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THE ECONOMICS OF CLIMATE CHANGE AND SCIENCE OF GLOBAL WARMING DEBATE: AFRICAN PERSPECTIVES

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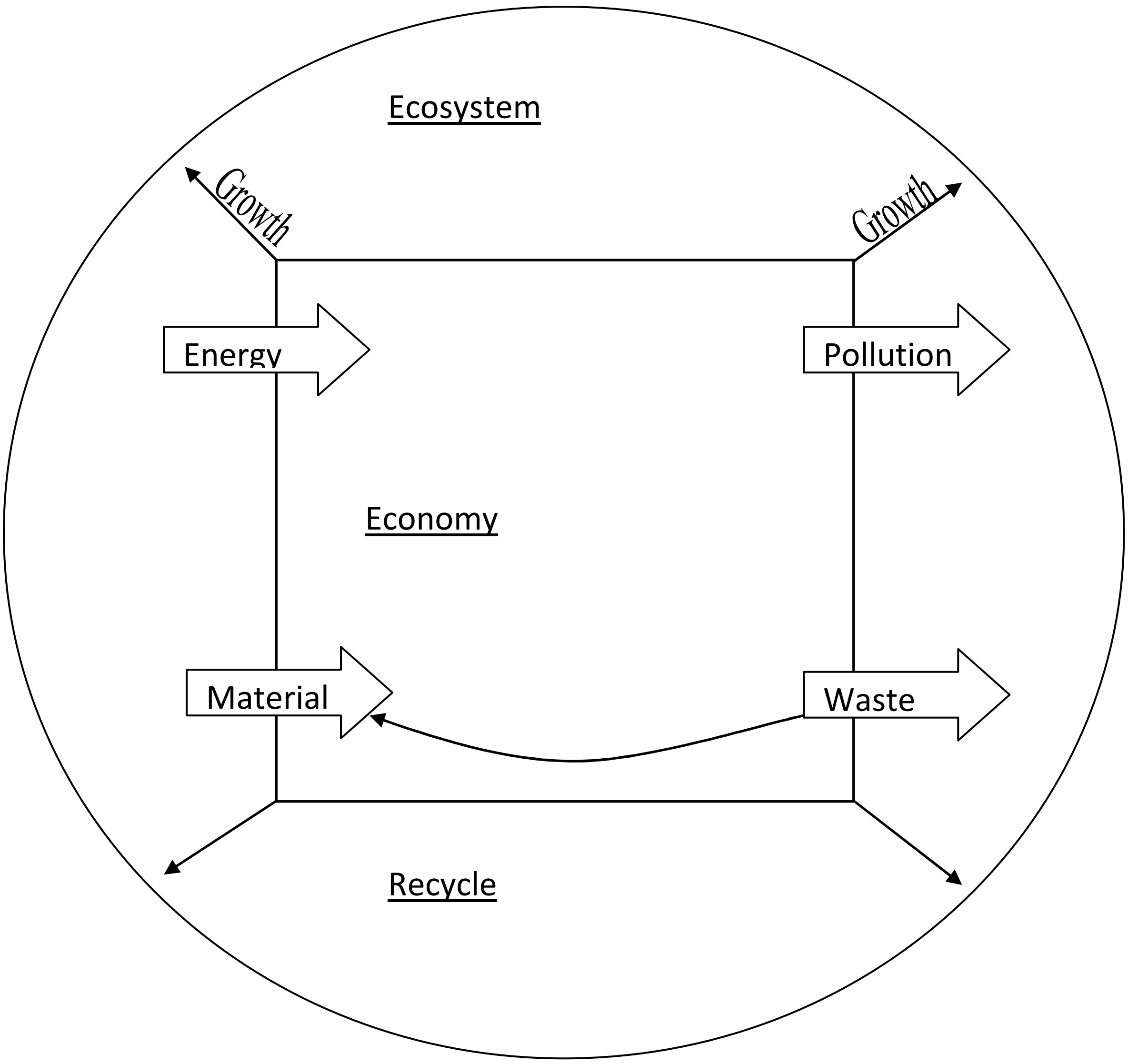
1.0. INTRODUCTION

Traditional economists viewed the economic system in terms of the reciprocal circulation of income between producers and consumers, and focused on the problem of allocating resources efficiently between different uses to meet unlimited wants. On the other hand, environmental and resource economists consider the environment (along with the planet's resources) as a sub-part of the economic system. Here, growth is conceptualized as a solution rather than as the cause of environmental problems, and the expansion of an economy can continue into the future by following a balance growth path (without any apparent limits). Unfortunately, scholars here argued that the narrowness of the neoclassical approach to environmental and ecological issues has made it difficult to understand and address environmental problems (Venecatachalem, 2007; Daly, 1996; Hallegatte,2011).

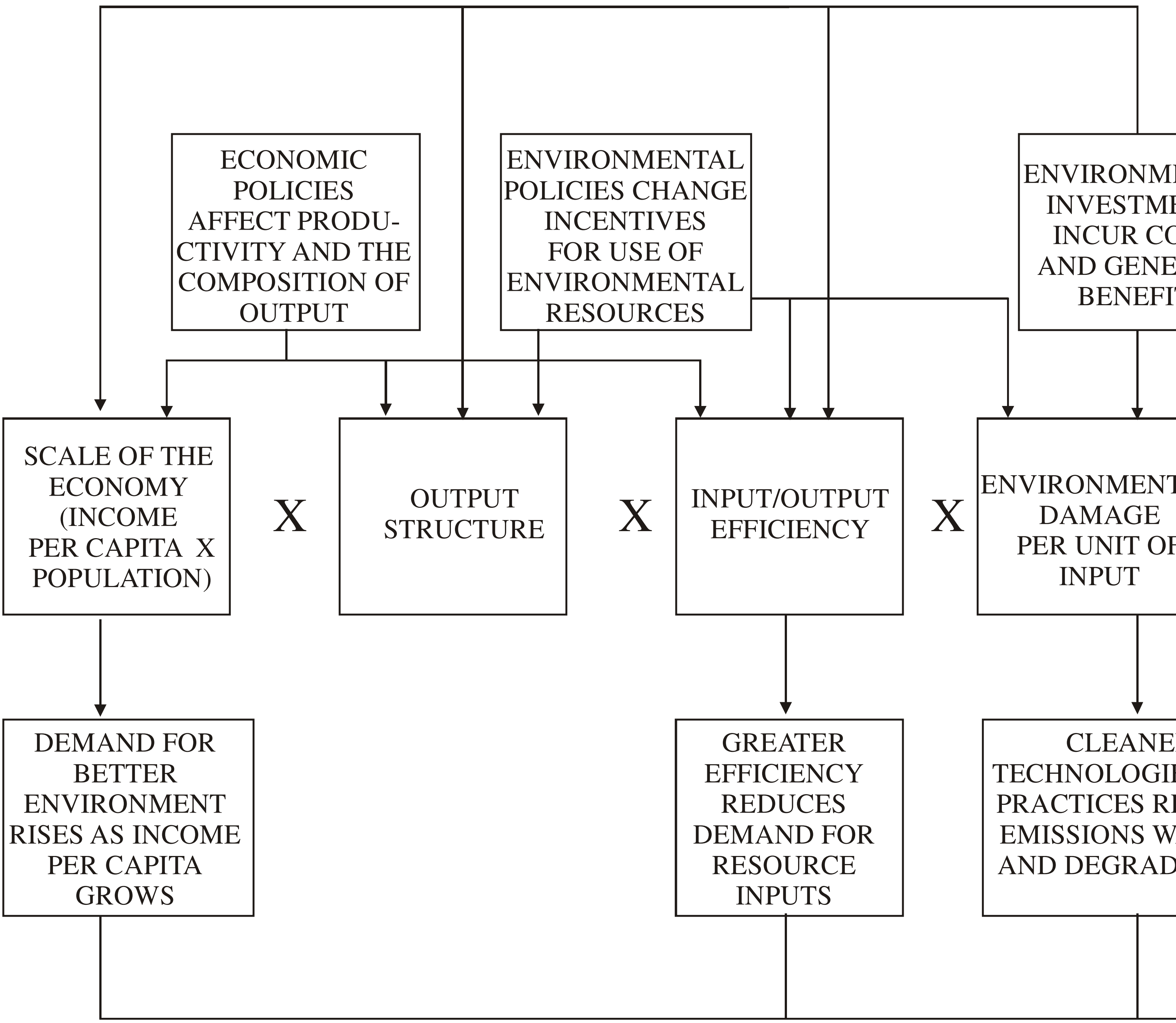
Critically, ecological economists have viewed the economic system as a part of the larger ecosystem, which is the source of natural resources used in an economy as well as a sink for the wastes produced in it. Figure 1.1 shows that it receives inputs (such as energy and material resources) from the broader natural systems and produce wastes and pollution as outputs. Here these inputs and outputs from and to the ecosystem constitute what is known as the through put of an economy (UNCTAD, 2012; Good land and Daly, 1996). Yet, it is important to note that whilst environmental economists focus on allocation issues, ecological economists emphasize the overall scale of the economy as a key policy issue. Thus, at the global level, as the economy grows bigger and bigger, it reduces the capacity of the ecosystem to perform its source and sink functions continuously. In other words, as the scale of economic activity increases, the earth's carrying capacity" will be exceeded.

FIGURE 1.1 THE EARTH SYSTEM: ECOSYSTEM AND ECONOMY SUBSYSTEM



However, in reality the relationship between the Inputs and outputs and the overall effects of economic activity on the environment are continually changing. Figure 1.2 illustrates that the scale of the economy is only one of the factors that will determine environmental quality. Therefore, the key question is whether the factors that tend to reduce environmental damage per unit of activity can more than compensate for any negative consequences of the overall growth in scale (World Bank, 1992).

FIGURE 1.2 ENVIRONMENT AND ECONOMIC ACTIVITY INT



Just as the past has been complex and nonlinear, any projections of the future are uncertain. Yet, the climate change may be the single factor that makes the future very different, impeding the continuing progress in human development that history would lead us to expect. While international agreements have been difficult to achieve and policy responses have been generally slow, the broad consensus is clear: climate change is happening (and it can derail human development)

In fact, it is expected to significantly affect sea levels and weather patterns and possibly human settlement and agricultural productivity. Clearly, climate change is one of the most complex challenges of the 21st century. Indeed, no country is immune and no country alone can take on the interconnected challenges posed by climate change (including controversial political decisions, daunting technological change) and far reaching global consequences, as the planet warms, rainfall patterns shift and extreme events such as droughts, floods, and forest fires become more frequent. Again, millions in densely populated coastal areas will lose their homes as the sea level rises. Poor people everywhere also face prospects of tragic crop failure, reduced agricultural productivity as well as increased hunger, malnutrition and disease.

Obviously, the impacts of a changing climate are already being felt with more droughts, more floods, more strong storms and more heat waves (taxing individuals, firms, and governments) by drawing resources away from development. Thus, continuing climate change (at current rates) will pose increasingly severe challenges to development. In fact, by century's end, it could lead to warming of 5^{o}c or more compared with preindustrial times and to a vastly different world from the present time. And yet with more extreme weather events, most ecosystems stressed and changing; many species are doomed to extinction while whole island nations threatened by inundation. Regrettably, even our best efforts are unlikely to stabilize temperatures at anything less than $2^{o}c$ above preindustrial temperatures warming that will require substantial adaptation (World Bank, 2010). In particular, sub-Saharan Africa suffered from natural fragility (two-thirds of its surface area is desert or dry land) and high exposure to droughts and floods; which are forecast to increase with further climate change. Notably, the region's economies are highly dependent on natural resources while biomass provides eighty percent of the domestic primary energy supply. Therefore, inadequate infrastructure could hamper adaptation efforts with limited water storage despite abundant resources. Similarly, water is the major vulnerability in North-Africa (word's driest region) where per capita water availability is predicted to halve by 2050 even without the effects of climate change. Here, the increased water scarcity combined with greater variability will threaten agriculture; and vulnerability is compounded by a heavy concentration of population as well as economic activity in flood-prone coastal zones.

In general, the growing concern about climate change and environmental issues presents several challenges for African countries in their quest for economic development.

Indeed, African countries have obligations under the United Nations Framework convention on climate change to contribute to the global mitigation and adaptation agenda. While there are currently no binding mitigation obligations parse on African countries; this may change in the future as greenhouse gas emissions rise faster (especially in African countries).

Thus, African countries will have to take these future potential developments in climate change negotiations into account when framing their development strategies. In other words, African countries have to become key players in the climate change policies; and these policies must be integrated into development strategy. Using the environmental impact and sustainability applied general equilibrium model, this paper investigates the African case scenarios. The rest of this paper is divided into six sections. Section two presents the science of global warming. The economics of climate change is the theme of section three. Section four discusses the African experience while analytical framework is presented in section five. Policy implications are highlighted in section six while section seven concludes the paper.

2.0 GLOBAL WARMING SCIENCES

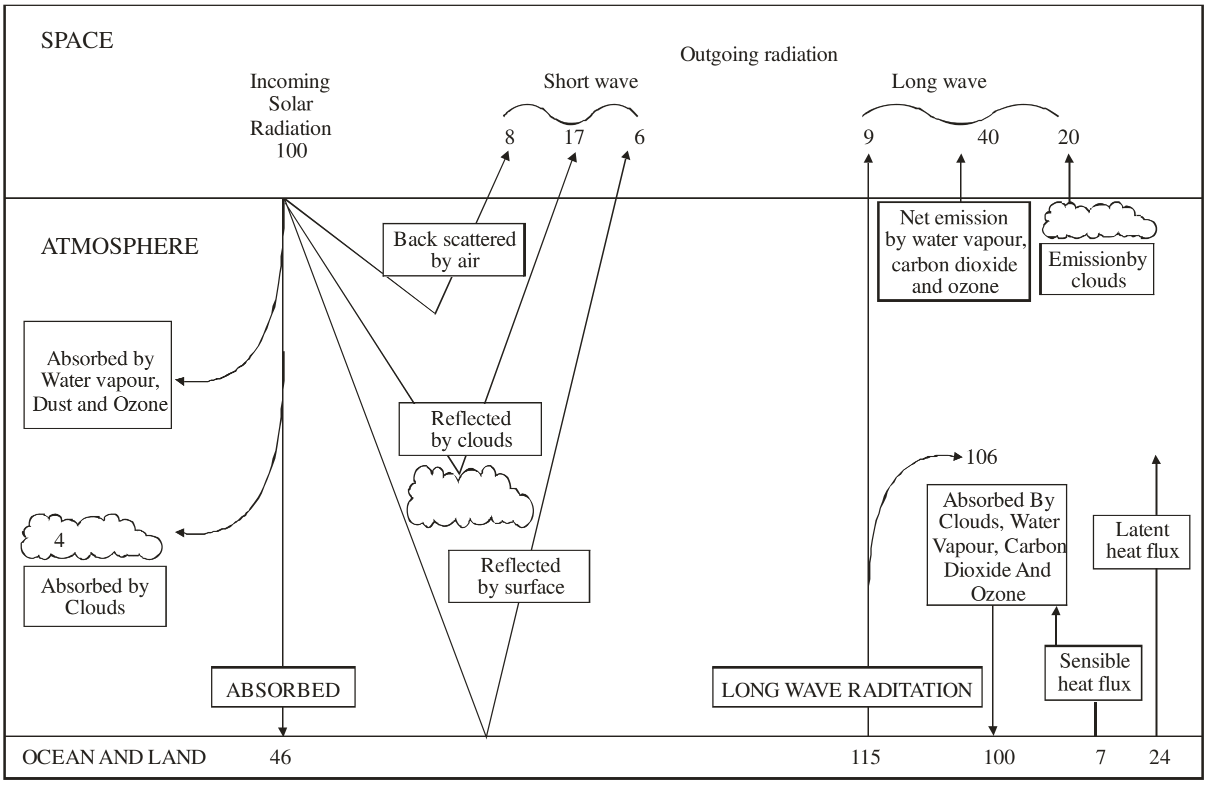
Generally, the world's population shares the use of global resources: the atmosphere (troposphere and stratosphere) and the oceans beyond the exclusive economic zones surrounding land masses. These resources are often known as the global resources because of their global ownership status. Thus, four global environment issues can be identifies: Global atmosphere in the context of the green house effect, global troposphere in the context of depletion of the ozone layer, Antarctica case and biodiversity. As a natural phenomenon, the green house effect is a process in which energy from the sun (solar radiation) passes through the atmosphere fairly freely, but the heat radiated back from the earth is partially blocked or absorbed by gases in the atmosphere. This blocking or absorption occurs at a lower frequency and can be trapped by atmospheric gases. Energy is therefore radiated from the sun at a high frequency and consequently not absorbed well by the atmospheric gases surrounding the earth. Figure 2.1 illustrates this process at work (Pearce and warford, 1993). And the reported numbers represent the index of incoming solar radiation (McCracken and Luther, 1986). Here, for every 100 units of incoming short wave solar radiation, some 31 units (8 + 17 + 6) is reflected back from the air, clouds and the earth's surface. This therefore leaves 69 units to account for. Of these, 23 units (19 +4) are absorbed by clouds, atmospheric vapor, ozone, and dusts. Then, the earth (including the oceans) absorbs 46 units (100 – 31 – 23). But incoming and outgoing radiation must balance. Thus, the 100 units (incoming radiation) minus 23 units (earth's surface) equals 69 units that must be reflected back as long wave radiation. However, these sums are complicated because long wave radiation going from the earth's surface does not pass through clouds vapor and atmosphere gases easily.

Clearly, this creates a bounce-back effect as can be seen at the right hand side of figure 2.1. Here, 24 units of long wave radiation are emitted as latent heat (heat carried into the atmosphere by water evaporating from the oceans as well as land surface waters). And yet another 7 units are emitted as sensible heat flux (direct heating of the atmosphere by the warm earth). Because there is a bounce- back effect of 100 units, outgoing long wave radiation must be 115 units since (115 – 100) + 7 + 24 = 4 6 which is the radiation absorbed by the earth's surface.

Consequently, this radiation absorbed by clouds, water vapor and carbon dioxide produces the green house effects (warming of the atmosphere indeed, this warming is natural and without it there could be no life on earth because the average temperature of the earth's surface would be below the freezing point of water. Thus, it is the additional warming that causes concern.

In fact, the atmospheric trace gases that trap the outgoing long wave radiation have been increasing, further reducing the ability of the radiation from the earth to travel through the gases and adding to the warming effect. In other words, without these increased gas concentrations, the earth would maintain its existing equilibrium temperature. With the gases, the temperature will increase and the increased warming has many potentially damaging effects. Clearly, the gases producing this layer around the earth are water vapor, carbon dioxide, methane, nitrous oxide, chlorofluoro carbons (CFCs) and ozone. Surely, these gases are a mix of natural events and anthropogenic factors (which are induced by humans). Indisputably, the climate is changing and there is a scientific consensus that the world is becoming a warmer place, principally attributable to human activities. In other words, the warming of the climate system is unequivocal. In fact, for nearly one million years before the industrial Revolution, the carbon dioxide (Co_2) concentration in the atmosphere ranged between 170 and 280 parts per million (PPM).

FIRURE 2.1 GREEN HOUSE EFFECT: GLOBAL WARMING



However, levels are now far above that range (387ppm) higher than the highest point in at least the past 800,000 years and the rate of increase may be accelerating. Here, some of the pollutants introduced by humans warm the earth and some cool it. Again, some are long-live and some are short-lived.

By trapping infrared radiation, carbon dioxide, nitrous oxide, and halocarbons warm earth and because the increased concentrations of these gases persist for centuries, their warming influence causes long-term climate change. In contrast, the warming influence of methane emissions persists for only a few decades and the climatic influence of aerosols which can either be heat-trapping such as black carbon (soot) or heat reducing such as reflective sulfates, persist for only days to weeks. Therefore, while a sharp decline in the Co_2 emissions from the combustion of coal incoming decades would reduce long term warming, the associated reduction in the cooling effect from sulfur emissions caused mainly by coal combustion would lead to an increase of about 0.5^oc. As at today, temperatures are already 0.8^oc above preindustrial levels. In facts, were it not for the cooling influence of reflective particles (such as sulfate aerosols) and the decades that in takes ocean temperatures to come into equilibrium with the increased trapping of infrared radiation, the global average temperature increase caused by human activities would likely already be about 1^oc warmer than it is today. Thus, the current elevated concentrations of green house gases alone are near to committing the world to a 2^oc warning, a level beyond which the world can expect to experience very disruptive dangerous consequences (IPCC, 2007a, IPCC, 2007b; Baker, 2007; Karl, et. al. 2009)

Regrettably, the physical impacts of future climate change on humans and the environment will include increasing stresses on and even collapses of ecosystems, biodiversity loss, changing timing of growing seasons, coastal erosion and aquifer salinization, permafrost thaw, ocean acidification; as well as shifting ranges for pests and diseases. Yet, the physical effects of future climate change will have varying impacts on people and the environment at different temperature increases and in different regions. However, if temperature reaches 2^{o}c above preindustrial levels, water availability will be reduced for another 0.4 – 1.7 billion people in mid latitudes and semiarid low latitude. Here, those affected by severe water shortages will be mainly Africa and Asia (world ban, 2010; Smith, 2009, and parry, 2007). At these higher temperatures, most coral reefs would die and some crops (particularly cereals) could not be successfully grown in the altered climates prevailing in low latitude regions. Again, about a quarter of plants and animal species are likely to be at increased risk of extinction. Communities will also suffer more heat stress and coastal areas will be more frequently flooded.

On the other hand, if temperatures rise to 5^{o}c above preindustrial levels, the consequences are enormous. Here, about three billion additional people would suffer water stress; corals would have mostly died off; some fifty percent of species worldwide would eventually go extinct; productivity of crops in both temperate and tropical zones would fall; about thirty percent of coastal wetlands would be committed to several meters of sea-level rise; and there would be substantial burden on health systems from increasing malnutrition and diarrhea and cardio respiratory diseases. Naturally, terrestrial ecosystems are expected to shift from being carbon sinks (storage) to being a source of carbon. And whether this carbon is released as carbon dioxide or methane, it would still accelerate global warming. Furthermore, many small Island states and coastal plains would be flooded by storm surges and sea-level rise as the major ice sheets deteriorate and the traditional ways of life of Arctic peoples would be lost as the sea ice retreats. In particular new analyses suggest that drought in West Africa and a drying of the Amazon rain forest may be more probable than previously thought (IPCC, 2007). Indeed, while scientific uncertainty has often been cited as a reason to wait for more evidence before acting to control climate change; the recently observed surprises suggest that uncertainty can cut the other way as well and that outcomes can be worse than expected. Consequently, the existence of uncertainties warrant a precautionary approach to climate change given the potential for irreversible impacts and the inertia in the climate system, in infrastructure and technology turnover as well as socioeconomic systems.

3.0 CLIMATE CHANGE ECONOMICS

Indeed, development that is socially economically and environmentally sustainable is a challenge, even without global warming. Thus, sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. That is, unmitigated climate change is incompatible with sustainable development. However, climate change is costly (whatever the policy chosen). Thus, spending less on mitigation will mean spending more on adaptation and accepting greater damages. Here, the cost of action must be compared with the cost of inaction. Unfortunately, this comparison is complex because of the considerable uncertainty about the technologies that will be available in the future, the ability of societies and ecosystems to adapt; the extent of damages that higher greenhouse gas concentrations will cause; and the temperatures that might constitute thresholds or tipping points beyond which catastrophic impacts occur.

Consequently, economists have typically tried to identify the optimal climate policy using cost- benefit analysis. However, these results are sensitive to the particular assumptions about the remaining uncertainties and to the normative choices made regarding distributional and measurements issues. Thus, economists continue to disagree on the economically or socially optimal carbon trajectory. Yet, the advocates of a more gradual reduction in emissions conclude that the optimal target (the one that will produce the lowest total cost) could be well above 3^{o}C (Nordhaus, 2008). Indeed, the large uncertainties about the potential losses associated with climate change and the possibility of catastrophic risks may well justify earlier and more aggressive action than a simple cost-benefit analysis would suggest. This incremental amount could be thought of as the insurance premium to keep climate change within a safer band.

In other words, spending less than half a percent of GDP as **Climate**

Insurance could well be a socially acceptable proposition. At present, the world spends about three percent of global GDP on insurance. But beyond the question of climate insurance is the question of what might be the resulting mitigation costs and the associated financing needs. In the medium term, estimates of mitigation costs in developing countries range between $140 billion and $175 billion annually by 2030. Table 3.1 shows that this represents the incremental costs relative to a business-as-usual scenario (World Bank, 2010).

TABLE 3.1 DEVELOPING COUNTRIES 2030 (2% TRAJECTORY):

MITIGATION COST AND FINANCING NEEDS

S/N	**MODEL**	**MITIGATION COSTS**	**FNANCING**
1	IEA (IEA, 2009)	–	565
2	MACKINSEY (Mckinsey, 2009)	175	563
3	MESSAGE (IIASA, 2009)	–	264
4	MINICAM (Edmond, 2008)	139	–
5	REMIND (Knopf, 2010)	–	384

However, financing needs will be higher as many of the savings from the lower operating costs associated with renewable energy and energy efficiency gains only materialize overtime. Unfortunately, financing has historically been a constraint in developing countries, resulting in under investment in infrastructure as well as a bias toward energy choices with lower upfront capital costs (even when such choices eventually result in higher overall costs). Yet, in the longer term, mitigation costs and income will increase overtime to cope with growing population and energy needs.

Table 3.2 shows that the present value of global mitigation costs to 2100 is expected to remain well below one percent of global GDP with estimates ranging between 0.3 percent and 0.7 percent (World Bank, 2010). However, developing countries mitigation costs represents a higher share of their own GDP (ranging between 0.5% and 1.2%). While few still debates the need for action to mitigate climate change, controversy remains over how much and how soon to mitigate. In fact, holding the changes in global average temperatures below dangerous levels would require immediate and global actions (actions that are costly) to reduce emissions from projected levels by 50 to 80 percent by 2050. Yet, the economic assessments of climate change policies must factor in the uncertainties about the size and timing of adverse impacts and about the feasibility, cost, and time profiles of mitigation efforts. Here, a key uncertainty missed by most economic models is the possibility of large catastrophic events related to climate change. In fact, the underlying probability distribution of such catastrophic risks is unknown and will likely remain so. Surely, more aggressive mitigation almost will reduce their likelihood (though very difficult to assess by how much). Thus, the possibility of a global catastrophic (even one with very low probability) should increase society's willingness to pay for faster and more aggressive mitigation to the extent that it helps to avoid calamity.

TABLE 3.2 GLOBAL 2100:

PRESENT VALUE MITIGATION COSTS (% OF GDP)

S/N	MODELS	WORLD	DEVELOPING COUNTRIES
1	DICE (Nordhaus, 2008)	0.7	–
2	FAIR (Hof, 2008)	0.6	–
3	MESSAGE (IIASA, 2008)	0.3	0.5
4	MINICAM (Edmond, 2008)	0.7	1.2
5	PAGE (Hope, 2009)	0.4	0.9
6	REMIND (Knopf, 2010)	0.4	–

Even without considering these catastrophic risks, substantial uncertainties remain around climate change's ecological and economic impacts. Again, the likely pace and ultimate magnitude of warming is unknown. That is, how changes in climate variability and extremes (not just changes in mean temperature) will affect natural systems and human well being is uncertain. These uncertainties only increase with the pace and amount of warming. And greater uncertainty requires adaptation strategies that can cope with many different climates and outcomes. Such strategies exist but they are less efficient than strategies that could be designed with perfect knowledge. Therefore, uncertainty is costly and more uncertainty increase costs. Without inertia and irreversibility, uncertainty would not matter so much; because decisions would be reversed and adjustments would be smooth and costless. But tremendous inertia (in the climate system, in the built environment, in the behavior of individuals, in the behavior of institutions) make it costly, if not impossible; to adjust in the direction of more stringent mitigation if new information is revealed or new technologies are slow to be discovered.

Consequently, inertia greatly increases the potential negative implications of climate policy decisions under uncertainty. And uncertainty combined with inertia and irreversibility argues for greater precautionary mitigation. In other words, the economics of decision making under uncertainty makes a case that uncertainty about the effects of climate change calls for more rather than less mitigation.

Despite the global economic chaos, the case for urgent action against climate change remains. And it becomes more pressing given the increase in poverty and vulnerability around the world. Thus, recent public debates have focused on the possibility of using fiscal packages to push for a greener economy, combating climate change while restoring growth.

In other words, how can both the economic slump and climate change be tackled with the fiscal stimulus? Investment in climate policy can therefore be an efficient way to deal with the economic crisis in the short term.

Yet, incorporating sound low-carbon and high resilience components in fiscal expansions to combat the financial crisis will not be enough to thwart the long-term.

Therefore, fundamental transformations are needed in social protection, in carbon finance, in research and development, in energy markets as well as in the management of land and water. Over the medium and long-terms, the challenge is to find new paths to reach the twin goals of sustaining development and limiting climate change. Clearly, reaching an equitable and fair global deal would be an important step toward avoiding worst-case scenarios. But it requires transforming the carbon—intensive lifestyle of developed countries and the carbon—intensive growth paths of develop countries. Consequently, modifications in social norms that reward a low-carbon lifestyle could prove a powerful element of success. But behavioral change needs to be matched with institutional reform, additional finance and technological innovation to avoid irreversible, catastrophic increases in temperature. And for dealing with climate change, additional climate — smart regulation is needed to induce innovative approaches to mitigation and adaptation. Indeed, such policies create an opening for the scale and scope of government interventions needed to correct climate change, which perhaps, is the biggest market failure in human history.

Therefore, an effective international climate regime must integrate development concerns, breaking free of the environment-versus-equity dichotomy. In other words, a multi track framework for climate action (with different goals or polices for developed and developing countries) may be one way to move forward. Certainly, this framework would need to consider the process for defining and measuring success in the global context. Clearly, promising initiatives are emerging but applying them on the necessary scale will require money, effort, ingenuity and information.

With the global economy set to quadruple by mid-century, energy-related carbon dioxide emission would (on current trends) more than double, putting the world onto a potentially catastrophic trajectory that could lead to temperatures more than 5°C warmer than in preindustrial times. In order to limit warming to 2°C, global emissions would have to peak no later than 2020 and the decline by 50 - 80 percent from today's levels by 2050, with further reductions continuing to 2100 and beyond. Delaying actions by 10years would make it impossible to reach this goal. Therefore, the inertia in energy capital stocks means that investments over the next decade will largely determine emissions through 2050 and beyond. Unfortunately, delays would lock the world into high carbon infrastructure and later requiring costly retrofitting and premature scrapping of existing capital stocks. <u>Indisputably and economically, the time for action is now.</u>

4.0 AFRICAN EXPERIENCE

Africa is the second largest of the earth's continents, covering about 30, 330,000 Sq Km (including its adjacent Islands). Geographically, the African continent is characterized by Plateau Land, with a few distinct mountain ranges and a narrow coastal plain. It is commonly divided along the lines of the Sahara Desert (world' largest desert) which cuts a huge swath through the northern half of the continent while the countries north of the Sahara make up the region of North Africa. Indeed, Africa has a proud (noble) history and it is widely believed that human life began in Africa. However, the last five hundred years in Africa have been dominated the by foreign colonization, political and ethnic struggles that have hampered Socio—industrial development. In fact the continent remains rural and it is the least developed of any continent after Antarctica. Although, agricultural is the main economic activity in Africa, devastating famine (disease outbreaks) are common. Yet, Africa is rich in natural resources; and part of its economic base is the export of this wealth.

Naturally, the African climate (more than that of any other continent) is generally uniform.

This observation results from the position of the continent in the tropical zone; the impact of cool ocean currents; and the absence of mountain chains (serving as climatic barriers). While several Africa climatic zones can be distinguished, Africa vegetation can be classified according to rainfall and climate zones. On one hand, the tropical rain forest (where the average rain is more than 1270mm) has a dense surface covering of shrubs, ferns, and mosses (above which tower evergreens) oil palms, and numerous species of tropical hardwood trees. On the other hand, a mountain forest zone (with average annual rainfall only slightly less than in the tropical rain forests) is found in the high mountains of Africa.

Fortunately, Africa is very rich in mineral resources, possessing most of the known mineral types of the world. In fact, many of these minerals are found in significant quantities (although with uneven geographic distribution). Apart from the abundant fossil fuels, major deposits of coal, petroleum, and natural gas exists. Other important minerals include gold, diamonds, copper, bauxite, manganese, nickel, platinum, cobalt, radium, germanium, lithium, titanium, phosphates, ore, chromium, tin, zinc, lead, thorium, zirconium, vanadium, antimony, beryllium, clays, mica, sulfur, salt, natron, graphite, limestone, and gypsum.

Traditionally, the vast majority of Africans have been farmers and herders who raised crops and livestock for subsistence. Here, manufacturing and crafts are carried on as part—time activities while industrial specialization, communication networks and elaborate governmental structures maintained the flow of commerce. Although, a number of Africa States have considerable natural resources, few have the finances to develop their economics. However, foreign private enterprise has often regarded investment in such underdeveloped areas as too risky. Yet the major alternative sources of financing are national and multinational lending institutions. Indeed, expectations in African nations for a better living standard have increased; and the prices of consumer and other manufactured goods have kept pace but the prices of most African primary products have lagged behind.

Regrettably, a worldwide recession in the early1980s multiplied difficulties that were initiated by the oil—price increases of the 1970s. In fact, serious foreign—exchange problems and ballooning foreign debt aggravated public discontent. Consequently, famine and drought plagued the northern and central regions and many refugees left their homes in search of food (thereby increasing the problems of the host countries).

Again, in the late 1980's and 1990's, protracted Local conflicts in some parts of the continent destabilized governments, halted economic progress and cost the lives of thousands of Africans. Yet, Africa has experienced solid improvement in economic performance in the recent years. The continent as a whole grew (statistically) at an average rate of 5.7% in 2006 and 5.8% in 2007 in real terms, up from an average of 3.4% in the 1998—2002 years (United Nations, 2009). Notably, the impressive growth since the beginning of the 21st century (its economics ability to weather the storm of the recent crisis and the resumption of growth by nearly all countries in 2010) suggest that Africa is one of the world's emerging economic powers. However, Africa's momentum slowed in 2011 (weighed down by contraction of economic activity in North Africa) due to political unrest as well as global economic and financial crisis. Yet, growth prospects remain optimistic, with output for the continent as a whole expected to recover strongly in 2012 and beyond.

Despite the observed accelerated growth in Africa over the past decade, progress in social development remains slow.

Regrettably, the experienced rapid economic growth has not translated into commensurate reductions in poverty and hunger in Africa (United Nations 2012).

Clearly, ensuring environmental sustainability has a great impact on reaching most of the other goals. In other words, preserving and properly managing the environment is an essential foundation for sustainable development and poverty reduction. In particular, emissions of CO_2 per capita are an important indicator in assessing progress towards environmental sustainability and climate change. Unfortunately, Africa is very vulnerable to climate change given its low capacity to respond and adapt; but the continent emits quite little greenhouse gas relative both to its population and to other regions. Tables 4.1, 4.2, 4.3, and, 4.4 shows the comparative picture of the emission intensities (impacts) in Africa as well as the rest of the world.

TABLE 4.1 COMPARATIVE ENERGY RELATED EMISSIONS: AFRICAN DATA

1	2	3		4	5		6	7	8	
		CO_2 EMISSIONS ANNUAL TOTAL MILLIONS METRIC TONS		CO_2 EMISSIONS PER CAPITA METRIC TONS	CO_2 EMISSIONS PER CAPITA METRIC TONS		CO_2 EMISSI-ONS ANNUAL WORLD TOTAL PERCEN-TAGE SHARE	CUMULA-TIVE EMISSIONS CO_2 EMISSIONS BILLION METRIC TONS	TOTAL PRIMARY ENERGY SUPPLY MILLION TONS (OIL)	
S/N	**COUNTRIES**	**1990**	**2005**	**2007**	**1990**	**2005**	**2005**	**1850–2005**	**1990**	**2006**
1	ALGERIA	68	91	4.1	2.7	2.8	0.34	2.8	23.9	36.7
2	ANGOLA	—	—	1.4	—	—	—	—	6.3	10.3
3	BENIN	—	—	0.5	—	—	—	—	1.7	2.8
4	BOTSWANA	—	—	—	—	—	—	—	1.3	2.0
5	BURKIN-AFASO	—	—	0.1	—	—	—	—	—	—
6	BURUNDI	—	—	0.0	—	—	—	—	—	—
7	CAMEROON	—	—	0.3	—	—	—	—	5.0	7.1
8	CAPE VERDE	—	—	—	—	—	—	—	—	—

9	CENTRAL AFRICA REP.	—	—	0.1	—	—	—	—	—	—
10	CHAD	—	—	0.0	—	—	—	—	—	—
11	COMOS	—	—	—	—	—	—	—	—	—
12	CONGO REP.	—	—	0.4	—	—	—	—	0.9	1.2
13	CONGO DEM. REP.	—	—	0.0	—	—	—	—	11.9	17.5
14	COTE D'IVOIRE	—	—	0.3	—	—	—	—	4.4	7.3
15	DJIBOUTI	—	—	—	—	—	—	—	—	—
16	EGYPT	81	149	2.3	1.5	2.0	0.56	3.2	32.0	62.5
17	EQUATORIAL GUINEA	—	—	—	—	—	—	—	—	—
18	ERITREA	—	—	0.1	—	—	—	—	—	0.7
19	ETHIOPIA	—	—	0.1	—	—	—	—	15.0	22.3
20	GABON	—	—	—	—	—	—	—	1.2	1.8
21	GAMBIA	—	—	—	—	—	—	—	—	—
22	GHANA	—	—	0.4	—	—	—	—	5.3	9.5
23	GUINEA	—	—	0.1	—	—	—	—	—	—
24	GUINEA BISSAU	—	—	—	—	—	—	—	—	—
25	KENYA	—	—	0.3	—	—	—	—	11.2	17.9
26	LESOTHO	—	—	—	—	—	—	—	—	—
27	LIBERIA	—	—	0.2	—	—	—	—	—	—
28	LIBYAN ARAB JAM	37	47	9.3	8.4	7.9	0.18	1.3	11.5	17.8
29	MADAGASCAR	—	—	0.1	—	—	—	—	—	—

30	MALAWI	—	—	0.1	—	—	—	—	—	—
31	MALI	—	—	0.0	—	—	—	—	—	—
32	MAURITANIA	—	—	0.6	—	—	—	—	—	—
33	MAURITIUS	—	—	—	—	—	—	—	—	—
34	MAYOTTE	—	—	—	—	—	—	—	—	—
35	MOROCCO	20	41	1.5	0.8	1.4	0.16	0.9	7.2	14.0
36	MOZAMBIQUE	—	—	0.1	—	—	—	—	6.0	8.8
37	NAMIBIA	—	—	—	—	—	—	—	—	1.5
38	NIGER	—	—	0.1	—	—	—	—	—	—
39	NIGERIA	68	97	0.6	0.7	0.7	0.36	2.3	70.9	105.1
40	REUNION	—	—	—	—	—	—	—	—	—
41	RWANDA	—	—	0.1	—	—	—	—	—	—
42	SAINT HELEN	—	—	—	—	—	—	—	—	—
43	SAOTME PRINCIPE	—	—	—	—	—	—	—	—	—
44	SENEGAL	—	—	0.5	—	—	—	—	1.8	3.0
45	SEYCHELLES	—	—	—	—	—	—	—	—	—
46	SIERRA LEONE	—	—	0.2	—	—	—	—	—	—
47	SOMALIA	—	—	—	—	—	—	—	—	—
48	SOUTH AFRICA	255	331	9.0	7.2	7.1	1.25	14.1	91.2	129.8
49	SUDAN	—	—	0.3	—	—	—		10.7	17.7
50	SOUTH SUDAN	—	—	—	—	—	—	—	—	—

51	SWAZILAND	—	—	—	—		—	—	—	—
52	TANZANIA	—	—	0.1	—	—	—	—	9.8	20.8
53	TOGO	—	—	0.2	—		—	—	1.3	2.4
54	TUNISIA	—	—	2.3	—		—	—	5.1	8.7
55	UGANDA	—	—	0.1	—		—	—	—	—
56	WESTERN SAHARA	—	—	—	—		—	—	—	—
57	ZAMBIA	—	—	0.2	—	—	—	—	5.5	7.3
58	ZIMBABWE	—	—	0.8	—	—	—	—	9.4	9.6
59	**LOW INCOME**	**549**	**70.7**	**0.3**	**0.7**	**0.6**	**2.66**	**24.0**	**400.2**	**575.5**
60	**HIGH INCOME**	**10999**	**13207**	**12.5**	**11.8**	**12.7**	**49.75**	**750.1**	**4479.4**	**5659.1**
61	**WORLD**	**20693**	**26544**	**4.6**	**4.0**	**4.2**	**100.00**	**1169.1**	**8637.3**	**11525.2**

TABLE 4.2: CARBON INTENSITY AND NON-CO_2 EMISSIONS: COMPARATIVE DATA

1	**2**	**3**		**4**	
		NON-CO_2 EMISSIONS ANNUAL TOTAL METRICTONS EQUIVALENT (MILLIONS)		CARBON INTENSITY ENERGY METRICTONS: CO_2 PERTON OIL EQUIVALENT	
S/N	**COUNTRIES**	**1990**	**2005**	**1990**	**2005**
1	NIGERIA	9.6	15.5	2.86	2.63
2	EGYPT	8.5	16.0	2.54	2.43
3	LIBYA	–	–	**3.16**	**2.65**
4	MOROCCO	–	–	2.72	3.08
5	NIGERIA	25.8	66.2	0.95	0.92
6	SOUTH AFRICA	10.6	12.5	2.79	2.59
7	LOW INCOME	115.5	256.4	1.38	1.26
8	**MIDDLE INCOME**	**1168.3**	**1279.4**	**2.41**	**2.49**
9	**HIGH INCOME**	**577.2**	**557.1**	**2.44**	**2.32**
10	**WORLD**	**1861.0**	**1978.9**	**2.39**	**2.35**

TABLE 4.3: LAND-BASED EMISSIONS: CO_2 (DEFORESTATION BASED) AND CH_4/N_2O (AGRIC BASED)

1	2	3		4		5	6		7	
		TOTAL EMISSIONS ANNUAL AVERAGE METRICTONS		PER CAPITA EMISSIONS ANNUAL AVERAGE METRICTONS PER RANK		AVERAGE SHARE TOTAL EMISSIONS PERCENTAGE %	ANNUAL TOTAL CO_2 EQUIVALENT METRICTONS MILLIONS		SHARE OF TOTAL %	PE CO EQ ME
		MILLIONS	RANK	PER	RANK					
S/N	**COUNTRIES**	1990-2005		**1990-2050**		**2000-2050**	**2000-2050**		**2000-2050**	**1**
1	CAMEROON	70	12	3.9	18	1.2	—	—	—	
2	CONGO DEM. REP OF	176	04	3.0	24	3.1	36	75	1.2	[illegible]
3	ETHOPIA	—	—	—	—	—	39	55	0.9	[illegible]
4	NIGERIA	158	05	1.1	40	2.8	75	115	1.9	[illegible]
5	TANZANIA	51	19	1.3	35	0.9	—	—	—	
6	ZAMBIA	106	09	9.3	06	1.9	—	—	—	
7	ZIMBABWE	40	22	3.1	22	0.7	—	—	—	

TABLE 4.4 2050: PROJECTED CLIMATE CHANGE IMPACT IN AFRICA

1	**2**	**3**	**4**	**5**	**6**	7	**8**
		PHYSICAL IMPACTS CHANGE IN TERMPERATURE ^{O}C	PHYSICAL IMPACTS CHANGE IN HEAT WAVE DURATION NO OF DAYS	PHYSICAL IMPACTS PRECIPTATION % CHANGE	PHYSICAL IMPACTS PRECIPITATION INTENSITY % CHANGE	AGRIC IMPACTS AGRIC OUTPUT % CHANGE	AGRIC IMPACTS AGRIC YIELD % CHANGE
S/N	**COUNTRIES**	**2000-2050**	**2000-2050**	**2000-2050**	**2000-2050**	**2000-2050**	**2000-2050**
1	ALGERIA	1.9	22.2	-4.9	7.2	36.0	-6.7
2	BURKINA FASO	1.4	5.7	0.3	0.0	-24.3	-4.4
3	CAMEROON	1.3	2.0	0.9	3.0	-20.0	-6.6
4	CONDO DEM REP	1.4	2.0	0.8	3.1	-14.7	-7.0
5	COTE DIVORE	1.3	1.9	-0.3	-0.2	14.3	-12.9
6	EGYPT ARABA REP OF	1.6	14.7	7.0	-1.6	11.3	-27.9
7	ETHPOPIA	1.4	3.1	2.4	5.0	-31.3	0.5
8	GHANA	1.3	1.3	1.0	0.8	-14.0	-10.1
9	KENYA	1.2	2.5	7.5	8.0	-5.5	6.1
10	MALAWI	1.4	7.5	-0.1	2.4	-31.3	-3.0
11	MALI	1.7	16.1	8.4	3.8	-35.6	-9.6
12	MOROCCO	2.1	21.1	-16.8	5.3	-39.0	25.2

13	MOZABIQUE	1.3	5.9	-2.7	1.4	-21.7	-10.4
14	NIGER	1.6	16.1	5.6	2.5	-34.1	-1.7
15	NIGERIA	1.3	4.1	0.6	1.1	-18.5	-9.9
16	SENEGAL	1.6	6.0	-1.9	3.1	-51.9	-19.3
17	SOUTH AFRICA	1.5	9.5	-4.5	1.4	-33.4	-5.2
18	SUDAN	1.6	9.5	-0.6	-0.1	-56.1	-7.0
19	TANZANIA	1.3	2.3	4.4	6.0	-24.2	-2.0
20	TO GO	1.3	1.5	-2.0	-0.5	—	-14.0
21	UGANDA	1.3	1.7	3.4	6.6	-16. 8	-5.0
22	ZAMBIA	1.5	8.1	0.6	3.9	-39. 6	1.3
23	ZIMBABWE	1.5	12.3	-3.7	4.8	-37.9	-10.6

TABLE 4.5: OZONE DEPLETING SUBTANCES: AFRICAN CONSUMPTION CHANGE

1	2	3	4	5	6	7
S/N	COUNTRIES	INCOME STATUS	AN INCREASE 200-2009 (%)	A REDUCTION IN MORE THAN 50% 2000-2009 (%)	A REDUCTION IN LESS THAN 50% 2000-2009 (%)	RGIONS
1	ALGERIA	UMC	-	-91.5	-	NORTH AFRICA (NA)
2	ANGOLA	LMC	-	-67.0	-	CENTRAL AFRICA (CA)
3	VENIN	LIC	-	-50.9	-	WEST AFRICA (WA)
4	BOTSWANA	UMC	66.7	-	-	SOUTHERN AFRICA (SA)
5	BURKINAFASO	LIC	-	-	-23.5	WESTERN AFRICA (WA)
6	BURUNDI	LIC	-	-86.5	-	EAST AFRICA (EA)
7	CAMEROON	LMC	-	-74.9	-	CENTRAL AFRICA (CA)
8	CAPE VERDE	LMC	-	-	-5.26	WEST AFRICA (WA)
9	CENTRAL AFRICA REP.	LIC	-	-	-26.5	CENTRAL AFRICA (CA)
10	CHAD	LIC	-	-	-	WEST

						AFRICA (WA)
11	COMOROS	LIC	-	-	-	EAST AFRICA (EA)
12	CONGO REP.	LMC	-	-74.9	-	CENTRAL AFRICA (CA)
13	CONGO DEM. REP.	LIC	-	-	-	CENTRAL AFRICA (CA)
14	COTE D'IVOIRE	LMC	-	-67.3	-	WEST AFRICA (WA)
15	DJIBOUTI	LMC	-	-94.2	-	EAST AFRICA (EA)
16	EGYPT	LMC	-	-71.3	-	NORTH AFRICA (NA)
17	EQUATIORIAL GUINEA	LIC	-	-71.9	-	CENTRAL AFRICA (CA)
18	ERITREA	LIC	-	-95.7	-	EAST AFRICA (EA)
19	ETIOPIA	LIC	-	-96.4	-	EAST AFRICA (EA)
20	GABON	UMC	83.3	-	-	CENTRAL AFRICA (CA)
21	GAMBIA	LIC	-	-74.2	-	WEST AFRICA (WA)
22	GHANA	LIC	42.3	-	-	WEST AFRICA (WA)
23	GUINEA	LIC	-	-	-	WEST AFRICA

						(WA)
24	GUINEA BISSAU	LIC	-	-85.0	-42.0	WEST AFRICA (WA)
25	KENYA	LIC	-	-	-	EAST AFRICA (EA)
26	LESOTHO	LMC	329.2	-84.7	-	SOUTH AFRICA (SA)
27	LIBERIA	LIC	-	-88.3	-	WEST AFRICA (WA)
28	LIBYAN ARAB J.	LMC	-	-91.9	-	NORTH AFRICA (NA)
29	MADAGASCAR	LIC	132.4	-	-	CENTRAL AFRICA (CA)
30	MALAWI	LIC	-	-91.5	-	EAST AFRICA (EA)
31	MALI	LIC	-	-52.3	-	WEST AFRICA (WA)
32	MAURITANIA	LIC	30.8	-	-	WEST AFRICA (WA)
33	MAURITIUS	LIC	-	-61.2	-	EAST AFRICA (EA)
34	MAYOTTE	UMC	-	-	-	EAST AFRICA (EA)
35	MOROCCO	LMC	-	-87.9	-	NORTH AFRICA (NA)
36	MOZAMBIQUE	LIC	-	70.7	-	EAST AFRICA (EA)

37	NAMIBIA	UMC	-	-74.9	-	SOUTH AFRICA (SA)
38	NIGER	LIC	-	-	-79.09	WEST AFRICA (WA
39	NIGERIA	LMC	-	-92.0	-	WEST AFRICA (WA
40	REUNION	-	-	-	-	EAST AFRICA (EA)
41	RWANDA	LIC	-	-87.5	-	EAST AFRICA (EA)
42	SAINT HELEN	-	-	-	-	WEST AFRICA (WA)
43	SATOME PRINCIPE	MC	2.5	-	-	CENTRAL AFRICA (CA)
44	SENEGAL	LIC	-	69.0	-	WEST AFRICA (WA)
45	SYCHELLES	UMC	55.6	-	-	EAST AFRICA (EA)
46	SIERRA LEONE	LIC	-	91.5	-	WEST AFRICA (WA)
47	SOMALIA	LIC	-	-	-42.4	EAST AFRICA (EA)
48	SOUTH AFRICA	UMC	-	57.1	-	SOUTH AFRICA (SA)
49	SUDAN	LMC	-	75.3	-	NORTH AFRICA (NA)
50	SOUTH	-	-	-	-	NORTH

	SUDAN					AFRICA (NA)
51	SWAZILAND	LMC	475.0	-	-	SOUTH AFRICA (SA)
52	TANZANIA	LIC	-	-94.6	-	EAST AFRICA (EA)
53	TOGO	LIC	-	-	-47.6	WEST AFRICA (WA)
54	TUNISIA	LMC	-	-89.2	-	NORTH AFRICA (NA)
55	UGANDA	LIC	-	-	-	EAST AFRICA (EA)
56	WESTERN SAHARA	-	-	-100.0	-	NORTH AFRICA (NA)
57	ZAMBIA	LIC	-	-92.7	-	EAST AFRICA (EA)
58	ZIMBABWE	LIC	-	-93.1	-	EAST AFRICA (EA)

From the above tables, the carbon dioxide emissions annual total (million metric tons) is the total CO_2 emission from the energy sector, including electricity (heat) production, manufacturing, construction, gas flaring, transportation, and other industries (WRI, 2008; world bank, 2010).

However, emissions from industrial processes (primarily cement production) that amounts to approximately four percent of global energy—related CO_2 emissions are not included. The carbon dioxide emissions change (%) is the percentage change in energy—related CO_2 emissions between 1990 (base year) and 2005. The carbon dioxide emissions per capita (metric tons) is the annual emissions divided by midyear population and expressed in tons of CO_2 per person. Again the carbon dioxide emission share of world total (%) is the share of worlds total energy—related CO_2 emissions attributed to a given country, income group or region. Similarly, the carbon dioxide emissions cumulative since 1850 (billion metric tons) is the cumulative CO_2 emissions between 1850 and 2005. Here, the sources of emissions include combustion of solid, liquid and gaseous fuels as well as cement production and gas flaring (DOE, 2009).

In contrast, the annual total none—CO_2 emissions (million tons of CO_2 equivalents) are the total methane (CH_4) and nitrous oxide (N_2O) emissions in CO_2 equivalent from the energy sector. This indicator includes emissions from biomass combustion; oil and natural gas systems, coal mining and other stationary and mobile sources. Here, the CO2 equivalent expresses the quantity of a mixture of greenhouse gases in terms of the quantity of CO_2 that would produce the same amount of warming as would the mixture of gases. Yet, the carbon intensity of energy (metric tons of CO_2 per ton of oil equivalent) is the ratio of carbon dioxide emissions to energy production; and this ratio measures the greenness of energy production that is expressed in tons of CO_2 per ton of oil equivalents. On the other hand, the carbon intensity of income (metric tons of CO_2 per thousand PPP &of GDP) is the ratio of carbon dioxide emissions to gross domestic product; and this measure is an indicator of the greenness of the economy that is expressed in tons of CO_2 per 1000 PPP dollars of GDP (WRI, 2008; IEA, 2008a; IEA, 2008b, World bank, 2010).

In general, carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement and include carbon dioxide produced during consumption of solid, liquid, and gas fuels (flaring) divided by midyear population. As a land—based emission, CO_2 emission estimates due to deforestation are derived from estimates of tropical forest cover change by the year 2005 (Houghton, 2009; FAO, 2005).

However, estimates of CO_2 emissions from deforestation vary across time as well as a result of uncertain data. In fact, there is a variation among estimates of deforestation rates and estimates of carbon stocks in the forests converted to other uses. Here, to accounts for year—to—year trends and measurement uncertainty, the numbers reported are based on average annual emissions between 1990 and 2005. Yet the rank is based on the average annual emission for the period 1990 to 2005. Again, the per capita CO_2 emissions (metric tons) is the annual average emissions from deforestation divided by midyear population expressed in tons of CO_2 per person while the ranking of per capita emissions is based on the sampled countries. Similarly, the average share of world total (%) is the share of CO_2 emissions based on average annual emissions between 1990 and 2005 as a percentage of global emissions due to deforestation. As a non-CO_2 emissions from agriculture, total methane and nitrous oxide are measured in CO_2 equivalent; which expressed the quantity of a mixture of greenhouse gases in terms of the quantity of CO_2 that would produce the same amount of warming as would the mixture of gases. Indeed, emissions in the agricultural sector result primarily from rice cultivation, agricultural soils, manure management and enteric fermentation (belching) from live stock.

The share of the world total (%) is the share of world total emissions from the agriculture sector attributed to a given country or a region. Here, per capita emissions (million metric tons of CO_2 equivalent) is the annual emissions from the agriculture sector divided by midyear population in 1990 and 2005 expressed in tons of CO_2 equivalent per person. On the other hand, per capita emissions rank is based on the sampled countries. As indicated, total primary energy supply (TPES) as a measure of commercial energy consumption, is the sum of indigenous production, imports, and stock changes, minus exports and international marine bunkers. Clearly, a lower share of fossil fuels and higher share of renewable sources in TPES is an indicator of countries path toward a green economy.

The projected physical impacts indicator is the projected physical impacts of climate change by the middle of the 21st century. Here, the selected indicators include change in average annual temperature; change in precipitation and precipitation intensity as well as change in heat wave duration. In fact, these projections estimates represent an ensemble mean of nineteen general circulation models used for the intergovernmental panel on climate change fourth Assessment. Clearly, the changes are estimated for the future time period 2030—2049 relative to 1980—1999; and these indicators are spatially weighted averages for each country. On the other hand, the projected agricultural impacts are the percentage change in agricultural output (defined as revenue per nature) between 2000 and 2080 based on preferred estimates (cline, 2007). Here, the impacts in agricultural yield are defined as an average percentage change in crop yields, between 2000 and 2050 for wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sun flower, and rapeseed.

Concerning consumption of ozone—depleting substances, the majority of Africa countries are on the right track. As shown in table 4.5, this indicator marks the commitment to reducing carbon dioxide emissions and progress in phasing out the consumption of ozone—depleting substances (such as chloro fluoro carbons) by countries that have ratified the Montreal protocol of 1987 (United Nations, 2012). Indeed, the majority of African countries has committed to full compliance with the protocol and has reduced consumption of ozone—depleting substances for instance, in Zimbabwe, one of the contributing factors to the reduction in ozone—depleting substances was a total phase—out of methyl bromide in the tobacco, grain fumigation and horticulture industries. However, some countries have increased their consumption of ozone depleting substance (owning to weak regulatory measures) and need to take steps to reverse this trend. Fortunately, some African countries have developed a new policy tool (informal prior informed consent mechanism) that will help strengthen the enforcement of countries system for the licensing imports of ozone depleting substance (UNE P, 2011).

5.0 ANALYTICAL FRAMEWORK

Conceptually, the alternative views of the relationship between the environment and the economy has led to the evolution of the new policy concepts of the 'green economy' and 'green growth'. Yet there are no consensus views on these terms and meaning. However, UNEP (2011) defines a green economy as one which is low- carbon, resource- efficient and socially inclusive. In other words, a green economy is one that results in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities. In fact, green growth can be regarded as a subset of the idea of sustainable development (narrower in scope) entailing an operational policy agenda that can help achieve concrete (measurable) progress at the interface between economy and environment (DECD, 2011). In general, sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. But such development rests on three pillars: economic growth, social equity and environmental sustainability. In contrast, the concepts of green economy and green growth place greater emphasis on the potential synergies between economic growth and environmental sustainability. Against this background, more attention need to be given to the nature of the relationship between the economy and the environment (the way in which such relationship evolves during the process of economic development) and the implications of that evolving relationship for the policy challenge of promoting development and poverty reduction in countries at different levels and stages of development in Africa.

Analytically, we attempt to build a developmental approach to the relationship between the economy and the environment. As a starting point, we assume as a starting point that the economy is best viewed as a subsystem of the earth-system and then considers how (within this vision) resource use and environmental impacts change during the economic development process. Essentially, this provides the basis for a strategic approach to sustainable development; which builds on the imperative of structural transformation for accelerated economic growth and poverty reduction (UNCTAD, 2012). Thus, the major views of the dynamics of development, resource use and environmental impacts are summarized as follows: IPAT equation, Environmental Kuznets curve hypothesis and socio-ecological metabolism (structural change). In fact, these views constitute a valuable framework to comprehend where countries at different levels of development stand in relation to their current and future use of natural resources and levels of environmental impact. Empirically, the World Bank's environmental impact and sustainability applied general equilibrium (ENVISAGE) model is designed to analyze a variety of issues related to the economics of climate change (Mensbrugghe, 2008). These issues include baseline emissions of CO_2 and other green house gases; impacts of climate change on the economy; adaptation by economic agents to climate change; greenhouse gas mitigation policies (taxes, caps and trade); role of land use in future emissions and mitigation; and distributional consequences of climate change impacts, adaptation and mitigation (at national and household level). Constructively, ENVISAGE is intended to be flexible in terms of its dimensions and the core database (that includes energy volumes and CO_2 emissions) is the global trade analysis project (GTAP) data base. Here, it divides the word into 113 countries and regions. The data base also divides global production into 57 sectors with extensive details for agriculture and food as well as energy (coal mining, crude oil production, natural gas production, refined oil, electricity, and distributed natural gas). Generally, the ENVISAGE model includes the following:

1. Capital vintage production technology that permits analysis of the flexibility of economies,
2. Detailed specification of energy demand in each economy,
3. Ability to introduce future alternative energy (or backstop) technologies,
4. CO_2 emission that are fuel and demand specific,
5. Flexible system for incorporating any combination of carbon taxes, emission caps and trade able permits;
6. Simplified climate module that links greenhouse gas to greenhouse gas emissions to atmospheric concentrations combined with a carbon cycle that leads to radioactive forcing and temperature changes,
7. Splitting of electricity into nuclear, hydro, renewable, etc.
8. Resource depletion module for coal, oil and gas,
9. Other greenhouse gases (such as agric-linked)
10. More detailed land-use module, and
11. Additional alternative technologies

Specifically, the model blocks include production, income, demand, expenditures, fuels, trade, product market equilibrium, factor market equilibrium, macro closure, climate module and model dynamics.

For the climate module's sequence, total emissions are derived and these lead to atmospheric concentrations (emissions directly add to the atmosphere) but concentrations in the atmosphere also interact with the ocean, creating a dynamic process that would continue even in the absence of emissions. Clearly, the atmospheric concentration has an impact on radiative forcing, that is, how much of the sun's energy is reflected back to space. Thus, there is a set of equations that links radiative forcing to temperature and these relations also contain an interaction with the ocean.

Here, these relevant equations are
Specified as follows:

$$EMI_{r,\ em,\ i,\ aa} = P_{r,\ em,\ i,\ aa}\ XA_{r,\ i,\ aa} \quad (5.1)$$

$$EMIT_{otr,\ em} = EMI_{r,\ em,\ i,\ aa} + EMIOth_{r,\ em} \quad (5.2)$$

$$EMIGbl_{Atmos,\ co_2} = EMITot_{r,\ co_2} + EMIOthGbl_{co_2} \quad (5.3)$$

Equation (5.1) determines the level of emissions (EMI) of type *em* for each unit of consumption of commodity *i* by agent *aa* (which covers all production activities and final demand accounts). Obviously, it is a fixed coefficient with respect to the demand level. Equation (5.2) defines the aggregate emission by region (or country). It is the double sum over all agents and inputs, with the possibility of an additional exogenous level of emissions (EMIOth). As shown by the equation (5.3) EMIGbl is the final summation across all countries and regions (with an additional exogenous component accounted for in the regional models). Notably, EMIGbl is indexed by *z* (which includes the different sinks for emissions. These modeled sinks include the atmosphere (atmos), the shallow oceans (upocn) and the deep oceans (dpocn). Clearly, all emissions CO_2 emissions are emitted to the atmosphere. Specifically, these three sinks are indexed by *z*; and for each period, there is a flow of carbon across the three sinks using a 3 x 3 transition matrix (K). Here, each column of the transition matrix represents the share of the stock in the sink that flows to a different sink. Thus, the diagonal element represents the share of the stock that stays in its own sink. The relevant equations are specified as follows:

$$Concz = K.Conc_z,-1+(12/44).EMIGbl_{z},_{CO_2},-1 \quad (5.4)$$

$$Forc_{atmos} = fCO2_x, \frac{\log10\ (Conc_{atmos}/ConcPI)}{\log_{10}{}^{(2)}} + ForcOth \quad (5.5)$$

$$Temp_{zt} = T.Temp_{zt,\ -1} + \Theta.Force_{zt} \quad (5.6)$$

Equation (5.4) determines the concentration level in each sink and the concentration level is equal to its lagged value (multiplied by the transition matrix). In the absence of new emissions, one can determine the long-term equilibrium by multiplying the matrix kn-times, where *n* is large enough that the transition matrix converges towards a constant matrix. Carbon emissions are entirely added to atmospheric concentration and these emissions in the model are in terms of CO_2, whereas concentrations and other relevant parameters are calibrated to carbon emissions. Thus, total CO_2 emissions are multiplied by the factor (12/44) to convert CO_2 to carbon. Again, equation (5.5) converts atmospheric concentrations to its impact on radiative forcing. This forcing is a logarithmic function (based 10) of concentration with two key parameters. The first is the pre-industrial concentration level (ConcPI) while the second is the amount of forcing induced by a doubling of concentration from its pre-industrial level (FCO_{2x}). In fact, this relation allows for an exogenous amount of forcing that could eventually be negative (as is the current case) due to SO_2 emissions. Similarly, equation (5.6) provides the link between temperature in the two sinks with their previous respective temperatures through a transition matrix (ϑ) and the incremental impact from forcing through the matrix (Θ). In fact, temperature measured as the increment to temperature in ^{o}C since1900 (like concentration) has interactions between the atmosphere and the oceans.

Consequently, the ocean is treated as a single sink and the subset *zt* of *z* covers only atmos and dpocn.

Essentially there are a number of different potential regimes to limit carbon emission and the simplest is just to impose a carbon tax, that is set the variable ϑ^{emi} to same value (measured as dollars per unit of emitted CO_2). However, emission caps can be set on either a single region (country) basis, with a differentiated carbon tax across regions (countries) or on a region-wide basis with a uniform carbon tax. Here, quota regions are indexed by *rq* and can be assigned one or more countries. The relevant equations are presented as follows:

$$\sum_{r \in rq} \text{EMITot}_{r,\, em,} = \text{X}^{cap}_{r,\, em,}\ \text{EMICap}_{rq,\, em} \tag{5.7}$$

$$\tau^{emi}_{r,\, em} = \tau^{emiR}_{rq,\, em} \tag{5.8}$$

$$\text{Quota}\Upsilon^{emi}_{r,\, em} = \tau^{emi}_{r,\, em}\ [\ \text{EMIQuota}_{\text{r, em}} - \text{EMITot}_{r,\, em}] \tag{5.9}$$

if cap and trade is active...

Here, equation (5.7) implements emissions caps for each agglomeration of regions subject to a cap (potentially just single country) and the sum of emissions across all regions belong to region rq is capped to EMIcap. In fact, equation (5.7) determines the regional emissions tax (ϑ^{emiR}) which will be uniform across all countries (regions) belonging to the aggregate region. Thus equation (5.8) is an accounting identity that equates the country (region) tax, ϑ^{emi}, to the region-wide emissions tax . Yet, the shifter in equation (5.7) allows for additional targeting. Similarly, equation (5.9) determines the value of the trade in emissions quota when country or region specific quotas (EMIQuota) are allocated. Here, the value of the quota is the difference between the quota and actual emissions (EMITot) valued at the emissions tax level. It is also assumed that the quota rents are recycled back to the government.

Empirically, the model dynamics are driven by three major factors as usually specified in most neo-classical growth models. The relevant equations are specified as follows:

$$KStock_{r} = (1-\delta_{r})\, KStock_{r\,-1} + XC_{r,\,inv,\,-1} \quad (5.10)$$

$$XFT_{r,\,captl} = (XFT_{r,\,captl,\,o}/KSTock_{r,\,o})\, KSTock_{r} \quad (5.11)$$

$$\lambda^{f}_{r,\,l,\,a} = \left(1+\pi_{r,\,a} + r^{\,l}_{r}\right) + \lambda^{f}_{r,\,l,\,a,\,-1} \quad (5.12)$$

Here, population and labor force growth rates are exogenous and the labor force growth rate is equated to the growth rate of the working age population (between 15 and 64). The second factor is capital accumulation and the aggregate capital stock in any given year (KSTock) is equated to the previous year capital stock, less depreciation at a rate of δ, plus the previous period's volume of investment, XC*inv* (as shown by equation 5-10). In fact, the latter is influenced by the national savings rate plus foreign savings as well as the unit cost of investment. Clearly, the aggregate capital stock variable takes two forms: KSTock (aggregate capital stock evaluated at fixed dollar prices) and XFT (normalized aggregate capital stock). Indeed, the normalized capital stock is equal to the tax inclusive base year capital remuneration, that is, the user cost of capital across sectors. It is normalized because its price is set to 1 in the base year while the ratio of the normalized capital stock to the actual capital stock provides a measure of the gross rate of return to capital. Here, it is assumed that both measures of the capital stock grow at the same rate and hence equation (56.11) that equalizes the ration of the two measures. Again, the third factor is productivity and there are a number of productivity factors peppered throughout the model. Basically, the key productivity factor is 8^f that corresponds to factor productivity. Clearly, there is a wedge between productivity in manufacturing and services that is represented by the factor B in equation (5.12). Typically, it is assumed that productivity in manufacturing is greater than in services. That is, B for manufacturing is positive and it is zero for services. Thus, in the calibration or business – as usual scenario, the uniform productivity factor (r^l) is calibrated to achieve some target level of per capital growth (at least for some period) including historical validation from the base year to some current year and including some medium term horizon.

6.0 **POLICY IMPLICATIONS**

Following Bussolo, et al (2008) some scenarios are derived with the use of ENVISAGE MODEL. In the standard business-as-usual scenario (reference or baseline), the key growth factors include labor and population growth, capital accumulation and productivity.

The scenario assumes that all existing policies (such as energy prices and investment) remain in place as well as established link between temperature change and agricultural productivity. Yet, another scenario removes agricultural damages and thereby providing a measure of how important these might be on a regional scale. Again, the mitigation scenario assumes full participation and an efficient mechanism for reducing emissions through a globally applied uniform tax on carbon emissions. Here, all tax revenues are recycled internally and there is no cap or trade system that could lead to a re-allocation of tax revenues across countries. Regrettably, the base line scenario leads to a carbon concentration that rises from around 390 parts per million (PPM) in 2001 to 560ppm in 2050. Clearly, this was well above any stabilization scenario of 450ppm promoted by some as an upper limit to avoid severe damages or the more modest target of 550ppm that many others perceive as a threshold not to surpass. As worrisome as the overall concentration level in 2050, the observed path was far from a stabilization scenario with concentrations likely to continue increasing well beyond 2050. In fact, the true objective was the overall rise in temperature that is driven by an increase in irradiative forcing given climate sensitivity rises to 1.75^{o}C relative to 1900 levels (IPCC, 2007).

In an attempt to measure the impacts of damages to agricultural productivity, other damages such as serve weather events, rising sea levels and increasing morbidity (mortality) were ignored. Here, the typical damage function has an economic variable that depends on temperature change as well as potentially other climate-related variables such as water availability. These functions are typically non-linear as damages are assumed to rise rapidly after some threshold is reached. The reported ENVISAGE model implemented a linear damage function under the assumption that changes in temperature through 2050 are likely to be relatively mild and a linear function is a relatively good approximation. This damage function was specified as follows:

$$\delta_{r,a,t} = \alpha^{o}_{r,a,t} + \alpha^{1}_{r,a,t} \frac{T_{t,} - T_{o}}{2.5 - T_{o}} \tag{6.1}$$

Where δ is the impact productivity in region *r* and activity a while T is the global mean temperature. Here, the parameter α^1 is taken from the estimates presented in Cline (2007) and represent the average percent decline in productivity when the global mean temperature reaches 2.5^{O}C. On the other hand, the parameter, α^o is set to 1 so that in the absence of the damage estimate (δ), the value 1 is taken.

This damage estimate enters the production function (as a multiplicative factor to the productivity variable) of the following generic form:

$$V_{r,a,t} = \sum_i a_{r,a,i} \left(\delta_{r,a,t} \lambda_{r,a,i,t} + X_{r,a,i,t}\right)^{Pr,a} \tag{6.2}$$

Where V is output (of activity *a* in region *r*); X is the vector of inputs (indexed by *i*), 8 is a set of efficiency productivity parameters); and *a* are the CES (primal) share coefficients. Specially, in the base year, all I parameters are initialized at I (but growing at some given geometric rate such as 2.25% per year). In fact, if all is equal to – 25%, then when the temperature increase reaches 2.5^{o}C; the impact on productivity will be a 25 percent decline. Thus, table 6.1 provides estimated agricultural damages for the modeled Africa region while table 6.2 provides the comparative real income impacts of agricultural climate change damages. As a methodological bench mark, the agro ecological model relies essentially on the physical and biological properties of growing crops. Essentially most crops have an inverts U-shape yield pattern where yields are low at some low temperature levels, increase until some optimum temperature, and then decline again as temperatures increase (for given water levels). Basically, these curves can be derived through experimentation from which can be derived the impact of temperature on crop-specific yields. In contrast, the Ricardian analysis takes a broader perspective on farm behavior and allows for adaptation to changes in the growing environment (water and temperature). Illustratively, if temperature increase has negative impacts on wheat yields; farmers will adapt and switch to grow more temperature tolerant crops such as corn. Thus, the impacts of water and temperature changes using Ricardian analysis are typically smaller than when using the agro ecological methodology. Yet increases in atmospheric carbon concentrations can be productivity enhancing as it improves the absorption of carbon by plants. In fact, in greenhouse experiments, this carbon fertilization effect has been shown to increase yields by up to fifteen percent. However, there is no consensus, how effective carbon fertilization is in the real world. Indeed, Cline (2007) presents two sets of best estimates (one with carbon fertilization and one without) as shown in table 6.1 below.

TABLE (6.1) AFRICAN AGRICULTURAL DAMAGE ESTIMATES

REGIONS	CLINE WITHOUT CARBON FERTILIZAT-ION 2085	ESTIMATES WITH CARBON FERTILIZAT-ION 2085	ENVISAGE WITHOUT CARBON FERTILIZAT-ION 2050	MODEL RESULTS WITH CARBON FERTILIZAT-ION 2050
SUB-SAHARAN AFRICA	-28.1	-17.4	-16.1	-9.9

TABLE (6.2) AGRICULTURAL CLIMATE CHANGE DAMAGES:

COMPARATIVE REAL INCOME IMPACT

	$2001 (BILLION)		PERCENT OF BASE LINE INCOME		PERCENT OF BASELINE INCOME			
REGIONS	2020	2030	2040	2050	2020	2030	2040	2050
MIDDLE EAST AND NORTH AFRICA	-4.5 -	10.0	-20.3	-35.5	-0.2	-0.4	-0.6	-0.8
SUB—SAHARAN AFRICA	-5.5	-13.9	-32.7	-71.0	-0.6	-0.9	-1.2	-1.5
DEVELOPING COUNTRIES	-101.3	-284.8	-703.2	-1508.8	-0.6	-1.0	-1.8	-2.6
WORLD TOTAL	-125.6	-326.0	-768.7	-1605.2	-0.2	-0.5	-0.9	-1.5

Empirically, this table provides his estimates (with and without carbon fertilization) and therefore represents a weighted average of existing estimates using both agro ecological and ricardian methodologies, with a weight (2/3) on the ricardian estimate.

In fact, these estimated damages represent the average change in yields in 2085 (where it is assumed that the average change in global temperature will be 2.5^{o}C.

Similarly, table 6.2 shows that by 2050, the loss in income from incorporating agricultural damages would total over $1.6 trillion ($2001) at the global level or 1.5 percent of total income, of which a very large portion would borne by sub-Saharan Africa and North Africa (respectively $710 and $350 billion).

Consequently, delaying global actions for more than ten years makes stabilization at 450ppm CO_2 emissions impossible. To achieve this target, global energy-related CO_2 emissions will need to peak at 28—32 gigatons in 2020 from 26 gigatons in 2005 and then fall to 12-15 gigatons by 2050 . This trajectory therefore requires a 2-3 percent cut in emissions for each year as from 2020 onward. Regrettably, most Africa countries are on their way to a high carbon path, with total global CO_2 emissions outpacing the worst—case scenario as projected by intergovernmental panel on climate change. Thus, new additions of power plants, buildings, roads, and railroads over the next decade will lock in technology and largely determine emissions through 2050 and beyond. Unfortunately, because energy capital stock has a long life, and a century to turn over urban infrastructure.

Therefore, delaying action would substantially increase future mitigation costs; effectively locking the continent into carbon-intensive infrastructure for decades to come. Even existing low-cost clean energy technologies will take decades to fully penetrate the energy sector. And given the long lead times for new technology development, deploying advanced will require today's aggressive action.

To avoid such lock—inks, the scale and rate of urbanization present an unrivaled opportunity (particularly for Africa countries) to make major decisions about building low-carbon cities with compact urban designs, good public transport, efficient buildings and clean vehicles. Indeed, one good feature of the inertia in energy infrastructure is that introducing efficient low-carbon technologies into new infrastructure offers an opportunity to lock in a low-carbon path. Therefore, Africa countries will install at least half the long lived energy capital stocks build between now and 2020. In other words, climate-smart development policies need to be tailored to the maturity of each technology and the national context. This can then accelerate the development and development of these technologies. Generally if Africans are to meaningfully address climate change, there is no option but to integrate development concerns and climate change. Obviously, the climate problem arises from the joint evolution of economic growth and greenhouse gas emissions.

Thus, an effective regime must provide the incentives to reconsider trajectories of industrialization and unravel the ties that have bound development to carbon. Turning this readiness into an effective climate regime requires simultaneously addressing multiple goals involving equity, climate as well as social and economic development. To ensure a climate regime that speaks to development concerns, it is useful to identify and engage opposing perspectives and then seek to transcend them.

To recognize and advance African countries mitigation efforts, the major new element needed in the climate regime is a new category of mitigation action that is broad and supple enough to incorporate a wide variety of actions. Fortunately, many African countries have begun to identify existing and potential policies and actions at the national level that (while not driven exclusively or primarily by climate-change concerns) contribute to climate mitigation efforts. As these policies and nations arise within national contexts, they inherently reflect a country's national circumstances as well as its development objectives and priorities. But mitigation will be neither effective nor efficient with abatement efforts in African countries.

Consequently, an equitable approach to limiting global emissions of greenhouse gases has to recognize that African countries have legitimate development may be jeopardized by climate change; and that they have contributed little (historically) to the problem. Thus, flows of climate finance (fiscal transfers and market transactions) from Advanced to African countries represent the principal way to reconcile equity with effectiveness as well as efficiency in dealing with the climate problem. In other words, financial flows can help African countries reduce their greenhouse gas emissions and adapt to the effects of climate change. Yet successfully tackling climate change will cost trillions and bearing these costs will be the international community national governments, state governments, local governments, firms and households. Yet, the principal instrument for catalyzing mitigation in African countries is the clean Development mechanism (CDM). This has grown beyond initial expatiations, demonstrating the ability of markets to stimulate emission reductions, provide essential learning; raise awareness and build capacity. But the CDM contains inherent in efficiencies, raising questions about the overall process and its efficiency as a financing instrument. Therefore, reversing the institutional inertia that constrains climate policy requires fundamental changes in interpreting in formation and making decisions. Domestically, a range of positive actions can be taken by national and sub national governments s well as by the private sector, media and scientific community in Africa.

Global and mostly irreversibly, climate change is a matter of cross-country and intergenerational distributive justice, affecting the billions of people who will live in the rest of this century and beyond. Therefore, the core challenge is to consider the policies and strategies that would be good for human development overtime; so that improvements exceed those of the past and ensure that previously disadvantaged groups are included in future expansions of freedom. Certainly, this must be in ways that overcome the limits of carbon-intensive growth so that human development is truly sustainable.

7.0 **CONCLUSION**

Indeed, African countries have had a relatively good growth performance over the past decade. However, there are indications that the current pattern of growth in the region may not be sustainable because of the fact that it is based on the use of non-renewable (exhaustible) natural resources that contributes to global warming and climate change. Although Africa has contributed the least to global greenhouse gas emissions, it is estimated that she will be the region mostly affected by climate change. In fact, it is estimated that Africa agricultural yields will greatly decline while millions of people in Africa will be at risk of increased water stress as a result of climate change.

Therefore, creating sustainable structural transformation in Africa requires better access to modern energy sources; improving energy efficiency as well as facilitating a switch from non-renewable to renewable energy sources. Thus, the policy options for increasing access to modern energy sources include rural electrification programmes and economic incentives to lower the relative cost of modern energy to households as well as firms in Africa.

Again, regional cooperation in energy production and distribution is equally crucial in enhancing access to modern energy in the region. The target of improving energy efficiency and the use of renewable energy can be achieved through technology transfer from the developed and emerging economics to Africa. Building national capabilities to access use and adapt existing technologies remain imperative for the emergence of modern African economics. In fact, there is need for African governments to strengthen inter-ministerial collaboration on environmental issues to ensure that these are addressed in a holistic manner by mains teaming of the environment into national development strategies. Yet, it is imperative that developed countries should provide financial the energy sector; facilitate technology transfer to support sustainable structural transformation; design the international trade regime as well as intellectual property rights regime in a way that facilitates the sustainable development process.

Thus, policy instruments need to be coordinated and integrated to complement each other and reduce conflicts. Policies, strategies and institutional arrangements also have to be aligned across sectors. Cross-sectoral initiatives are usually difficult to implement, because of fragmented institutional arrangements and weak incentives. Therefore, finding a champion is critical for moving the agenda forward. Collaboratively, low-carbon technology and policy solutions can put the world onto a $2^{o}C$ trajectory (but a fundamental transformation is needed to decarbonize the energy sector). Indeed, this requires immediate action as well as global cooperation and commitment from developed and developing countries (including Africa).

Essentially, there are win-win policies that governments can adopt now, including regulatory and institutional reforms; financial incentives and financing mechanism to scale up existing low-carbon technologies (particularly in the areas of energy efficiency and renewable energy). Clearly, adequate carbon pricing and increased technology development are essential to accelerate development and deployment of advanced low-carbon technologies. In other word, developed countries must take the lead in demonstrating their commitment to significant change at home, while also providing financing and low-carbon technologies to development countries (such as Africa).

Africa countries therefore require paradigm shifts in new climate-smart development models. For these transformative changes, the technical and economic means exist. But only strong political will and unprecedented global cooperation will make them happen. Truly, the time for action is now.

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