SUDAN Energy Sector: Current situation and future outlook

Ismail Elgizouli

1. *Introduction:*

1.1. Sudan Background: Location, Area:

Sudan is a vast country and one of the largest in the African continent with an area of 2.4 million square kilometers (WB 2016 indicators) with a low population density of 23 per square kilometer (world population review.com/ Sudan-population/ 2017).

Geographically the country lies between latitudes and longitude 15° 00 N and 30°00 E with varying rainfall zones ranging from 200mm and 1500mm and increasing from North to south. As the annual rain increases southwards, the vegetation changes from desert through Acacia desert scrub, Acacia woodland and broad leafed Savannah to tropical rain forest. Sudan's climate is very hot, every part of the country experiences average maximum temperatures of over 38°C during several months of the year. Also, Sudan has a tropical continental climate in a narrow fringe along the Red Sea coast and boarders 7 countries.

These geographical, natural characteristics has important energy resource related implications. Occupying such vast geographical areas with varying climatic condition the country is endowed with diverse energy resources ranging from oil, natural gas, biomass, hydro and most importantly renewable energy sources including solar, wind and geothermal energy resource potential that are abundant and well distributed across the country and could secure for long term strategic energy supplies.

1.2. Sudan energy demand drivers:

Drivers of energy demand are demographic (and social) as well economic and environmental. Increased cost of securing adequate energy services across vast areas to all of its population is a challenge. According the national census (2008) and indicated growth rates the total population of Sudan is estimated to be around 42 million inhabitants of whom 34% are urban dwellers (http://www.worldometers.info May 2017). Some estimates show that urban population has increased from only 11% in 1960 to 34% of total population in 2015 (World Bank indicators).

Urbanization is rapidly growing and consequently urban energy demand is increasing. The total population in Khartoum (Capital) according to some estimates ranges between 6-7 million represents 14-17% of the total population. Rural areas are remote while infrastructure is inadequate to support extension of centrally managed energy services.

Mentioned energy demand drivers emphasize the necessity of diversifying the countries energy supply mix by tapping renewable sources to secure low economic and environmental cost energy supply for economic growth as well rural and urban needs.

Another challenge is the energy requirement of economic growth. The pace of economic development is increasing rather higher compared to the historical conditions. Economic growth is a major energy demand driver. Energy is a critical input for achieving sustainable economic growth and is the key element in accelerating national economic development. Radical changes in the development of the whole economy are expected during the coming decades. Table () shows the growth rate of the economy during the years 2003 to 2015, GDP growth rate per annum (Table1) increased significantly with an average growth rate of 4.45% .

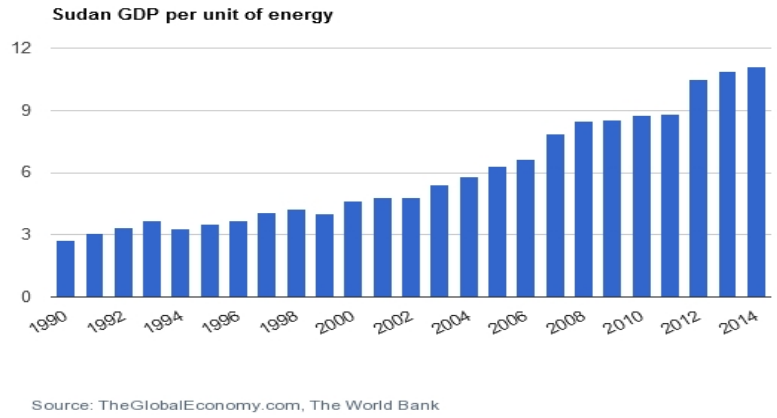
Table 1: Sudan GDP growth in constant 2010 US$

years	2000	2005	2010	2015
GDP in Billion US$	34.053	46.433	65.639	73.731

Source: World Bank national accounts data, and OECD National Accounts data files

However, GDP per unit of energy shows improvement in the efficiency of energy use from 3 to 11 GDP value per unit of energy.

Fig (1) Sudan GDP per unit energy

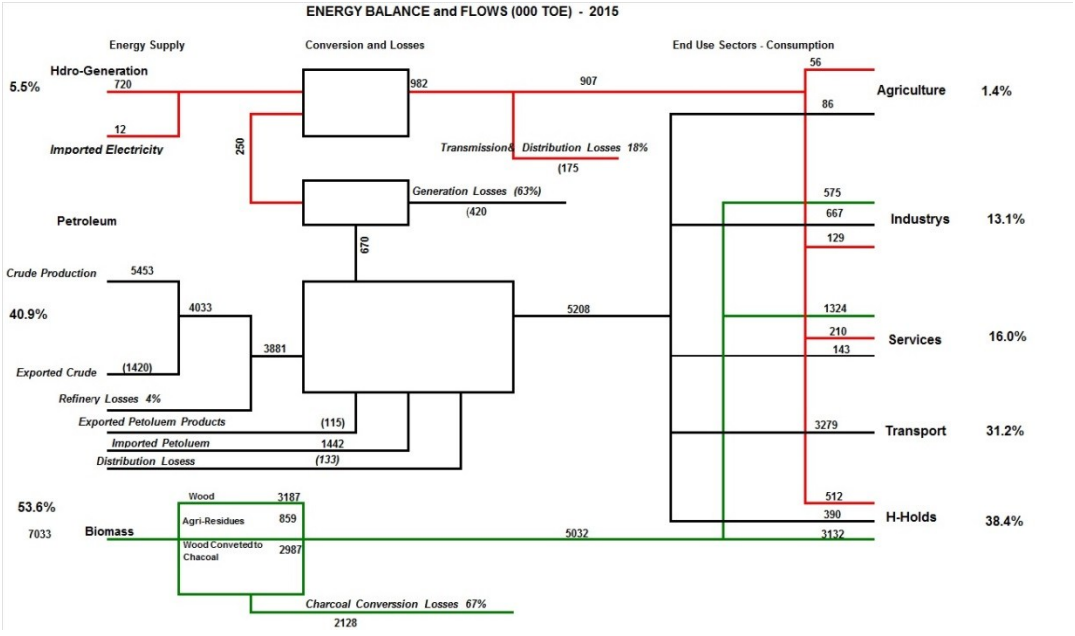


Future evolution of Sudan economy is the expected changes in the GDP share of the different economic sectors and more efficient use of energy.

2. Energy consumption patterns and trends:

Figure (2) below shows Sudan Energy balance for the year 2015 and depicts flow from different types of energy resources, conversion, transformation, distribution, losses through different processes and end user by sectors and type of final energy product consumption.

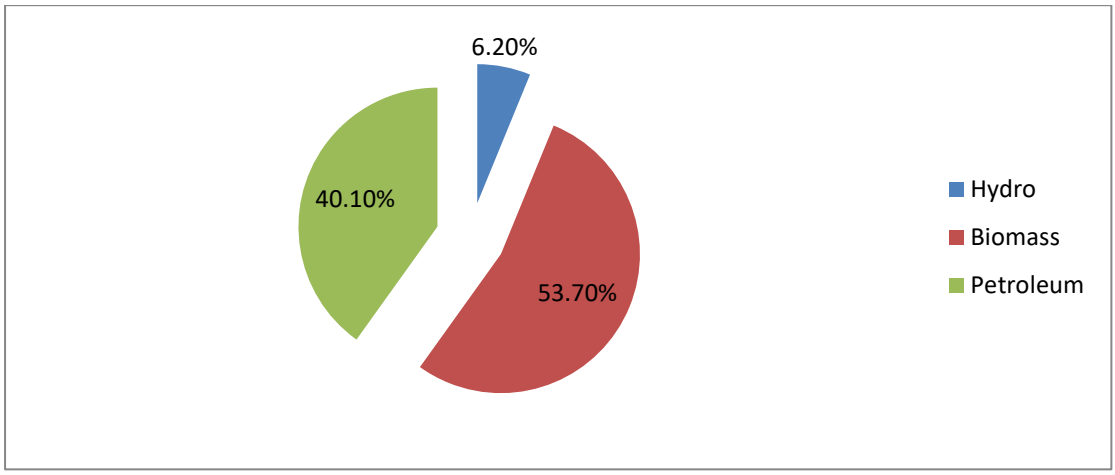
Fig (2) Sudan Energy balance 2015



Primary energy Supply:

Total primary energy supply for the year 2015 amounts to 13.1 million ton of oil equivalent where biomass represented 54% of the total primary energy supply followed by petroleum (40%) and hydro power (6.2%) including 1.5% imported through Ethiopian link power supply connection. (See figure)

Fig (3): Sudan: Primary Energy supply by type 2015



Biomass continued to be a dominant primary energy supply sources with an insignificant decrease mainly to petroleum supplies. Table () shows contribution of biomass to the total primary energy supply during the last 15 years. There is a decrease of the percentage contribution of biomass from 80.4% in the year 2000 to 53.1% of total primary energy supply. This decline in percentage may be seen as a positive sign that could contribute to alleviation of hazardous impacts on environment by both reduction of forest and green cover removal. However the total biomass input to primary energy supply has also increased in amount from 6 million toe to 7 million toe mostly from woody biomass. Programs are required to reduce both percent and quantities. Efforts on the demand side control by availing alternatives for example in cooking to reduce required supplies have faced disincentive due to removal of subsidies and liberalization of LPG markets leading to tremendous increase in prices. Policies to control tree cutting will not come to effect unless affordable alternatives are made available.

Table: (1) Primary Energy supply 2000 - 2015 (000 TOE).

Source	2000	%	2004	%	2007	%	2010	%	2015	%
Petroleum	1361	17.9	2478	27.7	3090	31.7	3935	35.7	5361	40.8
Electricity	135	1.9	186	2.1	329	3.4	518	4.7	804	6.1
Biomass	6115	80.4	6288	70.2	6323	64.9	6565	59.6	6979	53.1
Total	7610	100	8953	100	9742	100	11018	100	13144	100

Source General Administration for National Energy Affairs

Hydro power supply has increased significantly from 1.9% of total primary energy supply to 6.1% by establishment of Merwe hydro power generation. Hydro power generation also relieved primary

petroleum which would have increased at higher rates to provide for power generation now supplied by hydro sources.

Crude oil and Petroleum products supply have increased significantly during the period 2000 – 2015 with the large scale mining and oil exploration activities that required direct input as well supporting logistics mainly road transport in the absence of more efficient means e.g. railway and river vessels.

Total energy consumption and end use by sector:

Table (2) shows consumption of end use sectors by type of fuel and total energy consumption. It also shows consumption share of each end use sector from specific type of energy supply.

Table (2): Final Energy Consumption by Sector 2015 (000TOE)

sector	Electricity		Petroleum		Biomass		Total	%
Agriculture	56	6.2	86	1.9		0	142	1.4
Industry	129	14.2	667	14.6	575	11.4	1371	13.1
Services	210	23.2	143	3.1	1324	26.3	1677	16.0
Transport		0	3279	71.8		0	3279	31.2
Household	512	56.4	390	8.5	3132	62.3	4034	38.4
Total	907	100	4565	100	5031	100	10503	100

Source General Administration for National Energy Affairs

The main consumer of **biomass** is the household sector representing 62% of total biomass consumption or 3 million toe. Over 60% of biomass supply comes from woody biomass and used for cooking by households. This has serous implication on family's health through indoor pollution by smoke emitted from cooking firewood in addition to its negative on general environment as a result of emitted carbon dioxide and tree cutting. WHO identified health impact of smoke resulting from cooking by wood, residues and charcoal as number killer that affects women in particular in developing countries resulting in immature deaths of more than caused by Malaria, HIV, and TB collectively. Recent study by National Energy research center (household energy situation 2015) revealed that 49% in urban areas and 85% in rural areas use firewood for cooking while 82% in urban areas and 65% in rural areas use charcoal for cooking. Same survey indicated that 76% of Sudan population use low efficiency three stones for cooking using firewood. Loss of energy occurs at transformation to charcoal as well use of low efficiency stoves for wood or charcoal use for cooking. Service sector comes second in the use of biomass (26.3) again mainly for cooking and water heating. The third consumer is industry representing 11.4%. Brickmaking is the main consumer of biomass within industry sector.

Household sector consumes the largest share of electricity (56.4%) mainly in urban centers. National level of access to electricity is 34% according to the Ministry of water resources and electricity but far less in rural areas where access to electric power – according to some estimates is below 20% (UNDP human Development report 2015). Electricity consumption per capita has been estimated by the Ministry of Electricity at 233 KWh/year. Service sector is the second largest consumer of electric power (23.2%) followed by industry (14.2%) and a smaller amount in agriculture.

Inadequate supply for industry leaves only private thermal generation for the sector while low level of input to agriculture coincides with the low level of productivity due to limited use of technology that electricity would have provided access for (e.g. storage, irrigation water pumping and processing).

Table (3) shows that during the period 2000 – 2015 woody biomass remained the main biomass fuel consumed representing over 83% when combined with charcoal from the same woody sources.

Table (3) Biomass Consumption by Fuel Type (Million TOE)

Fuel	2000	%	2004	%	2007	%	2010	%	2015	%
Wood	3.85	62.5	3.96	62.4	4.04	62.6	4.12	62.7	3.187	63.3
Charcoal	1.26	20.5	1.29	20.3	1.3	20.2	1.33	20.2	0.986	19.6
Residues	1.05	17.0	1.1	17.3	1.11	17.2	1.11	16.9	0.859	17.1
Total Biomass	6.16	100	6.35	100	6.45	100	6.57	100	5.032	100

Table (4) below shows the development of hydro power share in total electric power generation rising from only 27% compared 73% thermal to 73% of total power generation in 2015. Imported hydropower from Ethiopia is expected to increase and suppress the need for thermal generation to their minimum as standby capacity.

Table (4): Electricity Generation by Type and Imported (GWH)

type	2008	%	2010	%	2012	%	2015	%
Hydro	1466	26.6	6202	82.7	6619	70.1	8365.75	73.3
Thermal	4041	73.4	1297	17.3	2817	29.9	2905.63	25.5
Imported	0	0	0	0	0	0	142.27	1.2
Total	5507	100	7499	100	9436	100	11414	

Transport sector consumes most of petroleum products (72%) mainly for energy intensive road transport. Loss of low energy intensity and low cost means for transport of people and goods represented by rail and river means have led to increased consumption of petroleum products that represent the main CO2 emitter and air polluter in the country. Second largest consumer of petroleum products is the industry sector using 14.1% with significant percentage used for thermal power generation.
Smaller amounts used by service sector (mainly LPG for cooking or diesel for power generation) and in irrigation mainly large irrigated schemes. Due to the loss of over 60% of crude oil supplies the country is burdened by export of some products (gasoil) and purchase of crude for local refineries from oil companies share in the limited local crude oil production.

Energy transformation and distribution:

Energy is transformed from one type to another at high levels of energy content losses. In 2015. Thermal generation losses of 63% amounted to 420,000 toe while transformation of wood to charcoal at 67 loss percent amounted to 2128,000 toe. Losses add to power distribution losses of 18% (175,000 toe) to make a total of 2723 or 21% of total primary energy supply according to General directorate of energy affairs.

End use Sectors by source of energy supply:

Table (5) shows relevant values of different energy sources on the total sector energy consumption in 2015. Total energy consumption of agricultural sector is represented from petroleum (60%) and electricity (40%). Main energy sources for industry are petroleum products (49%) and biomass (42%) while smaller portion of industry total energy consumption comes from grid electric power. This confirms what have mentioned above about reliance of industry on thermal power generation and intense use of biomass in brick making industry.

Services sector relies on biomass for 79% of its total energy consumption mainly for cooking and water heating with 8.5% of consumption in petroleum products mainly LPG for cooking and small part (12.5%) of electricity consumption for lighting and equipment's operation.78% of household energy consumption comes from biomass which is used for cooking together 12.5% from electricity for lighting, refrigeration, kitchen equipment's, water pumps and ventilation. The 9.7% of total household energy consumption which is supplied by petroleum is LPG and other products used for cooking in addition to lighting. Petroleum materials are seldom used for cooking.

Table 5: Final Energy Consumption By Sector 2015 (%)

	Electricity	Petroleum	Biomass	Total
Agriculture	39.4	60.6	0.0	100.0
Industry	9.4	48.7	41.9	100.0
Services	12.5	8.5	79.0	100.0
Transport	0.0	100.0	0.0	100.0
Household	12.7	9.7	77.6	100.0
Total	8.6	43.5	47.9	100.0

3. Sudan energy system and the environment:

Balancing energy and environment equation is a key input for attainment of the stated poverty reduction strategies in with the global SDGs and formulating sustainable programs and projects for poverty reduction. Sudan signed the UNFCCC in Rio1992 and ratified in November 1993 and signed the ratification of Kyoto Protocol in 2004. Sudan has a low per capita CO2 emission rate of an average of 0.3 Mt (see table Sudan indicators WB 2015) compared to per capita 17, 11, 14, 4.7 and 0.9 Mt United States, High-income OECD, Canada, Arab World and Sub-Saharan Africa (table (5). However Sudan faces serious negative environmental and climate change impacts. Most of the Sudanese population livelihoods are natural resource base that is sensitive to changes in temperature and precipitation. Low and intermittent rain fall due to climate change leads to reduced crop production, poor range and animal condition and consequent food insecurity and conflicts. Over 90% of Sudan's emitted CO2 comes from petroleum products use. Dependence on biomass mainly wood for 60% of the country's energy supply mainly to meet household cooking and brick making requirements stand as a direct cause for forest removal, decreased rainfall and desert encroachment at the expense of cultivable areas. Fig (4) shows Sudan carbon dioxide emissions 1980-2012

Fig (4): Sudan carbon dioxide emissions 1980 - 2012

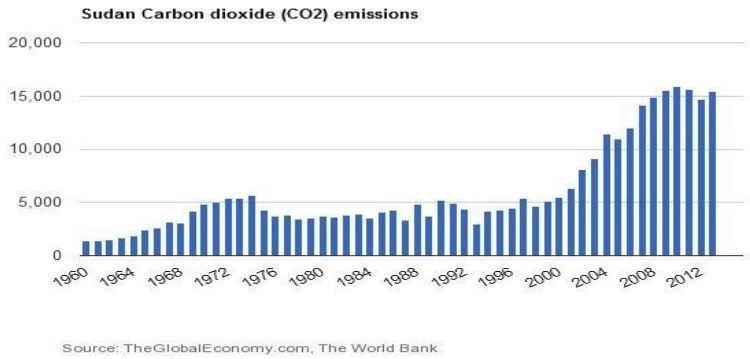
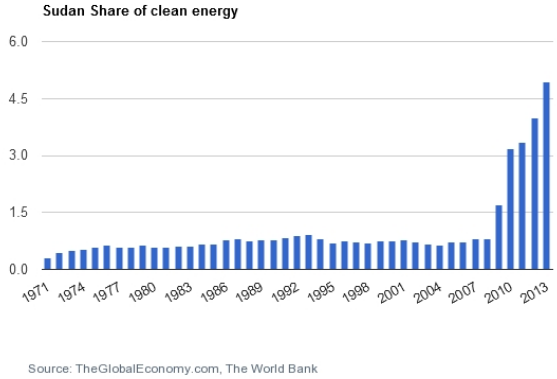


Table (6): World Development Indicators (CO2 emissions (metric tons per capita) 4/27/2017

Country Name	2010	2011	2012	2013
Arab World	4.7	4.6	4.9	4.7
Canada	14.5	14.5	13.9	13.5
China	6.6	7.2	7.4	7.6
United Kingdom	7.9	7.1	7.3	7.1
High income	11.5	11.2	11.1	11.0
North America	17.2	16.8	16.0	16.1
Sudan	0.4	0.3	0.3	0.3
Sub-Saharan Africa	0.9	0.9	0.8	0.8
United States	17.5	17.0	16.3	16.4
World	4.8	5.0	5.0	5.0

Source: WB indicators 2015

Fig (5) shows increase in the share of clean energy mainly by hyro power electricty generation and use of LPG for cooking.



4. The way forward

4.1. Rationale for renewable energy development in Sudan:

Available data from Sudan energy balance confirms that Sudan energy system faces serious discrepancies that constrain its ability to avail sustainable energy services for all. Dependence on non-renewable biomass has serious impacts on environment and population health. The massive use of wood and charcoal contributes to decrease in forest resources. Unorganized cutting of trees for wood and charcoal production occurs throughout the country. However, the pressure is greater on the limited biomass resources. Shortage of biomass resources lead to higher prices of wood and charcoal and consume a high percent of poor family's incomes.
Fossil fuel intensive transport and industry are the main emitters of carbon dioxide. Inefficient transformation of wood to charcoal and fossil fuel to electric power, distribution burden the energy system with significant losses. Inefficient end use technologies in for example cooking or brick and bread making further mount losses and negative environmental impacts.
Although Sudan has a very low per capita carbon dioxide emission rates but it is one of the most affected by global environmental change. A recent report by UNDP estimates loss of 70% of sorghum crop production by expected increase of temperature in Sudan during the period of 1930 – 1960. Locally dependence of the country population on wood fuel and charcoal leads to fast depletion of forest, low rainfall, desert encroach and loss of cultivable land threatening most of the populations food security. Renewables development can avail low cost, environment friendly source of energy.

The most oblivious is the fact the country is rich in renewable energy resources that are abundant and fairly distributed across the country. Those include wind, solar, agricultural residues, hydro power and geothermal potentials. In contrast to conventional energy renewable energy sources are well distributed across the vast area of the country and need little transmission and distribution costs compared to centralized systems.
Sudan enjoys significant renewable energy resource potential including average daily of 5.8 – 7.2 Kwh/m2 and wind speed of 4.2 – 8.1 meter/second at 80 meters above ground level (Solar and Wind Atlases – M of Electricity). Sudan has ambitious plan for rural electrification using renewable energy potential (e.g. 1.1 million rural household SHS plan) and policies exempting solar equipment from import tax have been issued since years ago. However lack of funds and lack of commitment to implement and enforce stated policies have made plans and arrangements ineffective**.**

Considering a country like Sudan where only 34% who mainly urban are serviced with electricity; renewable energy offers a feasible energy service and development of rural population. Renewable energy can initiate rural development by providing energy for essential economic and social as well as productive and educational activities.

Renewable energy can facilitate attainment of SDG goal of poverty reduction by providing rural poor access to energy services and renewable energy technologies for water pumping for domestic and irrigation thus increasing production and income of the poor while strengthening food and livelihoods security.