The Kenya Vision 2030 and the Environment: issues and challenges

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Abstract- *In this study Kenya's energy sector was overviewed for the period 1971-2004. The relation between total energy and total carbon dioxide emission was studied. Emissions of carbon dioxide from the combustion of fossil fuels that may contribute to long-term environmental degradation are projected through 2030 using various models. Using the models developed in the study, the potential of GDP growth will be around 6% annually and the continuation of rapid economic growth could lead to overwhelming problems of CO2 emission reduction and energy security. For sustainable development, several measures including improvements in energy efficiency, switching to renewable sources of energy, stockpiling energy, enforcing air protection and a carbon tax may be urgently required.*

Key Words: *Kenya; Macroeconomics; Energy; Environment*

1.0 Introduction

There is a growing recognition of the importance of incorporating environmental considerations in national development strategies. Will continued growth bring even greater harm to the environment? Or does an increase in income and wealth generate the desire for the amelioration of ecological problems? The answers to these questions are critical to the design of appropriate development strategies for developing countries.

The recently launched national strategy of Vision 2030 that aims at making Kenya a middle level income country is a case in point. The envisioned target growth in gross domestic product (GDP) of 10 per cent over the next three decades will inevitably result in heavy demand for energy, water, solid waste management and the manufacture and use hazardous and toxic substances in the country. This will be compounded by population growth particularly in urban areas, due to rural-urban migration, growing urbanization and rising living standards. The exponential growth in population may stretch the government's ability to answer infrastructure and service needs. Often the supporting infrastructure for the collection and treatment and disposal of sewerage and solid wastes is inadequate to cope with the amounts generated. This state of affairs raises problems of water and air pollution, public health and urban environmental degradation.

There is a challenge to balance the seemingly conflicting interest between concerns for the environment on one hand and economic growth on the other. The country is faced and grappling with difficult decisions and tradeoffs with regard to energy as it strives to achieve sustainable development. Energy is a prerequisite to economic development. Energy is the vital basis of the development of human society, which is linked with several aspects of the social production and daily life. On one hand expanding energy access to poor people is essential for alleviating poverty. Improving energy access for the alleviation of poverty also means promoting small and medium scaled business, industrial development and better transportation networks in a general effort to improve socio-economic well-being. All of these will require greater energy use. Coupled with the increasing population and living standards, the demand for energy in Kenya will steadily increase. To achieve these goals with minimal adverse effects on the environment is the basic goal of sustainable development.

However, energy use is both directly and indirectly associated with various immediate and long term environmental impacts which appear at various levels. In particular combustion of fossil fuels is known to be one of the major sources of green house gas (GHG) emission a significant contributor to global warming. Therefore, the primary environmental consideration affecting the energy sector is fuel related. Relatively little is known about the likely costs and benefits of implementing the Kenya vision 2030 strategy, but it is clear that energy demand will increase. Emissions of CO_2 caused by human activity are generally viewed as the most important single source of potential future warming. While there are no absolute answers and solutions differ by region, by country, a common thread in reaching solutions is being able to ask and address the right questions.

This study examines the likely environmental impacts of the targeted growth in vision 2030. We look at the relationship between selected measures of environmental quality and levels of GDP. The air quality variables used in our study are among the most commonly used indicators of air pollution. Focus on CO_2 is warranted because green house gases' atmospheric lifetimes differ substantially and relevant chemical processes are complex and nonlinear. Assessing the relative importance of green house gases for policy purposes is therefore not trivial. In addition roughly 80% of anthropogenic CO_2 emissions are produced by the combustion of fossil fuels. Consequently, there is great benefit to be gained from ensuring that the best approach in managing and regulating fossil energy demand and supply as soon as possible. Discussions on the approaches in managing and regulating energy to assist in the implementation of Vision 2030 should be started. This in turn will lead to a science-policy interface where researchers can come forward and fill in the information gaps, and assist policy makers and industry towards minimizing or eliminating the impacts of global warming, environmental degradation, hazardous and toxic substances on the human and natural environment.

A couple of studies have investigated the relationships between economic growth, energy consumption and environmental considerations in the advanced economies. One study investigated the relationship between energy demands, gross national product (GNP) the real energy prices and the estimation of CO_2 emissions for Japan, (Lester and Ninomiya, 2005). Another focused on the relationship between economic growth and energy consumption with recommendations for sustainable development for China (Zhidong, 2003). No study that we are aware of has focused on the relationship between economy, energy and the environment by modelling these components simultaneously in Kenya.

In this study we use an econometric model to construct projections of CO_2 emissions from fossil fuel combustion through to 2030.The overall objective of this study was to investigate and model the relationship between economic growth by means of GDP, energy consumption and CO2 emissions within the realm of Kenya's Vision 2030 strategy. Specific objectives were to:

(a) Develop a framework that will provide an analysis of the practical consequences of choices emerging from the Kenya Vision 2030.

(b) Model total energy consumption and total carbon dioxide emissions to predict the energy consumption and CO2 emission up to the year 2030.

(c) Recommend some policy considerations.

This study contributes to the literature and policy making in Kenya by investigating the relationship between increased economic activity and environmental quality. We utilize a well used set of environmental indicators for comparison. The measures of environmental quality are drawn from a common data source derived using comparable methods for different countries. The study provides a useful starting point for policy makers interested in the state of the ecosystem. To the best of our knowledge this is the first such study in Kenya.

The rest of the study is structured as follows: We detail the conceptual model structure in the subsequent section. The characteristics of the energy sector and CO_2 emissions in Kenya are discussed in Section 3. In Section 4, the data and modelling techniques utilized in the study are detailed. Lastly the results and projections from the models are given in Section 5.

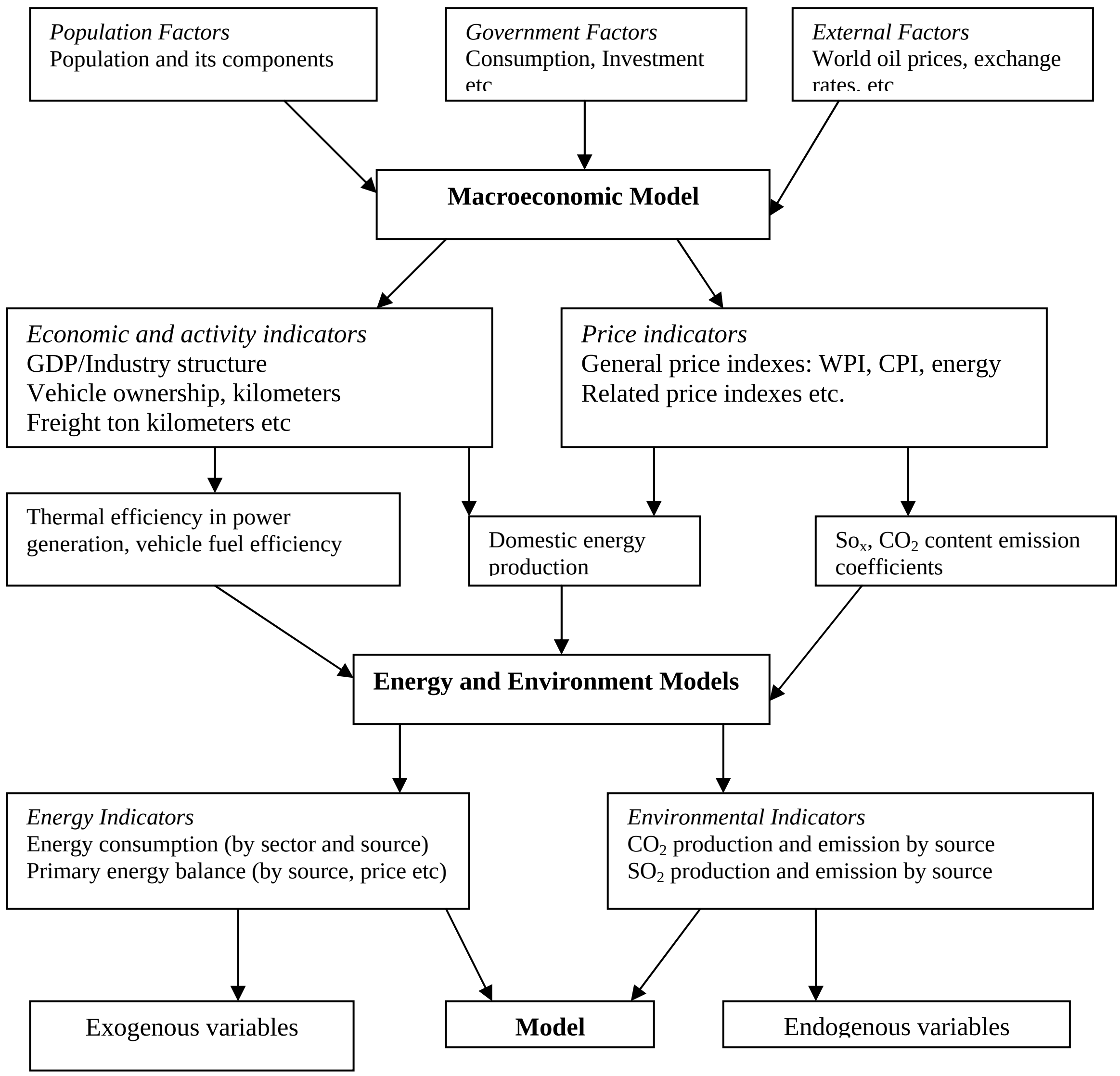
2.0 Conceptual Model Structure

The primary objective is to identify and quantify the key factors that are likely to affect the demand and supply for energy. Economic growth is by far the most important driver of energy demand. The link between total energy demand and economic output remains close. Consequently, projections for supply and demand for energy are subject to a wide range of uncertainties, including macroeconomic conditions, resource availability, technological developments and investment flows as well as government energy and investment policies. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. Population growth assumptions are based on the United Nations population projections. Kenya has not yet experienced a fertility transition. However, population growth will slow over the projection period in line with trends of the last two decades. As populations grow, providing them with access to commercial energy will be an increasingly pressing challenge. Combining population and GDP growth assumptions yields an increase in per capita incomes. Average end user prices for oil are derived from assumed price trends on wholesale world/ bulk markets. Tax rates are assumed to remain unchanged over the projection period.

Our model therefore consists of a macroeconomic, energy and environmental sub sector models as detailed in figure 1. The macroeconomic model is set to provide indicators influencing energy supply and demand, and the related pollutants emissions. In this sub sector other factors such as population indicators, fiscal policy indicators, technology and external factors such as world trade, oil price, and exchange rates, are treated as exogenous variables. The endogenous variables solved as results include: macro economic indicators such as the output of steel, cement, vehicle ownership, transport emissions and so forth, price indicators such as deflators for GDP and its components, consumer price index (CPI), World Price Index (WPI) and energy price indexes.

The energy sub sector, serves as the core of the model, which determine the energy flow from final energy consumption to primary energy supply and trading position. First, final energy demand is determined by sector and by energy source, based on economic activity indicators and price indicators obtained by the macro sub sector model. Thereafter the schedule representing the energy conversion sector calculates the required input for the output of transformed energy sources such as electricity and oil products. Lastly, primary energy consumption can be obtained through aggregation of energy requirements from end use sectors and transformation sectors.

Figure1: **Structure of the model**

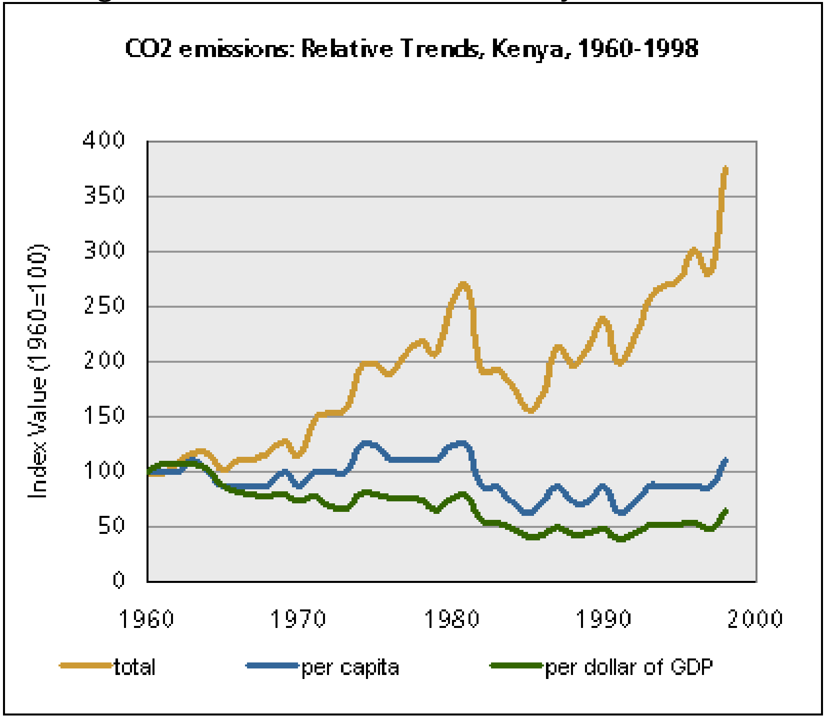


The environment sub sector model is designed to generate the energy-related production and emissions matrices of both SO_X and CO_2, following the energy balance table. Sulphur dioxide is an air pollutant produced when fossil fuels containing sulphur are burned. It contributes to acid rain and can damage human health, particularly that of the young and the elderly. Changes in government energy and environmental policies and the adoption of new measures to address environmental concerns, could have profound consequences for energy markets. The production of SO_X is estimated based on energy consumption obtained by the energy model and sulphur content coefficient and then emissions can be calculated based on the production and desulphurization coefficient. As for CO_2, the model assumes that emission is equal to production, based on the fact that plausible CO_2 control technology is available commercially at present even for the simulation period.

3.0 Sources of CO2 and historical emissions[1] in Kenya

Economic growth is by far the most important driver of energy demand. Energy poses a formidable challenge to achieving sustainable development. We need to use energy to alleviate poverty, promote economic growth and foster social development. Kenya's development in particular greatly depends on energy especially energy based on fossil fuels. But as we consume more energy, stress is placed on the environment at the local, regional and transboundary levels. The growth of various key sectors, especially industry and transport has resulted in considerable increase in energy consumption.

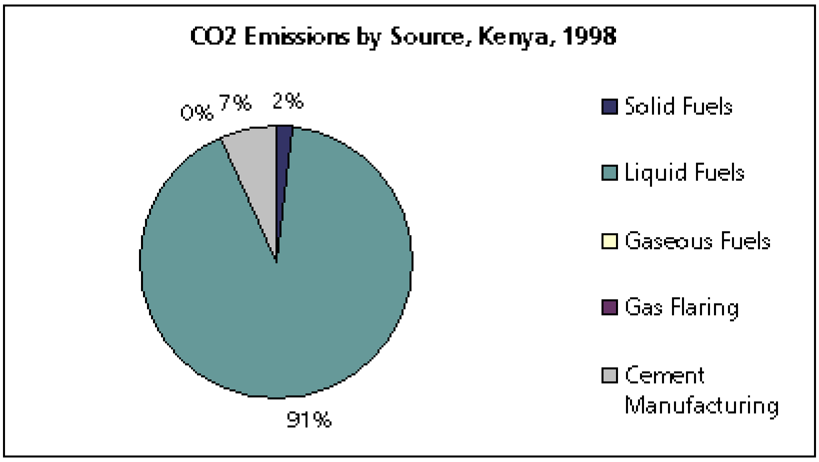
Figure 2: ***CO_2 emission trends in Kenya, 1960-1998.***



The link between energy demand and economic output remains close. Figure 2 illustrates the typical pattern that captures our model. There is a continuous and accelerating growth pattern of per capita CO_2 emissions with per capita gross domestic product (GDP). The results indicate that changes in per capita income and per dollar of GDP are sharply mapped with increased total CO_2 emissions. Figure 3 shows the sources of CO_2 emissions in Kenya for the year 1998. Energy related activities account for CO_2 emissions in Kenya. In particular, liquid fuels and cement manufacturing contributed 91 and 7 per cent of CO_2 emissions.

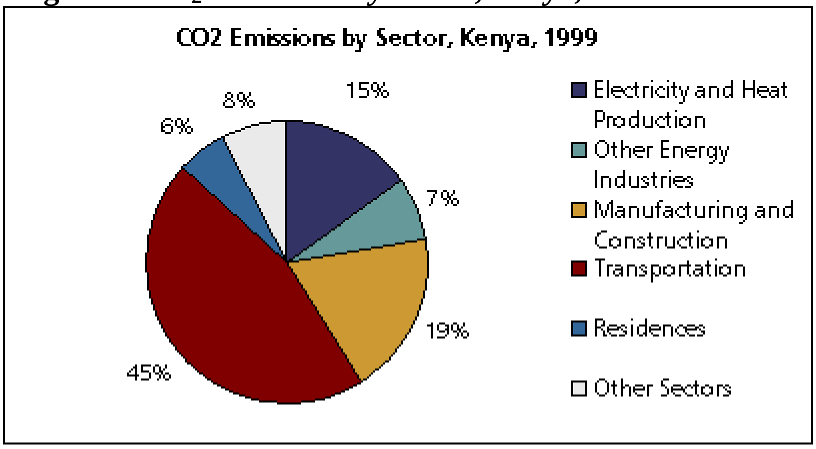
[1] CO_2 emissions are calculated by multiplying energy demand by an implied carbon emission factor. Implied emission factor vary differ between sectors.

Figure 3: ***CO_2 Emissions by Source, Kenya, 1998***



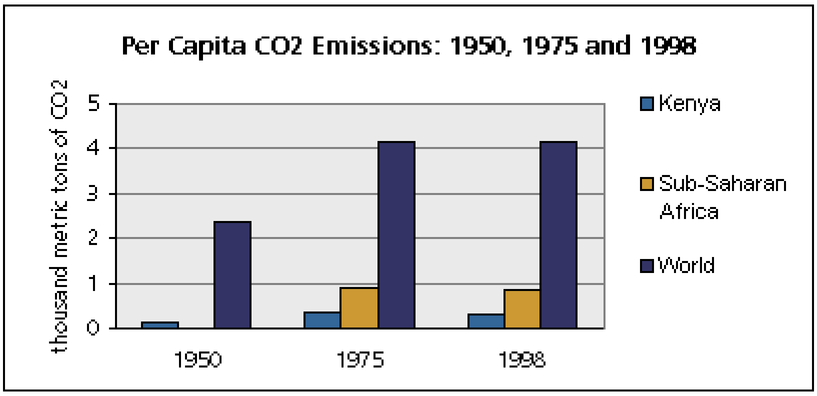
Energy consumption for different sectors is depicted in Figure 4 along with their contributions to CO_2 emissions for the year 1999. The transport sector generated around half of the CO_2 emissions (45%), closely followed by manufacturing and construction (19%), electricity and heat production (15%), other energy industries (7%), residences (6%) and others accounting for the rest.

Figure 4: ***CO_2 Emissions by Sector, Kenya, 1999***



The energy related CO_2 emissions presented above give an indication of what to expect in the future. Reliance on liquid fuels will remain high now and in the near future and transport will consolidate its position as the largest CO_2 emitter. The increase in the sector's emissions will occur due to increased car ownership which is expected to grow rapidly.

Figure 4: ***Per Capita CO_2 Emissions Trends by Region***



There has been a strong increase in emissions in the world over a thirty year period. Although Kenya's share of CO_2 emissions over the years is small compared to the rest of the world, the trend is an increasing one. Strong economic growth and heavy reliance on fossil fuels in transport, industry and power generation will drive this trend upwards. Emissions from Kenya and other SSA continued to increase (Figure 4). Presently, Kenya and SSA not only has lower per capita energy consumption; they also rely more heavily on biomass and agricultural waste, which are presumed to produce no emissions on a net basis. However, all biomass can be assumed to be replaced eventually following the anticipated economic growth. Tables 1 and 2 summarize the quantity of emissions and energy situation of Kenya, SSA and the world for comparison.

Table 1: Sectoral CO_2 Emissions Production and GDP Comparisons

Carbon Dioxide (CO2) Emissions **(in thousand metric tons of CO2)**	**Kenya**	**SSA**	**World**
Total Emissions, 1998	9131	515001	24215376
Percent change since 1990	57 %	10 %	8 %
Emissions as a percent of global CO2 production	0 %	2.1 %	
Emissions in 1998 from:			
solid fuels	176	292852	8654368
liquid fuels	8358	151843	10160272
gaseous fuels	0	16330	4470080
gas flaring	0	42110	172208
cement manufacturing	598	11865	758448
Per capita CO2 emissions, 1998			
(thousand metric tons of CO2)	0	1	4
Percent change since 1990	28 %	-12 %	-2 %
CO2 emissions (in metric tons) per million			
dollars Gross Domestic Product 1998	933	X	773
Percent change since 1990	34 %	X	-10 %
Cumulative CO2 emissions, 1900-1999			
(in billion metric tons)	217	16887	933686

Source: **WRI**

Table 2: CO_2 Emissions by Sector, 1999 (in million metric tons of CO_2)

Public electricity, heat production,			
and auto producers	1	X	8693
Other Energy Industries	1	X	1205
Manufacturing Industries and Construction	2	X	4337
Transportation	4	X	5505
Residential	0	X	1802
Other Sectors {d}	1	X	5640
Total Emissions All Sectors:	8	X	27180
CO2 Intensity, 1999			
Emissions per total energy consumption			
(metric tons CO2 per terajoule energy)	12	32	56
Emissions per Gross Domestic Product			
(metric tons of CO2/million $PPP)	260	X	582
Non-CO2 Air Pollution, thousand metric tons			
Sulfur dioxide emissions, 1995	62	5345	141875
Nitrogen oxide emissions, 1995	200	9309	99271
Carbon monoxide emissions, 1995	4339	177268	852415
Non-methane VOC emissions 1995	468	17375	159634

Source: **WRI**

3. 0 Data and model estimation

Data

The macro indicators mentioned above were mainly obtained from the Statistical Abstract, World Development Indicators, Penn tables and other official statistics. Energy supply and demand were collected from IEA statistics. The pollutant related indicators were derived from IEA estimates.

This study is based on national-level data on the following variables for the period 1971 to 2004:

C= CO_2 emissions from energy consumption, tones of carbon
Y= GDP, millions of 2000 U.S. dollars
N= population, million persons
E= energy consumption, millions Btu.

Data on C, which is CO_2 or carbon emissions and E were found in the International Energy Agency (IEA) reports. Values for CO_2 emissions by source are calculated by the IEA using the methods and emission factors in revised 1996 IPC guidelines. This includes data on industrial additions to the carbon dioxide flux from solid fuels, gas flaring and cement manufacturing. The energy data are based on United Nations estimates of national energy consumption. Energy consumption estimates by fuel types were derived as the difference between (production + imports) and (exports + bunker fuel increase in stocks). Per capita CO_2 emissions are amounts of CO_2 emitted, on average, from all sources for each person living in the country. Data on GDP were taken from World Bank development indicators. These were deflated using the GDP deflator and estimates of purchasing power parity exchange rates in 2000. No account is taken for depreciation of manmade assets or depletion and degradation of natural resources.

The econometric model(s)

In order to make use of our limited data-set as efficiently as possible we will largely focus on pooled time series models. Without imposing any dynamic specification in the model, the simple static ordinary least-square (OLS) estimator is used. The analysis employs equations of the following general form:

$$In(c_t) = \alpha_1 + G[\alpha_2 \ln(y_t)] + \varepsilon_t \tag{1.1}$$

Where c =C/N, y=Y/N, the α_1 is the year fixed effects, G is some reasonable flexible function, and ε_t is the error term. We employ per capita quantities because there is no compelling reason for national population to affect average behaviour. For pragmatic reasons we estimate our various functions as log-linear relationships. This specification is attractive principally because it yields constant elasticities, whose results are easy to interpret and compare with other studies. [2]We also include estimates of the structure of the per capita energy usage $e_t = E_t / N_t$ for purposes of comparison. We estimate equations of the form (1.1) with $\ln(e_t)$ as the dependent variable.

However, fuel demand can generally thought to be dynamic in nature, *i.e* there are time lags between changes in the exogenous variables and changes in fuel consumption. The time lags have several explanations which include habit persistence, slow turn over in stock of say vehicles, and the time required for manufacturers to shift from one technology to another. In order to reflect such time lags, one has to impose a feasible dynamic specification. In our study we focus on a simple and oft used dynamic model, the endogenous lag model, where endogenous variables are estimated as a function of the endogenous variable one period lagged (as well as of the exogenous variables). The main advantages of this model are that it produces immediate short-run and long run estimates, which is sparing with degrees of freedom and it often seems to produce reasonable estimates (see Frazen, 1994). One of its limitations is that it implicitly assumes the adaptation process to have a geometric declining form, which of course may not necessarily be the case.

Model for the Total Energy Consumption

To begin, energy consumption as a function of population growth, economic growth should be estimated to determine the relationship between these variables. Population growth and the GDP data for the years from 1971 to 2004 were used in the regression analysis as independent variables to predict the Total Energy Consumption (TEC). The variables in the regression model were in logarithmic format. The results from the regression analysis are in the Table 3.

[2] Two other functional forms, linear and the mixture were used and selection based on performing coefficient test and total tests.

Table 3: ***Regression results for Total Energy Consumption***

Independent Variables	Coefficients	Std. Error	P-Value
Constant	-16.78	0.42	0.001
Log of Population	0.53	0.17	0.004
Log of GDP	0.85	0.09	0.001

R^2=0.98, F statistic 4018.22 and *P-value=0.001*

From the results in Table 3, the TEC can be explained by population and GDP with high accuracy (R^2=0.98). One can therefore use the results from the model to project future total energy values for longer periods.

The prediction of population and potential GDP

To make predictions of population, the following natural increase formula was used:

$$P_n = P_0 e^{rn} \tag{1.2}$$

where P_n is the value from the 1999 census, P_0 the population in the 1989 census, e is the constant (2.7182), r is the rate of change of population within the specified unit of time between the two census periods, and n is period of time between the two censuses. To predict GDP it is assumed that the 10% annual economic growth increase, which is targeted can be realized through out. Results from those predictions are provided in Table 5 along with other assumptions.

The model for the Total Carbon Dioxide emission

A linear regression analysis between the TEC and TCO_2 data for the years 1971-1998 was run. The results from that analysis are given in Table 4.

Table 4*: *Regression results for TCO_2 emissions

Independent Variables	Coefficients	Std. Error	P-Value
Constant	-0.47	0.08	0.000
Log of Total Energy Consumption	1.12	0.01	0.000

R^2=0.97 F-Statistic=12,305.23 and *P-value=0.000*

Total energy consumption is significant at the less than 1 percent level. A 1 percent increase in total energy consumption leads to 1.12 percentage increase in total carbon dioxide emissions.

Table 5: Long run activities and price elasticity estimates

	Activity factor		Price factor	
Energy demand by sector	Variable	Elasticity	Variable	Elasticity
Manufacturing	Cement/steel	0.44	Electricity price	0.45
Energy	GDP per capita	1.01	Oil price	0.39
Transport	GDP per capita	2.17	Oil price	2.05
Electricity	GDP per capita	1.76	Oil price	0.33

Energy elasticity

Energy consumption by source and end sector is assumed as a function of real term energy price and activity factors such as GDP per capita and industrial output. Table 5 shows the long run elasticity of some main energy consumption activities based on the estimated equations. Generally, activity elasticity is higher than price elasticity; activity elasticity for clean energy sources is higher than that for less clean sources. These general trends have been observed in developed countries and are also to be observed in Kenya.

Projection Methods

In order to assess the implications of increased energy use, we use our estimates of the various equations and various assumptions to generate estimates over the period 1999-2030. The assumptions and scenario cases are summarized below.

Table 6: Key assumptions in BAU case for macro

Average annual growth rates	1999-2010	2010-2020	2020-2030
Government consumption	9.2%	6.1%	5.0%
Government investment	9.7%	5.5%	4.5%
World trade	3.5%	3.5%	3.5%
Absolute level	1999	2010	2030
Population(millions)	30	35	56
Exchange rate (Kshs/$)	65	65	65
Crude oil price ($/Barrel)	30	43	50

Assumption and cases

Although many cases can be introduced for the simulation analysis, this study only conducts Business As Usual (BAU) case for macroeconomic simulation and five cases for the energy-related simulations. The reference scenario (BAU) assumes that there will be no change in energy and environmental policies through the projection period. The share of taxes in energy prices is assumed to remain unchanged, so that retail prices are assumed to change directly in proportion to change in international prices.

We present five alternative scenarios which consider those policies and measures that the government might reasonably be expected to adopt taking account of technical and cost factors. The aim is to present a consistent picture of how the sector might evolve if the government strengthened environmental policies. The five alternative cases for energy-related simulation are developed by changing the set of assumptions, the five alternative cases are energy saving case, switching to non-fossil fuels case, combination case taking energy saving and fuel switching together, carbon tax case, and comprehensive case taking the three alternative measures together. The key assumptions are shown in Table 7.

Table 7: Key Assumptions for energy-related cases

			1999	2030
1	BAU Case			
		Thermal efficiency in thermal power plant (%)		
		Oil-fired	34	47
		Gas-fired	35	49
		Vehicle fuel efficiency (litre/100 ton-kilometres)	8.2	3.9
		Non-fossil fuel-fired capacity (GW)		
		Hydro	78	250
		Wind	0.29	81.2
		Geothermal, solar and other renewable	2.0	36,8
2	Energy saving case	Thermal efficiency will go up 2 points than that in BAU by 2030 Oil-Fired 47-49%; gas-fired 49-51% Vehicle fuel efficiency will be improved 23% from that in BAU to 3 litre/100 ton-kilometres		
3	Switching to non-fossil fuels	Non-fossil fuels-fired capacity in 2030 (GW)	This case	BAU
		Hydro	300	250
		Wind	162.4	81.2
		Geothermal, solar and other renewable	68.6	36.8
4	Combination case	Energy saving measures in case 2 and fuel switch measures in case 3 will be introduced together		
5	Carbon tax case	All measures adopted in case 2,3 and 5 will be conducted together (energy saving measures, fuel switch measures, fuel switch measures, carbon tax introduction from 2012)		

Main uncertainties to the assumptions

The projections presented in this study are subject to a wide range of uncertainties. Events may emerge that are different from either the reference or policy scenarios. The reliability of our projections depends both on how well the models represent reality an on the validity of the assumptions. The macroeconomic conditions are a source uncertainty. Slower GDP growth than assumed in both scenarios would cause demand to grow less rapidly than predicted. Political upheavals in some countries could have major implications for economic growth. Sustained high oil prices- which we have assumed away in the analysis would curb economic growth in Kenya.

Changes in environmental policies and the adoption of new measures to address environmental concerns, especially climate change could have profound consequences for energy markets. Improvements in the efficiency of current energy technologies and adoption of new ones along the energy-supply chain are potential sources of uncertainty.

Results of the simulation to 2030

Simulation results of macroeconomic factors

On the basis of the assumptions above, Kenya is able to sustain the rapid economic growth to the year 2030. Its potential GDP will grow by some 7% annually up to 2020, and thereafter GDP growth is expected to be 6% annually. The average annual growth rate will be 6.4% from 1999 to 2010, 6.1% from 2010 to 2020 and 5.2% from 2020 to 2030, with about one percentage point decline each decade. Although this growth rate is almost equal to the actual growth rate during the past two decades from 1980, it is still much higher than the predicted growth rate for the world. Table 8 presents the GDP growth accounting. The contribution rate of capital input will keep some 30%, but labour factor will slightly go down from 58% to 44%, reflecting the decrease of labour input due to technical progress and fertility decline.

Table 8:Kenya´s GDP growth accounting to 2030

	1980-1999	**1999-2010**	**2010-2020**	**2020-2030**
Potential GDP growth (%)	4.9	5.9	7.3	6.6
GDP growth (%)	4.8	6.4	6.1	5.2
By capital input	3	2.5	2	1.7
By labour input	1.9	0.7	0,6	0.2
By technical progress	4.9	4.2	3.5	3.3
Contribution rate to growth (%)				
By capital input	30.2	33.5	34.6	31.9
By labour input	57.6	51.3	46.4	43.7
By technical progress	12.2	16.2	19.0	24.4

Technology factor will become more and more important for economic growth; its contribution rate is expected double from 12% to 24%.

The size of GDP in 2030 will reach US$4.3billion in exchange rate terms and US$19.2 billion in purchasing power parity terms (PPPs), both with constant 1995 price. Due to the high expansion of GDP and low increase of population, per capita GDP in 2030 will go up rapidly, reaching US$2,200 in exchange rate term and US$19 thousand in PPPs. Taking account of the underestimation by exchange rate term and the overestimation by

PPPs, the reasonable level should be somewhere between this two, for example, around the average, US$ 8,000.

Regarding the macroeconomic structure, measured in nominal GDP, little change is expected in the share of secondary sector. The share of primary sector will continue going down sharply to about 5% by 2030 from 18% in 1999, and by to offset this decline, the share of tertiary or services sector is expected to increase from 33% to 47%.

As shown in Table 9, major energy-intensive industrial activity indicators, such as the output of steel, cement, vehicle ownership, etc., will increase rapidly. For example, by 2030, the output of steel is expected to surpass 200 million tons; vehicle ownership will reach 108 million vehicles and the penetration rate to population is expected to be up to 13%.

Table 9: Change of major industrial activity indicators to 2030 in Kenya

Activity	1980	1999	2010	2020	2030
Steel production (million ton)	37	124	176	208	235
Cement produciton (million ton)	80	573	769	961	1105
Ethylene production (million ton)	0.5	4.4	8.4	15	24.4
Vehicle ownership (million)	1.8	14.5	41.3	93.6	107.9.
Vehicle diffusion rate to population (per thousand)	1.8	11.5	30.2	64.3	85.8

Energy-related simulation results in BAU case

Energy-GDP intensity is expected to decline continually, but the annual rate of decline will slow down to 2.5%, much lower than 5.2% in the past 20 years. This pushes up the Energy-GDP elasticity to 0.58 from 0.41. It means that some new measures alternative to BAU should be adopted in order to achieve more improvement in energy efficiency.

The modernization of energy structure will be going on with respect to energy source switching and the change of consumption by sector. Regarding source switching, the share of the share of oil will go up to 28.4% from 23.3% by 2030 in primary energy consumption, from 88% to 73% in power generation, and from 48% to 22% in final energy consumption. On primary consumption base, the share of gas will rise sharply from 3.0% to 10.5%. While expected growth in renewable energy will be a strong 13.7% and 11.0% per annum. The share will still reach only 2.4% and 3.7% in 2030, respectively. Gas is expected as the main source to replace oil in power generation, electricity is expected to be the main source to substitute for oil in final energy consumption. On the other hand, regarding the change of consumption by sector, the share of industry and non-energy use in final energy consumption will decline sharply from 62.0% in 1999 to 41.9% by 2030. reflecting the expected rapid improvement in living standard and rapid progress in motorization, the share of transportation consumption will go up to 18.5% from 12.8%, and the share of consumption other sectors will rise to 39.5% from 25.2%.

A number of issues will pose challenges to the BAU case. The first one is regarding the energy security. Even assuming the self-sufficiency and optimistic domestic production for crude oil and natural gas, the shortfall of fossil fuel supply will increase to 710 Mtoe in 2030, including oil 567 Mtoe and natural gas 142 Mtoe, respectively. All of these have to be imported and consequently the share of import-dependence will go up to some 76% for oil and 52% for natural gas. Three points must be cleared. One is who can supply this to Kenya. Sudan looks like the potential supplier for natural gas based on the vast reserves. But, for oil, it seems difficult to find the suppliers, based on the limited reserves with the ratio of reserves to production just close to 50 years in 2000. Another point is whether Kenya has the economic ability to import. The ratio of payment for energy imports to total value of exports is estimated at about 10% in 2030, meaning that, it is not impossible economically, but the economic burden is likely to be heavy. Even if these two points get cleared, it is not evident whether Kenya can guard the infrastructure for energy imports such as sea line, pipeline, etc.

The second challenge is with regard to climate change. The CO_2 emissions from energy consumption in 2030 will increase to a projected 127 Mt-c.. Although per capita emissions will rise to 1.5t-c, still lower than the 3.0t-c in the OECD in 1999, Kenya's contribution to global GHG emissions will stand unacceptably high. Unlike SO_2 reductions, nothing but reducing the consumption of fossil energy can contribute to CO_2 emissions reductions.

The above analysis means that the BAU case is unlikely to be sustainable and substantial policy changes must be considered for energy import will drop from 9.8% to 9.1%. CO_2 emissions will be 5.5% lower, a result which shows us that both the effects and the limitation of the improvement in the technical efficiency of energy use with respect to power generation and road transportation. Although the above improvement in technical efficiency has the highest priority, it is not enough to resolve the BAU issues. The measures to improve technical efficiency should be extended to other energy consumption sectors such as industry and household. Further, measures to promote managerial efficiency, structural change such as macroeconomic structure, industrial structure, product mix, process and technology structure, plant scale structure, etc., should be adopted.

Case 3 the fuel switching case, assumes that non-fossil fuel power generation will be expanded further over the BAU case. Compared with the results in BAU case, in 2030, the primary energy consumption will be 1.6% lower, and fossil fuel consumption will decrease 7.0%. Fuel import is not changed from that in BAU, due to the assumption that non-fossil fuel power generation can only replace coal-fired power. CO_2 emissions will decrease.9%,. This result reflects both the effects and the limitation of the assumed fuel switching. In order to get more effects, it is necessary to expand the exploitable reserves and improve the converting efficiency of renewable energy.

Case 4 is a combination case based on Case 2 and Case 3. Compared with the results in BAU case, in 2030, the primary energy consumption will decrease 6.2%, and the fossil fuel consumption will decrease 12.0%. Fuel import is expected to decline from 710Mtoe in BAU to 661Mtoe, and the ratio of payment for energy import will drop from 9.8% to 9.1%. SO_2 production and CO_2 emissions will decrease 15.2% and 13.1%, respectively. Naturally, the effect is higher than either Case 2 or Case 3. However, it is still not enough to resolve the sustainability issues.

Case 5, the carbon tax case, assumes that carbon tax 10$/t-c will be imposed on energy consumption from 2012. Compared with the results in BAU case, in 2030, real GDP will decrease 0.04%, the primary energy consumption will decrease 7.3%, and the fossil fuel consumption will decrease 8.0%. In detail, coal consumption will decrease 15.3%, but oil consumption and natural gas will increase 2.4% and 0.4%, respectively. Fuel import is expected to increase from 710Mtoe in BAU to 729Mtoe, and the ratio of payment for energy import will rise from 9.8% to 10.1%. This result means the carbon tax might aggravate the energy security problem in Kenya. Case 6 is a comprehensive case based on Case 2, Case 3 and Case 5. Compared with the results in BAU case, in 2030 the primary energy consumption will decrease 13.5%, and the fossil fuel consumption will decrease 19.9%. Fuel import is expected to decline from 710Mtoe in BAU to 676Mtoe, and the ratio of payment for energy import will drop from 9.8% to 9.3%. On the other hand, SO_2 production and CO_2 emissions will decrease 26.3% and 23.4%, respectively.

All of the measures analyzed through the above simulations are effective in energy consumption reduction and pollutant emissions reductions; the most effective way is to take all of the measures together just as the comprehensive case. But the performances on energy security are quite different among these measures. Energy saving is effective, switching to non-fossil fuel is neutral, but carbon tax may be negative. This means it is hard to find a way to resolve all the issues with respect to energy security, air protection and CO_2 emissions reductions simultaneously and perfectly. In addition to the measures discussed above, the following measures should be considered.

a) Switching to gas. Because most of the energy-related environmental issues come from fossil oil consumption, and the energy security issue for Kenya is essentially the issue of oil-import, switching oil to gas will benefit environmental protection.

b) Measures for oil security such as establishment of strategic oil reserve, development of fuel cell vehicle, etc.

c)Measures for energy-related pollutant reductions such as promoting desulphurization, improvement in environmental monitoring and management, etc.

Conclusions

Kenya is likely to sustain a 6% economic growth in the coming 30 years. The expected continuation of rapid growth will lead to the modernization of energy source switching and the change of consumption by sector. On the other hand, under the assumptions of BAU, issues with respect to energy security, air protection and CO_2 emissions reductions will render this approach unsustainable.

It is hard to find a way to resolve the sustainability issues simultaneously and perfectly. In addition to measures analyzed by the simulation study such as energy saving, switching to non-fossil fuel and carbon tax, additional measures including the switching to gas, development of both traditional and high-tech clean coal technology, measures of oil security such as establishment of strategic oil reserve, development of fuel cell vehicle, measures for energy-related pollutant reductions such as promoting desulphurization, improvement in environmental monitoring and management, etc., should be adopted together.

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