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Estimating the Costs of Atmospheric Carbon Reductions in Mexico

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Abstract

Trading in carbon emissions is a means of ensuring that supplies with the lowest marginal costs of emissions reduction are commissioned first. To analyse the potential for Mexican suppliers to participate in an emissions trading market, the relative cost-effectiveness of a carbon sequestration project and carbon abatement project is assessed. The marginal costs of emission reductions for each project are estimated and compared using standardised data. The results show that the carbon sequestration project has lower marginal costs for carbon emissions reductions than the technology-based abatement. Factors such as timescale, discounting implementation costs, transaction costs, and technical assumptions are considered in this comparison. The high transaction costs to set up carbon sequestration projects and weak institutional capacity to monitor and enforce agreements are relevant factors. Even though the carbon sequestration project is more cost-effective than the renewable energy power plant, both projects may allow Mexican suppliers to enter a potential international carbon emissions trading market depending on demand and supply conditions and the rules of the market.

Key words: Carbon, Abatement, Sequestration, Marginal costs, Trading

1. Introduction

> 'Measured atmospheric levels of certain greenhouse gases (GHG), carbon dioxide (CO_2) chlorofluorocarbons (CFCs), methane (CH_4) and nitrous oxide (N_2O), have risen substantially in recent decades and are projected to enhance the earth's natural GHG effect, a phenomenon that could lead to global warming' (Intergovernmental Panel on Climate Change 1995:5).

Miller (2000:501) argues that CO_2 may be responsible for 50 to 60 per cent of the global warming from GHG produced by human activities since pre-industrial times. This makes it the most important GHG produced by human activities. The main sources of CO_2 are fossil fuel burning (70 to 75 per cent) and land clearing and burning (20 to 25 per cent). CO_2 remains in the atmosphere for between 50 to 200 years.

According to Miller (2000: 501), developed countries account for about 60 per cent of current CO_2 emissions. The United States alone accounts for approximately 25 per cent of global CO_2 emissions from human activities, followed by China (14 per cent), Russia (7 per cent), and Japan (5 per cent). However, emissions of CO_2 are increasing rapidly in developing countries that are industrialising rapidly, such as India (4 per cent) and Latin America (5 per cent). Mexico is the largest emitter within the Latin America region, producing 1.43 per cent of global GHG emissions.

According to the National Energy Balance (Mexico, Secretaría de Energía 1996:55), Mexico relies on fossil fuels for 84 per cent of its final use energy and 62 per cent of its electricity. One of the reasons for this reliance on fossil fuels is the low domestic energy price compared to international prices. Lower prices encourage higher fossil fuel use and thus higher levels of emissions. In Mexico, the prices of fossil fuels do not cover all the costs and benefits incurred by society in their production and consumption for two reasons: government subsidies, and negative externalities, such as those caused by CO_2 emissions, that are not reflected in final prices. One way to internalise the negative externalities is through an emissions trading (ET) system.

'ET is an environmental and cost-effective instrument to reduce CO_2 emissions' (Organisation for Economic Cooperation and Development 1998:19). The philosophy behind ET is that GHG can be reduced at minimum cost. This is because it is cheaper for some firms to reduce their GHG emissions than for others. It is therefore more cost-effective to allow the market to decide where emission reductions will be made rather than for governments to require uniform reductions across an economy.

In order to analyse the potential for Mexican suppliers to participate in an international ET market, it is important to evaluate whether Mexico has a comparative advantage in supplying carbon emission reductions (CERs). One way to do this is by estimating the marginal costs of Mexican alternatives for supplying CERs and comparing those costs with competing suppliers. The research reported in this paper assesses the relative cost-effectiveness of a carbon sequestration at Scolel Té and a carbon abatement project involving a hybrid power plant using renewable energy[1].

There is a broad existing literature on the effectiveness of reducing GHG emissions through carbon sequestration (for example, De Jong, Soto, Montoya, Nelson, Taylor and Tipper 1997; DTZ Pieda Consulting 2000; Lecocq and Chomitz 2001; Richards, Moulton and Birdsey 1993) and technology-based abatement in Mexico (Davison and Freund 2002; Mathai 1999). However, there is little research on each alternative's cost-effectiveness. The reason may be that there are only a few projects in Mexico, and information on some of them is just becoming available. Conversely, there are many GHG reduction projects around the world, especially through the Activities Implemented Jointly (AIJ) process established under the United Nations Framework Convention on Climate Change (UNFCCC). Nevertheless, it is difficult to compare project costs because the information available is inconsistent. For instance, many projects report their costs using different time scales, with inconsistencies in measuring costs, different discounting protocols, and the inclusion of transaction costs. For this reason, the research presented here involves the standardisation of data to allow a comparison of the marginal costs of atmospheric carbon reductions.

Exploring the costs of atmospheric carbon reductions provides insights into the most cost-effective abatement option to reduce carbon emissions in Mexico. It also allows a better understanding of the likelihood that Mexico will be sufficiently competitive as a supplier to participate in any future carbon ET market. The research also addresses whether these alternatives are consistent with sustainable development.

In Section 2, the approach taken in this research is detailed. The concept of comparative advantage gives a context for the research. Sections 3 and 4 provide brief summaries of the two case studies and present the results for each. The discussion of which alternative is more cost-effective is developed in Section 5, which also considers Mexico's place in the international context. Section 6 provides some policy recommendations as well as suggestions of areas for further research. Finally the major findings of the research are highlighted in Section 7 and some conclusions are made.

2. The Approach

There are two basic policy mechanisms that can be used to internalise social environmental costs such as those caused by GHG: Market-based Instruments (MBIs) and Command and Control (CAC). They imply government intervention in the market via prices (taxes and subsidies) or through quantities (CAC—includes standards, licencing and tradable permits) (Aslam, Cozijnsen, Morozova and Stuart 2001:120).

Increasingly, individual governments and international groupings of governments are opting for the use of MBI because of their cost effectiveness (Perman, Ma, McGilvray and Common 1999:142; Tietenberg 1998:7). The Kyoto Protocol for GHG reductions has specially identified an ET market as a suitable vehicle for implementing the agreed GHG reduction targets (Rosenzweig, Varilek and Birdsey 2002:5). For Mexican suppliers to participate in a carbon ET market, they will first need to assess whether they have a comparative advantage in providing

[1] Arizona Public Service Company (APS) in conjunction with Mexico's national electric utility Comisión Federal de Electricidad (CFE) agreed on a project to enhance the performance of an existing diesel generator-based mini-grid system in a remote village.

CERs. A firm has a comparative advantage in the production of a good if it can produce that good at a lower marginal opportunity cost relative to another firm (Suranovic 1999: 3).

The learning experience generated from several current pilot projects provides information on the marginal opportunity costs of alternative CER projects. This information may prove useful in the assessment of Mexico's comparative advantage in CER supply.

Besides the reduction of tonnes of carbon *per se*, the projects may also trigger sustainable development in the communities where they are taking place. There may be economic, social and ecological benefit spillovers to the local communities. Thus, as the projects are being undertaken, the capacity of communities to develop in a sustainable way may be enlarged. For example, local communities developing agroforestry and conservation practices for carbon sequestration may have an improved human resource capacity to implement, assess and monitor projects and raise environmental awareness within local communities. This could eventually lead to the further development of comparative advantage for Mexican suppliers of CERs. In the following two sections, the two case studies of Mexican projects designed to supply CERs are detailed.

3. APS/CFE Hybrid Power Plant

3.1 Project Background [2]

This renewable energy minigrid project involves the development of a hybrid power supply system. It will develop solar (17kW), wind (100 kW), and diesel (72 kW) capacity to displace a 205kW diesel generator. San Juanico, the project site in South Baja California, Mexico, is a fishing village of 400 people that is not connected to the electric supply grid nor expected to be connected in the foreseeable future. The diesel component of the hybrid system will operate for four hours each day, consuming about 90 litres of diesel per day.

A major feature of the project design is to minimise system load by using energy efficient appliances and by establishing a tariff structure that will allow participants at all levels of family income to conserve energy. This hybrid plant is the largest of its kind on the American continent. It is estimated that the project will reduce CO_2 emissions by 80 per cent, compared to the emissions from the existing diesel generator providing the same level of service. The project is a potential model for similar projects in other rural communities of Mexico and around the world.

3.2 Cost Calculations

The total costs of the project have been estimated in present value terms to total US$923,289 (Table 1). Project development costs incurred before 1997 and project implementation costs incurred after 1997 were all discounted (capitalised) to the baseline year of 1997. The discount rate used was varied between 5 and 10 per cent to determine the sensitivity of the cost calculations to variations in the cost of capital and the level of uncertainty integral to the climate change issue.

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[2] Information on the APS/CFE renewable energy minigrid project case study is mostly taken from the Activities Implemented Jointly Report of the UNFCCC (2000) and personal communication on 19th April 2002 with one of the supervisors of the project Mr. C.V. Mathai. For basic information regarding the project refer to the Appendix.

Table 1. Total costs of APS/CFE power generator (US$, 1997)

Year	Type of Cost Incurred	Amount	Discounted value at 5%	Discounted value at 10%
1995	Meetings with partners	25,000	28,940	33,275
1996	Resource monitoring, meetings	50,000	55,125	60,500
1997	Project feasibility study, coordination	60,000	60,000	60,000
1998	"In kind" services (engineering, construction support)	50,000	45,351	41,322
1999	Plant construction/ support	45,000	38,873	33,809
	Subtotal of project costs (wind and solar energy equipment, wiring materials, shipping & delivery, etc)	695,000	695,000	695,000
1997	Total		923,289	923,906

Total costs were calculated first by estimating the costs of generating electricity with the old diesel generator. Its infrastructure is quite simple, comprising a small roof (3.05 m by 4.57 m) with open sides. The old diesel generator had a capacity of 205 kW and operated only for four hours per day. In contrast, APS/CFE has a capacity of 549 kW, and operates 24 hours. APS/CFE requires more complex infrastructure and so has higher fixed costs, but provides 2/3 of its electricity from renewable energy and the other 1/3 from diesel. Therefore, 1/3 of the variable costs of the old diesel generator were incorporated into the variable costs of the APS/ CFE system. To make the two systems comparable, capacity and operation had to be made equivalent by multiplying the old diesel generator costs by 2.7 (for capacity) and its variable costs by 6 (for 24 hour operation). This put both systems under the same terms and allows the estimation of marginal costs (Table 2).

Table 2. Marginal costs of carbon emission reductions (US$, 1997)

Discount rate	5%	10%
APS/CFE total cost	1,120,043	1,051,444
Old Diesel total cost	630,249	469,340
Total Cost Difference	489,794	582,103.95
Carbon emission reductions (tonnes of C)	9149	9149
Marginal Cost (US$ / tonne of C)	53.54	63.62

The difference in the total costs of the APS/ CFE system reported in Tables 1 and 2 is due to the incorporation of diesel fuel costs. The 'Total Cost Difference' (Table 2) is the result of subtracting total costs of producing electricity with the old diesel generator from total costs of producing electricity with the APS/CFE system. By dividing this by the amount of additional carbon emission reduction achieved by the change, the marginal cost per tonne of Carbon sequestered equivalent (tC) is obtained. At a 5 per cent discount rate this cost is $53.54/tC while at a 10 per cent rate, the cost is $63.62/tC. In other words, it would cost around $50 to reduce carbon emissions by one tonne by implementing the APS/CFE abatement project

Note that this is an estimate of marginal cost and not average cost. Average total cost equals the total cost of the project divided by the number of tonnes of carbon sequestered. Marginal costs, in contrast, are the amount by which total costs are increased when carbon emissions are reduced by one unit. Whilst at a five per cent discount rate the marginal cost per tonne of carbon is US$53.54, the average cost of achieving emission reductions is US$122.42. It is important to emphasise the difference between average and marginal costs because considering average costs can lead to an overestimation of the costs of achieving CERs.

4. SCOLEL TÉ

4.1 Project Background[3]

Scolel Té (which means 'growing trees' in Tzeltal and Tojolobal) is a forestry and land-use project located in northeast Chiapas, Mexico. This project will assist farmers, primarily in nine Mayan indigenous communities located in highland and lowland ecoregions, to develop small agroforestry and forestry enterprises. Farmers will initially participate on an individual basis by establishing trees on existing pasture, fallow land, maize or coffee plantations.

The objective of the project is to promote carbon sequestration and sustainable farming practices by providing local farmers with technical assistance and financial incentives to shift from agriculture to agroforestry, to convert pastures to plantations, to restore degraded forest, and to manage natural forest more effectively. The GHG reductions from the project accrue from forest growth that would not have occurred in the absence of project activities. The carbon sequestered by these enterprises is expected to range from 16,500 tonnes per year to 1.21 million tonnes during the 30 year lifetime of the project. In addition, the project is expected to contribute to the social and economic welfare of the communities involved as well as aiding with the preservation of the region's rich biodiversity.

4.2 Cost Calculations

Total costs were estimated by summing both the costs of establishing and maintaining the tree component of the project and the opportunity costs of the foregone benefits from the 'business as usual' system of the regions of Tzeltal and Tojolobal. The cost elements include labour, equipment, site preparation, site protection and planting stock for the first rotation of the trees. Costs for additional rotations are expected to be covered from the sale of the tree products of the first rotation. Labour costs are based on local minimum wages.

Table 3 shows these costs separated by region and by forestry system, discounted to 1997 using 5 and 10 per cent rates.

[3] The information reported in this section is mostly taken from De Jong, Tipper and Montoya-Gomez (2000) and personal communication with B. De Jong and R. Tipper (15/3/02). For basic information regarding the project refer to the Appendix.

Table 3. Present value of marginal costs for carbon sequestration (US$, 1997)

Region Agroforestry system	Net carbon accumulation (tonnes of C)	Total costs 5% discount rate	Marginal Cost US$/tC 5% discount rate	Total costs 10% discount rate	Marginal Cost US$/tC 10% discount rate
Tzeltal					
Live Fence	92.30	$279	$3.02	$284	$3.07
Coffee with shade trees	115.90	$812	$7.00	$818	$7.06
Taungya	276.80	$1142	$4.12	$1147	$4.14
Enriched Fallow	276.80	$1998	$7.22	$2116	$7.65
Tojolabal					
Live Fence	39.10	$270.6	$6.92	$257	$6.58
Plantation	121.40	$2616.5	$21.55	$2489	$20.51
Taungya	123.90	$1353	$10.92	$1287	$10.39
Enriched Fallow	$123.90	$1562	$12.61	$1391	$11.23

The estimated costs of carbon sequestration for each system (Table 3), were based on the discounted direct costs of improving the current systems or establishing the new systems (live fence, coffee, taungya, enriched fallow) and the discounted opportunity costs during the first rotation for those systems where land-use is diverted from agriculture. These cost estimates are based upon an intermediate level of production intensity. The differences in costs within the same region are due to differences in costs of establishment and opportunity costs. The marginal cost by region was estimated by dividing the difference between total costs for each system and the original system by the total amount of carbon sequestered. Monitoring and administration costs were not estimated in detail in the Chiapas study but are expected to add about $2-6/ tC (Davidson and Freund 2000).

Several inconsistencies in the published studies were found when estimating marginal costs. Different data were presented by authors discussing the Scolel Té study (Davison *et al.* 2002; De Jong *et al.* 1997; DTZ Pieda Consulting 2000) (see Appendix). To ensure comparability, implementation costs were not considered in the estimation of the marginal costs. This is justified because implementation costs are large, fixed costs usually borne when a project is initiated. Therefore, after implementation, following projects will not have to incur such costs, which can therefore be omitted for the marginal costs calculations since they constitute fixed costs of the initial project. Marginal costs range from US$3.02 to US$21.55 at the 5 per cent discount rate and from US$3.07 to US$20.51 at the 10 per cent discount rate (Table 3). Even though this is a broad range, it allows the comparison that is the aim of this research.

5. Comparisons and Caveats

5.1 Scolel Té and APS/CFE

The marginal costs from both case studies are presented in Table 4.

Table 4. Marginal costs per tonne of Carbon for each case study (US$)

Project	Source	5%	10%
APS/CFE	Renewable energy generator	53.54	63.62
Scolel Té	Agroforestry	3.02- 21.55	3.00-20.50

Even though Scolel Té's marginal cost/tC covers a wide range between US$3.02 and $21.55 at a five per cent discount rate, it is still cheaper than APS/CFE, with a marginal cost of US$53.54. The comparison is similar for a 10 per cent discount rate. However, if the upper limit of the Scolel Té marginal cost range is considered (US$21), the difference between both marginal costs is US$32 per tC for the five per cent discount rate. If additional factors like implementation and transaction costs are taken into account, the difference may be smaller. Even though Scolel Té appears to be more cost-effective for generating CERs than the APS/CFE project, several issues should be considered before drawing any conclusions.

5.2 Some Caveats

If implementation costs and transaction costs are taken into account for the Scolel Té case study, the marginal costs may be comparable with the APS/CFE costs. According to Tipper (pers.comm., 15/4/2002) the Scolel Té project implementation costs are approximately US$12 to US$14 per tC, although it is expected that these costs will fall to US$11 per tC in following years. Davison and Freund (2000:3) state that while monitoring and administration costs were not estimated in detail for Scolel Té, they are expected to add up to about $2-6/ tC. These transaction costs sum to US$18 per tC, and if they are subtracted from the difference between marginal costs (US$32 per tC), the cost difference is then reduced to US$14 per tC.

It is also important to consider the high transaction costs to set up carbon sequestration projects. It is difficult to estimate these transaction costs. However, if they were taken into account, the marginal costs difference between projects may be minimal.

Another consideration is the different institutional capacities required for the two types of projects. Both projects require efficient monitoring to account for CERs and strict enforcement by the authorities. Although changing or improving institutions is costly, if the basic policies and institutions are not in place the feasibility and success of the projects will be jeopardised. The development of institutional capacity is therefore essential for the success of the projects. This will allow the provision of possible solutions for monitoring, auditing and certification, as well as creating certainty and clear rules, thus minimising transaction costs.

Location is important for the development of these projects. In the case of APS/CFE, the northwestern Mexican State of Baja California Sur was chosen because of its abundance in solar and wind energy resources. The Scolel Té project is located in Chiapas, Southern Mexico. This area was chosen because it covers two distinct bio-climatic and cultural regions: highland Mayan Tojolobal communities and lowland Mayan Tzeltal communities and because of its favourable conditions for the rate of growth of trees and thus carbon sequestration. For the projects to be successful, the location must be suitable.

5.3 Carbon Permanence

The issue of permanence in comparing carbon sources such as APS/CFE and carbon sinks such as Scolel Té is also relevant to the comparison. The avoided emissions of CO_2 in the case of the renewable energy power plant are permanent, that is, once they are avoided they will not come back. However, in the case of carbon sequestration they are temporary: when the trees are harvested CO_2 may be released back to the atmosphere. Smith *et al.* (2000:15) point out that 'non-permanent forestry projects slow down the build up of atmospheric concentrations, unlike energy projects, which actually reduce emissions. Non-permanent forestry projects should therefore be regarded as an intermediate policy option'.

The optimum time to abate CO_2 emissions is unclear. Because of the many uncertainties, it has often been assumed that the benefits of CO_2 abatement are the same in all time periods. As a consequence, schemes that provide abatement slowly over many years may be as beneficial as schemes that provide rapid abatement. However, it is generally accepted that economic resources in future are worth less to society than the same economic resources at the present time. If the optimum time to abate CO_2 is at some time in the future, it may be better to wait to undertake a project that achieves rapid abatement rather than undertake a project now that does not achieve abatement until a long time into the future (Davison and Freund 2000:5). Thus, time of abatement is also important to determine which alternative is a more cost-effective supplier of CERs.

According to Davison and Freund (2000:6), the levelised cost—that is, the cost discounted throughout the lifetime of the project according to when the CO_2 is sequestered—are US$67 per tC, using a five per cent discount rate for Scolel Té. The levelising process effectively trebles the marginal cost. There are no data relating to the levelised cost of the APS/CFE project. However, Davison and Freund (2000:6) suggest that it would be expected to double. Hence, overall marginal costs would be higher for both cases if marginal costs were levelised. This could have important CER trade implications since at such relatively high marginal costs, the two cases detailed in this paper may not be attractive suppliers of CERs. However, this also depends on the aggregate demand for CERs and the marginal costs of competing suppliers.

5.4 International Comparisons

To assess if Scolel Te and APS/CFE would be placed competitively among worldwide CER suppliers, it is useful to analyse different case studies throughout the world to compare their marginal costs/tC. There is a substantial literature (Prabhu 2000; UNFCCC AIJ 2000; World Resources Institute 2002) on the costs of alternatives for CERs. However, one of the limitations in comparing case studies across countries is that information and results are presented in many different ways. Some cases present undiscounted costs, some levelised costs and some discounted costs but do not provide their sources because of commercial confidentiality. Table 5 provides a summary of marginal costs/tC for a selection of different projects around the world.

Table 5. International case studies and associated costs (US$)

Country (Parties involved)	Name of Project	Type of Abatement	Carbon Sequestered (tonnes of Carbon)	Lifetime (years)	Total Cost (US$)	Average Cost* US$	Marginal Cost** US$
Vietnam	Genetically improved carbon stock	Afforestation	646,590	30	241,955	0.4	0.2
Belize	Rio Bravo	Sustainable Forestry	2,400,000	40	5,600,000	0.6	0.3
Bolivia	Noel Kempff	Sustainable Forestry	11, 786, 005	30	15,000,000	1.3	.65
Mexico	Sierra Gorda de Queretaro	Afforestation	170,279	5	504,000	3.0	1.5
Costa Rica	Biodiversifix	Land-use change & forestry	18,480,000	51	57,773,795	3.1	1.6
Indonesia	Carbon Sequestration in East Kalimantan	Reduced Impact logging techniques	66,000	40	330,000	5.0	2.5
Argentina	Rio Bermejo	Carbon Sequestration	4,345,500	30	6,926,000	1.6	0.8
Paraguay	Paraguay Forest Protection	Carbon Sequestration	14,600,000	30	4,000,000	0.3	0.2
Mexico	Sierra Norte de Oaxaca	Sustainable Agriculture	836,000	30	4,957,480	5.9	2.9
Chile	SIF	Afforestation	1,413,977	26	21,000,000	14.8	7.4
Costa Rica	Eco land	Forest Conservation	23,363	16	1,100,000	47.0	23.5
Burkina Faso	BF Sustainable Energy Management	Energy Efficiency	25,164,000	30	2,400,000	0.1	0.1
China Norway	CFBC & CHP Project in Shangqui Thermal Power Plant in Henan	Energy Efficiency	1,750,000	20	26,980,000	15.4	12.3
Fiji	Air Conditioner	Energy Conservation	13,850	10	73,500	5.3	4.2
Mexico	ILUMEX	Energy Efficiency	186,276	13	23,000,000	9.5	7.6
Australia	Solar Hot Water	Energy Efficiency	90	20	2643	29.0	23.2
Canada	Power Plant	Energy efficiency	2,010	10	1,266,000	1.5	1.2
Indonesia	Eastern Indonesia Hybrid Energy Project	Energy Efficiency	20,900	20	4,200,000	200.0	160.0
Average							**13.9**

Source: Adapted from several sources: C*Trade. Org and UNFCCC Activities Implemented Jointly projects.
* Average Costs are estimated by dividing total cost by carbon sequestered. The numbers are rounded to one decimal point. It is assumed decreasing cost industries, that is that MC<AC
**The marginal costs of CO_2 abatement are estimated by multiplying the average cost by 0.5 when fixed costs represent a large proportion of total costs, otherwise they are multiplied by 0.8. The magnitude of these adjustments have been determined in order to provide indicative results only.

Table 5 shows that many projects have lower marginal costs than the Mexican case studies detailed in this paper. This may be because some opportunity costs were omitted. Furthermore, some cases reviewed presented average costs/tC and not marginal costs/tC. This can lead to an overestimation of the relevant costs of CERs. The broad differences between the methodologies used in the case studies shown in Table 5 makes it difficult to make comparisons.

The two alternatives analysed in this study for Mexico, Scolel Té and APS/CFE, have marginal costs between around US$3 to US$63. Table 5 shows that the average of the marginal costs of the international case studies is in the order of US$14 per tC. This may mean that these Mexican suppliers do not have a comparative advantage in supplying CERs. However, this would depend on the extent of the demand for CERs. If demand is relatively high given limited supply possibilities, then projects with marginal costs greater than average may well be competitive. On the other hand, if demand is weak and there is abundant supply at low cost, then, potentially, only projects with marginal costs lower than US$14 per tC could be competitive.

6. Policy Recommendations

It is important to be aware in the case of carbon sinks that Scolel Te and other sequestration project CER suppliers will be custodians of the stored carbon during and after the lifetime of the project. Thus, the supplier or some alternative 'host' accepts responsibility for the ultimate discharge of the carbon to the atmosphere. This suggests that if both buyer and seller of the CERs were covered by the same system of emission monitoring and stewardship, then transaction costs would be lowered.

There are several risks involved with Scolel Te and other carbon sequestration projects: reversibility, long-term investment, unpredictable weather patterns (fire and floods), leakage and uncertainty, among others. Another concern is that such carbon investments may be foregoing control over a forest resource, which could be better used to provide goods, services and revenue directly to local populations. The renewable energy power plant APS/CFE is considered to be a less risky investment: however, the spillover of benefits to the community may also be less. The risk and spillover dimensions demonstrate the complexity of the tradeoffs involved between alternative CER investment projects. It would be useful to develop a project assessment framework that could allow project comparison not just in economic terms but also in terms of social and ecological benefits and costs.

The development of consistent methods of monitoring, reporting and verifying carbon reductions presents substantial challenges. However, reaching consensus about application will be critical to the success of any possible carbon ET market. Institutions will need to be secure and certain to lower transaction costs. In both cases—Scolel Té and APS/CFE—community participation was an important factor in the development of the project. Another issue is the distribution of benefits; in some cases reviewed, some people in the communities did not receive benefits. Women were sometimes left out. Therefore, a project structure where benefits reach all members of the community would enhance project adoption.

It can be difficult to compare the costs of different CER projects. Issues include differences in financial assumptions and differences in how GHG benefits are counted. However, Trexler and Associates (2002) have developed a model which allow users to standardise (from a private cost perspective) cost accounting approaches for over 100 carbon offset projects and to generate user-specified cost curves. Users are able to create mitigation cost curves specific to geographic region, project type and quality of carbon offsets in order to reach a decision regarding a project investment. These models could be very useful for comparing the different marginal costs between countries. A good exercise and an area for further research would be to standardise the marginal costs of the international case studies (Table 5) using this model.

A certification scheme is required to confirm that CERs are being supplied. However, certification is complex and usually requires detailed data that are not widely available. This has important cost implications for certification because of the need to undertake extensive research. In the case of forestry, standards for sustainable forest management already exist and could easily be expanded to include carbon sequestration. Certifiers may be able to link carbon sequestration with the certification of forest management and thus lower costs. For renewable energy power plants further research is needed in terms of lowering the costs of certification. Another recommendation is to consult the Prototype Carbon Fund (2002) operation handbook, to increase the likelihood that CER will be recognised by the Parties to the UNFCCC.

It is important to identify, characterise and measure barriers that inhibit CER supply, and make CER modelling techniques more consistent, reproducible and accessible. Areas for further research are the construction of a supply curve for CER, modelling technology learning, improving analytical tools for evaluating ancillary benefits, developing decision analytical frameworks for dealing with uncertainty as well as socioeconomic and ecological risk in climate policymaking.

7. Conclusions

The cost-effectiveness of two alternatives for CER has been assessed. The case studies were Scolel Té (a carbon sequestration project) and APS/CFE (a hybrid renewable energy power plant). The planning and implementation of both projects has been stated as a learning experience. They will enable future projects to be developed in a more cost-effective way and in less time because of the gains in technical knowledge. Every project is part of a learning curve that may allow cost reductions, thus providing opportunities for the development of new projects. Both projects contribute to environmental, economic and social development in rural areas. They serve as models for similar projects in Mexico and will aid in the implementation of sustainable development policies.

Ancillary benefits are difficult to measure. For example, CERs may result in a simultaneous reduction in local and regional air pollution. This may have effects on the population’s health. The problem is that these benefits are often tangible but not readily quantifiable due to uncertainties and their non-market character. Because of these limitations, the benefits of some CERs are incompletely characterised and are difficult to compare directly to mitigation costs for the purpose of estimating the net economic effects of mitigation. Since no analysis incorporates all relevant factors affecting mitigation costs, estimated costs may not reflect the true, complete costs of implementing mitigation actions.

Good governance to lower transaction costs is essential for the success of the projects and for the possible participation of Mexican suppliers providing CERs in an ET market. A strong and effective governance structure will provide political and economic stability. Mexico needs to develop institutional capacity in order to facilitate the complex process of approval, verification and monitoring that is required for CER projects. Also the creation of a coordinating body to facilitate investment and information dissemination regarding CER projects is essential in order to address transparency, efficiency, effectiveness and accountability issues.

Public policies aiming for sustainable development should be consistent in the sense that they provide incentives for the different participants to engage in reducing GHG and at the same time abide by the requirements. The development of management skills, training, education and raising environmental awareness among the population are all important factors if Mexican suppliers are to be competitive in a potential ET market.

It is useful to consider the circumstances under which both projects, Scolel Té and APS/CFE were developed, and to consider if total costs would have been different if they had been private-sector initiatives. If the projects had been specifically designed to supply carbon credits, the costs would have been lower, because of incentives to cut costs. Once a market for CER is created, a price for carbon credits will emerge and the question will be whether that price will be high enough to justify investments in CERs.

The start of the Chicago Climate Exchange market has brought forward the idea of a possible ET market across the USA, Canada and Mexico. However, it may be premature for Mexico suppliers to participate in such a market since the rules of the market are not well understood, nor are the pitfalls of the pilot projects fully recognised. In contrast, potential CER suppliers in the United States and Canada have more than 100 case studies on which to draw experience.

The analysis presented in this paper only includes two case studies. Therefore, no generalisations should be made from the findings. However, the specific carbon sequestration option considered has been shown to be more cost- effective than the specific renewable energy alternative for CER supply that was considered. Limitations such as carbon permanence and high transaction costs should be taken into account as well as the measure of ancillary benefits before drawing conclusions from the comparison. Mexican suppliers may be able to provide CERs depending on marginal cost and the conditions of the aggregate demand and supply of CERs. The participation of Mexican suppliers of CER may be a feasible alternative to reduce GHG as well as to promote sustainable development in Mexico. However, the rules of any future the carbon ET market should be clearly defined and well understood before suppliers engage in any trade.

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Appendix

Table A.1 Basic information on projects

	APS/CFE Renewable Energy Mini Grid Project	**Scolel Té**
Partners	Arizona Public Service (APS),Niagara Mohawk Power Corporation (NMPC), Mexico's National Electric Utility Comision Federal de Electricidad (CFE)	Unión de Crédito Pajal, Colegio de la Frontera Sur (ECOSUR), University of Edinburgh's Institute of Ecology and Resource Management (IERM)
Project Sites	San Juanico, Baja California Sur , Mexico	Tzeltal and Tojolobal zone, Chiapas, Mexico
Expected tCO_2 reductions	9149 tCO_2	1,210,000 tCO_2
Lifetime of project	30 years	30 years
Primary Activity	Alternative energy generation (hybrid power system: solar, wind, and diesel)	Sustainable Forestry and carbon sequestration
Sustainable Development benefits	Non GHG *Environmental Impact:* reduced SO2 and particulate emissions resulting from combustion of fossil fuels, minimal clearing of vegetation, increased noise and visual pollution from the wind component of the project, and potential diesel or battery fluid spills. *Sociocultural impacts:* Improved overall living standard in the community, increased available schooling hours and strengthening of local public institutions. *Economic Impacts:* Provide power to industrial or household production operations and promoting development of tourism through creation of a reliable infrastructure, among others.	*Environmental Impact:* preservation of biodiversity, reforestation, reduced soil erosion, improved watershed integrity, provision of sustainable source of timber and fuelwood, purchase of agrochemicals of higher quality and less toxic. *Sociocutural Impact:* improve welfare of women in participating communities and place incentive payments in hands of women where appropriate. *Economic Impacts:* Sale of proto-carbon credits, stimulation of forest-based enterprises; carpentry shops, ecotourism and sale of non-timber products.