Options for Reducing Greenhouse-Gas Emissions in Colombia 1998-2010

Humberto RODRIGUEZ
Fabio GONZALEZ

Colombian Academy of Sciences
Ap. Aereo 44 763
Bogota, Colombia

Phone / Fax (57-1) 268 2846, 244 3186

hrodrig@colciencias.gov.co
fgonzal@ciencias.ciencias.unal.edu.co

Deutsche Gesellschaft für Technische
Zusammenarbeit (GTZ) GmbH

Santafé de Bogotá, January 2000

OPTIONS FOR REDUCING GHG EMISSIONS IN COLOMBIA 1998-2010

Humberto Rodríguez M.[a] and Fabio González B.[b]

Abstract

Taking into account the Greenhouse Gas Emissions for Colombia in year 2010, different options for reduction of GHG emissions were considered. Twenty-four options were evaluated from the economical and technical points of view, with a total reduction potential of 31.7 Mton/year of CO2 equivalent. About 75% of this potential could be developed in the forestry sector and 25% in energy projects. If the proposed measures manage to be implemented, the country's emissions will be 143.5 Mton/year of CO_2 by 2010: this means that Colombia will have lowered its emissions not only to the 1990 level but down to 14% below this level

Key words: Emissions Reduction, Greenhouse Gas Emissions, Colombia, Mitigation Options

INTRODUCTION

The stated objective of the United Nations Framework Convention on Climate Change (the Convention) signed by 155 countries in Rio de Janeiro, Brazil, in 1992 is to bring about "stabilization of greenhouse-gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Article 2). As guiding principles for accomplishing this aim the Convention provides among other things that all Parties "should protect the climatic system for the benefit of present and future generations of humanity on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities," and that they "should take preventive measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects" (Article 3).

The Convention was adopted by Colombia on May 9, 1992 and approved by the Colombian Congress in Law 164 of 1995. The Supreme Court of Justice passed a favorable judgement on the constitutional nature of the Convention, which was

[a] GHG Working Group, Colombian Academy of Sciences and Departamento de Física, Universidad Nacional de Colombia, Santafé de Bogotá, D.C., email: hrodrig@colciencias.gov.co
[b] GHG Working Group, Colombian Academy of Sciences and Departamento de Física, Universidad Nacional de Colombia, Santafé de Bogotá, D.C., email: fgonzal@ciencias.ciencias.unal.edu.co

ratified on March 22, 1995 and came into force for Colombia on June 20, 1995. Colombia, as a Non-Annex 1 country, is bound by the following general commitments laid down for all nations signatories to the Convention:

- To develop, periodically update, publish and submit to the Conference of the Parties national inventories of anthropogenic emissions of all greenhouse gases not controlled by the Montreal Protocol;
- To use IPCC methodology in preparing the inventory; and
- To draw up, implement, publish and regularly update national programs containing measures for mitigating climate change through treatment of anthropogenic emissions.

The commitments of the industrialized countries listed in Annex 1 include the provision of financial assistance to the developing countries for preparing their national communications and the transfer of technologies to such countries to enable them to implement their emission-reduction programs. In this context, the *Inventory of Greenhouse Gases - Colombia 1990* [1] was prepared during 1995 and 1996 by the Colombian Academy of Exact, Physical and Natural Sciences (the Academy) with support from the German Technical Cooperation Agency (GTZ) and collaboration from the Environment Ministry. As a follow-up to the *Inventory* a second study, *Options for Reducing Greenhouse-Gas Emissions in Colombia 1998-2010*, was undertaken by the Academy in 1998, again with support from GTZ. In this study a projection of the GHG emissions Colombia 1998-2010 was carried out[2]. Methodological guidelines developed by UNEP [3,4] and the US Country Studies Programme [5] were followed in preparing the new study. The reason for adopting internationally accepted methodologies was to facilitate comparison between findings from different countries. This paper presents the main findings of the Emission Reduction Options for Colombia and proposes some general criteria for drawing up a Colombian National Plan for Reducing Greenhouse-Gas Emissions[a].

EMISSIONS REDUCTION OPTIONS

The option for reducing emissions consists in replacing present technology by one of the new technologies[b] or introducing new technologies instead of traditional

[a] The formulation and implementation of plans of this nature is the responsibility of the Ministries of the Environment, of Mines and Energy, of Agriculture, and of Development, as well as the National Planning Department, among others. Consequently, the Academy's proposal is presented not in place of action by Colombian state institutions but as a contribution by the country's scientific and technical community to discussions on an issue of such importance.

[b] These new technologies use energy in a more efficient and rational manner and hence reduce greenhouse-gas emissions either because they use less energy or because less amounts of residual matter is produced in combustion.

ones. Each of these new technologies is evaluated by conducting a technical, economic and environmental analysis, in which comparisons are made in economic and environmental terms between two technological options providing the same amount of energy or the same service with the same degree of reliability.

Costing[2,3] considers the project's useful life, investments costs, O&M, and the cost of fuel (taxes and subsidies are not taken into account) to be used for each one of the options (costs in US dollars). All these costs involve a net present value (NPV) annuality, and the total annual cost is estimated for both the reference option (to be replaced or traditional option) and the emission-reducing option. This net present value is estimated on the basis of the project's useful life and an annual discount rate of 10%.

The two options are compared in economic terms by calculating the cost increment as the difference between the costs of the reducing option and those of the reference option. A negative increment means that the proposed reducing option is more advantageous in economic terms than the reference option.

Likewise, greenhouse-gas emissions produced by the reference option and the reducing option are estimated. Emissions of carbon dioxide, nitrous oxide, and methane are estimated in tonnes per year, using emission factors from the 1996 IPCC methodology and fuel consumption for each option. All emissions are then reduced to CO_2-equivalent emission. The two sets of emission are compared to calculate the reduction in emissions, by subtracting the reducing-option's emission from the reference-option's. A positive result means that the new option does reduce the discharge of greenhouse gases into the atmosphere. A cost/benefit indicator for assessing the worth of an emission-reducing option is the ratio between the cost increment for the reducing option, and the reduction in discharge in terms of CO_2-equivalent emission. The unit for this indicator is dollars per tonne of CO_2 equivalent.

This cost-benefit ratio may be negative, zero, or positive. A negative ratio means that the option is economically advantageous and also reduces greenhouse-gas emissions. Because this option is economically viable, it is called "no regret" and should be adopted because the economic conditions exist for its implementation. A positive index means that the option is not economically advantageous and its implementation will ultimately depend on economic support, justified by its environmental advantages and/or by very particular conditions of application.

Mitigation options for the non-energy sector are evaluated in a similar way. In this case the reference option is to leave things as they are, and mitigation options involve upgrading or expanding carbon-dioxide sinks (afforestation and reforestation) or protecting present deposits (protection of natural forests, sustainable development programmes).

For Colombia, each technology's penetration scenario has been built by taking into account studies determining the technology's potential (e.g., cogeneration[6,7]), potential equipment demand (e.g. illumination [8]), etc. The selection of options in the field of forestry was based on knowledge obtained from over 15 years' successful experience in reforestation and forest-grazing systems established in regions offering development possibilities.

To analyze emission-reducing options in the energy sector it was necessary to prepare an energy capacity and generation mix. The purpose of the energy mix was to estimate average costs of future energy-generating equipment and the emissions resulting from expansion of the generating system in the period 2000-2010. Table 1 shows the structure of the country's electricity generation capacity up to 1996, expansions carried out in 1996-2000, and projected expansions under the LP1 to LP4 scenarios, together with each scenario's total by 2010.

Table 1. Structure Of Energy Generation Capacity

POWER	**Hydro**	**Coal**	**Gas**	**TOTAL**	
Until 1996	8017	918	1666	10601 MW	**Effective**
1996-2000	732	150	1783	2665 MW	**LP1**
2001-2010	2531	450	3607	6588 MW	**LP1**
TOTAL	11280	1518	7056	19854 MW	**LP1**
2001-2010	2864	1200	2529		**LP2**
TOTAL	11613	2268	5978	19859	
2001-2010	2014	900	3342		**LP3**
TOTAL	10763	1968	6791	19522	
2001-2010	1361	1600	3236	6197	**LP4**
TOTAL	10110	2668	6685	19463	

Percentage Share

	Hydro	**Coal**	**Gas**	**TOTAL**	**Scenario**
Until 1996	75,6%	8,7%	15,7%	100,0%	
1996-2000	66,0%	8,1%	26,0%	100,0%	
Final 2010	56,8%	7,6%	35,5%	100,0%	**LP1**
Final 2010	58,5%	11,4%	30,1%	100,0%	**LP2**
Final 2010	55,1%	10,1%	34,8%	100,0%	**LP3**
Final 2010	51,9%	13,7%	34,3%	100,0%	**LP4**

As can be clearly seen, power generation in Colombia is shifting from an expensive hydro-based (75.6%) but low-emission system in 1996, to a less capital-intensive but higher-emission system by 2010 (51.9% hydro, 48.1% gas and coal).

The options for reducing emissions in energy generation must be compared on the basis of the respective costs and emissions of the chosen scenario, LP4. Table 2 shows that 57.2% of the energy to be generated by the LP4 will come from gas-fired plants, 27% from coal-fired plants, and only 15.7% from hydroelectric stations. The immediate consequence will be a decrease in capital costs from $1,300 per installed kilowatt in a wholly hydroelectric system, to $836 per installed kilowatt in the LP4 mix but with an increase in emissions

Table 2. Projected Energy Mix, 2001-2010

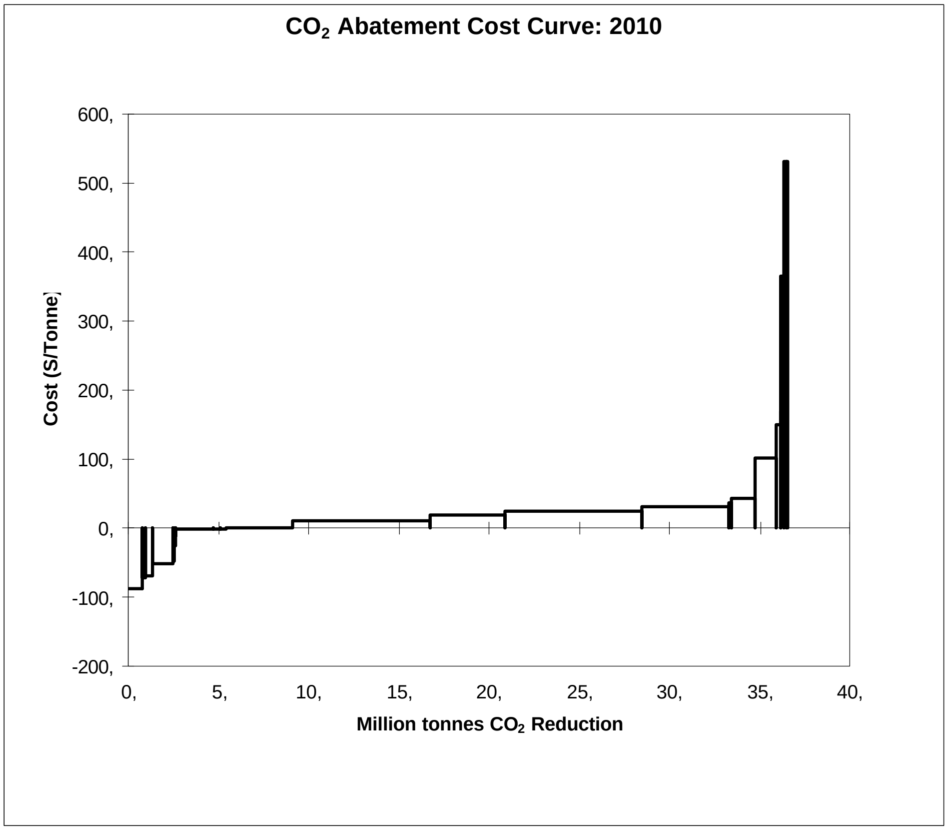
Investment	836	US$/kW		
Lifetime	20	Years		
Capacity Factor	7488	Hours		
Efficiency, average	0,433			
Losses	12%			
Operation and Maintenance	3,0%			

	Hidroelectricity	**Coal**	**Natural Gas**	
Investments	1300	1200	460	US$/kW
Lifetime	20	20	20	Years
Capacity factor	5361,79	7841,25	8207,97	Hours
Efficiency, average	95%	33%	34%	
Losses	12%	12%	12%	
Operation and Maintenance	1,50%	1,50%	1,50%	
Total Generation	46404	GWh/year		
Share	15,7%	27,0%	57,2%	100%
Generation	7297	12546	26561	GWh/year
Total Installed Power	6197	MW		
Share	22,0%	25,8%	52,2%	100%
Installed Power	1361	1600	3236	MW

On the basis of the chosen technologies and their penetration to the year 2010, a scenario of 24 emission-reducing options was developed, with assistance from

Riso and using UNEP's GAMCO software[9]. These options are arranged according to their cost/benefit index. Table 3 summarizes the findings for the emission-reducing scenario built for Colombia, and Figure 1 presents the corresponding abatement-cost curve.

Figure 1. Abatement Cost Curve For Reducing Greenhouse-Gas Emissions In Colombia Up To The Year 2010



In this scenario, the overall potential reduction in emissions by the year 2010 is 36.5 Mtonnes of carbon dioxide. Ten of the 24 options have a negative cost-benefit ratio. This preliminary analisis has not considered the transactional costs and the risk costs associated with the projects. Forestry options are prominent, for they produce most of the reduction in emissions by capturing CO_2: 24 Mtonnes by 2010, representing over 66% of the total. The remaining 34% of potential reductions is produced by the energy sector.

Table 3. Colombia's Greenhouse-Gas Reduction Scenario

Version: 28/5-1998 This is the GACMO model, developped by Joergen Fenhann, UNEP Collaborating Centre on Energy & Environment, RISOE.

Reduction option	$/ton$CO_2$	Unit Type	Emission reduction t CO2/unit	Units penetrating in 2010	Reduction in 2010 Mill.t/year	Cumulative Reduc. 2010 Mill. t/year	Reduction in 2010
Cogeneration (1 MW)	-87	MW	2.061	400	0,82	0,82	0,47%
Timer to DWH	-73	DWH with timer	1	200.000	0,11	0,93	0,53%
Efficient lighting	-69	Bulb	0,05	10.000.000	0,46	1,40	0,80%
Ethanol blend	-51	Plant	111.923	10	1,12	2,52	1,44%
Efficient motors	-48	kW	1	14.000	0,02	2,54	1,45%
Hydro Vs. CC	-26	MW	52	1.361	0,07	2,61	1,49%
Methane from sewage	-13	Plant	966	10	0,01	2,62	1,50%
Efficient boilers	-2	1 Boiler	4.164	500	2,08	4,70	2,69%
Gastrucks	-2	1 Small truck	16	26.910	0,43	5,12	2,93%
Gasbuses	-2	1 Bus	16	22.425	0,35	5,48	3,14%
Solarheater	0	Solarheater	2	100.000	0,21	5,69	3,26%
Biogas from landfills	1	Landfill	689.816	5	3,45	9,14	5,23%
Eucalipto Afforestation	11	14 ha	252	30.000	7,56	16,70	9,56%
Protector reforestation	18	ha	18	231.000	4,20	20,90	11,97%
Pine Afforestation	25	14 ha	252	30.000	7,56	28,46	16,30%
TECA-Afforestation	31	14 ha	161	30.000	4,84	33,30	19,07%
Wind turbines	36	kW	1	100.000	0,15	33,45	19,15%
Minihydro power	43	kW	6	200.000	1,24	34,69	19,87%
Microhydro	101	kW	1	1.000	1,24	35,94	20,58%
Gastaxies	149	1 Taxi	4	65.665	0,23	36,17	20,71%
Biogas for rural households	168	Digester	0	5.000	0,00	36,17	20,71%
Close Cicle	365	MW	73	1.500	0,11	36,28	20,78%
Combined Cicle	531	MW	75	3.000	0,22	36,51	20,90%
PV electricity 1	532	kW	1	20.000	0,02	36,53	20,92%

24

Total Emis in 2010: 174,63 Million tonnes

Among the options that have a positive ratio are "alternative energy sources" and "protective reforestation."

Reforestation options involve three types of projects:

1. **Protective reforestation**. Reforestation is carried out in aquifer-protection areas or in uninhabited regions such as upper mountain heights. The costs of this option are connected with land purchase, and with tree planting and maintenance for the first four years, after which time the forest is left to itself.

2. **Reforestation, with commercial exploitation.** These are 14-hectare modular projects carried out in depressed regions of the country (the Eastern Plains or the Atlantic coast) to offer employment to one family per module. Three hectares are allocated to provide for the family, while the other eleven are planted with pine trees (*Pinus caribaea*). The timber is commercially exploited in a 15-year rotation cycle.

3. **Reforestation, with stockbreeding and commercial exploitation.** These, too, are small 14-hectare single-family modular projects, but in this case commercial exploitation of timber is combined with stockbreeding, each project having 21 head of cattle. This is compatible with the types of tree planted (eucalyptus with an 8-year rotation, and teak with a 20-year rotation).

Reforestation options have a very high emission-reducing potential of 24 Mtonnes/year; and there is thought of involving 90,000 families in type 2 and 3 projects. This scenario is optimistic in that CO_2 uptake by planted timber forests is considered to continue at the full rate for a long time despite commercial exploitation of the forests.

The energy sector's ten emission-reducing options have a potential of barely 12.5 Mtonnes/year. This limited potential is due to the present system's very high hydro component (76% of installed capacity in 1996), and to the fact that by 2010 despite expansions under the LP4 scenario the system will still have a 52% hydro-power component with low emissions.

From the perspective of base-case emissions by the year 2010, a reduction of 36.5 Mtonnes of CO_2 would represent 21% of expected emissions of some 174 Mtonnes by then. If the proposed measures manage to be implemented, the country's emissions will be 138.1 Mtonnes of CO_2 by 2010: this means that Colombia will have lowered its emissions not only to the 1990 level but down to 17.4% below this level.

In the event that only the options proposed for the energy sector are implemented, net emissions by 2010 will be 161.5 Mtonnes, which means a reduction down to the 1990 level.

MACROECONOMIC IMPACT OF EMISSION-REDUCING OPTIONS

Colombia is a middle-income country whose long-term economic performance has been average in the context of Latin American, but in recent years there have been signs of economic slowdown. Annual economic growth fell from more than 5.0% during 1993-1995 to only 2.8% in 1998 and is expected to drop further to 2.0% in 1999. The economy is expected to show an upturn by the year 2000, with growth rates rising above 5.0% by the year 2002. During the nineties, the primary sector's growth has decreased significantly and the industrial sector has failed to show the expected dynamism, but the tertiary sector has grown.

Unemployment has risen sharply in Colombia in the nineties, up to 15.1% in September 1998, mostly affecting the less-educated and the underprivileged. The labour situation is not promising at the moment because of the budget crisis, the dynamic sectors' inability to absorb the unemployed, and certain structural features of the labour market.

The nineties have continued to see a marked inequality in income distribution (Gini index: 0.47), a great lack of equity and alarming levels of poverty: 55% of the population is under the poverty line, with 20% even under the line of indigence.

The balance-of-payments current account has deteriorated, going from a surplus of 5.5% of GDP in 1991 to a deficit of 6.6% in 1998. The aim is to bring the deficit down to 3.5% by the year 2002. Deterioration has been caused by a growing trade deficit, lower net transfers, and an increasingly negative service balance since 1995. The trade balance fell from a surplus of 7.0% of GDP in 1991 to a deficit of 3.8% in 1998. The deficit is expected to be reduced to 0.2% of GDP by the year 2002. The capital account's mounting surplus over 1992-1996 rose to 8.3% of GDP but dropped down to 4.8% in 1997-1998. It will go up again in 1999, to 6.2% of GDP, then down once more, to 4.0% by 2002.

The budget deficit, too, has deepened in the nineties. The problem is largely attributable to the central government, in particular to its current spending, especially transfers and personal services.

The greenhouse-gas programme under study envisages 24 options, whose costs are summarized in Table 4. The total amounts to $17,344 Millions, whereas the reference option costs only $1,623 Millions. The difference is explained by the fact that most of the projects are new ones and mainly in the nature of extensive reforestation projects, costing in all $12,139 Millions, or 69.9% of the total. The other options are for introducing new technologies, as against "leaving things as they are" ("business as usual" - reference cost 0). The proposed new-technology options involve an investment increment of $5,205 Millions over the "business as usual" option. It is worth noting that many of the options have a high domestic content, particularly the mitigation options based on reforestation by planting teak (*Tectona grandis*), pine or eucalyptus, and protective reforestation. A first estimation indicates that these projects would generate some 186,600 direct jobs over the periods under study, with a 100% domestic content. The new-technology projects have little domestic content and do not create many direct jobs compared with the forestry options.

Implementation of all the projects would require an annual expenditure estimated at around 1.7% of GDP.

Execution of these projects--essentially the job-creating forestry projects--should be considered not only in the context of environmental concerns, but also as an important means of achieving the aims of the plan called *Changes For Building Peace*.

The projects are fully consistent with the government's environmental intentions, for example: the forestry plan for greater restoration and conservation of strategic eco-regions so as to improve the quality of life of the population; clean production; and upgrading the quality of urban life. And even more important within the Colombia context, there is also the fact that several of the identified options for mitigating greenhouse-gas emissions could contribute to the peace process through investment and job creation in zones of social conflict, with the further result of relieving the problem of migration to urban areas.

Consideration is currently being given to creating a carbon exchange through which the advanced countries may buy greenhouse-gas reduction to meet their international commitments regarding the environment. Colombia should consider making effective use of this mechanism to attract foreign investment that will contribute to development and to a higher standard of living in the more marginalized areas and also help to meet the global objective of environmental protection.

Table 4. Costs And Impacts Of Mitigation Options

Reduction option	Units penetrating in 2010	Unit Type	Total Investment M US$	Total Reference M US$	National Share %	Imported Share %
Cogeneration (1 MW)	400	Mw	212	73	30	70
Timer to DWH	200,000	DWH with timer	8	0	25	75
Efficient lighting	10	1 million Bulbs	80	40	100	0
Ethanol blend	10	Plant	400	0		
Efficient motors	14,000	kW	6	0	90	10
Hydro Vs. CC	1,361	MW	2	1		
Efficient boilers	500	tonnes	49	0	10	90
Gastrucks	26,910	1 small truck	60	0		
Gasbuses	22,425	1 bus	50	0		
Methane from sewage	10	plant	1	0	30	70
Biogas from landfills	5	Landfill	88	0	30	70
Solarheater	100,000	Solarheater	100	15	70	30
Eucalipto Afforestation	30,000	14 ha	3,371	0	100	0
Protector reforestation	231,000	1 ha=	711	0	100	
Pine Afforestation	30,000	14 ha	3,575	0	100	0
TECA-Afforestation	30,000	14 ha	4,482	0	100	0
Wind turbines	100,000	kW	140	53	30	70
Minihydro power	200,000	kW	1,386	120	90	10
Microhydro	1,000	kW	3	2	90	10
Gastaxies	65,665	1 taxi	146	0		
Biogas for rural households	5,000	digesters	13	0	100	0
Close Cicle	1,500	MW	340	0	10	90
Combined Cicle	3,000	MW	1,940	1260	10	90
PV electricity 1	20,000	kW	180	60	50	50
24			17,344	1623		

CONCLUSIONS

This study reports on 24 options for reducing the GHG emissions of Colombia, ten of them presenting a negative index and should be further discussed and analyzed considering in addition the transactional and risk costs. The total potential reduction of 36.5 Million tons of CO_2 is a significant figure for Colombia and should be considered by the Government in its National Emission Reduction Strategy. These projects also represent a potential for CERs for the international CO_2 market.

ACKNOWLEDGEMENTS

The members of the Academy's Working Group on Climate Change thank the Environment Ministry, and the Mining and Energy Planning Unit (UPME) of the Ministry of Mines and Energy for providing valuable information and assistance for this work. They also express their gratitude to the German Technical Cooperation Corporation (GTZ) (H. Liptow, B. Boessl, and C. Maennling). Thanks are likewise extended to J. Fenhann and A. Villavicencio of the Risø National Laboratory in Denmark, and to M. Cames of the Öeko Institute in Berlin, for providing technical assistance.

BIBLIOGRAPHY

[1] González, F. **Inventario de Gases de Efecto Invernadero - Colombia 1990**. Academia de Ciencias Exactas, Físicas y Naturales (1998) Bogotá

[2] González, F. and H. Rodríguez. GHG Emissions in Colombia 1998-2010. In this proceedings.

[3] Halsnæs, K., J. Callaway and H. Meyer. The Economics of Greenhouse Gas Limitation - Technical Guidelines**.** UNEP Collaborating Centre on Energy and Environment. Risø National Laboratory (February 1998) Roskilde, Denmark.

[4] Halsnæs, K., G. Mackenzie, J.M. Christensen, J. Swisher, A.. Villavicencio. UNEP Greenhouse Abatement Costing Studies**.** UNEP Collaborating Centre on Energy and Environment. Risø National Laboratory (February 1998) Roskilde, Denmark.

[5] Sathaye, J. and S. Meyers. **Greenhouse Gas Mitigation Assessment: A Guidebook**. Kluwer Academic Publishers (1995) Dordrecht, Holland

[6] UPME Potencial de Cogeneración del Sector Industrial de Colombia, AENE para UPME, Ministerio de Minas y Energía. (1997) Bogotá, Colombia

[7] UPME Potencial de Cogeneración del Sector Terciario de Colombia, AENE para UPME, Ministerio de Minas y Energía. (1998) Bogotá, Colombia

[8] INEA. Directiva Ministerial sobre Alumbrado Público. Instituto de Ciencias Nucleares y Energías Alternativas (1995) Bogotá, Colombia

[9] Fenham, Joergen. GACMO. UNEP Collaborating Centre on Energy and Environment. Risø Labs. (1998) Roskilde. Dinamarca