FORM 1015

FORMAT OF PROJECT DESCRIPTION

1. Project Summary

Energy is a vital input in the production and delivery of goods and services. Mauritius, like it is in the rest of the world, relies heavily on the burning of fossil fuels to maintain its socio-economic activities. The historical and continuous accumulation of greenhouse gases (GHGs) is now known to perturb the climate system, and the impacts from these changes are constraining the future development of developing countries. Island states face unique vulnerabilities to climate change. The last two decades has witnessed efforts to curb the emission of GHGs, but the trends are not promising as far as avoiding irreversible climate change by the end of the century. Now more than ever, emission cuts by both developed and developing countries will be required on a wholesale scale by 2050 to avoid a climate regime wherein all countries will be ‘losers’. The ‘holy grail’ of virtually all countries in the world is to adopt sustainable development as a new model. One key aspect of this new model is to shift towards a low-carbon society. The proposed research will investigate alternative emission pathways for Mauritius for different atmospheric GHG stabilization levels. System Dynamics modeling will be used to propose low-carbon emission scenarios over the 2050 time horizon. The basket of viable technologies will be proposed for the different low-emission scenarios, and the investment costs will be estimated. Further, the potential for ‘green’ job creation will be investigated for the low-emission pathways relative to the business-as-usual situation. As a case study, the applicability of the System Dynamics methodology to develop Nationally Appropriate Mitigation Actions (NAMAs) will be demonstrated for Mauritius, and a general framework for developing NAMAs will be proposed.

The proposed research will bring kudos to Mauritius, as well as numerous socio-economic and environmental benefits. It directly supports the achievement of the ‘*Maurice Ile Durable’* vision.

2. Project Justification

Climate change has emerged as arguably the biggest threat to human development in the 21st century. The science is categorical that climate change is driven predominantly by the accumulation of greenhouse gases (GHG) through anthropogenic emissions. Since the atmosphere is a limited sink for GHG emissions as far as irreversible perturbations in the planet’s climate is concerned, the United Nations Framework Convention on Climate Change has the goal of preventing "dangerous" human interference with the climate system. The onus has been on developed countries that have historically emitted the bulk of accumulated atmospheric GHGs to reduce their emissions. The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions. These amount to an average of five per cent against 1990 levels over the five-year period 2008-2012. Developing countries do not have mandatory emission reduction targets under the protocol.

It is clear and undisputed that large-scale emission reductions in global GHGs is necessary by 2050 in order to avoid irreversible climatic change, and stabilization targets over the range 450 – 550 ppm of carbon dioxide equivalent have been proposed to limit the global average temperature increase to within 2ºC by the end of the century. The expediency of the matter is further revealed by the current emission trends that would result in a global average temperature increase in the 4 - 6ºC range. Under this scenario, all countries in the world would experience the detrimental effects of climate change and climatic variability. Given the current reality, both developed and developing (at least the polluters) countries will need to curb GHG emissions. Because of climate change, low-carbon, climate resilient (LCCR) development has emerged as the development pathway for nations, and in particular for developing countries that are more vulnerable to its negative impacts. An important requirement of this new paradigm is to ensure that the socio-economic development of developing countries is not penalized because of a situation that arose from the historical emissions of GHGs by industrialised countries.

This research proposes to investigate the implications of the development of Mauritius over the 2050 time horizon in a carbon constrained world. The innovativeness of the proposed project stems from the fact that neither systematic nor systemic applied research has been carried out in Mauritius to guide public policy on low-carbon development pathways to date. In order to bridge this gap, this proposal will use System Dynamics (SD) modelling as a planning tool to:

1. Develop a self-consistent and transparent SD model that integrates the complexities of Environment, Society and Economy, and which faithfully explains the historical development of Mauritius, including its GHG emissions;
2. Investigate the emission reduction potential of the actions and measures identified in the long-term (to 2025) energy strategy that is currently being updated;
3. Construct carbon intensity curves to 2050 based on different GHG stabilization scenarios, while taking into account the projected growths in the economy and population;
4. Identify the technologies and the investment costs for achieving low-carbon development. The financing opportunities through carbon credits, especially from Sectoral Crediting under dynamic baselines will be investigated; and
5. Use the previous steps to propose a framework for developing Nationally Appropriate Mitigation Actions (NAMAs).

The outcome of the proposed research is to provide a long-term, integrated development planning tool that will allow the country to formulate low-carbon policies, strategies and action plans. It provides a missing link in the Maurice Ile Durable, which has so far addressed climate change as an incidental issue. In particular, the proposed research will enhance the preparedness of Mauritius to leverage international finance that will flow through the UNFCCC in the near-future, and also highlight the opportunities for ‘green’ investment over the next four decades. Further, the SD model being modular in form can be upscaled to carry out scenario policy analysis in any relevant field or sector of development.

The proposed research does not require any clearance or authorisation.

3. Project Description

Outline of the Project

Overall Goal

The proposed project will enhance the capacity of Mauritius to pursue a low-carbon, sustainable development paths up to 2050, with numerous socio-economic and environmental benefits. The economic dividends would visibly be the market development of low-emission and carbon sequestration technologies, and the increased energy productivity in Mauritius. There would also be possibilities to generate carbon credits which could become additional incentives for cleaner technology transfer to Mauritius. Green investments to reduce net greenhouse gas (GHG) emissions has the potential to generate new skilled jobs, with the further possibility of being a platform for exporting technical expertise and even clean technologies to continental Africa. The obvious environment benefits would be the reduction of greenhouse gas emissions, whereby Mauritius plays its role fully in the global initiative to tackle climate change. The research activities will focus on the island of Mauritius, which is by far the largest emitter of GHGs of the Republic. A methodology based on Systems Dynamics (SD) modeling will be proposed for the formulation of Nationally Appropriate Mitigation Actions (NAMAs) for Mauritius as would be a requirement in the near-future under the United Nations Framework Convention on Climate Change (UNFCCC). Using Mauritius as a case study, a general framework for developing NAMAs using SD modeling will be proposed.

Project Purpose

The objective of the proposed project is to elaborate the viable pathways that would enable Mauritius to achieve reductions in GHGs, and hence strive towards a low-carbon society, under different atmospheric GHG stabilization scenarios by 2050.

Outputs of project

The following outputs are expected from this proposed project:

1. Develop a self-consistent and transparent SD model that integrates the complexities of Environment, Society and Economy, and which faithfully explains the historical development of Mauritius, including its GHG emissions;
2. Investigate the emission reduction potential of the actions and measures identified in the long-term (to 2025) energy strategy of Mauritius that is currently being updated;
3. Construct carbon intensity or per capita emission curves for Mauritius to 2050 based on different GHG stabilization scenarios, while taking into account the projected growths in the economy and population;
4. Identify the technologies and the investment costs for achieving the alternative low-carbon development pathways; and
5. Use the previous steps to develop Nationally Appropriate Mitigation Actions (NAMAs) for Mauritius, and to propose a framework for developing NAMAs. In particular, the critical ‘Measurable, Reporting and Verifiable’ dimensions will be addressed using the SD modelling approach. The financing opportunities through carbon credits, especially from Sectoral Crediting under dynamic baselines will be investigated;

These outputs also form part of the milestones of the proposed project. Section 4 elaborates on the project milestones and the activities related to each one of the five outputs.

Background of Proposed Project

Climate change is now universally recognized as a global problem, and it has emerged as arguably the biggest threat to human development in the 21st century. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) has noted that human-induced warming of the climate system is widespread. Anthropogenic warming of the climate system can be detected in temperature observations taken at the surface, in the troposphere and in the oceans. Climate modeling and analyses, which quantify the contributions of different natural and anthropogenic forcings to observed climatic changes, show that greenhouse gas (GHG) forcing alone during the past half century would *likely* have resulted in greater than the observed warming if there had not been an offsetting cooling effect from aerosol and other forcings. Importantly, it noted that it was *extremely unlikely* that the global pattern of warming during the second half of the 20th century could be explained without external forcing, and *very unlikely* that it is due to known natural external causes alone.[1] In short, current climate change and climate variability is due largely to the accumulation of GHGs in the atmosphere through human activities like the burning of fossil fuels, cement manufacturing, deforestation and from the anaerobic decay of various waste streams, and fugitive emissions from industrial processes. Carbon dioxide (CO_2) is the most important anthropogenic GHG and its emission is a direct consequence of the burning of fossil fuels, deforestation and manufacturing of cement. Before further discussion of the drivers of climate change, and the need to curb GHG emissions on a large scale, it is timely to note that there is mounting evidence that current and future climate change and climate variability will affect ecosystems (e.g. species extinction and reduced resilience to external changes), socio-economic sectors (e.g. food productivity and food security, water stress, vector borne diseases) and geographical regions (e.g. flooding of low-lying coastal zones). Regional analyses also show that socio-economically deprived societies are the most vulnerable and will be mostly impacted. Their adaptive capacity is the least since they are either not endowed with or have access to the resources required to enhance their resilience to or buffer climate change impacts.[2]

It was recognized as early as 1990 that a global treaty was required to deal with climate change. The United Nations Framework Convention on Climate Change (UNFCCC) was agreed to in 1992, opened for signature at the Earth Summit in Rio de Janeiro in the same year. It is no more than a framework for further action, and the action is to stabilize atmospheric GHGs at safe levels. It stipulates that the parties to the convention should do this 'on the basis of equity and in accordance with their common but differentiated responsibilities and respective capacities'. Developed or industrialized countries should 'take the lead in combatting climate change and the adverse effects thereof'.[3] The key principles of 'equity', 'common but differentiated responsibilities', and 'safe level of GHGs' need further explanation since they motivate both the rest of the proposal and are central to the current deadlock in international negotiations. The first two main terms are related to the principles of distributive ethics, and can be understood by looking at the atmosphere as a giant sink for pollutants, which in the present case are anthropogenic GHGs. Since the atmosphere is a common good, fairness dictates that every human being both current and future generations should have an equal right to it. By some societies polluting more than others we have a problem of intra-generational equity, and by current generations making use of the global sink without restrictions there is a problem of inter-generational equity. In both cases, the underlying pattern of human behavior is well characterized by the 'tragedy of the commons'.[4] Tackling climate change is a 'common' problem since the planet has only one atmosphere, and the mitigation-adaptation nexus binds all human beings together.

The 'differentiated responsibilities' places the onus of addressing climate change on the industrialized nations. This asymmetric split in responsibilities can be understood by looking at the chain of events that have led to the present problem (i.e. by taking a 'historical perspective'). The current perturbations in climate regimes, that will continue throughout the rest of the century even if GHGs were stabilized at a safe level today,[1] arose predominantly from the emissions of GHGs from developed countries since the onset of industrialization. According to this principle, we have to look at how the present situation came about, rather than merely looking at the present situation, before deciding whether a distribution of goods – i.e. emission of atmospheric CO_2 in the present case – is just or unjust. Approximately 90% of the cumulative CO_2 emissions have been emitted by 25 developed nations, including Australia, Canada, Japan, OECD countries and the USA, among others.[5] In doing so, developing countries are been deprived from using the atmosphere as a sink of CO_2 in the same historical way.[6] The historical perspective leads to the 'polluters must pay' principle – i.e. those you have created this unwanted present situation ought

[1] This is because the GHGs have long lifetimes resulting in their residents times in the atmosphere being of the order of several decades.

to carry the burden to 'fix' it. Hence, the onus ought to be on the developed countries that have historically emitted CO_2 in the atmosphere without restriction. It would, however, also be fair to limit the onus of emission reductions that is placed on the historical polluters to only 90%. The historical principle is the rationale behind the concept of 'common but differentiated' responsibility for stabilizing the stock of atmospheric CO_2.[7] There are two principles that underlie the historical perspective:[8]

1. Making polluters pay for the impacts of their actions internalises what would otherwise be an externality and creates a disincentive for future emissions;[9] and
2. The mismatch between beneficiaries of fossil energy (or flows of goods and services, and hence the generation of wealth, accruing from the use of fossil energy), and victims of climate impacts gives the beneficiaries special obligations. It cannot be justifiable to make those who have benefited and those who have not benefited, but who may be victims of climate change, bear equal obligations. This mismatch is also what motivates that actions to deal with climate change are taken based on 'respective capacities'.

The IPCC has set the 'safe level' for stabilizing GHG emissions at 450 ppm CO_{2e}[2] by 2050 in order to limit the increase in global surface temperature to within 2ºC (compared to preindustrial level) by the end of the century.[10] The GHG stabilization target is even more stringent at 378 ppm CO2e for a 80% likelihood of the limiting the temperature rise to 2ºC.[11] The IPCC has proposed global emission reductions by up to 85% over 1990 levels by 2050. A recent analysis has shown how extremely difficult, even impracticable, it would be to achieve such a large-scale global reduction in emissions by mid-century.[12]

However, other levels of GHG stabilization have been proposed depending on the range of motivation spanning a principled position taken at international climate negotiations by the most vulnerable countries to the cost of emission reduction argument. For instance, The Alliance of Small Island States (AOSIS), which are particularly vulnerable to the impacts of climate change, has consistently taken the position at UNFCCC negotiations to stabilize global CO_2 emissions at 350 ppm by the end of the century, and which would correspond to limiting the average global surface temperature to within 1.5ºC by 2100. This position is supported by the research work of James Hansen.[13] Achieving this target will not be a trivial task when we note that the atmospheric concentration of CO_2 was 393.69 ppm in June 2011.[14] By the end of 2010 when the stock of CO_2 in the atmosphere was around 392 ppm, the equivalent concentration of GHGs was at 448 ppm CO_{2e} – i.e. the proposed IPCC stabilization level in 2050.[15] The exceedingly stringent demands for emission cuts and even net removal of CO_2 from the atmosphere, as well as cost considerations have led others to propose higher stabilization levels. For instance, levels have been proposed at 550 ppm CO2[16] or between 550 and 650 ppm CO_{2e}.[17] The higher GHG stabilization levels also mean higher average global surface temperatures of between 2.5 and 3ºC relative to preindustrial level.[18] Another way of conceptualizing the stabilization of atmospheric GHGs is to look at the fixed allowable carbon budget by 2050 or 2100. This concept is further discussed below.

To date, the only mandatory global regime for binding emission reductions has been the Kyoto Protocol (KP) operating under the UNFCCC. The major feature of the KP is that it sets binding targets for 37 industrialized countries and the European community for reducing GHG emissions, which amount to an average of 5.2% against 1990 levels over the five-year period 2008-2012.[19] Under the Protocol, developed countries must meet their targets primarily through national measures. However, KP offers them an additional three market-based mechanisms – i.e. Emissions Trading, Clean Development Mechanism (CDM) and Joint Implementation (JI) – that have been proposed to stimulate green investment and help Annex 1 countries to meet their emission reduction targets in a cost-effective way. The Protocol covers only six GHGs or families

[2] This refers to 'carbon dioxide equivalents', which includes the effects of all long-lived GHGs and, in some contexts, the effects of other radiative forcing agents such as aerosols and land use changes.

thereof.[3] KP was by no means designed so resolve the climate change debate, and should be seen as a step towards a global response to addressing the issue.

Before assessing global and national trends in GHG emissions, a final note on what would constitute a proposal for a fair allocation of emission rights to the common sink – i.e. the atmosphere – is necessary. After comparing and contrasting several principles of fairness, Peter Singer has proposed the use of equal per capita future entitlements to a share of the capacity of the atmospheric sink, tied to current United Nations projection of population growth per country in 2050.[20] Equal per capita future emissions was chosen for both its simplicity, and hence its suitability as a political compromise, and because it seems likely to increase global welfare.

Global trends in GHG emissions

The earlier discussion has set the climate challenge facing humanity. At the same time as the science is becoming more worrying, growth of the world's greenhouse gases emissions has been accelerating. In the 1970s and 1980s global emissions of carbon dioxide (CO_2) from burning fossil fuels increased at 2% each year. In the 1990s they fell to 1% per annum. Since the year 2000, the growth rate of world's CO_2 emissions has almost trebled to 3 per cent a year.[21] The changes in the actual emissions of CO_2 since the early 1900s serve to show the scale of the problem. In the early 1900s, global CO_2 emissions increased at a rate of 22 Gt per decade, and the increase was at a rate of 245.7 $GtCO_2$ at the end of the 20th century. In the first decade of the 21st century, cumulative CO_2 emissions reached just over 286 Gt.[22] At this rate, annual global emissions will double every 25 years. For the past decade (2001-2010) the average annual increase of CO_2 in the atmosphere has been 2.04 ppm per year.[23] The present concentration of atmospheric CO_2 is the highest during at least the last 2 million years.[24]

The pie chart in Figure 1 shows the relative contributions of different gases to the stock of GHGs in the atmosphere. Carbon dioxide represents typically around 77% of global GHG emissions.

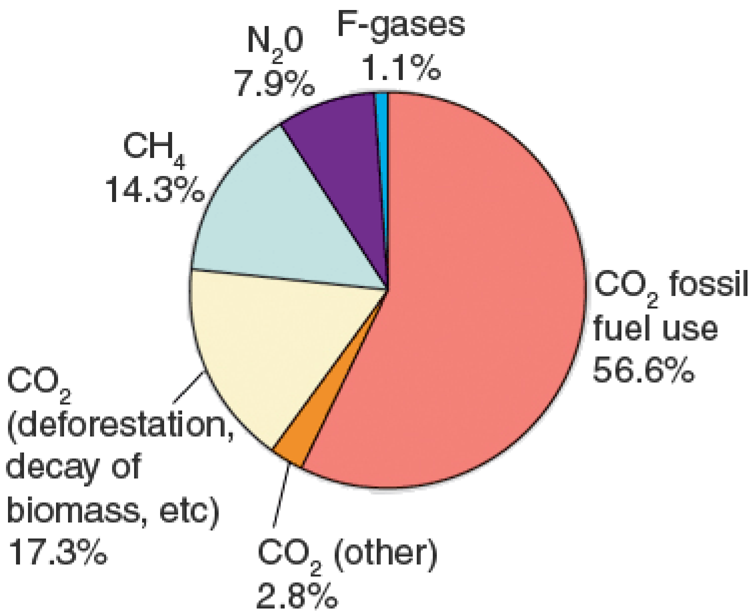

Figure 1. Typical breakdown of global GHG emissions (*Source: IPCC Climate Change 2007: Synthesis Report, Note: Other CO_2 includes cement production and natural gas flaring*).

Formulation of *any* architecture for climate stabilization will have to contend with the shift in the relative contributions of GHGs between developed and developing countries. Figure 2 shows a cross-over point around 2015 in the absolute emissions of CO_2 by developed and developing

[3] These GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

nations. These trends show that developing countries will have to play their parts towards climate stabilization within the next 40 years and beyond. This is especially important since there is a fixed carbon budget associated with stabilizing GHG emissions at any given level. For instance, AR4 notes that based on current understanding of climate-carbon cycle feedbacks, stabilizing emissions at 450 ppm would require cumulative emissions over the 21st century to be less than 1800 $GtCO_2$.[25] More recent studies have set a more stringent carbon budget between now and 2050.[26] In order to have a 75% likelihood of staying below the 2ºC rise in temperature over the preindustrial level, the global economy can only afford to emit a total of 1000 $GtCO_2$ between 2000 and 2050. More than one third of this budget has been used up by 2010. Also, the International Energy Agency (IEA) has shown that the 450 ppm stabilization target could not be achieved by OECD countries alone, even if they managed to reduce GHG emissions to zero.[27] This analysis shows that time is running out fast to take decisive action to reduce global emission in order to restrict irreversible climate change, and such action will require the cooperation and collaboration of all nations.

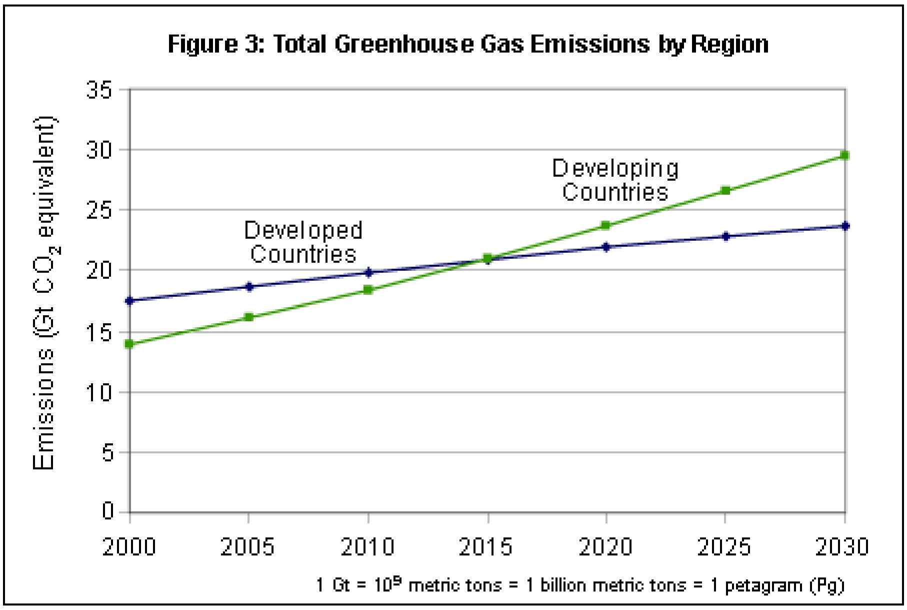

Figure 2. Total carbon dioxide emissions by developed and developing countries (*Source: http://www.epa.gov/climatechange/emissions/globalghg.html - accessed 30 July 2011*).

There have been proposition made based on contraction-convergence models to achieve per capita emissions of the order of 1-2 tCO_2/person in 2050.[28]

GHG emissions in Mauritius

The main GHG in Mauritius is CO_2, and arises from the burning of fossil fuels (coal, fuel oil, diesel oil, gasoline and kerosene). Although the national emission for Mauritius is small by global standards, it, nevertheless, has a relatively significant per capita CO_2 emission. For instance, emissions amounted to 3957.4 $ktCO_2$ in 2010, while removal by sinks was 250 $ktCO_2$. The energy industries contributed around 54.6% of this emission, followed by the transport sector which contributed 31.9% of the total emissions and the manufacturing industries with 9.1%. Probably of more importance here, is the relatively high per capita CO_2 emission of 2.9 tCO_2 for Mauritius in 2010.[29] This figure is 2.5 times higher than the per capita emission of Africa (~1.1 tCO_2/person), and 1.8 times higher than that of India (~1.5 tCO_2/person).[30] If the equivalent emissions of methane and nitrous oxide are taken into account, the net per capita GHG emission in 2010 was 3.8tCO_{2e}. This figure does not take Land Use, Land Use Change and Forestry (LULUCF) into account. Including LULUCF is expected to increase the per capita emission higher. As an example, a comparison of the national annual emissions statistics is compared with the GHG inventory carried out under the Second National Communications (SNC) under the UNFCCC. After carrying out detailed emissions from LULUCF, the SNC reports a per capita emission equal to 3.6tCO_{2e} in 2006.[31] Using the annual emission statistics that does not include emissions from LULUCF, the per capita emission in 2006 is found to be just over 3tCO_{2e}.

The red bars in Figure 3 show the Business-As-Usual (BAU) emission scenario until 2020 reported in the Initial National Communication under the UNFCCC for Mauritius.[32] The solid bars are the measured national emissions, while the open solid bars relate to removal by sinks. It can be seen that the emissions forecast in 1998 are still relevant, baring the dip in emissions in 2009 which followed the global trend due to the global financial crisis.

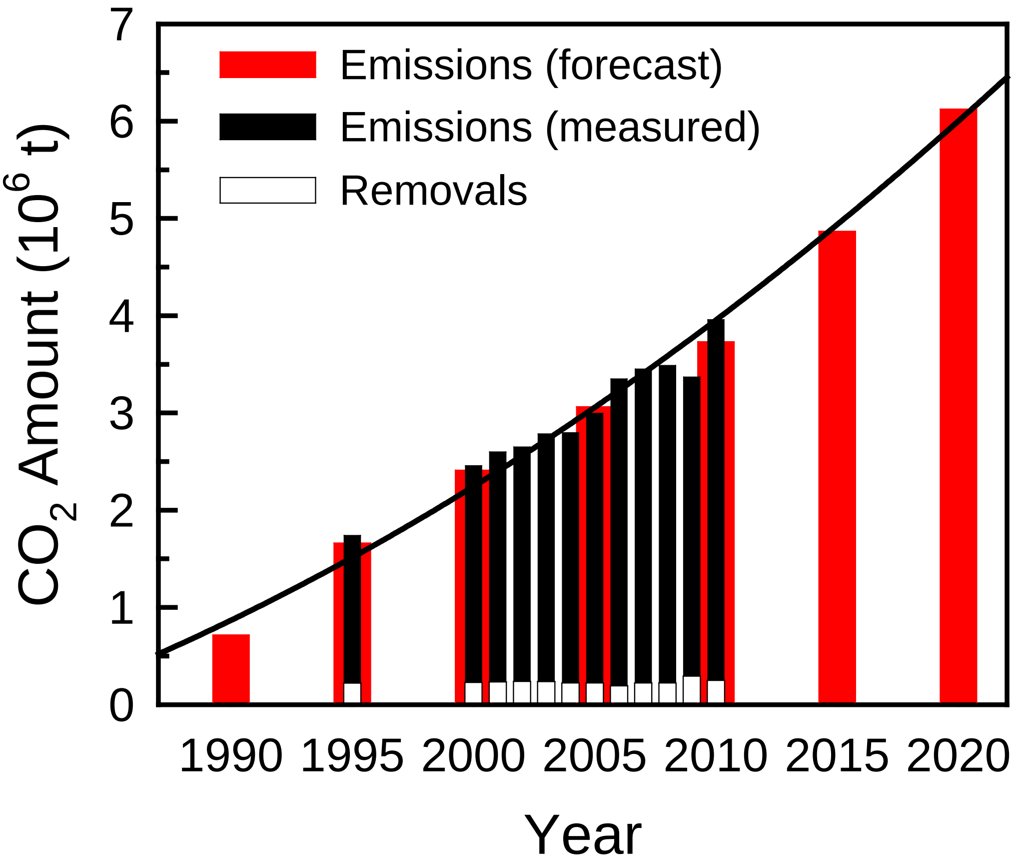

Figure 3. Forecasted and measured CO2 emissions for Mauritius: 1990-2020 (*Source: INC 1998*).

Two pertinent observations can be made from Figure 3:

1. The trend in past emissions closely matches the BAU scenario. If this trend continues, per capita emissions may reach ~4.5 tCO_2 in 2020, and if extrapolated to 2050 will lead to a per capita emission equal to 10.25 tCO_2; and
2. There is limited scope in Mauritius for the sequestration of CO_2 by sinks. This means that emission reductions at source will be the predominant means of future reductions in CO_2 in Mauritius.

The SNC has made projections of GHG emissions to 2040, and it has considered several options for emission reductions, including sequestration.[33] The results are summarized in Table 1. The analyses did not take into consideration the need to constrain GHG emissions as discussed above. Also, no investment analysis was carried out, and some options considered for mitigation in the energy industries may not be compatible with the *Maurice Ile Durable* vision (see below).

Table 1. Business as usual total GHG emissions and their reduction potential to 2040 (1000 tCO_{2e}).

Year	**2020**	**2030**	**2040**
Business as usual	5382	6286	7822
Reduction potential	1528	2317	3309

It is important to note here that the data reported here do not capture CO_2 emissions related to trade, including importation of CO_2 intensive goods like cement, aluminium and steel, tourism travel, and bunkering. Including these components of CO_2 would inevitably increase per capita emissions, and they can only be captured by applying the Territorial Approach to accounting for CO_2 emissions.[34]

<u>Transition to a low-carbon society</u>

The body of research on scenarios for low-carbon societies is on the rise, and the body of research in this field is increasing as nations strive towards low-carbon pathways to development.[35] There is a lot of technological and economic optimism in many assessments of the prospects for a low carbon economy.[36] A common theme in the IPCC 's 4th assessment report (reference 10), in the Stern Review (reference 16), and in numerous other analyses is that it is both possible and desirable to manage energy demand and to shift supply as we make the transition to an energy efficient, energy secure, low carbon economy. This optimism has been partially echoed in a recent online survey of 420 business organizations.[37] It showed that: (i) businesses have faith in climate science, (ii) they are highly aware of the options for reducing energy use and carbon footprints, and (iii) there is confidence in the economic opportunities associated with doing so. The survey also revealed some causes for concern, namely: (i) confidence in government targets was low, (ii) there was restricted access to capital and management time, and (iii) the networks for learning were at times poorly developed. The conclusion was that the prospects for incremental change were good, but those for radical change were much lower. Although the sample size of the survey can be construed as being very small, and hence not representative of the wider business opinion, it may still provide feedback for policy-decision making concerning the transition to a low-carbon society. There are, unfortunately, many reasons why the transition to a low-carbon society is proceeding at a frustratingly slow pace. These have to do with the lack of policy frameworks that give encouragement to industry and to the consumer to prefer low-carbon-based production and consumption over the conventional fossil fuel-driven system.[38]

In light of the earlier discussions, the proposed research will seek answers to the following questions**: What are plausible visions of a low-carbon society for Mauritius, what options exist to achieve the transition to a low-carbon society in the international context of constraining atmospheric carbon by mid-century on an equitable per capita basis, and what are the implications of those different options for its socio-economic development**? The current state of positioning of Mauritius relative to low-carbon development within the climate change context set out above is now reviewed.

<u>Lack of a climate-driven low-carbon strategy for Mauritius</u>

Although the Republic of Mauritius is among the first countries to ratify the Kyoto Protocol under the UNFCCC, it does not have national strategies to guide medium-to-long term mitigation and adaptation actions to tackle climate change. The formulation of the Long-Term Energy Strategy of Mauritius to 2025 is motivated predominantly by the Multi-Annual Adaptation Strategy (MAAS) for restructuring the sugar cane industry.[39] The proposed project seeks to redress this situation. Its scope falls squarely within the ambit of the Bali Action Plan that calls for a 'shared vision for long-term cooperative action', and the spirit embodied by the UNFCCC for a 'common but differentiated responsibility' to address the root causes of climate change. One positive aspect is that there are existing national initiatives that demonstrate the drivenness of Mauritius to benefit from the research proposed here.

Country Drivenness

Although Mauritius does not yet have a coherent strategy for reducing its greenhouse gas emissions, there are several ad hoc projects that are aligned with efforts to reduce emissions through a host projects. The proposed project to develop a Mitigation strategy on Climate Change for Mauritius could well be an umbrella under which all mitigation efforts could be housed, and to provide coherence to future mitigation actions in Mauritius. The main projects are outlined below.

- *Communications to UNFCCC* – As discussed earlier, the SNC reports on the business-as-usual emission scenario to 2040, as well as some mitigation and sequestration options. However, these communications do not necessarily cover nationally appropriate alternative low-carbon emission scenarios or measures that are coherent with other national initiatives like MID. The proposed research will evaluate the merit of the mitigation and sequestration options discussed in the SNC, as well as providing their investment costs;
- *Long-term energy policy of Mauritius* – The long-term energy strategy covers the 2025 time horizon only, and does not take into account broader necessities for development in a carbon constrained world. The proposed research will validate the energy strategy and carry out the investment cost analysis of the proposed technological solutions;
- *Carbon finance / CDM* – As a non-Annex 1 country, Mauritius can benefit from carbon credits by implementing projects that reduce GHG emissions. Thus far, Mauritius does not have any registered CDM project. Our analysis will investigate the potential of leverage carbon credits as a supplementary flow of foreign direct investment to support the sustainable development of Mauritius. Further, one of the outputs of the proposed research is to develop a framework based on SD modelling to formulate NAMAs, and Sectoral Crediting under dynamic baselines;
- *Maurice, Ile Durable project* - The programme is funded by the *Agence Française de Développement* (AFD, French Development Agency), the GOM and UNDP, and aims to contribute to a sustainable Mauritius that can effectively combat global climate change, primarily focused on reducing ROM's dependence on fossil fuels. MID is a vision that emanates from the Prime Minister to create a sustainable future for Mauritius. Specific objectives include strengthening ministerial capacity for programme implementation and initiating thematic changes, starting with the energy sector. A shortcoming of the MID is that the policy timeframe is only 10 years, which is not sufficient to tackle emission reductions in line with the climate change debate;
- *Master plan for Renewable Energy* – The Master plan is being formulated by the World bank, and its proposition will be used in the low-carbon scenario analyses proposed here; and
- *Resource Efficient and Cleaner Production* - This centre is hosted by Enterprise Mauritius acting under the aegis of the Ministry of Industry, Science and Research. The proposed research will draw on the emission reduction potential that has been assessed by the RECP programme.

Emissions and economic growth

The relationship between economic growth and rising carbon dioxide (CO_2) emissions is the chicken or the egg question of the climate change debate. A growth in industry, and hence emissions, will no doubt stimulate a country's Gross Domestic Product (GDP). Conversely, a higher GDP will often lead to a greater disposable income and higher standards of living which could manifest in more cars, more residential energy use and more consumption all of which will impact on a country's total emissions. A review of the econometric literature by the IPCC has revealed the following:[40]

- that the relationship between GDP per capita and CO_2 emissions per capita did not support an optimistic interpretation of the EKC hypothesis that emissions will decrease with economic growth; and
- the monotonically increasing relationship between economic activity and CO_2 emissions emerging from the data does not appear to be econometrically very robust, especially at country level and at higher GDP per capita level. The pessimistic interpretation of the literature findings that growth and CO_2 emissions are irrevocably linked is not supported by the data.

A recent study looking at any correlations between CO_2 emissions and economic growth also failed to validate the EKC hypothesis.[41] This result has two implications: (1) that continued economic growth will increase GHG emissions; and (2) that emission reductions may potentially reduce economic growth and hence the socio-economic development of Mauritius. Climate negotiations under the UNFCCC make it clear that the sustainable development of developing nations should not be jeopardized by any in-country emission cuts. **The research proposed here will investigate the growth-emission reduction nexus for Mauritius in more details.**

From Bali Action Plan (BAP) to NAMAs

There has been significant development under the Bali Action Plan (BAP) adopted by the Conference of Parties (COP) as decision 1/CP.13 in December 2007). For developing countries, BAP translates into the reduction of greenhouse gases through the development of nationally appropriate mitigation actions (NAMAs), supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable (MRV) manner. These concerted actions cover three of the four pillars of BAP, namely mitigation, adaptation, technology transfer and deployment, and financing.[42] The proposed project falls squarely under the ambit of the BAP.

During 2010, many developing countries submitted their NAMAs to limit the growth of their emissions, with appropriate and adequate support from industrialized countries in the form of technology cooperation, finance and help in capacity-building. NAMAs are grounded in the overall objective of ensuring sustainable development, and are aimed at achieving a deviation in emissions relative to what would otherwise be 'business as usual' emissions by 2020. Mauritius has not yet submitted NAMAs, but it has rather communicated officially to the UNFCCC that:[43]

> "90. Mauritius communicated that it has already embarked on a comprehensive Sustainable Development Programme as part of the "Maurice Ile Durable" initiative, which prioritizes renewable energy and energy efficiency.
> 91. Mauritius added that it intends to enhance mitigation efforts subject to the financial, technological and capacity-building support provided."

In addition, the scenario analyses of mitigation and sequestration options leading to low-carbon development routes will attempt to classify NAMAs into the following three categories that will allow Mauritius to be better prepared to leverage international funding for further developing and implementing NAMAs when it becomes available in a post-COP17 regime.[44]

- Unilateral NAMAs: mitigation actions undertaken by developing countries on their own;
- Directly supported or Conditional NAMAs: mitigation actions in developing countries, supported by direct climate finance from Annex I countries; and
- Credited NAMAs: mitigation actions in developing countries, which generate credits to be sold on the carbon market (e.g. sectoral crediting).

Developing countries are encouraged under the agreement to draw up low-carbon development strategies or plans, and this is exactly what the proposed research will attempt to achieve using System Dynamics modeling. In the case of 'credited' NAMAs, the proposed research will develop a framework, using Mauritius as a case study, for sectoral crediting based on dynamic baselines. The proposed methodology will demonstrate the fulfillment of MRV metrics based on sectoral GHG emissions that should accompany the underlying NAMA. Since the System Dynamics modeling uses the Social Accounting Matrix (SAM) and SNA (see below), the costs associated with achieving the NAMAs will be established.

Proposed methodology

Threshold 21 (T21) is a dynamic simulation tool designed to support comprehensive, integrated long-term national development planning. T21 supports comparative analysis of different policy options, and helps users to identify the set of policies that tend to lead towards a desired goal.

This insight into how different indicators of development interact with one another to produce an outcome deepens users' understanding of development challenges. More specifically, T21 allows the complex interactions between all aspects of development (economic, social and natural environment) to be considered, which often escape mental representations. T21 allows the unique positive and negative feedback loops between the three spheres of development – Economy, Society and Environment – to be set given the specific stage of development of a community or country.

The T21 model is the most diffused and validated System Dynamics model available today for long-term integrated development planning. It has been vetted by experts at the World Bank, UNDP, Carter Center, and Conservation International, among others, and found effective for integrated development planning.
T21 harnesses the strengths of other tools such as Econometric Models (EM), Social Accounting Matrix (SAM) and Computable General Equilibrium (CGE) models, making it an essential complement to them. It can incorporate sections from these and other sector models into its overall framework to draw on high quality modelling work; or it can use outputs from these models as inputs into certain sectors.

T21 conceptual framework
The conceptual framework behind T21 is illustrated in Figure 4.

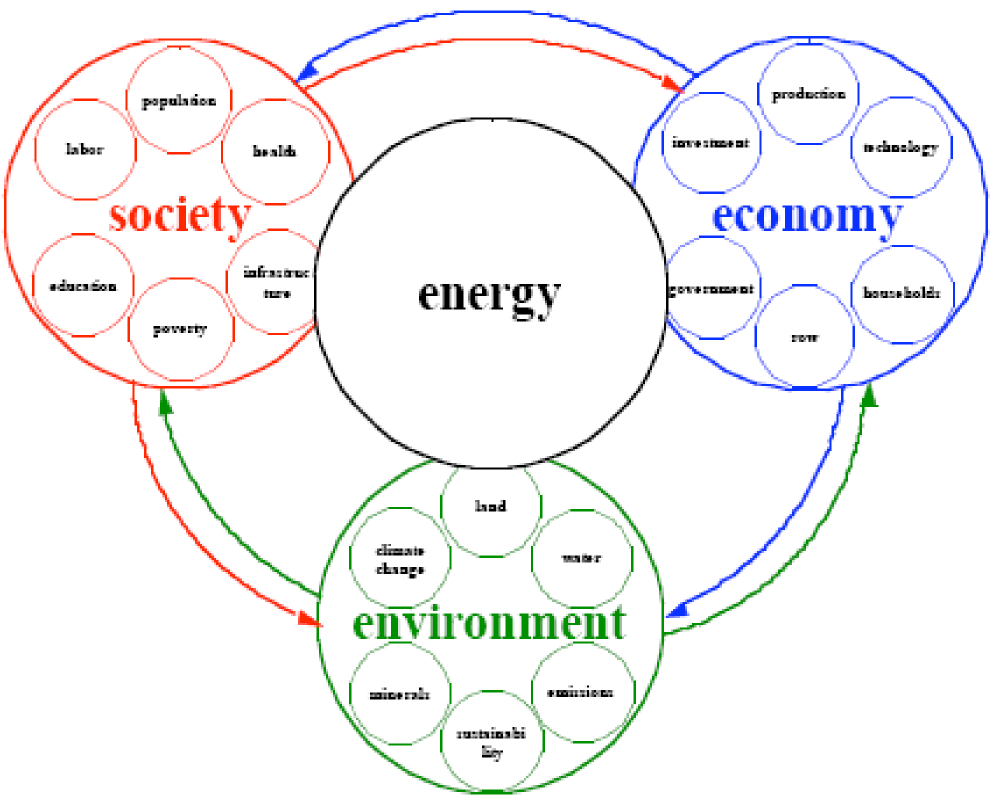

Figure 4. Conceptual framework of T21.

The following discussion expands briefly on the four spheres (Energy, Economy, Environment and Society) and highlights some of their main interactions.

The Social sphere contains detailed population dynamics organized by sex and age cohort and health (using 'life expectancy' as a proxy). It also includes employment disaggregated for the primary, secondary and tertiary production sectors.

The Economy sphere describes the three production sectors by augmented Cobb-Douglas production functions with inputs of resources, labour, capital and technology. A Social Accounting matrix (SAM) and a System of National Accounts (SNA) are used to elaborate the economic flows, and balance supply and demand in each of the sectors. Demand is based on population and per capita income, and distributed among sectors using Engle's Curves. This helps calculate relative prices and how they change over time as a result of income changes and other factors, which form the basis for allocating investment among the sectors. Standard IMF budget categories are employed, and key macro balances are incorporated into the model. Trade, current account transactions and capital flows (including debt management) are accounted for under the 'Rest of World' sector.

The Environment sphere tracks land allocation, fossil fuel emissions, and climate change. Land is further divided into urban, agricultural, fallow, forest and desert. There are feedback loops between greenhouse gases (plus other emission) from the consumption of fossil fuels, the carbon cycle, climate change and life expectancy.

The Energy sphere adds important feedbacks to Society, Economy and Environment. Energy, seen as a 'meta-technology', is used to produce food, heat houses, and fuel transportation, and, in sum, is ubiquitous to modern life. In a T21 model, Energy may be linked to Society through employment, access to electricity, and life expectancy. In parallel, population demands energy for residential use and for transportation. Economy is intertwined with Energy through energy demand and consumption for production activities. Both private and public investments to maintain and increase production capacity and improve energy efficiency (i.e. lowering the energy intensity of the economy). Energy prices negatively impact on GDP, decreasing total factor productivity, and energy expenditure reduces households' net income available for other discretionary consumption. Energy and environment are also interconnected through depletion of non-renewable resources, generation of greenhouse gases, and water and land utilization for energy and biofuels production.

All of the above interactions take place via negative and positive feedback loops that are captured mathematically as stochastic processes. The major feedback loops underlying Society, Economy, Environment and Energy being: (1) public and private economies, (2) resources and environment (Environment & Economy), (3) labour availability (Economy & Society), and (4) population and income (Economy & Society). The main feedback loops that will be captured in the System Dynamics model are shown in Figure 5.

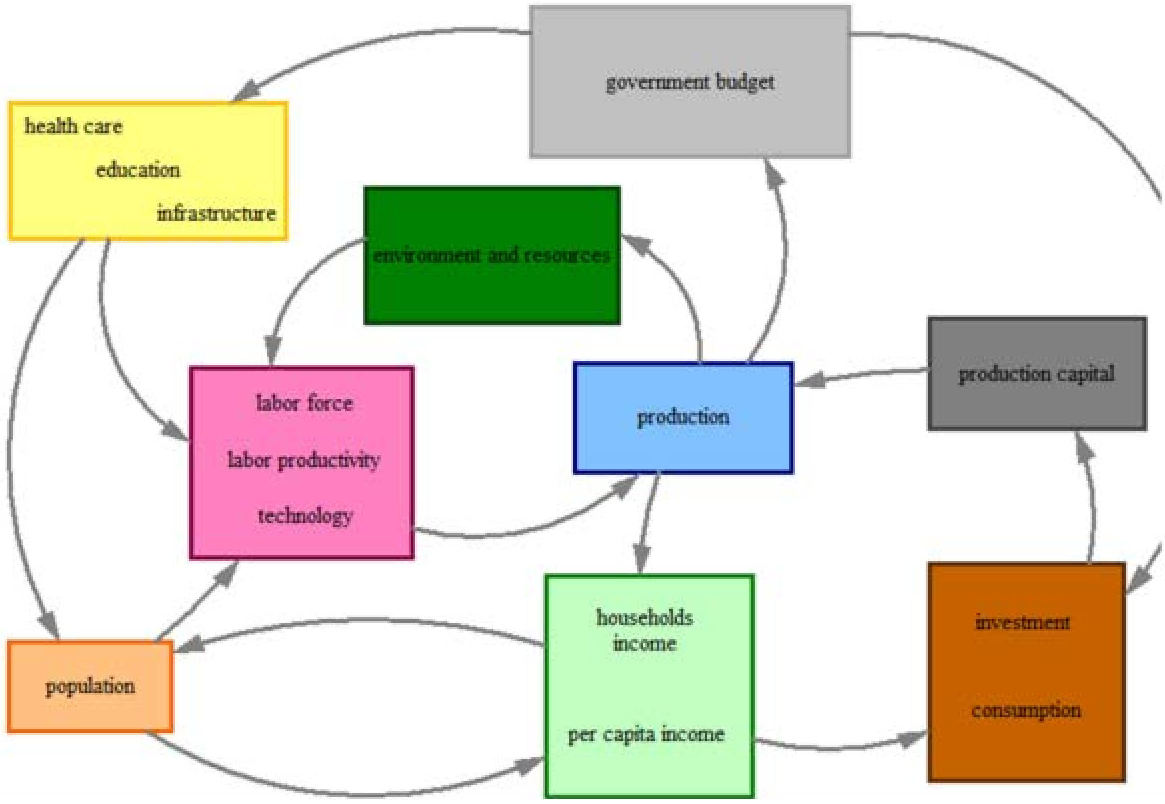

Figure 5. Main feedback loops that are modelled by T21.

A Primary Country Model (PCM) was developed for Mauritius in 2007 through funding received from the United Nations Development Programme (UNDP). The PCM integrates 12 sectors, including 4 in Economy (Government, Banks, Firms, Households), 4 in Society (Education, Health, Population, Infrastructure), and 4 in Environment (Water, Land, Energy, Air/Emissions). The proposed research will build on the PCM.

National Benefits

With climate change mitigation strategies and low-carbon development becoming mainstream on the agenda of governments worldwide, there is an increasing demand for countries to use dynamic, long-term planning tools to ensure their energy futures. There are also co-benefits in terms of energy security and job creation through green investments in the energy sector. The proposed project is expected to bring a suite of benefits to Mauritius, including:

- **Prestige**: The research outcomes will bring kudos to Mauritius foremost because it treats a topical research subject of international importance. The results of the proposed research will be disseminated worldwide. As discussed earlier, decisive actions to reduce GHG emissions is yet to materialize, and the proposed research can potentially send a strong message to policy makers elsewhere. Further, the use of System Dynamics modeling to develop NAMAs and sectoral crediting under dynamic emission baselines will be a new propositions, and will add to the basket of methodologies that are being proposed internationally;
- **Socio-Economic benefits**: There are several ways in which the results of this research will support the socio-economic development of Mauritius. It will provide a dynamic tool to investigate the impacts of green investments in the Energy Sector (Energy Industries and Transport), Waste Sector and Land Use Land Use Change and Forestry (LULUCF), among others, in Mauritius, and in particular (i) the type of technology (and their transfer) that would be required to reduce emissions, and (ii) 'green' job creation. These elements are also important for private investors;

- **Environmental benefit**: The large-scale deployment of emissions reductions technologies will help to reduce greenhouse gas emissions and thus mitigate the magnitude and severity of the effects of global warming. Although Mauritius is a very low emitter in absolute terms, it is nevertheless a relatively high emitter on a per capita basis;
- **Research training**: To date, there has been no systematic investigation of Energy Futures in a Carbon Constrained World, and their developmental implications for Mauritius. The investigators have been involved in using System Dynamics for development planning in Mauritius (see Section 6), and although those projects provide a platform for the research proposed here, they have not covered the scale and scope of the current research proposal. This proposal will contribute towards the furthering of research excellence in Mauritius;
- **Supporting the participation of Mauritius to the UNFCCC processes**: The results of the proposed research will put Mauritius in a better position to negotiate at Conference of Parties, especially in the context of formulating and implementing NAMAs for future emission reductions. Further, it will demonstrate the preparedness of Mauritius to accept and absorb any in-flows of Official Development Assistance for developing and implementing NAMAs. A crucial output of the research is the level of investment required for low-carbon development, which could be used to leverage financial support bilaterally or through multi-lateral institutions; and
- **Technology and knowledge transfer**: Through a strategic international collaboration, it will allow local researcher to have access to a long-term, dynamic planning tool, knowledge and expertise in System Dynamics modeling not available in Mauritius.

Through the above benefits, the project will make a significant contribution towards the 'Maurice Ile Durable' vision, and enhance the economic, social and environmental wellbeing of the nation.

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4. Project Activities, Cost Components and Milestones

Please see attached forms 1020 and 1030 for these details.

(i) Activities and cost components
As shown in Form 1020, the seven project milestones have been broken down in 10 activities. Five cost components have been used to justify the activities, and the discussion below elaborates on the rationale behind the costing.

1. **Consumables** – The main consumable used is internet access, and a rate of Rs800 / month has been used to cover this expense. Please note that this cost component is not applicable to all the activities;
2. **Local travel** – This component is applicable for Activities 2, 3, 4, 5, 8 and 9. Activities 2 and 9 consists of 6 visits each between PI and RA. Activity 3 consists of making 7 visits to the Central Statistics Office, Port Louis. Six meetings between PI and RA will be held over Activities 4 & 5. There will be 4 visits between PI and RA for Activity 8. All local travel are charged at a rate of Rs500/visit;
3. **Documentation publications** – This applies to a total of 7 progress and final reports, and a rate of Rs1500/report has been used;
4. **Page charges (other)** – The proposed research is expected to generate 3 publications in peer-reviewed international journals for which page charges have to be paid. The following assumptions have been made: (1) average number of page per article = 7; (2) page charges = US$150/page; and (3) exchange rate = Rs28/US$. These assumptions yield a total 'page charges' of Rs88,200; and
5. **Research Assistant (RA) Salary**–Since the local market is not responsive to the demand for System Dynamics modeling, ELIA is sending Mr Xavier Koenig to the University of Bergen, Norway to be trained as a System Dynamics modeler between April and May 2012. The total duration of the residential course is 6 weeks, and ELIA is investing around US$7,000 in Mr Koenig's training. This training is organized through our collaboration with the Millennium Institute. A monthly salary of Rs18,000 has been budgeted for the RA over the duration of the project. The CV of Mr Xavier Koenig is attached for your reference.
6. **Computing services** – A license for the software Vensim DSS will be bought from Ventana for modeling purposes. ELIA already has a license but it is being used by the PI and is not transferrable. A new license will be bought for the RA. The cost of the license is of the order of US$1,000.

In addition, the PI would like to make a statement of the value addition by the contributions of Dr A. Bassi who is expected to contribute 2 man-months of research time on the modeling part of the proposed project. This contribution is estimated at US$18,000 (i.e. Rs504,000 at an exchange rate of Rs28/US$) including overheads.

(ii) Milestones
Seven project milestones, which include the five outputs of the project, are proposed for the project. It is understood that they will be finalised following consultations between the Council and the PI. Please see Form 1030 for more details. The proposed project milestones are:

1. Literature review completed;
2. A self-consistent and transparent SD model that integrates the complexities of Environment, Society and Economy, and which faithfully explains the historical development of Mauritius, including its GHG emissions developed;
3. The emission reduction potential of the actions and measures identified in the long-term (to 2025) energy strategy of Mauritius investigated;
4. Carbon intensity or per capita emission curves for Mauritius to 2050 based on different GHG stabilization scenarios constructed;
5. Technologies and the investment costs for achieving the alternative low-carbon development pathways completed;
6. Framework based on SD modelling to formulate Nationally Appropriate Mitigation Actions (NAMAs) developed;
7. Final Report submitted;

5. Validation and Dissemination of results

Validation - Four levels of validation of results are proposed. The first level of validation of results is inherent to the SD modeling approach when its causal relationships are able to explain historical data (say over the last 20 years) faithfully. Another level of validation will take place when the results will be presented to the general public, experts and policy makers during a validation workshop that is usually organized by MRC. The third level of validation will take place when the results of the research will be peer reviewed internationally (see more on 'dissemination' below) as part of the process of publication in international journals. The final one will be through feedback obtained after any published work is disseminated worldwide through the Climate-L portal of the International Institute for Sustainable Development (IISD).

Dissemination

The results of the proposed research will be disseminated in the following three ways:

1. A final report as per the requirements of the MRC, and which will be accessible to the general public;
2. A summary of the results for national policy makers;
3. Presentation at a validation and dissemination workshop organized by MRC;
4. Publication of results in prime international journals like Energy Policy, Climatic Change, and Climate Policy, among others;
5. Presentations at national and international conferences when the opportunities arise, and depending on the availability of funds;
6. Since the research proposed here is of international interest, all published work will be circulated worldwide using the Climate-L portal of IISD; and
7. Through the website of ELIA (www.ecologicallivinginaction.com) after seeking permission from MRC.

6. Prior Research work undertaken by PI

The PI has been a cornerstone for the use and institutionalization of System Dynamics modeling for integrated development planning in Mauritius, with the collaboration of Millennium Institute and the Council for Scientific and Industrial Research, South Africa, since June 2007. The following shows the involvement of the PI with SD modeling, and more specifically with 'Energy Sector' modeling.

- As mentioned in the "project description", the proposed research will build on the Primary Country Model (PCM) that was developed at the end of 2007 for Mauritius. The PCM was used in System Dynamics training provided by MI in Mauritius in 2008, and in which the PI participated. The training also involved the development of an Energy Sector model for Mauritius to which the PI contributed;
- The PI, together with Professor Alan Brent, has held a research grant from the National Research Foundation, South Africa in 2008-2009 entitled "Towards establishing a modelling framework for a sustainable energy base in Southern Africa: Development of the T21 model for South Africa and Mauritius". Dr Bassi, Millennium Institute, was the Technical Advisor on this project. This project resulted in a publication: "K. Balnac, C. Bokhoree, Prakash Deenapanray, and A. Bassi**,** A System Dynamics Model of the Mauritian Power Sector, Proceedings of the 27 International Conference on the System Dynamics Society, Albuquerque, New Mexico, August 2009" (The paper is available at http://www.ecolivinginaction.com/articles/A%20System%20Dynamics%20Model%20of%20the%20Mauritian%20Power%20Sector.pdf);
- The PI has also been an Advisor on a MPhil thesis at the University Technology, Mauritius that carried out a comparative analysis of energy modeling using System Dynamics and Neural Networks. This activity has resulted in a publication: "K. Balnac, C. Bokhoree, J. Ringwood, and Prakash Deenapanray, A System Dynamics Tool to Estimate the Contribution of Mauritius' Power Sector to the Stock of CO2 Emissions, Proceedings of World Academy of Science, Engineering and Technology, Issue 68, July 2010 (ISSN: 2070-3740)";
- The investigators of the proposed project have recently carried out a case study of green investments in Mauritius using System Dynamics modeling that has resulted in a report: "Andrea M. Bassi and Prakash N. K. Deenapanray, Simulating the Impact of Green Investment - The Mauritius Case Study. 2010. Millennium Institute, Washington DC, USA"; and
- Deenapanray and Bassi have carried out preliminary analyses of the per capita emission of Mauritian to 2050 for different economic growth scenarios (GDP growth of 2% or 3.8%) and using a per capita world emission pathway reported in P. Baer, T. Athanasiou, S. Kartha, and E. Kemp-Benedict, The Greenhouse Development Rights Framework – The right to development in a climate

constrained world, Publication Series in Ecology – Vol1, Revised Second Edition (Heinrich-Boll Foundation, Christian Aid, EcoEquity, and the Stockholm Environment Institute, 2008). Two hypothetical emission curves (yellow for GDP = 3.8% and green for GDP = 2%) have been constructed for Mauritius as shown in Figure 6.

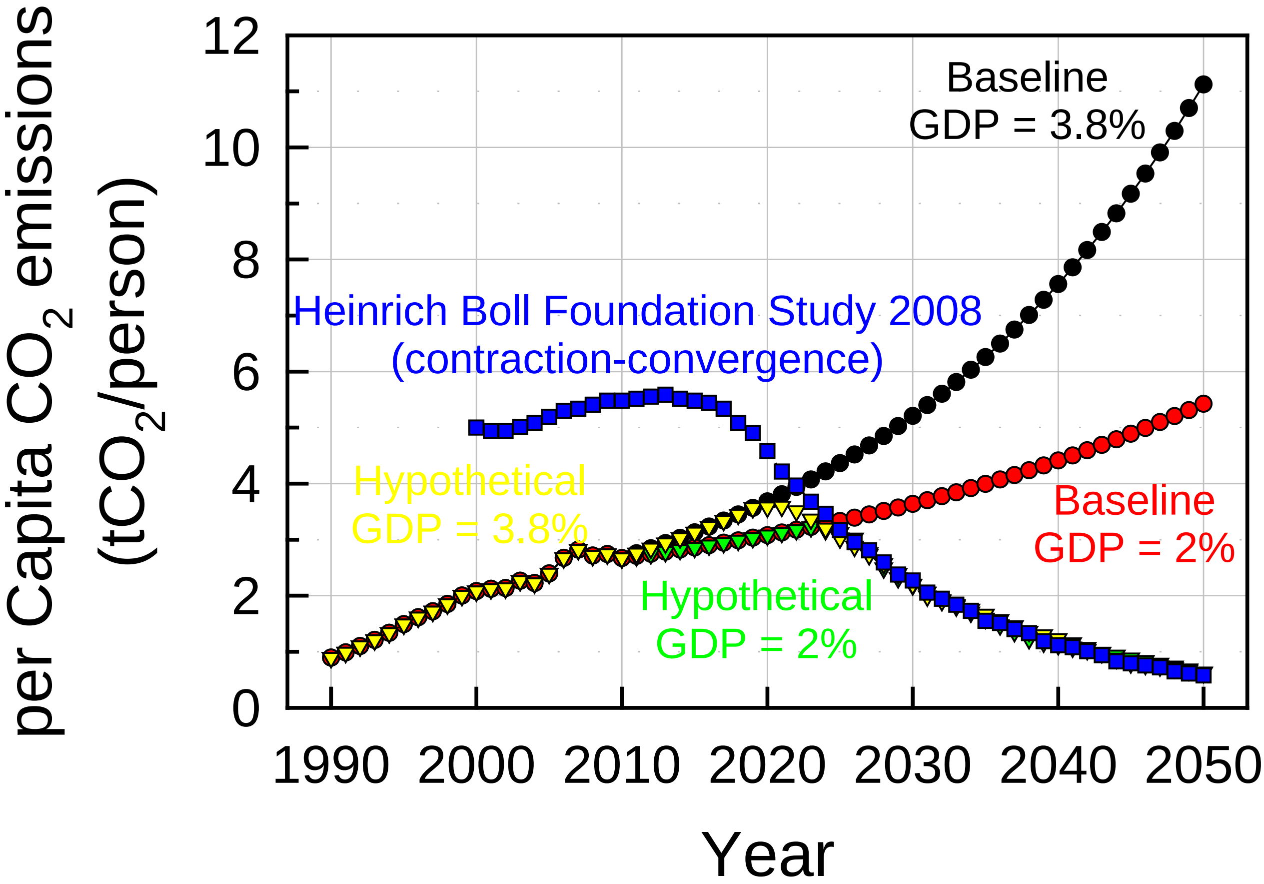

Figure 6. Construction of hypothetical per capita emission pathways (yellow and green) for Mauritius to 2050 for two different economic growth scenarios following a contraction-convergence emission model.

7. Result of previous work financed by MRC, if any

None.

8. Referees

The following national and international referees can be contacted for reviewing our proposal.

1. <u>Mr Alan Brent</u>

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9. Has this project proposal or a similar one, been submitted to any other organisation for either full or partial funding?

Neither this project proposal nor a similar one has been submitted to any other organization for funding consideration.

10. Facilities, equipment and other resources. (Identify the facilities to be used at each performance site listed and as appropriate, indicate their capacities, pertinent capabilities, relative proximity and extent of availability to the project).

- Computer – ELIA will provide a laptop to be used by the PI for the purpose of the proposed research, while the Dr Bassi will use his personal computer. Mr Koenig will also use his personal computer;
- Software – Vensim DSS will be used to build the System Dynamics model in the proposed research. This software is already available to the PI and Dr Bassi;
- Laboratory equipment: No laboratory equipment is required for the proposed research;
- Office – The PI will use the office of ELIA located at 74 Societe La Fleche, La Gaulette to carry out the proposed research, while Mr Koenig will work from his home. Regular meetings will be held between the PI and the RA;
- Online access to journals: The PI has access to the online library, including electronic journals, of the Australian National University. This facility will be used extensively for literature review;