WAGENINGEN UNIVERSITY
WAGENINGEN UR

Greenhouse Gas Emissions and Sustainable Development in the Clean Development Mechanism

August 2010

MSc International Development Studies Marwan El Solh

MSc Thesis Environmental Economics and Natural Resources
Prof. Justus Wesseler

Thesis Code: ENR-80436

Contents

Abstract 4
Chapter 1: Introduction 5
1.1 Problem Analysis 8
1.2 Objective 10
1.3 Methodology 11
1.4 Literature Review 12
Chapter 2: Clean Development Mechanism 22
2.1 CDM Implementation Models 25
2.2 CDM projects and Certified Emission Reductions (CERs) 32
Chapter 3 CDM Problems 36
3.1 Transaction Costs 36
3.2 Low Hanging Fruit Problem 40
3.3 CDM and Sustainable Development 42
Chapter 4: CDM Vietnam 47
4.1 Vietnam's Sustainable Development Criteria 49
4.2 Vietnam's Marginal Abatement Cost Curve 50
4.3 Vietnamese CDM Framework 51
4.4 Vietnamese CDM Initial Planning Phase & Criteria 53
Chapter 5: The Sustainable Development Impact of the Biogas Program for the Animal Husbandry Sector of Vietnam 57
5.1 Monitoring the Biogas Program 58
5.2 Technology 60
5.3 Economic Impact 61
5.3.1 Possible Economic Indicators 66
5.4 Environmental Impact 67
5.4.1 Possible Environmental Indicators 70
5.5 Social Impact 71
5.5.1 Social Indicators 73
5.6 Constraints 73
Conclusion 76
References 79

Abbreviations:

CDM National Executive and Consultative Board **CNECB**
Certified Emission Reduction **CER**
Clean Development Mechanism **CDM**
Clean Development Mechanism Investment Climate Index **CDM-ICI**
Designated National Authority **DNA**
Designated Operational Entities **DOE**s
Efficient Energy **EE**
Emission Reduction Points **ERU**
Global Warming Potential **GWP**
Greenhouse Gases **GHG**
Joint Implementation **JI**
Ministry of Natural Resources and Environment **MONRE**
Project Design Document **PDD**
Project Idea Note **PIN**
The Index of Sustainable Economic Welfare **ISEW**
The Netherlands Development Organization **SNV**
United Nations Framework Convention on Climate Change **UNFCCC**
Vietnam Union of Science and Technology Associations **VUSTA**

Tables

Table 1: Greenhouse Gases
Table 2: Transaction Costs
Table 3: Sustainable Development Criteria
Table 4: Registered Vietnamese CDM Projects
Table 5: Livestock Population (1000s)
Table 6: General Information on SNV Sample
Table 7: Costs of Materials in Ben Tre Province
Table 8: Average Money Saved per household Per Month
Table 9: Biogas Equivalents
Table 10: Opinion of Pollution Source
Table 11: Livestock Populations Between biogas Users and Non Biogas Users
Table 12: Market Share of Kyoto Mechanism

Figures:

Figure 1: Type of CDM Projects
Figure 2: The Sustainable Development Triangle
Figure 3: CDM Project Cycle
Figure 4: Bilateral CDM Model
Figure 5: Multilateral CDM Model
Figure 6: Unilateral CDM
Figure 7: The Hybrid Model
Figure 8: CDM Projects by Location
Figure 9: CER Price Volatility
Figure 10: Marginal Abetment Cost Curve
Figure 11: GHG Emissions vs. Sustainable Development
Figure 12: Issued CERs
Figure 13: Vietnamese Marginal Abatement Cost Curve
Figure 14: Fixed Dome Biogas Digester
Figure 15: Demand of Biogas Appliances

Abstract

The Clean Development Mechanism (CDM) is one of the three mechanisms proposed in the Kyoto Protocol to help curb greenhouse gases (GHG). The definition of CDM in the Kyoto Protocol is*: allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tone of CO_2, which can be counted towards meeting Kyoto targets.*

The CDM has two objectives. The first one is to reduce GHG emissions and generate CERs. The CERs could be used to contribute to the donor country's emission limit. The second goal is to promote sustainable development in the host country. There are various stakeholders involved in the CDM and CDM projects are all over the world. China and India are the two most dominant hosts for CDM because there marginal abatement cost is relatively low compared to other developing countries.

This thesis will focus on investigating the two objectives of the CDM. Can both goals be harmonized together within one CDM project and how can sustainable development be evaluated? To investigate this, a potential CDM project in Vietnam will be discussed. In Collaboration with the Vietnamese Ministry of Agriculture and Rural Development, the Netherlands Development Organization (SNV) initiated the Biogas Program for the Animal Husbandry Sector of Vietnam in 2003

Chapter 1: Introduction

The impacts of greenhouse gases (GHG) are a major concern in the world today. The absence of any legally binding action in the outcome of the United Nations Climate Change Conference in Copenhagen depicted how vast the disagreements are. The conference was supposed to build up on the previous international agreements and mechanisms introduced by earlier agreements. The Kyoto Protocol terminates in 2012, and there is currently no agreement on GHG for after 2012

The United Nations Framework Convention on Climate Change (UNFCCC) is one of the first international treaties that introduced the problem of GHG emissions. The treaty took place in Rio de Janeiro in June 1992. With regards to GHG part of the objective stated *"stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"* (http://unfccc.int). This treaty set no quota or enforcement mechanisms on greenhouse emissions for individual countries. The treaty achieved setting protocols that would set mandatory limits in the future. The main protocol was the Kyoto protocol.

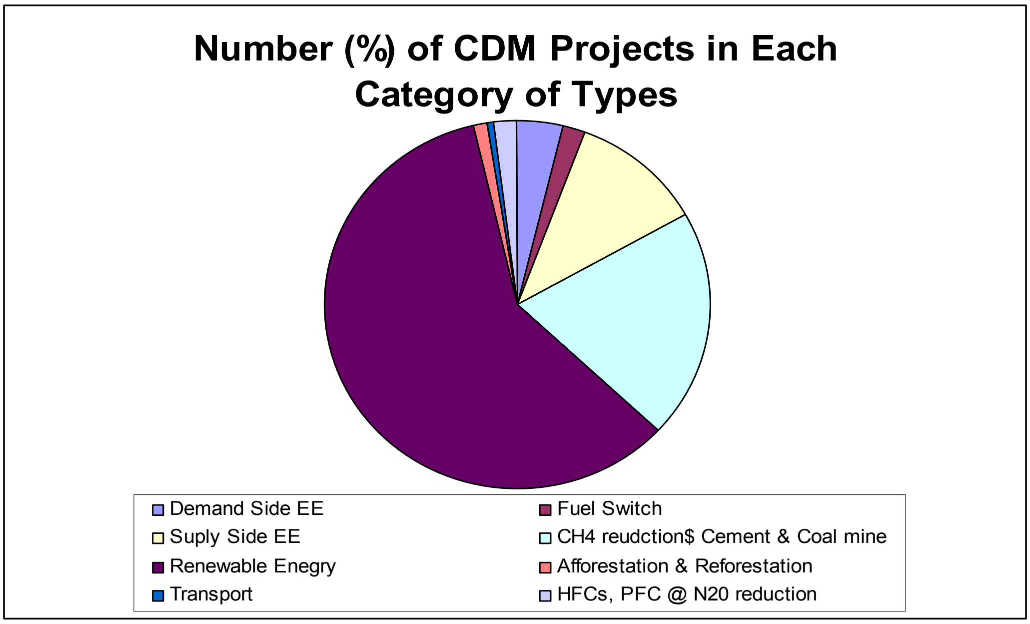
The Kyoto Protocol was created in 1997 and was implemented in February 2005. The agreement set binding targets for 37 industrialized countries and the European Union. The main objective of the protocol is to reduce the emissions of 6 GHG (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydro fluorocarbons, and per fluorocarbons) by 5.2 percent of the 1990 over the period 2008-2012 (the first commitment period, during the period countries are eligible to sell and trade permits).

The Kyoto protocol offers three mechanisms to help curb GHG emissions. One of the mechanisms put forward is emission trading. A more common name is the cap and trade system; this system uses economic incentives for achieving a reduction of GHG. The idea is to allocate a certain quota of emissions. If a government wants to reduce carbon emissions, they set a certain amount they consider suitable. They issue permits that they sell off to firms; each permit allows a firm to emit a fixed amount. Firms that can reduce GHG cheaply will sell their permits to other firms that cannot reduce their emissions cheaply. What makes this concept even more attractive is that it can be adopted at an international level. An international carbon market is not a single carbon market; it is an aggregate of domestic carbon markets. International agreements such as the Kyoto protocol are essential in providing international policies and support for domestic polices in order to provide a linkage between the international policy and domestic polices (such polices are the international level of GHG emissions and domestic levels) (Bell & Drexhage 2005).

The second mechanism is the Clean Development Mechanism (CDM). The definition of CDM in the Kyoto Protocol is*: allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tone of* CO_2*, which can be counted towards meeting Kyoto targets* (http://unfccc.int). The two main objectives of CDM are to reduce GHG emissions and promote sustainable development. The idea is to put developing countries on the path of sustainable development with the help (finance and technology) from developed countries. The CER enables countries to benefit from investing their resources in reducing GHG emissions in other developing countries. This is only possible because climate change like most other environmental problems are not bounded by any borders but a phenomenon that effects the whole world.

The third and final mechanism is the Joint Implementation (JI). The definition of the JI in the Kyoto protocol: *allows a country with an emission reduction or limitation commitment under the Kyoto Protocol to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of* CO_2*, which can be counted towards meeting its Kyoto target* (http://unfccc.int). This is very similar with the CDM except the main difference is that JI is between two industrialized countries as opposed to an industrialized country and developing country. These three mechanisms should be used to help fulfill the main objective of reducing GHG by 5.2% of the 1990 levels.

There are many different types CDM projects that can grant CERs. There were 3,188 projects at the end of March 2008. 978 of these projects are registered, 188 where in the process of registration, and 2,022 (nearly two thirds) where at the validation stage.



Source: http://cdm.unfccc.int/

Figure 1: Type of CDM Projects

The chart above categorizes CDM projects by type. The main CDM project which accounts for about 60 % of all projects deal with renewable energy. The second largest type is projects that deal with CH_4 reduction (20%). The third most significant projects are demand side EE (11%). Demand side EE deals with projects that promote efficient energy in household practices (supply side EE deals with efficient energy in various industries). The remaining 5 categories account for 9.5 percent of all CDM projects.

1.1 Problem Analysis

In collaboration with the Ministry of Agriculture and Rural Development the Netherlands Development Organization (SNV) initiated the "Biogas Program for the Animal Husbandry Sector of Vietnam" in 2003. The main objective of the project is the *"Improvement of living livelihood and standard of rural area in Vietnam through exploration of direct and indirect economic benefits of biogas technology at household level" SNV User Survey* (2009).

This project is operating throughout Vietnam. In 2009 the project was responsible for 77,000 operating biogas plants in 39 provinces. They are aiming to install 164,000 biogas plants in 50 provinces reaching 800,000 people SNV User Survey (2009). The project is expected to last till 2016 and it's expected to abate 7.5 million tCO_2. The project is still in the registration process and will not be able to receive any CERs until registration is complete (Duc Minh, 2005). Producing biogas from livestock waste has many advantages, according to the economywatch.com they include:

- Eco friendly energy production
- Workload reduction in rural areas
- Improvement in hygiene

- Conversion of livestock waste to fertilizer
- Environmental benefits at a global scale/protect the earth's natural resources

In order to be considered a CDM project, the project needs to satisfy the CDM's twin objectives of reducing GHG gases and promote sustainable development. Currently sustainable development is a very popular notion. Governments and organizations all over the world emphasize the importance of sustainable development repeatedly. However despite its importance its definition is rather ambiguous. Even more ambiguous is measuring sustainable development. There are other problems associated with CDM. The current format and organization has come under criticism, mainly the delay in applications and other paper work due to bureaucracy, at both the national and international level.

The Biogas Program for the Animal Husbandry Sector of Vietnam is a potential CDM project. The Vietnamese livestock sector mostly consists of small scale farmers and the main role the SNV will play is disseminating the technology to as many rural households as they can. The conversion of livestock waste to biogas reduces GHG emissions. How much each individual digester contributes to GHG emission depends on the prior manure management techniques. Since the nature of this project is all over Vietnam and not in one specific location this raises a control problem. In order to accrue CERs the biogas digesters need to be operating sufficiently and accurately. How can the SNV assure this, and do household digesters promote sustainable development.

1.2 Objective

Based on the information in the introduction and problem analysis the main objective of the research is *"Does the Biogas Program for the Animal Husbandry Sector of Vietnam fulfill the twin objectives of the CDM?*

To help fulfill the objective the following research question and sub research question need to be considered

GENERAL RESEARCH QUESTION

- Is the current CDM format adequate?
- What are the problems with the current CDM?
- Can CDM incorporate GHG abatement and sustainable development in one mechanism?
- How can The Biogas Program for Animal Husbandry Sector Vietnam be evaluated for sustainable development?

SUB-RESEARCH QUESTIONS

- Do CDM projects enable the population to live sustainable?
- Who is benefiting more from CDM, the host country or donor country?
- What type of social, economic, environmental indicators could be used to measure sustainable development?
- How does the price of CERs affect the overall CDM status?
- What types of problems are there in The Biogas Program for the Animal Husbandry Sector of Vietnam?

1.3 Methodology

In order to answer the research questions stated the following methodology will be obtained. The methodology is developed on the basis of the problem analysis and objectives

LITERATURE REVIEW

A big portion of this thesis will rely on the various literature reviews. The first literature review will go over the concept of sustainability. In order to fully understand how the CDM promotes sustainability, the concept of sustainability needs to be explored further. The second literature review deals more with the institutional set up of the Kyoto protocol, mainly the CDM procedure. The main point of this review is to identify problems that have been observed in various projects around the world and to evaluate the format of CDM.

DATA COLLECTION

There will be a case study dealing with Vietnam and the SNV's biogas project. Interviews were conducted with various representatives of the Vietnamese ministries of Agriculture and Environment. The interviews mainly dealt with the Vietnamese biogas policy. I also interviewed two local representatives of the SNV in Hanoi. They granted me with user surveys of the participants of SNV's project. They also provided with various technical documents on the program and technologies.

In addition these interviews I also interviewed households in two provinces near Ho Chi Minh City. The provinces were not part of the SNV project, however they were similar. The interviews mainly dealt with the user's experience with biogas. These interviews provided me with some insight on how biogas technology can affect their everyday lives.

1.4 Literature Review

The sustainable development concept has been researched by many scholars. In 1987 the Brundtland commission concluded that current development practices are harming the environment and the well being of future generations will be threatened if the current practices are maintained. It defined sustainable development as *"meeting the needs of present without compromising the ability of future generations to meet their needs"* (Giddings et al., 2002). This definition was also adopted by the World Commission on Environment and Development. It emphasizes the nature of scarcity by incorporating future generation's demand in the definition. It acknowledges that resources need to be used efficiently and effectively in order to maintain them for future generations. The World Wildlife Fund's definition of sustainable development is *"Improvement in the quality of human life within the carrying capacity of supporting ecosystems."* (Goodland, 1995) This definition is similar but it places more importance on the environment. *"Within the carrying capacity of supporting ecosystems,"* emphasizes the importance of harmonizing development with the environment.

The above definitions refer to achieving economic and social development in ways that do not exhaust the country's natural resources or degrade the environment. Spangenberg (2005) explains that societies are composed of four dimensions, economic, social, environmental, and institutional. Each of the dimensions is complex entities that continue evolving over time. In order for the society to be sustainable each of the dimensions has to survive and evolve. In addition the interlinkages between the dimensions enable the dimensions to co-evolve together in one single unit. In order to get better insight on sustainable development, environmental, economic, and social sustainability will be explored further.

The simplest definition of Environmental Sustainability is to maintain natural capital. Environmental sustainability is a scientific concept that is bounded by biophysical laws. In order to achieve environmental sustainability, the ecosystem needs to be maintained. Environmental sustainability focuses on the overall viability and health of the ecosystem. An ecosystem is an integrated system of living species, their habitat, and the processes that affect them. The resilience of an ecosystem is the potential of preserving its function in light of any change or disturbance. Natural resource degradation, pollution, loss of biodiversity, and other negative impacts on the environment are harmful because they make the ecosystem more vulnerable by undermining its overall health and reducing its resilience. When the environment is sustainable all the elements are alive in balance are capable of reproducing themselves (Munasinghe, 2007).

Goodland (1995) expanded the definition to economic activities. Any waste emissions from a project or activity should be kept bounded by the local environment. The emissions should not reach a level that degrades the environment and threatens the future of the planet. This is known as the output rule. The input rule deals with renewable and non-renewable sources. The harvest rates of renewable sources need be within the regenerative capacities of the natural system. As for non-renewable sources, their depletion rates should be set lower than the rate at which renewable substitutes are developed through technology and investment. Consumption per capita should be limited within the eco-system. This does not necessarily imply an optimal rate, rather a more sustainable approach where consumption patterns do not harm the ecosystem (Goodland 1995).

In other words humanity needs to live in harmony with the environment. We should not damage the environment and this will lead to a preservation of natural capital (Daly, 1973). Achieving environmental sustainability is not as straightforward as the definition. Each country or region has specific environmental problems, for example some countries need to cut down on pollution whereas other countries may need to improve the harvest rates of their renewable resources (Goodland, 1995).

In economic terms, sustainability can be defined as the maintenance of capital. Sir John Hicks in 1946 defined income as *"the amount one could consume during a period and still be as well off at the end of the period."* Solow (1991) offered a similar definition on sustainability *"to conduct ourselves so that we leave to the future the option or capacity to be as well off as we are. Not to satisfy ourselves by impoverishing our successors"* (Daly & Goodland 1996). These definitions cover the economic aspect, the notation of preserving resources today for the benefit of future generation can be defined as intergenerational sustainability. Economic sustainability also includes man-made capital, whereas environmental sustainability deals exclusively with natural capital.

Sustainability, specifically environmental aspects were absent from the traditional economic theory. However, scholars have been exploring the idea for centuries. Thomas Malthus in 1798 was concerned with producing food from a finite amount of land to a growing population. He predicts that the world will reach a point were the population will be so overwhelmingly large that we won't be able to feed everyone (Pezzy &Toman 2002). William Stanley Jevons put forward the Jevon Paradox in his book "The Coal Question" (1865). The dilemma concerned coal production. Jezmon was concerned with the amount of coal reserves since it's a main input of production. The more coal extracted the more progress and production there will be. The dilemma arises when technological improvements enable coal to be extracted at a faster rate. According to Jevon this will inevitably lead to higher consumption and a faster depletion of coal reserves (Alcott 2005).

Lewis Cecil Gray was the first economist to introduce the problem of a depleting resource to a firm (mine) operating in a perfectly competitive environment. He was mainly interested in the optimum extraction path. The main assumptions are: perfect competition, the resource is homogenous, fixed stock, resource is extracted and sold immediately, and U-shaped cost curves. The last assumption reflects on the variable output proportions. According to Gray the mine is subject to diminishing productivity. Too much spending on the other factors of production could lead to a decrease in production. This is why, according to Gray, delaying extraction could be more profitable for the owners. Gray had two solutions, one in which he discounted profits and the other one with no discount. In the latter case he found that the extraction rate was a constant which provided the highest profit. In the discounted case, he determined that the optimum extraction path is declining at an increasing rate (Crabbe, 1983).

Harold Hotelling also contributed greatly to the economics of natural resources. Hotelling felt that the static models that were dominant in the discipline were not able to explain exhaustible resources. Hotelling studied the relation between extraction and economic theory. Hotelling found that producers have more of an incentive to extract everything at present which would lead to a grim outcome for future generations. His reasoning was that at certain interest rates it would be more profitable for the producers to extract and sell than save for future generations (Levhari & Liviatan 1977). These theories provided a different insight at the time however they did not really have serious impacts on policy makers. However they were debated thoroughly in academia circles.

The real shift in economic thinking towards the environment happened about 50 years ago. The main factor that contributed to this shift was the increasing world population. According to US Department of Commerce the world population increased from about 2.5 billion in 1950 to approximately 6 billion in 2000. This is a significant increase and the depletion of natural resources became more evident as consumption and production increased. Dasgupta and Heal (1974), Solow (1974), and Stiglitz (1974) researched about sustainable consumption in one sector growth models constrained by nonrenewable resources. All three papers have economic models were natural resources are finite, nonrenewable, and essential to production. All three models include the notion that man made capital may be substituted with natural resources if the properties are similar (Pezzy & Toman 2002). These three authors are often referred to as 'optimists' because they all concluded that sustainable consumption is possible if certain conditions are met. It is possible because all three consider it possible to substitute, or eventually substitute man made factors for natural resources in the production function. Therefore they assumed that elasticity was greater than one. In the following years many authors contributed to the discipline and however, they were the first authors to tackle these issues.

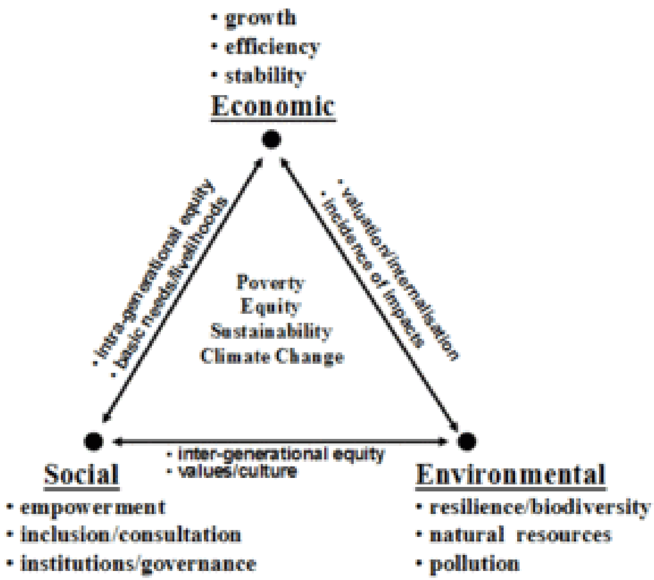
The main aim of Dasgupta and Heal's *The Optimal Depletion of Exhaustible Resources* is to investigate problems associated with incorporating exhaustible resources with economics theory. The aim was deduced from realizing the role natural resources play in economic growth. The authors predicted that when resources become depleted, economic growth will become constrained. They are interested in investigating the optimal extraction path of an exhaustible resource. The paper maximizes the present value of the consumer's utility using a constant discount rate. Technological progress is absent in this paper (Dasgupta & Heal 1974).

One of the main findings of Dasgupta and Heal's work is that in the long run consumption and utility converge to zero. This happens because of a positive utility discount rate coupled with a scarce resource. Consumption will increase in the beginning and once it reaches a peak will continue to decrease (Pezzy & Toman 2002).

Stiglitiz's *Growth with Exhaustible Natural Resources: Efficient and Optimal Growth* and Solow's *Intergenerational Equity and Exhaustible Resources* were quite similar and both stirred a lot of controversy and debate. Both authors are trying to determine the conditions needed to achieve a sustainable level of per capita income. Stiglitz assumed a positive population growth and technical progress over the years. He showed that it was possible to achieve a continual growth of per capita consumption (Petith, 1999). Stiglitizt believed that there were three economic forces that could break the limitations imposed by exhaustible resources. These forces are technical change, substitute man made factors of production with natural resources and, returns to scale (Stiglitiz, 1974). Technical progress was absent from Dasgupta and Heal's work, but it would of surely affected the results if added. Stiglitz in his paper explains that technical progress is essential because there are numerous examples in history where it improved production methods and inputs. Solow had a similar conclusion in his paper concluded that a constant growth of consumption could be achieved by substituting man made capital with natural resources.

Social sustainability deals to the ability of the society to achieve social goals. The overall wellbeing of the human being is considered in this area. Maintaining human rights, reducing poverty, equity, etc. are all aspects considered. Environmental sustainability deals with the health and preservation of the ecosystem, social sustainability deals with the health and preservation of social and cultural systems. This is done by enhancing human capital and strengthening social values which will help maintain social equity. The cultural system deals with social values, norms, and cultural aspects such as language. Cultural system helps preserve social cohesion and networks which helps in maintaining social order (Magalhaes, 1994).

Environmental, economic, and social sustainability are all part of sustainable development. The diagram below depicts this.



Source: Munasinghe, 2007

Figure 2: The Sustainable Development Triangle

The triangle shows the various aspects of sustainable development. All three aspects work together in order to achieve sustainable development goals. The goals are achieving economic growth to contribute to social development within the limits of the environment.

Humans interact with the environment through economic institutions. Institutions can be seen as social decision makers that consist of political, social, and economic influences. They operate within the norms of the society and can be considered as the rule of the game. The design and aims of the institutions will determine how the institution deals with the allocation of natural resources as well as the distribution of income that is generated from them (Politylo & Veeman, 2002). In order to achieve sustainable development institutions need to efficient, and if they are not then they need to be restructured. Market failures can undermine the role of institutions on managing natural resources. Market failures can lead to an excessive depletion of the resource (Panayotou, 1993).

The Brundtland report paved the way for new approaches to development. Measuring sustainable development requires a focus on the three pillars (economic, social, and environment), the health of the environment, and the various capital stocks. Evaluating a project's *sustainability* needs to cover these three groups (Goosens, et al., 2010).

Measuring sustainable development can also be quite problematic. The conventional measures for development include GDP and other indices such as human development index. GDP is the total market values of good and services produced by workers and capital within a country's border. The GDP is maybe an adequate economic indicator however it is insufficient for sustainable development. The definitions of sustainability mentioned earlier deal with preserving and maintaining various capital and GDP does not reflect this. Sustainable development is often unique to its country. Environmental problems are different in each country and sustainable development goals different from country to country. Measuring sustainability needs to reflect this (Dasgupta, 2007).

Some indices have been developed in order to measure sustainability. Green GDP was developed in the 1990s in reaction to the drawbacks of measuring sustainability through the normal GDP. Green GDP incorporates costs of natural resource depletion and an assessment on the various types of pollution (air, water, etc.) to GDP. This may sound adequate but in reality it is very hard to incorporate all this in one figure. The first drawback is this requires a lot of data and information; this may not be a problem for developed countries however the same cannot be deduced for developing countries. In 2006, the Chinese government released a green GDP estimate. The green GDP used various environmental aspects and concluded that economic loss due to environmental degradation accounts for 3% of the 2004 Chinese GDP. However, critics claimed that not all pollution costs were included and some natural resources were not even considered. Therefore, the 3% of economic loss from environmental degradation is much higher and does not accurately represent the economic damage caused by environmental degradation. (Wu J, Wu T, 2010)

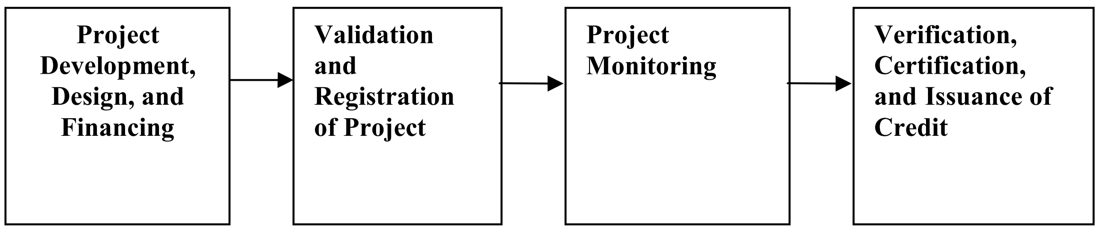
The Index of Sustainable Economic Welfare (ISEW) was developed in the 1980s by Herman Daly and John Cobb; it considers the links between environment, economy, and society. The ISEW is based on the GDP and is computed the following way: *ISEW = Personal Consumer expenditure – adjustment of income inequality + services from domestic labor – costs of environmental degradation – defensive private expenditures + non-defensive public expenditures + economic adjustments – depreciation of natural capital* . (Goosens, et al., 2010) This index has also faced many criticisms and the main ones are: does not take the value of household labor, the welfare effects of income inequality, and the welfare loss due to environmental degradation into account. It also considers defensive expenditures as contributions to welfare. (Neumayer, 1998)

There are a few other indicators designed for sustainability but they all have some drawbacks and are not widely used. The fact that they are not commonly used means that these indices cannot be found for every country or region. The most common and acceptable way to measure sustainable development is through indicators. Indicators should be: policy relevant, resonant, scientifically valid, and measurable. Using a set of indicators reduces the uncertainty attributed to one overall sustainable indicator, such as the Green GDP and ISEW. Various organizations such as the World Bank and Governments have identified many indicators that covers various dimensions of sustainable development. This enables the measure of sustainable development to be specific to one country or project and to one aspect of sustainable development. For example a set of environmental indicators such as air pollution measures the environmental aspect of sustainable development; income per capita measures the economic aspect of sustainable development, and so on. This is known as the fitness-for-purpose approach. In other words the fitness-for-purpose approach advocates the use of specific indicators for specific purposes. (Levett, 1998)

Chapter 2: Clean Development Mechanism

The CDM aims to increase investment in emission reduction projects. The CDM was not exempt from any controversies and many issues were debated thoroughly. The CDM was tackled in the Eighth Conference of the Parties, the conference adopted modalities and procedures for small-scale CDM project activities *UNDP CDM User Guide (2003)*. The main issue that was being debated was the format of the CDM process. CDM links developed countries with developing countries, both countries have different objectives, yet, they have to work on one project.

The figure below summarizes the 4 main steps of the CDM (project cycle). This process involves various stakeholders, and there were more than one suggestion for the format.



Source: *UNDP CDM User Guide 2003*

Figure 3: CDM Project Cycle

The first step is *Project Development, Design, and Financing*, this step involves various studies (feasibility, finance, etc.) in order to design suitable and relevant projects. There are various stakeholders that are eligible for this step: governmental bodies (ministries, agencies, etc.), municipalities, foundations, financial institutions, private sector companies, and NGOs UNDP *CDM User Guide (2003)*. If this step is over taken by a non-governmental actor then they have to seek government approval (to make sure that the objectives are inline with the nation's sustainability goals). It is not necessary for one sole stakeholder to work on this, in reality, it is normally a mixture of stakeholders mandated by a governmental body (in many cases the government is also directly involved) (Baumert, et al., 2000)

The initial documents that need to be submitted are the Project Idea Note (PIN) and Project Design Document (PDD). These documents are specific for CDM registration. PIN is a report that provides basic information about the project. Such information are: type and size of project, location, estimated about of GHG reduction, suggested lifeline, finance, and the project's socio-economic or environmental effects. PDD is an in-depth project description that includes project description, baseline study, monitoring plan, stakeholders' comments, and details on ecological, socio-economic and development effects. The PIN is more of an introductory document where the PDD is a more complete version. The PDD is provided as a basis for the CDM project evaluation. The most important areas of the PDD are the quality of baseline, monitoring plan, economic and technical aspects, and sustainable development effects (ecological and socio-economic). This is the main criteria considered for evaluation.

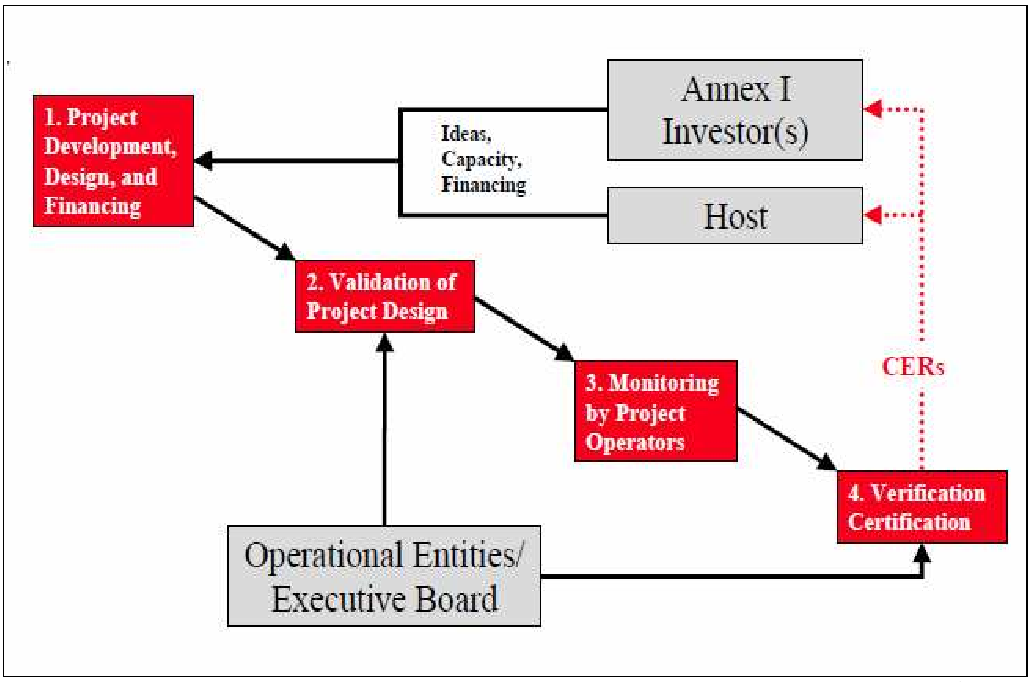
The second step, *Validation and Registration of Project*, is essential for a project to be an adequate CDM project. Activities in this step include approving a project baseline, ensure monitoring guidelines, and register with CDM Executive Board (PDD is evaluated in this step) (Baumert, et al., 2000). The CDM Executive Board supervises CDM and reports directly to the Conference of Parties. The board has ten members representing both developed and developing countries. The board is responsible for: making recommendations on amendments to the CDM project (including process), monitoring plans and project boundaries, mandating and suspending of operational entities, reviewing accreditation procedures, developing and maintaining a CDM project registry, reviewing project validation and verification and issuing verified CERs *UNDP CDM User Guide (2003).*

One of the tasks of the executive board is *mandating and suspending of operational entities*. CDM projects require various institutions and entities to run smoothly. In many cases these institutions already exist or existing institutions take up the new responsibilities brought by CDM. Designated operational entities (DOEs) are domestic or international legal entities that have been accredited by the CDM executive Board. They are responsible for many tasks, and are also involved in the second step. The responsibilities they are designated for include the following: validation of CDM activities in the initial period of the project, making CDM project design publicly available, receiving public comments on the CDM documents, incorporating stakeholder comments, and verification and certification of CERs during the operation of the project UNDP *CDM User Guide (2003)*. In other words these DOEs are under the umbrella of the executive board and they are the representatives of the CDM board on the field.

The third step is to monitor the project. This is very straightforward and is often fulfilled by the project operators. They have two main objectives and those are to track project performance during operation, and collect data and keep records in order to ensure transparency. The fourth step, *Verification, Certification, and Issuance of Credits*, is undertaken by the CDM executive board and the DOEs. (Baumert, et al., 2000). The main objective in this step is to assess the amount of emissions reduced and issue the CERs.

2.1 CDM Implementation Models

The figure in the beginning of this chapter outlined the basic steps that a CDM project needs to undertake. The first three steps involve many stakeholders, (project development and financing) it could be more flexible and incorporate various stakeholders. In this section I will explain three models that were discussed in the negotiations and summarize their strengths and weakness.



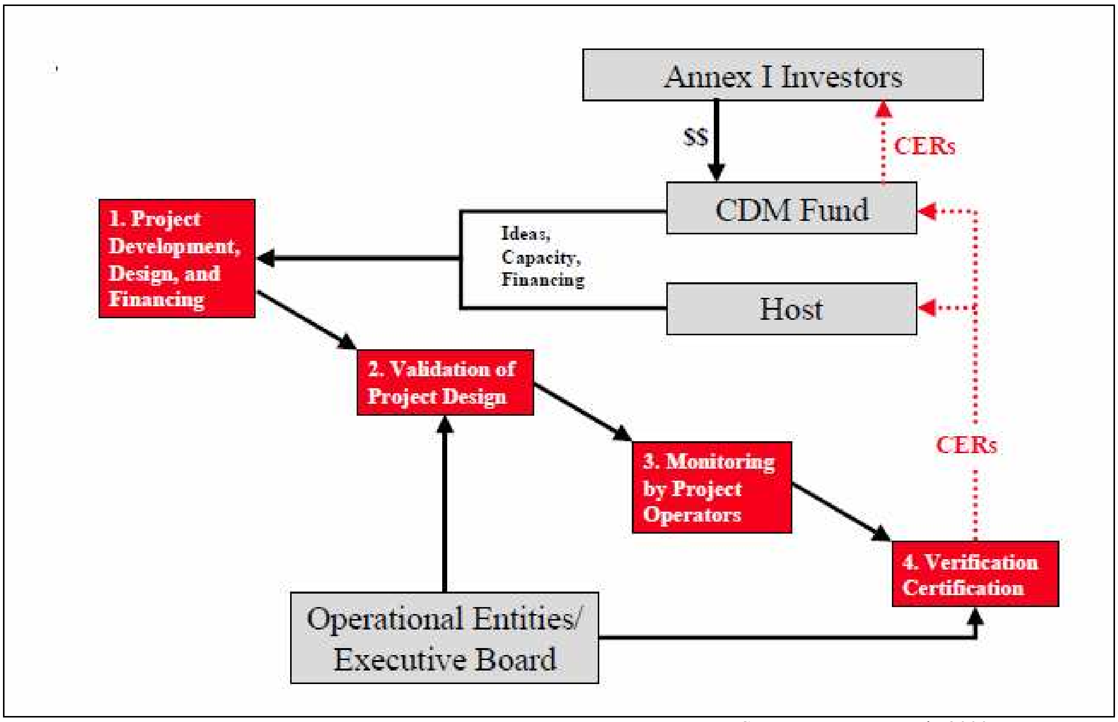
Source: Baumert, et al., 2000

Figure 4: Bilateral CDM Model

Figure 3 shows the bilateral CDM model, this model is considered to have the least institutional machinery. This model foresees a direct involvement of the Annex 1 country in the development, financing, and possibly operation of the CDM project. This model is considered decentralized in which the project selection, financing, and sharing of credits are worked out between the interested parties (host government, developers, investors, etc.). The figure shows that prior to the first step Annex I countries/investors interact with the host country which will lead them to the first step.

This approach is very similar to how current foreign direct investment is sorted and it is highly advocated by many developed countries and large developing countries. The reason for the high enthusiasm is that it gives more flexibility to project developers and it still gives the Annex 1 country complete autonomy on choosing where they should invest their money.

Developing countries do not really favor this because there is no geographical quota for projects. In order for projects to be dispersed all around the world many developing countries tried to press for a geographical quota. Foreign aid is not dispersed evenly among developing countries; often aid is very active in some countries and almost inexistent in others. This brings us to the first concern of the model, studies have shown that under a format with no geographical quota 75 percent of CDM projects will be concentrated in China and India, where the lowest abatement costs exist. In reality most of the CDM projects are concentrated in these two countries (Chauhan & Gupta 2009).



Source: Baumert, et al., 2000

Figure 5: Multilateral CDM Model

The second model is the Multilateral CDM model. This model can also be seen as a “mutual fund for CDM projects” and is dubbed the “fund” approach. Figure

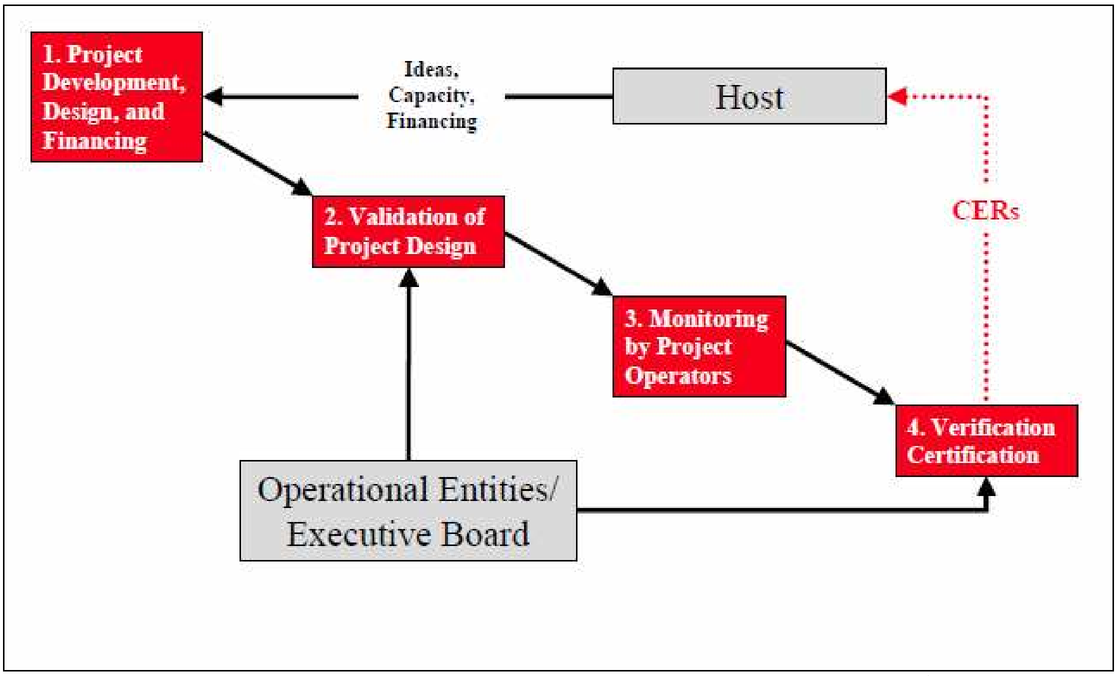
5 shows that Annex I countries invest in a centralized CDM fund. Subsequently, the CDM fund invests in various potential CDM projects. The model also shows the CERs path, in the bilateral model the CERs went directly to the two governments involved. In this case once emission reductions from project activities are certified, they would reach Annex I countries through the CDM fund. The investors would receive CERs proportional to the amount of money they invested in the fund. The CDM project development and plan will be under the jurisdiction of the CDM fund; this will be accomplished in cooperation with the host country. This model overcomes the geographical problem stated in the bilateral model section by introducing the CDM fund. The CDM fund chooses which projects to undergo independent from the Annex I countries.

This is quite different from the first approach, first of all there is clear distinction between the Annex I country and the host country. Annex I countries are not as influential in this case since the CDM fund is considered an independent entity. The main advantage of this model is that the host country (developing country) are not bound by any requirements from Annex 1 countries, they will be dealing directly with the CDM fund. This decreases the political influence; aid is often linked with many other issues (political, trade, etc.).

This model obviously did not enjoy support from Annex 1 countries. One of the arguments against this model is that the absence of Annex 1 countries in the initial stages of the project may undermine the project. This notion is based on the idea that developing countries will increase their bargaining power by dealing directly with CDM fund and not with Annex 1 countries. As opposed to Annex 1 countries, the CDM fund will not be as demanding as Annex 1 countries. The CDM fund's mandate is more compatible with the interests of developing countries. This could result in unfair and inefficient outcomes (Baumert, et al., 2000).

Another underlying issue in this model is how many projects can the CDM fund finance? It seems very unpractical to have one fund that plans, negotiates with host country, finances, etc. all the CDM projects. This arrangement, with a sole fund is known as *Single Supplier Arrangement*. Since this arrangement was met with stiff resistance from annex 1 country another approach was introduced, *Multiple Funds Arrangement.* This arrangement was put forward after the shortcomings of the original single supplier arrangement in the multilateral model. As opposed to having one fund, this arrangement advocates a variety of funds from different organizations and institutions. The institutions can either compete or cooperate in their CDM funds. Under this approach, multiple CDM funds would different mandates and principles. The CDM fund managers would pick projects that are inline with their mandates and principles. (Baumert, et al., 2000) This is still considered to be a multilateral model, and although it's different from the single supplier arrangement, in principle they are same. One arrangement relies on one centralized fund, whereas the other one relies on many funds. Having various CDM funds compete for projects could decrease transaction costs and improve efficiency. It is also possible to have specialized CDM funds, for example a fund that deals solely with transportation which funds CDM projects in the transportation sector. The multiple funds arrangement gives the host country a chance to choose which fund, at the same time it does not necessary undermine the Annex 1 countries since they can choose which CDM fund to invest in.

The third model is the unilateral model. Figure 5 summarizes the format of this model. The most significant feature of this model is the absence of Annex 1 countries in all the different stages. The host country is in charge of project development and finance. The host country is free to develop and fund domestic activities that reduce the emission rate. An independent third party which could be a designated operational entity or directly from the CDM executive board is in charge of approving the project design and certifying the claimed emission reductions. The CERs are issued to the host country who can sell the CERs to any interested party. The price is pre-determined between the countries, brokered by a third party, or auctioned off.



Source: Baumert, et al., 2000

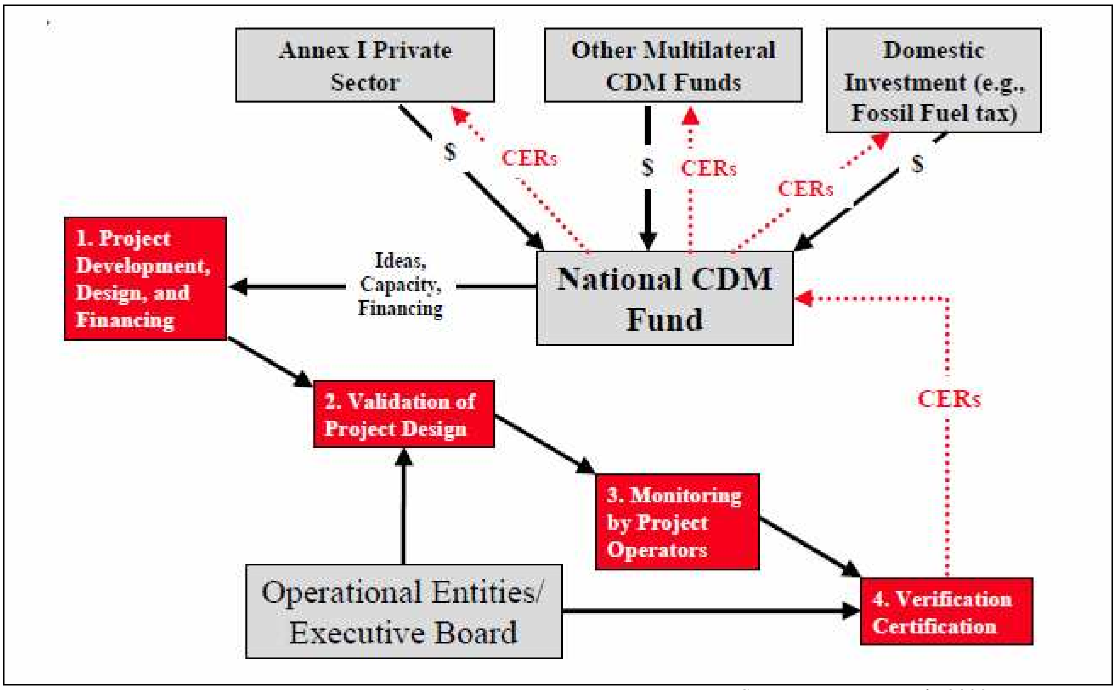
Figure 6 Unilateral CDM

This model is very different from the other models and it puts all the responsibility on the developing country. Initially this approach was not taken seriously because the majority of the policy makers and researchers did not think it was possible that developing countries could finance and run their projects on their own. The main constraint is the financial one; developing countries have very limited resources compared to developed countries. However, in the negotiations of the Kyoto protocol many developing countries especially South American countries claimed they should be able to invest in projects resulting to CERs to be issued for them, in which they can sell for profit (Baumert, et al., 2000).

Advocates for this model argued that transaction costs would be lower since the project would involve domestic actors who are more aware of barriers than foreign investors. CDM are considered risky projects, many Annex 1 countries are reluctant in investing in them. There are many factors that contribute to the riskiness of the CDM project. CDM is part of the carbon market, and there are many risks linked with the carbon market which could have strong effects on the project. Developing countries are also prone to many problems; these problems can be political, economic, or social. These problems could have dire affects, for example political instability could lead to a civil war, and at this point an active CDM would be ineffective. The unilateral model reduces this risk since investment would be from domestic sources. This could lead to CDM projects being active in areas that foreign investors would not be willing to invest in. (Baumert, et al., 2000)

Many countries would not be able to invest from their own resources. This is the biggest drawback of this model, no external funds. Many of the world's poorest counties would not be able to set up its own CDM projects. Environmental issues are not as pressing to developing countries as developed countries, therefore without external funds developing countries may not be investing in an emission reduction project. However, if the value of CER is high enough, it can be a powerful incentive for developing countries to undertake CDM projects on their own.

These are the three main CDM models, they have different formats however the goal is the same. It is possible to mix these three approaches into one model, the hybrid model. This model integrates various aspects from the different models into one model.



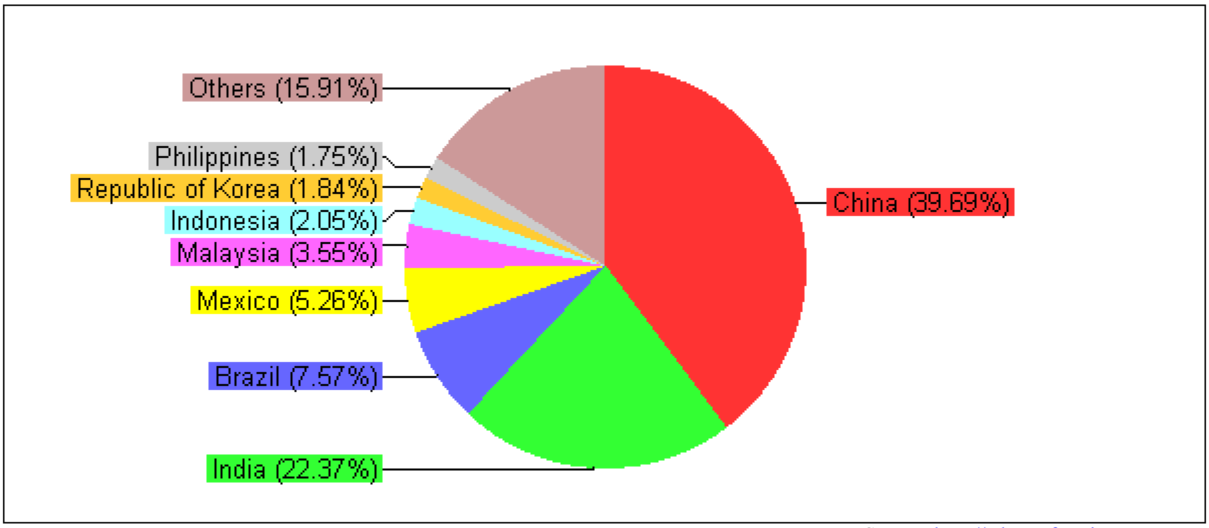
Source: Baumert, et al., 2000

Figure 7: The Hybrid Model

The figure above is an example of a hybrid model. This model incorporates elements from unilateral and multilateral models. The National CDM fund is designated by the host country, and they are the main player. Similarly to the unilateral model, this model gives the host country many significant duties by having domestic institutions take charge of project selection and development. This model also supports decentralized funds, domestic investment, and private sector from Annex I countries. These attributes make the model inline with the multilateral model.

The Hybrid model can be different, but it indicates the flexibility of the models. In this case the model was manipulated in order to provide the positive features of the unilateral and multilateral models. In light of this many stakeholders advocated what they called “open architecture CDM.” Open architecture CDM consists of the different CDM models operating in parallel together (including the hybrid). No model should be mandatory but participating countries can choose between them according to their preferences. (Baumert, et al., 2000) This approach is very flexible and allows room for modifications and improvements. In theory each model has advantages and disadvantages but in reality many other issues might come. An open architecture approach has the potential to improve the process of CDM (learning by doing).

2.2 CDM projects and Certified Emission Reductions (CERs)



Source: http://cdm.unfccc.int

Figure 8: CDM Projects by Location

CDM projects have been increasing over the years. The figure above shows the location of all CDM projects. China is the highest with about 39% followed by India. There is a substantial difference between the rest of the countries and China and India. China and India account for more than 50% of the CDM projects.

The price of one unit of CER is not very straightforward. Like most prices, this price is also volatile to many factors and the price is not fixed. There are three different pricing estimates: World Bank published data on prices, discounted European Union Allowance price, and Point Carbon data. The methodologies for concluding the price of the three approaches is rather complex. All three methodologies involve looking at data of previous transactions of emission reduction projects. The prices for each approach is the following: (Sinclair, 2006)

- World Bank published data on prices **USD 7.20 per ton CO_2**
- Discounted European Union Allowance Price **USD 7.62-8.40 per ton CO_2**
- Point Carbon data **USD 7.62-16.51 per ton CO_2**

The prices will be linked with the international carbon market. Therefore government policy can directly influence the price by imposing a carbon tax or a price floor for carbon to ensure that the price will not be too small that it's negligible. The value of the CER also implicates the whole CDM status. Prices that are too low will not be an incentive for a host country to promote CDM projects. Although a low price will encourage annex 1 countries to invest even more. One can conclude that under the framework of CDM annex 1 countries will keep investing in CDM as long as the marginal abetment cost of 1 ton of CO_2 is less in the host country than their own cost.

JP Morgan, 2009

Figure 9: CER Price Volatility

Figure 9 shows the CER's price from March 2008-June 2009. The price was rarely constant and like most markets, this market is not exempt from price fluctuations. The graph shows us the range of CER price from EUR 7.39-23.88. There are a few explanations for this price volatility. The first sets of factors are demand factors. The EU has the largest demand for CERs (estimated to be 80%). The reason for this large demand is because the EU has linked the CDM with the European Union Greenhouse Emission Trading System (EU ETS). The complications and obstacles that were present in the negotiations of the Kyoto protocol lead the European Union create their own trading system that is applicable solely to the EU. This trading scheme was designed to help European countries meet their Kyoto requirements. Global economic downturn has reduced European production leading to lower emission, decreasing the necessity for CDM projects for the period of 2008-2012.

There are also supply factors, most of the supply of CERs come from China and India. This puts both countries in a unique position and can influence the overall price of CERs. Weather also plays a role, in exceptionally hot and cold season's energy requirements increase because of the cooling and heating respectively (Betz, 2006).

GHGs differ in their ability to trap heat in the atmosphere. Their ability to trap heat affects the value of the CERs. Their ability to trap heat is called the Global Warming potential. Table 1 summarizes the GWP for the main GHGs.

Gas	Pre-industrial baseline	Natural additions	Man-made additions	Total Concentration	GWP
Carbon Dioxide (CO2)	288,000	68,520	11,880	368,400 (99 %)	1
Methane (CH4)	848	577	320	1,745 (0.471 %)	21
Nitrous Oxide (N2O)	285	12	15	312 (0.084%)	310
Misc. gases (CFC's, etc.)	25	0	2	27 (0.007%)	---
Total	289,158	69,109	12,217	370,484	---

Source: Blasing 2010

Table 1: Greenhouse Gases

CO_2 is used as the standard because it constitutes of about 99% of the total GHG concentration. It therefore has a GWP multiplier of 1. All other GHG ability to trap heat is compared with the ability of CO_2 to trap heat. Methane and Nitrous oxide have a GWP of 21 and 310 relatively. However, both gases account for less than 1 percent of total the GHG concentration. CERs are awarded based on the global warming potential of the gas. For example, 1 CER unit of methane abatement is 21 times more than 1 CER unit of CO_2.

Chapter 3 CDM Problems

CDM projects have been on the rise since mid-2005, it has led to more than 400 project submissions with a combined CO_2 abatement of 570 million t CO_2 eq. Many participants and observers criticized the handling of the project cycle since some problems arose (Michaelowa, 2005). At the international level, the slow approval process has been criticized. This problem is caused by the lack of finance and human resources; it became more evident with the increase of CDM projects. At the national level, procedural and institutional problems have been acting as a barrier for CDM projects. These problems consist of the lack of local experts on the CDM procedure, lack of local intuitional support for CDM projects, and high transaction costs (Kimura, et al., 2006).

3.1 Transaction Costs

Most projects including CDM projects require many different types of costs. Some of these costs are normal costs found in every project (such as administrative costs, operational costs) and other costs are specific to CDM projects. CDM projects require certain paperwork for registration (project validation, registration, negotiating contracts with the CER purchasers) and verifying the CERs. CDM transaction costs are components of a CER price that are not determined from the physical process of reducing GHGs from the atmosphere or from the demand of the CERS (Chadwick, 2006). Many observers have noted that identifying, financing, negotiating, and project agreements may incur large transaction costs. This will inevitably lead to policy makers to favor large capital intensive infrastructure as opposed to smaller scale project. Many of these small scale projects involve renewable energy; therefore many of these could eventually be overlooked since they would be considered inefficient and uncompetitive. In this section I will explain the various transaction costs that are imposed by the CDM. The table below summarizes the range of the various transaction costs.

Transaction Cost	Low	High
PIN	5,000	15,000
PDD	15,000	50,000
Host Country Approval	0	5,000
Validation	10,000	40,000
Legal/Contracting	10,000	20,000
Total	40,000	130,000

Source: UNDP CDM User Guide 2003

Table 2: Transaction Costs

The PIN is not a very lengthy process and not necessary expensive. The cost will depend on the project proponent's CDM knowledge and expertise. Many countries often have to hire a consultant because of the lack of local experts. This may also increases transaction costs. The main component of the PIN is a feasibility study; the PIN has the potential to cost up to US $ 15,000 *UNDP CDM User Guide (2003).*

The PDD is considered to be the most costly transaction cost, the same factors that affect the cost of the PIN effect the cost of PDD. The most costly components of the PDD are the baseline methodology and the monitoring plan. The baseline methodology needs to satisfy the *additonality* requirement.

Article 12.5 of the Kyoto protocol states *"Reductions in emissions that are additional to any that would occur in the absence of the certified project activity."* This means that GHG abatement from CDM projects needs to be additional, in other words GHG emissions need to be less than the situation with no CDM project. This concept is called additionality.

The main problem with additonality is proving that a CDM project satisfies this requirement. The Dutch Cerupt group planned various renewable projects; however they had to withdraw all of them because none of them were able to prove additionality. Additionality requires a comparison between the situation with a CDM project and the situation with no CDM project (Business as Usual). All the renewable projects of the Dutch Cerupt project were considered business as usual projects (Pearson, 2004).

The difficulties emerge because comparing with the business as usual situation is hypothetical, it's not an actual one. Another problem is the overestimation of reductions. The host country and the donor country would benefit from an overestimate of reductions, the host country gets more money from the CERs and the donor country will be able to generate more CERs from their investment. Many other renewable energy projects have faced this problem (Burian, 2006).

If the PDD is completed in a sufficient manner then the validation is straight forward. However this is not the always the case, the PDD is often ambiguous which complicates the validation process by making it longer and more expensive. The problems are often associated with an inadequate baseline, additionaltiy, inadequate monitoring plans, and technical issues *UNDP CDM User Guide (2003).*

The host country approval and the legal/contracting depend on the local environment. Many developing countries are plagued with bureaucratic constraints which lead to additional costs. Approval by the host country is not very costly; however it has the potential to take a lot of time. India, for example, has a lot of experience in CDM projects and they have successfully been able to reduce the costs and duration of these two costs. Both these factors depend on the institutional format and polices of the host country (Kimura, et al., 2006).

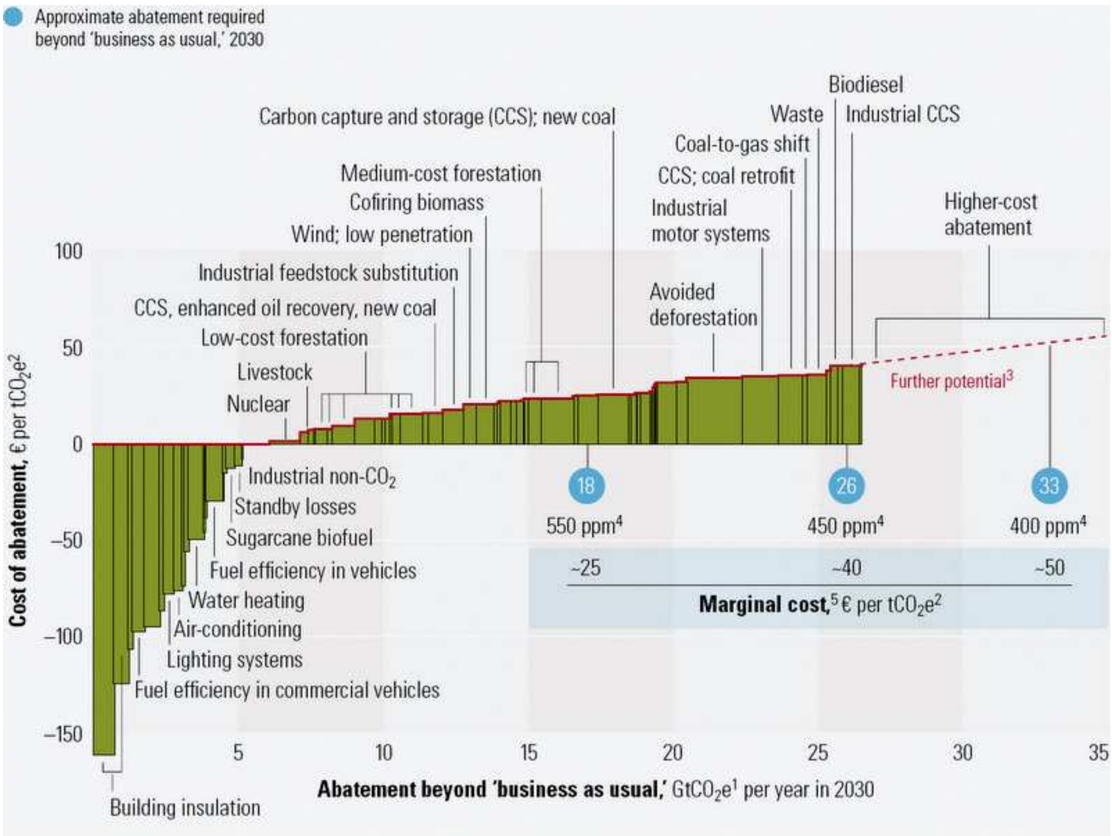
The table represents most of the major costs that are incurred before the commencement of the project. Post registration costs include monitoring, verification and certification, and issuance of CERs. All these costs are required for the CERs. The project needs to be monitored and verified in order to verify that the CERs represent GHGs reductions. The bigger the project the higher the transaction cost are. The problems that have been identified are problems that deal with the organization and development of CDM projects.

Looking at table 2, transaction costs have a very large range. There is a sum of US $ 90,000 difference between the low and high estimates. Many factors influence the magnitude of the cost. The main problem with high transaction costs is that smaller projects will be overlooked in favor of larger projects. For example, consider a project that has a cost of US $ 200,000 and CDM transaction costs of US $ 100,000. In this case the transaction costs represent one third of the total cost. The transaction costs make the project more expensive, less attractive to implement, and reduce the net present value of the project.

In 2008 smalls scale projects accounted for 44% of all CDM projects. There are many small scale projects that deal with the reduction of methane. Since the GWP of methane is 21 the CERs will be large enough to offset the high transaction costs. (Fenhann, 2008) The price of the CERs is probably the main determinant of a project. If methane did not have a GWP of 21, and a GWP of 1 (like carbon dioxide) than the small scale project would not be as beneficial (in terms of CERs generated) The higher the price is the more of an incentive it is to initiate CDM projects, including smalls scale projects.

3.2 Low Hanging Fruit Problem

One of the criticisms of the CDM was that it forced developing countries to sell off their cheap emission reduction options. This would be problematic in the future; it would require developing countries to invest in expensive emission reduction options when they commit to a reduction target in the future, making them worse off. Their future abatement costs would be higher and would result in foregone opportunities to earn revenues on the international permits market. This problem is called the low hanging fruit problem (Pareja, 2009).



Source: Envist, et al., 2005

Figure 10: Marginal Abetment Cost Curve

The figure above shows a global cost curve for greenhouse gases. It plots the potential size of each abatement measure versus the cost of that measure. The horizontal represents the amount of GHG abated and the vertical access represents the cost. This is also similar to country's cost curve. For the sake of this explanation let's assume that this marginal abatement cost curve represents a non annex 1 country. On the far left the abatement measures all deal with efficiency measures. These activities are displayed on the figure and are considered to be the cheapest options. CDM projects will start off with the far left and it will keep going right until the CERs values will not be feasible. The figure above indicates that abatement costs could reach about 50.

One of the main assumptions of the low hanging fruit problem is that non annex 1 countries will eventually have an emission reduction target in the future. With the absence of a post-Kyoto agreement on GHG emissions this may not be the case. There are also many determinants that effect the implementation of a CDM project and not only costs. High transaction costs and institutional barriers could deter the availability of CDM projects (Pareja, 2009).

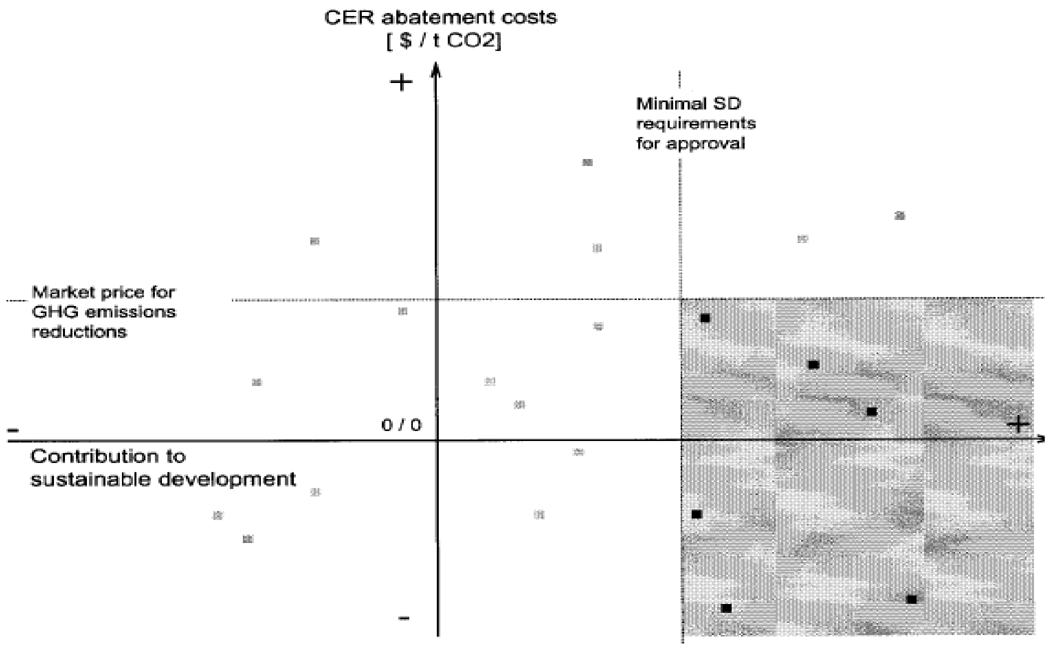
In a paper called How to design and use the clean development mechanism under the Kyoto Protocol (2007) by Germain, Magnus, and van Steenberghe, they investigated the low hanging fruit problems under different CDM formats. In the unilateral model the low hanging fruit problem is non-existent since the host country undertakes all the projects. As long as their positive permit prices countries would always benefit from implementing CDM projects. For bilateral and multilateral developing countries may have to be compensated a bit more than the permits price. IF the permit price is large then they take a portion of the surplus if not then they should be compensated to avoid the low hanging fruit problem.

Some authors have argued that the low hanging fruit problem shouldn't be considered very problematic. Developing countries are receiving money from the CERs and under perfect CDM market conditions there is no more low hanging fruit problem. Perfect information will enable the host country to choose the most adequate and effective problem. The problem occurs when the donor countries have market power or when the permit prices are increasing and the host country cannot benefit from the higher returns. Proper management and full disclosure of information can avoid this problem. (Narain & van't Veld 2008) Also Akita (2003) argues that technological transfer can offset the low hanging fruit problem in the future. The extent of this problem may be contested however it is something host countries need to consider. It is important to note that the host country chooses which CDM projects to undertake, nothing is forced upon them.

3.3 CDM and Sustainable Development

I explained the various aspects of sustainable development in the literature review in the first chapter. Some observers believe that the main problem to achieving sustainable development through CDM projects is the nature of the CDM. CDM is part of a market and not a development fund, so the main objective for developed countries is to generate tradable permits through projects in developing countries. This inevitably leads to a situation in which countries will try to invest in any project to gain CERs as opposed to invest in projects that accrue the most benefits. (Environmental, Social, & Economic) If the carbon market is not regulated and if the carbon price fluctuates then it would affect the status of CDM projects. The right economic polices, such as price floors, carbon taxes, etc. can reduce the threat of this problem (Pearson, 2004).

The donor country does not necessary have to be interested in promoting sustainable development, as long the project generates adequate CERs then it could be considered beneficial. This leads us to the twin objective problem of the CDM. The CDM has two main objectives, to promote sustainable development in the host country and reducing GHG emissions to help annex 1 countries achieve their targets. This generated quite a lot of controversy in the negotiation phase. Some participants supported the twin objectives however many participants saw it as a constraint. *"Effective instruments can only have one objective. The CDM is an instrument to produce cost-efficient GHG emission reductions. Forget about sustainable development within the CDM"* (Sutter, 2003 P. 64). On the other hand advocates of the CDM believed that a project can contribute to both objectives



Source: Sutter 2003

Figure 11: GHG Emissions vs. Sustainable Development

Figure 11 is a hypothetical qualitative distribution of CDM projects and their assumed impact on each of the objectives. The X axis represents the contribution to sustainable development, and the Y axis represents the CER abatement costs. The grey box shows all the CDM projects that contribute positively to both objectives. This chart emphasizes that some projects may not be able contribute to both objectives. In order to fulfill the twin objectives then CDM projects need to clarify and introduce prerequisites for CDM projects. This of course could increase the duration of the CDM project cycle and could also cause an increase in CDM transaction costs. There are currently no international sustainable development standards, and the competitive supply side of CDM projects could cause a trade off in favor of the cost efficient emission reduction objective. This is possible because there are no incentives for the host country and annex 1 countries to achieve specific sustainable development standards. There are a potential large amount of projects that satisfy each of the objectives. Projects that somewhat contribute to both objectives exist and the selection process needs to make sure that both objectives are considered. The host country has the final decision which projects that will be undertaken in their country, and it is also their prerogative to acknowledge if the CDM project is contributing to sustainable development? (Pareno & Sutter 2007)

Many countries have established their own criteria for sustainable development. CDM projects get evaluated on the basis of these criteria. In practice this not always the case, many observers expressed their concern that many projects in Asia are being registered with no real sustainable development impact. The main reason for this is that some countries lack the capacity to set appropriate criteria to evaluate sustainable development (Kimura, et al., 2006). In a study done by Parreno and Sutter (2005) they evaluated the registered projects. This study was done in the beginning of the CDM only 16 projects were registered. They concluded that only 1% of the registered projects could have a significant impact on sustainable development. 72 % of the projects were considered to have a significant and measurable impact on emission reductions.

There is potential to achieve both aims of the CDM. The main problem is choosing the appropriate projects that contribute to both aims. With the absence of general sustainable development standards for CDM, it puts the host country as the sole actor responsible for achieving sustainable development. With the prospects of getting financial benefits from CERs, governments are prone to accept any project that can produce CERs. Pearson (2004) argues that to avoid this then host countries should be penalized for any negative impacts caused by the project. He argues this because at the time both China and Vietnam were using the money gained from the sale of CERs to subsidize fossil fuel extraction.

Recognizing the potential problem of the CDM's twin objective, in 2003 the WWF and a small number of non-governmental organizations commenced the Gold Standard. The Gold Standard is a quality standard for carbon emission reduction projects that incorporates sustainable development benefits. The Gold Standard is used in the CDM and joint implementation. Its main purpose is to ensure that CDM projects satisfy both its objectives. The Gold Standard supports only two types of projects, renewable every and demand side energy efficiency projects. These two projects use technologies that are not very environmental risky. In order to achieve sustainable development a methodology deploying environmental and social indicators is sued. According to the WWF website the Gold Standard is based on these principles:

- Standards that can be supported by a wide range of stakeholders, in particular environmental groups and others who believe in the overriding importance of maintaining environmental integrity.
- A balance between environmental rigor with practicality in terms of application by project developers and operational entities.
- Avoidance of elevated transaction costs or bureaucratic procedure.
- Direct compatibility with the CDM and JI project planning and monitoring.
- Simple procedures, easily handled by standard CDM project.

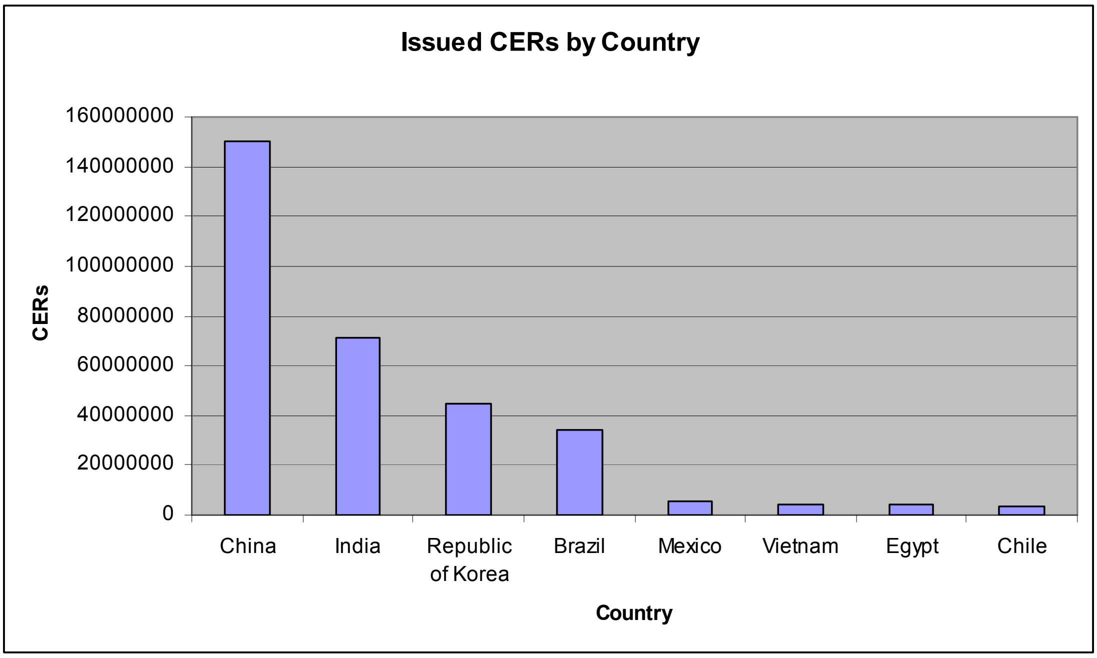
- A Global Standard, readily applicable in a variety of local and national contexts and across different sectors.

The Gold Standard is an example of a mechanism that helps achieve both goals is possible. The Gold Standard is a perfect example of how non-governmental organizations can cooperate in the CDM.

Chapter 4: CDM Vietnam

The CDM investment climate index (CDM-ICI) measures the investment climate for CDM projects. The index ranges between 0 (lowest)-100(highest). Malaysia and South Korea have the highest indices in Asia, 91.7 and 90.2 respectively. This is considered to be a very good climate. The index is based on the country's environment (political, administrative, financial, etc.). Both China and India are considered to have the cheapest mitigation options however this does not affect the CDM investment climate index. China and India have an index of 83.3 and 80.7 respectively, which is considered a good climate. Vietnam is considered to have an average climate with an index 54.4 (ranked 25). The Vietnamese investment conditions, lack of transparency in administrative and government, taxation of CDM projects, and the slow process of registration all contributed to the low score. Vietnam is not the most attractive destination for CDM projects (Schmitt, 2009).

Although Vietnam's CDM-ICI is ranked 25 they were ranked 6th in the world in terms of issued CER amount. Figure 12 shows the global ranking of CERs that were issued by 2009.



Source: http://cdm.unfccc.int

Figure 12: Issued CERs

What is interesting from this figure is that the numbers of CERs issued per country is not really related to the CDM ICI ranking. Malaysia is considered to have the highest CDM ICI, however they do not have the highest number of CERs, in fact they are not in the top 8 as shown in the graph. Republic of Korea has the second highest CDM ICI but they have the third highest CERs after China and India. This indicates that the most important factor is the cheap abatement options. China and India have the cheapest options therefore they have the highest number of CERs. Vietnam is ranked 6th with about 4.5 million CERs.

The majority of the large rural population in Vietnam relies on non-commercial biomass energy such as fuel wood. Therefore, Vietnam's per capita commercial energy consumption is very low. Vietnam is rich in natural resources, Vietnam has an estimate of 600 million barrels of oil reserves, and they extract about 370,000 barrels a day. Vietnam still relies on oil imports because of the lack of refining options in Vietnam. Vietnam also has access to natural gas and coal, it is estimated that they have reserves of 6.8 trillion cubic feet and 165 million short tons respectively. Consumption of all three sources is small however this is increasing and it is expected to continue increasing (Langdon, 2008).

Vietnam also has a lot of potential for renewable energy. Heavy rainfall and many rivers make hydro-power plants a viable option. There are over 400 small hydro stations; it is also believed that around 100-500 family hydro power generators are being utilized. The Vietnamese government has also invested in solar energy; there are currently 5 photovoltaic power stations in Vietnam. (MONRE, 2005)

4.1 Vietnam's Sustainable Development Criteria

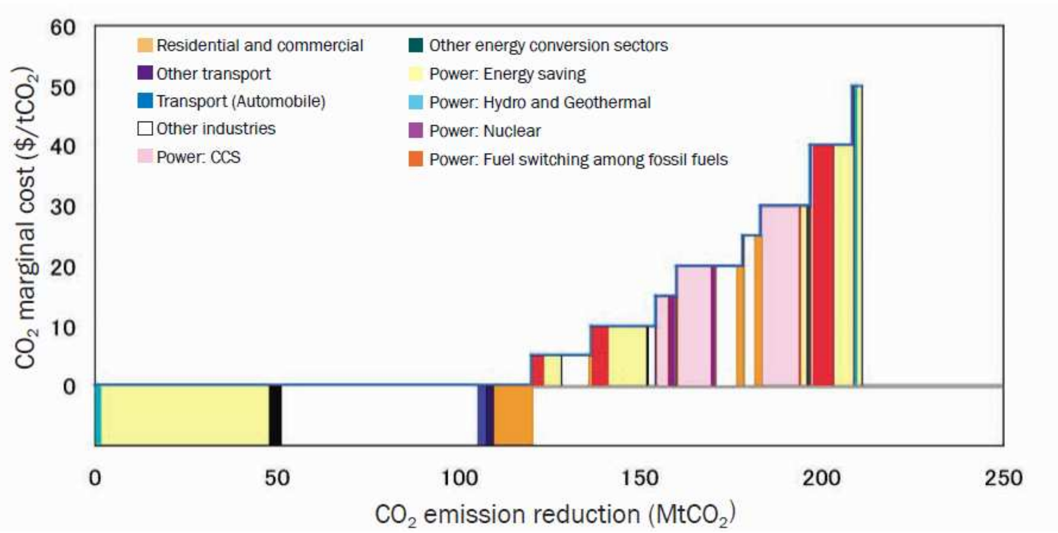
One of the problems with CDM in Vietnam is the absence of concrete sustainable development criteria. The government through the Ministry of Planning and Investment has a set of sustainable development criteria:

1. Human beings are the center of sustainable development
2. Consider economic development as the central task, appropriately and harmoniously combine with the social development; reasonably exploit, and effectively utilize natural resources in accordance with the principle "all aspects: economic, social and environmental ones enjoy benefits."
3. Protection and improvement of environment quality are to be considered as an inseparable factor from the development process.
4. The development process must equally satisfy the needs of the current generations without causing obstacles for the life of future generations
5. Science and technology is the foundation and momentum for the country's industrialization, modernization, quick, strong and sustainable development.
6. Sustainable development is the cause of the whole Party, authorities at all levels, the ministries, sectors and localities, agencies, businesses, social organizations, population communities and the whole people.

7. Tightly attach the establishment of an independent and autonomous economy to the international economic integration on basis of self imitative
8. Social-economic development, environmental protection should be closely combined with guarantee of national defense and security as well as social safety and order.

These principles are the basis of any sustainable development indicator. The various ministries and level of government are in charge of developing a set of sustainable development criteria which adequately measures the nature of their activities and their impact on natural resources.

4.2 Vietnam's Marginal Abatement Cost Curve



Source: ADB, 2009

Figure 13: Vietnamese Marginal Abatement Cost Curve

The figure above depicts the Vietnamese marginal abatement cost curve calculated by the Asian Development Bank (ADB). The ADB projects that total CO_2 reduction potential in 2020 is around 211 $MtCO_2$. To fulfill this potential it is estimated that an investment of US $ 1.8 billion in clean technologies is needed, this accounts for 1.3 percent of the GDP in 2020. The far left of the graph below zero summarizes the net negative mitigation options of Vietnam. This can account for a reduction of 120 $MtCO_2$, which is more than half the projected potential reduction for 2020.

The net negative cost options in Vietnam consist of energy savings in power plants, industry and household appliances. Switching gases also has a high mitigation potential and these activities include switching from coal to gas power generation and from fossil fuel to nuclear power. The costs of the mitigation options range from net negative costs to 50/tCO_2.

4.3 Vietnamese CDM Framework

The next sections will cover the CDM institutions present and current CDM projects.

Designated National Authority (DNA)

Each country has a Designated National Authority (DNA). A DNA is an organizational entity that is in charge of CDM projects for the specific country. Everything related to CDM, from the initial registration phase to the final phase of CER validation is done with accordance of the DNA. The Vietnamese Government mandated the Ministry of Natural Resources and Environment (MONRE) of Vietnam in 2003. As the DNA MONRE were in charge of the following tasks: (Manh Hoa, 2005)

- Building national assessment criteria, regulations and guidelines for the CDM
- Assess CDM projects at the national level
- Assessing the PIN and PDD of CDM projects

- Providing CDM information to interested investors, related organizations, consultants and public
- Managing and coordinating CDM activities and investment in Vietnam

CDM National Executive and Consultative Board (CNECB)

Following the creation of the Vietnamese DNA the CDM National Executive and Consultative Board was created. The CNECB consist of 12 representatives from various ministries and one representative from the Vietnam Union of Science and Technology Associations (VUSTA). The ministries represented are: Ministry of Florien Affairs, Finance, Planning and Investment, Science and Technology, Industry, Agriculture and Rural Development, Training and Education, and Trade. There are three representatives from MONRE, a chairperson, permanent representative, and a secretary. The CNECB are responsible for two tasks: (Duc Minh, 2005)

- Providing consultation to MONRE on polices related to development, implementation managm3ent of CDM activities in the country.
- Providing consultation on guidance and assessment for CDM projects in Vietnam under the Kyoto Protocol and UNFCC.

All potential CDM projects are given to CNECB and they are in charge of evaluating them. This board is under the umbrella of MONRE and they are the only two Vietnamese entities that deal CDM projects.

The CNECB consists of representatives from various ministries because of the nature of CDM projects. CDM projects can be involved in almost every major sector, and the representatives in the CNECB are in charge for evaluating CDM projects that concern their sector.

4.4 Vietnamese CDM Initial Planning Phase & Criteria

Agencies, State-owned enterprises and private companies from developed countries are eligible to commence a CDM project in Vietnam. The CNECB identified the following areas suitable for CDM projects: efficiency, conservation and saving of energy, recovery and utilization of methane from landfill and coal mining for generation, fossil fuel switching, renewable energy, recovery and utilization of associated sectors, and afforestation and reforestation. Registering CDM projects in Vietnam go through the following process: (Duc Minh, 2005)

Formulation:

Project participants are in charge of preparing the PIN and PDD. The complete PIN is sent for approval to the International Division of MONRE. Upon approval of the PIN, the project participants start working on the PDD. Once the PDD is complete an English and Vietnamese version needs to be approved by the concerned Ministry and provincial or local government. The PDD gets sent to MONRE and the CDM executive board.

Evaluation:

The CNCEB is responsible for evaluating the project. There are three sets of criteria. The first set of criteria is sustainability. The following table summarizes the main points:

Economic Sustainability	National Income Generation	• Growth National Income • CER Revenues
	Economic Externalities	• Technology Transfer • Import Substitution
Environmental Sustainability	Green House Effect	• GHG Emission Reduction (Additionality)
	Non GHG Pollution	• Non GHG Air Pollution • Non GHG Water Pollution
	Waste	• Waste Generation Rate
	Ecosystem	• % Change in Forest Cover • Soil Erosion • Likely Effect on Biodiversity
Social and Institutional Sustainability	Poverty Eradication	• Creation of Rural Employment • Increase Household Income
	Quality of Life	• Improving of Living Conditions
	Readiness of Implementing Agency	• Public Sector • Private Sector

Source: MONRE 2005

Table 3: Sustainable Development Criteria

CNCEB compares the project with the criteria summarized in the table above. The CNCEB look into all aspects of sustainable development, and they declare if the project satisfies sustainability or not. The second criteria they look at is commercial viability. This includes local and international demand as well as the CDM's project to investors. The final criteria is feasibility. Before the CNCEB approve the project it needs to attain support from local authorities and the central authority. The project also has to have enough infrastructure and manpower so that it could operate successfully. These criteria are somewhat related to economic sustainability. MONRE wants to make sure that any CDM projects will increase economic opportunities therefore CDM projects should have the potential to expand and generate funds in the long run. (MONRE, 2005)

Approval:

The CNCEB evaluates the PDD based on the criteria and sends it to MONRE for the final approval.

Registration:

Once approved, MONRE will send the PDD with an endorsement letter to the CDM executive board for registration. Registration with the CDM executive board is essential for the verification, certification, and issuance of CERs.

As of 2009 MONRE approved 98 PDDs and registered only 9 with the CDM executive board (Hai Ann, 2009). There is quite a difference between the two figures and this indicates the complications of registering CDM projects. It's not exactly clear why there is such a lag in registering projects. As mentioned earlier many observers criticized the international arrangements for registering CDM projects. The table below shows the 9 registered projects and how much CERs are expected:

Project	Expected CERs
Dong Thanh Landfill Recovery in Ho Chi Minh City	1,476,183
Rand Dong Oil Field, Gas Recovery and Utilization	674,000
Binh Thuan, Wind Power Plant	57,989
Cao Phong Reforestation	2,665
Song Muc Small Hydro Power Rehabilitation Project	4,298
Suo Tan Hydro Power	14,641
So Lo Hydro Power	17,576
Myong Sang Hydro Power	4,920
Phu Mau Hydro Power	13,395

Source: Japan Carbon Investors Forum

Table 4: Registered Vietnamese CDM Projects

Most of the projects deal with renewable energy. Looking at the marginal abatement cost curve presented in the beginning of the section many of the registered projects are part of the non negative costs. Considering the low hanging fruit problem it is quite evident that these projects can be classified as cheaper mitigation options. The ADB projects that after an investment of US $ 1.8 billion in clean technologies marginal abatement options will be greater than 50/tCO_2. Compared to the options available today this figure is significantly more expensive. The information is not enough to conclude that Vietnam will be worse off in the future because of the expensive mitigation options. However, one can conclude that if Vietnam in the future intends to meet emission requirements abatement will not be as cheap.

Technological progress and the nature of the CDM projects can compensate any potential low hanging fruit problem. For example a project that generates or contributes significantly to economic opportunities in the long run can offset the magnitude of the low hanging fruit problem. There are various owners for the CDM projects. The owners include: State owned, private sector, public private partnership, and joint venture among foreign and partners and Vietnamese partners. Various private and public stakeholders can get involved in CDM, therefore, CERs revenue can be enjoyed by the various stakeholders.

Chapter 5: The Sustainable Development Impact of the Biogas Program for the Animal Husbandry Sector of Vietnam

In the past 20 years Vietnam initiated a series of reforms that was aimed at reducing rural poverty. Vietnam has a population of about 86 million with over 50 percent of the population living in rural areas. The agriculture sector has been achieving a 4% growth rate over the past 4 years. The agriculture sector is responsible for 22% of the GDP and more than 50% of the population is employed through this sector. One of the main contributors to this growth rate is the expansion of small holder livestock production. The livestock sector accounts for 27 percent of the total agriculture sector. It is expected to grow to 42 percent by 2020 (World Bank Livestock Report, 2009). Table X summarizes the growth rate of various livestock populations.

Type Of Livestock	2000	2005	2008	Average Growth rate 2000 - 2008 (%)
Buffaloes	2,900	2,920	3,000	0.42
Cattle	4,130	5,540	6,725	6.28
Dairy cows	35.0	104.1	160.1	20.93
Horses	126.5	110.2	103.5	-2.48
Goat/Sheep	543.9	1,314.2	1,777.6	15.95
Pig	20,190	27,430	26,700	3.56
Poultry	196,100	219,910	247,000	2.93

Source: *ISPONRE Strategy Report* (2009)

Table 5: Livestock Population (1000s)

The table above shows the various livestock population for the years 2000-2008. With the exception of horses all livestock populations show an increasing growth rate. Cows and Goat/Sheep have the highest rate with 20.93 % and 15.95% respectively. Livestock production is one of the major sources of income and food for households. The output of small scale household-based livestock represent about 70 percent of the overall livestock production (World Bank Livestock Report, 2009)

5.1 Monitoring the Biogas Program

In the problem analysis section the Biogas Program for the Animal Husbandry Sector of Vietnam was introduced. Since this project is all over Vietnam monitoring the digesters to ensure they are operating properly and fulfilling the original goals may be complicated. First of all in order to be eligible for CDM the project planners need to be prove the additional emission reduction caused by the project; comparing the baseline situation without the project with the project situation taking into account.

When I visited the SNV office in Hanoi, Vietnam in January 2010 I was told by (add name from my notes) that each region has a technical team mandated by the SNV to offer technical and monitoring support. In addition to this every household that participates in the project needs to disclose the following information:

- Livestock type and population
- Average weight of livestock
- Household population
- Manure management practice (before installation of biogas digester)
- Farming pattern
- Fuel use
- Local/regional climate

Every year the SNV conduct a User Survey. A user survey will be conducted every year to a different sample of the participants. This is the only annual monitoring process the SNV undertakes in order to assess the impact of the project. The 5 objectives of the user survey are:

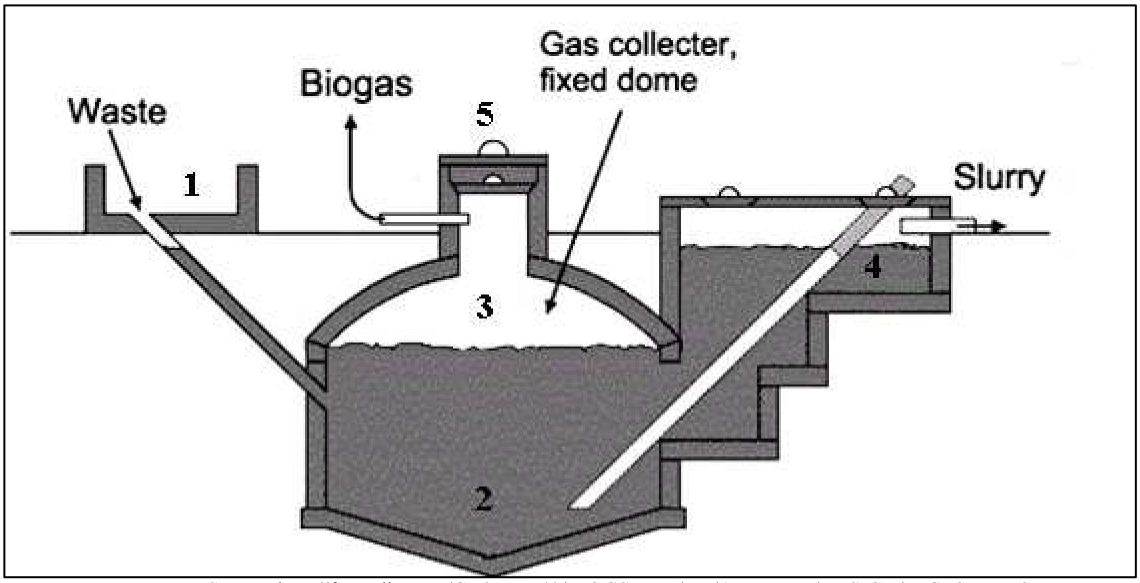
1. Survey the products and services provided by the Biogas Program

2. Assess the social, economic and environmental impact from the utilization of biogas plants.
3. Assess the socio-economic condition of the clients, categorize the clients into three groups:
    - Relative poorer households
    - Average households
    - Well-off households
4. Survey what biogas products are being used by the farmers (stove, filter, lamp, electric generator, etc.)
5. Deduce a demand for biogas from the survey results.

The user survey of 2009 was taken in 7 provinces the biogas program was present in Vĩnh Phúc, Hưng Yên, Nình Bình, Quảng Ngãi, Bình Định, Bến Tre, and Bà rịa-Vũng Tàu. 211 households were surveyed and the average size of the biogas digester was 11.22 m^3. The household's were small-medium scale livestock farmer (5-30 heads/heard).

I also conducted interviews in two districts on the outskirts of Ho Chi Minh City, Tan Uyen District, Binh Duong Province and Cu Chi District, Ho Chi Minh City. These districts were not part of the SNV project, however many households operated a fixed dome digester. The characteristics between the households that use digesters in this district is almost identical to the characteristics of households participating in the SNV project. I interviewed about 20 households and I was interested in learning their experience and overall views towards operating a biogas digester. The results were similar in each district. There were very few differences and most of the households shared the same type of experiences.

5.2 Technology



Source: http://fastonline.org/CD3WD_40/BIOGSHTM/EN/APPLDEV/DESIGN/DIGESTYPES.HTML

Figure 14: Fixed Dome Biogas Digester

The figure above is of a fixed dome model. The main components of the digester are located underground. Placing the digester underground enables the production of biogas all year round. Other digesters that are exposed to the outside environment cannot function during the rain. This is especially a big advantage in Vietnam since their climate consists of a 4-6 month rainy season. It also takes up less space and the waste inlet can be close to the livestock pen which facilitates the collection of dung. The livestock waste is mixed with water and put into the digester (1). The main tank (2 and 3) is where the anaerobic digestion takes place. The biogas rises (3) and is stored in the tank; there is a pipe on the top (5) connected to the household. The biogas waste remains into the tank (2) and also in the displacement tank (4). One of the drawbacks of this system is that the biogas waste does not all come out and eventually the main tank will overflowed with biogas waste. However according to a biogas engineer it takes many years for the tanks to get completely filled up.

This is the basis of the technology that is being spread to the participants of the SNV project. The fixed dome digester is originally Chinese, and the actual digester used in this project are modifications of the original model. All the equipment is purchased locally. *The information in the following section is mostly from the SNV user report 2009, unless stated otherwise*

5.3 Economic Impact

	Area (km2)	Population (1000people)	Density (ng/km^2)	Income Per Capita (1000VND)	Agricultural land (1000 ha)	Ruminant (1000 heads)	Pigs (1000 heads)	Poultry (1000 heads)
Hung Yen	923.4	1,167	1,214	6,672	55.5	48.9	615	6,623
Vinh Phuc	1,231.8	1,014	823	6,480	58.9	168	490.5	7,050
Ninh Binh	1,388.7	937	674	6,108	62.7	65.8	372.3	3,394
Quang Ngai	5,152.7	1,302	253	5,460	122.6	329.6	502.8	2,405
Binh Dinh	6,039.6	1,593	264	6,636	135.6	326.7	621.4	4,269
Ben Tre	2,360.2	1,360	576	7,368	136.2	172.4	280.3	3,565
BR-VT	1,987.4	961	484	9,312	109	53.4	278.1	1,857

Source: *SNV User Report 2009*

Table 6: General Information on SNV Sample

The table above has some general information on the provinces surveyed by the SNV. The income per capita ranges from 5,500,000 VND to 9,500,000 this is approximately US $ 280 to US $ 480. The main input for the biogas digester is the waste from the pig, according to a biogas expert I interviewed in Vietnam the properties of the pig waste make it the most suitable for biogas production.

There are various materials that need to be bought in order to successfully build a biogas system. Table X summarizes the materials and costs needed to build a 10 m3 fixed dome biogas digester in Ben Tre Province:

Material	Quantity	Cost (1000 VND)
Cement	1.1 tons	1512
Solid Brick	3500 pieces	3150
Sand	3 m3	600
Gravel	1.5 m3	300
Pipes (entrance, exit, and gas collecting)	3.5 m	580
Steel	15 kg	180
Conductor Wire	30 m	210
Manometer	1 piece	40
Valves	1 set	100
Biogas Using Device		
Biogas single cooker	1	500
Lamp	1	70
Labor		3760
	Total	11002

Source: SNV User Survey 2009

Table 7: Costs of Materials in Ben Tre Province

Small scale farmer would not be able to afford a biogas digester without any financial support. The average income per capita in Ben Tre province is 7,368,000. The cost of the digester displayed above is larger than the average income of the province. The SNV project offers financial aid as part of the program. Initially each household that joins the program will receive 1 million VND under the condition that they build the digester before 2009. After 2009 the grant raised by .26 million VND; totaling 1.26 million VND. 177 out of the 210 households surveyed in the SNV report received the cash assistance. In order for a household to be eligible for the cash assistance they have to register themselves with the local Commune People's Committee as well as the project which takes up to 120 days.

In addition to the SNV loans the local government, and local associations and groups offer grants and low interest loans. In the Cu Chi District the Women's union offered grants and loans with no interest for farmers. For example one of the households I interviewed installed a digester that costs 15 million VND including the cooker and all the other materials required. The initial deal was a 14 million loan in which the farmer pays back every month 250,000 VND and a 1 million VND. Once 9 million VND was paid the remaining 5 million VND was written off as a grant. Each district has a different system, and this is not available in every district. I also visited Tan Uyen District, Binh Duong Province and there was no financial support from the provincial government or any association, livestock farmers had to rely on themselves.

Biogas is mainly used for cooking, the alternative source for cooking would either be cooking gas or firewood bought or salvaged from nearby fields. The biogas produced is also used for lighting and heating. Table X shows the average money saved per household in each one of the districts sampled in the SNV survey.

Item	Vinh Phuc	Hung Yen	Ninh Binh	Binh Dinh	Quang Ngai	BR-VT	Ben Tre
Salvaged firewood	14.55	34	22	25.67	47.33	33	147.1
Bought firewood	150.33	29	55	48	63.33	117.67	21.29
Gas	26.67	16.33	19.33	24.7	31.5	65	15.16
Charcoal	36.67	17.48	2	4.33		2.33	0
Peat	33.33	10.27	12.67	0	1.33	0	0
Total	**261.55**	**107.08**	**111**	**102.7**	**143.49**	**218**	**183.55**

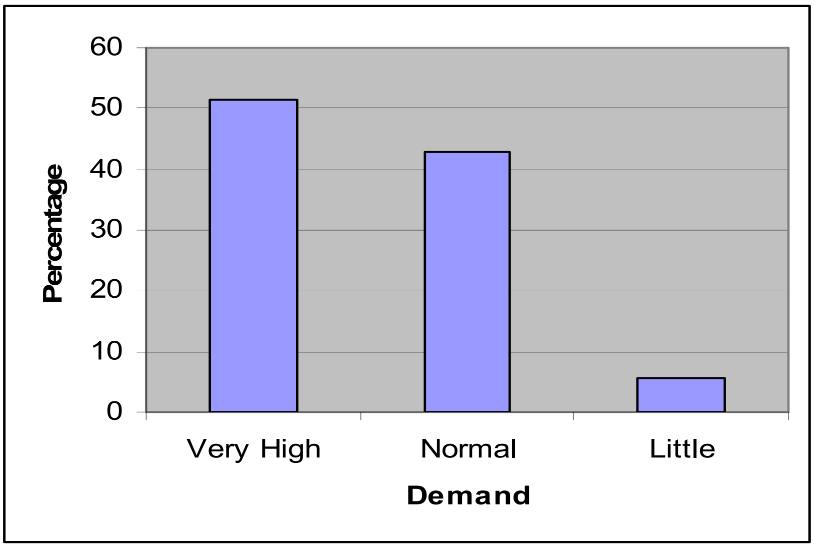
Source: SNV User Survey 2009

Table 8: Average Money Saved per household Per Month (1000 VND)

The salvaged firewood was valued at the current price of firewood. The higher amount of gas and firewood saved in monetary terms indicates how important the two main sources were for cooking prior to the installation of a biogas system.

Charcoal and peat are also used, all these resources are not used anymore after biogas installed. This allows the household to save money and the table indicates that households save from 100,000 VND to about 250,000 VND depending which district they are in. These numbers represent the alternative energy value and opportunity cost of biogas. If we compare the total of money saved to the income per capita then we can conclude that a biogas digester enables rural households to save a considerable amount of their income.

The biogas market has a huge potential in Vietnam. There are various digesters and biogas appliances that can be used. Most farmers that I visited were not aware of other uses for biogas however, they all seemed to be enthusiastic about using the biogas more. Currently there is no adequate market and farmers face limited choices. The SNV project has facilitates the dispersion of technology, there are more technologies that can be used and this can create a big biogas market. Nepal has a very active biogas market. Nepalese policy on biogas focused more on market development by paving the way for private sector investments. Nepal has currently 62 private biogas construction companies, 5 factories producing appliances, and over 140 state and private financial organizations that are help the users by providing low interest loans. (ISPONRE, 2009) This attracts many employees, and the biogas industry in Nepal is responsible for employing thousands of people. The Vietnamese government has realized this advantage and plan to progress their biogas market.



Source: SNV User Survey 2009

Figure 15: Demand of Biogas Appliances

The chart above is the demand of biogas appliances from the SNV sample. About 90 percent of the demand constitute very high and normal demand. Only about 6 percent had a little demand. This is part of the criteria that all CDM projects in Vietnam face. The commercial viability, considering the potential demand and the majority rural population the biogas market has the potential to be very beneficial and if from the Nepalese example we can conclude there is a high potential to employ workers in this field.

Biogas production can also diversify the farmer's income. The main source of income is from livestock. Some farmers have a small plot of land for vegetables and fruits to be consumed at the household (excess is sold). In the second district I visited, the Cu Chi district farmers faced the problem of too much biogas production. The farmers realized with the excess biogas produced they would be able to produce rice wine. Each farmer I visited in that district produced about 10-15 liters of rice wine a day. Each liter sells for about 17,000 VND. This is an example of diversifying ones income that was caused by biogas production.

Since this is a CDM project the CERs sold from GHG reductions can be considered as an economic benefit. It is estimated that the project will deduce about 7.5 million tCO_2eq. Methane is reduced and this figure represents the conversion to carbon dioxide units (using the GWP). Figure 9 showed the price volatility of the CER. The price ranged from EUR 7.39 to 28.88. At 7.39 Euros, 7.5 million tCO_2eq would be worth about 55 million Euros. At 28.88 Euros, 7.5 million tCO_2eq would be worth 216 million Euros. The latter figure is unrealistic, the data that was displayed on the various estimates show that the price of CERs would be around 7. Nevertheless, the amount of money received from the CERs for this CDM project would be a substantial figure. This is the biggest economic benefit, and developing countries can use the revenue from the CERs to finance various sustainable development projects.

5.3.1 Possible Economic Indicators

The SNV user report covers various economic aspects of the CDM project. It especially concentrates on the impact on the household. I think in this aspect the economic indicators used are adequate. They give us a complete picture of how the biogas digester has been beneficial to the household in economic terms.

What is missing is a set of indicators that represents commercial viability. The SNV user survey ask the household about their demand on biogas appliances. This is the only measure of commercial viability. From the households I interviewed they all bought their digester equipment and appliances (stove, lamp) from an engineer. The user survey should include all points of sales available near the districts they sampled. The producers/sellers could also be included in the survey. They can offer insights on what barriers are hampering the dispersion of technology and other issues that affect the industry. The final measure they can use is the number of people the biogas program employs, directly and indirectly.

The source of finance needs to also be included. When I visited the Cu Chi District I met with a representative of the local people's community and he explained to me how the women's union obtained the money for the biogas loans. The women's union obtained their money from the Ministry of Environment as part of an initiative to improve the environment. There are also other NGOs and private companies that are involved in financially aiding households in installing biogas digesters. The survey should include what sources the locals have access to. This will give a more complete understanding on the amount of finance needed. The survey covers the SNV financial package and they ask questions about the procedure of obtaining the SNV funds to the households.

These indicators need to be included because I believe that the current survey is not measuring the complete economic impact. I think these indicators are important, especially the biogas market indicators because they can give us an idea on how much money is involved. This will be necessary when thinking the long term status of the project. This project is supposed to last till 2016, can the biogas market (through sales and amount of people employed) generate enough money to replace the SNV's aid mechanism?

5.4 Environmental Impact

The main environmental impact is how much GHG are reduced. The conversion of livestock waste to biogas and the utilization of biogas and bio-slurry contributes to the reduction of GHG. Domestic biogas enables GHG emissions to be reduced in three ways:

- Modification of the traditional manure management practice

- Substitution of conventional domestic energy sources
- Substitution of chemical fertilizer

There are various techniques to deal with manure and each technique is responsible for a certain amount of emissions. Methane is the main gas emitted. Many households discharge the waste in the environment or compost the waste in and outside the animal cages. Generally over time discarded waste will slowly emit methane. Biogas plants generate the maximum amount of methane from manure and when combusted the methane is destroyed. Using biogas to cook meals reduces emissions from livestock manure. The SNV calculates that the modification of the traditional manure practice is responsible for about 2100 kg CO_2 per digester. They got this number by assuming the emissions from non treated waste from 8 pigs, 1 dairy cattle, 1 non dairy cattle, and 0.5 buffalo. Using the conversion factors of the International Panel for Climate Change they came up with that figure.

The second source of emission reduction comes from the substitution of conventional energy sources. Looking at table X (amount of money saved) shows what type of resources are saved by using biogas. The 2 most significant resources are firewood and cooking gas (butane). The case was similar in the two districts I visited. Most of the households relied on these two sources of energy before they installed the biogas digesters. Biogas digesters will decrease the demand of these two natural resources. The decrease demand of firewood because of biogas could reduce deforestation and the environmental consequences associated with that. Discarding the waste in the environment, which was the norm before biogas digesters could cause soil erosion and degrade the water supply.

The SNV estimate that each 8m^3 biogas digester can produce about 864 m^3 of biogas a year. This is approximately 2.3 m^3 a day. The SNV converted this amount to the equivalent of conventional energy using data from the a survey of the Institute of Energy. Based on the amount of biogas produced they estimated a reduction of 2900 kg CO_2eq per year. There are various studies that investigate biogas equivalents. The table below are the equivalent of 2.8 m^3 of biogas of Paul Harris in 2008:

Natural Gas	1.7 m^3
Propane	2.5 liters
Butane	2.2 liters
Gasoline	1.8 liters
# 2 Fuel	1.6 liters
Coal	2 kg
Fuel wood	4.5 kg

Source: Harris 2008 (7)

Table 9: Biogas Equivalents

The table above indicates that biogas has the potential to replace most of these conventional sources of energy.

The use of the biogas slurry for fertilizer has many agricultural advantages, and many tests have proved higher production yields that commercial fertilizer. The SNV calculated that for 0.5 ha of bio slurry that is replaced with chemical fertilizer 500 kg CO_2eq is reduced. The problem is the bio slurry is not used that much. The bio slurry is very wet making its transportation and application difficult. Most livestock farmers have a small plot of land in which they harvest fruits vegetables for personal use and sell the surplus. Only a few households from the ones I interviewed used the slurry. The SNV realized that many farmers do not use the slurry properly so they have dropped the amount of GHG reduced from the slurry from the overall calculations.

The SNV predict that each digesters contributes to about 5tCO_2eq is reduced per digester from the waste treatment and the substitutions from the conventional sources of energy. These are exploratory calculations based on general equivalents. None of these calculation are specific to Vietnam.

The two main environmental impacts from biogas digesters are the reduction of GHG emissions and the preservation of natural capital. The quantity of biogas produced has direct implications in how much of the conventional sources are saved. Most of the users are aware of the positive affects of biogas. One of the main reasons users installed biogas was because of the potential improvements in the environment. The fact that the digesters is under the ground reduced the bad odor caused by the livestock. The table below is the pollution source according to the respondents.

Province	**Livestock (%)**	**From food processing (%)**	**Livelihood activities (%)**	**Other source (%)**	**Total opinion (%)**
Vĩnh Phúc	41.9	14.0	39.5	4.7	100.00
Hưng Yên	67.7	3.2	29.0	0.0	100.00
Ninh Bình	62.1	3.4	31.0	3.4	100.00
Bình Định	76.5	14.7	8.8	0.0	100.00
Quảng Ngãi	55.6	16.7	25.9	1.9	100.00
Bà Rịa-Vũng Tàu	54.5	10.9	34.5	0.0	100.00
Bến Tre	54.5	10.9	34.5	0.0	100.00
Tổng số	59.8	9.6	29.2	1.4	100.00

Source: SNV User Report 2009

Table 10: Opinion of Pollution Source

All the sampled provinces believe that livestock is the biggest source of pollution. Biogas can drastically decrease pollution, and this is what is mostly felt by the livestock farmers.

5.4.1 Possible Environmental Indicators

Before I went to Vietnam to research the economics of biogas production I assumed that the amount of pollutants and GHG emissions were constantly recorded. The case was not as I anticipated beforehand. The SNV user survey only asks the users about their opinions but there is nothing concrete. The amount of emissions reduced through digesters that I mentioned in the preceding section was based on hypothetical conversion factors obtained form other research and institutions.

Each province should have tests to measure the amount of pollutants in the atmosphere. The amount of biogas produced is not recorded. The SNV conducted a few tests to obtain a general idea of how much gas is produced but there are no measures taken to record how much biogas each digester is producing. Similarly there is no data on how much waste is put in the digester. The user survey ask how much money is saved from previous sources, however if they record the amount then they get a better idea on how much resources they are saving.

5.5 Social Impact

The main social issue is the human health. Most of the households that had little children that I interviewed were concerned with the exposure of waste to their children. Biogas production reduces the threat because most of the waste is used in the digester.

The biogas system improves environmental conditions and it often improves the quality of health of the household members as well as their livestock. In a study done by Nguyen Quoc Chinh of the Faculty of Economics and Rural Development of Hanoi Agriculture University, she investigated the health perceptions of 12 farmers. She asked them to compare the symptoms of runny nose and headaches before and after biogas systems were installed. She also asked the rate of doctor visits for the two periods. 66% of the respondents claimed they had runny noses on a non regular basis, 100% of them said they had none after the system was installed. Before the biogas system 8% had regular headaches, 58% had headaches sometimes, and 8% believed they had headaches at a normal rate. After the biogas system none of them had bad headaches, and 91% believed they had a normal rate of headaches, and 8% had headaches sometimes. 16 percent of the respondents claimed they were visiting the doctor at an increasing rate, as opposed to a 100 % of the respondents said there visits to the doctor was not as frequent. These figures indicate a positive influence on human health.

The animal health is also improved. Table X shows the average number of livestock between biogas users and non biogas users in the SNV report.

Livestock	Biogas user	Non-biogas user
Buffaloes (head/household)	0.51	0.32
Pig (head/household)	26.65	18.12
Poultry (head/household)	71.40	21.62

Source: SNV User Survey.

Table 11: Livestock Populations Between biogas Users and Non Biogas Users

For biogas users every 2 households had an average of one buffalo; whereas about every three non biogas users had one buffalo. The pig and poultry populations are more straightforward. Biogas users had an average of 26 pigs and 71 poultry. Non biogas users had an average of 18 pigs and 21 poultry.

The reduction of firewood used saves a lot of time. Most households would buy and collect firewood, normally the females of the household search for the fuel wood. Since the biogas is used for cooking it eliminates the need of searching for wood. According to some of my respondents this has saved them a lot of time.

The project also offers training to participants. Most participants attended the training. The training contributes to the improvement of the human being and can also increase awareness in livestock and environmental issues. One of the areas that needs extensive training is the application of biogas. The proper utilization has environmental and economic benefits. Overall, training offers a formal technique to acquire knowledge which would be beneficial to one's everyday life.

5.5.1 Social Indicators

The SNV user report does not consider human health, only livestock health. They should include certain indicators to measure the impact of human health. Since biogas is growing and not every household has a digester installed a comparison on human health affects can be compared. Just like the way they measured the livestock health. Besides this I think they are covered on social indicators. The Vietnamese government has been going through reforms in the last 20 years and they have many social indicators that can be used to assess the impact of the biogas digester.

5.6 Constraints

The SNV biogas project is present throughout the country. This enables the project to reach as much people as possible. There has been a biogas presence in Vietnam before the SNV undertook their project. The Vietnamese government has been experimenting with biogas since the 60's and by the 90's biogas digesters were being installed in various rural areas. The SNV project started in 2003 and has been aiding the government in spreading biogas technology to rural areas. Realizing the potential benefits to the environment and the overall economy the Vietnamese government drafted a biogas strategy in 2009. The main objective is: *"Ensuring the sustainable development in animal husbandry in order to meet the needs of socio-economic development, at the same time achieve the objective on environmental protection, contribute for the sustainable development of the country, and improve the living standards of people."*(ISPONRE, 2009)

The SNV project has complemented the Vietnamese government's effort to spread biogas technology in rural areas. The project gained a lot of support from the government since it was aiding a current practice. From the objective of the Vietnamese government's biogas strategy it is evident that they believe the use of biogas technology can contribute to GHG abatement and sustainable development.

The fact that biogas technology was being dispersed in Vietnam before the SNV may conflict with the additonality requirement. The CDM project did not offer any new technology, and if the SNV was not active the households would eventually installed a biogas digester since the Vietnamese government already have a biogas program. In fact, this project was not initially designed to be a CDM project. The SNV had prior experience with biogas in Southeast Asia. In Nepal the SNV had a very successful biogas project and they extended the project to include Vietnam. CDM status was not an original objective of the SNV in Vietnam. With the emergence of Kyoto protocol's mechanisms they were able to apply for CDM status.

Regardless of getting CDM approval, this project will continue. Based on this, it seems that it shouldn't be categorized as a CDM project. The whole point of the CDM is to help Annex 1 countries reduce GHG emissions. In this case no reduction is really happening.

Another problem is the monitoring problem. Some of the households I visited did not utilize the gas at all. They would release the methane in the atmosphere. This was only small portion and the SNV user report also acknowledges a small portion of their sample released the methane directly. This 7.5 million tCO_2eq reduction is merely an estimate and there is a possibility that the actual reduction is that much, especially if the households start releasing methane directly into the atmosphere. This is why I believe that every biogas digester should have a record of how much gas is produced. This will give a better idea on how much each digester contributes to the overall GHG reduction.

Conclusion

The CDM is a popular mechanism. The table below summarizes the results from 8 economic models on the market share of the different Kyoto mechanisms

	Emission Trading and Joint Implementation			Clean Development Mechanism		
Model/Author	Traded Quantities (million tons CO_2	Market Volume (million 2000 USD)	Market Share (%)	Traded Quantities (million tons CO_2)	Market Volume (million 2000 USD)	Market Share (%)
ECN	880	3250	42	1239	4956	58
EPPA	774	6189	23	2651	21208	77
G-CUBED	1503	10523	45	1815	12705	55
GREEN	972	6802	40	1456	10190	60
HAITES	1192	11917	36	2108	21083	64
Poles	986	5918	32	1606	12848	68
SGM	1309	10472	44	1665	13317	56
ZHANG	576	1727	35	1071	3212	65

Source: Springer, 2003

Table 12: Market Share of Kyoto Mechanism

All eight models conclude that the CDM would have the highest market share. It ranges from 50-77 percent. This is not really surprising; the CDM deals with cheaper abatement options and annex 1 countries would prefer to meet their requirements through the CDM rather than expensive local mitigations options.

One of the problems is registering the project with the CDM executive board. Donor countries have pledged grants to fund the human resources and administrative tasks of the board in order to speed up the process. I feel the main problem is that it is highly centralized. All CDM projects around the world have to go through the same process. If they can break up the CDM executive board to regional executive boards, it would make it more efficient and the regional executive board could have more of a presence in the CDM project

The various CDM models indicate there are various institutional approaches that can be undertaken. None of the models are specified as the default approach, and I think this is a positive step. Each country and region has unique conditions and the various models can be adapted to those conditions. An open architecture approach is the most ideal because of its flexible nature. With regards to choosing a model, I think the most important factor that should be taken into consideration is the transactions costs.

The CDM's twin objectives do not necessarily complement each other. This complicates the nature of CDM. I think one objective would be better; having a mechanism trying to fulfill two objectives may overlook one of them. There are many mitigation options which do not necessarily promote sustainable development, and these could be overlooked because of the twin objectives. At the same time there options that support both of the objectives; the SNV project is a perfect example of the twin objectives being fulfilled.

I think they should standardize sustainable development criteria, relying on the host country's standard may not be adequate. This will also support the twin objectives. With no standardized sustainable development criteria much is left to interpretation. Vietnam has a set of vague principles which do not necessarily translate to simple measurable indicators. There is still no agreement for the post Kyoto era, but CDM has been popular and a similar mechanism will probably be included in any future treaties. If they intend to continue the twin objectives, standardized sustainable development criteria will be necessary in the long run, to help ensure none of the objectives are disregarded

I think the additionality requirement needs to be revised. It is important to have a sort of measure to ensure that the claimed GHG abated are actually abated in reality. Proving additionaltiy is tricky and costly. In this case the SNV are participating in a project that the government has been working on prior to the commencement of the project. However they are still investing money and spreading clean technology to provinces that did not have access to it. Additionality needs to be clarified because it remains ambiguous, which is evident from the SNV project.

Evaluating sustainable development is essential for realizing the complete impact of CDM projects. The SNV perform an annual survey where various factors are considered. They need to concentrate on individual digesters more. The input output of the biogas of each digester and air pollution of each area need to be recorded. This requires a lot of manpower and money. A portion of the CER revenue should contribute to this. This project has the potential to generate more than 50 million Euros from the CERs. This is a substantial figure and I think the majority of it should be used to contribute to the nation's sustainable development fund.

Does this project achieve sustainable development? The Brundtland Commission defines sustainable development as *"meeting the needs of present without compromising the ability of future generations to meet their needs."* The Biogas Program for the Animal Husbandry in Vietnam satisfies this definition. The livestock waste is treated adequately and reduces GHG emissions. The biogas is mainly used for cooking. The conventional sources of cooking that were used before the biogas are being saved. The proper waste disposal improves the overall hygiene of the area which reduces health problems for humans and animals. There is still room for improvements and the project will last till 2016, so the complete impact on sustainable development will not be known until the closing stages of the project.

References

ADB, 2009. The Economics of Climate Change in Southeast Asia: A Regional Review. Philippines, Asian Development Bank.

Alcott, B., 2005. Jevons' Paradox. Ecological Economics, 54 p. 9-21

Akita, J. (2003). A simple model of CDM low-hanging fruit. In: Sawa, T. (editor). International frameworks and technological strategies to prevent climate change. Tokyo: Springer, 66-96

Baumert, K., Kete, N., & Figures, C., 2000. Designing the Clean Development Mechanism to Meet the Needs of a Broad Range of Interests. Washington DC, World Resource Institute.

Bell, W., & Drexhage, J., 2005. Climate Change and the International Carbon Market. Winnipeg. International Institute for Sustainable Development

Betz, R., 2006. What is Driving Price Volatility in the EU ETS. Australia, University of NSW

Blasing, J., 2010. Recent Greenhouse Gas Concentrations. Washington, Carbon Dioxide Information Analysis Center.

Burian, M., 2006. The Clean Development Mechanism, Sustainable Development and its Assessment. Germany, Hamburg Institute of International Economics

Crabbe, P., 1983. The Contribution of L.C Gray to the Economic Theory of Exhaustible Natural Resources and Its Roots in the History of Economic Thought, Journal of Environmental Economics and Management, 10, p 195-220

Chadwick, B., 2006. Transaction Costs and the CDM. Natural Resources Forum, 30 p. 256-271

Chauhan, C., & Gupta, A., 2009. India, China's CDM success becomes the world's envy. [online] available at: http://www.emergent-ventures.com/DesktopModules/WhatsNew/Download/633977077262211250-HindustanTimes-Print.pdf [accessed at July 14, 2010]

Daly, H., 1973. Toward a Steady State Economy, San Francisco: Freeman.

Daly, H., & Goodland, R., 1996. Environmental Sustainability: Universal and Non-Negotiable. Ecological Applications, 6(4), p 1002-10017

Dasgputa, P., 2007. Measuring Sustainable Development: Theory and Application. Asian Development Review, 24 (1) p 1=10

Dasgputa, P., & Heal, G., 1973. The Optimal Depletion of Exhaustible Resources. The Review of Economic Studies, 41, 9 3-28

Duc Minh, N., 2005. Clean Development Mechanism in Vietnam. Hanoi, UNDP

Enkvist, P., Naucler, T., & Rosander J. 2005. A Cost Curve for Greenhouse Gas Reduction. London, McKinsey

Germian, M., Magnus, A., van Steenberghe V., 2007. How to Design and use the Clean Development Mechanism Under the Kyoto Protocol. Environ Resource Econ, 38 p 13-30

Giddings B., Hopwood B., O'Brien G., 2002. Environment, economy and society: fitting them together into sustainable development. Sustainable Development, 10, p 187–196

Goossens, Y., Makipaa, A., Schepelmann, P., 2010. Towards Sustainable Development: Alternatives to GDP for Measuring Progress. Belgium, Wuppertal Institute.

Goodland, R., 1995. The Concept of Environmental Sustainability. Annual Review of Ecology and Systematics, 26, p 1-24

Harris, P., 2008. Biogas Notes. Australia, The University of Adelaide.

Japan Carbon Investors Forum, 2005. CDM Implementation In Vietnam and Opportunity for Investment. [online] available at: http://www.meti.go.jp/english/information/downloadfiles/JCIF/vietnam.pdf [accessed August 16, 2010]

JP Morgan, 2009. Understanding CER Price Volatility. [online] available at: http://www.latincarbon.com/2009/docs/presentations/UnderstandingCERpriceVolatility_Steinacker.pdf [accessed August 18, 2010]

Kumura, C., Srinivasan, A., & Iyadomi, K., 2006. Clean Development Mechanism. In Srinviasan, ed. Asian Aspirations for Climate Regime Beyond 2012. Japan, Institute for Global Environmental Strategies

Langdon, C., 2008. Energy Profile of Vietnam. [online] available at http://www.eoearth.org/article/Energy_profile_of_Vietnam [accessed June 15, 2010]

Levett, R., 1998. Sustainability Indicators – Integrating Quality of Live and Environmental Protection. The Royal Statistical Society, 161(3). P 291-302

Levhari, D., & Liviatan, N., 1977. Notes on Hotelling's Economics of Exhaustible Resources. The Canadian Journal of Economics, 10(2), p 177-192

Magalhaes, A., 1994. Sustainable Development Planning and Semi-Arid Regions. Global Environmental Change, 4, p 275-279

Manh Hoa, H., 2005. Potential CDM Projects in Vietnam. [online] available at: http://www.iges.or.jp/en/cdm/pdf/activity02/1_2_4.pdf [accessed June 5, 2010]

Michaelowa, A., 2005. CDM: current status and possibilities for reform. Germany, Hamburg Institute of International Economics.

Ministry of Natural Resources and Environment of Vietnam, MONRE, 2005. Technical report on the identification and assessment of technology needs for GHG emission reduction and climate change adaptation in Hanoi, Vietnam

Ministry of Planning and Investment of Vietnam, MPI, 2008. Report on Sustainable Development Implementation in Vietnam. Hanoi, Vietnam

Munasinghe, M., 2007. Sustainable Development Triangle., [online] available at: http://www.eoearth.org/article/sustainable_development_triangle [accessed June 25, 2010]

Narain, U., & van't Veld, K., 2008. The Clean Development Mechanism's Low Hanging Fruit Problem: When Might It Arise, and How Might It Be Solved. Environmental and Resource Economics, 40(3) p 445-465

Neumayer, E., 1998. The ISEW – not an Index of Sustainable Economic Welfare. Social Indicators Research, 48, p 77-101

Pareja, P., 2009. The CDM, the Low Hanging Fruit Issue and post-2012 Climate Policy. Switzerland, University of Bern.

Pearson, B., 2006. Market Failure: why the Clean Development Mechanism won't Promote Clean Development. Journal of Cleaner Production, 4, p 35-39

Panayotou, T., (1993 Empirical tests and policy analysis of environmental degradation at different stages of economic development, World Employment Program Research Working Paper WEP2-22/WP 238

Parreno, J. & Sutter, C., 2007. Does the current CDM deliver its sustainable development claim? An analysis of officially registered CDM projects. Climatic Change, 84 p 75-90

Pezzy, J., & Toman, M., 2002. The Economics of Sustainability A Review of Journal Articles. Washington, Resources for the Future.

Petith, H., 199. Georgescu-Roegen versus Solow/Stiglitz and the Convergence to the Cobb-Douglas. Barcelona, Edifici B, Universitat.

Politylo, J., & Veeman, T., 2002. The Role of Institutions and Policy In Enhancing Sustainable Development and Conserving Natural Capital. Alberta, University of Alberta

Quoc Chinh, N., 2005. Dairy Cattle Development: Environmental Consequences and Pollution Control Options in Hanoi Province, North Vietnam. [online] available at: http://www.idrc.ca/uploads/user-S/11502734231ChinhRR6.pdf [accessed April 20, 2010]

Schmitt, S., 2009. CDM Market Brief. Germany, DEG KFW Kankengruppe

Sinclair, G., 2006. Price of Kyoto Complaint Emission Units. New Zealand, New Zealand Treasury

SNV., 2009. Final Report on Biogas User Survey 2009. Hanoi, SNV

Springer, U., 2003. The Market for Tradable GHG Permits Under the Kyoto Protocol: a Survey of Model Studies. Energy Economics, 25, p 527-551

Solow, R., 2001. Sustainability: An economist's perspective. The Eighteenth J. Seward Johnson Lecture to the Marine Policy Center,. Economics of the Environment: Selected Readings. New York: Norton. 179-187

Solow, R., 1974. Intergenerational Equity and Exhaustible Resources. The Review of Economic Studies, 41, p 29-45

Spangenberg, J., 2005. Economic Sustainability of the Economy: Concepts and Indicators. Int. J. Sustainable Development, 8(1/2), p. 47-64

Stiglitz, J., 1974. Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths. The Review of Economic Studies, 41, p 123-137

Sutter, C., 2003. Sustainability Assessment of Energy Related Projects Under The Clean Development Mechanism of the Kyoto Protocol. PhD Swiss Federal Institute of Technology Zurich

UNDP, 2003. CDM User Guide. [online] available at: http://www.undp.org/energy/climate.htm [accessed May 25, 2010]

Wu, J., & Wu. T., 2010. Green GDP. Berkshire Encyclopedia of Sustainability, [Online] available at: http://leml.asu.edu/jingle/Web_Pages/Wu_Pubs/PDF_Files/Wu+Wu-2010-GreenGDP.pdf [accessed August 22, 2010]