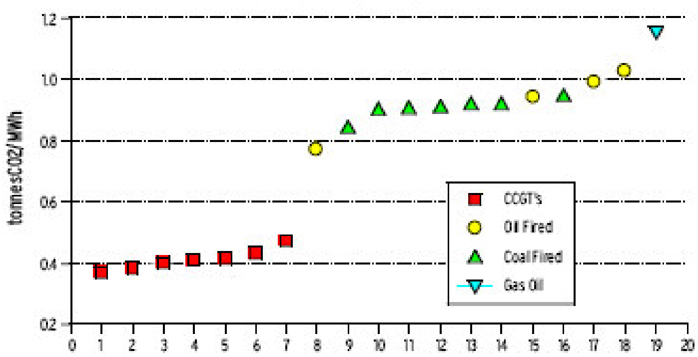
In practice, the cost associated with carbon emission is linked to energy deliver cost. This is because power generators, in order to maintain power output, have to purchase carbon credits or take advantage of free allocation where it is provided, and this has a direct cost or opportunity cost.

Where free allocation is in place, power generators may experience increase in revenue with little increase in cost. This stems from the fact that the market price is favourably disposed to a marginal generator that may be using more carbon permit per unit of power output.

A scenario using a generator that runs on natural gas can be used to assess the price implications of carbon trading. A power generator using natural has the option to sell gas and carbon in the carbon market rather than generating, if the price of gas and carbon, the production cost, surpasses the price of electricity. On the other hand, the gas-fired generator will generate power whenever the price of power exceeds its short- run marginal cost.

Power generation from different energy sources are usually associated with various levels of emission (see figure 5.1).

Figure 5.1 Carbon factors of Generation



Source: www.sungard.com

Gas- fired generators emit the least amount of CO_2 per MWh of energy produced, when compared to other fossil fuel based generators. Coal, on the other hand is the most carbon-intensive of all fossil fuels and emits more than twice what a gas fired plant emits per MWh . Higher electricity prices reflect the increased costs of fossil fuels for generation and the incremental cost of additional investments. This makes gas fired generators, in particular, closed cycle gas turbine (CCGT) more favourable given the carbon factor.

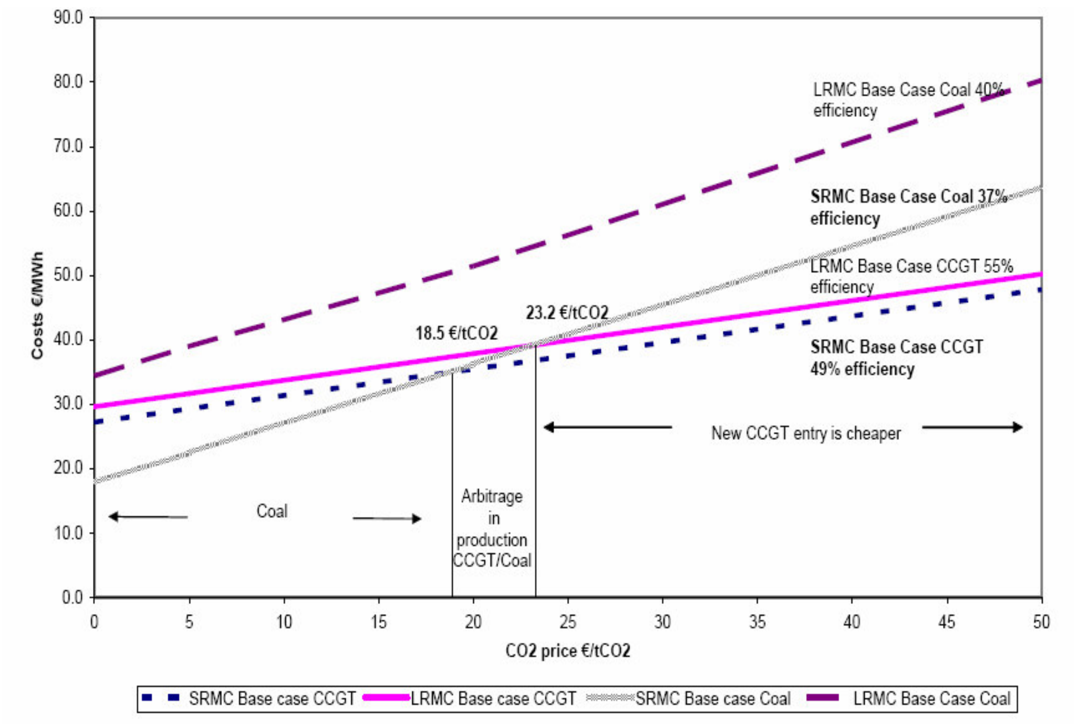
However, if CO_2 prices are reflected in electricity prices, opportunity cost would be recovered and investments by the present operators and new comers would not be distorted. This invariably means the emergence of a carbon price would not hamper investment in new plant or capacity expansion.

The emergence of carbon price could favour the investment in renewable energy such as wind and solar. This however depends largely on the generation capacity as renewable energy sources are not entirely reliable for the supply of energy.

Of all the power generating plants, the CCGT are favoured for capacity addition in the future EU environmental framework where gas is available. This stems from the fact that their unique advantages as regards emissions, efficiency, and costs compared to coal fired plants make it likely that power generators will favour building gas plants against coal plants.

In a situation where the price pf carbon emission becomes high, the impact of carbon emission limitation may be so considerable that power generators may need to decide between keeping the coal plants running and building more energy efficient CCGT plants. Figure 5.2 compares the short-run marginal cost and the long-run marginal costs and depicts the most profitable level of maintaining a coal fired plant rather than building a new gas fired plant.

Figure 5.2 Comparisons between Coal and CCGT Plants' Competitiveness



Source: IEA

If the carbon prices are in the range of €0 and €18.5, the operating cost of a coal plant in this is less than the long-run marginal cost of a CCGT plant. This makes the coal plants most preferred in this scenario.

However, if the carbon emission cost is in the range of €18.5 and €23.2, the CCGT plants become the technology of choice.

At a price more than €23.2 per tonne of CO_2 it is advisable for power generators to retire their coal fired plants in favour of modern CCGT plants.

5.2 Investment Decision

In terms of power generation, CCGT generators are most favoured. This is as a result of their unique advantage of low carbon emission, flexibility, and ease of additional capacity compared to other fossil fuel generators. Investment in CCGT however depends mainly on the price volatility and infrastructural development of gas network.

WEO outlook shows that the share of gas in European electricity generation is expected to increase significantly, from 16 per cent to 41 per cent in 2030 (IEA, 2002).

Development of infrastructural network for gas in the EU demands huge investment. This is because most of the gas for the future is expected to come from the Middle East and Africa. In general, for the capital to be raises, the market prices of gas have to be sufficiently high to allow for investment with sufficient return. This infers that to make gas sources profitable, gas prices are likely to rise, there by causing a rise in electricity prices adding to the increase as a result of costs associated with carbon emission.

Renewables and nuclear power plants, unlike fossil fuel generators, do not participate in the trading of emission allowances. The costs associated with the development of the non-fossil fuel power plants, makes them less favourable compared to coal fired plants and CCGT generators.

Investment in non-fossil fuel power plants is most likely if a high emission cap is placed on fossil fuel generation.

According to the Boston Consulting Group, wind power is making significant stride as a result of the improving cost position and subsidies from government. For wind power to be competitive with CCGT generators, the CO_2 emission price has to be very high. Investing in wind power is higher as a result of the diffuse nature and as such cannot be relied on for periods of peak demand, when it is most needed.

Adopting a policy of redundancy and diversity is therefore necessary. Redundancy in this case means spare capacity to back up wind-generation capacity. Diversity is important, to guarantee that a large proportion of generating capacity is not disabled by a single failure.

This means that the additional costs associated with investing in wind power largely depends on if existing plants or new conventional plants can sustain power demand when the generating capacity of wind power plants is not enough.

It follows that apart from hydro, for generation mix based on renewable energy sources, it would be difficult to provide such security of supply. It is therefore not rational to work on the premise that a carbon price will stimulate their construction in little time.

Nuclear technology compared to CCGT plants, has relatively low fuel cost and high operating cost. In power generation, economies of scale tend to favour very large plants and this result in a relatively large capital commitment to a single project and thus associated investment risk. Investments in nuclear energy have slowed down however as a result of public disapproval, litigation, construction delays and threat to the environment. A case for investment in nuclear technology with the introduction of emission cap is most likely if solutions were found to security and environmental matters. Report from Boston Consulting Group suggests that between 2012 and 2020, after 40 years of operation, 25 GW of prime based load is due to be closed in Europe. The report shows that the generation capacity displaced within the aforementioned time frame would put pressure in the power industry, thereby increasing the demand for gas. Investment in existing nuclear power plants to prolong their life span could therefore delay the pressure expected from the power market.

5.3 Fuel switching

Fossil fuels, globally dominate in the supply and conversion of energy. A major shift from coal to gas in terms of power generation may play a crucial role in curbing carbon emission. Reports from the International Energy Agency (IEA, 2002) suggests that a shift from coal to oil implies a reduction to 17 per cent in carbon emission, from oil to gas 23.5 per cent, and from coal to gas 43 per cent per unit of energy. This indicates that one effect of CO_2 emission cap could be an increase in gas consumption relative to coal.

The switch to lower-carbon emission fuel, particularly gas, is dependant on various factors such as price volatility, availability and distribution costs.
A decision to switch is widely perceived to be strategic in the sense that national interests, such as employment and energy security may be affected. Countries like Poland have coal as the only significant domestic source of energy.

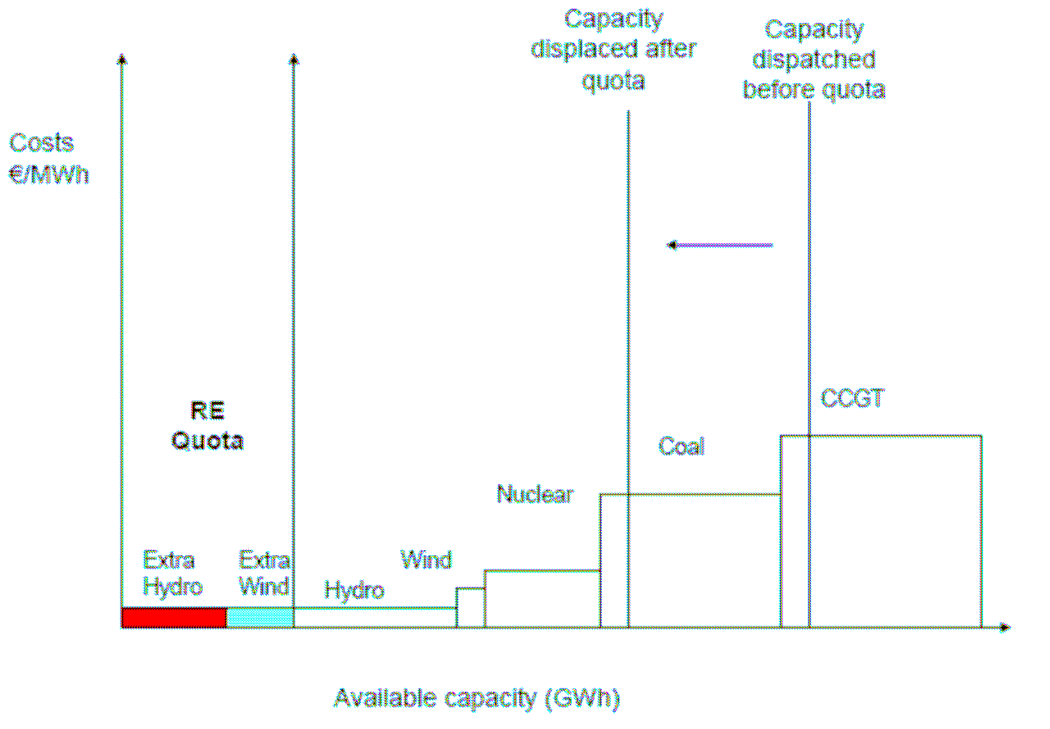
Interlaboratory Working Group (Int, 2000) reports that the economics are in most cases unfavourable with the current price levels of coal and gas. This gives credence to the fact that the switching of coal plants to gas plants would translate to investments in gas pipeline network to supply the fuel switched power plant. The likelihood of a switch is prevalent if a high carbon emission is put in place.

Another option of curbing emission from coal plants is the replacement of coal by biomass in existing boilers or co-combustion. Biomass fuels are not listed in the CO_2 emission in the IPPC Methodology. This is due to the fact that for every kWh produced by biomass fuel, direct co-combustion reduces the CO_2 emission by 0.918kg/kWh. Thus, co-firing biomass with clean coal is an emerging technology which may be deployed to new coal fired plants. The likely replacement however depends on several factors: environmental, technical, financial and legal limitation imposed by the authorities.
In the UK, for instance, co-firing for renewable certificates must end in 2011.
Investment in the refurbishment of existing coal plants is another solution to curb CO_2 emission. Improvements in the design of boilers and turbines can also reduce CO_2 emission.

5.4 Renewable Obligation

The deployment of renewable energy technology provides a good option of curbing CO_2 emission. This is evident in the directive adopted in October 2001 by the EU to promote electricity generated from renewable energy sources (RES) in the internal electricity market.
As such, there is a direct link between the development of renewable resources and carbon emission reduction associated with power plants.
Increase in the use of renewable power production leads to lower thermal production, which in turn leads to decrease in total amount of emission (Jensen et al, 2003). The figure below shows how some fossil fuel powered stations are displaced with the introduction of renewable energy production quota.

Figure 5.3 Merit order with the emergence of Renewable Energy Obligation



Source: IEA

From the figure above, renewable energy sources such as hydro and wind are the most competitive as a result of the cost implication. This entails that companies that decide to opt for renewable energy sources such as wind and hydro, as an avenue to meet their renewable obligation, may decide to displace fossil fuel technologies such as coal and CCGT, on the spot market, on the assumption of stable demand in power.

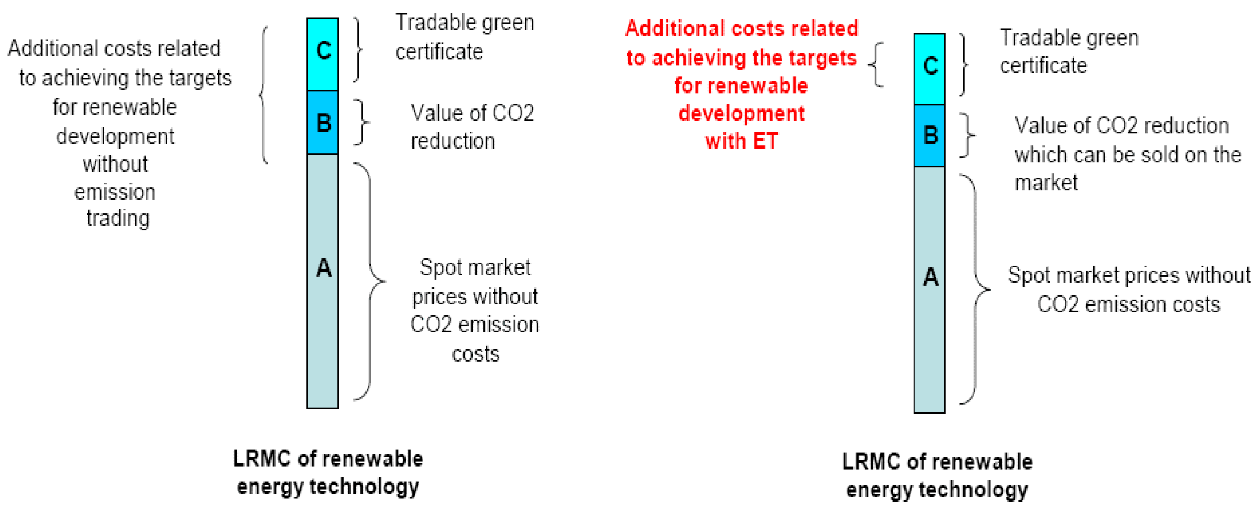
If Renewable Energy (RE) generators are included in the power market alongside fossil fuel generators, three parties interact; RE generators, fossil fuel generators and the consumers.
RE generators and fossil fuel generators supply the power market with electricity which the consumers are at liberty to purchase.

The fossil fuel generators have the right to hold a number of allowances that correspond to the amount of emission resulting from power generation.
These emission allowances can be purchased or sold by the fossil fuel generators.

On the other hand, the RE generators hold the right to sell green certificates known as the Tradable Renewable Energy Certificates (TRECs) based on the amount of power they produce, on the certificate market. In this case the buyers of such commodities depend on the holders of the renewable obligation; generators or electricity suppliers. The TRECs hold the value of CO_2 reductions achieved by investment in renewable energy.

In principle, the TRECs could hold a certain value that corresponds to CO_2 reduction as producing power from renewable energy resources reduces total emission. Quantifying the amount of emission avoided by renewable energy generation limits the linkage between the CO_2 emission markets with the green certificate market. However, if there is a value attached to every CO_2 reduction, which can be sold on the allowance market, the value of green certificates could be split into the value of CO_2 reduction and the remainder which represents the TREC.
Figure shows the interaction between TRECs and value of CO_2 reduction.

Figure 5.4 Breakdown of Renewables' Interaction with Carbon Emission Allowance



Source: Morthorst (2001)

From the illustration above, A stands for the price of electricity at the spot market. B stands for the value of CO_2 reduction achieved which is the price on the emission trading market. The remainder, C, corresponds to the added cost of developing renewables. The total revenue realised is made up of TREC (B+C) and the spot price of electricity (A).

In the scenario where carbon costs are reflected fully in the electricity price, a renewable generator who sells at the market price will profit from windfall for its electricity that covers emission reduction which results from the production of non-carbon electricity.

Chapter 6

CONCLUSION AND POLICY IMPLICATIONS

6.1 Conclusion

The energy systems are bound to witness major changes as a result of limits placed on greenhouse gas emission by various climate change policies of which emission trading is one. On the other hand, the strength of fuel shift depends largely on the cost associated with carbon emission.

The Impact of the EU ETS in terms of power generation is thus expected to bring about significant shift in the primary energy consumption, towards low carbon technologies.

However, the change in fuel mix in the EU can best be achieved through feed-in-tariff, tradable carbon emission allowance, and green certificates. Redundancy and diversity in power generation is also crucial in achieving the right fuel mix suitable to regions within the EU.

As a result of the EU ET Directive, prices for electricity in Europe are susceptible to increase and volatility. This is because excess generation capacity from high carbon emitting plants such as coal are expected to be shut until the gains from marginal thermal generation are sufficient to keep the plants going. In a scenario where renewable technologies are linked to carbon emission allowance, the green certificate prices would reflect the higher cost of renewables and the low returns from electricity sale.

Emission trading in EU Member States is subject to the internalisation of the value of the greenhouse gas emissions. As such, coal fired generators in some Member States could benefit from the forecast upward growth in wholesale electricity prices. However, in the long run, inefficient coal-fired and oil fired generators are expected to be retired as a direct consequence of carbon constraints. This is due to the fact that coal fired plants emit about thrice the amount of carbon than gas fired plants.

It follows therefore that future generation technologies will strive to achieve the following objectives

- high efficiency to limit fuel consumption and emission,

- clean emission to minimise the impact on the environment,
- low capital cost to limit investment,
- limited generation capacities with short lead times and distributed sources to minimise uncertainties and risks

Of all the generating plants, modern CCGT plants meet most of the criterion given above. Nuclear, hydro, renewables technologies meet some of the requirements. Coal fired plants in existence are the least favoured in this regards. The emphasis therefore is on developing environmentally friendly and clean coal technologies such as fluidised bed combustion (FBC) and zero carbon emission technologies. A move to further bring down CO_2 emission will require investing in new technologies in gas – and coal - based combined – cycle generation. Other options under various stages of development for curbing CO_2 emission include pressurised fluidised bed combustion (PFBC), integrated gasification combined-cycle (IGCC) and zero carbon emission technologies.

Combined cycle gas turbine (CCGT) generators are thus expected to profit the most from the introduction of carbon emission cap.

Emission trading in the EU has thus evolved as a tool for turning the burden of pollution reduction into a capital venture. Once a primarily theoretical tool, emissions trading has gained wide acceptance by regulators and industry officials and is now in use across the world. As it gains increasing recognition, governments and firms will need to understand how to structure and prepare for these schemes

6.2 Policy Implication

The implementation of the first phase of the EU ETS has the tendency of increasing the price of electricity in the EU Member States and this depends largely on the price of an emission allowance, (marginal cost of emission trading) the emission factor of the marginal production technology to generate electricity, and to the extent to which the price of emission trading is passed to the electricity consumers. However, the extent to which carbon emitting power plants pass their carbon costs to the electricity market depends largely on price setting mode within the power market and the on the allocation methods that are being developed by the EU Member States.

From an economic and energy point of view, the power generators stand to lose if the price is not passed to the end users.
However, if consumers bear the full costs of electricity, the power generators will benefit (as a result of rent economic rent accrued from the allocation of emission for free), while the energy intensive firms that are not able to transfer the higher electricity costs to their customers (which results in loss of economic production and income). This consequence in the form of free allocation of permits to producers, gives rise to the transfer of rent from government and taxpayers to producers. Therefore, it is mandatory to replace free allocation of emission allowance by auctioning and using revenues to reduce tax burden of industry and to improve the overall competitiveness of domestic industries and to improve the overall competitiveness of domestic industries, thereby providing compensation for the ET-induced increase in the price of electricity.

In general, whatever the allocation method, creating a cap and trade regime has a cost implication on the producers and consumers of electricity. This is because various cap levels have price impacts on consumers, irrespective of permits freely allocated to power producers.

The future level of emission prices therefore will have the most significant implication for forward electricity prices and the productivity of existing power stations. Efforts therefore by policy makers should be channelled towards reducing emission prices by ensuring that the EU trading scheme is accessible in terms of both of both geographic and industrial reporting.

REFERENCES

Barker T., Ekins, P and Johnstone (Eds) (1995). Global Warming and Energy Demand, Routhlege, London.

Baron, R. & S. Bygrave, 2002, *Towards International Emissions Trading: Design Implications for Linkages*, OECD and IEA Information Paper, COM/ENV/EPOC/IEA/SLT (2002)5

Berry, T. (1995) Power Systems Economics, Peregrino, London.

Bucknall, D. Emission Trading: Has the energy trading given up? Available online: http://www.kwi.com/downloads/whitepapers_articles/Emissions%20trading.pdf. Last assessed on July 3, 2005.

Carbon Market Overview. Available online. http://www.co2e.com/trading/MarketHistory.asp. Last assessed on June 20, 2005.

Council Decision 2002/358/EC of 25 April 2002. Available online: http://europa.eu.int/comm/environment/climat/docs.htm. Last assessed on August 1, 2005.

Eckermann, F et al. The Role of Transaction Costs and Risk Premia in the Determination of Climate Change Policy Responses. Available online: ftp://ftp.zew.de/pub/zew-docs/dp/dp0359.pdf. Last assessed on August 12, 2005.

Eddies, M. ‘Climate Convention and Kyoto’, Power Economics, February 2001. pp 23-25.

Emissions Trading Schemes. Available online: http://www.defra.gov.uk/environment/climatechange/trading/. Last assessed on June 20, 2005

EU Emission Trading. Available online: http://europa.eu.int/comm/environment/climat/pdf/emissions_trading_en.pdf. Last assessed on June 20, 2005.

Greenhouse Gas Market Overview. Available online: http://www.co2e.com/images/cm/CO2e%20GHG%20Market%20Overview. Last assessed on June 20, 2005.

IEA (2000): *World Energy Outlook – 2002 Edition*, IEA/OECD, Paris

IEA (2002): *Beyond Kyoto Energy Dynamics and Climate Stabilisation*, IEA/OECD, Paris.

IEA (2002): *Dealing with Climate Change: Policies and Measures in IEA Member Countries*, IEA/OECD, Paris.

IEA (2002): Energy Policies of IEA Countries 2002 Review, OECD/IEA, Paris.

IEA (2002): *World Energy Outlook – 2002 Edition*, IEA/OECD, Paris.

IEA (2003): *CO Emissions from fuel combustion- 2003 Edition: 1971-2000*, IEA/OECD, Paris.

IPPC, (2001). Climate Change. (2000). Third Assessment Report, Cambridge University Press, UK.

Johnstone, N. The Use of Tradable Permits in Combination with Other Environmental Policy Instruments. Available online: http://www.oecd.org/dataoecd/24/17/32427205.pdf. Last assessed on August 10, 2005.

Khatib, H. (2003). Economic Evaluation of Projects in the Electricity Supply Projects, Institute of Electrical Engineers, London.

Klasson, K. and Davison, B. Estimation of Carbon Credits in Carbon Dioxide Sequestration Activities. Available online: http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/p40.pdf. Last assessed on August 11, 2005.

Kyoto Protocol to the United Nations Framework Convention on Climate Change. Available online: http://www.cnn.com/SPECIALS/1997/global.warming/stories/treaty/. Last assessed on June 12, 2005.

Lane, L. Allocating Carbon Emission Allowance to Consumers. Available online: http://www.cpc-inc.org/library/files/15_lanenov01.pdf. Last assessed on August 2, 2005.

Lawrence, E.O. Estimating Carbon Emissions Avoided by Electricity Generation and Efficiency Projects: A Standardized Method. Available online: http://eetd.lbl.gov/EA/EMS/reports/46063.pdf. Last assessed on August 11, 2005.

Lefevere. J. The EU Greenhouse Gas Emission Allowance Trading Scheme. In: Yamin, F (Ed). Climate Change and Carbon Market. 2005, Earthscan, London. Pp75-110.

Mckee B. (2002): 'Solutions for the 21st Century – Zero Emission Technologies for Fossil Fuels – 'Technology Status Report', IEA, Paris, May.

Morthost P.E. (2001). Interactions of a tradable green certificate market with a tradable permit market. Energy Policy 29 pp 345-353.

Moura-Costa, P. Carbon trading and investment in clean energy projects. Available online: http://www.ecosecurities.com/300publications/ESL_Clean_Project.pdf. Last assessed on June 12, 2005.

Mullins, F and Karas, J. EU Emission Trading: Challenges and Implementation of National Implementation. Available online: http://www.riia.org/pdf/research/sdp/EUETSworkshopreport.pdf. Last assessed on August 12, 2005.

Obehthur, S and Ott, H. (1999). The Kyoto Protocol: International Climate Policy for the 21st Century, Springer Verlag, Berlin.

Philibert, C and Reinaud, J. Emission Trading: Taking Stock and Looking Forward. Available online: http://www.iea.org/textbase/papers/2004/trading.pdf. Last assessed on August 1, 2005.

Point Carbon. Carbon Market. Available online: www.pointcarbon.com. Last assessed on July 1, 2005.

Raufer, R. (1998). Pollution Market in a Green Country Town: Urban Environmental Management in Transition, Praeger, Connecticut.

Reilly, J. (2002). MTT EPPA Model Projections and the US Administration Proposal, MIT EPPA Technical Note 3, March.

Reinaud, J. Emissions Trading and Its Possible Impacts on Investment Decisions in the Power Sector. IEA Information Paper. Available online: http://www.iea.org/textbase/papers/2003/cop9invdec.pdf. Last assessed on August 1, 2005.

Sijm, J. The Impact of the EU Emission Trading Scheme on the Price of Electricity in the Netherlands. Available online: http://www.ecn.nl/docs/library/report/2004/rx04015.pdf. Last assessed on August 1, 2005.

Sikorski, T. EU Emissions Trading: What does it mean for an electricity generator? Available online: http://www.sungard.com/products_and_services/energy/zainet/euemissionstrading.pdf. Last assessed on July 4, 2005.

Sorrell, S and Skea, J. (2003) Pollution for Sale: Emission Trading and Joint Implementation, Edward Elga, Cheltenham.

The Conference of the Parties, Sixth Session, Part 2. Available online: http://unfccc.int/cop6_2/index-8.html. Last assessed on July 11, 2005.

The European Union Greenhouse Gas Emission Trading Scheme (EU ETS).Available online: http://europa.eu.int/comm/environment/climat/emission.htm. Last assessed on July 10, 2005.

The Kyoto Mechanisms. Available online: http://unfccc.int/kyoto_mechanisms/items/1674.php. Last assessed on June 13, 2005.

The Kyoto Protocol. Available online: http://unfccc.int/kyoto_mechanisms/items/1673.php. Last assessed on June 13, 2005.

The United Nations Framework Convention on Climate Change. Available online: http://unfccc.int/2860.php. Last assessed on June 13, 2005.

UNFCC, Article 4.3. Available online: http://unfccc.int/resource/docs/cop7/13a01.pdf. Last assessed on June 13, 2005.

United States Environmental Protection Agency. (2003). Tools of the Trade: A Guide to Designing and Operating a Cap and Trade Programme for Pollution Control, EPA430-B-03-002.

Willem, S. and Baumert, K. (2003). Climate Actions and Institutional Capacity: Current and Future Challenge, OECD and EIA Information Paper, COM/ENV/EPOC/IEA/SLT (2003)X.

Wollansky, G and Freidrich, A. (2003) A guide to carrying out Joint Implementation and Clean Development Projects, Version 1.1., Austrian Federal Ministry of Agriculture, Forestry, Environment and Waste Management, Vienna.

Yarmin, F. (2005) Climate Change and Carbon Market, Earthscan, London.