MAPS

Mitigation Action in Developing Countries

Country Study for Colombia

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Mitigation Action Plans & Scenarios

Abstract

This paper presents the Colombian Count Study developed under the Mitigation Actions Plans and Scenarios (MAPS) Initiative. The document seeks to understand how the mitigation actions have been conceptualized and could be approached in Colombia. It is divided in two parts. The first part presents the contextual framework in which the NAMAs will be undertaken. It starts with a brief description of the socio-economic and political context as well as with a summary of the GHG inventories and the experience with CDM projects. It then deals with the current climate change internal policy and presents the international agreements in the area. It finishes with a description of the undergoing mitigation actions as well as future projects. The second part contains the bases used to identify NAMA proposals for Colombia. According to the general requirements that a NAMA should meet to obtain support from the UNFCCC, two NAMA proposals are developed. The first one is related to the introduction of electric vehicles for private and massive transportation. The latter is related to a combination of potato crops with forestry and farming activities. This part ends with a short identification of the measurement, reporting, verification (MRV) requirements for the successful implementation of these NAMAs.

JEL Classification: D62, I21, J24

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Abbreviations and Acronyms

DANE	Departamento Administrativo Nacional de Estadística
	NationalStatistics Administration Department
DNP	Departamento Nacional de Planeación
	National Planning Department
CC	Climate Change
CDM	Clean Development Mechanism
CIF	Certificado de Incentivo Forestal
	Forestry incentive Certificate
CONPES	Consejo Nacional de Política Económica y Social
	National Council of Economic and Social Policy
CREG	Comisión de Regulación de Energía y Gas
	Energy and Gas Regulation Committee
DOE	Department of Energy
EEPPM	Empresas Públicas de Medellín
	Public Enterprises of Medellin
EIA	Energy Information Administration
ENSO	El Niño-Southern Oscillation
EPSA	Empresa de Energía del Pacífico S.A.
	Pacific Energy Enterprise
FEO	Firm Energy Obligations
GCCM	Group of Climate Change Mitigation
GDP	Gross Domestic Product

GHG	Greenhouse Gas
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia *Institute of Hydrology, Meteorology and Environmental Studies*
LCDS	Low Carbon Development Strategy
MADR	Ministerio de Agricultura y Desarrollo Rural *Ministry of Agriculture and Rural Development*
MAVDT	Ministerio de Ambiente, Vivienda y Desarrollo Territorial *Ministry of Environment, Housing and Territorial Development*
MEM	Mercado de Energía Mayorista *Wholesale Energy Market*
NAMA	Nationally Appropriate Mitigation Action
PML	Primer Metro Línea *First Metro Line*
REDD	Reducing Emissions from Deforestation and forest Degradation
SITP	Sistema Integrado de Transporte Público *Integrated Public Transport System*
UNFCCC	United Nations Framework Convention on Climate Change
UPME	Unidad de Planeación Minero Energética *Mining and Energy Planning Unit*

1 Current Framework

This part contains the National Current Framework that is relevant to the analysis of mitigation of climate change. First, the socio-economic and political context of the country is presented together with a brief overview of the GHG Emissions Inventory. Section 1.3 presents the way the CDM has worked in Colombia mentioning the strength and weaknesses of the mechanism. The following section includes the Climate Change Internal Policy with special interest in the Institutional Arrangement within the country. Related to this section, section 1.5 analyzes a letter sent to the UNFCCC which represents an International Agreement. Finally, this part ends with a section that contains undergoing mitigation actions.

1.1 Socio-Economic and Political Context

1.1.1 Socio-Economic

In the recent past, the Colombian economy has shown positive growth rates which have been mainly caused by the increase of internal and external demand, together with a rise of international prices of food and fuels[1]. The economy experienced a boom from 2001 until 2007 with annual growth rates above 4.9%. In particular, the 2007 growth rate was 6.9% which was the highest in the last 30 years. In year 2008 this tendency changed with a growth rate of 2.7% and kept dropping until 2009 and reached 0.8%. Figure 1.1 shows the Colombian GDP growth rate for years 2001 until 2009.

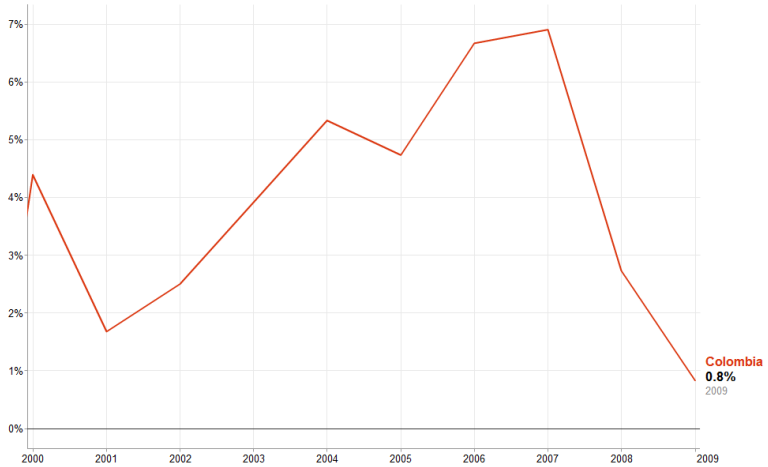


Figure 1.1. Colombian GDP growth rate for years 2001 until 2009.
Source: [40].

According to DANE data, the GDP at current prices went from 101.231 billion dollars in year 2000 to 234.045 billion dollars in 2009. This is shown in Figure 1.2.

[1] This section was written based on [40].

The drop in economic performance that is evident in Figure 1.1, can be explained mainly by the international financial crisis in 2008. In particular, in 2009, the crisis contracted private demand by 3.9%, causing the smallest growth rate of the decade. Nevertheless, Colombian endured the crisis with a relatively good performance especially when compared to Mexico, Venezuela and Chile where the GDP contracted 6.5%, 3.3% and 1.5%, respectively.

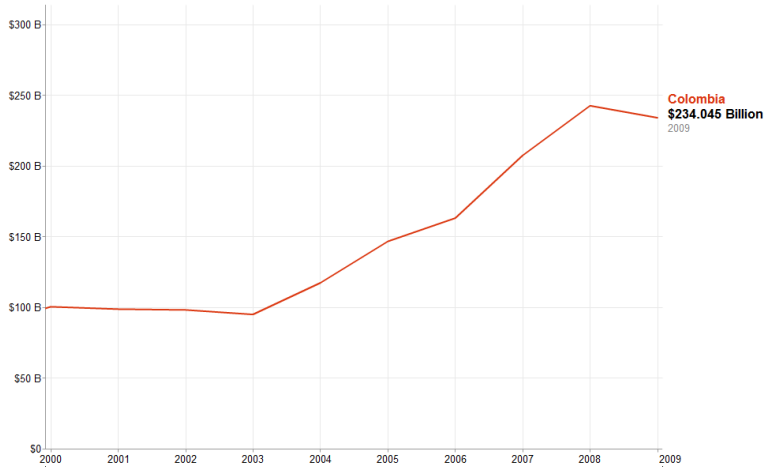


Figure 1.2. Colombian GDP current prices.
Source: [40].

Along the last decade, the participation of different economic activities in the total GDP has remained relatively constant. The participation of sectors in total GDP 2009 is showed in Figure 1.3.

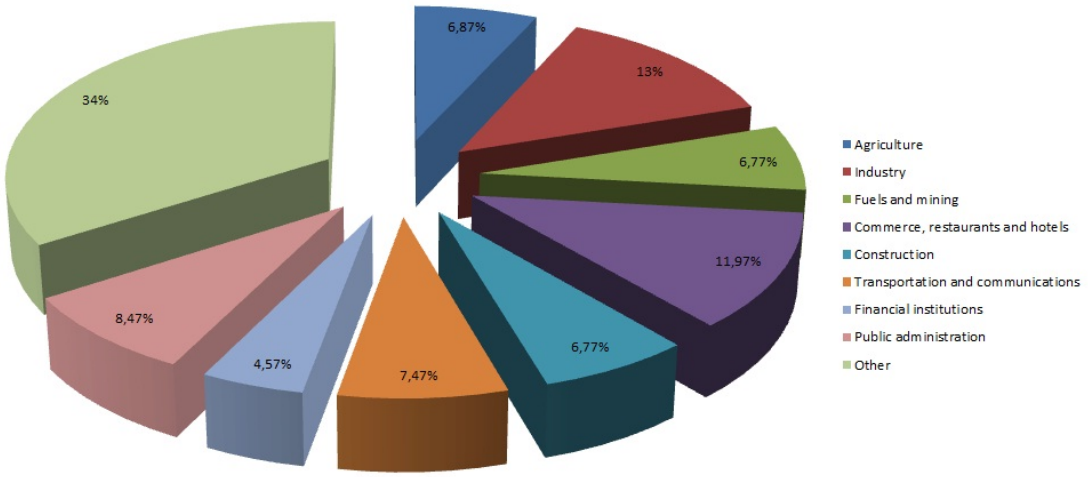


Figure 1.3. Participation of different economic activities on total GDP.
Source: [40].

Similarly, the sector that has gained more participation in the last few years is construction that went from 4.3% in 2000 to 6.6% in 2009. On the other hand, the sectors which have been loosing the most participation is the social and personal services sector together with the agricultural sector.

As was mentioned beforehand, the construction sector shows the most dynamic average growth rate with 9%. On top of that, the growth rate of this sector during the financial crisis was 14.6%. One reason for this is that during times of crisis, investors seek safer sectors such as real estate. Another sector that is very dynamic is transportation, storage and communications with 6.7%. An important fact worth noticing is that the mining sector went from having negative growth rates in 2001 and 2002, to having a growth rate of 9.6% in 2009.

The economy grew 4.5% in 2010. It is expected that for 2011 the growth rate will be 5%, with an inflation rate of 2,5% and low interest rates that encourage investment. The revaluation of the peso is also imminent and is expected to keep this upward trend due to the increase in foreign investment. This will negatively affect Colombian exports.

The sustained growth that the Colombian economy has been experiencing has had an impact on GHG emissions. The section in which the inventory is presented will perform a rigorous analysis of this issue. Nevertheless, it is very important to take a closer look at the National Development Plan (NDP) in which the government states what the fundamental pillars (*locomotoras*) for economic development for 2014 will be: mining and energy, housing, transport infrastructure, innovation and agriculture. . By looking at them one can see that they are strongly related to GHG emissions and, therefore, it is possible to deduce that the emissions will increase. It is stated in the NDP that, by definition, the *locomotoras* are sectors that have an accelerated growth rate in comparison with the rest of the economy

1.1.2 Political

The government is divided into three branches: legislative, executive and judicial. There are other independent and autonomous institutions which perform other tasks such as the National Planning Department, Control Organisms and Electoral Organizations.

The legislative branch is composed of the Congress of the Republic. The Congress is divided into two chambers, the Chamber of Representatives and the Senate. Its mandate is to make the laws and perform political control over the administration.

The judicial branch is organized into ``four roughly coequal, supreme judicial organs; the Supreme Court of Justice (highest court of criminal law; the Council of State (which is the highest court of administrative law; the Constitutional Court (which preserves the integrity and supremacy of the constitution; issues rulings on the constitutionality of laws, amendments to the constitution, and international treaties); and the Superior Judicial Council (this latter body administers and disciplines the civilian judiciary; it also resolves jurisdictional conflicts arising between other jurisdictions).'' Under these four courts are the judges and tribunals. The task of all the mentioned above is to enforce the Political Constitution of Colombia and the law.

The executive branch is constituted by the President of the Republic, the Vice-president, 13 Ministries, the Administrative Departments, the Special Administrative Units, the Public Establishments, the Public Industries and Enterprises, the Departments, the Districts and the Municipalities. The 13 Ministries are: the Ministry of the Interior and Justice; International Affairs; the Ministry of Economy; the Ministry of Defense; the Ministry of Agriculture and Rural Development; the Ministry of Social Protection; the Ministry of Mines and Energy; the Ministry of Industry, Trade and Tourism; the Ministry of Education; the Ministry of

Environment, Housing and Territorial Development- MAVDT; the Ministry of Information Technology and Communications; the Ministry of Transportation; and the Ministry of Culture. A division of some Ministries is expected in September 2011. The Ministry of Interior and Justice will be divided in two, the the Ministry of Social Protection will be divided into the Ministry of Health and the Ministry of Labor and the MAVDT will divide the housing and environmental tasks into two different Ministries.

The 7th of August 2010, Juan Manuel Santos was sworn in as President of the Republic after two four-year periods of Álvaro Uribe Vélez. The government's plan continues Uribe's famous Democratic Security Policy but goes further and states new objectives: ``moving towards social development, more employment, less poverty and prosperity, in general, for the whole population''[10].

1.2 Colombia's GHG Emission Inventories

The Institute of Hydrology, Meteorology and Environmental Studies – IDEAM – is the entity in charge of coordinating and writing the GHG inventory in Colombia. Until now, two inventories have been published, the first one for the years 1990 and 1994 and the second one for the years 2000 and 2004. Presently, the IDEAM is finishing the inventory for the period from 2005 until 2008.

For the construction of both inventories, the IDEAM followed the IPCC methodology presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The first communication (1990-1994) was developed with a bottom up methodology, while, for the second communication, a top down methodology was used. The inventories report emissions of the three direct GHG; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) and three other GHG with indirect effects; carbon monoxide (CO) , nitrogen oxides (NO_X), volatile non-methane organic compounds (COVDM) and sulfur dioxide (SO_2). In addition, the 2000-2004 inventory includes hydrofluorocarbons (HFC) and perfluorocarbons (PFC). The evaluation includes five modules: energy, industrial processes, agriculture, LULUCF and waste management.

Figure 1.4 presents the total GHG emissions in CO_2eq for each module. According to IDEAM, from 1990 to 1994 the emissions increased 15.8%, going from 129.368 Gg of CO_2eq in 1990 to 149.867 Gg of CO_2eq in 1994. In 2000 total emissions were 177.575 Gg of CO_2eq; this number increased to 180.008 Gg of CO_2eq in 2004, which means that in the period 2000-2004 there was a 1.37% increase. In addition, the average annual growth rate in the period 1990-2004 was 1.98%. These changes were principally produced by the growth of the country, not to mention the fact that the IDEAM had more sources of information for the second inventory.

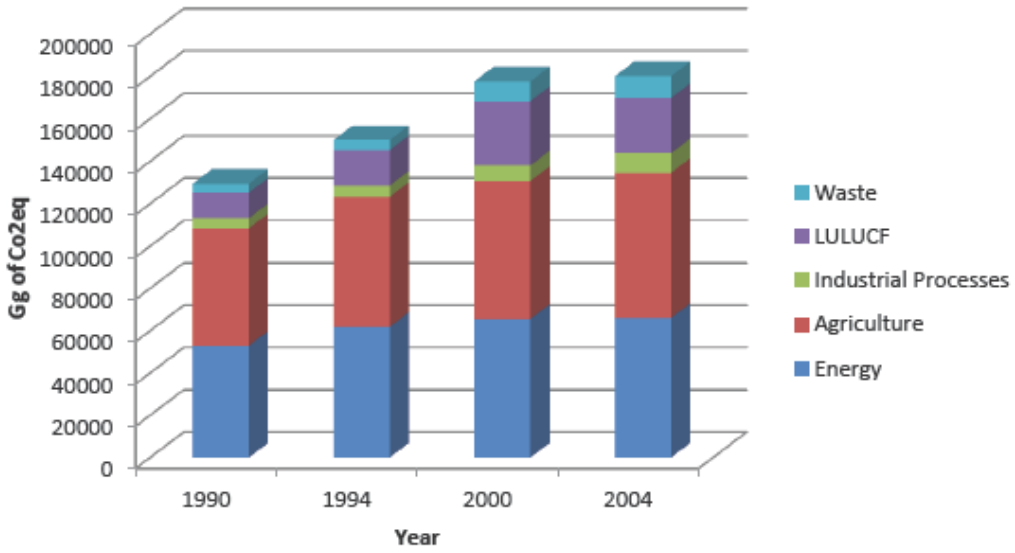


Figure 1.4. Total emissions of GEI per module and year.
Source: [23].

On the other hand, Colombia's participation in total world emissions is 0.37%. Within Latin America, Brazil is the biggest producer of emissions, followed by Mexico, Argentina, Venezuela and Colombia.

At a sectoral level, energy and agriculture form 75% of total emissions. However, from 1994 to 2004 the emissions of these two sectors grew 24.6% and 23.7% respectively. During this same period, emissions from industrial processes grew 90% and LULUCF and waste grew more than 100%.

The main concern with this inventory is the LULUCF sector. First of all the methodology used to build the two inventories (1990-1994 and 2000-2004) changed radically making them incomparable. This reflects some of the weaknesses of the information available in the country. For example, in the CO_2 emissions in land use for the 1990-1994 inventory, only mineral soils were considered; while, for the 2000-2004 inventory, emissions for organic and limed soils were included.

Another issue that this study identified is the difference in calculations of deforestation rates. According to the National Forest Development Plan (2001) there is no trustworthy information on this matter. The wide variety of estimations range from 200.000 to 600.000 hectares in these last years [47]. According to the document "Colombia – A vision for the second centennial" (2004) the mean yearly deforestation rate for the country is 89.000 ha, and for the REDD document, this value is 101.300 ha for the period 1994-2001.

1.3 Clean Development Mechanism (CDM)

The Climate Change Mitigation Group is in charge of the CDM affairs in Colombia. They develop the national CDM portfolio in all sectors and are in charge of the technical aspects of the National Approval Process.

Until 2011, the portfolio includes 154 projects related with Industry, Energy, Waste Management Forestry and Transport sectors from which 66 are approved by Colombia's Designated National Authorities (Ministry of Environment) and 29 are registered in the United Nations Framework Convention on Climate Change UNFCCC [31]. The annual emissions reduction potential of GHG of the whole portfolio is 20,935,440 tons of CO_2e per year [39]. Table 1.1 shows the number of projects and the annual emission reduction of GHG in tons of CO_2 per year divided by sector.

Table 1.1. Annual Potential Emission Reduction of GHG by sector.

Project sector	Number of projects	% in total number of projects	Annual emission reduction (Ton CO_2e/yr)	% in annual emission reduction
Industry	61	40%	8,916,437	43%
Energy	41	27%	5,768,392	28%
Waste Management	22	14%	2,565,353	12%
Forestry	17	11%	2,366,517	11%
Transport	13	8%	1,318,741	6%
Total	**154**		**20,935,440**	

Source: [31].

Figure 1.5 ilustrates the share of each technology used in the industry's CDM until 2010. Energy efficiency and capture and use of associated gases are the most used technologies in this sector and have 20% and 13% share, respectively.

Figure 1.6 shows the amount of projects in the energy sector, divided by technology. As we can see, 88% of the energy CDMs portfolio has renewable energy as the technology used to reduce GHGs emissions; these thirty six projects, in particular, approximately reduce 5,023,655 tons of CO_2e per year[30].

In the waste management sector, most of the mechanisms used to reduce GHG emissions are related with landfills as can be seen in Figure 1.7.

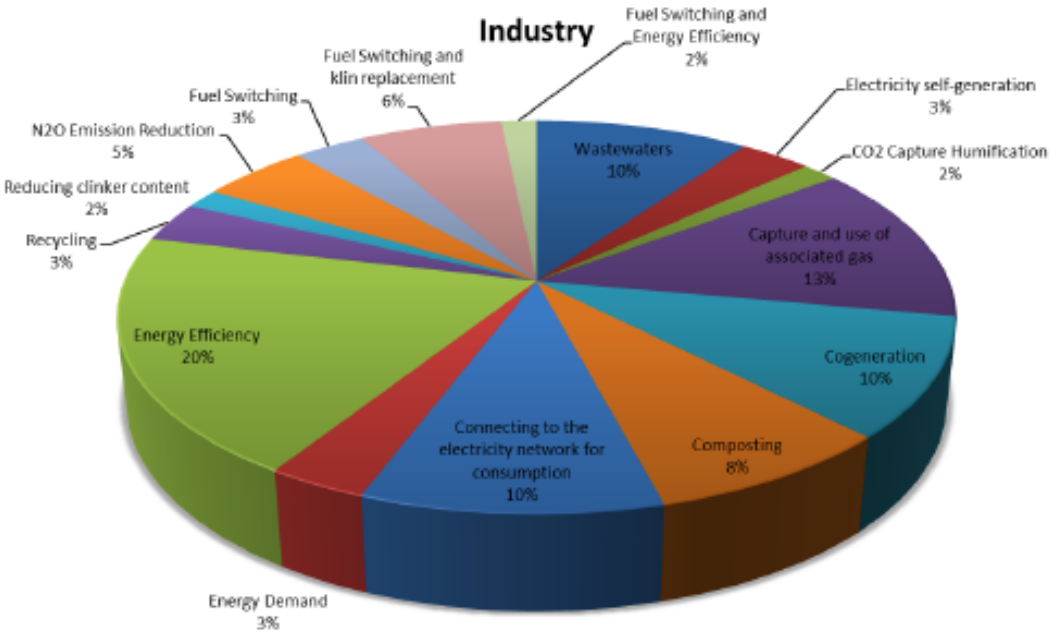


Figure 1.5. Technologies' share in Industry's CDM portfolio.
Source: [31].

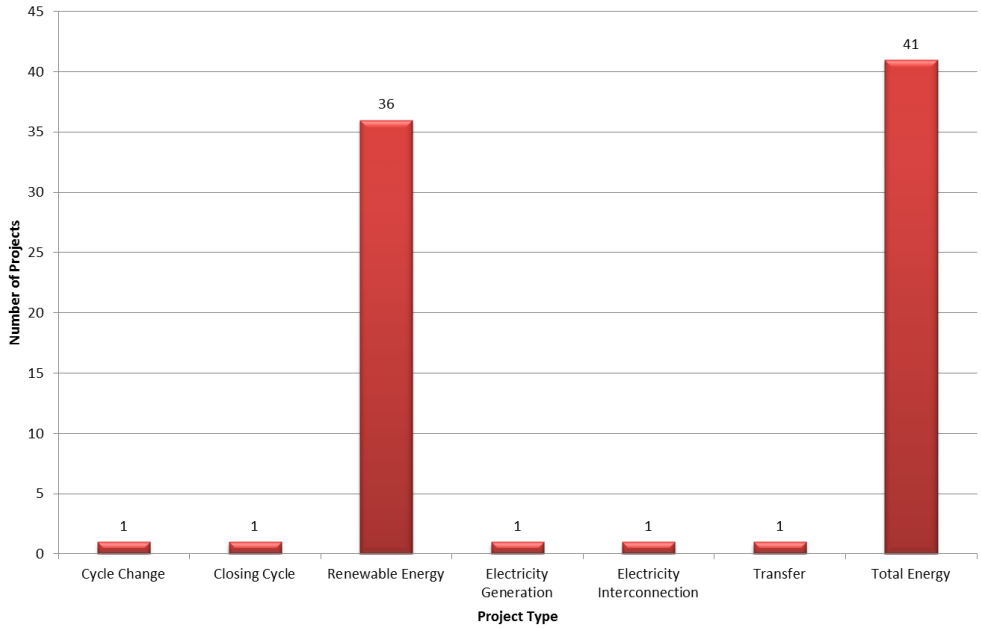


Figure 1.6. Technologies' share in the Energy Sector's CDM portfolio.
Source: [31].

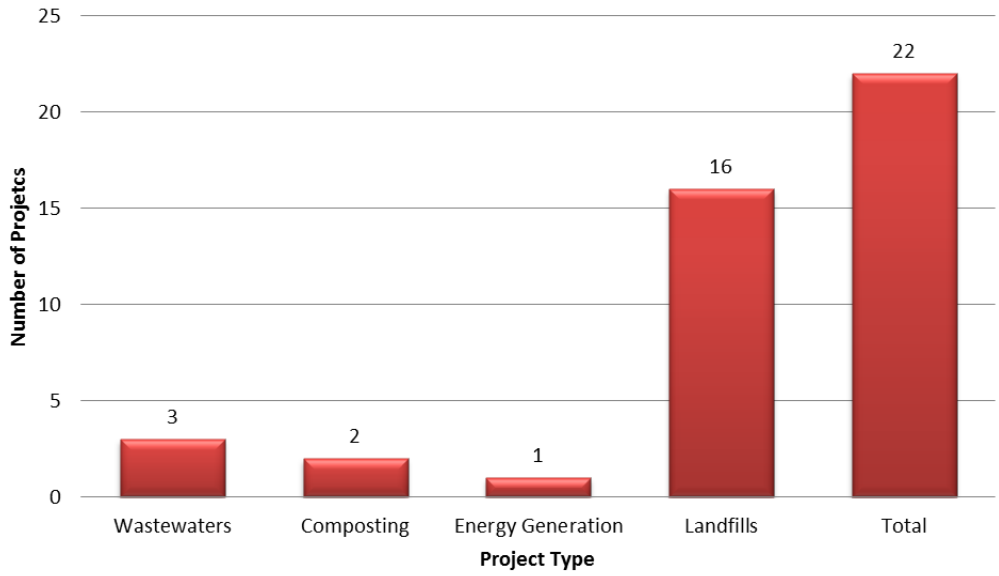


Figure 1.7. Technologies' share in the Waste Management Sector's CDM portfolio.
Source: [31].

Figure 1.8 shows the number of projects that are being developed, or were developed in the transport sector. Colombia is known for its BRT systems that work in many cities of the country. These became CDM projects and have 62% share in the GHGs emissions reduction of the transport sector, that is approximately a reduction of 820,726 tons of CO2e per year [30].

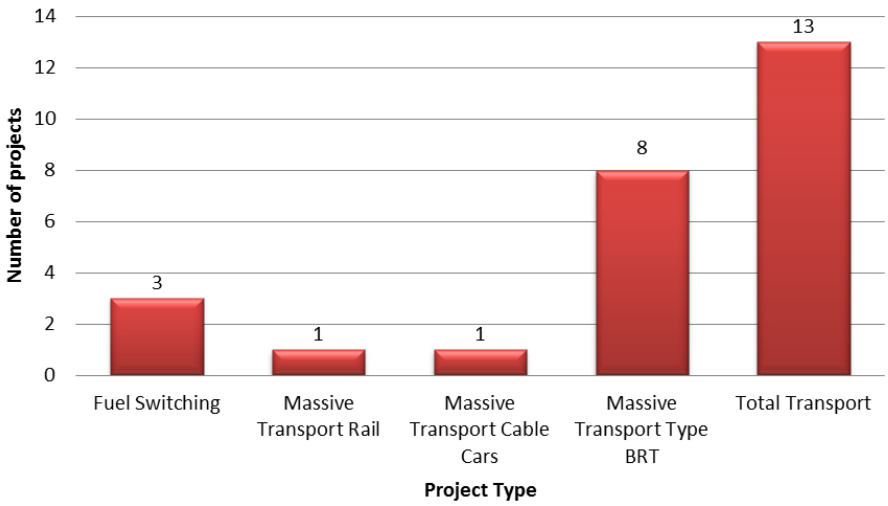


Figure 1.8. Technologies' share in the Transport Sector's CDM portfolio.
Source: [31].

In the forestry sector, almost all of the projects of the portfolio (16) are related with reforestation and micro watersheds developments.

Table 1.2 shows the amount of registered projects divided by sector, and their annual potential reduction of GHG emissions in tons of CO_2e per year. Even though the potential emission reduction of Colombia's portfolio has a bigger share in the industry sector (61%), the waste management sector is actually reducing more GHG at present.

Table 1.2. Annual Emission Reduction of GHG by sector's registered projects.

Project sector	Number of projects	Annual Emission Reduction (Ton CO_2e/yr)
Industry	8	1,467,762
Energy	7	186,954
Waste Management	10	1,526,766
Forestry	2	277,918
Transport	2	263,517
Total	**29**	**3,722,917**

Source: [3].

Table 1.3 shows the amount of projects that have issued CER in Colombia and how many CER have been emitted in tons of CO_2e, by sector [39].

The industry projects include fuel switching (petroleum fuel for natural gas) and changes in the production process to reduce GHG emissions. Four of the five projects of the energy sector are small hydroelectric power plants. The only project in the waste management sector consists of the installation of a landfill gas collection and flaring system in Pasto, Colombia. The transport sector projects are related to the implementation of sustainable mass urban transport systems [39].

Table 1.3. Emitted CER by Sector.

Project sector	Number of projects	CER emitted (Ton CO_2e)	% of the total amount of CERs emitted
Industry	2	219,060	29%
Energy	5	395,250	45%
Waste Management	1	277,044	2%
Forestry	--	--	0%
Transport	2	102,427	23%
Total	**10**	**993,781**	

Source: [3].

Even though, Colombia has extensive opportunities to reduce GHG emissions by developing and implementing CDM projects, only 18.8% of the projects of the portfolio (twenty nine projects) are registered with the UNFCCC and only 6% (nine projects) have issued CERs. These projects have produced $91,230,000 dollars of revenues from sales of CERs from 2007 to 2010 [30]. In our opinion, the main reasons that have hindered the success of CDM projects in Colombia are the GHG related risks that investors face, the difficulties of demostrating the additionality of the project and the amount of requirements and procedures specially related with the monitoring and verification process.

The risks perceived by investors to produce GHG offsets are high, the most important are: (i) a baseline risk due to the possibility that changes in this baseline could invalidate ''additionality'' and, therefore, the ''certifiability'' of the GHG offsets deriving from a project; (ii) a market price risk due to the uncertainty of the market value that the GHG offsets will command once produced, as the price of offsets is likely to fluctuate based on their actual supply and demand at any point in time; and (iii) a transaction costs risk due to uncertainties inherent in the costs of offset verification, monitoring, certification, trading and other requirements that CDM rules might impose.

As far as additionality is concerned, experience has shown the difficulties of demostrating that effective reductions have been reached. This process involves huge transaction costs, making it almost impossible for some valuable projects to pass as CDM. We found that in our country the transaction costs of undertaking a CDM project and the time to get approvals (delays and bottlenecks) have been also huge. In some cases, many companies prefer not to embark upon one of these projects, which end up being very expensive. Related to this is the very extensive and demanding monitoring and certification procedure that has to be included in a project formulation which also makes the construction of CDM very complicated. These factors together make the process long and cumbersome.

High transaction costs might reduce the marginal abatement cost advantage that make GHG offset production in Non-Annex I countries a potentially lucrative proposition for investors in the first place. Therefore, these risks reduce the number of projects carried out and, in Colombia's case, have made it difficult to undertake projects in less profitable and more volatile sectors (i.e. Forestry sector).

Finally, it is important to note that while the projects that are actually undertaken are very profitable, they not always help Colombia's sustainable development. CDM was proposed to fullfil at least two goals: as a cost effective way to reduce emissions and as a means of helping developing countries to achieve sustainable development.

Taking into account the limitationes mentioned above, we believe that the emissions reduction approach should change worldwide. Industrialized countries should meet their obligations for financial transfers to developing countries (for mitigation and adaptation) in a way that is independent from and additional to their emission reduction obligations. An important additional problem with offsetting mechanisms is that they allow these two obligations to be traded off of one another. Fund-based approaches should be utilized instead.

1.4 Current Climate Change Internal Policy

Colombia's environmental policy is mandated by the Law 99 of 1993 that created the National Environmental System - SINA. This system is defined as the set of guidelines, norms, activities, resources, programs and institutions that allow the implementation of the general environmental principles stated by the Colombian Political Constitution and the Law 99 of 1993. The SINA is constituted of the Ministry of Environment, DNP, the Regional Autonomous Corporations, local authorities and research institutes attached to the Ministry. The National Environmental Council aims to ensure inter-sectoral coordination in public policies, plans and programs regarding the environment and renewable natural resources.

Specifically relevant to climate change was Colombia's adoption of the United Nations Framework Convention on Climate Change by means of Law 164 of 1994. This implies an agreement on the objectives stated in the convention[2]. Specifically, those related to climate change are contained in Article 4.1 of the convention [38]:

1. "Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties;

2. Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change;

3. Promote and cooperate in the development, application and diffusion, including transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transportation, industry, agriculture, forestry and waste management sectors;

4. Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems;

[2] This section was written based on [15].

5. Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods;

6. Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change;

7. Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies;

8. Promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change, and to the economic and social consequences of various response strategies;

9. Promote and cooperate in education, training and public awareness related to climate change and encourage the widest participation in this process, including that of non- governmental organizations; and

10. Communicate to the Conference of the Parties information related to implementation, in accordance with Article 12."

In 2000, Colombia validated the Kyoto protocol by means of Law 629. In that same year, the Ministry of the Environment coordinated the National Strategy for CDM Implementation.

In 2001, Colombia presented the First National Communication to the UNFCCC. This Communication prepared by IDEAM contained information on vulnerability, possible adaptation actions and the inventory mentioned above.

In 2002, the MAVDT together with the Planning Department, wrote the Guidelines for Climate Change Policy. It contains the main strategies for mitigation and adaptation developed in the UNFCCC, the Kyoto Protocol and the First National Communication. This document did not assign any institutional responsibilities or follow up mechanisms and, therefore, its implementation has not been successful. To resolve this, the Council of Economic and Social Policy- CONPES[3] presented the official document on July 14, 2011.

[3] CONPES is a council lead by the President of the Republic. The members are the Vice-president, all of the Ministers, the Director of the Planning Department, the Director of the Administrative Department of the Presidency and the Director of the Administrative Department of Science, Technology and Innovation- COLCIENCIAS.

The aim of the CONPES is to establish an institutional arrangement to articulate a strategy between sectors in order to facilitate and enhance the formulation and implementation of policies, plans, programs, methodologies, incentives and projects on climate change, including climate as the main variable in the design and planning of development projects. The institutional arrangement slightly changes with the creation of the National System for Climate Change- SNCC which is conformed by the Executive Commission for Climate Change- COMECC, a Financial Management Committee, an Orientating Group, a Consulting Group and four Permanent Sub-Commissions.

It is intended to enhance mainly four strategies changing the way the country understands climate change and sustainable development in general. These four strategies are:

- The National Adaptation Plan.
- The Low Carbon Development Strategy.
- The National Strategy for Emissions reduction due to Deforestation and Forest Degradation.
- The Strategy for Financial Protection against Disasters.

It is necessary for the country's productive force in all municipalities to implement adaptation and mitigation actions because the SNCC will only coordinate and articulate the initiatives with the specific objective of aligning the participants with the priorities of the Government. CONPES does not intend to create new institutions; it just aims to improve the relationship between the existing ones.

1.4.1 Institutional Arrangements

Colombia has defined institutional arrangements for the formulation and implementation of Climate Change policy. The CONPES document mandates the tasks that have to be performed by each institution.

The recently created Ministry of Environment and Sustainable Development - MADS - is the product of splitting the Ministry of Environment, Housing and Territorial Development- MADVT into two.

There are some functions of the Ministry included in the law 99 of 1993 regarding climate change:

1. Determine the norms and regulations regarding the impact of human activities on the environment.
2. Dictate general regulations to control and reduce geospheric, hydro, landscape, acoustic and atmospheric contamination in all of the national territory.
3. Establish discussion mechanisms with the private sector to adjust activities according to the environmental goals of the government.

According to this, the GHG mitigation actions are included in the range of competence of this Ministry. In consequence, it has been leading most of the country's efforts on the matter. The Group of Climate Change Mitigation was created specifically for this purpose. The objective of this group was at first, to encourage

and approve all CDM projects, promote mitigations actions and support the country in international negotiations.

Ministry of International Affairs: The Direction of Multilateral Economic, Social and Environmental Issues is in charge of defining the position of Colombia regarding international environmental agreements.

National Planning Department - DNP: The DNP is a technical entity directly linked to the Presidency. It is in charge of designing, orienting and evaluating Colombian Public Policy. The Sub-direction of Sustainable Environment Development is part of this institution and is in charge of planning all environmental issues within the DNP. Lately, this entity developed a group of professionals whose task is to study the economic impacts of climate change. This is a continuous process to evaluate the impact of climate change through adaptation and mitigation. It is important to say that this entity will play the role of executive secretary of the recently created SNCC.

Ministry of Agriculture and Rural Development - MADR: This Ministry is in charge of the agricultural, fishing and rural development policy. Since 2008, the Ministry finances research projects in adaptation and mitigation of climate change for the agricultural sector.

Institute of Hydrology, Meteorology and Environmental Studies - IDEAM: This institute is directly linked to the MAVDT but has an independent administration. It is in charge of obtaining, analyzing and disclosing information on hydrology, meteorology, geomorfology and soil use in order to optimize use of natural resources. This institution also coordinates the Environmental Information System and prepares annual reports on the State of the Environment. This report includes information on atmospheric contamination, deforestation and degradation of the natural resources in general.

Mining and Energy Planning Unit - UPME: This Unit is directly linked to the Ministry of Mines and Energy but it has independent administration. It is in charge of planning the developing the mining sector and the use of energetic resources. One of its main tasks is to write the National Energetic Plan together with the Reference Expansion Plan of Generation and Transmission for 2010-2024.

Related to climate change, the UPME calculates the GHG emissions of the National Electric System, develops the environmental information system for the Mining and Energy sectors, designs and promotes energy efficiency programs and encourages the use of non conventional energy sources.

1.4.2 Comments on the Legal and Political Framework

It is worth noticing that a successful Low Carbon Strategy will depend on the successful operation of the institutional array proposed in the recent CONPES document. As was mentioned above, the SNCC will be headed by the COMECC. This Commission is integrated by the Ministries of Agriculture, Mines and Energy, Transport, Social Protection, International Affairs, Environment and Sustainable Development; Housing, City and Territories, and Finance. The director of Risk Management Office of the Ministry of Finance. The Deputy of the DNP will chair it. The relevance of the commissioners creates high expectations about the effectiveness of the policy recommendations.

However, we do believe that valuable lessons could be taken from the operation of similar schemes already proposed in Colombia for ruling environmental and science and technology issues. As well, the Brazilian

experience should provide us with valuable lessons. Brazil also has an inter-ministerial arrangement as a steering Committee to provide leadership in this area. The main difference is that the Ministry of Science and Technology chairs the Commission. Long term policies and strategies are required in this field. Brazil has been able to enhance powerful measures in the field of bio-fuels and energy consumption. In the LULUCF sector results have not been very easy to obtain.

1.4.3 National Development Plan 2010-2014

It was mentioned before that the National Development Plan 2010-2014 builds on Uribe's Democratic Security policy but goes further stating new objectives: ``sustainable growth and competitiveness; social prosperity, security, justice and human rights.''[10] According to this plan, economic growth shall be boosted mainly through infrastructure, housing, agro, mining and innovation.

This Plan contains environmental strategies for the three sectors that are directly related to the mitigation of Climate Change: Mining and Energy, Transportation and Environmental. In the last paragraph of the socio-economic context section of this document, it is mentioned that the plan causes some concerns about the environmental consequences of the country's development plans.

Mining and Energy

The National Development Plan 2010-2014, contains a subchapter devoted to the energy basket and its efficiency. Practically, all of the strategies included in this chapter are closely related to GHG emissions. The following are the main strategies that shall have an impact on emissions mitigation [10]:

1. The growth of the energy sector must be based on sustainability and will be based on renewable resources.

2. Campaigns to promote the efficient use of fuels and the use of massive transportation.

3. Evaluate the possibility of including more biofuels.

4. Design help mechanisms for the industry and commercial sectors in order to implement the Rational Use of Energy programs.

5. Promote energy saving campaigns in households.

6. Allow LPG as fuel for vehicles and expand its use in the petrochemical industry.

7. Promote new uses for coal.

8. The mining sector must certify that its activities meet all environmental requirements.

9. A 3% reduction in total energy intensity.

Transport

The Plan has a section called ``Environmental sustainability and GHG mitigation strategies'' contained in the ``Infrastructure and Transportation'' chapter. In this section the Ministry of Transportation states that it will present a project to the Global Environment Facility to define the strategies and actions that promote emissions reductions, including strategies to promote the use of clean fuels, vehicles with clean technologies and the use of rails and rivers. It is also supposed to seek international financial support by presenting the above as NAMAs. The promotion of electric and hybrid vehicles or the use of combustible gas are also mentioned in the Plan. Also, the Ministry should create incentives in order to replace old vehicles.

Environment

The chapter ``Environmental Sustainability'' contains most of the environmental issues together with the disaster management. The following is a list of the strategies regarding Climate Change that were not explained in the previous sections.

1. Reduce emissions from deforestation and forest degradation (REDD). This enables the economic development of indigenous communities through access to the international carbon market.

2. Support the inter-sectoral pact for legal forestry.

3. Implement the strategy against forest fires.

4. Support the production of cleaner fuels.

5. Implement the strategy for friendlier cities as an energy efficiency option for households.

6. State possible barriers for the highly emitting production and promote the adoption of clean production certificates.

7. Implement the Low Carbon Development Strategy for Colombia through mitigation actions in every sector.

8. National Adaptation Plan.

1.5 International Agreements on Climate Change - UNFCCC

This chapter refers to a letter sent to the UNFCCC on August 2, 2010, which clearly states Colombia's pledges contained in Appendix II of the Copenhagen Agreement.

1.5.1 Unilateral Actions

Seventy-seven percent (77%) of total Energy will be generated from renewable sources [4]

As an unilateral mitigation action, the Government has tentatively established that by 2020, at least 77% of the installed capacity for power generation will correspond to renewable technology. It is important to note that renewable includes hydroelectric capacity which has been the dominant source for electricity production in Colombia. This compromise will mean a decrease in thermal capacity by 10 percentage points of what we have today. The previous figure results from the outcome of a Reliability Charge mechanism recently put into place. Despite this, it is important to note that the Colombian electricity market is neutral from a technological point of view, so any agent could install thermal capacity if decided to do so. Also note that the country is vulnerable to abnormal El Niño events, especially dry periods.

In this section we introduce the electricity market as well as describe the Reliability Charge mechanism and the results of the first two auctions which have already been undertaken.

Based on the mandates of the 1991 Constitution, by means of Law 142 of 1994, also known as the Law of Public Utilities, a competitive market model for the provision of public utilities in Colombia was introduced. The main goal of these reforms was to increase efficiency in the provision of public services, which should result in lower electricity prices, better quality of the service and a higher coverage index. Another goal refers to the introduction of private capital to increase the number of agents in the industry and to guarantee expansion of the network services.

For the power industry in particular, Law 143 of 1994 established the scheme that governs the different activities of generation, transmission, distribution and commercialization of electricity. In this sector, the reform was aimed to overcome the following market inefficiencies: (i) the public economic constraints threatening the capacity headroom of the overall system; (ii) the misleading power generation costs declared by power producers which were to be minimized by central planning; and, finally (iii) two major national black outs in 1983 and between 1992 and 1993 evidencing the inefficient water management policies of the central coordinator.

The participation of the Government in this competitive market model is carried out through an institutional structure that has not been modified since 1994, and which has three instances: definition of energy policy; regulation; and surveillance and control. The definition of energy policy is carried out by the Ministry of Mines and Energy. A major part of the energy policy is undertaken by the Planning Unit of Mines and Energy (Unidad de Planeación Minero-Energética, or UPME). The regulatory function is exercised by an independent unit CREG (Energy and Gas Regulation Commission), which is comprised of eight members. The task of surveillance and control over the provision of public utility services is carried out by the Superintendency of Public Utility Services.

In Law 143 of 1994 key elements and guidelines for the Wholesale Market (MEM is the Spanish Acronym) are also established; these came into operation on July 20, 1995. The operation, planning and coordination of the resources of the National Interconnected System are exercised by the National Dispatch Center (the

[4] This section was written based on: (i) the official documentation of CREG about the Reliability Charge, (ii) two working papers of Angela Cadena, Juan Manuel Alzate and Juan Benavides. Figures and tables were taken from the latest version of the Expansion Plan for Electricity Generation and Transmission.

System Operator). The MEM also relies on a central agency called Administrator of the Commercial Interchange System (the Power Exchange) for its effective operation; this agency is in charge of the registration of contracts, and the settlement and billing of all transactions that take place in this market.

Currently, the Colombian electricity sector contains a mixture of public- and privately-owned companies. In the generation sector, there are about three dozen active companies, and the major players are EMGESA, EPM, ISAGEN, Geselca, EPSA and Chivor.

Colombia's market has evolved as a hydro-dominated power market. Nowadays it counts on 13.5 GW of installed capacity for electricity production (67% hydro, 33% thermal, Figure 1.9). This capacity affords a peak-load of 9.3 GW. The hydroelectric production share oscillates between 90% and 45% of the system load according to the hydrological season. The aggregated water regulation capacity of the hydroelectric park is about 2.5 months which is (approximately) equal to the duration of a typical dry season in Colombia. Abnormal ENSO events, prolong either its duration or its intensity.

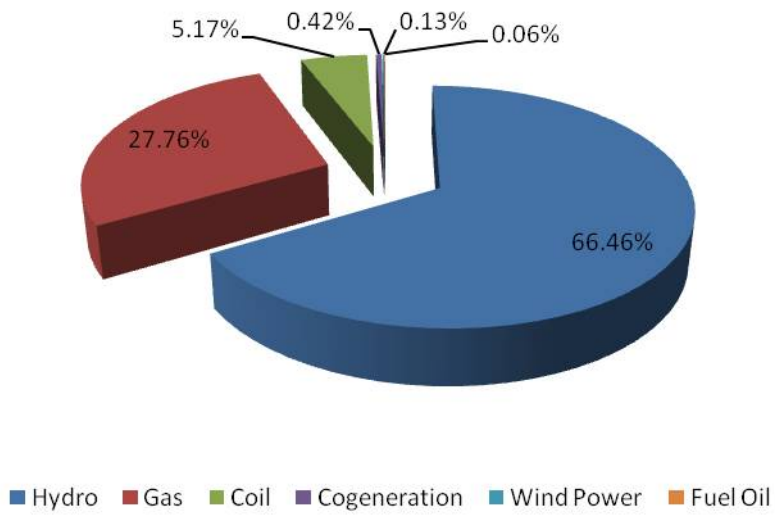


Figure 1.9. Participation net effective capacity by technology 2009.
Source: [42].

Today, the system load is 55 TWh/yr (156 GWh/day) and increases at an annual rate around 3.5%. The residential load share is 43%, followed by industrial (34%) and commercial (15%) loads. The daily load profile is spiky around nineteen hours, the on-peak hour.

To guarantee the reliability in the long term supply of electric energy, a Capacity Charge was established in 1996 as an income stabilization instrument for power generators. Despite the effectiveness of the capacity market in the five years following its introduction, the mechanism became stagnant afterwards. The administrated nature of the mechanism was strongly criticized by producers. CREG proposed a new market based mechanism [7], called Reliability Charge, which conveys a long term gesture to promote new investments in generation resources in Colombia, in order to guarantee the availability of electric energy at efficient prices in periods of scarcity.

This new regulation started to be implemented on December 1, 2006. The Reliability Charge, also known as the Firm Energy Market, intend to remunerate Firm Energy Obligations (FEO) auctioned to power producers

as required by the system itself in a medium-term planning horizon (i.e. 5 years). It favors income stabilization for power producers and, thus, the capacity installation process should overcome extremely dry seasons. The mechanism works as a call-option. Producers holding the option receive a risk premium in exchange of their commitment to deliver their correspondent FEO during scarcity periods (i.e. when the spot exceeds the scarcity price), at the scarcity price.

The mechanism was designed to be backed by 4 security rings progressively activated as required: a firm energy secondary market, a voluntary demand response program, the dispatch of last resource generation resources, and finally, FEOs reconfiguration auctions.

Two FEO auctions took place in May 2008. In the first one, a descendant clock auction, 3 state-owned projects competed against 7 private-owned projects. 351 MW of thermal capacity and 78 MW hydro capacity were allocated at 13.998 US$/MWh, as illustrated in Table 1.4.

Table 1.4. Energy requirements in the first auction firm's energy reliability charge.

Name	ORF start year	Capacity MW	OEF energy GWh/year	Resource
Gecelca	2012	150	1,116	Coal
Termocol	2012	201	1,678	Fuel
Amoya	2011	78	214	Hydro
Total		**429**	**3008**	

Source: [42].

The second auction, a sealed bid auction, held the same day allocated 2,991 MW to big hydroelectric projects, at the same price as the other result, shown in Table 1.5.

As a result of this preocess, the country will count on 77% of hydro capacity and a maximum of 23% of thermal capacity in 2018. These outcomes, which strengthen the hydro-dominated feature of the market in terms of the installed capacity, increase the vulnerability of the system in the face of climate events. In 1992, a severe drought left the country unable to meet electricity demand, leading to power rationing and periodic blackouts.

Table 1.5. Firm energy obligations through sealed bid auction on the reliability charge.

Name	ORF start year	Capacity MW	OEF energy GWh/year	Resource
Cucuana	2014	60	50	Hydro
Miel II	2014	135	184	Hydro
Sogamoso	2014	800	2,350	Hydro
El Quimbo	2014	396	1,650	Hydro
Porce IV	2015	400	962	Hydro
Ituango	2018	1,200	1,085	Hydro
Total		**2,991**	**6,281**	

Source: [42].

The FEO of the new Reliability Charge scheme establishes a legal link between the demand and the supply of the MEM. Demand is determined by CREG based on UPME's forecast of end-users needs. Supply is determined by generation companies. If electricity demand growth rate changes or allocated generation

resources fails, a FEO reconfiguration auction will be called by CREG. The hydro - thermal composition could slightly change.

1.5.2 Actions with Financial Support

Colombia will reduce deforestation in the Colombian Amazon rain forest to 0 by 2020

In Colombia the main causes of deforestation according to some government reports are the extension of agriculture and livestock, the displacement of people and settlements, illegal mining, illicit crop cultivation, wood extraction for sale and consumption as well as forest fires. Due to these causes, the total deforested area in the whole region during the last monitoring undertaken from 2000 to 2007 by the Scientific Institute of Amazonic Research- SINCHI was 768,300 Ha; this means that the annual deforestation rate in Colombia is 153,600 Ha/year [24].

Colombia has various legal, technical and economical instruments for deforestation control and reduction such as: Forest Organization, Management of Natural Forest Exploitation, Ban Establishment, Mobilization Safe-Conducts, Operations Log-Books, Environmental Licenses, and Special Management Areas. The economic instruments consist of Conservation Forest Incentive Certificates- CIF, Tax Exemptions, and Payment for Environmental and Ecosystem Services- PSA [33].

However, the regulatory framework is somewhat disperse and confusing. It has been issued for different activities and with diverse objectives and scopes. All of this enables and generates multiple interpretation criteria. The main organizations established to control the deforestation in Colombia are the MAVDT, the Administrative Special Unit of the National Natural Parks System and the Ministry of Agriculture and Rural Development. The actual undertaking of control activities is difficult, mainly because most of the deforestation causes are generated outside the forestry sector. There are several contradictory interests, eg. conservation vs. profitable land use. Taken all of this into account, this target seems to be extremely optimistic.

It is considered that an adequate policy framework should overcome the institutional barriers and seek the balance between efficiency, effectiveness and social justice. The causes of deforestation associated with governance include the lack of definition in land deeds, the recognized rights of ethnic minorities, and the inconsistency between the forestry regulatory framework and the sectoral regulation that has established very confusing procedures that may actually promote illegality.

Since the Political Constitution of 1991 came into force, the environment has gained a stronger legal and institutional position; the country has faced a series of challenges, like finding a balance in the present regulations concerning the management of forest resources - natural or planted, the definition of the institutions responsible for its application, the establishment of a series of incentives, and the creation of mechanisms that allow the articulation with related regulatory frameworks, such as territorial planning and land-use, as well as the economic and financial tools that contribute to the achievement of the objectives in conservation and sustainable use.

Colombia will stimulate the growth of biofuels production

The purpose of this NAMA is to stimulate the production of biofuels such as ethanol and biodiesel without threatening any natural forest or, indeed, the food supply. The aim is to fortify the participation of these

biofuels in the national markets in order to achieve mandatory mixes of at least 20% of the total volume of fuel used by 2020.

According to [34], Colombia has natural competitive advantages in this area such as the ones shown below:

- Government incentives and an advanced regulatory framework: Colombia has the most developed regulatory framework in the region along with Brazil. e.g: Up to 100% Income tax exemption for new investments in late-yield crops.

- Diversity of regions suitable for crop development: Out of 41 million hectares suitable for agro development, 6.5 million have potential for biofuels.

- High crop Yields: Colombia is the world's fifth palm oil producer and counts with the highest sugar cane productivity due to its location in the tropical zone with the highest efficiency in bioenergetic production.

- Colombia's biofuels production does not threaten its alimentary security: 41 million hectares available for crop development, privileged weather conditions and a surplus in the production of raw materials. The 6.5 million hectares suitable for biofuels are mostly inappropriate for the development of alimentary related crops.

- Colombia is a leader in the sustainable production of biofuels: regulation for the consumption of biofuels to achieve greenhouse effect gas reduction (ethanol use at 10% (E10) and currently biodiesel at 5% (B5)) together with the availability of land for biofuels related crops where it is no longer possible to have forest or jungle.

However, the number of hectares for cultivation of sugar cane is not expected to grow, so we do not expect an increase in the existing mix of ethanol (it is presently 10%). On the other hand, it is expected that more than 500,000 hectares will be added to the 443,000 hectares currently in use for palm oil by 2020, and so, according to experts of the MAVDT the mix of biodiesel is likely to increase to approximate 15% in 2020.

1.5.3 Actions Related to Carbon Markets

Support the use of the market as mitigation mechanism

Colombia supports the use of the carbon market as a GHG mitigation mechanism. The Group of Climate Change Mitigation was created in 2002 to encourage and approve all CDM projects, it promotes mitigation actions and supports the country in international negotiations. In addition, a CONPES document called ``National Strategy for the sale of environmental services and the Climate Change mitigation'' issued in 2003 contemplates the following recommendations:

- The creation of the Inter-sectoral Technical Committee for the mitigation of Climate Change. Its task is to design and guide all proposals for Climate Change Policy. It will be the main consultant of the MADVT in the approval of CDM projects.

- The MAVDT will establish the procedures and issue the criteria for the approval of the CDM projects.

- The MAVDT together with the Ministry of Mines and Energy, the Ministry of Agriculture and Rural Development and the Ministry of Industry, Commerce and Tourism will include the concept of environmental services of Climate Change mitigation in their programs and general policy.

Consequently, in 2004 the MAVDT issued Resolution No. 0453 and Resolution No. 0454. The objective of Resolution No. 0453 is to establish the procedures and issue the criteria for the approval of the CDM projects, as it was proposed in the CONPES document. On the other hand, the objective of Resolution No. 0454 is to create and regulate the Inter-sectoral Technical Committee for the mitigation of Climate Change. This Committee was initially created with two different kinds of members, permanent and subject specific. The permanent members are:

- The Coordinator of the Climate Change Mitigation Group of the MADVT.

- The Director of the Urban Development and Environmental Policy Direction at the National Planing Department.

- The Director of Colciencias.

These members can invite subject specific experts to the meetings. The tasks assigned to this Committee are:

- Design and guide all proposals for Climate Change Policy.

- Develop recommendations for the approval of projects that apply to the CDM.

- Follow up the implementation of the CDM projects in the country.

- Develop a strategy to get national and international resources to finance Climate Change mitigation projects.

- Make sure the country has all the technical knowledge required to implement such projects.

Unfortunately, these Resolutions and, therefore, the Committee were countermanded by the Resolution 0552 of 2009, that modified the initial structure of the Committee leaving only the officials of the Vice-ministry of Environment as permanent members. Thus, the Committee lost the inter-sectoral content that was initially intended.

At the end of year 2010, the MADVT issued the Resolutions 2733 and 2734 that updated the requisites and procedures for the approval of CDM projects.

Total emissions reduction of up to 54.8 Mt CO_2 by 2012 through the implementation of the CDM in the energy, forest, industrial, transportation and waste management sectors

As it was mentioned above, the identification of reduction options, project registration and approval process to finally have CERs emmisions come up have been cumbersome and long. Therefore, we consider this goal to be a bit over optimistic.

Emissions reduction by deforestation and forest degradation program

The first and fundamental objective of the Reduced Emissions by deforestation and forest degradation program (REDD), is to decrease carbon dioxide emissions caused by forest clearing activities. Bali's Action Plan stated that a comprehensive measure to mitigate Global Change must include political approaches and positive incentives that allow a reduction in emissions derived from deforestation and forest degradation, while considering conservation function, sustainable forest administration, and the rise in carbon stock in developing countries' forests [13].

The REDD mechanism has a broad-spectrum potential. While it oppose Global Change, it can help reduce rural poverty by providing incentives to communities settled in forests, and can also contribute to the conservation of biodiversity and to the promotion of the maintenance of vital ecosystem services.

Colombia, as well as the other Kyoto Protocol signatories, is negotiating the details that will define the way that REDD actions can be implemented under the framework established by the UNFCCC. At the same time, the country has been moving forward in the attainment of international support in order to strengthen its technical capacity and respond to the technological, human and institutional requirements associated with the development of REDD projects.

The country's main strategy is to strengthen the capacity of tracking and monitoring the forest coverage, as well as the standardization of base lines for REDD projects. In this moment the nation is developing the proposal document of the country's preparation, which involves several institutions like the MAVDT, UAESPNN[5],IDEAM and the World Bank.

In the broad-spectrum of potentialities of the REDD mechanisms, it is possible to highlight several things: About 48% of the 1,038,700 km^2 of continental land of the country has forest and rainforest coverage [33], which indicates that there is a huge amount of land where REDD projects could be implemented. Annual deforestation ascended to 101,300 ha/year in the period 1994-2001, and the primary causes of this problem are well known. Also, more than half of the country' natural forest are located in lands that belong to Indigenous and Afro-Colombian communities, which gives legal security as to land possession.

On the other hand, REDD mechanism has a series of limitations, which include the following: There are zones in the country where it is not possible to guarantee deforestation control by means of projects involving local communities. However, the regions where this does not occur have been clearly identified. It is necessary to develop a forest inventory, and to improve the monitoring of changes in forest coverage by adding more levels of detail to the tracking. Likewise, it is mandatory to quantify the carbon contents in different ecosystems more accuractly in order to improve the exactness of figures concerning historical

[5] UAESPNN: Administrative Special Unit of the National Natural Parks System.

deforestation at a local and national level. Armed conflict continues to be present in diverse rural zones throughout the country, generating a constant threat to possible REDD projects [33].

Encourage commercial reforestation through the use of Forest Incentive Certificates

The Government created and regulates the Forestry Incentive Certificate (CIF for its Spanish acronym), by means of Law No. 139 of 1994 and its Regulatory Decree No. 1824 of 1994, which compensates the environmental and social benefits generated by reforestation.

This Certificate represents a direct payment that the Government makes for the creation of new commercial forest plantations in order to cover part of their establishment and maintenance expenses. These plantations must be established on land suitable for forestry with one or more tree species to produce wood and alternative products such as essential oils, latex, resins, tannins and gums.

The recognition could be:

- 75% of total net costs of a plantation which makes use of native species, which are those that by natural distribution and origin have been reported within the geographic boundaries of the country.
- 50% of the costs of plantations with introduced species, which are those whose origin comes from a natural range outside of the country boundaries.
- 50% of total net maintenance costs incurred from the second to the fifth year after planting, whatever the type of species.
- For those Establishment and Forest Management Plans for which an Incentive for maintenance of natural forest is requested, this could be paid for an area equivalent to 20% of the new area under the CIF for the establishment of the plan.

After fifteen years of operating the Forestry Incentive Certificate, the Ministry of Agriculture and Rural Development structured a proposal for updating the CIF Operational Manual which aims to optimize its implementation and operation.

This proposal was submitted for consideration by the Council members of the CIF, and once the feedback to the proposal is received, the new CIF Operational Manual will be formally adopted. Thus, the corresponding institutions will have the tools to improve the implementation and operation of the incentive, from the technical point of view, as well as from a regulatory perspective[20].

1.6 Undergoing Mitigation Actions and Future Projects[6]

1.6.1 Energy

Expand reliance on wind power by 2020 to 5 percent of Colombia's electricity generation (could also include target and incentives for geothermal)

According to the UPME's Reference Expansion Plan of Generation and Transmission for 2010-2024, electricity demand will reach 80,000 GWh in 2020 (being . 56,200 GWh in 2010). To supply this demand, UPME estimates that a new generation capacity of 3470 MW is required. We assume that the target means supplying 5% of the new demand using wind plant, that is 1190 GWh. Therefore, by using a capacity factor of 0.34, this means that we are expecting to install a new wind power capacity of arounf 400 MW, that is 11.5% of the new installed capacity.

In agreement with [6], the potential of energy generation with wind power is about 35,000 MW. At the present time, Colombia has 19.5 MW installed with wind power in the Guajira region since 2004. Moreover, ISAGEN is working in the design and economic evaluation of a new wind farm of approximately 31.5 MW, which is also located in La Guajira. This measure has pros and cons as is listed below:

Pros: the local experience in management and use of this technology, big potential for power generation, local interest to increase the generation of energy which is reflected in research (e.g San Andrés (Universität Freiburg Institut für Forst- und Umweltpolitik)) and new projects (e.g Jouktai (ISAGEN)) undertaken by private firms and wind availability (speed above $10m/s$ in Jepirachi). With the information provided in [17] wind power is a good option to complement hydro-generation because, as is shown in Figure 1.10, in any dry period, Jepirachi produces 10% percent more energy than its yearly average [45] and vice versa.

Cons: wind power has some disadvantages over traditional generation plants in Colombia such as hydro and thermal (coal and natural gas) plants. According to the total system levelized cost of a new generation plant provided by the DOE/EIA in [16], the levelized cost of wind power is higher than those of hydro, coal and natural gas. In addition, the capacity factor of wind power is the international capacity factor [16], around 34% compared with 52% in hydro, 85% in coal and 87% in natural gas plants. That means that the installed capacity necessary to produce 1 MW is higher.

Considering this information, the expansion of the total installed capacity of generation in Colombia with wind power could be feasible if we consider the complementarity projects between wind power and hydro generation. CREG has already issued a procedure to estimate the energy that a wind project can commmit as firm energy. However, 400 MW of wind power in 2020 seem to be very high given the current projects under study and the commited capacity under the reliability charge mechanism.

[6] This section was prepared base on a report prepared by Center for Clean Air Policy after different meetings and interviews.

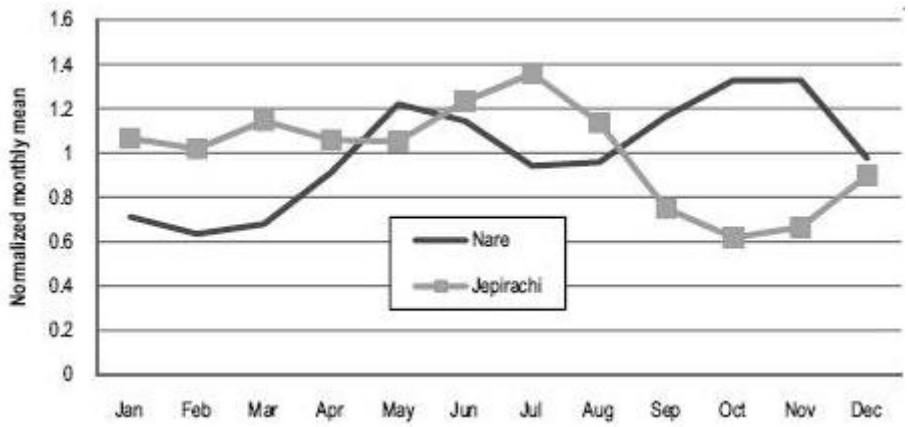


Figure 1.10. Mean Monthly Values at the Santa Rita Dam Site on the Nare River.
Source: [45].

Increase the reliance on energy efficiency as a way to reduce potential reliance on thermal generation as backup to extensive hydro resources

This measure proposes a strategy to improve the energy efficiency of electricity-consuming equipment in order to reduce reliance on thermal generation as firm backup to hydro resources. The Ministry of Mines and Energy believes there are extensive opportunities for energy efficiency in the residential and commercial sectors such as programs to encourage efficient lighting, incentives for using efficient appliances, and replacing inefficient motors. The energy efficiency and renewable energy action plan has established indicative specific energy efficiency goals per sector.

According to the consultants, this measure has the pros and cons that are listed below:

Pros: there are a variety of possible actions to encourage efficiency and UPME is assessing various financial or market options.

Cons: Colombia does not have an energy service company sector of any significance, and commercial banks have no experience financing such measures. Generators currently have no incentives to promote demand reduction by their customers – as it would simply reduce generators' revenues.

The research group agrees with the concerns of the consultants. In addition, we could add that the results obtained from the different initiatives have been rather poor. However, things would appear to have started to change in this new era of high oil prices and environmental concerns.

Additionally, as may be seen from the title of the potential NAMA, if we assume that the goal is to promote energy efficiency in the context of a demand response program, it could be of much interest. The reliability charge has been presented above; it has a security ring called voluntary disconnectable demand. Promoting demand participation would be of a tremendous significance for the retail market.

1.6.2 Transportation

Electric vehicles

The transportation sector is one of the main GHG emitters in Colombia. According to IDEAM (IDEAM, 1999 and IDEAM, 2007), the GHG emissions were 129,4 $MtCO_2eq$ in year 1990 and 178,8 $MtCO_2eq$ in 2004. In

2004, the emissions of the agricultural and energy sectors were 38.1% and 36.65% of the total country emissions respectively. Energy emissions are conformed by transportation (12,1%), generations and transformation of energy (8,5%), manufaturing industry (7,3%) and fugitive emissions (5,1%). The contribution of the transportation sector is significant because of its big share of total energy consumption. According to UPME, the transportation sector is responsible for more that one third of the total final energy demand. On top of this, 90% of the sector uses fuels that come from oil.

Some utilities (EMGESA, CODENSA and EEPPM) are fostering an initiative to introduce electric vehicules for public and freight transportation. In particular, there is an ongoing initiative of a NAMA for electric transportation in Bogota and its suburbs. The research group is evaluating a NAMA aimed at the substition of gasoline cars by electric vehicules for urban transportation nationwide. This proposal and results are presented in the next part of this document.

Reduce transport-related emissions by supporting integrated urban strategies to complement Bus Rapid Transit efforts in key cities across Colombia

Colombia has eight Bus Rapid Transit systems operating in its most important cities. Bogotá, Medellín, Cali, Barranquilla, Bucaramanga, Cartagena and Pereira are implementing sustainable mass urban transport systems to improve the mobility of the citizens while reducing GHG emissions.

However, these projects are part of a National Land Use Plan ("Plan de Ordenamiento Territorial") that integrates physical and socio-economic planning of the country. To execute this Plan, the government uses an instrument call Master Plans. In this section we are going to explore some urban strategies that complement BRT's system in Bogotá, given the master plan of the city, that have more or less the same strategies that could be implemented in the other cities that have BRT systems.

Bogotá's mobility system, the Master Plan for 2006 (Decreto 319. Movilidad para Bogotá Distrito Capital) has the ``policies, strategies, programs, projects and goals related to mobility of the Capital District, and establishes general rules for achieving safe mobility, which is fair, intelligent, articulated, environmentally friendly, institutionally coordinated, and financially and economically sustainable for Bogotá and the region" (Decreto 319. Movilidad para Bogotá Distrito Capital. Artículo 8). At an environmental level, the Plan aims to reduce levels of pollution from mobile sources and to incorporate environmental criteria to produce a system of eco-efficient mobility.

Taking the above into account, the Plan defines an integrated public transport system for Bogotá that has to guarantee, among other things, the right of the citizens to a healthy environment, by generating an organized, efficient and sustainable public transport system in the urban area of Bogotá. (Decreto 319. Movilidad para Bogotá Distrito Capital. Artículo 13). Act 309 of 2009, Articule 1, ``Adopción del Sistema Integrado de Transporte Público'' adopts the Integrated Public Transport System, the "SITP" as the district public transport system in the city of Bogotá. Bogota's integrated public transport system had to be made up of:

- Massive transit.
- Public transport system.
- Individual public transport.

- Network modal interchanges.
- Station networks.
- Toll networks.

In order to obtain an improvement of the public transport and prepare for further integration, in 2007, Bogotá's authorities began technical studies that were oriented to establish:

- Hierarchy of routes.
- The definition of the modernization process of transportation equipment.
- The definition of infrastructure.
- The adoption of the tariff system.
- The integration of revenues.

Nowadays, the SITP has structured its base line, it has hierarchized roads, it also has a conceptual, detailed engineered, operational, financial, legal and rate design and it has a defined collection system. Moreover, in 2008, the local authorities hired a firm to undertake the "conceptual design of the network of mass transit subway and operational design, financial and legal dimensions of the first line under the integrated public transport system, SITP, for the city of Bogotá" to then continue with the basic design and construction details.

The District has finished the first three stages, with 30 products, starting with the diagnosis document, the transport model, trip matrices, present and future scenarios, legal and regulatory framework, executive summary, financial analysis and recommendations of the transport sector, economical and technical technologies' document, evaluation of different networks for the subway -SITP-, selection of the subway network of SITP, prioritization of subway network lines -SITP-, database, flat designs of the First Metro Line - PML and its area of influence, procurement specifications of engineering, environmental and socio-land studies for the PLM Bogotá, terms of reference of the infrastructure design for the PLM and an analysis of the tariff structure of the Integrated Public Transit system. The document for the financing ofthe project has just been signed. The next step is to hire an environmental, and social study and to design the infrastructure for the PLM.

Another strategy to complement the SITP is to build a Metro Cable in Bogotá. Until now, the district has identified 8 paths for locations and according to the multi-criteria analysis classification; they found that the path Tunal Portal - Paradise in Ciudad Bolivar, was chosen as a priority. This option was socialized with the local mayor of Ciudad Bolivar and has begun phase of technical studies at the profile of this path.

An additional strategy to reduce transport-related emissions is the bike path system, which consists of a growing network of exclusive lanes (more than 300 kilometers) for the exclusive use of bicyles.

Expand freight truck clunker scrappage program and provide financing incentive for diesel engine retrofits

The current situation of the freight transportation business and the scrappage incentives has some facts worth mentioning. In Colombia, the average age life span of the truck fleet is 23 years and the existing scrappage programs are very limited. Since 2008 only 4,000 of more than 200,000 trucks have been scrapped. On top of this, there is no current program for engine technology renewal in Colombia. The air pollution and CO_2 emissions are significant and have major health effects in urban areas.

As well as in any other NAMA, there are several policy barriers and obstacles for achieving the goal. First, it is important to highlight that freight is a public service with nationally regulated rates. Truck owners are private individuals who operate under government regulation in a competitive market. Such market provides very few incentives for air pollution improvements and the drivers tend to be individual operators who do not have enough capital to improve the efficiency of their engines even though it would improve their bottom line. There is also an important political issue with the fact that Truckers are politically influential, well-organized and very resistant to change.

In order to overcome all these issues, some potential national policy actions are proposed. For example, the expansion of truck scrappage program. The introduction of an incentives program is also necessary, more specifically for the engine retrofit. The addition of a new financing mechanism is a viable solution, specially with the help of the NAMAs donors. This financial support should match the program where donors contribute to cover portion of costs if penetration of program helps develop the UNFCCC objectives.

Expand rail and water freight options as way to reduce truck freight traffic and related emissions

This subsection also begins with a brief description of the current situation on the matter. The new National Development Plan 2010-2014 calls for increase in the rail and water freight infrastructure. The specific goal set by this government is to double freight railways in the next 4 years and increase the navigable area of the Magdalena river by 4 times - from 200 km to 800 km- by 2014.

98% of freight in Colombia is moved by truck. The main exception are the privately built rail lines run by coal companies to ports for the exportation of coal. The expansion of the rail and the navigable transportation has direct air and GHG benefits as well as indirect benefits due to reduced congestion of auto traffic.

Nevertheless, there are a few policy barriers and obstacles to the implementation of a project like this. To expand navigable waterways will require dredging and environmental permits. There is a very complicated bureaucracy. Also, there is a need to renew the old technologies in order to introduce efficient ones for waterway transport. This is complicated due to the low cost of two-stroke engines when compared with clean technologies.

On top of all this, there is of course the political resistance from organized truckers associations that would have their incomes reduced by this project. There are also several issues with the location of the proposed expanded rail lines.

In order to overcome all these issues, some potential national policy actions are proposed. First of all, it is very important to propose policy goals to the Congress in order for them to understand the magnitude of

the project and demand their collaboration. Once this is carried out, there could be a way of creating new financing mechanisms.

The nature of the financing support required is the concessional loans sort. The main advantage of this financing instrument is to reassure the long term. Of course for this to be done, there must be some risk guarantees for the investors and developers.

2 Specific Examples of Mitigation Strategies

This part contains a preliminary proposal for a NAMAs in the Transport and Agriculture sectors. First, the regulatory framework, basic elements and possible templates for a NAMA are presented. Then, a proposal for a NAMA related to the introduction of Electric Vehicles in the urban transport sector and a preliminary approach for a NAMA in the potato crops are presented. This part ends with a short proposal for a MRV system and conclusions.

2.1 Designing a NAMA Structure

2.1.1 Regulatory Framework and General Elements for all NAMAs

NAMAs originated in the 2007 Bali Action Plan paragraph 1 (b)(ii) which states that "enhanced national/international action on mitigation of climate change" should include "nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner."

At the COP16 in Cancún, the Parties from developing countries agreed to implement NAMAs voluntarily to reduce business-as-usual emissions by 2020. On the other hand, for the developed countries, the Cancun Agreements confirmed the pledges made under the Copenhagen Accord, namely "to provide fast-start finance in the amount of USD 30 billion for the period 2010-2012. Long-term funds are committed annually to reach USD 100 billion (EUR 0.72 billion) per year as of 2020" [21]. These funds target mitigation and adaptation activities in developing countries.

Even though 8 million EUR have already been assigned, the regulatory framework under which NAMAs will operate is unclear and there is no guidance or official examples of NAMA design. There are three different ways of funding NAMAs:

- Domestically supported NAMAs;
- Internationally supported NAMAs;
- Market-based or credited NAMAs.

The electric vehicle NAMA proposed in this document falls into the second and third category.

In order to obtain support from the UNFCCC, the NAMA must have at least some general elements. The Cancun Agreements build on the NAMA concept as it was first presented in the Bali Action Plan and they include these four general elements:

1. NAMAs should be appropriate for the national circumstances and development needs of the developing country.
2. NAMAs should promote the country's sustainable development.

3. NAMAs are accessible to developed country support (technology, finance, and capacity building).

4. They should be Measurable, Reportable, and Verifiable (MRV). The NAMAs (and the support from developed countries) are subject to international or internationally defined MRV.

There are no technical limitations on how an action may become a NAMA except that it has to meet the measurement, reporting, and verification requirements (MRV) as well as climate goals. A plausible NAMA proposal may include elements such as a "description of the current situation, how the action reduces emissions below business-as-usual, resources and international support required, an implementation plan, and MRV provisions" (NCCPF 2010). For actions that require international support, the Cancun Agreements state that the MRV can be domestically subject to international supervision in accordance with the Convention guidelines. The point of the MRV is to standardize a model applicable to different NAMAs in order to make them understandable for the international community.

A proper NAMA design should attract the private sector to contribute financially in order to meet the pledges made in the Cancun Agreements. "Despite the financial incentives from the CDM, many mitigation activities that are financially viable are not taken. NAMAs should identify and remove the barriers that these mitigation activities face" [21].

2.1.2 Specific Elements for these NAMAs

The extra elements that have to be included in the NAMA proposal are both sector and country specific. Some technical, social and economic issues that must be included are exclusive of the transport and agricultural sectors in Colombia. These issues will be addressed by building a baseline and showing how the NAMAs create scenarios that diverge from business-as-usual. There are two templates that complement each other in demanding all the information needed to build the two NAMAs properly.

In July 2010, The Global Climate Change Consultancy together with Ecofys updated the "Sectoral Proposal Templates that aim to support developing countries in proposing sectoral emission baselines under a post-Kyoto climate regime. The sectoral approach underlying this work is seen as a means to scale-up investments in clean technology and systems in developing countries" [22].

The objective of these two firms when writing the sectoral proposal templates was to build a tool for countries to provide understandable information on the sectors, and therefore, facilitate negotiations at an international level. The key issue is that developing countries prepare their proposals so they,

1. "can be understood by the other countries during the process"

2. "will be seen as a credible starting point with the right ambition level"

3. "provide means to negotiate the proposals through analysis of specific underlying elements and drivers."

As it was mentioned before the template is based on the analysis of the following three scenarios:

1. "The Reference scenario which includes currently implemented national projects, existing external support and the effect of CDM projects."

2. "The Sector crediting baseline representing the 'Reference scenario' plus additional, future national projects and future external support. Thus, the sector crediting baseline would be set at a conservative level, meaning that the amount of emission credits granted to the country would be smaller to some extent than the reduction below the BAU level."

3. "The Ambitious scenario represents the emission level which is considered to be achievable if induced by the sectoral no-lose target."

Specifically, the template is organized as follows. It begins with basic background information on the country such as size, population, main metropolitan areas, geographic characteristics, GDP, GDP growth and main economic activities. This part of the template is the same for all sectors. To be more precise, the template has a section regarding the historical and present situation of the sectors.

In order to follow the objective of building a baseline, the template has a section regarding sector specific policies. This section includes currently implemented national policies and measures, current and planned external support, planned national policies, further policies, new external support, CDM projects in the sectors and a comparison with policies implemented internationally. With all this information to hand, the modeler can build the scenario projections. For this, it is important to state the assumptions for the three scenarios mentioned above. Following the results section, there must be some conclusions about the political commitments for the sectors.

The Center for Clean Air Policy (CCAP) is a recognized think tank based in Washington D.C. They developed their own template that has been discussed with members of many ministries in many different countries. It requires very specific information but goes in the same direction as the template mentioned above. The main difference between the two is that this template requires much more detailed financial information and does not require a scenario building methodology.

2.2 NAMA: Electric Vehicles

The beginning of this subsection is a brief description of the most relevant studies for the Electric Vehicles NAMA as a justification for choosing this specific project. Most of the alternatives for environmental friendly transportation technologies are included in the Fourth Assessment Report of the IPCC, therefore a brief review of the document is in order. Following this, two studies (one international and one national) shall be presented, followed by the most representative transportation project in Colombia: Transmilenio.

The **Fourth Assessment Report of the IPCC** categorized 13 mitigations options under 6 categories for the road transportation section. All these mitigation actions are valid for both Private and Public transportation. Categories 1-3 are mainly technological while 4-6 are mainly educational (cultural).

1. Reducing vehicle loads:

    a. A 10% reduction of total vehicle weight. This can improve fuel economy by 4-8%.

b. Aerodynamics improvements for better vehicle performance, especially at high speed.

c. Control System and Airflow Management in mobile air conditioning. This contributes to mitigate GHG emissions in two ways, by direct emissions from leakage of refrigerant and indirect emissions from fuel consumption.

2. Improve drive train efficiency:

a. Advanced direct injection helps through engine efficiency. This means less fuel consumption.

b. Hybrid electric drive trains combine a fuel-driven power source with an electric drive train. This technology replaces partially gasoline/diesel consumption with electricity, which in the Colombian case has nearly 0 emissions.

3. Alternative fuels:

a. Pure Biofuels or a mix with other automotive fuels. These are fuels made from Biomass.

b. The use of Natural Gas because of its good emissions characteristics.

c. Fuel cell vehicles7 that use pure Hydrogen or a mix with other automotive fuels.

d. Pure electric vehicles powered from off-board electricity delivered through a conductive contact or by electricity acquired from the grid and stored on-board in batteries.

4. Well-to-wheels analysis[8] of technical mitigation options. The intention is to study the entire fuel pathway in order to determine the validity of the mitigation action.

5. Road transport: mode shifts
   a. The expansion of public transport in the form of large capacity buses, light rail transit and metro or suburban rail.

   b. Non motorized transport taking into account the local conditions.9

6. Improve driving practices (Eco-driving) with the help of formal training programmes or on-board technology aids. Such practices include smoother deceleration and acceleration, keeping engine revolutions low, shutting off the engine when idling, reducing maximum speeds and maintaining proper tire pressure (IEA, 2001).

[7] Vehicles that gain their energy from chemical fuels.

[8] Complete vehicle fuel-cycle analysis.

[9] "`In Bogotá, in 1998, 70% of the private car trips were under 3 km. This percentage is lower today due to bicycle and pedestrian facilities. The design of streets was so hostile to bicycle travel that in 1998 bicycle trips accounted for less than 1% of total trips."'[26].

The Role of Driving in Reducing GHG Emissions and Oil Consumption [4]

The Role of Driving in Reducing GHG Emissions and Oil Consumption is a study undertaken by Embarq and the WRI. The study explores whether technological improvements alone can achieve the reduction targets in oil consumption and GHG emissions consistent with recent legislation on climate change. The study finds that the United States must achieve significant improvements in vehicle technology and reduce vehicle miles traveled per capita (compared to business as usual) to meet these targets.

According to the study, the U.S. Department of Transportation should take the following actions [4]:

1. "Encourage states and regions to boost usage of existing funding flexibility to increase investments in transportation strategies that reduce VMT, GHG emissions, and oil use."

2. "Provide technical support for standardized evaluation of programs and projects."

3. "Simplify public access to DOT's project spending databases to promote evaluation of spending patterns and encourage transparency and accountability."

The Evaluation of Electric Transportation Alternatives in Colombia [48]

The Evaluation of Electric Transportation Alternatives in Colombia was undertaken by the Econometria Consulting Company which was hired by UPME. The aim of the study is to evaluate the viability of alternative (electric) transportation systems at regional and urban levels. The study consists mainly of an impact evaluation based on simulations of feasible technology alternatives. The main conclusion of the study is that for all alternatives, except taxis, electric or hybrid technology is more expensive that the traditional means of transportation.

Specifically in private transportation, the introduction of hybrid and electric cars can only be expected in the long term due to limited driving range and high costs. For other private vehicles such as electric bikes and motorbikes, the introduction is more imminent due to lower costs. Nevertheless, the price differential to regular combustion vehicles may impose a barrier together with the long time it takes them to charge.

In public transportation, the introduction is more plausible because entire fleets can be bought at a much more accessible price. The main constraint is that for heavy duty vehicles, the maximum capacity is 3 tons.

For Massive Public Transportation (Metro, cable car, etc.) which are vehicles powered from off-board electricity delivered through a conductive contact, each case should be studied on its own merits. The reason for this is that every city has different needs and resources.

Transmilenio

Transmilenio is Bogota's Bus Rapid Transport System (BRT). It was introduced in 2000 as part of a city transformation that aimed at reducing the dependence. Specifically, the aim of Transmilenio is to get people to switch from private to public transport and improve the standards of comfort, speed and security. In 2007, the system transported an average of 950.000 passengers per day.

The public sector is in charge of the investment in infrastructure of the stations and the 84km of trunk routes[10], and the private sector is in charge of the operation of the system. The average time taken by a traveler decreased 32% since the introduction of Transmilenio. The travel fare is 6% higher than the private bus companies enabling them to be competitive and profitable.

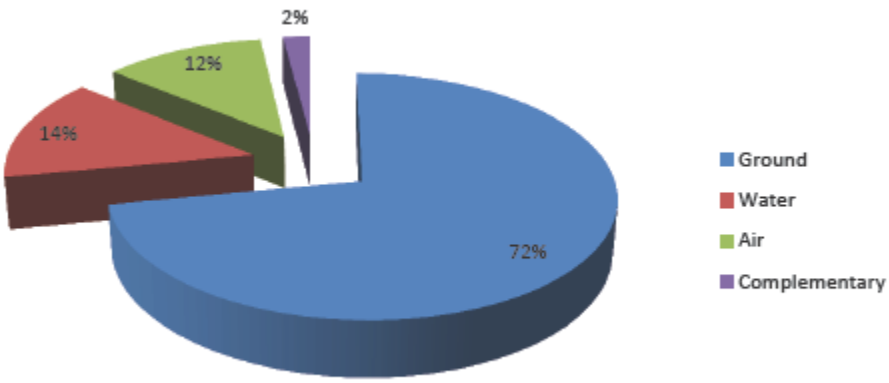
One of the key environmental impacts of this BRT is that 10% of the Transmilenio passengers switched from privately owned vehicles, making reference to one of the IPCC actions mentioned above. "For the year 2015 the goal of the Transmilenio project is to have 85% of the population of Bogota live within 500 meter of a Transmilenio station. This includes a projected increase to a total of 207 km of trunk lines [...] The latest phases of the Transmilenio project (Phase II - IV) have been accepted as the first CDM project in the transport sector and for the years 2006 till 2012 an average emission reduction of 246,563 t CO_2/years was estimated" .[49]

2.2.1 Descriptive Analysis of the Transportation Sector in Colombia

The objective of this subsection is to present a descriptive analysis of the transportation sector in Colombia. The economic and demographic growth that Colombia has experienced in the last 50 years has lead to an important transformation of the sector, switching from maritime and rail, to road and massive urban transportation systems.

In this sense, the car manufacturing sector forms 0.5% of the total national GDP. Within this sector, there are three main subsectors: manufacture vehicles, vehicles' body and autoparts. Nevertheless, in comparision with with international standards, this participation is relatively low. In the United States, the participation of the transportation sector in total GDP is 14%. Figure 2.1 shows that the most representative modes of transportation in Colombia is ground transportation.

According to the Ministry of Transportation (2008), there are 5.3 million vehicles in Colombia. From this total, Figure 2.2 shows the distribution of the different vehicles with motorcycles being the highest represented . A fact worth noticing is that the metropolitan area of Bogota, together with that of Medellin, both have 50% of the total.



[10] These enable the uninhibited movement of the buses.

Figure 2.1. Participation of the different modes in the transportation GDP, 2007.
Source: [8].

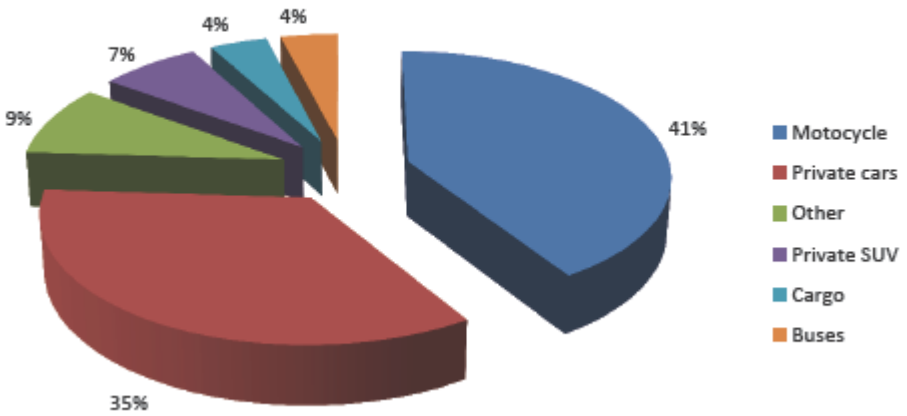


Figure 2.2. Percent distribution of different vehicles.
Source: [44].

The private vehicle category includes taxis with a 18% participation. In the bus category, the biggest participation is for public service but 25% are private (e.g. schools). For climate change analysis, the age of the fleet is important. 16% of the total vehicles are 20 years or older. This is because of the lack of a scappage policy and the interest of the low income population to have a cheap car. The high age of the fleet means more accidents, more fuel consumption and high GHG emissions. In Colombia there are 120 vehicles per 1000 people. This is still a small amount but is growing at very high rates.

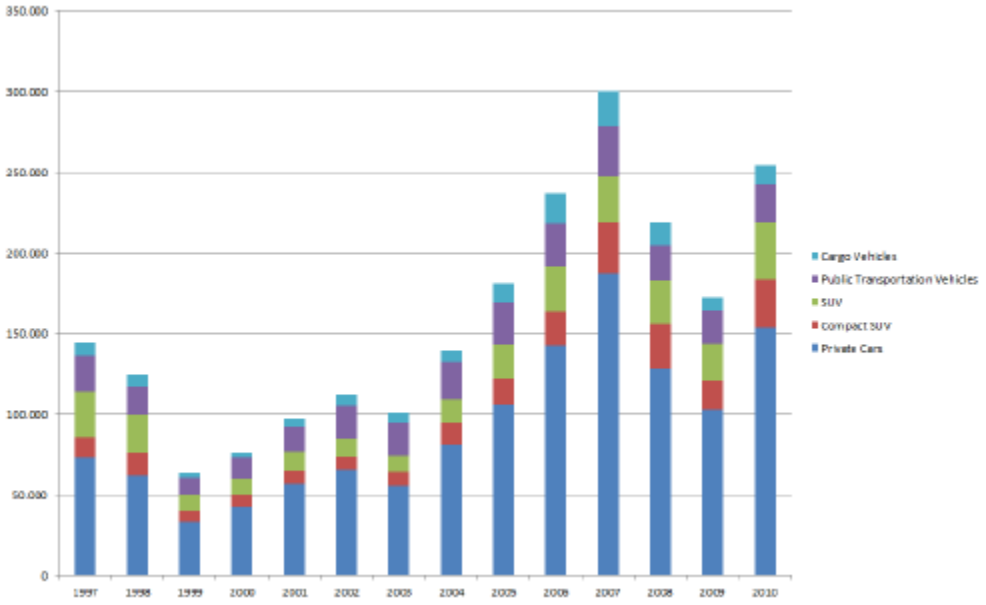


Figure 2.3. Number of national and imported vehicles sold.
Source: [40].

Figure 2.3 shows the number of national and imported vehicles sold in Colombia from 1997 to 2010. The graph is divided into 5 different categories: private cars, SUV's, compact SUV's, public transportation vehicles and cargo vehicles. The biggest proportion corresponds to private cars followed by the other four categories that are roughly equally representative. 2007 held the record for the highest sales, which was followed by 2010. The slow downturn of the industry has a strong correlation with the financial crisis of the end of the first decade of the century.

[37] found that the transportation demand is pro-cyclical with respect to private consumption and national GDP. The paper demonstrates in an analysis from 1993 until 2008 in which it is shown that between 1993 and 1999 both transportation demand and private consumption experienced a progressive downturn and a respective recovery from 2000 onwards. Nevertheless, the recovery does not appear to be as dynamic as it was before the 1998- 2000 crisis. The average growth rate of the transportation GDP in the period of study is 4.4%.

It is important to notice that the expenditure on transportation is more volatile than private consumption. When the economy experiences a boom, the expenditure on transportation increases more with respect to private spending and when the economy experiences crisis, it is the other way around.

Other situations that have encouraged the growth of the fleet in Colombia are, for the example, the increase in monthly income that lowered the cost of vehicles. Another important reason is the lack of a secure and efficient public transportation system. Also, the lack of taxes that take into account the externalities associated with private transportation [44].

[14] estimates that the scenario without constraints would lead to a fleet with 7.3 million vehicles and 9.4 million motorcycles for year 2030. The forecast for population in that year is 56 million inhabitants. The rate of vehicles per 1000 people is 130 which is still small compared to other countries. Lastly, the modes of transportation chosen by the Colombian people are shown in Figure 2.4.

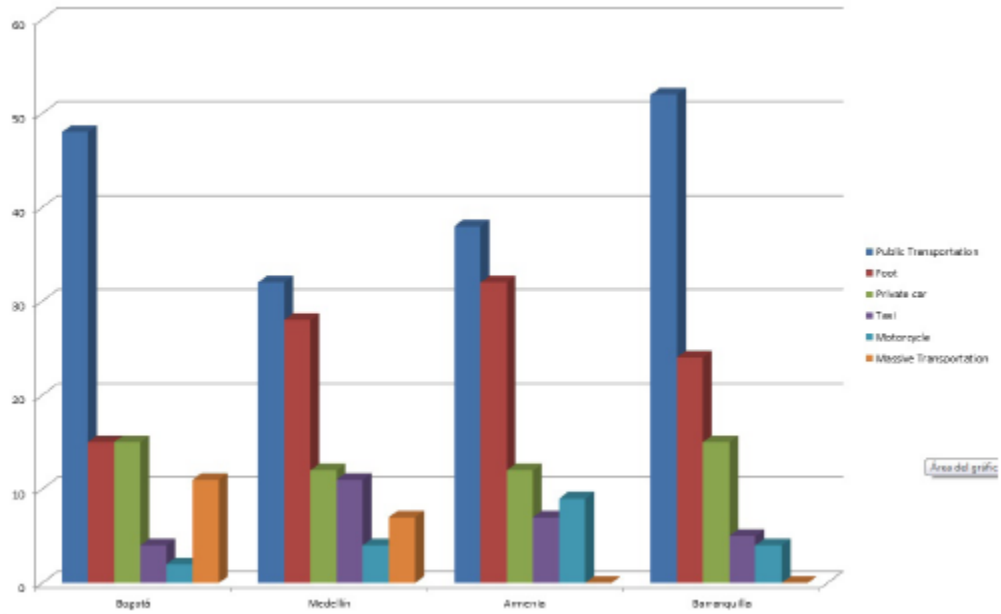


Figure 2.4. Modes of transportation chosen in some cities.

Source: [44].

The most remarkable feature about Figure 2.4 is that in every city, the most representative mode of transportation is public (collective) transportation. The number of buses per person (3.1 per 1000 people) in the main cities of Colombia is much higher than in other Latin American cities, such as Santiago, Curitiba or Quito.

2.2.2 GHG emissions in Colombian Transportation Sector

Emissions accounted for national inventories include those corresponding to CO_2, CH_4 y NOX and greenhouse gases precursors. In the case of Colombian transportation sector, CO_2 responds for 99.3% of total emissions in 2004.

Emissions in the transportation sector are due to the use of energy carriers and for that reason they are accounted for the energy module. In 2004, energy use was responsible for 36.65% of the national emissions. Within the energy module, transportation contributed with 33% of the total emissions. For accounting effects, the transport sector is divided in four subsectors (national air transportation, automotive, railway transportation and national navigation). The automotive subsector has the biggest share in the transport emissions. In 2004, Colombian automotive subsector emitted 89.5% of the whole emissions from the transportation sector of which 99.3% were CO_2 emissions. Using IPCC emission factors and statistics of the consumption of energy carriers from the UPME (Bureau of Mining and Energy Planning) it is possible to reproduce an approximate path of the CO_2 emissions on the automotive transportation subsector in Colombia separated by type of end use. Figure 2.5 shows the approximate path of those emissions built using the sources mentioned above.

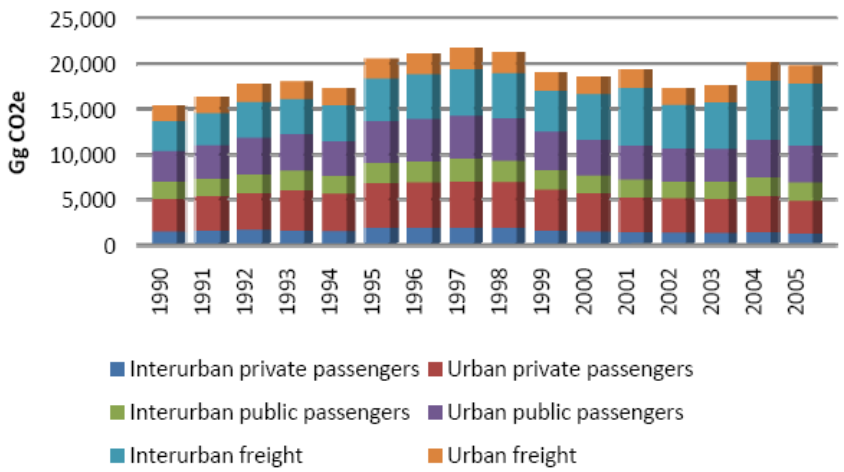


Figure 2.5. Emissions of GHG in Colombian transportation sector. 1990-2005.

As can be seen, passenger transport is responsible for about a half of the total emissions within the automotive subsector of which about two thirds are related to the urban passenger transportation. The above shows that urban passenger transportation (public and private) is principally responsible for the emissions of one third of the total of the entire energy module, which means 12% of the national emissions in 2004.

2.2.3 NAMA description

International experience on electric transportation and available technologies

Electric traction is not a new technology, on the contrary, it has been dominant in massive transportation for a long time; however, it experienced a significant lag in the private transportation sector [44]. A the end of the 19th century, problems associated with the electricity supply together with the discovery of substantial oil wells in the United States and the lack of environmental interest, limited its development. Nowadays the situation is reversed and need for new sustainable technologies in the private transportation sector is imminent.

Shortly after the first oil crisis, the need to decrease the consumption of liquid fuels became evident. Since the transportation sector had been dominated by the internal combustion technology for a while, General Motors started a pilot project to include electric vehicles in the company's portfolio but this project was quickly rejected because of the high costs and reduced competitive advantage. Nevertheless, in the next 20 years some enterprises, mainly in Europe, kept on working in prototypes that generally remained undeveloped, except for some models of the Norwegian vehicle Think-City.

During the 90's the initiative took off again because of the new oil crisis, social pressure and socio-environmental studies that proved the long term consequences of continuing with the present energy model. In this way, Toyota and Honda developed models of completely electric vehicles such as the EV1 and the RAV4 which for the first time presented good performance. Nevertheless, these units had no success due to the low political interest and strong competition.

However, the development of the technology made people realize that electric traction vehicles offered a real alternative. This phenomena created a movement in the United States, Canada and Japan that promoted the boom of the initiative. The commitment of these countries helped the companies keep electric technology research in their I+D budgets.

Technical limitations mainly related to batteries made the development of hybrid vehicles as the main alternative that overcomes the issues of the pure electric technology. Evidence of this boom is Toyota Prius presented in 1998, which is until now the most successful hybrid traction car in the market. This initiative lead by Toyota got many adepts like Honda, Ford, Chrysler, Lexus and many other groups and research centers. Nowadays, the electric traction technology (hybrid or full electric) has many models, as is shown below [44]:

- Massive Transportation Systems:
    - Trolleybuses.
    - Hybrid buses.
    - Articulate hybrid buses.
    - Trams.
    - Electric subways and trains.

- Private Transportation Systems:
    - Hybrid vehicles.
    - Hybrid plug-in vehicles.
    - Electric vehicles.
    - Electric motorbikes and scooters.
- Confined Transportation Systems:
    - Tourism electric vehicles.
    - Cargo electric and hybrid vehicles.
    - Electric vehicles for handicapped people.

A conclusion of the previous list is that there are two main technologies: hybrid and completely electric. The hybrid technology basically consists of a regular combustion engine which is attached to a generator that produces electricity for the engine. Nowadays, this technology is more efficient in comparision with regular engines. On top of the regular Hybrid electric vehicles (HEV) there are the Plug-in Hybrid electric vehicles (PHEV). On the other hand, there is the full electric technology. This technology can, in turn, be divided in three categories: 1)Battery powered vehicles; 2) electric vehicles powered by overhead lines; 3) electric vehicles powered by compressed air or solar panels.

Fuel consumption and modes of transportation: technologies used in Colombia

The amount of energy consumed by transportation in Colombia makes it the greatest final energy consumer in the internal market. During 2004, internal consumption of energy in the country was 274.993 Teracalories (Tcal). The transportation sector consumed 80.237 Tcal in that same year, which was 29,17% of the total; this was followed by the industrial sector with a share of 21,22%. The UPME reports the Colombian energy consumption in the national energy balance on a yearly basis. In these balances, transportation energy consumption appears disaggregated by modes of transportation, energy type, road transportation and kind of service. Road transportation is, between the different types of transportation, the greatest energy consumer (84,53% among the sectorial total). The services identified and reported by UPME in the road transportation are six: private interurban passenger transportation, private urban passenger transportation, public interurban passenger transportation, public urban passenger transportation, interurban freight and urban freight. Figure 2.6 shows the distribution of energy consumption by type of fuel and kind of service.

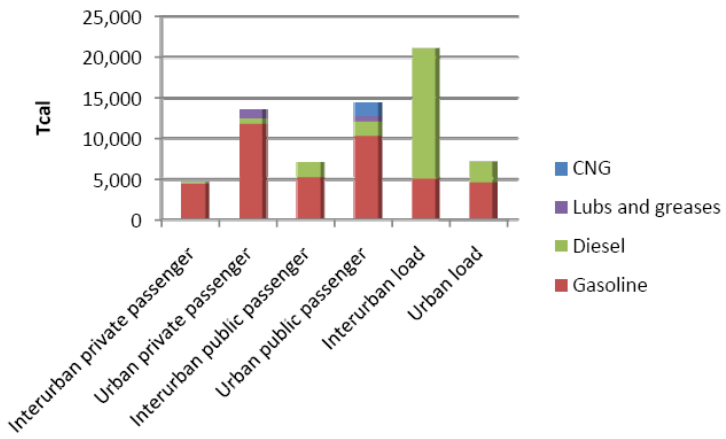


Figure 2.6. Energy consumption in the Colombian transportation sector. 2004.
Source: [43].

It can be seen that gasoline is the main fuel used in the road transportation followed by diesel. In 2004, compressed natural gas (CNG) was used only by public urban passenger transportation vehicles (taxi cabs). The description above is not necessarily the present-day situation. In the recent years there have been an increasing number of vehicle conversions from gasoline to CNG due mainly to high oil prices. As a result, CNG consumption has increased in the last years. It is important to mention that currently all the gasoline and diesel available in the country contains a percentage of biofuels (ethanol for gasoline and biodiesel for diesel). Users have no choice but to use the mix of fossil fuels and biofuels. Other important changes that have taken place on the recent years are the net increase of the automotive fleet and the incorporation of some BRT systems in the main urban centers of the country. At 2011, there are 6.240.962 motorized vehicles on the roads in Colombia, 43,3% of which are motorcycles. The total, which does not include motorcycles, is 3.533.224 motorized vehicles. Of that total, freight represents 21,1% of vehicles and passenger transportation the remaining 79,9%. Table 2.1 shows the current Colombian vehicle fleet composition according to information of Colombian Ministry of Transportation.

Table 2.1. Composition of the Colombian road transportation fleet. 2011.

Type	Number of vehicles
Automobile	2,088,097
SUVs	479,661
Light bus	74,942
Medium bus	59,198
Heavy bus	90,054
Light truck	465,036
Medium truck	199,272
Heavy truck	31,442
Dump truck	33,183
Agricultural Machinery	6,103
Industrial Machinery	6,236
Motorcycle	2,700,221
Adapted motorcycle	520
Load adapted motorcycle	6,779
Quad	218
Total	**6,240,962**

In general, buses and trucks use diesel as their main fuel. In contrast, motorcycles and automobiles (privates and cabs) mainly use gasoline. As mentioned above, in recent years there have been an increasing number of vehicles conversions from gasoline to CNG. These conversions occur mostly between automobiles but, small urban trucks are also switching fuel.

Currently, there are seven massive passenger transportation systems in the country; six of them are based on BRT systems. Those systems operate in the main cities and metropolitan areas of Colombia: Bogota, Barranquilla, Cali, Cartagena, Pereira, Bucaramanga and Medellin. This last system is the only one that uses electricity for massive passenger transportation in the whole country. The corporative organization of those transportation systems and the size of their participation in the total of mobilized passengers make them ideal candidates for the implementation of clean development measures, such as the one proposed in this document. The corporative organization of the sector can facilitate the design and implementation of the measures, while a big share of the market of passenger transportation contributes to ensure that the impact will be as high as is possible. Those systems are relatively new (and consecuently the buses), so the replacement of the old fleet will start in at least 15 years. For that reason, the NAMA evaluated in this document will consider only the small size vehicles.

2.2.4 Definition of the NAMA Proposal

This section defines the NAMA proposal. First of all, the UPME forecasts of fuel consumption in the transportation sector until 2030 are presented. These forecasts are used as a baseline for the NAMA, mainly the estimate of gasoline consumption. Then a cost and emissions comparison of the different technologies is considered for urban transportation (passengers -private and public- and light freight). We compare different vehicles that supply the same transportation service, ie, we change one specific internal

combustion vehicle for its electric equivalent. The following section explains the *ad-hoc* dimension given to the NAMA and the consequences for fuel consumption and emissions reductions per mode of transportation. The last subsection contains the aggregate results for all the modes and the impact on gasoline and electricity consumption together with the emissions reduction.

UPME´s fuel consumption forecast

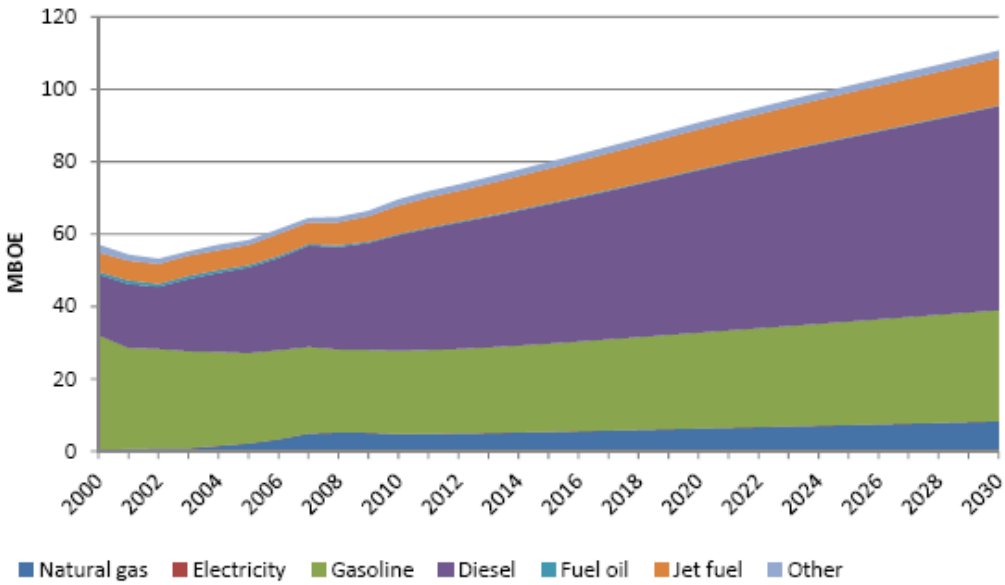


Figure 2.7. Energy consumption in Colombian transportation sector. Historical and forecast. 2000-2030.
Source: [46].

Figure 2.7 contains the UPME forecasts for the consumption of seven different fuels in the transportation sector. There is an important positive trend with values from 2002 to 2030 almost doubling. According to this forecast the consumption of Diesel and Natural Gas will increase the most. This forecast is for the whole transportation sector and includes air, road, marine and fluvial transport. In this Country Study, we only consider road transportation. The consumption of fuel in the road transportation sector is divided into several uses: Private and public passengers and both urban and interurban freight. The figure does not show this share but most of the analysis will take this into account. Furthermore, this specific NAMA will work with consumption in urban areas nationwide.

Costs and emissions comparisons of a technology change

To build the cost structure, there is a need to characterize the different technologies available in the sector. The selection of the vehicles that were compared was carried out according to the information available as to two similar vehicles- a internal combustion engine and an electric engine. The main idea of the model is to compare the cost and emissions reduction of a technology change.

Each technology is thought to cover a specific part of the demand and they are characterized by manufacturer. Each technology has different technical characteristics such as efficiency and average annual traveled distance; investment costs together with operation and maintenance costs. For electric vehicles there is also a difference in the battery life that is related to battery type. Four different types of electric vehicles were evaluated: two passenger vehicles (Smart and Chana - Benni), a bus and a small freight vehicle (Renault Combi). Passenger vehicles could be used in both private and public services. The main

difference between both services is the yearly average travel distance that was estimated based on the information available for Bogotá (9000 km/year for a private car and 73000 km/year for a taxi).

Table 2.2 summarizes the comparison explained above.The cost showed is the additional cost of replacing one gasoline vehicle for its electric substitute. The emission reductions showed are the savings made by switching the fuel in vehicles. The main explanation for the difference in the costs between a taxi and a private car is the number of times that the battery has to be replaced. Since the battery life is calculated by the number of cycles that it can be charged, the car that travels longer average distances faces higher costs for battery replacement. Both the second and the fourth column represent taxis. The taxi has the same technical specification but the difference is the average annual distance traveled (73.000km/year). The last two columns represent private freight vehicles. These vehicles have different technical specifications and travel long distances (12.000km/year). The difference between the last two columns is the mechanism through which the battery is bought. The sixth column has a regular method in which the battery is bought together with the car and replaced when the battery life is met. On the other hand, the last column models a battery rent system already implemented in Spain. The system consists of renting a battery for 48 months (and up to 15000 km/year utilization) with a fixed rate.

Table 2.2. Costs of switching from internal combustion to electricity in a 20 year period.

	Smart	Smart - Taxi	Chana - Benni	Chana - Taxi	Small bus	Renault Combi	Renault Combi- rent
Cost	13,705.3 €	6,200.8 €	1,882.6 €	2,670.1 €	36,009.5 €	1,304.6 €	-122.6 €
Emission reduction (Ton CO_2)	23.7	133.1	19.6	158.6	1056.6	48.2	87.9
Cost of reduced Ton (EUR/Ton CO_2)	578.1 €	46.6 €	96.3 €	16.8 €	34.1 €	27.1 €	-1.4 €

NAMA long run scenario by mode

This section shows the modeling of the NAMA scenario of energy consumption. The first step was to separate the consumption forecast for each type of service from the UPME's gasoline consumption forecast showed above. That forecast is the baseline for the measure. In each type of use (public and private passenger transportation and freight), a technology substitution path was modeled. In the model, the introduction of the new technology (electric cars) is undertaken by two different mechanisms, one is the substitution of some of the old cars that are replaced by new ones and the other is the participation in the growth of the fleet. The first way in which electric cars can be introduced in the market is by substituting old gasoline cars. In each sector a useful life for the fleet was assumed according to the Colombian context. To simplify the calculations, a constant substitution rate was used. A portion of the current gasoline fleet will be renewed on an annual basis. A proportion of that new fleet will be electric cars. The participation of the electric cars in the substitution of the old gasoline vehicles will be modulated by a penetration rate. That penetration rate is different for each sector, as will be explained later. On the other hand, the forecast shows that the gasoline demand will increase over the next 20 years. The model considers that the average consumption of gasoline will remain unchanged. In that sense, the higher the gasoline consumption, the bigger the fleet. The additional fleet is fulfilled by traditional ICE cars in the baseline, but in the scenario some of those new cars are electric. In summary, the sectors are differentiated by the penetration rate of

the technology and the rate of scrappage. The fleet forecast for each sector is shown in Figure 2.8 to Figure 2.10, and its energy consumption will be shown in Figure 2.11 to Figure 2.13.

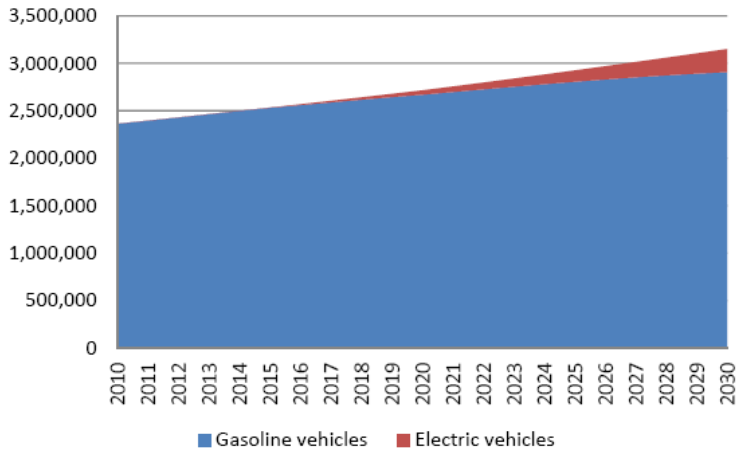


Figure 2.8. Colombian private passenger automobile fleet (gasoline and electricity). Vehicles. 2010-2030.

Figure 2.8 presents the private automobile fleet forecast. The fleet forecast was carried out starting with the consumption forecast for this sector and using an average consumption per vehicle. As mentioned above a useful lifetime for the vehicles was assumed. In this case that lifetime was estimated to be 25 years. That value could be considered high, but taking the Colombian context in account, it is a reasonable value. The penetration starts at 2015 and, for that year, the rate of substitution for electric vehicles was assumed to be 5%. That rate increases throughout time and reaches 20% in 2030. As can be seen, the participation of electric vehicles is not really high in this sector due to the low rate of scrappage and the values of the rate of penetration.

Figure 2.9 shows the taxi fleet forecast in Colombia. Taking in account that the collective and massive transportation sector in Colombia uses Diesel as its main fuel, the gasoline consumption of the public passenger transportation, as has been reported (by UPME), is mainly due to the taxi fleet. For this substitution forecast, a useful life of 10 years was assumed. The penetration rate is higher than in the private passenger transport sector. The penetration of electric vehicles was modeled starting at 2015 with 5% and growing until 2030 where it reaches 30% of the new cars. As can be seen, the gasoline powered fleet decreases over the time in contrast with the observed tendency of the private passenger fleet, where the gasoline fleet keeps growing along the time. This difference can be explained considering that the number of electric vehicles that enter each year to substitute the old vehicles that are being thrown away is higher than the number of vehicles entering due the increase in the demand. As the lifetime of the taxi fleet is shorter than for the private cars the substitution for electric vehicles occurs faster.

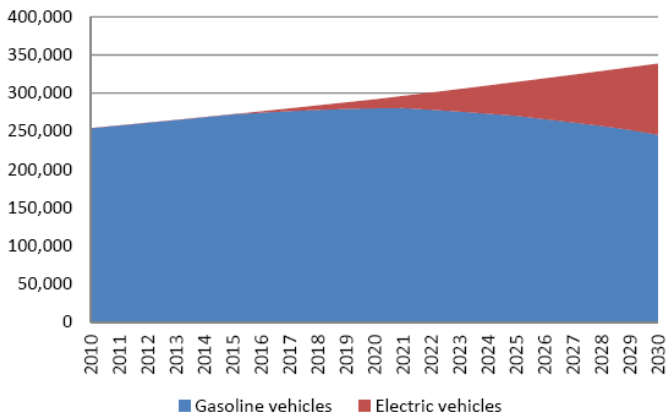


Figure 2.9. Colombian taxi fleet (gasoline and electrity). Vehicles. 2010-2030.

The urban freight fleet is a kind of hybrid between both public and private passenger transportation and its forecast is shown in Figure 2.10. In the model, the urban freight fleet has a lifetime similar to that of private automobiles. But, this sector has a penetration rate close to the electric vehicles in public transport. The lifetime considered for freight fleet is 20 years. The penetration rate is the same than the used for taxi fleet. That is, of the total of new gasoline cars that should enter the fleet in 2015, 5% uses electricity as its fuel. In 2030 this percentage is 30%. This higher penetration rate in both sectors, public passenger transportation and freight, is explained by the strategies that utilities companies in Colombia are designing to boost the penetration of the electric vehicles into the market. They are focusing their efforts on the public transportation and freight. On the other hand, the program of fuel substitution (gasoline for natural gas) that was developed during the last two decades showed that the two sectors mentioned above experienced a more dynamic transformation towards the new technology. This is the motivation to calculate the *ad-hoc* penetration rate.

Figure 2.11 shows the energy consumption forecast of the private passenger fleet. As can be seen, the participation of electricity compared with gasoline is almost marginal in the total final energy consumption. It happens because of the high efficiency of the electricity vehicles. These vehicles satisfy the needs of transportation and use less energy. In fact, the penetration of electricity in this sector produces a net reduction of energy consumption of 6,62% in 2030.

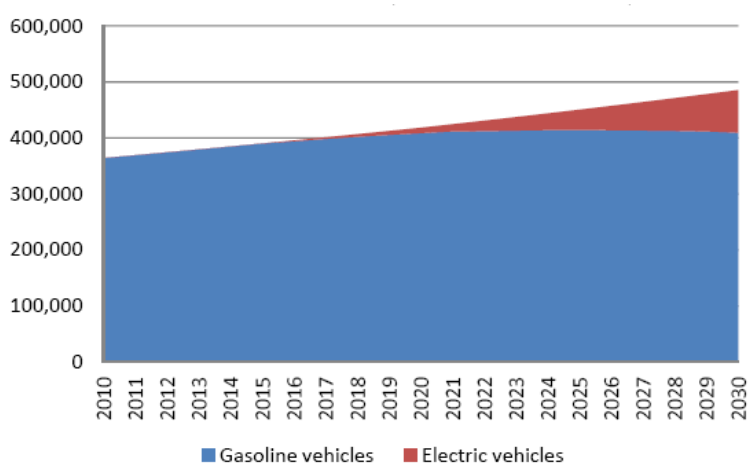


Figure 2.10. Colombian urban freight fleet (gasoline and electricity). Vehicles. 2010-2030.

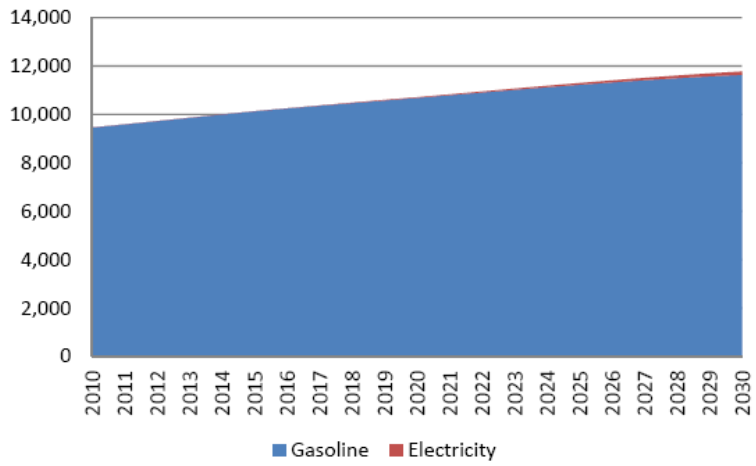


Figure 2.11. Private passenger automobile consumption (gasoline and electrity). Tcal. 2010-2030.

Figure 2.12 shows the energy consumption of the public passenger transportation sector. The net energy savings by 2030 as effect of the use of electricity are 23,5%. The total consumption of gasoline in 2030 is less than the current value. This measure ensures that the growing in the demand of energy of this sector will be fully satisfied by electricity. As was explained before, this sector has the highest penetration of electricity.

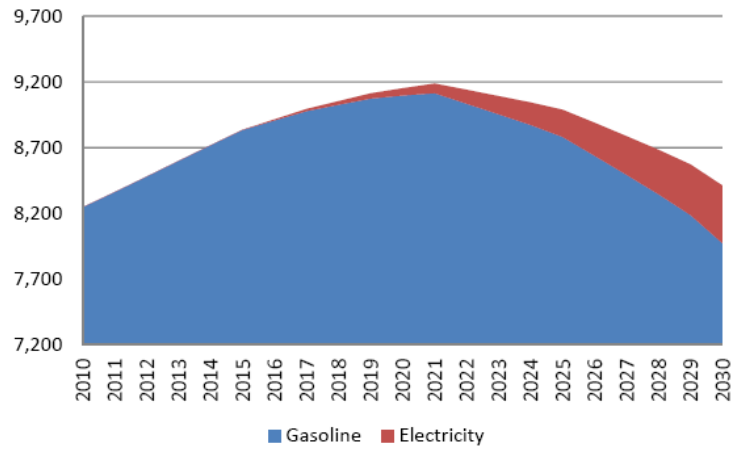


Figure 2.12. Taxi fleet consumption (gasoline and electrity). Tcal. 2010-2030.

Finally, Figure 2.13 presents the energy consumption in the freight fleet. As in the public passenger transportation sector, electricity responds for the growth of the sector. In this particular case, electricity fulfills the additional demand since 2021. Since that year, gasoline consumption decreases. As electricity is more efficient than gasoline, the consumption of energy grows at a lower rate than that of the fleet (which means that the growth is less than that of the freight demand).

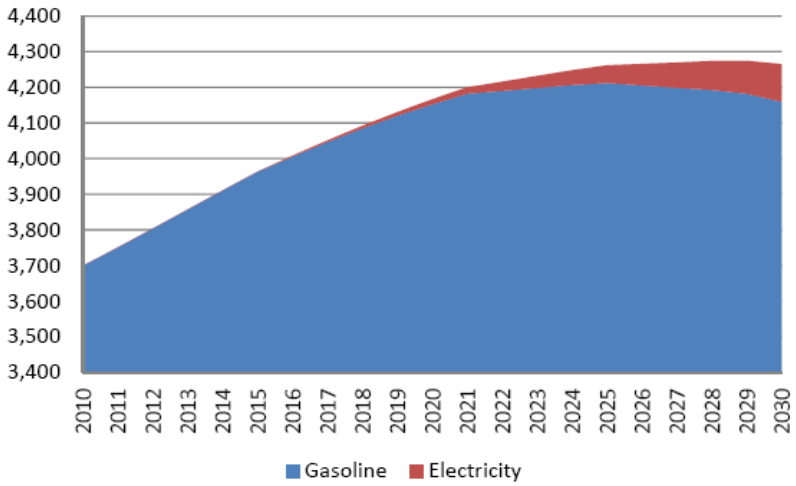


Figure 2.13. Urban freight fleet consumption (gasoline and electricity). Tcal. 2010-2030.

Results

This subsection summarizes the results. An interesting fact is that the electricity penetration in the transportation sector produces a decrease in the energy consumption in the long term. This is due to the higher efficiency of the electric technology; in other words, it is because the electric vehicle travels, on average, longer distances with the same amount of energy. Table 2.3 summarizes the avoided CO_2 emissions and cost of mitigation in different sectors of the urban transportation. Once the number of electric vehicles that starts operation each year in every sector is identified and using the information presented previously the net effect is calculated. The sector in which this measure has the highest abatement potential is that of public passenger transportation. This result is obtained despite of the fact that the number of electric taxis in 2030 is less than a half of the number of electric private vehicles in the same year. In the whole period, 4,7 Mton of CO_2 can be avoided in the private passenger sector at a cost of 96,28 EUR per ton; 14,8 Mton of CO_2 in the public passenger sector at a cost of 16,84 EUR per ton and 3,7 Mton reduced in the freight sector at 27,1 EUR per ton.

Table 2.3. CO_2 emissions avoided and cost of mitigation in different sectors in the urban transportation.

	Automobile		Taxi		Freight vehicles	
	Aditional cost (EUR)	Emission reduction (t CO_2)	Aditional cost (EUR)	Emission reduction (t CO_2)	Aditional cost (EUR)	Emission reduction (t CO_2)
2010	$ 0	0	$ 0	0	$ 0	0
2011	$ 0	0	$ 0	0	$ 0	0
2012	$ 0	0	$ 0	0	$ 0	0
2013	$ 0	0	$ 0	0	$ 0	0
2014	$ 0	0	$ 0	0	$ 0	0
2015	$ 3,293,709	34,207	$ 502,118	29,822	$ 351,612	12,983
2016	$ 13,009,078	135,107	$ 4,194,286	249,112	$ 1,646,807	60,807
2017	$ 13,867,166	144,019	$ 4,509,853	267,855	$ 1,850,173	68,316
2018	$ 16,049,410	166,683	$ 6,466,859	384,088	$ 2,539,173	93,756
2019	$ 17,663,585	183,447	$ 6,820,821	405,111	$ 2,759,884	101,906
2020	$ 21,998,066	228,463	$ 8,862,907	526,397	$ 3,480,081	128,499
2021	$ 23,495,008	244,010	$ 10,229,852	607,584	$ 4,400,766	162,494
2022	$ 25,952,321	269,531	$ 18,392,369	1,092,383	$ 7,270,982	268,474
2023	$ 27,129,144	281,753	$ 18,668,255	1,108,769	$ 7,380,047	272,501
2024	$ 29,704,268	308,497	$ 18,948,279	1,125,400	$ 7,490,747	276,588
2025	$ 32,177,373	334,181	$ 19,840,760	1,178,408	$ 8,033,391	296,625
2026	$ 38,242,269	397,169	$ 24,385,489	1,448,334	$ 9,640,930	355,982
2027	$ 40,902,629	424,799	$ 24,751,271	1,470,059	$ 9,785,544	361,322
2028	$ 47,264,997	490,876	$ 25,122,540	1,492,110	$ 9,932,327	366,741
2029	$ 50,121,609	520,543	$ 26,141,666	1,552,639	$ 10,536,845	389,063
2030	$ 58,971,486	612,455	$ 31,038,184	1,843,459	$ 12,272,015	453,132
Total	**$ 459,842,117**	**4,775,738**	**$ 248,875,508**	**14,781,532**	**$ 99,371,324**	**3,669,189**

As a co-benefit, gasoline substitution implies a reduction in other atmospheric pollutants emissions such us particulate matter (PM). It is not the primary objective of fuel substitution, but is a positive impact reached at the same time without additional investments. Particulate material has an important effect on the public health. This kind of pollutants is responsible for many cardiovascular and respiratory diseases and deaths. As the net impact on the public health depends not only of the amount of PM emitted, but also on their concentration in the atmosphere, the economic impacts of the reduction obtained are not calculated. This estimation falls outside of the scope of this study. Regardless of the above, it is true that a reduction of the emissions of PM is beneficial for the environment and the citizens' health in general. For this estimation a 0.003 g/km emission factor was used, according to [41]. As the savings depend of the travel distance and the penetration of the clean technology, public passenger transportation is the sector with more benefits, reaching a reduction of 27,5% of the emissions of 2030 and a 8,77% net reduction on the evaluated time period (15 years). This reduction is shown in Table 2.4.

Table 2.4. particulate material emissions avoided in different sectors in the urban transportation.

	Automobile		Taxi		Freight vehicles	
	PM avoided emission (ton PM)	% reduction	PM avoided emission (ton PM)	% reduction	PM avoided emission (ton PM)	% reduction
2010	0.0	0.00%	0.0	0.00%	0.0	0.00%
2011	0.0	0.00%	0.0	0.00%	0.0	0.00%
2012	0.0	0.00%	0.0	0.00%	0.0	0.00%
2013	0.0	0.00%	0.0	0.00%	0.0	0.00%
2014	0.0	0.00%	0.0	0.00%	0.0	0.00%
2015	0.0	0.07%	0.0	0.07%	0.0	0.07%
2016	0.2	0.34%	0.4	0.64%	0.1	0.39%
2017	0.4	0.61%	0.8	1.23%	0.1	0.73%
2018	0.7	0.93%	1.3	2.07%	0.2	1.20%
2019	0.9	1.27%	1.8	2.93%	0.3	1.70%
2020	1.2	1.68%	2.6	4.02%	0.3	2.31%
2021	1.6	2.11%	3.4	5.25%	0.5	3.07%
2022	1.9	2.57%	4.9	7.47%	0.7	4.32%
2023	2.3	3.04%	6.5	9.65%	0.9	5.55%
2024	2.8	3.54%	8.0	11.79%	1.1	6.76%
2025	3.2	4.07%	9.6	13.98%	1.3	8.03%
2026	3.8	4.70%	11.6	16.63%	1.6	9.52%
2027	4.4	5.35%	13.7	19.25%	1.8	11.00%
2028	5.0	6.09%	15.7	21.82%	2.1	12.45%
2029	5.7	6.85%	17.9	24.43%	2.4	13.95%
2030	6.6	7.75%	20.4	27.50%	2.7	15.68%
Total	**40.8**	**2.63%**	**118.6**	**8.77%**	**16.0**	**5.03%**

Figure 2.14, Figure 2.15, and Table 2.5 summarize the results of the substitution of traditional ICE vehicles for electric ones in the urban transportation sector. In Figure 24, the composition of the fleet is presented. There is a 33,36% increase of the total fleet in the 20 year period evaluated (2010-2030). The growth of the traditional ICE fleet is 19,49% in the same period. That means that a significant proportion of the fleet growth is covered by electric vehicles. As observed in the taxi and freight fleets, there is a reduction in the total energy consumption. This reduction is the main responsible for the reduction of the emissions of CO_2 and MP. A reduction of 23,22 Mton of CO_2 is reached at a cost of 34,79 EUR per ton. It is important to mention that the avoided CO_2 emissions include the additional emissions due to the increment on the electric generation to satisfy the new transportation demand.

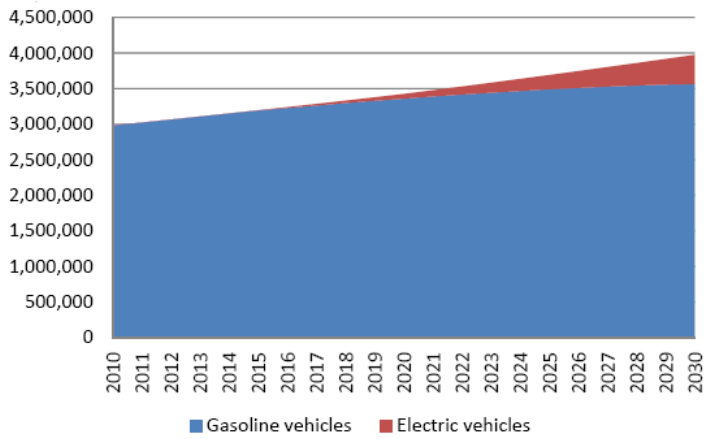


Figure 2.14. Colombian urban (private and public) passenger and freight fleet (gasoline and electricity). Vehicles. 2010-2030.

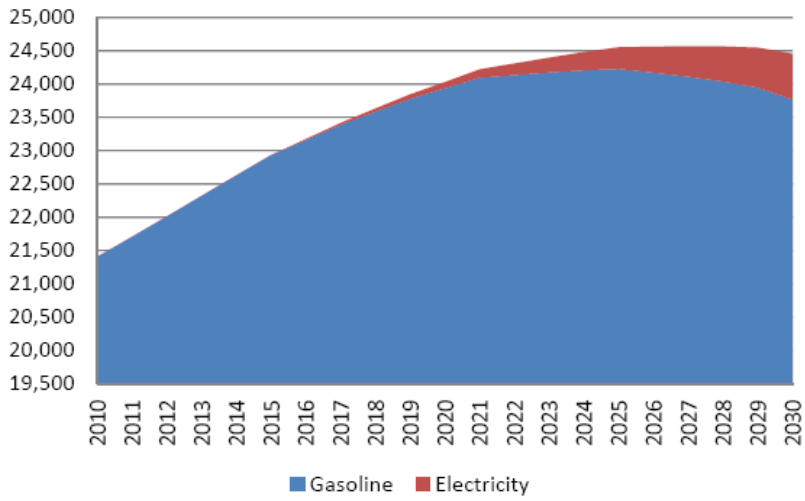


Figure 2.15. Colombian urban (private and public) passenger and freight fleet consumption (gasoline and electricity). Tcal. 2010-2030.

Table 2.5. Avoided emissions and cost of the measure in the whole urban transportation sector.

	Aditional cost (EUR)	Emission reduction (t CO_2)	MP avoided emission (ton PM)	% reduction in PM
2010	$ 0	0	0.0	0.00%
2011	$ 0	0	0.0	0.00%
2012	$ 0	0	0.0	0.00%
2013	$ 0	0	0.0	0.00%
2014	$ 0	0	0.0	0.00%
2015	$ 4,147,438	77,013	0.1	0.07%
2016	$ 18,850,171	445,026	0.7	0.47%
2017	$ 20,227,192	480,190	1.3	0.89%
2018	$ 25,055,442	644,527	2.1	1.43%
2019	$ 27,244,290	690,464	3.0	2.01%
2020	$ 34,341,054	883,359	4.2	2.72%
2021	$ 38,125,625	1,014,088	5.4	3.52%
2022	$ 51,615,672	1,630,387	7.5	4.80%
2023	$ 53,177,446	1,663,022	9.7	6.06%
2024	$ 56,143,295	1,710,486	11.8	7.32%
2025	$ 60,051,524	1,809,214	14.2	8.62%
2026	$ 72,268,687	2,201,485	17.0	10.18%
2027	$ 75,439,444	2,256,179	19.9	11.74%
2028	$ 82,319,864	2,349,727	22.9	13.32%
2029	$ 86,800,120	2,462,245	26.0	14.93%
2030	$ 102,281,684	2,909,046	29.7	16.82%
Total	**$ 808,088,949**	**23,226,459**	**175.4**	**5.45%**

2.3 NAMA: Potato Crops

In this country study our aim is to propose a NAMA related with potato crops in Colombia. In the first part of this chapter, we present the agriculture sector and its significance in the country's economy and discuss the importance of fostering sustainable crops. Next, we present a brief literature revision about mitigation measures developed both abroad and in Colombia. Finally, we present a proposal related with a NAMA in potato crops.

2.3.1 The Agricultural Sector in the Colombian Economy

The importance of agriculture in the economic and social development in Colombia is well known, as it generates more than 20% of national employment and accounts for more than 60% of employment in rural areas. Figure 4.1 shows the number and the percentage of people employed in rural areas and in the agriculture sector between 2008 and the first part of 2009. It shows that the agricultural sector is the engine for employment in the country, representing over 67% of employees in rural areas. From the 4.36 million jobs created in the sector, 2.94 million are related to agriculture, forestry, hunting or fishing. However, the unemployment rate in the sector has been increasing in the last few years, reaching 8.6% in 2010, 0.8 percentage points more than in 2009 (7.7%). This behavior is the result of the cold wave that battered the country, which affected, among others, the livestock sector that is a major generator of employment in rural areas[27].

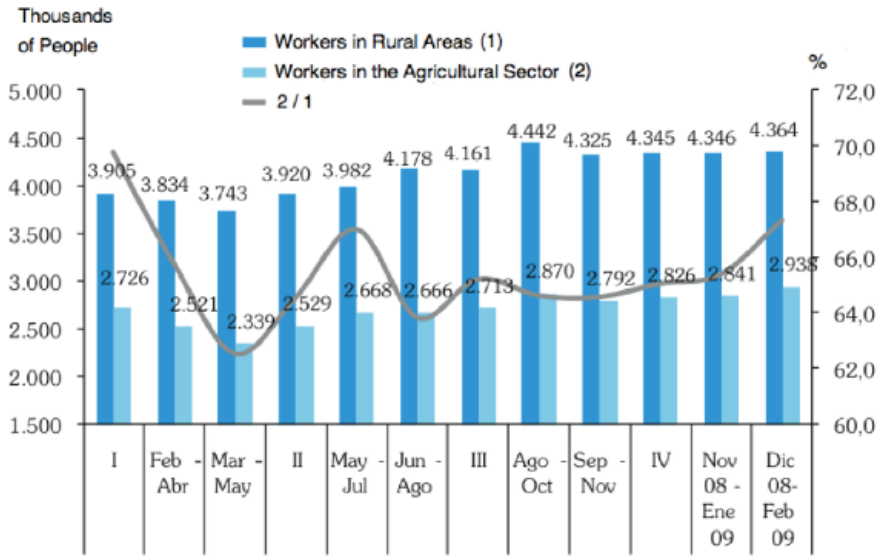


Figure 2.16. Occupation in Rural Areas.
Source: [27].

Likewise, the sector has been losing dynamism in its long-term growth. The share of agriculture in total GDP has been declining going from 17% in 1990 to 7.5% in 2007 and to 6.5% in 2010 as a result of a sector's lower growth compared with the rest of the economy, because while the economy grew at an average annual rate of 3.5%, agriculture did at a rate of 1.7% per year[23]. However, the government has the goal to raise the agriculture growth rate to 5.3% in 2014[11]. Figure 2.17 shows the behavior of agricultural GDP and total GDP in the last ten years.

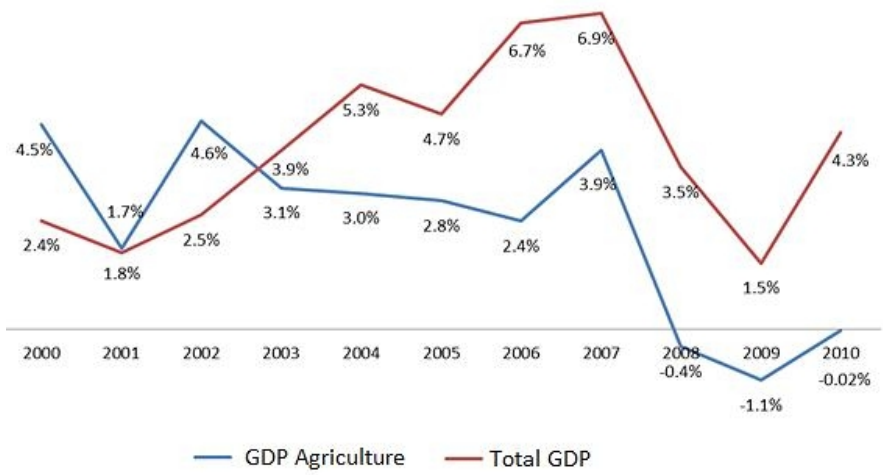


Figure 2.17. Percentage changes of total GDP and agricultural GDP at constant prices of 2005.

In relation to the exports and imports of the agricultural sector, the former have increased but have actually decreased as a share of the total exports in Colombia in the last decade, going from 9.93% in 2002 to 6.09% in 2011. The latter have increased in the last ten years, but also decreased as a share of the total imports in the country, going from 7.16% in 2002 to 4.92% in 2010[8] [41]. It is important to mention that

in the past few months Colombia signed two free trade agreements with Canada and the United States so big changes in the trade balance of the agricultural sector are expected.

Regarding food inflation (consumer price variation of food, IPCA), this dropped from 10.92% in 2002 to 5.32% in 2003, and grew until 2008 when it reached 13.17%. However the cold wave decreased the IPCA in 2009, when it reached - 0.32%. Given that food represents 30% in total inflation, this variable has followed closely the behavior of the IPCA[8].

In Colombia, the agricultural and rural sector is considered an engine for the future because it is expected to achieve a sustainable growth in output above the national average. It is also expected to generate wealth, jobs and quality benefits to the economy in terms of productive linkages with other sectors, market deepening, reduction of poverty, food security and welfare for the population, with environmental considerations that ensure sustainability in the long term.

2.3.2 The Agricultural Sector and the Environment

In relation to the environment, the agriculture and rural development engine must promote, together with the Ministry of Agriculture, sustainable land management through planning and the implementation of environmentally appropriate production technologies. It is also necessary to implement the National Sustainable Biotrade Program in coordination with the Ministries of Agriculture and Rural Development and Trade, Industry and Tourism. Regarding the latter, the government and its entities must develop a policy of clean fuels for the transport sector and give incentives to the import sector and the domestic industry for the production of clean technology vehicles.

The sector also has to adopt corporate environmental responsibility schemes and mechanisms of public information and performance indicators of environmental compliance and must incorporate environmental variables in sector planning.

The specific goals of the government are: the creation of action plans for sector environmental management (housing, infrastructure, agriculture and mining); the creation of Strategic Environmental Assessment for the housing, infrastructure, agriculture and mining sectors and; the establishments of environmental units for the four sectors mentioned before.

All of the above are aimed at supporting the development of the National Plan for Adaptation to Climate Change, the Colombian Strategy of Low Carbon Development, the National Strategy to Reduce Emissions from Deforestation and Forest Degradation and the Financial Protection Strategy against disaster as strategic actions for the country.

According to the national inventory carried out by the Institute of Hydrology, Meteorology and Environmental Studies of Colombia [23] this sector represents the largest contribution to total national emissions. In 2004 the sector contributed with 38.1% of the total emissions, equivalent to 68,565.79 Gg CO_2 eq. Table 2.6 shows the estimated GHG emissions module in agriculture for 2004. It can be seen that 98% of the total module emissions come from the following three categories: enteric fermentation (48.5%), agricultural soils (47.5%) and rice crops (2%). Additionally, one can infer that 96% of the emissions within the enteric fermentation category are mainly due to emissions from three species: non-dairy cattle (91%), dairy cattle (2.8%) and horses (2.9%).

Table 2.6. Agriculture GHG emissions - year 2004.

Source of Greenhouse Gas and Sinks Category	CH_4	N_2O	NOx	CO	Gg CO_2 eq	Module's Share (%)
Total Agriculture	**1699.93**	**106.06**	**3.9**	**132.71**	**68565.58**	
Enteric fermentation	**1583.74**				**33258.54**	**48.5%**
Dairy Cattle	43.8				919.8	
Non-dairy cattle	1441.26				30266.46	
Buffalo	9.27				194.67	
Sheep	14.15				297.44	
Goats	18.86				396	
Horses	46.64				979.44	
Mules and asses	6.58				138.2	
Pigs	3.18				66.8	
Poultry						
Manure Management	**44.61**	**0.81**			**1187.91**	**1.7%**
Dairy Cattle	1.15				24.15	
Non-dairy cattle	24.15				507.15	
Buffalo	0.32				6.72	
Sheep	0.51				10.71	
Goats	0.79				16.59	
Horses	4.95				103.95	
Mules and asses	0.71				14.91	
Pigs	4.13				86.73	
Poultry	7.9				165.9	
Anaerobic						
Liquid systems						
Solid Storage		0.81			251.1	
Other (specify)						
Rice Crops	**65.34**				**1372.14**	**2.0%**
Irrigated	34.98				734.58	
Dry	30.36				637.56	
Deep water						
Agricultural Soil		105.14			32593.4	47.5%
Prescribed burning of savannas	2.5	0.03	1.12	65.64	61.8	0.1%
Field burning of agricultural residues	3.19	0.08	2.78	67.07	91.79	0.1%

Source: [23].

Generic mitigation options in the agricultural sector have been proposed by the IPCC, 4th Assessment Report, as is summarized in Table 2.7.

Table 2.7. IPCC Mitigation Measures.

		Mitigative effects[a]		
Measure	Examples	CO_2	CH_4	N_2O
Cropland management	Agronomy	+		+/-
	Nutrient management	+		+
	Tillage/residue management	+		+/-
	Water management (irrigation, drainage)	+/-		+
	Rice management	+/-	+	+/-
	Agro-forestry	+		+/-
	Set-aside, land-use change	+	+	+
Livestock management	Improved feeding practices		+	+
	Specific agents and dietary additives		+	
	Longer term structural and management changes and animal breeding		+	+

Notes:
a + denotes reduced emissions or enhanced removal (positive mitigative effect);
- denotes increased emissions or suppressed removal (negative mitigative effect);
+/- denotes uncertain or variable response.

Source: [25].

2.3.3 International and National Low Carbon Strategies

International Strategies

In countries like Brazil or Costa Rica, agro-pastoral systems are being developed. The options that have been considered include making adjustments in grazing cycles that take into account the availability of forage (pasture) and grazing when it has the best nutritional quality[32]. Another option that is being developed in Costa Rica is the reduction of agrochemicals. A study argues that new forms of nitrogen application must be explored to determine the true potential of reduction, which can be very significant without reducing dry matter or quality of pastures and, for instance, without harming milk production. They proposed as mitigation options the reduction of the amount of nitrogen applied; changing the nitrogen sources and the methods of application and the adjustment of fertilizers according to crop uptake curves. That is to say that the application is carried out in accordance with the amount of crop growth stage, when more nitrogen is required, since the efficiency of absorption and utilization is greater than at any other stage of the crop. In this study, they present the costs of the mitigation actions, and present an abatement GHG curve that includes the two options mentioned before [32].

In Brazil, agriculture is one of the most important sectors in terms of emissions and abatement opportunities because it is the second largest emitter of greenhouse gases and accounts for approximately 25% of Brazilian emissions, a number that is expected to increase to 30% in 2030. The importance of agriculture comes from the fact that Brazil is the largest producer of agricultural products in the world, supplying the increases in demand for food worldwide.

Half of these emissions come from raising livestock, in particular from enteric fermentation and organic waste. The other half results from agricultural practices such as the pre-burning of land for cultivation and the overuse of nitrogen fertilizers [28].The mitigation options for the agriculture sector that are being developed in Brazil are:

1. Improved pasture management to make more intensive cattle breeding.
2. Improvements in the efficiency of fermentation of ruminants.
3. Recovery of farmland, by planting grass and increasing soil fertility through proper selection of nutrients, application of organic substrates as waste or fertilizer, etc.
4. Recovery of flooded areas (organic soil).
5. Improving nutrient management on farms (including rice).
6. Waste management.

The average cost of these initiatives in the agricultural sector is about €2 per tCO_2 in 2030. It requires very little investment and can probably be implemented through small changes in current farming practices[28].

National Strategies

Colombia does not have many projects oriented to reduce GHG emissions in activities which make the largest contributions to the agriculture inventory (enteric fermentation, agricultural soils and rice crops). Some of the projects that are being developed by the Government involve strategies for the whole sector and are related with the rationalization of farming costs, the promotion of research, innovation and technology transfer, improvements in the sector's financing, the stimulation of the agricultural sector's growth and the support of social enterprise projects and productive partnerships.

There is a project developed by the CIAT (International Center for Tropical Agriculture) that evaluates investment and financial flows for mitigation and adaptation actions in the agricultural sector in Colombia. They examine two specific actions: one related with the reduction in the use of fertilizers and water and waste management in selected rice crops in Colombia, the other is associated with GHG reductions through pasture improvements and genetic improvement of cattle [5]. Specific strategies have been identified for the two actions, having defined the technology needed and the time frame; they also have determined the costs for the implementation of the different strategies. Nevertheless, the actions have yet to be implemented.

In the sugar cane industry, CENICAÑA has been proposing and implementing different mitigation actions. Sugar mills contribute significantly to the economy, not only directly, but also by the impacts that their operations generate in other sectors and actors. The most important effects occur in employment, intermediate production, payment of taxes, gross domestic product (GDP) and wages [19]. One option already in course is the minimum tillage in sugar cane crops in the Valle del Cauca to reduce N_2O emissions in the sugar cane fields.

2.3.4 NAMA Description

The research group agreed that the NAMA should be developed from a cropland management measure. Given the importance of the sugar cane industry, some experts of the sector as well as from the research group initially proposed to develop a NAMA related with the development of agriculture according to agro-ecological areas throughout the region. The area cultivated with sugarcane in the Cauca River valley is very

heterogeneous regarding soil and climate conditions. Therefore, the adoption of the right technology package for each zone had a lot of potential as a NAMA. With this action, the use of water, fertilizer and fuel would be reduced due to the characterization of the appropriate agro-ecological zones for each production system. The proposed NAMA was defined as the transference of these technology developed by CENICAÑA to each farmer in each region. Nevertheless, officials from CENICAÑA and the industry told us that there is already a technology transfer program within the cane growers' association.

Looking in the same field, a new farming system in potato crops was examined and is being proposed as a potential NAMA in this Country Study. Potato crops have been a traditional agricultural sector in Colombia.

Potato Sector's Description

Colombia was ranked 20th among potato producers in the world in 2003, although its actual share of production is marginal (0.9%). The top 5 producers (China, Russia, India, USA and Ukraine) accounted for 53% of the 311 million tons that were produced in 2003. The 5 main exporters are the Netherlands, Germany, France, Belgium - Luxembourg and Canada, which accounted for 66% of the 7.9 million tons. Netherlands, Belgium - Luxembourg, Italy, Spain and Germany are the largest importers of potatoes for consumption, accounting for 51% of imports.

National Importance of Potato Crops

Potato cultivation in Colombia took fourth place in national agricultural production in the 2003 with 2.9 million tons, was ninth with 165,294 hectares in crop extension and sixth in value of production. In real terms, the value of production in the period 1990-2002 grew at a rate of 1.2%, almost the same growth rate that showed agriculture without coffee (1.3%) and lower than the vegetative growth population over the same period (1.9%). The product has a share of 34% in average of the temporary crops production in Colombia, and a 10% share of the temporary crop's area. Figure 2.18 shows the share of potato's crops production and area cultivated in the total of temporary crop in Colombia[2].

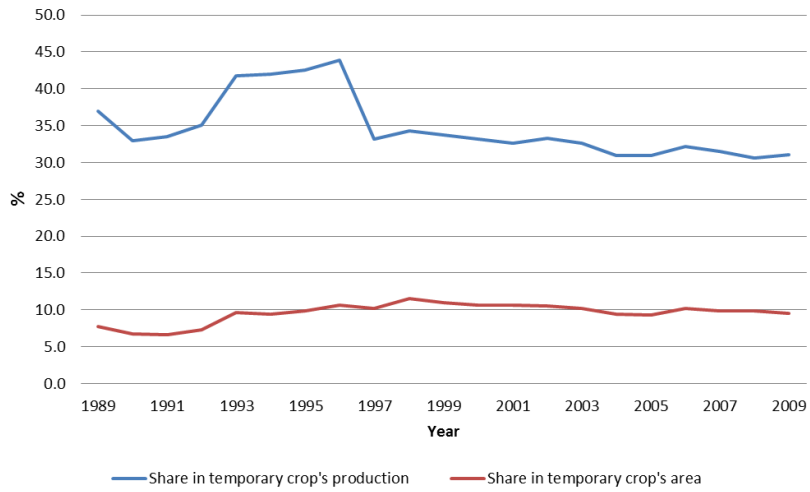


Figure 2.18. Share of Potato Crops in Temporary Crops.
Source: [2].

Colombia has more than 30 different potato varieties. Of these varieties, nearly 10 species are considered commercially important. There are large differences in potato cost structures across the country. This

situation depends on regional conditions (climate, topography, social and economical conditions) and also depends on the potato type (susceptibility to pests and diseases, nutritional and water requirements).

The area cultivated has not changed significantly in the last twenty years as can been seen in Figure 2.19. The yields of the potato crops in Colombia have remained stable in the same period as shown in Figure 2.20.

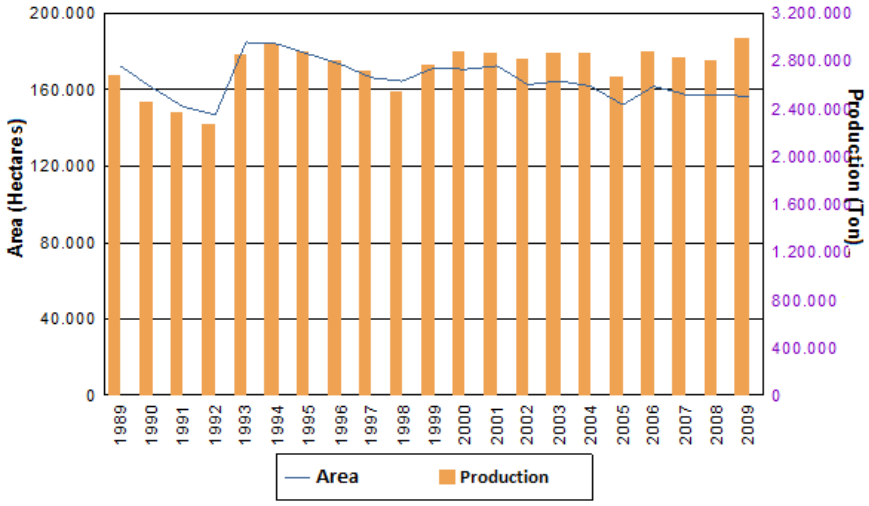


Figure 2.19. Potato Production and Cultivated Area.
Source: [2].

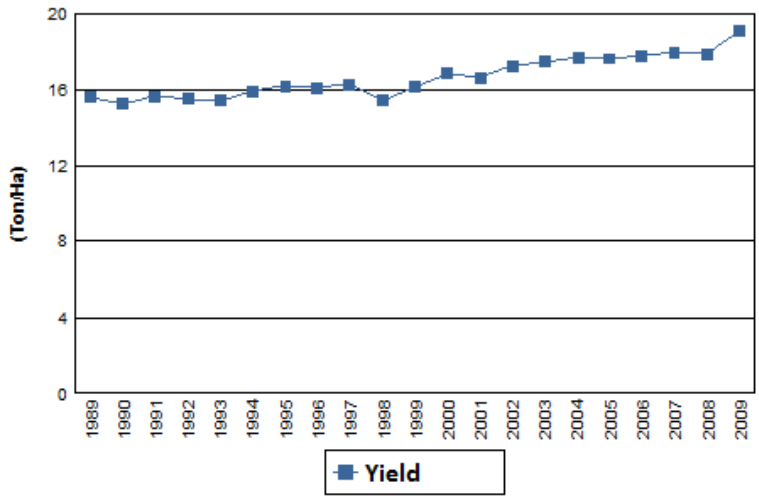


Figure 2.20. Yield of Colombia's Potato Crops.
Source: [2].

About 110,000 families are directly involved in potato production. This represents more than 20 million daily wages per year[18]. It generates more than 100,000 direct jobs, and generates other jobs indirectly created by the input distribution processes, packaging, machinery, seeds, processing and marketing. It is the product of agricultural origin that has the largest demand for fungicides and insecticides and the second

for chemical fertilizers, after coffee. Additionally, it constitutes the activity that uses the most ground transportation services with more than two million tons per year, a number that increases with the mobilization of inputs required for production.

Because the potato is a high consumption product, it has an important share in the family consumption basket, resulting in an important role in the general price index of the economy and a huge impact on the Colombian families' budget. In the periods of greater contribution, 30% of inflation can be explained by changes in prices of potatoes.

With respect to commerce, the potato trade balance has increased in the last eight years in comparison with the ten years before. Figure 2.21 shows the behavior of potato's trade balance in the past twenty years. Most part of the potato´s production is for national consumption. Colombia exports fresh potatoes to Venezuela, and exports different potato varieties to United States, Japan and to some European countries.

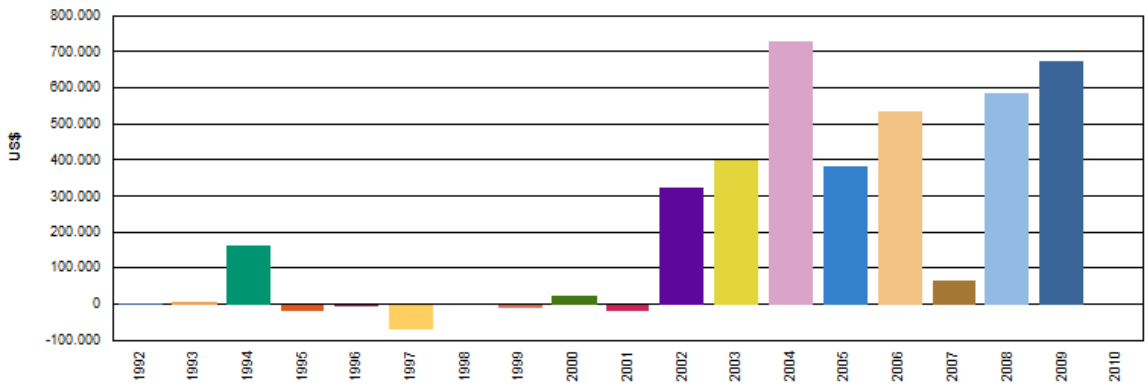


Figure 2.21. Potato's Trade Balance.
Source: [2].

Regional Importance of Potato Crops

Traditionally, potato production is distributed in fourteen departments. In 2009, Cundinamarca had the highest potato production (37.8%) followed by Boyacá (26.3%), Nariño (17.4%), Antioquia (6.5%) and Santander (5.6%)[27]. Geographically, production units are scattered mainly in the cold regions of the Andean zone. In Cundinamarca, 94% of the planted area is located between 2,500 and 3,500 meters. Overall, about 75% of the potato planted area in the country has a rugged and undulating topography, with slopes greater than 25% that difficult the use of machinery.

In three of the main producing departments, Cundinamarca, Boyacá and Nariño, it is the agricultural activity that generates the most jobs and revenue, and is the cornerstone of the regional economy in these departments.
Farmers use different techniques in managing crops. One common practice is to move crops around the areas due to the high risk in the incidence of diseases and pests if they stay in the same area for a long time. Some characteristics of the most important crop areas are presented below.

- Cundinamarca and Boyacá: in high-altitude zones of the "Cordillera Oriental" (eastern mountain chain) there are potato crops cultivated as unique crops and also there are potato crops combined

with dairy farming. In lower zones farmers use crop rotation, combining potatoes with other vegetables, grass, cereals and legumes. Nariño: in high-altitude mountain zones, potato crops are rotated with grass which is use for dairy cattle feeding, and is also rotated with other vegetables.

- Antioquia: in this area potato crops are combined with grass, beans and vegetables among other crops. In the north zone potatoes predominate with grass rotational crops.

Producers can be classified in three groups:

- *Small producers* sow up to 3 hectares, use simple technologies and are located in lands generally unsuitable for mechanization, at an altitude between 2,700 and 3,500 m. They are up nearly 90% of the farmers and produce about 45% of the total production potato in the country. Precise data on Cundinamarca and Boyacá show that small farmers are 95.4% of the total and occupy 56.2% of the cultivated area in the region.

- *Medium farmers* use better technology, sow from 3 to 10 hectares, are about 7% of the potato farmers and have a share of 35% of the total production. In the two departments these farmers are more common and they have a share of 4.1% of the total farmers and occupy 24% of the cultivated area.

- *Large producers* sow more than 10 hectares, represent about 3% of the producers and have a share of approximately 20% of the total potato crop in the country. In Cundinamarca and Boyacá they represent only 0.8% of the farmers, occupying 19.7% of the total cultivated area of potatoes. They are farmers with financial capacity and use technical production processes.

According to the above, potato crops in Colombia tend to be smallholder in nature, with little use of technology, the largest in the country and particularly in the departments with the largest area planted and production. As a result of the different types of producers and of technologies and processes used by them for planting in different regions, the yield per hectare varies greatly among the producing departments.

Conventional Farming in Potato Growing in Colombia

The potato is a temporary crop which produces two crops per year. As was mentioned above Colombia has potato crops in 14 departments, in areas between 2,000 and 3,000 meters above sea level and between 8°C and 13°C[18]. Optimum production zones based on the quality and quantity of the product are from farms located between 2,500 and 3,000 m. There are two marginal production areas in which the main limiting factors are: diseases and pests in the temperate climate between 1,500 and 2,000 m, and frosts in the highlands between 3,500 and 4,000 above sea level. 90% of commercial potato production is carried out on hillside land and 10% on flat lands.

Traditional agricultural practices used by small potato producers in the country include preparing soil for planting in rows across the slope. When the slopes are less than 25%, mechanical traction and the plow is used; on land with greater slope, the preparation is carried out with oxen, and a moldboard plow manually using a hoe. Planting is carried out before the start of the rainy season to take advantage of rainwater for crop germination and development.

The work of covering the seed and fertilizer application is done manually with a hoe. For maintenance of the crop are commonly used back and tractor sprayers, usually, with no calibration, using a single type of nozzles for all products and without protective gear.

The hilling is held approximately two months after planting with the use of hand hoe; thirty days after planting fungicides are applied, often from seven to nine days, led to the foliage of the plant; insecticides are applied between seeding and hilling. These activities vary from region to region and depend on the susceptibility of the varieties planted and the location of the crops.

The main disease is "the drop", so generally products are applied to prevent this disease every two weeks on an individual basis, depending on the weather. In the rainy season when the crop is flowering, the application of products is weekly; some farmers apply adherents to the herbicides and fungicides at this stage of production. Pests must be controlled with insecticides. This excessive use of agro-toxics, without knowing their active ingredients, results in higher costs and increased contamination of soil and water by toxic waste.

Harvesting is done three months after planting by hand with the use of tools like the hoe. The harvest, collection, packing, weighing and load consume around 24% to 35% of the labor costs.

Environmental damages due to crops mishandling

Moorlands and other conservation areas such as natural national parks and rivers are threatened by potato crops. The agricultural frontier expansion, the potato growing demand and high fertilizers use, are reasons why potato crops are damaging ecosystems. Other reasons such as the lower cost of land in the upper mountain zones and lower incidence of diseases in the higher zones continuously motivate farmers to cultivate up in moorlands.

Many cultivation zones in Boyacá, Cundinamarca and Nariño are superposed with moorlands areas. More than 40% of Colombian moorlands are located in these departments.

It is known in Nariño that deforestation problems and inappropriate farming practices have caused soil degradation and reduction of the water availability, among other negative effects [9].

Most of the potato cultivated area in Caldas, Tolima, Risaralda and Quindío are located inside the natural national park "Los Nevados"[35]. In this area, potato crops have been diminishing their yield. A high proportion of suitable land has been abandoned and another proportion, under intensive farming practices, is highly deteriorated.

Elements for a NAMA's Design

Studies results reported in national and international literature suggest that combining potato crops with other forestry and farming activities in order to structure silvopastoral and agroforestry systems, improve crop productivity among other benefits. Here we list some benefits related with silvopastoral and agroforestry systems:

- Improvements in productivity as a result of a greater nutrient contribution from plants to soils. For this reason, fertilizer requirements diminish. According to Agronet (2010) fertilizers represent about 25% of the potato production cost. On the other hand, the reduction in the amount of

fertilizers (nitrogen) has to do with the reduction of nitrous oxide emissions. Nitrogen fertilizers are a major greenhouse emission source in agriculture.

- Agroforestry systems reduce soil erosion. Potato production costs are reduced because no external inputs are required to improve soil conditions. It also reduces the pressure related with the agricultural frontier expansion.

- A living fence is one of the arrangements among agroforestry systems. Trees serve as fences besides serving as sources of fuel wood, posts and food. In this way live fences can contribute to reduce pressure on ecosystems and forests. Living fences reduce runoff and soil erosion. They are used to protect grasslands and crops from wind. Some trees also contribute to nitrogen soil fixation diminishing fertilizer requirements. Another benefit has to do with lower costs; living fences represent 54% savings compared to conventional fences[29].

- In addition to reducing emissions by lowering the use of nitrogen fertilizers, these systems act as a carbon sink. Agroforestry systems capture a greater amount of carbon compared with monocultures. According to Melo (2007) an agroforestry system can permanently store between 0.1 and 3.6 ton C/ha-year. The amount of carbon stored is a function of several variables such us trees and shrubs specie, type of system arrangement, and systems age, among others. According to studies conducted in Nariño, carbon stored in trees can vary between 3 and 25 tons per hectare[36] .

Available data to design the NAMA

We select Nariño as the analysis zone because of its important participation in national potato production and because several specific studies have been carried out in that region therefore data is available. In particular, professor Anibal Leon has developed an intense activity around this crop in this region. We intended to evaluate the NAMA for a small specific area and then, depending on the results, propose the NAMA expansion to other potato cultivation areas in the country.

There is information available regarding trees and shrubs species which could be used in Nariño agroforestry systems. There is also data for some species about their capacity to store carbon, under different agroforestry arrangements. Additionally there is data available about implementation costs for some systems. A description about the available data is presented below.

- Recommended arrangements of agroforestry systems: different kinds of problems related with agriculture were identified in a study conducted in the Pasto river basin[9]: deforestation, inappropriate farming practices and land degradation. Among other negative effects that have resulted in reduction of water availability. Considering this situation, the following arrangements were recommended:

    - An agroforestry system consisting of living hedges. This is particularly recommended for areas with a steep slope. Their principal function is to reduce and prevent erosion. It is formed by a double tree barrier, planted around the crop. The planting is done in a triangular shape to reduce runoff and to retain the soil transported by water.

- Agroforestry systems combining potato crop with other vegetables, using a barrier made with grass and alfalfa. In each hectare barriers are made with ten row downs according to the level curves. The distance between row downs is 10 meters, and distance between plants is 20 meters. This system helps in reducing soil drag in hillside areas.

- Trees and shrubs species recommended for their use in agroforestry systems: according to the studies developed in the region there are some species with higher potential to be used, because of the knowledge farmers have about them and because most of them have many other uses. These species are mentioned below: *Acacia decurrens, Acacia jorullensis, M. pubescens, Alnus acuminata*, *Cestrum nocturnum*, *Tournefortia fuliginosa, Lafoensia acuminata* and carob (*Prosopis juliflora).*

- Other species tested in that area are: Quillotocto (*Tecoma stans*) and Cajeto (*Cytharexylum subflavescens*)[29] [36]. These species are highly used in the region, and so have an important potential for being use in agroforestry systems.

- In another study developed by Rivera and León, 15 species of trees and shrubs were identified as being the most commonly used in Nariño: Alder (*Alnus acuminata*), Colla Blanca (*Verbesina arborea*), Eucalyptus (*Eucalyptus globulus*), Encino (*Weinmannia sp)*, Amarillo (*Miconia theazeans*), Chilca (*Baccharis latifolia*), Cancho (*Brunnelia sp*), Manduro (*Clusia sp*), Mano de Oso **(*Oreopanax sp.*),** Pinus (*Pinus patula)*, Cypress (*Cupresus lusitanica*), Chilacuán (*Schefflera marginata*), Acacia Amarilla (*Acacia decurrens*), Ahumado (*Ocotea sp.)* and **Pumamaque** (*Schefflera sp*.). This study found that farmers usually do not know the additional benefits of the species used for living hedges such as: erosion reduction, nitrogen fixation, better soil quality, higher organic matter content in soils, its role as a niche of several species of animals and plants and their usefulness in protecting water sources, among others.

- Some of these tree and shrub species have been evaluated in different types of agroforestry systems. Specifically there is available data about the carbon stored in the aerial and root biomass of the species mentioned below: aliso (*Alnus jorullensis*), *Alnus acuminata, Tournefortia fuliginosa, Acacia decurrens, Lafoensia acuminata* and *Cestrum nocturnum.*

- Information regarding agroforestry systems costs: in the study developed by Del Castillo (2008) an estimation of implementing and maintaining agroforestry systems in the Pasto river basin was carried out (Table 5.3). According to this study, costs vary around $250,000 and $1,750,000 (Colombian pesos 2008). In addition to the practices listed in Table 2.8, there are other practices recommended as a complement, these include reduced tillage as well as using organic fertilizers. These measures also improve erosion and sedimentation problems and improve soil conditions and nutrient content.

Table 2.8. Agroforestry systems cost in the Pasto river basin.

Description	Cost (Labor input per hectare, $Col/ha-yr)		
	Initial	Maintenance	Total
Revegetation 1 ha	1,255,000	434,450	1,689,450
Fallow land 1 ha	393,300		393,300
Scattered tress 128 tress/ha	217,400	30,000	247,400
Silvopastoral system, living hedge 400m	564,850	185,000	749,850
Living hedges with tress surrounding crops 1000m	1,526,000	220,000	1,746,000
Living hedges with Brazilian grass, king grass and alfalfa	328,400	60,000	388,400
Hillside ditches 900m	880,000	200,000	1,080,000
Improve pasture	377,400	377,400	754,800
Fencing and surveillance	393,300		393,300

Source: [9]

Limitations in designing the NAMA

We found some difficulties to propose a complete NAMA in this Study, which can be summarized as follows:

- Technical information regarding traditional practices is required to estimate baseline emissions; specifically information about the average amount of fertilizers applied to soil at different crop stages is required. Also information about burning practices, use of manure as fertilizer and information about the tillage system used is also needed.

- To estimate benefits from NAMA, we need to know how much crop yield increases in different arrangements, and by how much fertilizer requirements are reduced during the different stages of the crop.

- To estimate carbon reduction, we need to know the time lag between the implementation of the system and the moment it begins to generate benefits from carbon sequestration, as well as the average total carbon content in the biomass of the specific species of trees and shrubs used in the agroforestry system.

Having this information, we need to take into account the following for the elaboration of the proposal:

- To identify the potential area where the NAMA could be implemented.

- To design the methodology for assessing net emissions in each system, delimitate the system and define the period to be considered for quantifying emissions from the system.

After evaluating agroforestry systems in Nariño, information regarding the potential to implement it in other areas will be needed.

2.4 Measuring, Reporting and Verifying System

In this chapter we present a brief description about the MRV system we are proposing. A complete document, explaining the MRV system and the specific indicators, is available in Spanish. The MRV structure we propose is based on the existing verification system that Colombian Government uses in order to verify the accomplishment of the goals proposed in the National Development Plan (NDP). Within this scheme is the SIGOB, which is an information system implemented by the National Planning Department and the Presidency. It consists of verifiable numerical targets and indicators. The evaluation of the NDP is reported periodically to ministries, administrative departments, sector agencies, council of ministries, the National Planning Council and the National Congress [12].

Most of the indicators of our MRV system were selected from the Government´s indicators group. We designed additional indicators for the cases in which we considered the Government´s indicators did not accomplish our goals. These were selected and designed taking different levels into account. Some of them are related to the NDP goals and are macro, while others represent actions in the specific sectors the NAMAs are implemented. There are different indicators according to NAMA stages, so there are indicators for the implementation stage and others for monitoring of the NAMAS after they have been implemented. Finally, we proposed indicators to monitor the results of NAMAS and their contribution to the country's development goals (sustainable development), and other indicators related with the reduction of greenhouse gases emissions.

The verification mechanism for supported NAMAs would be defined between the parties involved in the same. These NAMAs could by verified by an independent certified accreditation entity (national or international). Regarding unilateral NAMAs, the Minister for the Environment should define a standard methodology to carry out the verification process. This standard methodology should include guidelines on: actors and responsibilities; schedule of reporting, monitoring and verification activities; reports and documentation, measure and monitoring processes and data quality, among other aspects.

2.5 Conclusions

This chapter concludes the country study. The most interesting findings will be summarized together with the conclusions that are derived.

In general, climate change has been gaining relevance in the formulation of public policy in the country.

There are many issues that need to be confronted and are difficult to overcome but the Ministry of Environment and Sustainable Development and the National Planning Department are advancing in the right direction. These institutions are working hard in building the coherence of institutional arrangements and capacities within them as well as in national universities.

There is a generalized concern in the country regarding adaptation and mitigation of climate change. The productive sectors are increasingly getting involved in the implementation of such measures.

The NAMAs are an interesting alternative taking into account the country's context and some important efforts have been done in order to define it.

The motivation for the introduction of NAMAS is evident in the declaration of interest written by the government. It is important to highlight the fact that these declarations made to the UNFCCC do not have a viability analysis to guarantee that they are in fact real pledges.

The exercise of structuring two specific NAMAs from scratch leads to some interesting conclusions. For the energy and transport sector, the difficulty resides in the identification of technology, but, in general, measures are more seizable that the ones in the agro sector. The team ran into severe difficulties when building the measures in the agriculture sector. The main reason for this is the fact that they have to be conceived in a background that considers the agriculture system as a whole. When building extensive measure in the energy and transport sectors this has to be done as well, but the analysis can begin analyzing specific characteristics (i.e. economic improvements). Another difficulty that was found is the fact that not many studies of this kind have been done in the agriculture sector.

With respect to MRV, since the NAMAs are of national interest, it is proposed that the verification of these measures be linked to the development interest of the countries. They must give information to the national government which is related to the evolution of the pledges.

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