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NEEDS Project – National Economic, Environment and Development Study for Climate Change

Options for Mitigation of Greenhouse Gas Emissions in Costa Rica: Towards Carbon Neutrality in 2021

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Contents

Presentation

The Costa Rican NEEDS (National Economic, Environment and Development Study for Climate Change) project is an initiative of the Ministry of the Environment, Energy and Telecommunications (MINAET), promoted by the UN Framework Convention on Climate Change (UNFCCC). The project was carried out by the INCAE Business School under a memorandum of understanding between UNFCCC and MINAET. It also benefited from technical support and coordination of the Fundación para el Desarrollo de la Cordillera Volcánica Central (FUNDECOR).

The analysis is based on an estimate of potential costs and impacts at the national and sectoral levels of the use of alternative technologies and production practices on the country's capacity to reduce greenhouse gas (GHG) emissions. In the case of Costa Rica, the analysis focuses specifically on its potential to achieve carbon neutrality (CN) by 2021, one of the main objectives of the country's national climate change strategy (ENCC).

This report was prepared by consultants Luis Rivera and Francisco Sancho under the direction of professor Lawrence Pratt, Director of the Latin American Center for Competitiveness and Sustainable Development at INCAE Business School. It is based on the following technical documents (in Spanish).

Modelación de escenario de crecimiento económico 2010-2030 (Modelling of the economic growth scenario 2010-2030) – Luis Rivera.
Modelación de variables clave y proyección de emisiones de CO_2 (Modelling of key variables and CO_2 emissions projections) – Francisco Sancho and Luis Rivera.
Identificación y evaluación de iniciativas y proyectos de mitigación en el sector energético, de transporte, residencial, industrial y desechos sólidos (Identification and evaluation of mitigation initiatives and projects in the energy, transport, housing and solid waste sectors) – Francisco Sancho and Luis Rivera.
Proyección de emisiones de CO_2 *en el sector forestal y agropecuario: Departamento de Ciencia y Tecnología. Fundación para el Desarrollo de la Cordillera Volcánica Central (FUNDECOR)* (CO_2 emissions projections in the forestry and agricultural sector: Department of Science and Technology. Fundación para el Desarrollo de la Cordillera Volcánica Central [FUNDECOR]) – Germán Obando and Johnny Rodríguez.
Identificación y evaluación de iniciativas y proyectos de mitigación en el sector forestal y agropecuario: Departamento de Ciencia y Tecnología. Fundación para el Desarrollo de la Cordillera Volcánica Central (FUNDECOR) (Identification and evaluation of mitigation projects and initiatives in the forestry and agricultural sector: Department of Science and Technology. Fundación para el Desarrollo de la Cordillera Volcánica Central [FUNDECOR]) – Germán Obando and Johnny Rodríguez.

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The conclusions and opinions expressed are those of the authors and do not necessarily reflect the positions of MINAET or the UNFCCC, or those of the public sector organizations that contributed data, provided input and proposals for the study. Comments and observations can be sent to Lawrence Pratt (lawrence.pratt@incae.edu), Luis Rivera (luis.rivera@consultor.incae.edu) or William Alpízar (walpizar@imn.ac.cr).

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ABBREVIATIONS

ARESEP	Autoridad Reguladora de Servicios Públicos (Regulatory authority of public services)
BAU	Business as usual (current tendency)
BCCR	Banco Central de Costa Rica (Central Bank of Costa Rica)
CATIE	Tropical Agriculture Research and Training Center (this is the official English title and is thus capitalized)
CDM	Clean Development Mechanism
CER	Certified Emissions Reductions
CFL	compact fluorescent lamp
CGE	computable general equilibrium
CH_4	methane
CLACDS	Latin American Center for Competitiveness and Sustainable Development
CNC	Consejo Nacional de Concesiones (national concessions council of the general comptroller's office)
CN	carbon neutral
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CONACE	Comisión Nacional de Conservación de Energía (National commission for energy conservation)
DIGECA	Dirección de Gestión de Calidad Ambiental (Directorate for the management of environmental quality)
DSE	Dirección Sectorial de Energía (Sectoral energy directorate)
ENCC	Estrategia Nacional de Cambio Climático (national climate change strategy)
FONAFIFO	Fondo Nacional de Financiamiento Forestal (National fund to finance forestry)
FUNDECOR	Fundación para el Desarrollo de la Cordillera Volcánica Central (Fund for the development of the Cordillera Volcánica Central)
GAM	Gran Area Metropolitana (greater metropolitan area)
GDP	gross domestic product
Gg	giga gram
GHG	greenhouse gas
Ha	hectare
ICE	Instituto Costarricense de Electricidad (Costa Rican electricity institute)
IMN	Instituto Meteorológico Nacional (National meteorological institute)
INEC	Instituto Nacional de Estadística y Censos (National institute for statistics and census)
IPCC	Intergovernmental Panel on Climate Change
ITCR	Instituto Tecnológico de Costa Rica (Costa Rican Institute of Technology)
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LPG	liquefied petroleum gas
LULUCF	land-use, land-use change, and forestry
MIDEPLAN	Ministerio de Planificación (Ministry of Planning)
MINAET	Ministerio de Ambiente, Energía y Telecomunicaciones (Ministry of the Environment, Energy and Telecommunications)
MOPT	Ministerio de Obras Públicas y Transporte (Ministry of Public Works and Transport)
MT	metric tonne
MW	megawatt
NEEDS	National Economic, Environment and Development Study for Climate Change Project
NO_x	nitrous oxides (NO and NO_2)
OCIC	Oficina Costarricense de Implementación Conjunta (Costa Rican office for joint implementation)
PES	Payment for Environmental Services
PRUGAM	Plan Regional Urbano de la Gran Área Metropolitana de Costa Rica (Regional urban plan of Costa Rica's greater metropolitan area)
REDD	reduced emissions from deforestation and forest degradation
SINAC	Sistema Nacional de Áreas de Conservación (national system of conservation areas)
TFP	total factor productivity
TJ	terajule
TREM	Tren Eléctrico Metropolitano (metropolitan electric train)
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States dollar
DR-CAFTA	United States-Dominican Republic-Central America Free Trade Agreement

1. INTRODUCTION

Background

The Costa Rican National Economic, Environment and Development Study for Climate Change (NEEDS) project is an initiative supported by the United Nations Framework Convention on Climate Change (UNFCCC). Its main objective is to support countries (not among Annex 1 states) in analyzing financial requirements for the implementation of projects to mitigate and adapt to climate change.

In the case of Costa Rica, the focus is on the analysis of specific sectors and projects capable of contributing to the reduction of greenhouse gas (GHG) emissions. The analysis looks at the potential to achieve carbon neutrality (CN) by 2021, one of the main objectives of the country's national climate change strategy (ENCC).

Costa Rica has made considerable efforts in promoting sustainable environmental management and especially climate change mitigation at the national and international levels. Since the 1970s, the country has made important investments in forest protection and biodiversity through its national system of conservation areas (SINAC). For over a decade almost US$400 million have also been spent on reducing deforestation through the Payment for Environmental Services (PES) system. From the perspective of sustainable energy and the reduction of GHG emissions, over 90% of the country's electricity is currently being generated from renewable sources.

The sources of financing for these national efforts have been largely fiscal in nature (taxes on fossil fuels), local funds, and foreign debt. International cooperation has played a positive though comparatively minor role.

The country has led discussions within the UNFCCC, was a pioneer on the emerging carbon markets, has developed various projects under the Clean Development Mechanism (CDM),[1] and has established the ambitious goal of reaching carbon neutrality by 2021.

Climate change is a political priority for Costa Rica. The ENCC comprises six strategic areas (mitigation, adaptation, measuring, capacity building, awareness raising and public education, funding), with the common objective of aligning policies with climate change as part of a long-term strategy for sustainable development.[2]

1 Table A1 in the annex provides details of national projects developed under the CDM.

2 The mitigation and adaptation measures evualated are aligned with key sectors of the economy, such as tourism, electricity generation, forests and the payment for environmental services, among other core areas seeking to consolidate a sustainable development strategy that strengthens the country's competitive performance and contributes to mitigating climate change.

The main objectives of the strategy are to achieve a climate neutral economy by 2021, reduce sectoral and geographical vulnerability in the face of climate change, and develop an information system that is precise, reliable and verifiable. It also seeks to building capacities, educate and raise awareness among the population, as well as create the financing mechanisms required to promote the national agenda.

Objective and Focus

The mitigation analysis is based on the estimation of costs and potential impacts at the national and sectoral levels on the capacity of the country to reduce GHG emissions, which would result from the use of alternative technologies and productive practices.

The main objective is to provide policy makers with an analysis that includes potential options, alternative scenarios, and costs associated with mitigation, consistent with the country's sustainable development objectives. A direct result of the analysis is the construction of a GHG mitigation cost curve. This curve establishes a relation between the quantity of GHGs (in tonnes of CO_2 equivalent) that can be reduced through different options under consideration, and the unit cost: dollars per tonne of CO_2 equivalent.

The final objective of the mitigation cost curve is to present different options, according to their mitigation potential and associated costs. To this end, the average, incremental and marginal costs need to be differentiated. Given that it is discrete curve rather than a continuous one with various "blocks" of mitigation options, the "cheapest" options to the most "expensive" options also need to be considered, reflecting increased costs (supply) in the face of higher prices per tonne.

The scope of the study is both technical and financial. Although institutional and policy design aspects are identified for evaluation in the promotion of a carbon neutral strategy, it is based on the assumption that future planning conditions are a given, so as to focus on recommending mitigatory measures based on the quantitative analysis. The work is based on four components:

- The scope of the mitigation evaluation (in this case 2010-2030) and the methodology to be used (particularly the conceptual and analytical focus, as well as the working tools)
- The identification, delimitation and characterization of the technologies and productive practices with greatest mitigation potential and consistency with national sustainable development objectives, based on a cost/benefit focus.
- The estimate of costs and potential impacts of different technologies and policy measures on GHG emissions.

- The analysis of the following sectors:
  - Land use and land use change
    - i. Agricultural sector
    - ii. Forestry sector
  - Energy supply and demand
    - i. Generation by source and technology
    - ii. Total consumption (industry, residential, services, transport)
  - Solid waste management

The general focus of the work is summarized in figure 1. An evaluation at the macro level (from the most general to the most specific, or top down), and at the micro level with a detailed analysis of projects working towards their aggregation to evaluate global effects (or bottom up), is carried out. In the study phases various analytical tools were used and are detailed on the following chapters. The steps involved in the study were:

1. Collection of information to establish the baseline. The point of departure was the most recent GHG inventory carried out by the national meteorological institute (IMN). Other available secondary sources of information were also evaluated. No surveys or field work were carried out to access primary sources of information.
2. Projections and assumptions on economic growth and other pertinent social and environmental variables at the national and sectoral levels.
3. Evaluation of individual (sectoral) potential of different technological options.
4. Cost/benefit analyses to identify the best technological options.
5. Building of the national mitigation curve, based on the following criteria:

a. Potential to reduce GHG emissions

b. Cost/benefit analysis of the option

c. Other indirect economic impacts (if relevant)

d. Consistency with national development goals

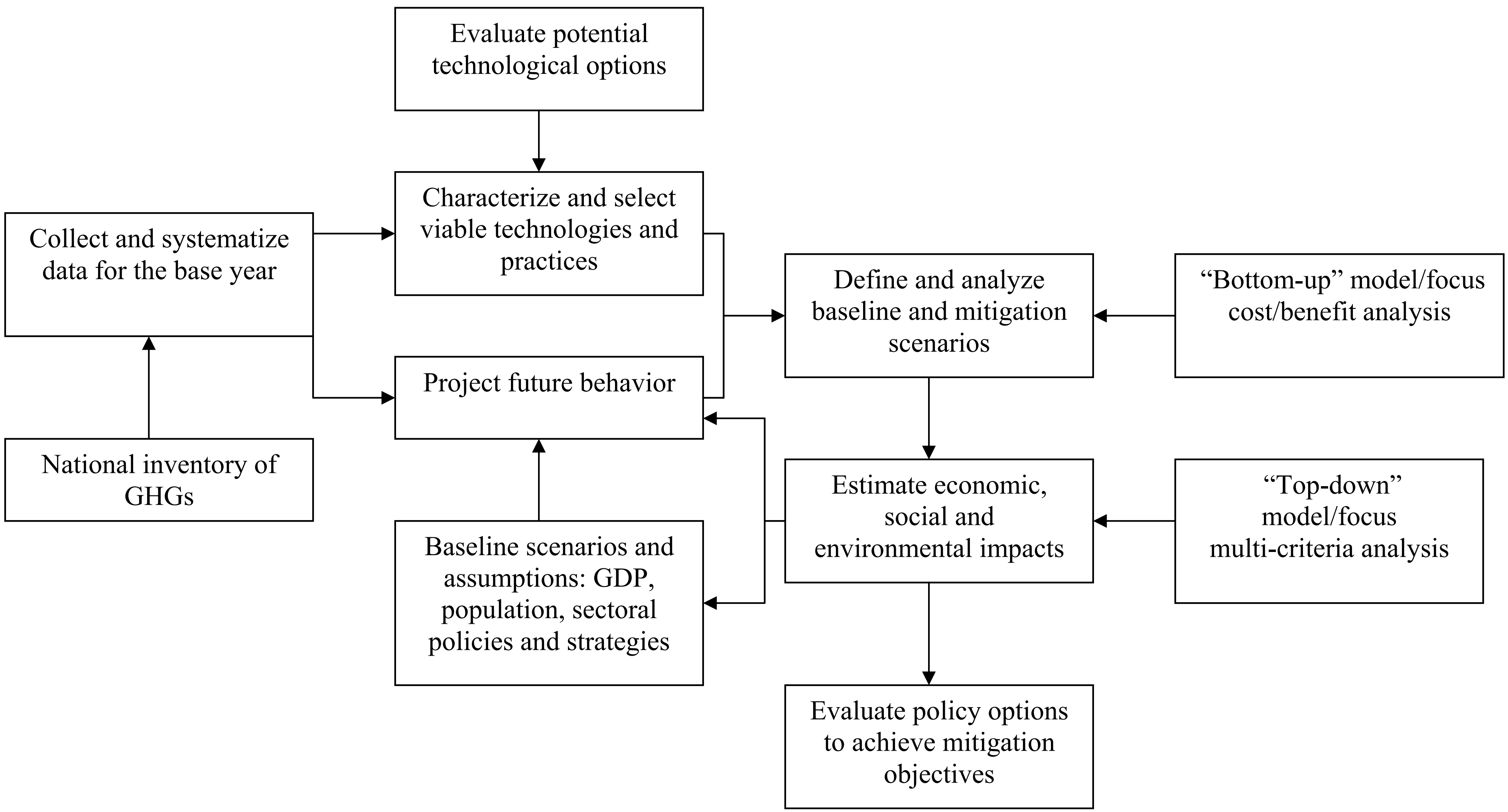
e. Implementation feasibility

f. Long-term sustainability

g. Availability of data and information for follow up and adjustments.

6. Evaluation of the institutional and policy environment to promote the identified options.

Figure 1 General Structure of the Analysis of Mitigation Options



Source: Adapted from a methodology developed by the Lawrence Berkeley National Laboratory (LBNL).

2. EMISSIONS INVENTORY AND TRENDS

Costa Rica's new GHG inventory which was part of the Second National Communication to the UNFCCC indicates that the energy and agricultural sectors are the country's main GHGs producers (table 1).[3] This is the result of fossil fuels used in the transport sector, methane emissions from cattle, and the intensive use of agrochemicals in agricultural activities.[4] In agriculture, emissions seem to have stabilized, while in other sectors they have been increasing. In the case of land use change sector, this has consolidated as an important source of carbon capture (in the forestry sector).

Table 1 Greenhouse Gas Emissions (Gg CO_2e)

Source	2000	2005
Energy	4,805.6	5,688.6
Industrial Processes	449.8	672.5
Agriculture	4,608.6	4,603.9
Land Use Change	-3,160.5	-3,506.7
Waste Management	1,236.9	1,320.9
Total	**7,940.5**	**8,779.2**

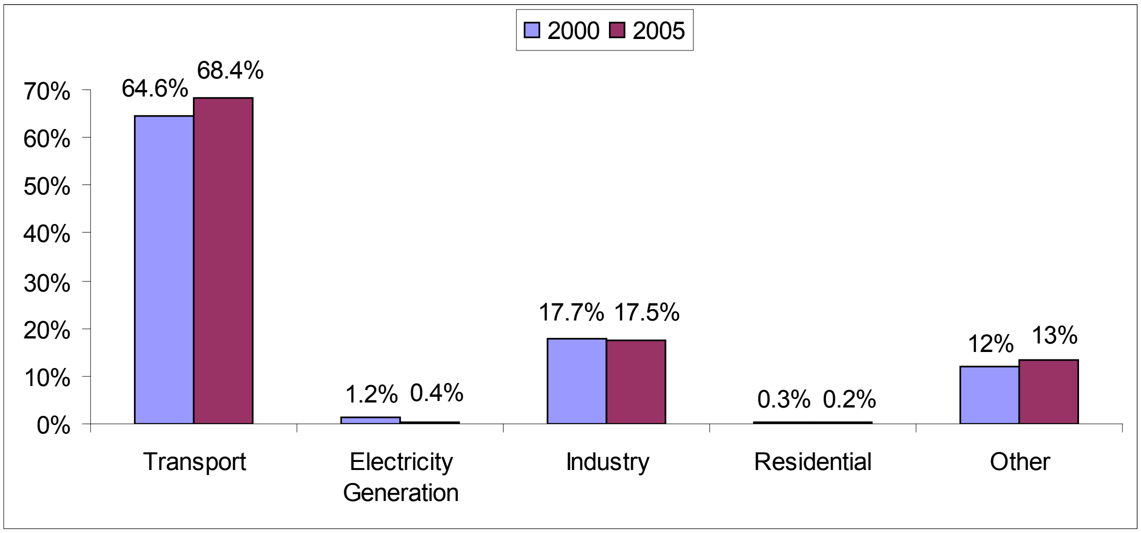
Source: MINAET and IMN (2009).

The issue of emissions from the energy sector focuses on the transport sector, since 90% of the country's electricity generation depends on renewable resources, mainly hydroelectricity. On the other hand, emissions from agricultural activities have tended to stabilize over recent years, after having peaked in the 1990s. As far as change in land use is concerned, the role played by the forestry sector in carbon capture is to be noted. Forest conservation policies, the protection of national parks and the Payment for Environmental Services (PES) scheme, among others, have resulted in the consolidation of a forestry sector that makes an important contribution to mitigating greenhouse gases.

3 Tables A2, A3, A4, and A5 in the annex provide further details of emissions by main sectors.

4 The transport sector generates 70% of total emissions due to energy use, representing 45% of the country's total emissions.

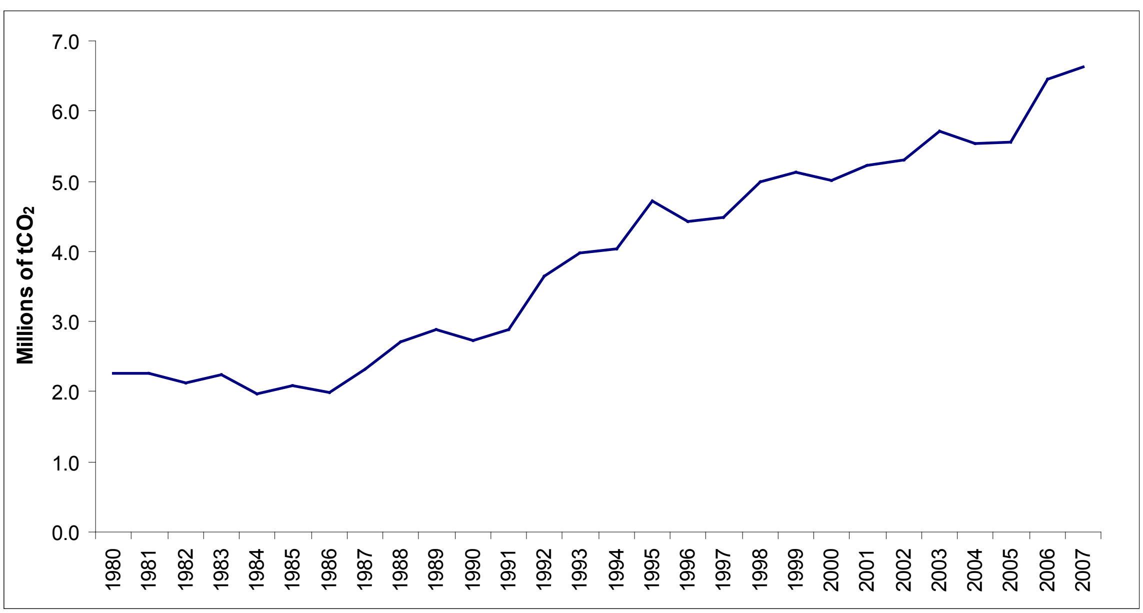
Figure 2 Distribution of Emissions within the Energy Sector



Source: Based on data from MINAET and IMN (2009).

Country emissions from fossil fuels have tripled over the last three decades (fig. 3). This indicates that Costa Rica's economic growth has resulted in a considerable increase in emissions from fossil fuel sources, particularly in the transport and industrial sectors.

Figure 3 CO_2 Emissions from Fossil Fuels (millions of metric tonnes)



Source: Based on data from the U.S. Energy Information Administration.

A tool frequently used in exploring aggregated determinants of emissions is the Kaya identity.[5] According to this identity a country's emissions can be broken down into the product of four basic factors: a) CO_2 emissions per unit of energy, energy consumed per GDP, per capita GDP, and population:

$$CO_2 = \left[\frac{CO_2}{E}\right] \times \left[\frac{E}{GDP}\right] \times \left[\frac{GDP}{POP}\right] \times POP$$

Estimations of possible emission scenarios can be made based on this identity taking into consideration the behavior of its components, and the business as usual (BAU) baseline scenario. The possible implications of mitigation measures in the future can be identified using the behavior estimations of each of the components. Likewise, assumptions can be made on emissions goals and establish the impact on determinant variables.

As CO_2 emissions are related to the product of various factors, changes cannot be expressed simply as the sum of absolute changes to these factors. In this sense, Bacon and Bhattacharya (2007) suggest using the Divisia index (mean log) to obtain a more precise decomposition.[6] Thus, emissions variations between year 0 and a year t will depend on changes to each component expressed as:

$$\Delta CO_2 = [CO_{2t} - CO_{20}] * \left[\left\{\ln\left[\frac{C(t)}{C(0)}\right] \Big/ \ln\left[\frac{CO_{2t}}{CO_{20}}\right]\right\} + \left\{\ln\left[\frac{E(t)}{E(0)}\right] \Big/ \ln\left[\frac{CO_{2t}}{CO_{20}}\right]\right\} + \left\{\ln\left[\frac{Q(t)}{Q(0)}\right] \Big/ \ln\left[\frac{CO_{2t}}{CO_{20}}\right]\right\} + \left\{\ln\left[\frac{P(t)}{P(0)}\right] \Big/ \ln\left[\frac{CO_{2t}}{CO_{20}}\right]\right\}\right]$$

Where:
C = Carbon intensity from the energy (in fossil fuel use)
E = Energy intensity of GDP
Q = Per capita GDP
P = Population

Based on historic data, table 2 shows the behavior of each component of the Kaya identity for Costa Rica between 1980 and 2007. As can be seen, emissions during the 1980s and 1990s can mainly be explained by an increase in energy intensity, national production and population growth. During the previous decade the country showed an improvement in per capita energy consumption, but emissions related to energy use increased. This coincided with an increase in economic growth and, to a lesser degree, population growth.

5 Kaya, Y. (1990): "Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios." Paper presented to IPCC Energy and Industry Subgroup, Response Strategies Working Group.

6 What is sought is to approximate changes in components as a continuous function of time, as relative changes in total emissions.

Table 2 Composition of Emissions Changes due to Fossil Fuel Use

Change (Distribution %)	1980-1990	1990-2000	2000-2007
Carbon intensity (of energy)	-55.6%	-16.8%	28.9%
Energy intensity (of GDP)	29.5%	32.8%	-46.8%
Per capita GDP	-19.5%	50.3%	75.1%
Population	145.6%	33.8%	42.9%
Emissions due to fossil fuel use (millions of tCO_2)	+0.47	+2.27	+1.82

Source: Own elaboration with data from the U.S. Energy Information Administration, based on Bacon and Bhattacharya (2007).

This demonstrates the need to identify the main sources of GHG emissions when analyzing increases, to enable a focus on priority areas of action for policy recommendations. This macro focus should, however, be complemented with a more detailed analysis (at project level) to enable feasibility analysis of action to be taken to achieve greater economic growth that is less energy intensive and with lower emissions.

3. EMISSION PROJECTIONS

This section provides details on baseline estimations for Costa Rica of net GHG emissions, based on the country's electricity and oil consumption, as well as emissions from the forestry and agricultural sectors.

In the case of oil, projections were initially made for each individual sector: residential, industrial, commercial, general, and transport. However, in order to establish sufficiently sturdy statistical regression models, these sectors were grouped, with the exception of the transport sector for which oil consumption is separate. In this case models were established for the consumption of gasoline, diesel and other oil derivatives. Oil consumption, other than for transport, was established by grouping all other sectors together.

The electricity sector was modeled aggregating all sectors, despite the fact that its characteristics and studies carried out by the sectoral energy directorate (DSE) facilitate individual modeling. However, for the purpose of projections and the application of mitigation and abatement models, the aggregated model meets the objectives of the study.

First, the projection of baseline variables from which the respective projections are used in regression models (population, the number of housing units and the population per housing unit, gross domestic product, and oil prices) are presented, followed by adjustments in energy use on which a baseline scenario is estimated to enable projections. Estimations of GHG as CO_2 equivalent (CO_2e) resulting from oil use are then calculated. Information from secondary sources is also used to approximate future emissions generated from growth in solid waste.

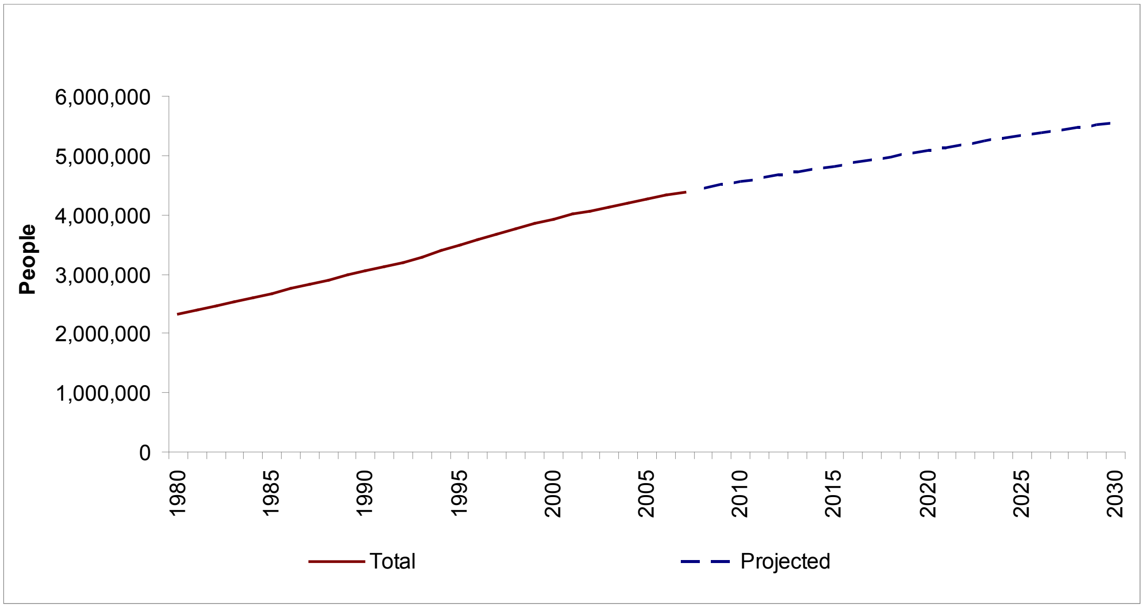
Regarding the forestry and agricultural sectors, projections are made on land use and changes to land use to identify the potential contribution of each sector to mitigating emissions. The study is deepened using a new methodology that draws on satellite images to carry out a more detailed inventory of current land use and that over recent years. In this manner a baseline can be estimated following a business as usual scenario.

Projection of Baseline Variables in Estimating Emissions due to Energy Consumption

Population and Housing

Population projections are those of the national institute for statistics and census (INEC) which projects population increase up to 2030. After 2023, the rate drops below a 1% annual growth rate. In 2008 the population reached 4,451,205, in 2021 it will attain 5,136,625 inhabitants, and by 2030 it is projected to reach 5,563,132.

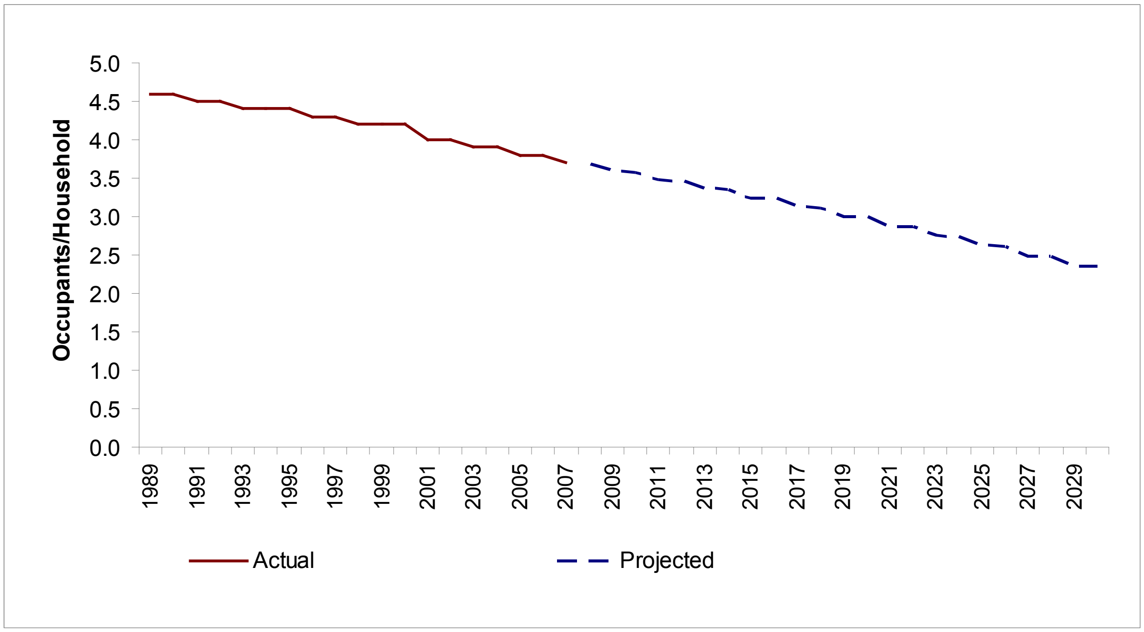
Figure 4 Historical and Projected Population



Source: Own elaboration with data from INEC.

A most important aspect in modeling the baseline scenarios is the country's projected number of houses. The population of the period was applied to the number of houses to thus obtain the number of people per household. An autoregressive model with two lags was applied to the resulting time series. The model was highly significant. The projected numbers of occupants per housing unit is estimated at 2.9 up until 2021, starting at 3.69 in 2008, and reaching 2.35 occupants per housing unit in 2030.

Figure 5 Historical and Projected Number of Persons per Household



Source: Own elaboration with data from INEC.

Gross Domestic Product

The Computable General Equilibrium (CGE) model, developed by Rivera and Rojas-Romagosa (2010)[7] is used in making projections of changes to the country's gross domestic product (GDP) up to 2030. This is a recursive dynamic model, resolved for each projected year, linking results through exogenous shocks in key variables such as production factors and productivity levels. In this manner a growth path for production is estimated serving as a baseline for subsequent analyses. In all cases *deviation* from the growth rate in production is calculated and compared with the model's estimated baseline. The annual growth rate until 2030 is then established, using 2004 as the base year.

For this exercise an annual growth rate of 3% is assumed for production factors (land, work, and capital) as well as a 1.5% annual increase in total factor productivity (TFP). The issue of TFP is key, as literature indicates that although Costa Rica has performed modestly when compared with other developing nations, maintaining a rate of growth in sustained productivity over the long term is a fundamental condition of accelerating economic growth.[8]

7 Rivera, L. and H. Rojas-Romagosa (2010): *Human Capital Formation and the Linkage between Trade and Poverty: The Cases of Costa Rica and Nicaragua.* Trade and Integration Division, ECLAC. Forthcoming.

8 Monge-González, R., L. Rivera and J- Rosales (2010): *Productive Development Policies in Costa Rica: Market Failures, Government Failures and Policy Outcomes.* IDB Working Paper Series 157. March.

In considering the importance of international trade to the country's growth, simulations were also carried out of the expected impacts of the free trade agreement with the United States (following Francois et al. 2008)[9] and the association agreement with the European Union (based on Rivera and Rojas-Romagosa, 2009).[10] It is important that these agreements be considered as growth over the next two decades is expected to depend to a large extent on international trade, as it has done over recent years with the country's increased integration in the international economy.

Figure 6 shows the growth rates estimated with the model, for both for "high" and "moderate" growth curves.[11] Acceleration in growth rates is to be noted when connections are strengthened as a result of integrating the trade blocks offered by the US-Dominican Republic-Central America Free Trade Agreement (DR-CAFTA) and the European Union. The highest growth rates can be observed the moment the agreements are consolidated when the schedule for the elimination of trade barriers comes into effect. The productivity increase simulated in the model is also factored into these rates.[12]

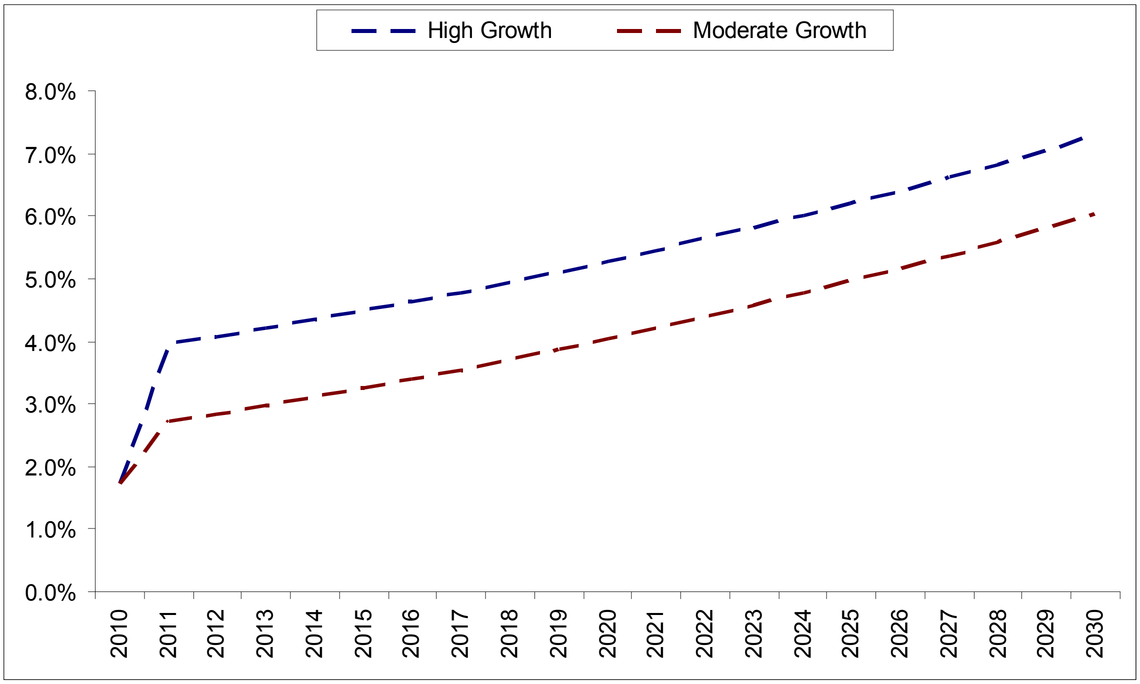
9 Francois, J., L. Rivera and R. Rojas-Romagosa (2008): "Economic Perspectives for Central America after CAFTA: A GTAP-based Analysis." CPB Discussion Paper 99. CPB Netherlands Bureau for Economic Policy Analysis.

10 Rivera, L. and H. Rojas-Romagosa (2009): "Análisis de Impacto sobre la Sostenibilidad (AIS) ante un Acuerdo de Asociación entre la Unión Europea y Centroamérica." *In* S. Heieck et al., eds, Política Comercial en Centroamérica: Perspectivas del Acuerdo de Asociación con la Unión Europea y Retos para las Pequeñas y Medianas Empresas. Alajuela, C.R.: INCAE Business School.

11 Two growth paths were considered in analysing the sensitivity of total projected emissions to the GDP growth rate. However, as no great difference was noted in the emissions projections that are developed in a later section, the results presented in this report are based mainly on the "high" growth curve. Nonetheless, several estimations based on the "moderate" scenario are included as a reference. Average annual growth rates for the 2010-2030 period in both cases are 5.28% (high) and 4.09% (moderate).

12 It should be remembered that these estimations are based on assumptions on the economy's future behavior. It is recommended that these be reviewed in the future as progress is made on GHG emission mitigation plans and projects. It should also be remembered that simulations are based on scenarios that do not take into account other possible effects of internal and external variables on the economy's growth pattern. Furthermore, in this instance, only static effects (efficiency in productive resources reallocation) resulting from the opening up of trade are being considered. Other possible changes that have dynamic impacts, such as increased direct foreign investment or endogenous changes in productivity, are not evaluated.

Figure 6 Projected GDP Growth (2010-2030)



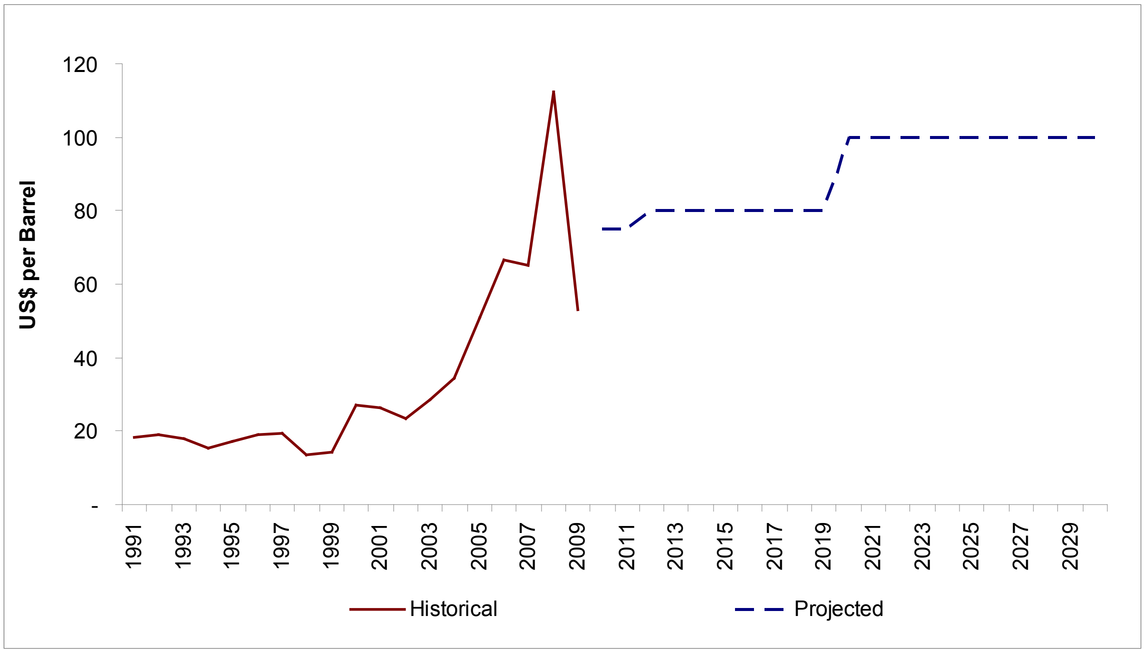
Source: Own elaboration.

Oil Prices

As far as projections are concerned, it is assumed that international oil prices will not fall below US$75 per barrel in the future, rising to US$80 during the current decade, and then to US$100 in the following one.[13] In making such assumptions on the future behavior of oil prices, the application of regression models provides us with the price of fuels for use in estimating energy consumption.

13 The projections of the International Energy Agency suggest average barrel prices that vary between US$100 and US$200 until 2030. See World Energy Outlook 2009. IEA/OECD. Paris. 2009.

Figure 7 Historical and Projected Oil Prices



Source: DSE and own estimations.

Energy Consumption

In estimating energy consumption and resulting emissions, the possibility of sectoral models by economic activity was analyzed, distinguishing emissions from residential, commercial, industrial, transport and general sectors. This would allow sectoral mitigation measures to be considered. However, due to the relative importance of the transport sector in the consumption of oil derivatives, representing 68%, and the importance of oil derivatives in energy consumption, representing 58% of the country's energy consumption, modeling by sector is more difficult to set up as accounting for energy by sector excludes consumption from transport, making resulting figures difficult to correlate with the macro-variables associated with the activity.[14]

The methodology chosen was to consider the electricity sector as a whole, without breaking electricity consumption down by economic sector. A similar criterion was applied to energy consumption from firewood, biomass, and those classified as other sources. The focus was different in the case of oil as consumption was broken down into diesel, gasoline, and other oils. This breakdown was made in order to provide a more detailed analysis of the consumption of oil derivatives due to their considerable relative importance in the country's total energy consumption.

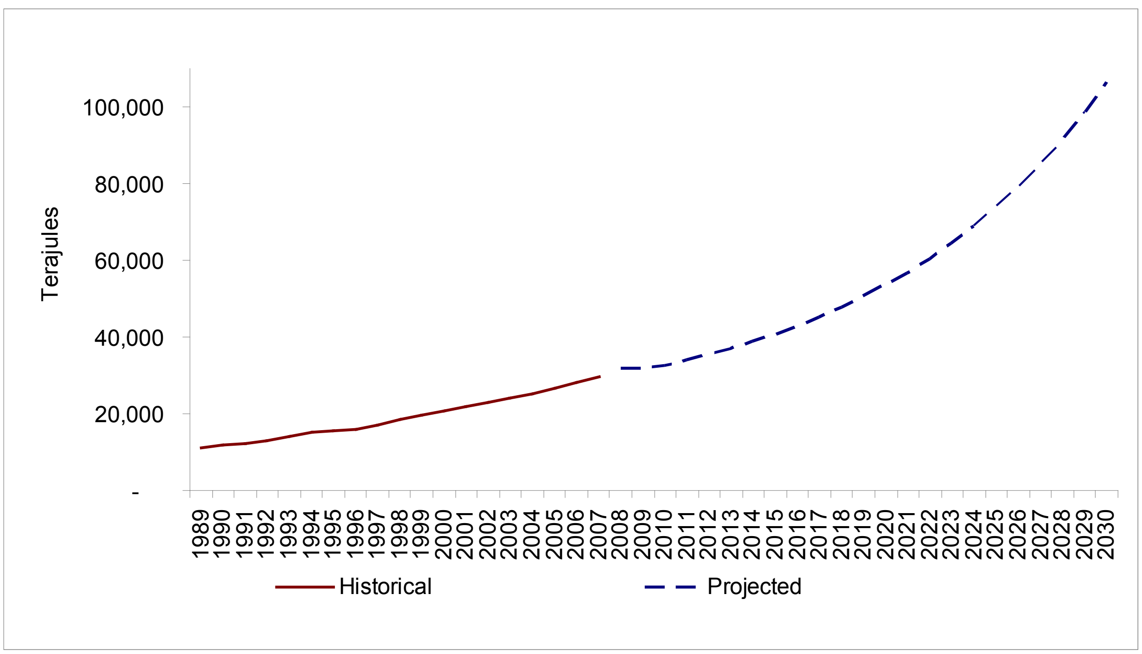
14 This limitation was pointed out by DSE personnel who noted these difficulties when providing suggestions as to how to carry out the modelling.

Electricity Consumption

Electricity consumption has shown a strong association with national production over the last decades. Regarding real GDP (1991 baseline), the association is almost perfect until 1999, with electricity consumption falling a little more than proportionally in 2000 and 2001, but finding a close association again from 2002 onwards.

Estimated future electricity consumption is based on a regression adjustment. In comparing historical and projected figures, it can be seen that growth in electricity consumption between 1989 and 2007 was 5.5%. For the period of the project, this growth rate will be 5.7% on average. In the year 2008 electricity consumption was 31,850 terajules (TJ), while for 2021 consumption is expected to rise to 56,843 TJ, and for 2030 it will reach 106,451 terajules.

Figure 8 Historical and Projected Electricity Consumption



Source: Own elaboration with DSE data.

Firewood and Biomass Consumption

According to DSE[15] the main sources of firewood are trees in fields, coffee plantations, scrubland, as well as waste from gap felling, and sawmill waste, which has suffered changes due to the introduction of new agricultural and livestock technologies, such as the elimination of shade trees in coffee plantations and the use of coffee varieties of shorter stature that produce less firewood from pruning.

In its analysis of the fifth national energy plan 2008-2021, DSE also indicated that there is a considerable information gap on this activity, as estimates of the annual potential of this resource date back to 1986-1987 and includes a comparison with figures on the potential of the resource in the biomass survey of 2006, a fact which could render the comparison invalid as it covers completely different periods. It is on these points of reference that consumption time series have been built.

Taking these and other limitations into account, a projection model was developed based on a regression using the period 1993 to 2001 as a baseline, when increased firewood consumption appeared more moderate and thus showed a greater correlation with real GDP. This, according to DSE, is due to inefficient management of scrubland, population growth, and industrial demand, which have put considerable pressure on the resource, driving it to overuse.[16] It is possible therefore, that the strong peak in consumption between 2002 and 2007 – that might in fact be the result of the previously mentioned poor estimations – could simply be unsustainable due to firewood production limitations.

Historical data revealed an average annual growth rate in consumption of 5.0%, while during the projected period the average growth rate is 4.9 per cent. The year 2008 shows a consumption of 12,565 TJ, with 28,309 TJ estimated for 2001, and 47,470 TJ for 2030.

Biomass consumption for energy production has similar limitations, although the analysis indicated a stronger relation to real gross domestic product. Once the adjustment has been made, while the average growth rate over the historical period covered was 3.6%, it reaches 3.1% over the projected period. The year 2008 thus shows a consumption of 9,491 TJ, while 12,752 TJ are estimated for 2021, and 17,558 TJ for 2030.

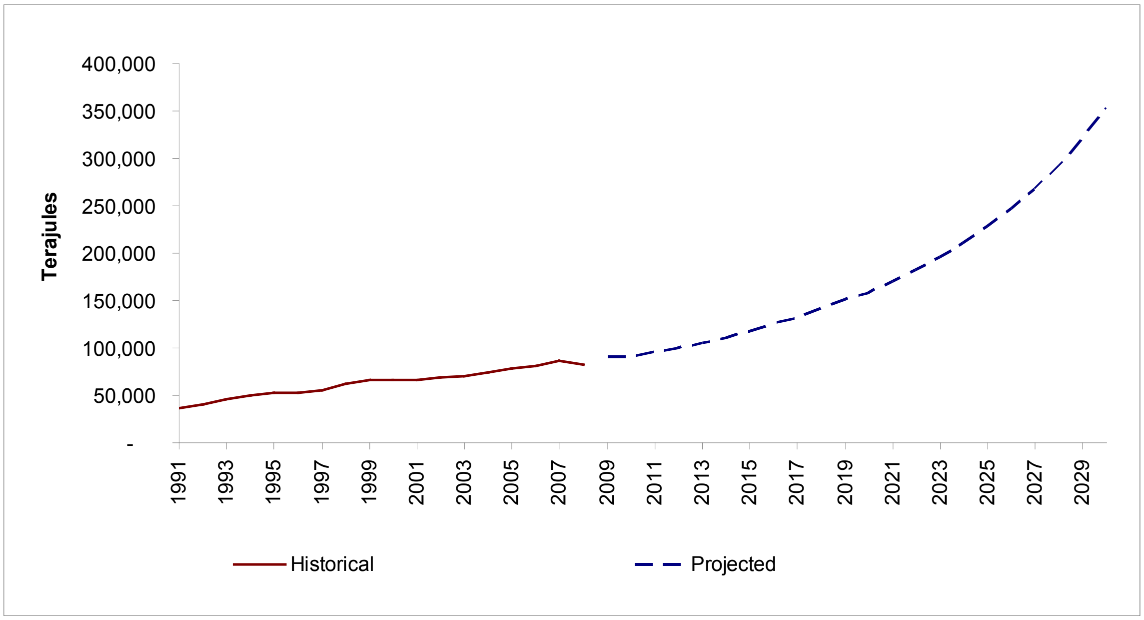
15 Dirección Sectorial de Energía (DSE). Diagnóstico V Plan Nacional de Energía 2008-2021, San José, Costa Rica: February 2008, page 74.

16 Dirección Sectorial de Energía (DSE). Diagnóstico V Plan Nacional de Energía 2008-2021, San José, Costa Rica: February 2008, page 74.

Consumption of Oil Derivatives

As mentioned, the consumption of oil derivatives was subdivided into the consumption of diesel, gasoline and other oils. Total estimated oil consumption was estimated at 81,949 TJ in 2008, projected to 169,626 TJ in 2021, and reaching 352,996 TJ in 2030.

Figure 9 Historical and Projected Oil Consumption



Source: Own elaboration with DSE data.

Diesel and Gasoline Consumption

Adjustments were made to oil consumption based on the fleet of load bearing vehicles, the fleet of public transport vehicles, and the price of diesel. The ratio number of people per vehicle was used in estimating the fleet. This indicator enables the use of a fleet-population ratio which is of a reasonable order of magnitude. In the case of gasoline, the fleets of private vehicles, motorcycles and other vehicles, and the average price of *super* and *regular* gasoline[17] were used as explanatory variables.

Diesel and Gasoline Prices

It was noted that the national pricing policy of diesel and gasoline was closely linked to the behavior of oil prices, particularly after 1998. Adjustments were made in both cases in estimating the relationship.

17 Local gasoline standards according to their octane level.

Total Energy Consumption

Table 3 shows total projected consumption of energy according to the different sources analyzed, this being 145,674 TJ in 2008, 276,049 TJ in 2021, and 540,270 in 2030. Oil is the primary energy source for 58% of energy consumed in 2008, and this is projected to reach 61% in 2021, and 65% in 2030. This indicates that the national tendency towards greater dependency on petrol derivatives in satisfying energy consumption will follow the BAU scenario.

Table 3 Total Energy Consumption in BAU (High-Growth) Scenario (TJ)

Year	Oil Derivatives	Electricity	Firewood	Other Biomass	Others	Total
2008	81,949	31,850	17,565	9,492	4,818	145,674
2009	91,129	31,850	17,565	9,492	4,818	154,855
2010	90,570	32,456	17,840	9,584	4,909	155,359
2011	95,412	33,893	18,488	9,797	5,122	162,713
2012	99,863	35,442	19,182	10,023	5,353	169,862
2013	105,433	37,115	19,925	10,262	5,601	178,336
2014	111,463	38,924	20,722	10,514	5,870	187,492
2015	118,002	40,883	21,577	10,780	6,160	197,402
2016	125,126	43,008	22,497	11,062	6,475	208,168
2017	132,905	45,317	23,488	11,361	6,817	219,888
2018	141,420	47,834	24,557	11,679	7,189	232,678
2019	150,739	50,574	25,710	12,015	7,594	246,632
2020	158,381	53,569	26,959	12,373	8,036	259,319
2021	169,626	56,843	28,309	12,752	8,519	276,049
2022	182,113	60,468	29,788	13,161	9,054	294,584
2023	195,805	64,409	31,379	13,591	9,634	314,817
2024	210,982	68,746	33,110	14,050	10,272	337,161
2025	227,876	73,528	34,996	14,540	10,974	361,914
2026	246,706	78,814	37,056	15,064	11,750	389,390
2027	267,867	84,669	39,310	15,624	12,608	420,078
2028	291,904	91,165	41,779	16,224	13,560	454,632
2029	319,783	98,392	44,489	16,868	14,617	494,148
2030	352,996	106,451	47,470	17,559	15,794	540,270

Source: Own estimation with data from ICE, DES, and MINAET.

Emissions from Oil and Solid Waste use – BAU Scenario

Table 4 shows conversions factors applied in estimating CO_2 emissions in accordance with Intergovernmental Panel on Climate Change (IPCC) guidelines.

Table 4 Conversion Factors for Calculating CO_2 Equivalent Emissions

Oil	0.0691	Gg CO_2/ TJ
Wood/firewood	0.1127	Gg CO_2/ TJ
Biomass	0.1007	Gg CO_2/ TJ
Diesel	0.0742	Gg CO_2/ TJ
Gasoline	0.0700	Gg CO_2/ TJ

Source: IPCC

Table 5 shows estimated net GHG emissions due to oil consumption, reported as CO_2 equivalent. In the following estimations emissions from firewood and biomass are not taken into consideration, given their CO_2 capture, which is considered in the forestry sector estimates presented in the following section. The estimate and projection of solid waste emissions presented by DIGECA (2009), complemented by the authors' own projections, are also used.

Table 5 CO_2 Emissions – BAU (High Growth) Scenario Projected until 2030. Energy Use and Solid Waste Sectors (Gg CO_2e)

Year	Oil Derivatives	Electricity	Firewood	Other	Solid Waste	Total*
2008	5,663	176	1,979	955	1,418	8,212
2009	6,297	176	1,979	955	1,452	8,880
2010	6,258	224	2,010	965	1,487	8,934
2011	6,593	234	2,083	986	1,523	9,336
2012	6,901	245	2,161	1,009	1,559	9,714
2013	7,285	256	2,245	1,033	1,597	10,171
2014	7,702	269	2,335	1,058	1,635	10,664
2015	8,154	282	2,431	1,085	1,674	11,195
2016	8,646	297	2,535	1,114	1,715	11,772
2017	9,184	313	2,646	1,144	1,756	12,397
2018	9,772	331	2,767	1,176	1,798	13,077
2019	10,416	349	2,897	1,209	1,841	13,815
2020	10,944	370	3,037	1,245	1,885	14,444
2021	11,721	393	3,189	1,284	1,930	15,328
2022	12,584	418	3,356	1,325	1,977	16,304
2023	13,530	445	3,535	1,368	2,024	17,367
2024	14,579	475	3,730	1,414	2,073	18,541
2025	15,746	508	3,943	1,464	2,123	19,841
2026	17,047	545	4,175	1,516	2,174	21,282
2027	18,510	585	4,429	1,573	2,226	22,894
2028	20,171	630	4,707	1,633	2,279	24,713
2029	22,097	680	5,012	1,698	2,334	26,809
2030	24,392	736	5,348	1,767	2,390	29,285

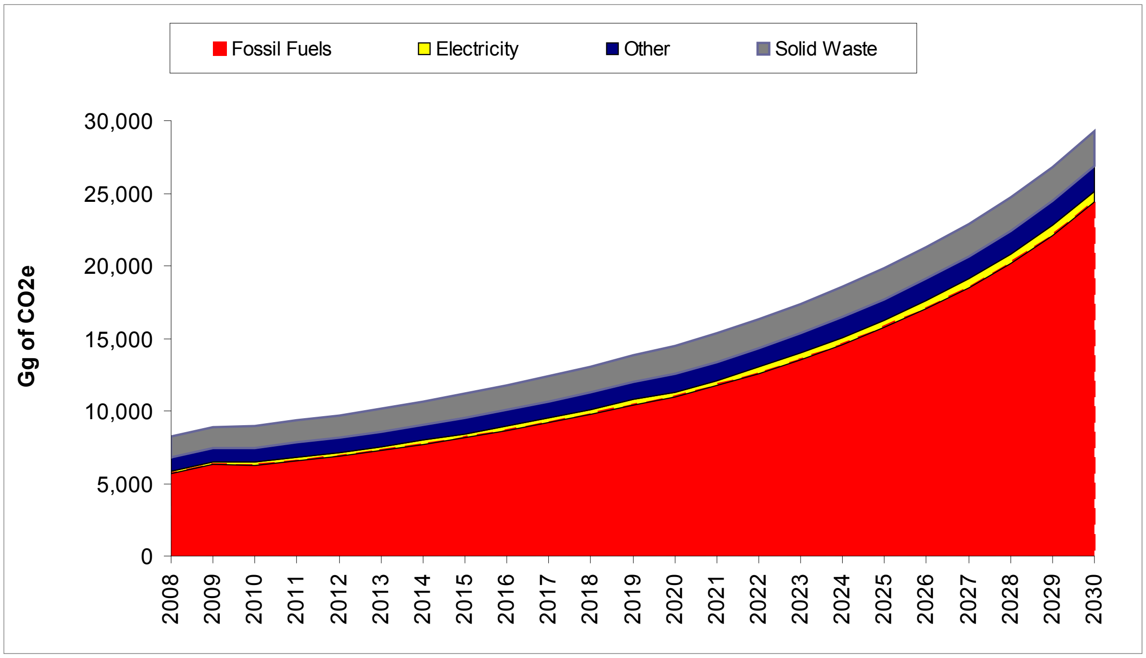
* Does not include projected emissions for firewood and biomass.

Source: Own estimation with data from ICE, DES, and MINAET. ICE, DSE, MINAET, and DIGECA (2009).

It is to be noted that estimates of CO_2 emissions from oil consumption and the equivalent emissions due to increases in solid waste reached 8,212 Gg in 2008. Projections for 2021 indicate these will reach 15,328 Gg, while in 2030 they will reach 29,285 Gg, for these sectors (figure 10).[18]

18 In the case of estimates for the "moderate" growth scenario, results up to 2021 are almost 1 million tonnes less of CO_2, while the difference up to 2030 are almost 4 million tonnes less. Figure A1 in the annex shows the results.

Figure 10 CO_2 Emissions BAU Scenario (High Growth) Projected until 2030 – Energy Use and Solid Waste Sectors



Source: Own estimation with data from ICE, DSE, MINAET, and DIGECA (2009)

Forestry and Agricultural Sectors

Forestry Sector

The baseline is established for emissions projections in the forestry sector (BAU scenario) through the development of land use maps and projections on the dynamics of forest cover until 2030. Land use maps used were made available by IMN for the years 1980 and 1990, and those developed by FONAFIFO for 2000 and 2005. Seventy-one per cent (3,626,195 ha) free from cloud cover and observable of a total of 5,110,575 hectares were evaluated between 1980 and 2005.

With reference to table 6, the land use categories found in the different classifications of the set of images used (1980, 1990, 2000 and 2005) were re-codified into a group of sixteen (column 1) so as standardize these in all maps. These were then re-classified into new categories (column 3). This regrouping is necessary to ensure logical results when analyzing land use changes (cross tabulations) for distinct dates within the study (1980-2005 period) and to which dates are assigned to regeneration cohorts. Review of the re-classifications revealed that the 1980 secondary forest (Category 2) was only catalogued in one of the images used in obtaining a map of the whole country, comprising various images. It was thus decided to group this category under forest cover (Category 1), eliminating the option to register secondary forests in 1980. Land use categories 4, 5 and 6 were finally excluded from all classifications.

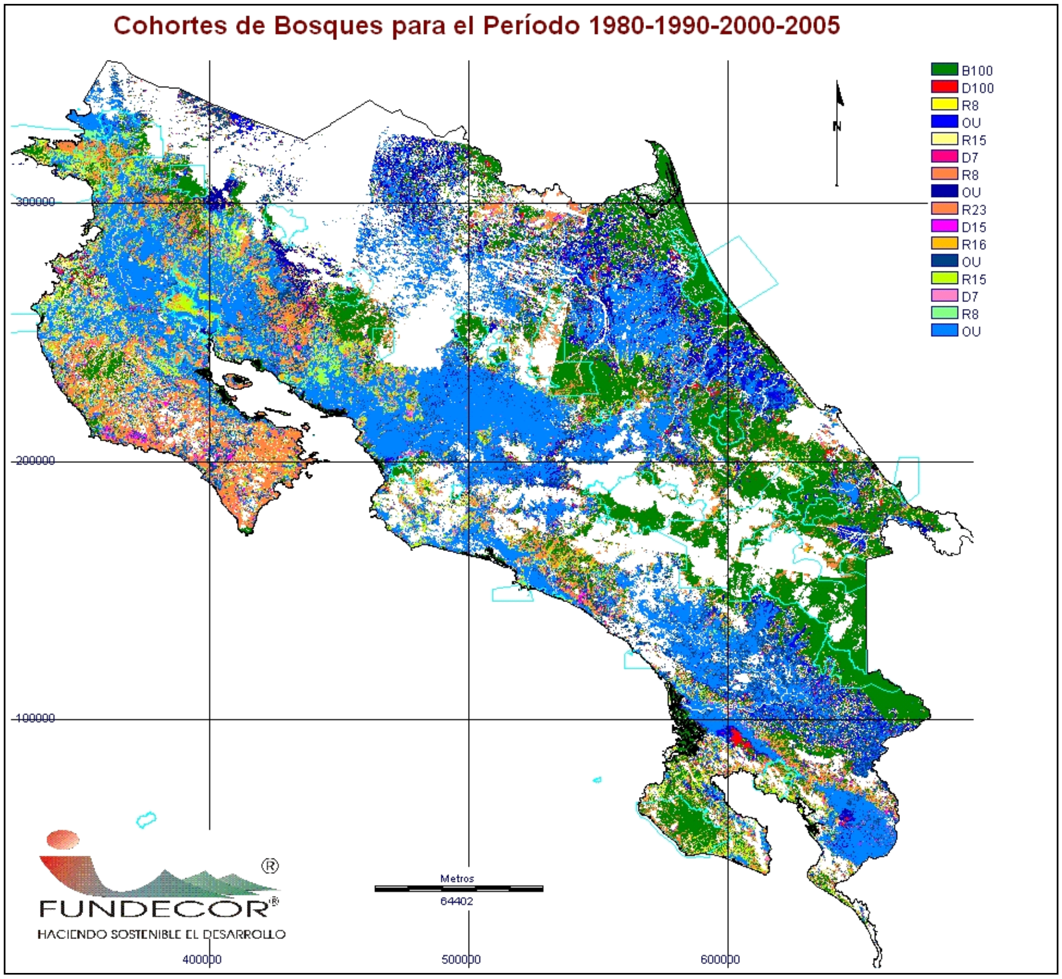
Table 6 Land Use Classification and Re-Classification

Initial Category	Description	Re-classification	Description
1	Primary forest	1	Forest cover
2	Modified and/or intervened forest	2	Secondary forest 1980
3	Pasture with trees	3	Other use
4	Crops and pasture	3	Other use
5	Scrubland	3	Other use
6	Bare soil	3	Other use
7	Bodies of water	5	Water
8	Reforestation	4	Clouds/no data
9	Clouds, cloud shadows and no data	4	Clouds/no data
10	Urban	3	Other use
11	Páramo	6	Páramo
12	Wetlands	1	Forest cover
13	Mangrove	1	Forest cover
12	Not-classified, frontiers	4	Clouds/no data
15	Mixed use	3	Other use
16	Deforestation according to FONAFIFO (defined with images 1997-2000-2005)	3	Other use

Source: Own elaboration with data from IMN and FONAFIFO.

Map 1 shows the 16 possible options in land use change dynamics for the period 1980-2005. The location of different forests by age or cohorts that have remained visible through satellite imagery since 1980 can be noted, as well as areas where deforestation has taken place and those where there is regeneration.

Map 1. Cohorts of Permanent Forests in Costa Rica for the Periods 1980-1990-2000-2005



Source: Own elaboration with data from IMN and FONAFIFO.

The dynamics of land use change were studied from 1980 so as to date land use cohorts and thus establish the average age of the retained regeneration noted in the 2000-2005 period. Ten-year periods were used between 1980 and 2000 to capture the net change in forest cover, avoiding short-lived regeneration and the temporary loss of forest cover so as to offer conservative estimates of forest regeneration, in line with IPCC's best practices.

As the last period (2000-2005) covers five years, the projection of the mitigation scenario "Maintaining the strengthened PES calls for the best estimate of the effect of current policy on changes in land use. Although the PES program was established in 1997, it had its greatest effect during the 2000-2005 phases.[19]

19 The Payment for Environmental Services (PES) program, designed as a financial mechanism to promote the conservation of the country's forest resources, is provided for under Forest Law 7575 of April 16, 1996. It establishes that environmental services provided by forests and forest plantations are those that have a direct effect on protecting and improving the environment, and for which reason land owners should receive payments in compensation for the benefits their forests and plantations provide to society. The PES program as currently applied in Costa Rica includes three categories: PES-Protection, PES-Reforestation, and PES-Forest Management. The conservation of habitats with high levels of biodiversity, watersheds of socio-economic importance,

It is thus hoped that the tendency observed during this period continues over the following 25 projected years (2005-2030).

The country was divided into four clearly differentiated strata of land use dynamics (table 7). The values of land use dynamics were extracted from each of these, to be subsequently re-grouped into four types of cover.

Table 7 Dynamics of Land Use Change during the 2000-2005 Period for the Four Country Strata (Differentiating regeneration according to respective age, cohort)

Period 2000-2005			id	Whole country cloud free ('80,'90,'00, '05)	Rest of country (excl. Guanacaste) outside National Parks	Only Guanacaste outside National Parks	National Parks in rest of country (excl. Guanacaste)	National Parks in Guanacaste
B100	A	B100	1	901,022	587,666	47,210	244,640	21,506
B100	A	OU	2	42,248	37,543	3,478	983	244
OU	A	R22	3	36,269	28,888	4,641	1,232	1,508
OU	A	OU	4	138,186	131,396	4,722	1,330	738
R22	A	R27	5	53,894	36,868	8,572	4,684	3,770
R22	A	OU	6	12,459	10,212	1,928	164	155
OU	A	R22	7	15,569	11,075	2,420	287	1,787
OU	A	OU	8	134,555	123,075	8,682	850	1,948
R27	A	B100	9	408,747	171,801	186,153	33,252	17,541
R27	A	OU	10	50,462	28,296	21,398	404	364
OU	A	R22	11	68,394	30,544	34,876	606	2,368
OU	a	OU	12	263,300	193,199	67,362	844	1,895
R22	a	R27	13	179,972	83,123	78,216	5,446	13,187
R22	a	OU	14	54,058	32,944	20,057	208	849
OU	a	R22	15	84,746	42,509	33,542	923	7,772
OU	a	OU	16	1,182,314	864,212	295,629	1,688	20,785
			Totals:	***3,626,195***	***2,413,351***	***818,886***	***297,541***	***96,417***

Source: Own elaboration. Old growth forest and late regeneration (B100), Medium term regeneration (R 27 years), early regeneration (R 22 years) and other use (OU)

and biological corridors connecting existing national parks and biological reserves is possible when these payments are directed at carefully selected priority areas. The program is financed mainly through public funds acquired through a tax on fossil fuels. However, there is increasing participation of direct beneficiaries of environmental services, notably hydroelectric companies, water bottlers, and tourism companies. There are two main assumptions: i) it is more profitable for the country to invest in the conservation of forest resources that provide environmental services than invest in infrastructure to correct problems resulting from forest lost, and ii) it is more convenient, from both the social and economic perspectives, to invest in financing PES than in purchasing land to create totally protected areas, such as national parks.

The tendency of forest cover to project in each stratum between "n" stages is described in a transition matrix of 4 x 4 stages (figure 11). Forest cover is considered to be distributed between stages known as: other use (OU), early regeneration (R22), medium term regeneration (R27), regeneration and grown up forest (B100). An estimate was made of the proportion t_{ij} of the cover of state j that moves to state i in a period of five years between 2000 and 2005. This transition matrix is identified as $T = (t_{ij})$.

Figure 11 Forest Cover Transition Matrix

$$[1{,}424{,}898 \quad 163{,}147 \quad 200{,}097 \quad 625{,}209] .. X .. \begin{bmatrix} & OU & R22 & R27 & B100 \\ OU & 0.921 & 0.729 & 0 & 0 \\ R22 & 0.265 & 0 & 0.735 & 0 \\ R27 & 0.141 & 0 & 0 & 0.869 \\ B100 & 0.060 & 0 & 0 & 0.940 \end{bmatrix}$$

Source: Own elaboration with data from IMN and FONAFIFO.

An estimate of annual emissions in thousands of tonnes of CO_2 for each five-year period was based on a calculation of the different stocks between the periods. The estimate of each annual projected stock was carried out on the basis of secondary forest totally occupying a site in 35 years and, both for forest in Guanacaste and in the rest of the country, average biomass of total occupation being 60 and 100 tonnes per hectare of carbon, respectively. The stock of each regenerated cohort was estimated based on the current age over the total time required to occupy the whole site (age/35 years) multiplied by the carbon of the total occupation of the stratum.

BAU Scenario in the Forestry Sector

According to Tattenbach et al. (2006) the penetration of FONAFIFO's PES program has never exceeded 25% of forests outside national parks and biological reserves. There is an unsatisfied demand for PES services with forest owners waiting due to quota limitations, or with farms of over 300 hectares that are unable to enter the program straight away, or else due to lack of property rights. The sustainability of the PES program is also still uncertain in that its funding comes mainly from taxes and loans that in the end are paid by Costa Rican society, and whose willingness to pay in the future could change suddenly in the face of a world economic or energy crisis.

According to Obando (2008), as the PES program implemented by FONAFIFO is mainly to reduce emissions from deforestation and degradation (REDD), its capacity to raise external funding through the sale of "forest credits" is limited. This is due to additionality problems Costa Rica has in REDD projects or to the lack of participation of forest projects in carbon credit markets (Hamilton et al. 2007).

The possibility of maintaining the PES program's current level of penetration is thus considered to be low, as the most probable scenario of the forest sector is business as usual, in which the PES is unfunded.

In the absence of PES it is thought that medium term (R27) and early (R22) regeneration will double throughout the country, while old forest growth (B100) will remain unchanged. In Guanacaste the recuperation of other use areas (OU) to secondary forest will be reduced by half, with the rest of the country remaining the same as that observed during the 2000-2005 period. The transition matrices remain the same for national parks.

The preceding development will result in 3% deforestation of national territory during the 2000 to 2030 period (table 8). Nonetheless, stabilization of the total forested area is expected to stabilize at 2 million hectares, with an increase of approximately 600,000 hectares, but with a substantial fall in early and late regeneration that will become highly unstable, and a recuperation of barely 100,000 hectares from other uses (OU).

The levels of carbon captured and stored will barely increase by 40,000 tonnes of CO_2 over the 30 years of the projected period. Carbon dioxide emissions over the same period will be reduced by barely 1,000 tonnes (table 9).

Table 8 Projected BAU Land Use in Ha (without the PES program)

Year	Other use (OU)	22-year regeneration (R22)	27-year regeneration (R27)	Total forest cover (B100)	Total country
2000	2,710,648	423,345	647,186	1,329,397	5,110,575
2005	2,861,199	235,697	237,792	1,775,886	5,110,575
2010	2,859,921	242,932	128,721	1,879,002	5,110,575
2015	2,851,212	239,369	129,817	1,890,177	5,110,575
2020	2,847,141	236,335	126,024	1,901,075	5,110,575
2025	2,844,911	234,451	123,117	1,908,096	5,110,575
2030	2,843,862	233,232	121,242	1,912,240	5,110,575

Source: Own elaboration with data from IMN and FONAFIFO.

Table 9 Carbon Stocks and Emissions in BAU Scenario (without PES program)

Year	Total country (ha)	Area covered	Carbon stocks (CO_2 1,000 tonnes)	Emissions (CO_2 1,000 tonnes)
2000	5,110,575	47%	700,687	
2005	5,110,575	44%	701,170	(97)
2010	5,110,575	44%	706,217	(1,009)
2015	5,110,575	44%	707,743	(305)
2020	5,110,575	44%	747,681	(138)
2025	5,110,575	44%	746,068	(33)
2030	5,110,575	44%	743,862	35

Source: Own elaboration with data from IMN and FONAFIFO.

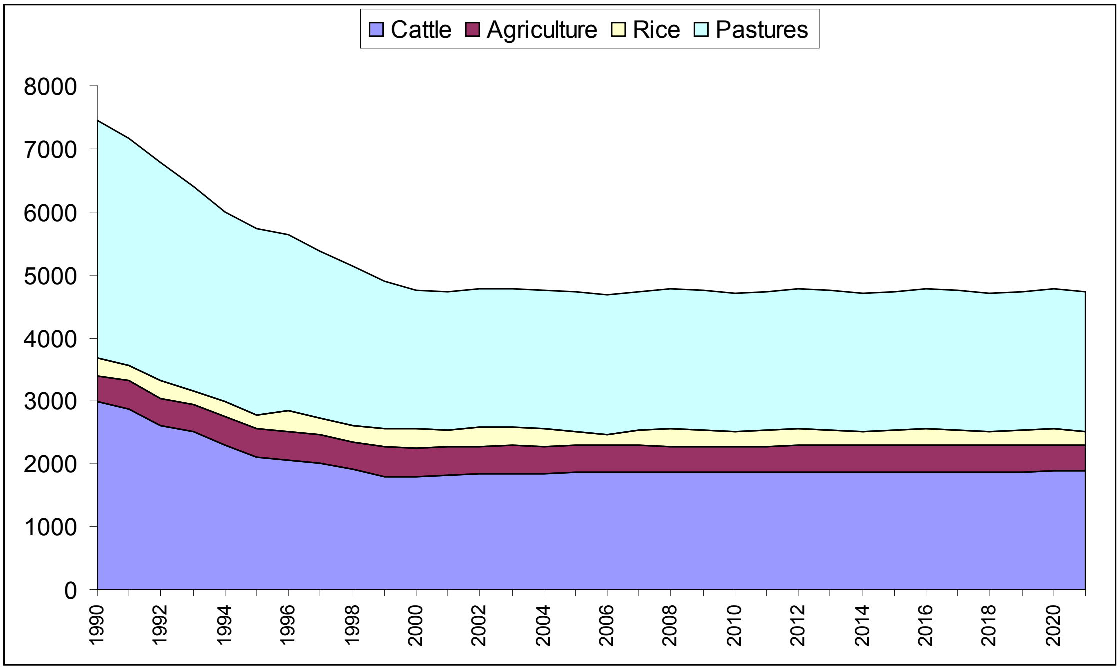
BAU Scenario for Agricultural Sector

Estimates of emissions from the agricultural sector focused specifically on methane and nitrous oxide gas emissions from livestock (cattle), agriculture (separated into rice and other agricultural products), and from pastures. These gas emissions are calculated according to the area necessary for the development of each component, and CO_2 equivalencies are then established. Thus, for example, one tonne of nitrous oxide produces 0.31 tonnes of CO_2, while one of methane is equivalent to 0.021 tonnes of carbon dioxide.

Data examined are initially from 1990 on (with the exception of the livestock component which is based on information from 1988). Information analyzed generally comes from regional statistics of institutions such as the Ministry of Planning (MIDEPLAN) and projects carried out by the Tropical Agriculture Research and Training Center (CATIE). The agricultural sector's emissions under the BAU Scenario were projected until 2021.

Pastures are the highest producers of CO_2, with values ranging from 2,000 to 3,700 tonnes, followed by cattle that produce between 1,800 and 2,900 tonnes. Agriculture and rice emit less CO_2, with values ranging from 200 to 400 tonnes of CO_2. Initially they produce almost 7,500 tonnes annualy, dropping drastically in the first ten years, to stabilize at around 4,700 tonnes CO_2 over the next 20 years.

Figure 12 Total and Projected Emissions of Agricultural Sector for the 1990-2021 Period – BAU Scenario (CO_2e 1,000 tonnes)



Source: Own elaboration with data from MIDEPLAN and CATIE.

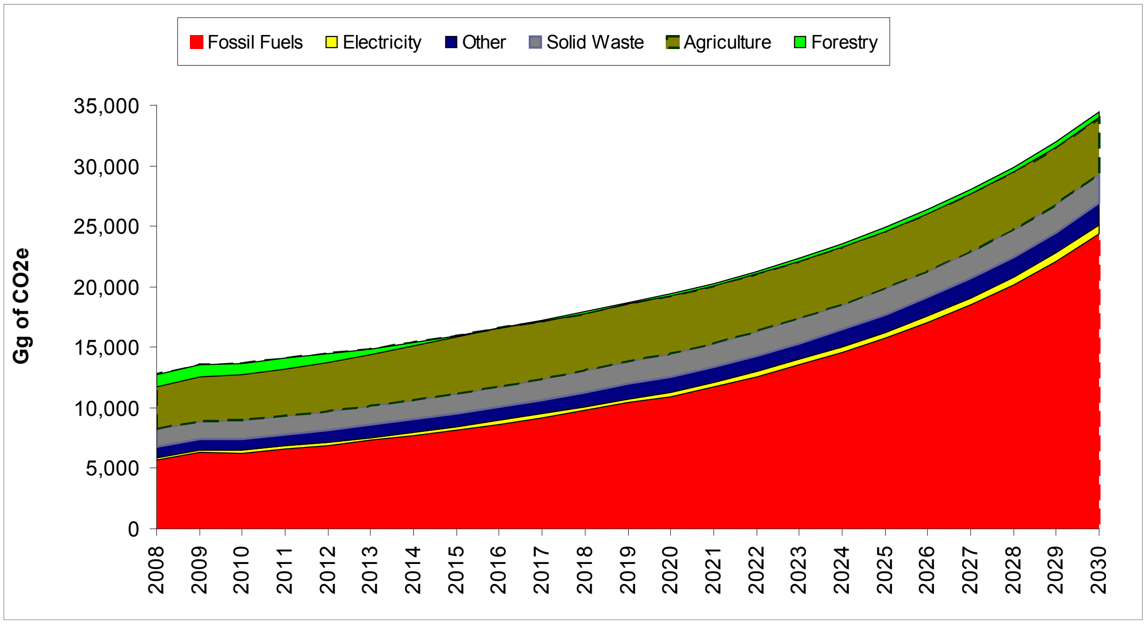
Projected Total Emissions – BAU Scenario

With projections based on current tendencies (business as usual) for those sectors under scrutiny, it is estimated that total CO_2 emissions will reach 20,255 Gg of CO_2e for a high emissions scenario in 2021, reaching 34,479 Gg of CO_2e 2030 (figure 13).[20] This is due to the predominant use of fossil fuel, mainly by the transport sector that is directly linked to economic growth, as the main source of emissions. The agricultural sector will continue being an important contributor, as will emissions from solid waste.[21] On the other hand, the forestry sector is not expected to have an important impact as emissions mitigator in line with the BAU scenario described in the previous section.

20 If starting from a moderate growth scenario respective values will be 19,220 and 29,939 Gg of CO_2e, as indicated in Figure A2 of the annex. This suggests that projections of growth and emissions do not significantly change results for 2021, when it is expected to carbon neutrality. However, for 2030, a greater rate of growth will imply, given the current business as usual status of energy (and emissions) intensity of economic growth, higher levels of GHG emissions.

21 In the case of emissions from the agricultural sector, it is assumed that emission levels reached in 2021 will remain constant for the remainder of the decade.

Figure 13 Total Projected Emissions Period 2008-2030 – BAU (High Growth) Scenario



Source: Own estimation with data from ICE, DSE, MINAET, MIDEPLAN, FONAFIFO, IMN, CATIE and DIGECA (2009).

The projected increase in emissions from fossil fuels is directly linked to the country's economic growth patterns. In observing the Kaya identity (table 10) emissions components, it is to be noted that the contribution of carbon intensity due to energy use falls while the energy intensity of GDP would increase less than in the previous decade. The increase in per capita GDP and population will be the main drivers of emissions due to fossil fuel use in 2021. Hence the need to make an effort to decouple economic growth from emissions, satisfying energy demand with a reduced dependency on fossil fuels.

Table 10 Composition of Emissions Changes due to Fossil Fuel Use

Changes (Distribution %)	2008-2010	2010-2015	2015-2021
Carbon intensity (of energy)	16.0%	14.8%	-6.3%
Energy intensity (of GDP)	54.4%	16.8%	16.3%
Per capita GDP	0.7%	42.8%	64.5%
Population	28.8%	25.6%	25.5%
Emissions from fossil fuel use (millions of tonnes of CO_2)	+1.07	+2.7	+3.6

Source: Own elaboration with data from ICE, DSE, and MINAET, based on Bacon and Bhattacharya (2007)

4. INTERVENTION MEASURES AND MITIGATION POTENTIAL

The methodology used in estimating marginal costs involves estimating a flow of net costs and emissions avoided with each mitigation measure, over a 20-year horizon from 2010 to 2030. The figures are converted into *colones* (national currency) at the 2009 value for the cost flow so as to work in real terms. Once the net cost flow has been identified it is assigned its current value with a 12% discount rate. A dollar exchange rate of 591 colones is used to give resulting figures their net dollar value. Net costs consider the investment cost and other costs associated with intervention measures from which associated benefits are subtracted. These costs are estimated on an annual basis to obtain the net flow over the period under analysis.

In the case of CO_2e reduced by each intervention project, the quantity of emissions avoided annually is estimated so as to build the projected flow up to 2030. This flow is adjusted to current value using a zero percent discount rate, meaning that tonnes of CO_2e become more valuable as emissions are avoided in the future, reflecting the relevance climate change is likely to assume in the future.

The present value of net cost related to the present value of emissions avoided enables the marginal cost of CO_2e to be established. It is important to point out that each intervention measure has an effect on the baseline. This baseline has therefore already considered the effects of other previously implemented intervention measures, according to the sequence of analysis followed.

In the case of measures taken in the transport sector, studies by DSE suggest that there would be a greater impact when these are implemented in a specific order. The sequence of measures analyzed thus followed DSE criteria as follows:

1. Restrictions on vehicle use
2. Biofuels
3. Hybrid vehicles
4. Streamlining procedures
5. Flex-fuel vehicles
6. Car pooling
7. Electric trains
8. Public transport
9. Electric vehicles
10. Cycle paths

11. Decongesting roads
12. Four-day week
13. Moving home
14. Efficient driving
15. Improved road infrastructure (PRUGAM)
16. Compressed air vehicles

Measures are implemented in the following order for the industrial sector:

1. Electricity savings within the industry
2. Efficient boilers
3. Efficient motors
4. Fluorescent lighting
5. Solar heaters
6. Efficient air conditioning

Measures are to be taken in the following order in the residential sector:

1. Education of households
2. Fluorescent light bulbs
3. Timers on water heaters

Other measures evaluated included:

5. ICE expansion plan based on renewable sources
6. Landfills
7. Low-cost housing

The following options were examined in the forestry and agricultural sectors:

1. Continuation of the current PES program
2. Implementation of the strengthened PES program
3. Agropastoral systems
4. Reduction of agrochemical use

Details of a brief analysis of intervention measures follow, with results expressed in tonnes of CO_2 emission reductions (and the marginal cost per tonne of CO2 equivalent. As previously mentioned, in this case possible reductions under the BAU (high growth) scenario are evaluated.

Transport Sector

Vehicle Restrictions in San José

This measure involves prohibiting the entry of vehicles in the capital city (San José) one day a week according to the vehicle's registration number. In projecting the country's fleet of vehicles, it is estimated that the measure limits entry into the restricted area of about 2.06% of vehicles, enabling a projection of the total fleet of vehicles affected by the measure. The restriction is in force 250 days a year and it is estimated that an average of 1.5 people travel in each vehicle affected by the restriction. People who are unable to use their cars will travel by bus, requiring two buses for the outward journey and two buses for the return journey home from work. The costs of buses are considered within San José (according the regulatory body of public services, ARESEP, in July 2009). Estimates of fuel (diesel, gasoline, and LPG) savings in liters per year are used in calculating the flow of net costs. Only the cost of alternative means of transport, the payment of buses, is considered as a cost. In calculating the flow of emissions avoided conversion factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for petrol, and 0.0631 Gg per TJ for LPG are used. The result is that until 2030 the project enables a reduction of 3,025,631 tonnes of CO_2 at a marginal cost of -US$29 per CO_2e tonne. This negative cost indicates that the *non-regret measure* has a US$29 net benefit for society for each CO_2e tonne, which should, in principle, already be providing benefits.

Biodiesel

This measure consists of mixing diesel with biodiesel in a 75/25 ratio. This mixture is in line with improved new generation technologies of vehicles, as the majority of diesel motors currently use a mix that does not exceed 10% of biodiesel. The calorific values of diesel and biodiesel are considered as the same or the purposes of this study and that all diesel vehicles will use the proposed mix. This measure is applied from 2010 to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, and 65% in the fourth year, reaching a 100% implementation in the fifth year. Prices for biodiesel and diesel are used in the projection, considering that the price of diesel is 20% higher. With these parameters the equivalent in consumption of liters of diesel is obtained and projections of diesel and biodiesel for the mixture are applied. The cost of the mixture is calculated as a combination of the cost of diesel and biodiesel. The incremental cost represented by the consumption of the mix compared with having only used diesel is considered. Emissions saved are considered using a factor of 0,70 Gg per TJ for diesel, and 0,068 Gg per TJ for biodiesel. The result is a reduction of 266,905 tonnes of CO_2 at a cost of US$820 per tonne of CO_2 equivalent.

Bioethanol

The measure involves using a 7% mix of bioethanol with gasoline, considering that bioethanol will cost 9% more that gasoline. The calorific values of gasoline and bioethanol are considered to be the same for the purposes of this study. All gasoline vehicles will use the proposed mix according to the following schedule: applying to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, and 65% in the fourth year, reaching 100% implementation in the fifth year. The costs of bioethanol and gasoline are projected until 2030. Estimated gasoline consumption is based on the projections of the vehicle fleet, while estimates of gasoline used, gasoline saved, and quantities of ethanol are based on the proportions of the proposed mix. These quantities are estimated in liters, so that the costs of using only gasoline and using bioethanol are calculated by applying the projected prices, the incremental cost being the result of the difference between them. Quantities are converted into terajules by estimating the emissions of both types of fuel. A factor of 0,077917 Gg per TJ is used to calculate CO_2e emissions for gasoline, and 0,06868 Gg per TJ for bioethanol. The result is reduction of 1,393,907 tonnes of CO_2 at a cost of US$58 per tonne of CO_2 equivalent.

Hybrid Vehicles

According to DSE and a survey of the transport sector, 45% of the vehicle fleet are cars and taxis. It is assumed that 30% of the vehicles considered have a price similar to the hybrid Toyota Prius. Both diesel and gasoline vehicles (private cars and taxis) will be substituted. The proportion of this type of vehicle is based on the projection of the vehicle fleet. This measure is applied is to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, 65% in the fourth year, reaching 100% in the fifth year. Projections for the price of gasoline and diesel are used. The cost of the vehicle substituted is US$24,000 based on the cost of a 2009 Toyota Corolla, with the cost of the hybrid car at US$33,000 based on the cost of a 2009 Toyota Prius. The difference is used as the incremental cost. Petrol consumption of the Corolla is 13.74 km/L and 20.9 km/L for the Prius. The expected savings in gasoline are calculated on the basis of these figures, implying an annual savings of 9.16%. The estimate in savings in gasoline and diesel is made using the projections in the prices of both fuels, and the total expected savings is calculated as a benefit. Total savings are deducted from the incremental cost to establish the net flow. Emissions flow is estimated applying a factor of 0.07 Gg per TJ for diesel, and 0.077917 Gg per TJ for gasoline. The result is a reduction of 9,081,852 tonnes of CO_2 at a cost of -US$38 per tonne of CO_2 equivalent.

Streamlining Procedures

It is estimated that 70% of the national vehicle fleet is concentrated in the greater metropolitan area (GAM), 25% of which is estimated to be traveling to carry out a variety of procedures for government dependencies. It is assumed that 5% of vehicle trips could be replaced if procedures are carried out by telephone or by

Internet. The cost of the calls is calculated considering a 10% failure rate, and a cost of US$1 for Internet use per remote procedure. This result in a 0.88% savings in gasoline and diesel, which is converted into liters to estimate the expected savings based on price projections for gasoline and diesel. The cost of virtual procedures is deducted from these savings. In this manner the expected net savings flow is calculated. Savings in emissions are calculated based on a factor of of 0.07 Gg per TJ for diesel, and 0,077917 Gg per TJ for gasoline. The result is a reduction of 917,666 tonnes of CO_2 at a cost of -US$91 per tonne of CO_2 equivalent.

Flex-Fuel Vehicles

This measure is an extension in the use of bioethanol with technology developed to mix 30% bioethanol and 70% gasoline, known as flex fuel. It is considered that 13% of the vehicle fleet can be substituted with flex-fuel vehicles. This measure is applied to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, 65% in the fourth year, reaching 100% in the fifth year. It is expected that bioethanol will cost 9% more than gasoline. The calorific power of both gasoline and bioethanol is considered as equivalent. The cost of bioethanol and gasoline is projected until 2030. The consumption of gasoline is, one again, based on the projections of the vehicle fleet, with the quantity of gasoline used, gasoline saved, and the quantities of ethanol, based on the proportions of the proposed mixture. These quantities are estimated in liters, so the costs of using only gasoline and using bioethanol are estimated by applying the projected prices, with the incremental cost being the difference between both of them. Quantities are converted into terajules in estimating emissions of both types of fuel. A factor of 0,077917 Gg per TJ is used for gasoline, and 0,06868 Gg per TJ is used for bioethanol in calculating the CO_2 equivalent emissions, resulting in a reduction of 452,772 tonnes of CO_2 at a cost of US$19.5 per tonne of CO_2 equivalent.

Car Pooling

It is considered that 12% of the working population would be willing to participate in car pooling, according to data used by the DSA extracted from the population of the state of Maryland in the United States of America. It is estimated that 12% of private diesel vehicles will follow this regime. This measure is applied is to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, 65% in the fourth year, reaching 100% in the fifth year. The average number of people who travel in each vehicle is 1.5; the average distance traveled by people who use their car to get to their place of work is 10 km; and the average petrol consumption of private vehicles is 15.57 km/L. With these parameters the quantity of fuel saved in liters is calculated, and the savings flow estimated based on the application of the projected price of diesel and gasoline. Factors of 0,07 Gg per TJ for diesel, and 0,077917 Gg per TJ for gasoline are used in calculating emissions avoided, resulting in a reduction of 10,429,920 tonnes of CO_2 at a cost of -US$73 per tonne of CO_2 equivalent.

Electric Trains

It is estimated that the electric train project will start in 2014. The proportion of cars, taxis and buses substituted by the train is 5%, while the proportion of the country's total load to be transported by train will be fifty percent. All diesel trains will be substituted. According to official figures, the investment in the metropolitan electric train (TREM) is US$345 million, while that calculated for the inter-oceanic (to link the main ports on each coast) electric train is US$1,500 million. These parameters enable fuels savings to be calculated for the displaced fleet. Savings are converted to colons based on the projected prices of diesel, gasoline and LPG. The energy requirements of electric trains and the proportion of electricity from geothermal sources are estimated. The net flow of expected savings is calculated by adding the investment costs. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 10,188,960 tonnes of CO_2 at a cost of US$73 per tonne of CO_2 equivalent.

Integration of Public Transport

It is expected that public transport be integrated along axes that optimize routes and avoid duplications, and also connect with other transport projects, such as the metropolitan electric train. A reduction of 5% in the number of vehicles that enter San José is proposed, being equivalent to 23.36% of the national automotive fleet. The average trip of people using their cars to got to work is 10 km. The average petrol consumption of private vehicles is 10.57 km/L. Each person who does not use their car would use public transport. It is considered that 1.5 people travel in each car. It is considered that each person will require two outgoing trips and two return trips from work. The costs of buses are considered within San José (according to the regulatory body of public services, ARESEP, in July 2009). These parameters allow the fuel savings to be estimated at 4.67%. These savings are converted to colons based on the projected prices of gasoline and LPG. The net flow of expected savings is calculated by adding the investment costs. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 3,685,342 tonnes of CO_2 at a cost of -US$78 per tonne of CO_2 equivalent.

Electric Vehicles

According to the DSE survey carried out of the transport sector, 43.9% of the total vehicle fleet are cars. Fifteen per cent of the fleet of private cars and taxis will be substituted. This measure is applied to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, 65% in the fourth year, reaching 100% in the fifth year. The average cost of a compact car in 2009 is US$16,000. The cost of an electric Reva i 2009 is US$17,500. The incremental cost and fuel savings are based on these parameters. These savings are converted to colons based on the projected prices of diesel, gasoline and LPG. The net flow of expected savings is calculated by adding the investment costs. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 9,081,852 tonnes of CO_2 at a cost of -US$38 per tonne of CO_2 equivalent.

Cycle Paths

According to DSE assumptions, based on results in different countries around the world, it is estimated that 5% of people who use private vehicles and public transport would change to using bicycles. The cost of building cycle paths is US$350,000 per kilometer. With an 800 km distance of appropriate areas, the total cost of construction would be US$280 million. Fuel savings are calculated to be 5%. These parameters enable the flow in fuel savings to be calculated. Savings are converted to colons based on the projected prices of diesel, gasoline and LPG. The net flow of expected savings is calculated by adding the investment costs. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 4,383,263 tonnes of CO_2 at a cost of -US$18 per tonne of CO_2 equivalent.

Decongesting Roads in San José

This project includes engineering works and transport planning which, together with other previously mentioned measures, results in decongesting the city of San José. This measure is applied to 5% of the fleet in the first year, 15% in the second year, 35% in the third year, 65% in the fourth year, reaching 100% in the fifth year. With the parameters of vehicle performance in congested traffic estimated at 23.23 L/100 km and in free-flowing traffic at 15.43 L/100 km, fuel savings can be calculated at 10.84%. These savings are converted to colons based on the projected prices of diesel, gasoline and LPG. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 3,685,342 tonnes of CO_2 at a cost of -US$317 per tonne of CO_2 equivalent.

Four-day Week

Of the estimated 200,000 public employees, 50,000 are considered to be working in the Greater Metropolitan Area. Of these employees, 40% use private transport to travel to work. It is estimated that 1.5 people travel in each vehicle. It is assumed that the working week of these employees involves four days in the office and one day working from home. These assumptions result in fuel savings of 0.64%. These savings are converted to colons based on the projected prices of diesel, gasoline and LPG. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 401,670 tonnes of CO_2 at a cost of -US$73 per tonne of CO_2 equivalent.

Moving Home

Promoting and providing incentives for workers within the greater metropolitan area who use private transport to move home is considered, so that their new home lies within an average radius of 10 km from their workplace. This measure is applied to 5% in the first year, 15% in the second, 35% in the third, 65% in the fourth, and reaching 100% in the fifth year. It is considered that this measure would result in 3.5% fuel savings. These are converted to colons based on the projected prices of diesel, gasoline and LPG. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided. The result is a reduction of 2,182,574 tonnes of CO_2 at a cost of -US$86 per tonne of CO_2 equivalent.

Efficient Driving

An annual investment of US$150,000 is assumed to promote an education and information campaign on efficient driving among taxis, buses and load (heavy and light) vehicles. The campaign will impact savings in both diesel and gasoline. Of these vehicles it is assumed that 5% of these will be driven in an efficient manner, with a greater proportion of taxis (16.8%), and of buses and heavy load vehicles (9.9%). This measure is applied to 5% of the fleet in the first year, 15% in the second, 35% in the third, 65% in the fourth, and reaching 100% in the fifth year. It is considered that this measure could result in a fuel savings of 0.84%, being converted to colons based on the projected prices of diesel, gasoline and LPG. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided, resulting in a reduction of 226,249 tonnes of CO_2 at a cost of -US$57 per tonne of CO_2 equivalent.

Improved Road Infrastructure (PRUGAM)

Five road infrastructure improvement projects are considered within PRUGRAM, these being the north and south ring road, the road to Heredia, the Coris-Cartago-San José route, and improvements to the Cartago-San José road. These projects were selected on the basis of official studies carried out by MOPT and ENGEVIX in 2009. Estimated investment flows and incremental benefits for the 2014-2030 period were used. Based on these results and fuel savings, the mitigation potential of this group of projects was estimated. Investments reach over US$120 million. The mitigation potential of 867,111 tonnes of CO_2 is calculated at a cost of -US$166 per tonne of CO_2 equivalent.

Air-powered Vehicles

According to DSE a survey of the transport sector indicated that 43.9% of fleet are cars. Fifteen percent of vehicles that are not yet included in previously mentioned intervention measures will be substituted, with the alternative being considered for compact cars. The measure is applied to 5% of the fleet in the first year, 15% in the second, 35% in the third, 65% in the fourth, and reaching 100% in the fifth year. A projection of the cost of compressed air is made. The average cost of a 2010 compact vehicle is US$10,000. The cost of the compressed air vehicle MDI City CAT 2010 is US$12,000. Fuel savings and incremental cost are estimated based on these parameters. These savings are converted to colons based on the projected prices of diesel, gasoline and LPG. The net flow of expected savings is calculated by adding the investment costs. Factors of 0.07 Gg per TJ for diesel, 0.077917 Gg per TJ for gasoline, and 0,0631 Gg per TJ for LPG are used in calculating emissions avoided, resulting in a reduction of 3,766,978 tonnes of CO_2 at a cost of US$35 per tonne of CO_2 equivalent.

Industrial Sector

Electricity Savings by Industry

A US$100,000 annual campaign is undertaken to promote training and technical assistance to encourage energy savings in the industrial sector. These programs are expected to result in energy savings of six percent. The cost per kWh is projected until 2030. Savings made are as a flow and are adjusted to current value. A factor of 0.0691 Gg per TJ is used in estimating emissions in the generation of geothermal electricity, estimated as being 10% of total electricity generation. The result is a reduction of 330,752 tonnes of CO_2 at a cost of -US$785 per tonne of CO_2 equivalent.

Efficient Boilers

This measure is based on the assumption that there are 600 boilers working nationally in different applications, and 100% of which could achieve savings in the use of bunker fuel with appropriate technology. This measure is applied to 5% of total boilers in the first year, 15% in the second, 35% in the third, 65% in the fourth, and reaching 100% in the fifth year. Each efficient boiler has a cost of US$250,000. A projection of the price of bunker fuel is made until 2030. Bunker savings and their equivalent in colons are calculated. A net flow of savings is established, considering the cost of the investment. A factor of 0,0032568052 Gg per TJ is used in estimating emissions. The result is a reduction of 48,286 tonnes of CO_2 at a cost of US$2,005 per tonne of CO_2 equivalent.

Efficient Motors

A total of 35,000 electric motors is considered. It is assumed that 50% of standard installed motors can be changed for models with the same power but greater efficiency. The measure is applied to 10% of the total in the first year, 25% in the second year, 55% in the third, 85% in the fourth, and reaching 100% in the fifth year. The cost of efficient motors is US$400. The consumption of motors that can be replaced implies a saving of 4% in energy consumed by this item. The kWh cost is projected until 2030. Savings made are calculated as a flow and are adjusted to current value. A factor of 0.0691 Gg per TJ is used in estimating emissions in the generation of geothermal electricity, estimated as comprising 10% of total electricity generation. The result is a reduction of 15,826 tonnes of CO_2 at a cost of -US$78 per tonne of CO_2 equivalent.

Energy Efficient Lamps in Industry

With this measure incandescent, 2,700 lumens, 100 W light bulbs, each costing US$1, will be replaced by compact, 25 W fluorescent bulbs, each costing US$5. The average lifespan of a compact light bulb is five years, so reinvestment would be made at that time. It is estimated that there would be a savings of 10% in energy used for lighting by industry. The measure is applied to 20% in the first year, 40% in the second, 60% in the third, 80% in the fourth, and reaching 100% in the fifth year. The kWh cost is projected until 2030. Savings made are calculated as a flow and are adjusted to current value. A factor of 0.0691 Gg per TJ is used in estimating emissions in the generation of electricity from geothermal sources, estimated as being 10% of total electricity generation. The result is a reduction of 15,581 tonnes of CO_2 at a cost of -US$705 per tonne of CO_2 equivalent.

Solar Heaters for Industry

This measure involves the installation of solar heaters in 40% of total heaters in industry. The investment is US$5,000 per heater and 4.2% a savings in electricity is estimated. The measure is applied to 5% of the total heaters in the first year, 15% in the second year, 35% in the third, 65% in the fourth, and reaching 100% in the fifth year. These savings are calculated as a flow and converted to current values. A factor of 0.0691 Gg per TJ for electricity generated from geothermal sources, estimated as 10% of total electricity generation, is used in estimating emissions. The result is a reduction of 4,603 tonnes of CO_2 at a cost of US$248 per tonne of CO_2 equivalent.

Efficient Air Conditioning in Industry

This measure involves changing 1000 W air conditioning systems costing US$570,000 for 800 W systems each costing US$700,000. It is assumed that this equipment is in use 12 hours daily. Fifty percent of industry is reached with a total savings of 20% in energy consumption for air conditioning. The measure is applied to 5% systems in the first year, 15% in the second, 35% in the third, 65% in the fourth, and reaching 100% in the fifth year. Savings are calculated as a flow and converted to current values. A factor of 0.0691 Gg per TJ for geothermal energy, estimated to represent 10% of total electricity generation, is used in estimating emissions. The result is a reduction of 4,855 tonnes of CO_2 at a cost of -US$8.8 per tonne of CO_2 equivalent.

Housing Sector

Education of Households

An annual US$100,000 campaign to train and educate in the efficient energy use and conservation will be promoted. Savings in electricity consumption are estimated at 7%. The kWh cost is projected until 2030. Savings are calculated as a flow and converted to current values. Factors of 0.0691 Gg per TJ for geothermal energy, estimated to represent 10% of total electricity generation. Results are 230,861 tonnes of CO_2 reduced at a cost of –US$832 per tonne of CO_2 equivalent.

Energy Efficient Lamps Households

As in industry, with this measure incandescent 2,7000 lumen, 100 W light bulbs costing US$1 each, will be replaced by compact, 25 W fluorescent bulbs each costing US$5. The average lifespan of a compact light bulb is five years, so reinvestment would be made at that time. It is assumed that 40% of incandescent light bulbs in households are changeable, in that they remain switched on at least five hours a day. Calculations are based on an average of three light bulbs being changed per household (per year?). Based on the projection of the number of households, energy savings in lighting are estimated at thirty percent. The cost per kWh is projected until 2030. Savings made are calculated as a flow and are adjusted to current value. A factor of 0.0691 Gg per TJ is used in calculating emissions in the generation of electricity from geothermal sources, estimated as representing 10% of total electricity generation. The result is a reduction of 80,075 tonnes of CO_2 at a cost of -US$820 per tonne of CO_2 equivalent.

Timers for Heaters

With this measure timers will be established in 21% of households, being those with heaters, and will result in savings in electricity consumption. This measure is applied to 20% of target households in the first year, 40% in the second, 60% in the third, 80% in the fourth, reaching 100% of target households in the fifth year. The cost of timers is US$85. The cost per kWh is projected until 2030. Savings are calculated as a flow and adjusted to current value. A factor of 0.0691 Gg per TJ is used in estimating emissions in the generation of electricity from geothermal sources, estimated as being 10% of total electricity generation. The result is a reduction of 10,046 tonnes of CO_2 at a cost of US$1,206 per tonne of CO_2 equivalent.

Other Measures

ICE Expansion Plan Based on Renewable Sources

This measure takes into account evaluations carried out as part of ICE's plan to expand electricity generation up until 2025 (ICE, 2007). Incremental costs of the scenario involving the greatest dependency on renewable sources, compared with the scenario involving greater dependency on geothermal sources are also taken into account, while emission reductions that could result from an increase in more renewable electricity sources are also considered. Estimates made by ICE are projected until 2030. Investments in this measure are fundamental in slowing down fossil fuel consumption and reducing dependency on fossil fuels. The option to increase electricity generation from renewable sources will result in costs amounting to US$26 per tonne and a total reduction in emissions of 44.5 million tonnes of carbon dioxide.

Landfills

In this case measures are based on estimates made by DIGECA (2009) on the potential to mitigate emissions through the management of large-scale landfills in the country's greater metropolitan area. Estimates are projected until 2030, assuming new projects. Investment parameters and reported costs by Bitrán & Asociados (2006) are also used. The option to cogenerate electricity in landfills using methane is also evaluated. This measure offers a reduction potential of 14.1 million tonnes of CO_2 at a cost of -US$29 per tonnes of CO_2 equivalent.

Low-Cost Housing

The possibility of building low-cost housing with a minimal energy footprint is evaluated, mainly through the use of less cement and steel in construction (and the transport of these materials). The analysis is based on work carried out by the Technological Institute of Costa Rica (ITCR) reported by Solano (2005). Estimations until 2030 are made, with the annual construction of 15,000 houses. Energy savings are projected comparing traditional options for houses for low-income families, comparing incremental investments required in promoting a project of this type. Estimates indicate a reduction potential of 299,403 tonnes of CO_2 at a cost of -US$1,968 per tonne of CO_2 equivalent.

Forestry and Agricultural Sectors

Two scenarios were analyzed in estimating mitigation in the forestry sector: one maintaining the current PES, and a strengthened PES program. Comparison of the scenarios indicated important differences in the recovery of forest cover. The current 47% forest cover could be increased to 54% under the current PES program and to 65% if the program were strengthened. This represents differences of up to 21% in improved forest cover if the PES could be strengthened from the business as usual scenario, or by 11% if the PES continues operating in its current manner.

In terms of hectares, the difference between the proposed scenarios, without the PES forest cover would increase from 1.3 to 1.9 million hectares of total forest cover (B100) at the end of the projected period (2005-2030), while with the strengthened PES total forest cover (B100) could reach 2.4 million hectares by the end of 2030.

Gains from the conversion of Other Use areas (OU) to forest cover, whether early regeneration (R22), late (R27) or grown up (B100) forest, would increase by over one million hectares should the PES be strengthened, but only 400,000 hectares should the current PES program be maintained, and only slightly more than 100,000 hectares in the absence of the PES program.

Regarding carbon stocks, with the strengthened PES program 300,000 more tonnes of CO_2 would be captured by the end of 2030, while by maintaining the current PES program, only 150,000 tonnes would be captured. In the absence of the PES program, the increase in carbon absorption capacity would increase by only 43,000 tonnes over the analyzed period.

Under the scenario in which the current PES is maintained, the tonne of CO_2 would reach US$3.39. This cost is established by considering a PES price that is 20% higher (US$76.80) than the current price, so as to allow for possible increases in land returns. In addition, only half of the PES program will result in emissions reductions; the remainder being responsible for providing other environmental services such as water, biodiversity conservation and scenic beauty.

The cost per tonne of captured carbon dioxide under the strengthened PES scenario would be US$2.40, considering a PES price that is double its current value (US$128) given that this payment will be aimed at improving regeneration retention in which the probability of land returns is higher. It is important to clarify that the strengthened PES scenario is only possible if the current PES scenario is maintained. The total cost per tonne of CO_2 in implementing both measures (current and strengthened scenarios) would thus be US$ 5.79.

Maintaining the Current PES Scenario

This scenario assumes no change in the application of the current PES program for the 2000-2030 period from that observed during the five-year period, 2000-2005. According to FONAFIFO, by the end of 2005 slightly more than 251,000 hectares had been integrated in the PES program, representing a 13% level of penetration.[22] In order to guarantee this level of penetration over the 2005-2030 period a growth in area and budget for the program, in accordance with the increase in forest cover from regeneration and avoided deforestation, is assumed.

22 The distribution of hectares covered by the payment for environmental services, by year and by type at: http://www.fonafifo.com/paginas_espanol/servicios_ambientales/sa_estadisticas.htm

Changes in land use can be seen in table 11 if the PES is maintained at current levels for the 2000-2030 period. Approximately 1 million hectares of total forest cover (B100) is recovered, while other use (OU) areas would result in the recovery of some 400,000 hectares.

Table 11 Land Use Projection Ha – Current PES Scenario

Year	Other use (OU)	22-year regeneration (R22)	27-year regeneration (R27)	Total forest cover (B100)	Total country
2000	2,710,648	423,345	647,186	1,329,397	5,110,575
2005	2,646,169	288,886	329,599	1,845,922	5,110,575
2010	2,562,003	275,216	224,042	2,049,314	5,110,575
2015	2,489,613	261,304	212,200	2,147,457	5,110,575
2020	2,430,705	250,167	200,574	2,229,129	5,110,575
2025	2,382,211	241,500	191,383	2,295,481	5,110,575
2030	2,342,024	234,667	184,296	2,349,589	5,110,575

Source: Own elaboration with data from IMN and FONAFIFO.

Table 12 shows carbon stocks and emissions according to land use projections in which growth of the country's forest cover can be seen to increase from 47% to fifty-four percent. There would also be an approximate increase of 150,000 tonnes of CO_2 in carbon stocks, and the 10,000 tonnes CO_2 emissions in 2005 would be reduced to less than 3,000 tonnes by 2030.

Table 12 Projected Carbon Stocks and Emissions – Current PES Scenario

Year	Total country (ha)	Total forest cover (%)	Carbon stocks (CO_2 in thousands of tonnes)	Emissions (CO_2 in thousands of tonnes)
2000	5,110,575	47%	700,687	
2005	5,110,575	48%	752,245	(10,312)
2010	5,110,575	50%	783,761	(6,303)
2015	5,110,575	51%	806,009	(4,450)
2020	5,110,575	52%	824,507	(3,700)
2025	5,110,575	53%	839,892	(3,077)
2030	5,110,575	54%	852,761	(2,574)

Source: Own elaboration with data from IMN and FONAFIFO

Strengthened PES Scenario

This scenario considers the probability that improving carbon absorption capacity in national parks is limited as the anthropogenic effect in these areas is minimal or zero. Likewise, it is considered that the marginal profit of reducing deforestation will not be cost effective in the Province of Guanacaste due to low deforestation rates, but that improvements to the program would be effective if implemented in other parts of the country, i.e. excluding national parks and Guanacaste.

The increased penetration of the PES program, necessary to reduce anthropogenic deforestation in regeneration by 50%, was calculated using a preliminary econometric model adjusted to exclude national parks and Guanacaste. This model presents deforestation (d) as a function of an index of income from land (C) and the level of penetration of the PES program (P). The adjustment of this model is good (0.845 R^2), both coefficients being significant (0.000003 for C and 0.042445 for P). For a further explanation of the construction of this type of model see Tattenbach et al. (2006).

$$d = 0.1496388 * \mathrm{C} - -0.3647466 * \mathrm{P}$$

It is considered that recuperation of forest cover will take place as a result of conversion of degraded pastures. It is important to clarify that forest cover recuperation from other uses is expected to be the result of reforestation projects, in that natural regeneration is not considered viable being a low income activity. This would involve the establishment of 256,000 hectares of forest plantations at an annual reforestation rate of 12,800 hectares.

Table 13 describes the land use changes should the PES program be strengthened. It is to be noted that approximately 1 million hectares of land under other use (OU) could be converted to highly stable sites in recuperation. Total forest cover (B100) with more than 1.4 million hectares recovered could be achieved in 25 years.

Table 13 Land Use Projection Ha – Strengthened PES Scenario

Year	Other use (OU)	22-year regeneration (R22)	27-year regeneration (R27)	Total forest cover (B100)	Total country
2000	2,710,648	423,345	647,186	1,329,397	5,110,575
2005	2,452,616	448,165	352,592	1,857,202	5,110,575
2010	2,246,847	403,342	373,044	2,087,343	5,110,575
2015	2,085,787	367,879	335,130	2,321,779	5,110,575
2020	1,956,797	340,388	305,272	2,508,119	5,110,575
2025	1,853,387	318,595	282,188	2,656,404	5,110,575
2030	1,770,392	301,274	263,934	2,774,975	5,110,575

Source: Own elaboration with data from IMN and FONAFIFO

As can be seen in table 14, growth in national forest cover would change from 47% in 2000 reaching 65% in 2030, recovering over 20% of national territory. This implies an increase in CO_2 stocks of approximately 300,000 tonnes for the period, and a 70% drop in CO_2 emissions from almost 20,000 tonnes in 2005 to slightly over 6,000 tonnes in 2030.

Table 14 Projected Carbon Stocks and Emissions – Strengthened PES Scenario

Year	Total country (ha)	Total forest cover (%)	Carbon stocks (CO_2 in thousands of tonnes)	Emissions (CO_2 in thousands of tonnes)
2000	5,110,575	47%	700,687	
2005	5,110,575	52%	799,595	(19,782)
2010	5,110,575	56%	869,381	(13,957)
2015	5,110,575	59%	929,262	(11,976)
2020	5,110,575	62%	977,212	(9,590)
2025	5,110,575	64%	1,015,684	(7,694)
2030	5,110,575	65%	1,046,613	(6,186)

Source: Own elaboration with data from IMN and FONAFIFO

In calculating the cost of the strengthened PES scenario over the 2010-2030 period it was deemed necessary to double the current payment of US$128/ha/year to improve the retention of the regeneration, due to the likelihood of increased income from land with regenerated forest. In the case of reforestation, a PES of US$900/ha was considered.

As can be seen from table 15, the figures involved in avoiding deforestation, added to the costs of reforesting or regenerating areas, reach almost US$488 million, representing US$24 million annually and a cost of US$2.40 per tonne of CO_2, assuming that 50% of PES is to capture carbon, with the remainder providing other environmental services such as biodiversity, water, and scenic beauty.

It would also mean avoiding the emission of over 100 million tonnes of CO_2 between 2010 and 2030. It would also result in an annual reforestation rate of 12,824 hectares, with an increase in carbon stock of 10 tonnes/hectare. In terms of recuperated areas, there would be 256,000 hectares more under the strengthened PES scenario, in addition to the 100,000 ha recuperated under the current PES scenario, representing a total of over 350,000 hectares.

Table 15 Impact on Mitigation and Associated Costs – Strengthened PES Scenario

Analyzed variable	Unit	Value
Total cost 2010-2030	US$	488,210,639
Price PES	US$/ha	128.0
PES deforestation avoided	US$	257,383,860
PES reforestation/regeneration	US$	230,826,779
Total CO_2 emissions avoided	tonne CO_2	101,814,496
Cost PES tonne CO_2	US$/ha	4.80
Cost of carbon per tCO_2	US$/ha	2.40
From “other use” to current PES	ha	96,401
From “other use” to strengthened PES	ha	352,876
Área to be reforested	ha	256,474
Annual rate of reforestation	ha	12,824
Cost of PES reforestation	US$/ha	900
Annual CO_2 increase	tonne/ha/year	10
Annual CO_2 production	CO_2 /year	134,344

Source: Own elaboration with data from IMN and FONAFIFO.

Mitigation in the Agricultural Sector

According to estimated methane emissions for each production system (meat, dairy, dual-purpose), greater potential for reduction exists in beef cattle. This is based on the traditional management of pastures, the number and type of animal within this production system, and the current low production rate of this type of system.

On this assumption, if the area of improved pasture is increased, grazing cycles adapt to the availability of fodder which is browsed when it is of the highest nutritional quality, and significant reductions in methane emissions are quite possible while improving the animal's response in terms of weight gain.

Increased efficiency in food conversion which is the result of genetic improvements to the animals should also be considered. Efficiency in food conversion refers to the quantity of energy consumed compared with that actually used by the animal, so by improving this ratio energy loss in the form of methane can be reduced.

Another real possibility of reducing the generation of GHGs is through nitrous oxide, originating mainly from the application of nitrogenous fertilizers to pastures. Fertilization is common practice in intensive dairy farming that calls for pastures with a high carrying capacity, nutritional value, and a high production of fodder.

New sources of nitrogen and application techniques should be explored to ascertain the real potential for reduction which, according to preliminary estimations, could be quite significant and not negatively affect dry material and the quality of pastures, and thus having no detrimental affect on dairy production.

As in the dairy sector, the main problem of GHG emissions in the agricultural sector is nitrous oxide due to the application of nitrogenous fertilizers. The mitigation option should be aimed at reducing applied nitrogen, using alternative sources of nitrogen and application methods, and adjusting applications to crops' absorption ratios. In other words, applications should be made according to the phenological stage of specific crops when there is most demand for nitrogen and when crop absorption efficiency and use is greatest.

A PES system was developed as part of the "Integrated Silvopastoral Approaches to Ecosystem"[23] project by CATIE and FONAFIFO to eliminate barriers to the adoption of improved systems of pasture, establish fodder banks, reduce the use of nitrogen fertilizers, and integrate forestry components in farms' production systems. This relatively small payment, approved for a limited period of time at the beginning of the adoption of silvopastoral systems, would be sufficient to improve the outcome of these and conventional livestock systems. This silvopastoral project was carried out on cattle farms in the canton of Esparza in the central

23 CATIE, 2008. Project: Integrated Silvopastoral Approaches to Ecosystem. Tropical Agriculture Research and Training Center. Final Evaluation by the Project Executors and Beneficiaries: Main Lessons Learned.

Pacific region (96 farms with a total 3,124.5 ha). An increase in forest cover, and improved pastures with a high density of trees and living fences were among the benefits of these payments.

Carbon dioxide equivalent emissions per hectare were calculated and associated with each component of the sector, on the basis of data analyzed and projected and in combination with values obtained from the cited silvicultural project, on reductions in emissions in improved pastures, as well as the fixation capacity of the silvopastoral component. This information enabled the total reduction capacity of the agricultural sector to be calculated that, multiplied by a baseline reduction of 400,000 tonnes of CO_2, enables the area required for the application of the agricultural PES program to be calculated.

The annual cost of the program was estimated using a PES baseline price of US$300/ha over four years, allowing the price per tonne of CO_2e to be calculated and included in the program. Carbon dioxide equivalent emissions per hectare of 1.8 tonnes for pastures and 1.5 tonnes for cattle were obtained based on an area greater than the 1.2 million hectares of pasture, plus the annual production of CO_2e for 2010. Emissions for the silvopastoral component were calculated on the known indices of a 0.36% reduction in nitrous oxide, and a 0.20% reduction in methane for improved pastures, that are multiplied by the previously cited emissions values.

The difference between emissions associated with pastures and livestock, less the emissions of the silvopastoral component, allow a 0.65 reduction in nitrous oxide to be established that, added to the reduction of 0.30 for improved pastures, plus the known value of 1.50 from the silvopastoral component, results in a 2.45 CO_2e per hectare.

Estimating a reduction of 400,000 tonnes of CO2e, compared with the previously mentioned reduction value of 2.45, 163,104 ha is the area to be covered by the agricultural PES program in order to achieve the proposed reduction. This number of hectares, at US$300/ha/year, for a period of four years, implies an annual cost for the agricultural PES program of almost US$10 million, implying a cost of US$24.47 per tonne of CO_2e (table 16).

Table 16 Estimate of Emissions Mitigation and Associated Costs in the Agricultural Sector

Estimated variable	Unit	Value
Total pastures in CR	Ha	1,227,000
N_2O reduction due to improved pastures	%	0.36
Methane (CH_4) reduction due to improved pastures	%	0.20
CO_2 capture of silvopastoral component	%	(1.50)
Emissions associated with pastures	tonne CO_2e/ha	1.80
Emissions associated with cattle	tonne CO_2e/ha	1.52
Reduction N_2O emissions silvopastoral PES	tonne CO_2e/ha	1.15
Reduction Methane (CH_4) emissions silvopastoral PES	tonne CO_2e/ha	1.22
N_2O reduction due to improved pastures	tonne CO_2e/ha	(0.65)
Methane (CH_4) reduction due to improved pastures	tonneCO_2e/ha	(0.30)
Total reduction	tonne CO_2e/ha	(2.45)
Area to be covered by agricultural PES program	Ha	163,104
Price of agricultural PES program	US$/ha/year	300
Total cost of program	US$	195,725,396
Annual cost of program	US$	9,786,270
Total emission reductions of program	tonne CO_2e/year	400,000
Price of program	US$/tonne CO_2e	24.47

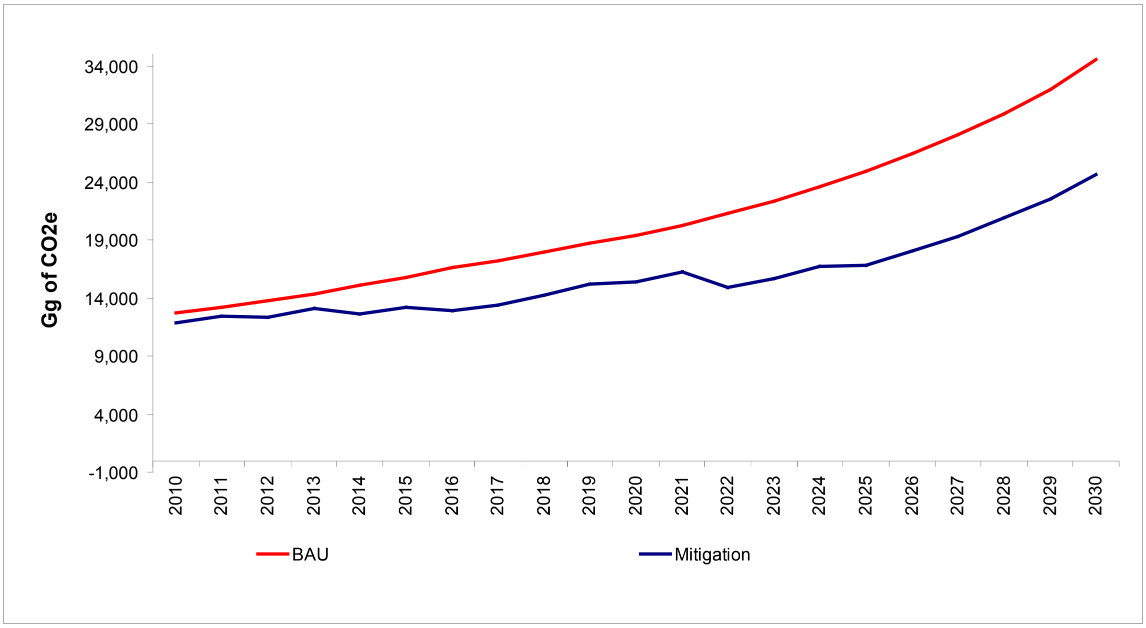
Source: Own elaboration with data from MIDEPLAN and CATIE.

Total Potential for Mitigation

Mitigation measures relating to energy use (transport, industry, residential, housing and electricity generation) and solid waste management that were evaluated indicate an aggregate mitigation potential of 4,027 Gg of CO_2e in 2021 and 9,856 Gg of CO_2e in 2030. As a result, if these measures were implemented the country's total emissions would reach 16,228 Gg of CO_2e in 2021 and 24,263 Gg of CO_2e in 2030 (figure 14).[24] Although this would be an important contribution to mitigation, it is clear that the measures evaluated would only partially compensate for the trend towards increased total emissions in the country over the next two decades.

24 The results of scenarios contemplating a moderate growth rate are to be found in the annex, in Figures A3, A4 and A5.

Figure 14 Emissions under BAU (High-Growth) Scenario and with Mitigation Measures in Energy Use and Solid Waste Management Sectors (2010-2030)

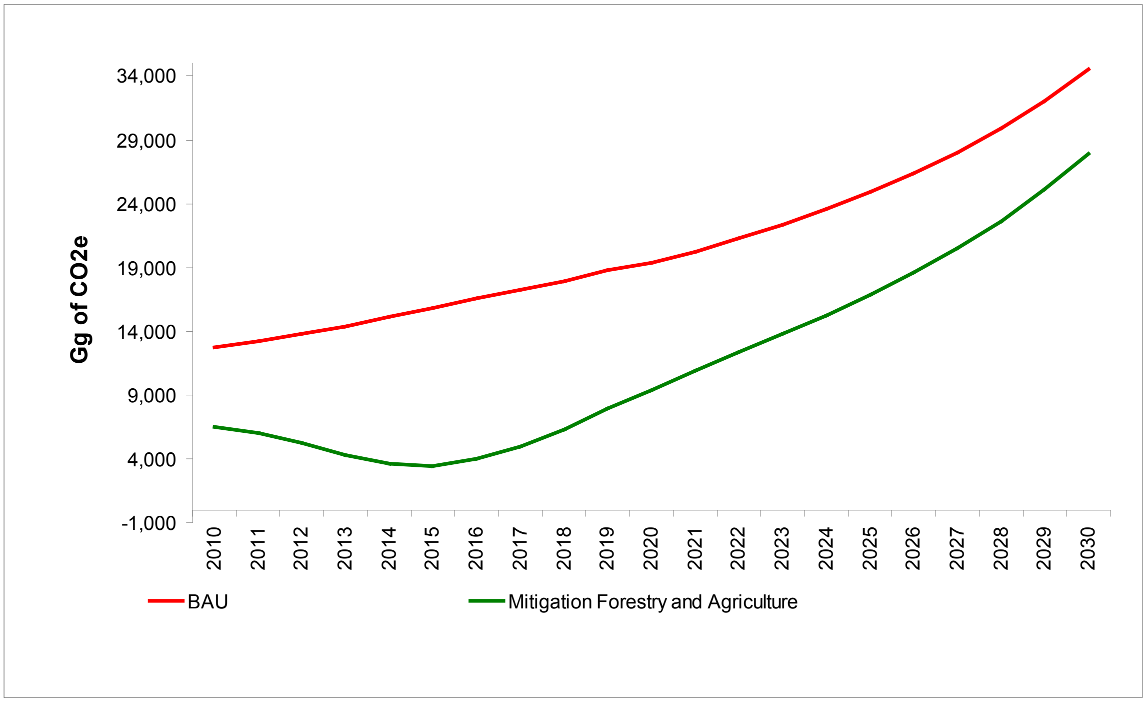


Source: Own elaboration with data and proposals of DSE, ICE, PRUGAM, MOPT, and MINAET, and own estimations.

On the other hand, measures analyzed for the forestry and agricultural sectors indicate much greater potential for mitigating emissions (figure 15). Should these be implemented, total emissions would reach 10,883 Gg of CO_2e in 2021 (representing a reduction of 9,373 Gg of CO_2e) and 27,893 Gg of CO_2e in 2030 (representing a reduction of 6,586 Gg of CO_2e). It is clear that interventions in land use and land use change sector alone could not compensate for the emissions the country would produce if growth and energy use patterns remain the same as they are currently.

In analyzing the aggregate impact of all possible mitigation measures evaluated in this study, it is considered that its total impact would result in a reduction of 315 million tonnes of CO_2e over the 2010-2030 period. Over 80% of this mitigation potential is concentrated in five measures: expansion of generation from hydroelectric and other renewable sources, electric trains, improvements to road infrastructure, landfills, and the forestry sector. In addition, measures taken to ensure a transport sector that is less dependent on fossil fuels will make a significant contribution to reducing GHG emissions.

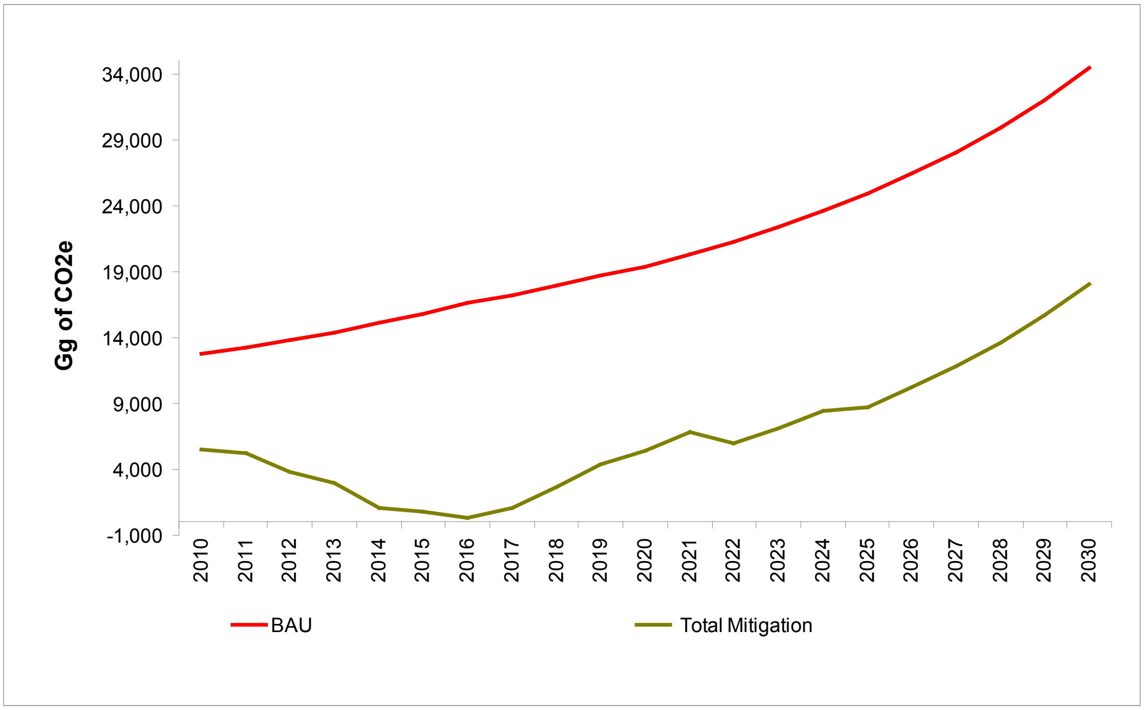
Figure 15 Emissions under BAU (High-Growth) Scenario and with Mitigation Measures in Forestry and Agriculture Sectors (2010-2030)



Source: Own elaboration with data and proposals of DSE, ICE, PRUGAM, MOPT, MINAET, FUNDECOR, and own estimations.

If all measures analyzed were implemented total emissions would reach 6,856 Gg of CO_2e in 2021 (with a total reduction of 13,399 Gg of CO_2e from the baseline) and 18,037 Gg of CO_2e in 2030 (with a reduction of 16,442 Gg of CO_2e). These projected levels indicate that, if the country were to carry out at least the mitigation measures indicated, in 2021 – after more than a decade of growth – it would have an emissions level similar to that of the mid 1990s. On the other hand, the measures analyzed would contribute to a 47% reduction in total emissions under the business as usual scenario by 2030.

Figure 16 Emissions under BAU (High-Growth) Scenario and with Total Mitigation Measures (2010-2030)



Source: Own elaboration with data and proposals of DSE, ICE, PRUGAM, MOPT, MINAET, FUNDECOR, and own estimations.

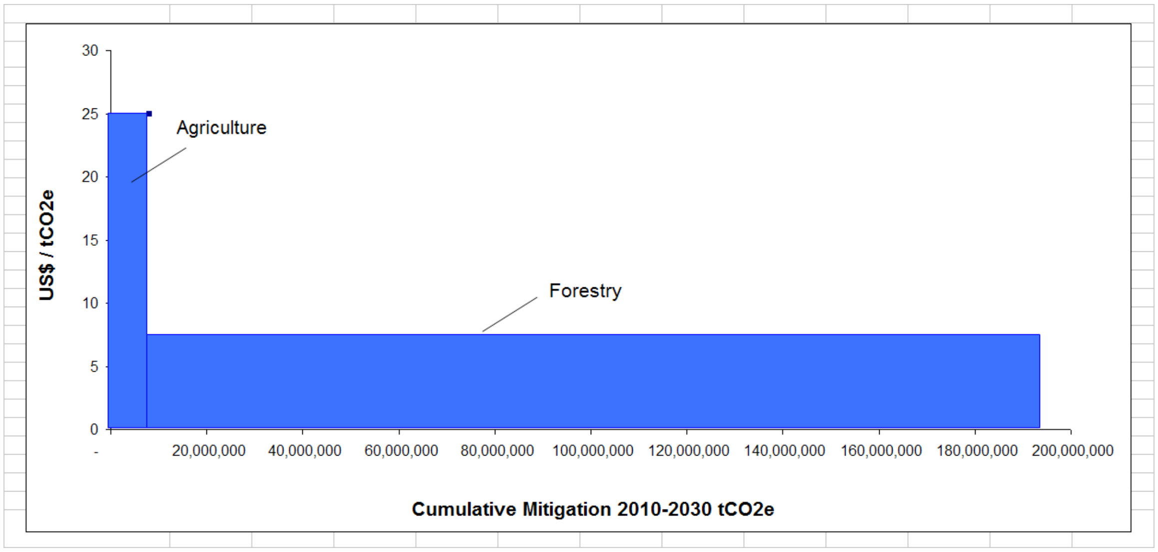
Total Costs of Mitigation

A variety of mitigation options were analyzed, involving different costs and contributions to emissions reductions. An important conclusion is that although Costa Rica has an economy that is less carbon intensive that other developed and developing nations, investments required to reduce dependency on fossil fuels and grow with fewer GHG emissions are substantial. Table 17 shows the results of intervention measures studied. Measures have been organized according to the level of costs per tonne of CO_2 equivalent (many with a negative cost, indicating a net benefit), starting with the least expensive ones.[25]

Total investments required to promote the mitigation measures have been estimated at US$7,800 million, equivalent to 30% of GDP in 2009. The cost per tonne of CO_2 in the case of measures within the forestry sector of close to US$7 is notable, with an estimated mitigation of 185 million tonnes during the 2010-2030 period. Possibilities within the agricultural sector are more expensive being close to US$25 per tonne of CO_2 (figure 17).

25 Table A6 in the annex depicts the results for the moderate growth scenario.

Figure 17 Marginal Abatement Costs Forestry and Agriculture



Source: Own elaboration with data of IMN, FONAFIFO, MIDEPLAN and CATIE.

In the case of measures relating to energy use and the production of solid waste, there are a wide variety of costs and mitigation possibilities. Almost 96% of estimated mitigation potential would involve costs of between ranging from –US$166 to US$73 per tonne of CO_2 (figure 18).

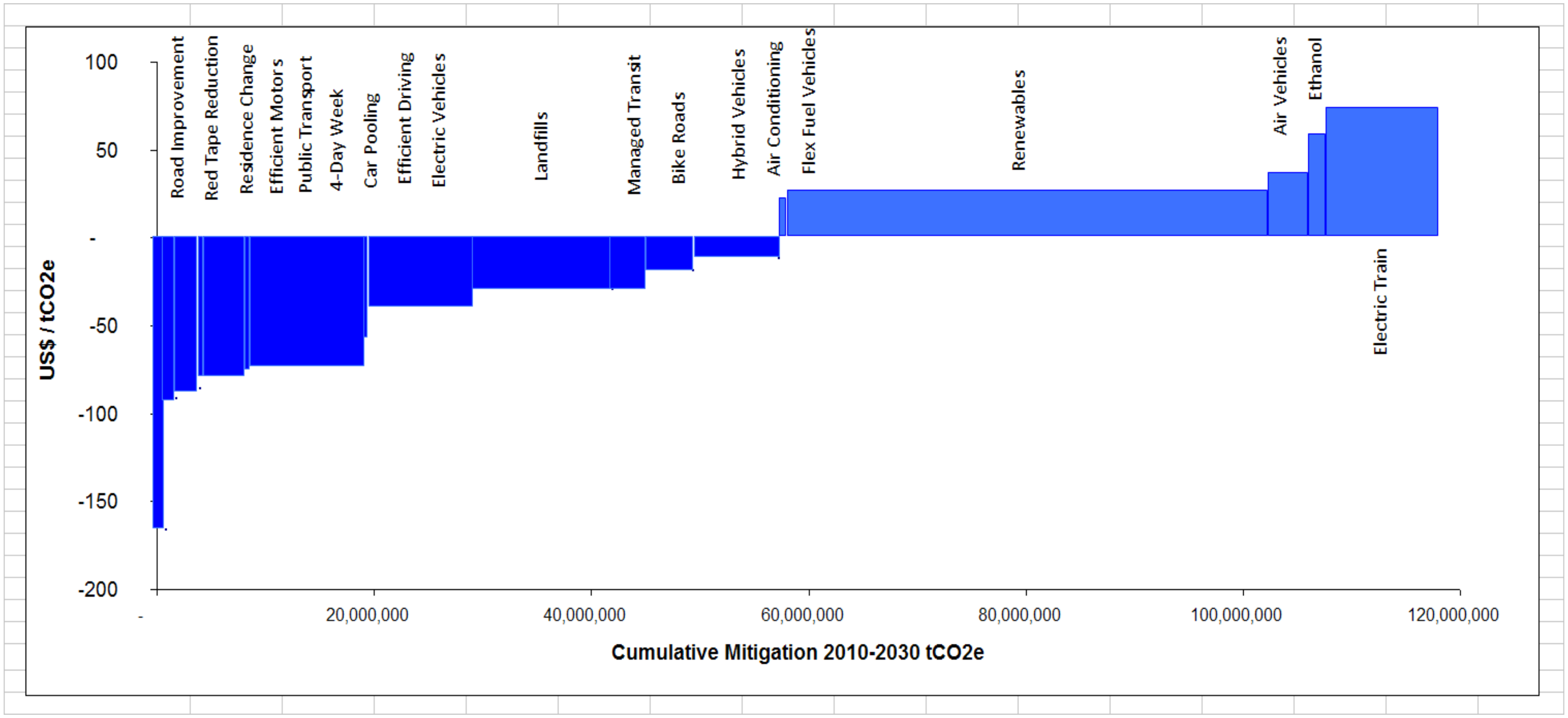
Table 17 Mitigation Options – Costs and Abatement Potential (2010-2030)

Intervention	Description	US$ per tCO_2e reduced	Mitigation tCO_2e	Accumulated mitigation tCO_2e	Average annual mitigation tCO2e
Low-income housing	Building of houses accessible to low-income families. Houses built with wood and materials with lower energy footprint (mainly substitutes for cement and steel)	-1,968.4	299,403	299,403	14,970.2
Education of households	Campaign to educate and create domestic energy conservation skills, promote energy efficiency and acquisition of energy efficient kitchen equipment	-832.0	230,861	530,264	11,543.0
Fluorescent light bulbs (households)	Substitution of traditional light bulbs with compact fluorescent ones in offices and factories that require more than five hours daily of artificial lighting	-819.6	80,075	610,339	4,003.7
Energy efficiency (industry)	Training in energy conservation, energy efficiency and adoption of efficient technologies and improved production standards in companies	-784.7	330,752	941,091	16,537.6
Fluorescent light bulbs (industry)	Replacement of traditional light bulbs with compact fluorescent ones in households	-705.3	15,581	956,672	779.0
Decongesting roads	Series of measures to reduce traffic congestion in metropolitan area, including infrastructural improvements, engineering solutions, and changes to public transport system	-317.1	3,685,342	4,642,014	184,267.1
PRUGAM (improvements to road infrastructure)	Implementation of five infrastructural development projects on San José ring road. Diversification of alternative routes and improved connections between commercial and residential areas	-165.9	867,111	5,509,125	43,355.6
Streamlining procedures	Substitution of conventional procedures in government institutions with digital ones	-91.2	917,666	6,426,791	45,883.3
Moving house	Urban planning and incentives to re-locate near workplace	-85.7	2,182,574	8,609,365	109,128.7
Efficient motors	Substitution of 50% of fossil fuel industrial motors with efficient technologies	-77.8	15,826	8,625,192	791.3
Public transport	Integration of public transport routes to reduce inefficiencies	-77.8	3,685,342	12,310,534	184,267.1
Four-day week	Civil servants working from home one day a week	-73.1	401,670	12,712,204	20,083.5
Car pooling	Promotion of car pooling (12% of vehicles in metropolitan area)	-72.6	10,429,920	23,142,124	521,496

Intervention	Description	US$ per tCO_2e reduced	Mitigation tCO_2e	Accumulated mitigation tCO_2e	Average annual mitigation tCO2e
Efficient driving	Training of truck and bus drivers in improved driving techniques and vehicle maintenance	-56.6	226,249	23,368,373	11,312.5
Electric vehicles	Use of electric vehicles (10% of total fleet)	-38.2	9,081,852	32,450,225	454,092.6
Landfills	Capture and use of methane for electricity generation in five of the main rubbish dumps	-29.2	14,126,206	46,576,431	706,310.3
Vehicle restrictions	Vehicle restrictions one day a week	-29.0	3,025,631	49,602,061	151,281.5
Cycle paths	Building of cycle paths	-18.5	4,383,263	53,985,324	219,163.1
Hybrid vehicles	Use of hybrid vehicles (10% of total fleet)	-11.4	7,921,688	61,907,012	396,084.4
Air conditioning	Use of efficient air conditioners in industry and commerce	-8.8	4,855	61,911,867	242.7
Flex-fuel vehicles	Use of flex-fuel vehicles (5% of total fleet)	19.5	452,772	62,364,639	22,638.6
ICE renewable sources expansion plan	Electricity generation from renewable sources (92%) until 2025	26.2	44,500,000	106,864,639	2,225,000
Compressed-air vehicles	Use of compressed air vehicles (15% of fleet of compact vehicles)	35.1	3,766,978	110,631,617	188,348.9
Ethanol	Mix of ethanol with fuel	57.7	1,393,907	112,025,524	69,695.3
Electric trains	Use of electric trains for transport in metropolitan area and inter-oceanic freight	73.2	10,188,960	122,214,484	509,448
Solar heaters	Use of solar heaters in industry	248.2	4,603	122,219,088	230.2
Biofuels	Bio fuel mix (15% of diesel).	819.9	266,905	122,485,993	13,345.3
Timers on water heaters	Timers on water heaters in households	1,206.3	10,046	122,496,039	502.3
Industrial boilers	Use of efficient boilers in industry	2,004.9	48,286	122,544,324	2,414.3
Forestry sector	Upkeep and improvement of national system of conservation areas. Expansion of the PES program	7.0	185,000,000	307,544,324	9,250,000
Agricultural sector	Reduction of GHGs through improved pastures, agropastoral systems, and reduced use of synthetic fertilizers and agrochemicals	25.0	8,000,000	315,544,324	400,000

Source: Own elaboration with data and proposals of DSE, ICE, PRUGAM, MOPT, MINAET, Fundecor, and own estimations.

Figure 18 Marginal Abatement Costs Energy, Industrial, Residential and Solid Waste Sectors



Source: Own elaboration with data and proposals of DSE, ICE, PRUGAM, MOPT, MINAET, and own estimations.

5. LESSONS LEARNED

The NEEDS project offers valuable lessons that will contribute to the future implementation of the mitigation measures evaluated. It will also make important contributions to the national climate change strategy (ENCC). More importantly, it will serve as the basis for the detailed analyses of national and sectoral projects and policies to mitigate climate change and achieve carbon neutrality.

A crucial aspect is the participation of diverse sectors in the project implementation process. Its validation and broad discussion among stakeholders within the public and private sectors, academia, and civil society in general are fundamental to achieving a high quality end product of practical value for the recommendation of concrete actions.

The formal inauguration of the NEEDS project process involved an initial workshop to launch the initiative, with the participation of representatives from the public and private sectors, academia, diverse areas of civil society and international organizations. The main objective was to promote the NEEDS project in Costa Rica, share opinions and perspectives, get feedback from key actors in different sectors, and establish the foundation for the project's formal commencement. Once the NEEDS study was concluded a second workshop was held to present and discuss results. This involved the participation of representatives from a variety of sectors. Interest in the project has been broad. The consultation process provided the following general results:

- A general consensus on the part of participants from the public and private sectors, and civil society of the importance of the NEEDS project, and the need to provide follow up the evaluated mitigation actions. A network of key actors from different sectors, whose feedback will be most helpful in promoting the proposed mitigation measures, was consolidated.
- The creation of the internet portal http://conocimiento.incae.edu/~operac/needsminaet/, so that more people have access to results of the NEEDS project. This will facilitate diffusion and discussion of conclusions, so as to motivate further research and analysis.
- The identification of actions by the private sector and civil society organizations, providing important insight into how to integrate private initiatives into different mitigation options analyzed.
- Feedback on possible funding mechanisms from different public and private, national and international organizations, in identifying financial and technical sources for the implementation of the ENCC (national climate change strategy).

The methodology and results of potential carbon capture in the forestry sector were also presented and validated with IMN and FONAFIFO, the organizations responsible for the land use, forestry and agricultural sectors in the National Communications to the UNFCCC secretariat, so as to validate and compare the focus of the NEEDS project. Likewise, technical meetings were held with representatives of DSE, the national concessions council (CNC) regarding the TREM project, PRUGAM, MOPT, and other public sector organizations, so as to collect information and obtain an overview of future policies and strategies of the energy use sector. Direct communications were also maintained with MINAET, IMN and the Costa Rican Office for Joint Implementation (OCIC) throughout the process. This office, located within MINAET, is the national focal point for the UNFCCC, and the project coordinator.

This coordinating role is crucial in that a project such as NEEDS requires considerable quantitative and qualitative information that is usually difficult to obtain. Necessary data and baseline studies are scattered throughout public institutions and private organizations, requiring considerable effort to collect and process. Coordination with all pertinent organizations and the opening up of permanent communications channels also needs to be ensured.

In this sense, the NEEDS project has demonstrated the importance of close coordination, not only in carrying out the study, but also, and more importantly, in the future implementation of the mitigation measures evaluated. Efforts to mitigate GHG emissions will fall within the framework of the ENCC that seeks to strengthen capacity building, educate and raise awareness among the population, as well as create necessary funding mechanisms to promote the national agenda involving actions and policies in the face of climate change. The mitigation measures evaluated are aligned with key sectors of the economy, and form the basis of a long-term sustainable development strategy that will strengthen the country's competitiveness and contribute to mitigating climate change.

A preliminary analysis of mitigation measures evaluated from the perspective of necessary involvement of government ministries clearly shows how inter-institutional work will be indispensable in achieving the mitigation goals aimed at carbon neutrality (CN). Numerous institutional arrangements at the MINAET level and through other government bodies will be necessary in consolidating the institutional framework required to promote the mitigation measures analyzed (table 18). A key conclusion of NEEDS is that proposed mitigation measures require a horizontal focus, and the implementation efforts of the ENCC have already made progress in this sense.

Nonetheless, close coordination and inter-institutional cooperation with an umbrella approach for CN will be key at the government level to ensure the coverage and integration of the necessary policies, and that these benefit from political support at the highest level. The ENCC should be given top priority within the state and its administrative structures.

Table 18 Institutional Involvement in Mitigation Measures

Intervention	MINAET	Electricity Sector	Public Works and Transport	Public Education	Housing	Health	Treasury
Low-cost housing		X			X	X	
Education of residents/ families		X		X	X		
Fluorescent light bulbs (households)	X	X		X	X		
Energy efficiency (industry)	X	X					X
Fluorescent light bulbs (industry)	X	X					
Decongesting roads	X		X	X		X	
PRUGAM (improvements to road infrastructure)			X				
Streamlining of procedures			X	X			X
Moving house		X	X		X	X	
Efficient motors	X	X					
Public transport	X		X	X	X	X	X
Four-day week		X	X	X			
Car pooling			X				
Efficient driving			X	X			
Electric vehicles	X	X	X				X
Landfills	X	X				X	
Vehicle use restrictions			X				
Cycle paths			X	X	X	X	
Hybrid vehicles	X	X	X				X
Air conditioning	X	X					
Flex-fuel vehicles	X	X	X				X
ICE expansion plan for renewable sources		X					X
Compressed air vehicles		X	X				X
Ethanol	X	X					X
Electric trains		X	X				X
Solar heaters	X	X					X
Biofuels	X	X					X
Timers on heaters		X					
Industrial boilers		X					X
Forestry sector	X						X
Agricultural sector	X					X	X

Source: Own elaboration

Another key issue is financing of the evaluated mitigation measures. The strategy should opt for accessing existing financial mechanisms and instruments, and development assistance, to be complemented by innovative financial solutions in addressing the mitigation and adaptation requirements. Greater availability of funds could be possible through involvement of the private sector in efforts promoted by international organizations, taking into account the enormous financial load of actions needed to address climate change.

Costa Rica has invested considerable national resources over recent decades in achieving an economic growth that is less carbon intensive. This is mainly the result of long-standing policies to generate electricity from renewable resources and determined efforts to halt deforestation and ensure that a high percentage of national territory retains its forest cover through the promotion of protected areas and national parks, and participation of the private sector through the PES system.

These experiences are already consolidated and lessons learned from them abound. In the future the country should be capable of attracting more private local and international investments, as well as resources from international development banks and through bi-lateral assistance to strengthen existing and proven policies and programs, so that financial resources from a variety of sources are clearly aligned with the goal of carbon neutrality. Such investments are to be supported by public and private mitigation measures, and the development of a competitive production and export platform based on the sustainable use of natural resources, and slowing climate change.

Foreign direct investment can make an important contribution to such initiatives if external resources are channeled towards environmentally friendly sectors and industries, as well as renewable energy sources and more efficient transport systems. It would thus be possible to consolidate a business climate favoring productive activities that are funded with national as well as overseas capital that contribute to the sustainable use of natural resources and specifically base their competitiveness on the sustainable use of the country's natural capital. Likewise, the consolidation of a carbon neutral business environment would ensure that resources are channeled from the private sector to different businesses involved, ranging from energy generation from renewable sources and forest conservation, to the growth of industries involving cutting edge technologies and materials. The promotion of clusters of companies aligned with carbon neutrality should be a central component of the country's development policies.

6. CONCLUSION

The study identified a series of mitigation measures that would significantly reduce CO_2 emission levels by 2011. Projections indicate that the country could follow a high rate of economic growth while mitigating a considerable quantity of emissions, compared with the established baseline.

The forestry sector provides competitive options with a high potential for abatement. On the other hand, a variety of actions are required on the part of the transport sector (with differing costs) in order to consolidate a less carbon intensive economy. Given that this sector is the main contributor to the country's total emissions (historically and projected), carbon neutrality will depend to a considerable degree on the mitigation projects promoted.

The country also needs to continue with its efforts to ensure electricity generation from renewable sources. Modern technologies would contribute to reductions in energy consumption in both the industrial and domestic sectors, while also contributing to reducing emissions. A national sectoral focus will be a key factor in a mitigation strategy seeking carbon neutrality by 2021. The potential of an efficient treatment of solid waste is equally important given that the majority is not handled in an efficient manner, and its potential in the cogeneration of electricity is wasted.

Estimates indicate that carbon neutrality requires costly investments. Institutional efforts, policy changes and new business strategies are also called for. A common goal focusing on a less carbon intensive economy is crucial in promoting the evaluated measures. The necessary funding will require public and private efforts to overcome political barriers, market distortions and special interests that limit the allocation of resources to advanced technologies that contribute to mitigating emissions. Inter-institutional coordination is also essential in addressing carbon neutrality from cross-cutting economic, social, environmental and political dimensions.

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8. ANNEXES

Annex 1 Table A1. Projects Developed under the Clean Development Mechanism in Costa Rica

Date of registration	Title	Purchaser	Period of CERs*	Annual reductions tCO2e
13 Oct 05	Rio Azul landfill gas and utilization project in Costa Rica	Netherland	August 2004-August 2014	156,084
03 Mar 06	Cote small-scale hydropower plant	Canada, Netherlands, Finland, France, Sweden, Germany, United Kingdom, Japan, Norway	April 2003-March 2010	6,431
09 Mar 07	La Joya Hydroelectric Project (Costa Rica)	Spain	September 2006-September 2013	38,273
23 Mar 07	Tejona Wind Power Project (TWPP)	Netherlands	January 2003-December 2012	12,600
30 Nov 07	Switching of fuel from coal to palm oil mill biomass waste residues at Industrial de Oleaginosas Americanas S.A. (INOLASA)	Germany	November 2007-November 2014	38,212
05 Jun 08	CEMEX Costa Rica: Use of biomass residues in Colorado cement plant	United Kingdom	January 2009-Dicember 2018	42,040

Source: http://cdm.unfccc.int/Projects/registered.html, last accessed 20 November 2009.

Annex 2 Table A2. Total Greenhouse Gas Emissions (2000)

Sector	Total emissions (Gg)								
	CO_2	CH_4	N_2O	HFC	CO	NO_x	NMVOC	SO_2	Total CO_2e
Energy	4,717.2	1.7	0.17	NA	165.8	21.5	27.6	3.8	4,805.6
Industrial processes	387.5	NA	NA	0.043	NA	NA	24.4	0.22	449.8
Agriculture	NA	99.59	8.12	NA	1.41	0.029	NA	NA	4,608.6
Land Use change	-3,262.2	4.4	0.03	NA	17.2	0.5	NA	NA	-3,160.5
Solid Waste management	NA	58.9	NA	NA	NA	NA	NA	NA	1,236.9
Total	1,842.5	164.6	8.3	0.043	184.4	22.0	52.0	4.0	—
Total CO_2e	1,842.5	3,456.4	2,573	62.3	ND	ND	ND	ND	7,940.48

Source: IMN, MINAET. 2009

Annex 3 Table A3. Total Greenhouse Gas Emissions by Sector (2000)

Sector	Percentage of emissions
Energy	60.6%
Industrial processes	5.6%
Agriculture	58%
Change in land use	- 39.7 %
Solid waste management	15.5%
Total	100%

Source: IMN, MINAET. 2009.

Annex 4 Table A4. Total Greenhouse Gas Emissions (2005)

Sector	Total emissions (Gg)								
	CO_2	CH_4	N_2O	HFC	CO	NO_x	NMVOC	SO_2	Total CO_2e
Energy	5,492.7	4.9	0.3	NA	246.4	25.1	37.6	4.5	5,688.6
Industrial processes	496.6	NA	NA	0.121	NA	NA	31.4	0.38	672.5
Agriculture	NA	100.4	8.05	NA	1.07	0.025	NA	NA	4,603.9
Change in land use	-3,667.7	6.93	0.05	NA	60.6	1.72	NA	NA	-3,506.7
Solid waste management	NA	62.9	NA	NA	NA	NA	NA	NA	1,320.9
Total	2,321.6	112.2	8.4	0.121	308.1	26.8	69	4.9	
Total CO_2e	2,321.6	2,356.8	2,604	175.9	ND	ND	ND	ND	8,779.2

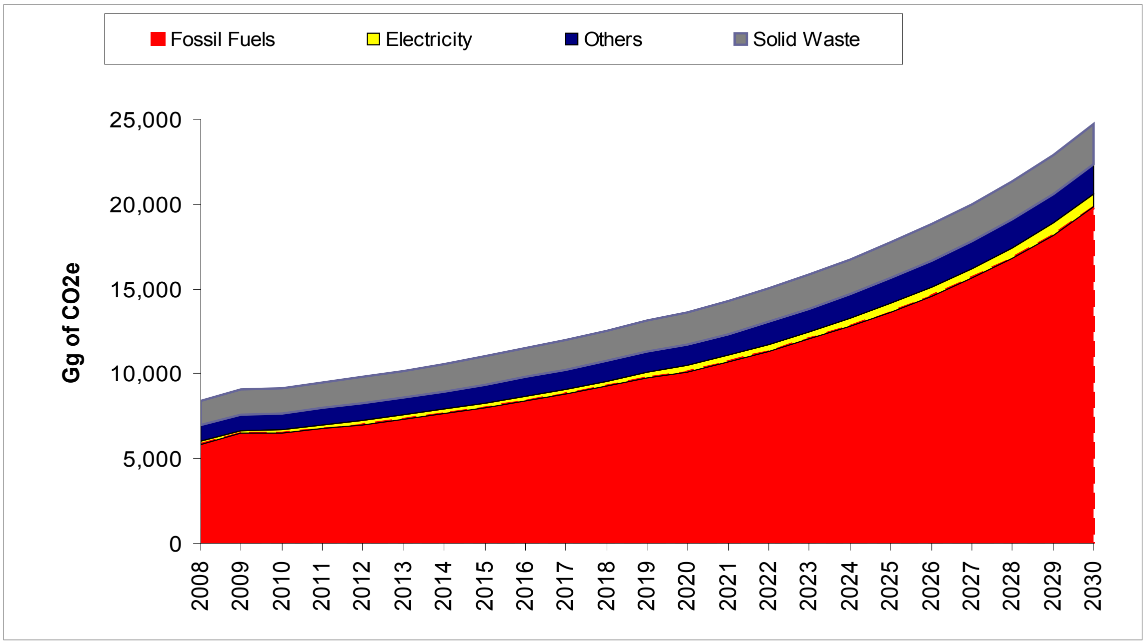
Source: Instituto Meteorológico Nacional, MINAET. 2009

Annex 5 Table A5. Total Greenhouse Gas Emissions by Sector (2005)

Sector	Percentage of emissions
Energy	64.8 %
Industrial processes	7.7%
Agriculture	52.4%
Change in land use	- 39.9 %
Solid waste management	15%
Total	100%

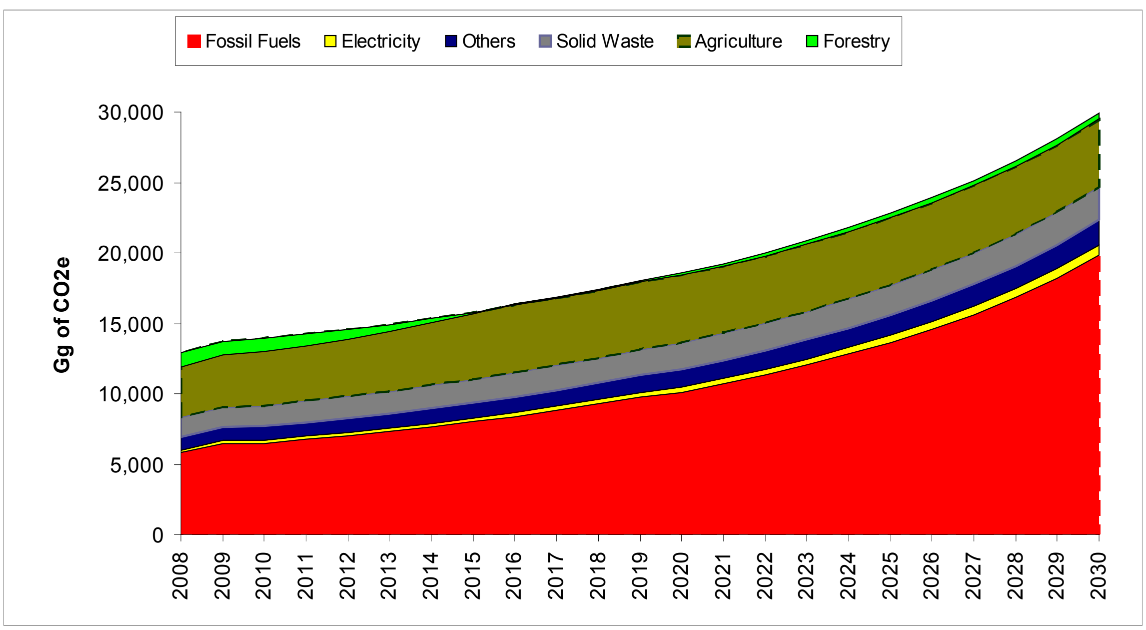
Source: IMN, MINAET. 2009

Annex 6 Figure A1. CO_2 Emissions BAU (Moderate-Growth) Scenario Projected until 2030 – Energy Use and Solid Waste Sectors



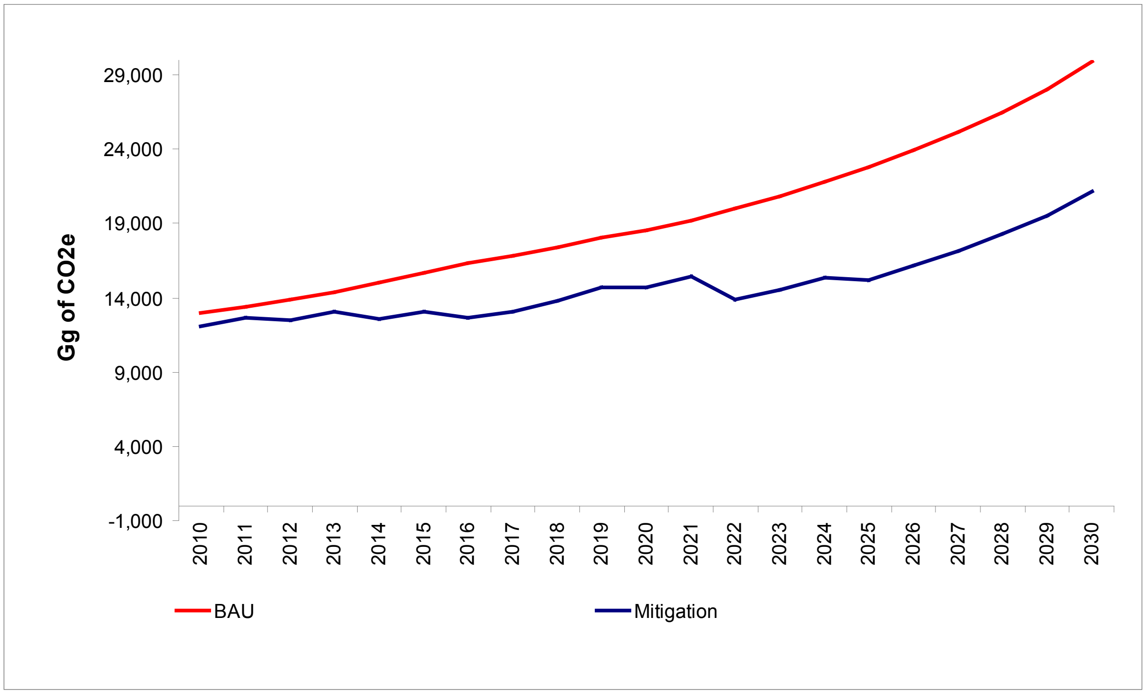
Source: Own elaboration with data of ICE, DSE, MINAET and DIGECA (2009)

Annex 7 Figure A2. Total Emissions Projected until 2030 – BAU (Moderate-Growth) Scenario



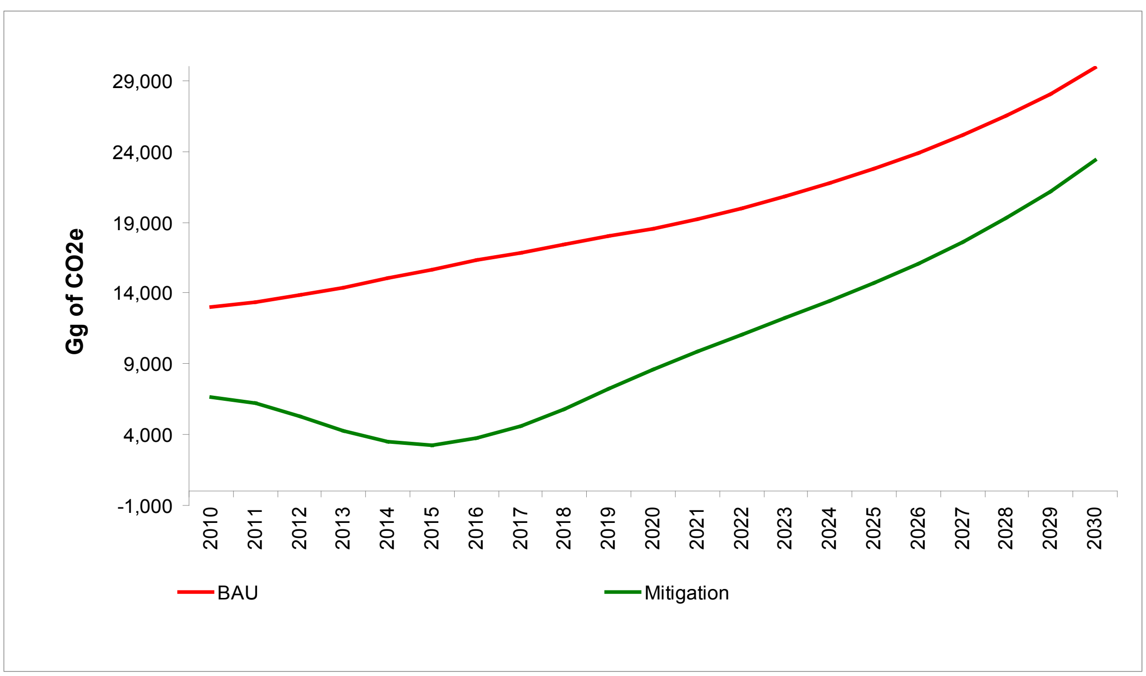
Source: Own elaboration with data of ICE, DSE, MINAET, MIDEPLAN, FONAFIFO, IMN, CATIE and DIGECA (2009)

Annex 8 Figure A3. Emissions under BAU Scenario (Medium-Growth) Projected until 2030 – Mitigation in Energy Use and Solid Waste Sectors



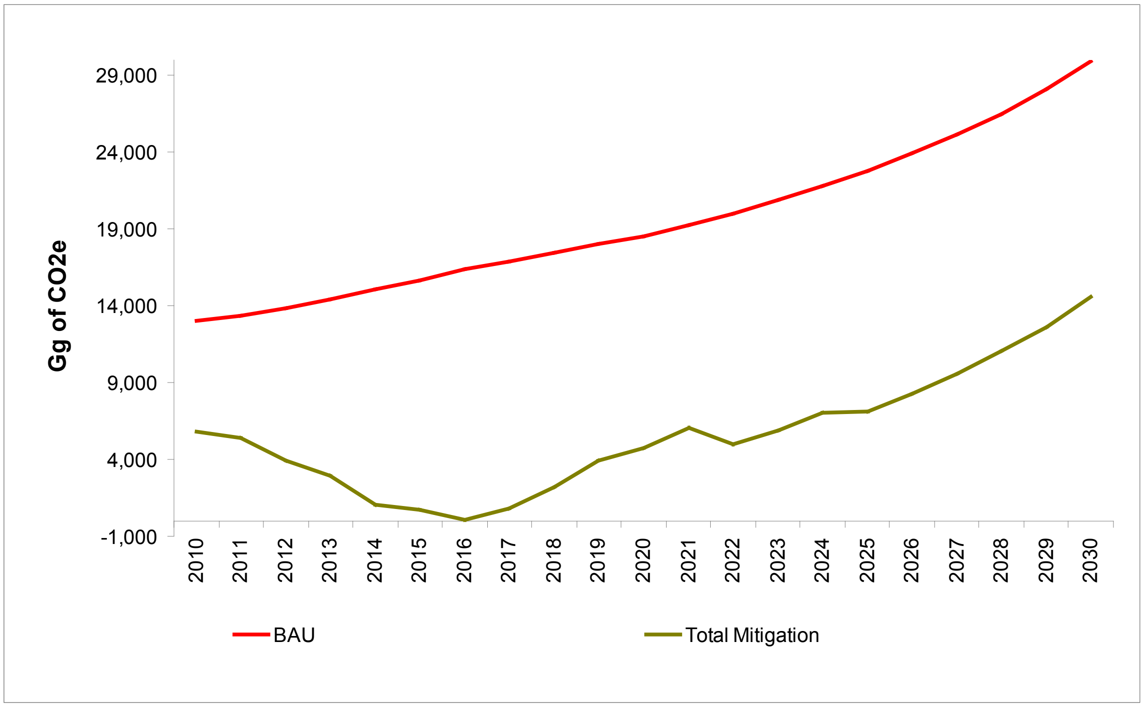
Source: Own elaboration with data of ICE, DSE, PRUGAM, MOPT, MINAET, and own estimations.

Annex 9 Figure A4. Emissions under BAU Scenario (Medium-Growth) Projected until 2030 – Mitigation in Forestry and Agricultural Sectors



Source: Own elaboration with data of ICE, DSE, PRUGAM, MOPT, MINAET, FUNDECOR, and own estimations.

Annex 10 Figure A5. Emissions under BAU Scenario (Medium-Growth) and with Total Mitigation Measures (2010-2030)



Source: Own elaboration with data of ICE, DSE, PRUGAM, MOPT, MINAET, FUNDECOR, and own estimations.

Annex 11 Table A6. Mitigation Options – Costs and Abatement Potential (Medium-Growth Scenario) (2010-2030)

Intervention	US$ per tCO2e reduced	Mitigation tCO2e	Accumulated mitigation tCO2e	Average annual mitigation tCO2e
Low-cost housing	-1,968.4	299,403	299,403	14,970.2
Education of households	-832.0	230,861	530,264	11,543.0
Fluorescent light bulbs (households)	-819.6	80,075	610,339	4,003.7
Energy efficiency (industry)	-785	330,752	941,091	16,538
Fluorescent light bulbs (industry)	-705	15,581	956,672	779
Decongesting roads	-347	2,989,723	3,946,395	149,486
PRUGAM (improvements to road infrastructure)	-166	867,111	4,813,506	43,356
Streamlining of procedures	-99	743,469	5,556,975	37,173
Moving home	-92	1,769,334	7,326,309	88,467
Efficient motors	-79	2,989,723	10,316,032	149,486
Public transport	-78	15,826	10,331,858	791
Four-day week	-77	325,619	10,657,477	16,281
Car pooling	-76	8,458,755	19,116,232	422,938
Efficient driving	-58	198,776	19,315,008	9,939
Electric vehicles	-41	7,325,408	26,640,416	366,270
Landfills	-29	14,126,206	40,766,622	706,310
Vehicle use restrictions	-22	2,512,217	43,278,839	125,611
Cycle paths	-19	6,388,657	49,667,496	319,433
Hybrid vehicles	-10	3,594,583	53,262,079	179,729
Air conditioning	-9	4,855	53,266,934	243
Flex-fuel vehicles	21	364,825	53,631,759	18,241
ICE expansion plan for renewable sources	26	44,500,000	98,131,759	2,225,000
Compressed air vehicles	37	3,035,281	101,167,040	151,764
Ethanol	61	1,142,758	102,309,798	57,138
Electric trains	87	9,278,427	111,588,225	463,921
Solar heaters	248	4,603	111,592,828	230
Biofuels	853	239,695	111,832,523	11,985
Timers on heaters	1,206	10,046	111,842,569	502
Industrial boilers	2,005	48,226	111,890,795	2,411
Forestry sector	7	185,000,000	296,890,795	9,250,000
Agricultural sector	25	8,000,000	304,890,795	400,000

Source: Own elaboration with data and proposals of DSE, ICE, PRUGAM, MOPT, MINAET, Fundecor, and own estimations.