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An energy system planning model for the industrial sector in Nigeria

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Abstract
This paper reports the energy system modelling projection in the industrial sector of Nigeria. It is carried out to provide a long term perspective on the Scenario buildings for the industrial energy system of Nigeria. The projections have inter-sectoral consistency only to the extent those of the Federal Republic of Nigeria have to the inter-industrial linkages, which are no doubt important. However, it appears that input-output tables have not been instructed and regularly impeded and expanded as part of the planning scenarios that have been generated on the contested demand, which is to assume constant energy intensity in future years. The basis for projecting energy demand in the industrial sector is to estimate the likely changes in energy consumption intensity and the ratio of energy consumption to value added. It is considered expedient and pragmatic to use a scenario for constructing an optimal level forecast, projecting a desirable energy equilibrium pattern for the year 2010.

Keywords: energy system planning, industrial sector

1. Introduction

On the basis of the available database for Nigeria as partly documented, energy demand scenarios are constructed over the medium term to the year 2010 including "snapshots" for the intermediate target years, 1995, 2000 and 2010 as well. This is done with reference to pre-specified sectoral growth rates for major energy consuming sectors, namely, the industrial sector, transport sector, agricultural sector, commercial/ service/government sector and household sector under three distinct scenario assumptions.

It should be noted that our projections have inter-sectoral consistency only to the extent to those the Federal Republic of Nigeria has. The inter-industrial linkages are no doubt important, however, it appears that input-output tables have not been constructed and regularly updated and expanded as part of the planning process in the Federal Republic of Nigeria. Even in countries like India, where input-output tables have been in use for ensuring inter-sectoral consistency, the energy sector as of now has not been treated in sufficient detail.

Furthermore, only fixed input-output coefficients have been used which indicate the impact of technological change is not considered. Therefore, the feasibility and usefulness attempting to make an input-output model for Nigeria in making its energy demand projections (and energy supply analysis) over a time horizon extending to 2010 seems doubtful. It is in this context, that a relatively simple scenario approach has been adopted for making energy demand projections in the context of Nigeria.

Three energy demand scenarios have been generated which may be broadly characterised as follows:

- Scenario I, where major sub sectors growth rates remain essentially unchanged from the trends observed in the past, and where the ratio of energy consumption to activity level represents an average intensity observed during the past one or more decades. The five major energy consuming sectors are disaggregated to the extent possible.
- Scenario II, where the total energy demand mix may change as the economy adapts to a relatively high energy intensity growth path particularly in the sub-sectors of electricity, non-coking coal, fuel oil and naphtha. (Satsangi *et al*., 1987).
- Scenario III, where the total energy demand mix may change further as energy conservation and demand management measures are adopted, thereby reducing electricity consumption intensity as well as the consumption intensity for non coking coal and fuel. For a developing country

like Nigeria, more and more energy will be needed in the coming years to sustain the process of economic development. Satsangi's (1987) recent interest in the field of energy planning problems has increased with amazing rapidity, the world over. Significant progress has been recorded with projects in this field with much work on methodological research into development of a detailed system such as petroleum and energy (Hafele, 1974; Hafele and Manne, 1974; Hudson and Jorgenson, 1975). Some of these findings have been dealt with in greater detail with the implications of different energy planning models (Behling *et al*, 1977). The working paper for the seminar on energy resources for the future (Huffman, 1977) provided a review of the studies on energy planning modelling. An energy policy model formulated for developed countries often relied on econometric analysis at sectoral or subsectoral levels or other sophisticated techniques such as the input – output model, mathematical programming and reference energy systems.

2. Methodology

The simplest method of projecting aggregate energy demand is to assume constant energy intensity for future years. This may be adjusted for changes through conservation by estimating the likely conservation potentials for future years. Furthermore, if the industrial sector itself is disaggregated into several industrial groups or subsectors such as chemical and fertilizers, textiles, metals/alloys and other manufacturing, industry and mining the likely changes in the composition of industrial output may also be used to estimate changes in the aggregate energy demand.

On the basis of data for the period 1995 to 2000 , the following significant regression relationship has been identified to project, vt, value added in the industrial sector of Nigeria in Billion Naira as a function of, t, time elapsed in years (1995=1).

$Vt = 0.6384x10^2 + 0.248x10^2\ t\ R^2 = 0.983\%(1)$
$(0.1067 \times 10)^2\ (0.145 \times 10)^1$
{0.9999} {0.99999} [0.99999]

The basis for projecting energy demand in the industrial sector is to estimate the likely changes in energy consumption intensity – the ratio of energy consumption to value added and make use of the following equations for consumption:

$Et=£^4{}_i={}_1\ kit\ vit;\ ct + ft = Qt\ vt$ (2)

Where

Et/ct/ft = total electricity/non coking coal/ fuel oil consumption in year t in million/tonne oil equivalent (mtoe)

vit = value added in sub-sector i in year t in Million (1995/2000 prices).

$Vt = £4_i = {}_1\ vit$

Kit = electricity consumption intensity in sub-sector i in year t (mtoe/Nbillion)

Gt = intensity of non-coking coal plus fuel oil consumption in year t (mtoe/Nbillion)

i = 1, for chemical and fertilizer industry

i = 2, for textile industry;

i = 3, for basic metals /alloys industry, and

i = 4, for other manufacturing industry and mining.

2.1 Scenario I demand projections

This is a trend extrapolation scenario. The following pieces of information were utilized to project energy demand, Scenario I as shown in Table 1.

- Values added in the Industrial Sector were estimated for 1995, 2000, 2005 and 2010 as per regression equation .1 of section 2.1 referred to above.
- The data source for value added figures also supplied relevant information, although indirectly, regarding percentage shares of value added in chemicals and fertilizers, textiles, metals/ Alloys and others.
- In view of non-availability of any information regarding electricity consumption intensity in Nigeria, these were assumed to be the same as applicable in the case of India.
- Similarly, intensity of consumption of non coking coal and fuel oil was taken to be the same as applicable for India. The non-coking coal and fuel oil consumptions were then bifurcated equally among the two constituent subsystems.
- The Naphtha demand, Nt, in year t in mtoe is projected on the basis of the following regression equation identified from data for the period 1995 to 2000:

$Nt = 0.21922x10^5 + 0.17911x10^5\ t\ R^2 = 0.933(4)$
$(0.15138 \times 10^5)\ (0.2439 \times 10)^4$
{0.907} {0.99999} [0.99999]

Where

Nt = the naphtha consumption in mtoe,

t = the time in years (1976 = 1).

2.2 Scenario II demand projections

As in Scenario I, the sectoral shares of values added in the chemical and fertilizers, textiles, basic metals/alloys and other industries are projected to increase gradually in line with the past trends as well. However, the energy demand in Scenario II is assumed to increase as the economy adopts a relatively higher energy intensity path.

The following specific assumptions have been made in projecting energy demand for Scenario II as shown in Table 2:

- The data for value added is taken to be same as for Scenario I.
- The relative shares of value added for the various constituent industries are also taken to be same as in Scenario I.
- Electricity consumption intensity is assumed to increase by 3% over Scenario I estimates.
- Similarly, an assumption is made that energy intensity for non-coking coal and fuel oil as well as for Naphta consumption is up by 3% over figures assumed in Scenario I.
- As in Scenario I, the total demand of non-coking coal and fuel oil I, is partially sub-divided among its two constituents.

The basic assumptions of Scenario II should be contrasted with the trend observed in other Non-OPEC developing countries like India, which would be trying to diversify away from energy intensive industries (such as Aluminium, Ferro-silicon etc).

Table 1: Scenario I energy demand projections for the industrial sector

	Unit	*1995`*	*2000*	*2005*	*2010*
a. Value added billion Naira		9.03	10.23	11.19	12.39
b. Share of value added					
— Chemicals and fertilizers	%	20.17	23.62	26.37	29.82
— Textiles	%	19.89	23.54	26.45	30.10
— Metals/alloys	%	20.59	23.74	26.25	29.40
— Others	%	39.35	29.10	21.93	11.68
c. Electricity intensity chemicals and fertilizers	mtoe/bill. Na.	3.6	3.6	3.6	3.6
—Textiles	mtoe/billion Naira	1.6	1.6	1.6	1.6
—Metals/Alloy	mtoe/billion Naira	6.1	6.1	6.1	6.1
Others	mtoe/billion Naira	0.96	1.08	1.145	1.21
d) Electricity demand	mtoe	24.17	30.581	35.9268	43.227
e) Non coking coal and fuel oil intensity mtoe/billion Naira	16	16	16	16	
f) Non-coking coal and fuel oil mtoe	14.44	16.36	17.90	19.9	
- Fueloil demand mtoe	7.22	8.18	8.95	9.95	
—Non coking coal demand mtoe	7.22	8.18	8.95	9.95	
g) Naphtha demand	mtoe	10.7867	14.368	17.957	21.5333

Table 2: Scenario II energy demand projections for the industrial sector

	Unit	1995	2000	2005	2010
a. Value added	Billion Naira	9.03	10.23	11.19	12.29
b. Share of value added					
— Chemicals and fertilizer	%	20.17	23.62	26.37	29.82
— Textiles	%	19.89	23.54	26.45	30.10
— Metals and alloys	%	20.599	23.74	26.25	29.40
— Others	%	39.45	29.10	21.93	11.68
c. Electricity intensity Chemicals and fertilizer	mtoe/bil. Na	3.6	3.708	3.82	3.93
—Textiles	mtoe./billion Naira	1.6	1.65	1.67	1.72
—Metals and alloys	mtoe/billion Naira	6.1	6.28	6.31	6.5
Others	mtoe/billion Naira	0.96	0.98	1.00	1.03
d. Electricity demand	Mtoe	24.17	27.880	32.330	43.22
e. Non coking coal & fuel oil					
Intensity mtoe/billion Naira	16	16	16	16	
f. Non - coking coal & fuel oil demand mtoe		14.44	16.36	17.90	19.9
- Fuel oil demand	mtoe	7.22	8.18	8.95	9,95
- Non - coking coal demand	mtoe	7.22	8.18	8.95	9.95
g. Naphtha demand	mtoe	10.7867	14.368	17.957	21.5333

2.3 Scenario III energy demand projections

The value added and its relative shares among the constituent industries are taken to be same as in Scenarios I and II. In view of the conservation orientation of the scenario, the following changes are considered with reference to Scenario I.

1. The electricity consumption intensity is assumed to be reduced by the use of proper sized, higher efficiency motors with power factor correction equipment.

   The relative economics of using more suitable or higher efficiency motors is assumed to be the same. With the use of such motors, the electricity consumption intensity projected is expected to reduce by about 8% by 2010 in the textiles, metals/ alloys and other categories of industries while that in chemicals and fertilizers is observed to remain unchanged.
2. Fuel oils and non-coking coals are conserved by the use of industrial boilers air- pre-heaters, economizers, furnaces recuperators and refrigerators as well as low grade solar industrial process water heating systems. The economics of applying heat recovery equipments and solar IPWH systems is assumed to be the same. The combined use of fuel oils and non-coking coals are assumed to be reduced by about 5% by the year 2005. Also, with the use of solar IPWH systems, a further combined reduction in demand of approximately 2 million tones of oil equivalent (mtoe) of fuel oils and coal demand is anticipated by 2010.
   - The demand for naphtha, however, is assumed to remain unchanged with reference to Scenario 1.
   - It is only a gradual uniform reduction in demand for electricity, fuel oils and non-coking coals, which is projected to take place as mentioned in the foregoing discussions.

2.4 Results

With the construction of a scenario building approach for an energy planning model in the industrial sector of Nigeria, the following results were obtained:

- Scenario I reviewed where major subsectors growth rate remain unchanged from the trends observed in the past, and where the ratio of energy consumption to activity level represented an average intensity.
- Scenario II indicated where the total energy demand-mix may change as the economy adopts a relatively high energy intensity growth part.
- Scenario III indicates where the total energy demand-mix may change further as energy conservation and demand management measures are adopted thereby reducing electricity consumption intensity as well as the consumption intensity for non-cooking coal and fuel in industry.

2.4.1 Discussion

The scenario building approach is particularly suitable where an input-output economic analysis is not feasible due to uncertainties in technological choices and the market environment. No doubt, the scenario approach is data intensive and entails considerable approximations, but the feasibility available to the analyst may be effectively used to analyze various policy options.

The policy options themselves become visible only due to the insight provided by this method in a rather simple manner.

3. Conclusion

This paper analysed the energy planning model industrial sector of Nigeria in a simple approach of projections to 1995, 2000, 2005 and 2010. The basis for a projection plan in the industrial sector is to estimate the likely changes in energy consumption intensity and the ratio of energy consumption to value added.

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