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United Nations Conference on New and Renewable Sources of Energy

Nairobi, Kenya
10-21 August 1981

Distr.
GENERAL

A/CONF/100/NR/11 *
20 March 1981

ENGLISH ONLY

NATIONAL REPORT SUBMITTED BY

THE SUDAN **

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1. Background

1.1 Geographical and Socio-Economic Conditions of Sudan

Sudan lies in Central Africa between latitudes 4^{o} and 22^{o} North and Longitudes 22^{o} - 38^{o} East. It is the largest country in Africa with an area of 2.5 millions square kilometers. The population is just under 18 millions with rate of growth of 2.7%. Nearly 85% of the population live in rural area, but the rate of urbanization is increasing fast.

The labour force is estimated to be around 5 million person and at least 70% of this force is engaged in agriculture. The Country is rich in water, animal and land resources. The climate ranges from tropical in the South to extremely arid in the Northern desert. Rainfed land is abundant in the South, South West and South East, while the Nile river and its tributaries, the White Nile and the Blue Nile constitute the principal life sustaining arteries above the twelfth parallel.

Cultavable land is estimated to equal 80 million hectars but only 31 million hectars are utilized so far for crops production and grazing. The animal wealth is about 51.3 million heads. As for mineral and energy resources the Sudan has an important potential which remained untapped for a number of economical reasons - the shortage of foreign exchange and lack of infra structure being the main ones.

1.2. The Present Situation of the Major Economic Sectors

1.2.1. Agriculture

Agriculture is the dominant economic sector in Sudan. Crops production and animal herding employ the majority of the nation population and contributes the largest share of G.D.P. which amounted to 31.5% in 1979/80.

Almost all Sudan exports are provided by agricultural crops. The national development plans interlink the development

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in all sectors with agriculture as agriculture assumes the leading role in national economy. So far, moderization of agriculture is limited and traditional agriculture prevails small owner farming with primitive tools and equipment and hence low productivity is still dominent. The country has undertaken lately measures that promote moderization in agriculture.

Modern commercial agricultural projects which are export oriented are the main components of the nation development plan. These include projects at Kennana, Sennar, Rahad, Blue Nile, Damazine and others. Agriculture consumed 13.6% of the commercial energy produced in 1979/80.

1.2.2. Industry

Industry in Sudan is in its infancy and gradual move towards industrilization is witnessed. The growing industry makes use of locally produced raw materials and is characterized by the pre-dominance of import - substitution activities. Intergration of agriculture and industry is emphasized in the national development plans particularly in agricultural/livestock processing.

Also promotion of mining and mineral industries, tapping the vast mineral resources of the Sudan, is a high priority policy for the government. A number of commercially feasible industries have already started in Sudan like chromite processing and cement production. Natural gas has been found in the Red Sea area and gypsum and asbestos are targeted for future investment. Recent discoveries of light crude oil have been made in Sudan and a small refinery of 5-6 thousand barrells per day is scheduled to be erected soon.

Industry now consumes about 18.4% of the total commercial energy produced.

1.2.3. Transport and Communications

The fact that Sudan is a large country with wide dispersion of centres of population warrants the establishment of

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a country wide net work of high ways, railways, inland water ways and air services, to promote development in all economical sectors.

The existing railway system is incapable to meet transport requirement for export and import products that need to be moved more than 1000 miles to and from Port Sudan. This situation has led to an enormous growth on road traffic aggravating the energy intensity of transportation. This sector is the major user of commercial energy and the percentage consumed by it in 1979/80 reached 54.5%. The road linking Khartoum to Port Sudan and passing through the agriculturally and minerally rich regions of Gezira, Blue Nile, Kassala and Red Sea provinces is now completed. The roads linking Khartoum to Damazine and Kosti via Sennar are under way to completion. Plans are in progress to revitalize the railways by increasing capacity through track improvement. The harbour at Port Sudan is receiving special attention to improve all services and also Suakin old harbour is under rejuvenation. The conventional tele-communication systems exist and sophisticated equipment such as micro-wave links and satellite communication have been introduced in the country.

Table (I) shows the contribution of the different economical sectors to the G.D.P. for the year 1979/80.

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Table (1). Contribution of Different Economical Sectors to G.D.P. 1979/80

Economic Sector	Contribution to G.D.P. in 1000 Sudanese Pounds	% of Total G.D.P.
Agriculture	1006.2	31.5
Industry	263.7	8.2
Mining	88.0	0.3
Electricity and Water	36.4	1.1
Construction	200.7	6.3
Trade	496.0	15.5
Transportation	419.2	13.1
Government Services	312.7	9.8
Other Services	455.2	14.2
TOTAL	3198.9	100.0

Export Earnings 1979/80 = LS. Million 232.7

Imports 1979/80 = LS. Million 477.3

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2. The Present Energy Situation in Sudan

2/1. General

The main present sources of energy in Sudan are imported oil, locally produced wood fuel and to a much lesser extent hydro electric power. The quantity of crude oil imported during 1979/80 and processed in Port Sudan refinery amounted to 1 million tons and in addition about 200,000 tons of processed oil were also imported. Oil products and electricity generated thermally and hydro-electrically constitute the only commercial source of energy which amounts to 22.66% of the estimated total energy consumption in the country for the fiscal year 1979/80. Non commercial energy in the form of fire wood, charcoal, agricultural crop residues and animate power contributed 77.34% of the total energy consumed in 1979/80.

2.2. Commercial Energy :-

2.2.1. Petroleum Products

Petroleum products are the principal commercial fuels in the country. They constitute 98% of the total commercial energy used. With the exception of hydro power used for a portion of electricity generation and a small amount of baggasse, petroleum products supply virtually all modern sectors with their energy requirements including that used in transport, modern industry and processing and mechanized agriculture. For the last 5 years, there was an annual increase in petroleum products consumption averaging 6.3%. In industry the annual growth of petroleum products consumption averaged 9.6% and it ranged between 4.9% and 6.7% in other commercial sectors.

2.2.2. Electric Power

Electric power contributed 2% of the total commercial energy used in 1979/80. Of the total 892 G.w.h. generated, 233 G.w.h. or 26.1% was thermally produced from 17 isolated stations and 659 G.w.h or 73.9% was produced hydroelectrically from 3 stations.

Contd/6...

Two national grids exist in the country. The Blue Nile grid links Roseris hydroelectric power station via Sennar hydrostation with the major load centers of Khartoum and connects Sennar station to Gezira and White Nile provinces. The Eastern grid links Khashm El Girba hydroelectric station with the major load centers of Kassala province.

The currently installed capacity of electricity power is inadequate for current needs and is one of the major constraints on industrial sector productivity and growth. It is also responsible for the low foreign investment and the slow expansion of industry.

Production figures for the last 5 years show an average annual growth of 10.5% in overall electricity generation. Growth in consumption have risen in the same period by 13.5% in industry, 5.7% in residential and services sector and 2% in agriculture. Development of electricity generation passed through two stages. The third stage which is under development is the power III project which aims to double electricity capacity by the year 1983.

Table II shows national grids, thermal and hydroelectrical energy generated in 1979/80.

2.3. Non Commercial Energy

2.3.1. General

Non commercial energy in the form of wood fuel, agricultural crops residues and animate power contributed 77.34% of the total estimated energy consumed in the country during 1979/80. The share of each source was estimated as follows :-

Wood Fuel		
Fire wood	69.13%	
Charcoal	5.99%	75.12%
Agricultural Residue		
Crops residue	0.78%	
Animal refuse	0.59%	1.37%

Contd/7...

Table (II). National Grids and Thermal and Hydro Stations Installed Capacity and Energy Generated in 1979 - 80.

National Grids and Electricity Stations	Installed Capacity MW	Energy Generated 1979 - 80 G.W.h.		
		Hydro	Thermal	Total
Blue Nile Grid	229.3	637.5	110.7	748.2
Eastern Grid	20.4	21.3	—	21.3
Dueim	0.9	—	3.7	3.7
Kassalla	5.1	—	5.6	5.6
Atbarra	13.0	—	21.4	21.4
Dongolla	0.4	—	1.2	1.2
Shendi	1.2	—	4.3	4.3
Port Sudan	14.1	—	32.9	32.9
Malakal	0.9	—	1.0	1.0
Wau	0.9	—	1.0	1.0
Juba	6.0	—	36.8	36.8
El Obied	5.1	—	5.3	5.3
Umroaba	1.3	—	2.8	2.8
El Fashir	1.3	—	2.5	2.5
Nyala	0.9	—	3.9	3.9
TOTAL	300.9	658.8	233.2	892.0

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Animate Power	0.85%
Total	77.34%

2.3.2. Wood Fuel ;-

a. Fire Wood

The total amount of fire wood consumed in 1979-80 was estimated to be 10.65 million tons. Nearly 98% of this quantity was utilized as house hold fuels and in domestic services and bakeries, mostly in rural areas. About 2% of the total fire wood consumed was the only available fuel for the rural industries of brick burning, pottery, tobacco curing and production of steam for the processing of vegetable oils etc.

Almost all the fire wood produced was obtained from the natural forests and the desert scrub. Wood fuel plantations contribution was about 1.3%.

Fire wood is obtained for house hold consumption either free or at very low cost but royalties are collected against the amounts used in bakeries and rural industries. A considerable amount of fire wood is railed and road transported to the big population centres from distances reaching more than 500 kilometers to be used mainly as fuel in bakeries and in brick burning. Cost of transported fire wood is very high.

b. Charcoal

The main house hold and domestic fuel in urban areas of Sudan is charcoal. In 1979-80 the amount produced and consumed totalled approximately 550,000 tons. Like fire wood, charcoal is obtained from natural forests. It is produced by the primitive local earth kilns where quality is poor and recovery percentage very low, not exceeding 15%. Unlike fire wood, charcoal is costy. It is railed and transported by road and river from far, away distances.

The total amount of wood fuel in the form of fire wood and charcoal removed from the forests annually exceeds 13

million tons. The annual rate of increase of consumption is 2.2%. This sort of utilization of wood fuel already has its bad effects shown in the desert creep, soil degradation and increased aridity in many parts of Northern, Central and Western Sudan. Meanwhile the expansion in agriculture stripes more lands annually from their forest cover. The afforestation program is meager and inadequate to curb the adverse change in environment. This situation beside its harmful effects on agriculture, the major economic sector of the country, will also affect seriously fire wood supply and demand balances in the near future.

2.3.3. Agricultural Residues

The Sudan, being an agricultural country, has a great potential of crops residue to be utilized as energy. Quantity of crop residue so far estimated exceeds 3 million M.T. annually. At present only a small portion is used in the rural areas as house hold and domestic fuels. In case of bagasse, it is utilized in the sugar factories for the generation of electricity, where the amount generated is estimated to be 20 G.w.h.

The use of the animal refuse is negligible and is only practised in some parts of the Northern Province.

2.3.4. ANIMATE POWER

As for animate power, the contribution in total energy consumption is considerable and is estimated to be 0.87% of the total energy. Animate power is mainly used in irrigation, agriculture, transport and house hold and domestic services.

Table III ; Sumarises total energy consumption in 1979/80.

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Table (III) T O T A L E N E R G Y C O N S U M P T I O N 1979 - 80

TYPE OF ENERGY	UNITS	Quantity Available locally for Energy	Quantity Imported 1000 Tons	Cost 1000 £S	% of Total Cost	Oil Equivalent 1000Tns	% of Total Energy Used	% of Commercial Energy	Per capital 79-80 E.Cons Kg.Oil	Per capital 79-80 Cost £.S.	Distribution Among Economical Sectors % Residential + Service	Electricity	Industry	Transport	Agriculture
(A) COMMERCIAL															
Oil I	1000 Tons	—	1202	128689	70.82	1106	21.63	98.0	61.44	6.661	4	6.4	15.7	55.5	18.4
2. ELECTRICITY															
i. Hydro	G.W.H.	658.8	—	—	—	50.8	1.00	1.47	1.04	—	—	—	—	—	—
ii. Thermol Oil	"	213.2	—	—	—	*(16.5)	—	0.48	—	—	—	—	—	—	—
iii. Thermol Biomass	"	20.0	—	—	—	1.7	0.03	0.05	0.09	—	—	—	—	—	—
Total Electricity		892.0	—	53000	29.18	69	1.03	2	3.83	2.700	47.4	—	49.6	—	3.00
TOTAL COMMERCIAL		892.0	1202	181689	100.00	1158.2	22.66	100.00	65.27	9.361	7.2	6.3	18.4	54.5	13.6
(B) NON-COMMERCIAL								% of Non Com. E							
(1) Biomass															
(i) Wood Fuel															
(a) Fire Wood	1000 Tons	1065	—	6000	11.10	3534	69.13	—	196.43	0.333	98	—	2	—	—
(b) Char-Coal	1000 Tons	550	—	33000	61.05	306	5.99	—	17.00	1.833	100	—	—	—	—
Total Wood Fuel		11200	—	39000	72.15	3840	75.12	97.15	213.43	2.166	99	—	1	—	—
(ii) Agri-Residue															
(a) Corp. Residue	1000 Tons	120	—	15	0.03	40	0.78	—	2.22	—	75	25	—	—	—
(b) Animal-Refuse	1000 Tons	50	—	12	0.02	30	0.59	—	1.66	—	100	—	—	—	—
Total Agr. Residue		170	—	27	0.05	70	1.37	1.75	3.88	0.002	86	14	—	—	—
(2) ANIMATE	Million H.P hour	750	—	15000	27.84	43.5	0.85	1.10	2.41	0.833	25	—	—	30	45
TOTAL-NON-COMMERCIAL		—	—	54027	100.00	3953.5	77.34	—	219.72	3.001	97.534	0.002	0.014	0.004	0.005
GRAND TOTAL		—	1202	262689		5112	100	—	282.29	12.362	77.2	2.5	4.1	11.9	4.3

* ( ) Included in Oil

G.D.P (1979-80) £S.179.4 Per Capita, Total = LS.3198.9 millions

All Energy Consumption per capital £.S.of G.D.P.(Kilogram Oil equivalent) $= \frac{5112 (1000 \text{ Tons})}{3198.9 (\text{millions})} = 1.60$

Commercial " " " " " " " " " " $= \frac{1158.5}{3198.9} = 0.36$

Non Commercial " " " " " " " " " " $= \frac{3953.5}{3198.9} = 1.24$

3- The Role of New & Renewable Energy Resources in the country's Future Economy

3.1 General

As stated earlier in this paper, the two main fuel sources for Sudan, are, at present, imported oil fuels and locally produced wood fuels. With the present rise in the prices of oil fuels and their serious effect on the country's balance of payments and the country's development in general, consideration of new & renewable sources of energy is pertinent. The present pattern of utilization of wood fuel is both wasteful and harmful to the country's economy. The need to develop the use of wood fuel more efficiently and economically is urgent and should go hand by hand with the developing of other new and renewable resources.

3.2 The Development of Biomass

3.2.1. Wood fuel :-

a- fire wood :-

Inspite of the fact that huge amounts of fire wood, to the extent of more than 10 million M.T, are burned directly as fuel with heat recovery not exceeding 6%, it is not easy to convert this type of fuel into the modern forms of energy like methanol or gaseous energy; the main reasons being the scatterment of the resource and the costy operation of collection - let alone the difficulties of introduction of modern technologies that entail a lot of financing, experties and the social problems. For these reasons fire wood is going to be used in the same pattern, may be for the next two decades. There is however, small hope of increasing the efficiency of use to raise the % age of efficiency system by +2 or 3% age and that is where fire wood is used in such industries and services like bricks burning, lime production and steam production.

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b- Charcool :-

As for this type of fuel there is a wide scope to develope both production and consumption methods to reduce waste enormously and to render more volume, available with the same volume of raw materials. The Forest Department in the Sudan is planning to improve on charcool production and to raise quality and production recovery through the introduction of modern types of kilns.

Some types of French metalic kilns were introduced in the country. The expansion of their use was limited to certain factors- e.g. transportation from place to place and the small production capacity they have. Since all charcool is produced now from natural forests, which are characterized as scattered and where mechanized agriculture is expanding among these natural forests pushing this resource further away from consumption areas; the installation of modern kilns in these natural forests will not be feasibly economical. Stationed modern types of kilns can ecconomically be used with wood fuel plantations where the resources at the raw materials can be renewed annually through the managed growth. So, for the development of wood fuel as a major source of energy in the Sudan the establishment of wood fuel plantation is very important in the rang of 120,000 Hectares annually. The present rate of afforestation does not exceed 7000 hectares or only 6% of what should be planted per annum which can result in defficiency of wood fuel production just after 1985. The reason for this meager afforestation program is mainly financial, since at least LS.250 are required to establish I hectare of plantation including tending and protecting operations for the first five years of

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the plantation age. This cost can greatly be reduced if the concerned population can be attracted to participate in all or some of the plantation operations. Such measures require public alertness through a vast and detailed program of education and social culture. Recently Sudan has been aided by some of the international agencies into this effect e.g. the International Council of Churches is working on an affroestation program in the Nile Province where farmers are taking an active part in it.

The second important activity is to improve on charcool consumption efficiency. This is taken over by the Energy Institute in the Sudan where work is under way for the development of local stoves using charcool. Table IV shows the wood resources in the Sudan, the annual losses and the allowable cut that can be utilized as wood fuel.

Table V: shows wood fuel supply & demand analysis in the Sudan up to the year 2000.

3.2.2. Agricultural Crops and Crops Residues :-

There is a great potential in the Sudan to use crops and crops residues as source of fuel. As for crops it is not likely for the coming ten years to use any of the energy rich crops like sugar cane, sweet sorghum & cassava for fuels because of priority of food production. But, after that they will surely contribute considerably to the problem of energy. In the case of agricultural crops residues the potential is already big. At least 3,089,000 M.T. of Crops residue is available now to be utilized as energy. This amount is estimated to give 1.58 million tons of oil equivalent if directly combusted, 120 millions Gallons of alcohol if distilled,3700 million cu ft of biogas and 37000 mill. cu.ft of lowBTU gas if it is gasified. The main difficulties in utilizing residual crops now are collection and

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Table (IV) Shows The Wood Resources In Sudan, Annual Losses and Allowable Cut to Be Used As Fuel

Type of Forests In Sudan	Area in Square Kms	Total Growing Stock in million tons	Annual Allowable Cut in million tons
Protective Forests on dry and Semi arid area	42,000	16.3	—
Natural productive Forests	413,000	428.3	21.41
Forests Plantations	1,361	2.4	0.13
Sub - Total	456.361	447.0	21.54
Annual Losses	Area In Square Kms	Wood in Million tons	
1. Due to fire	25.0	0.25	
2. Due to over grazing	283.0	0.29	
3. Due to shifting agric.	217.0	0.22	
4. Due to drought spells and other causes	167.0	0.17	
5. Due to expansion of mechanized agric.	667.0	0.65	
Sub - Total	1359	1.58	1.58
Residual Wood Used For Other Purposes			2.63
Net Allowable Annual Cut for Wood fuel			17.33

Contd/15...

Table (V)

FUEL WOOD SUPPLY / DEMAND ANALYSIS IN SUDAN UP TO THE YEAR 2000 BASED ON RENEWABLE ENERGY TASK FORCE STUDY WITH SOME MODIFICATIONS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
YEAR	POPULATION In millions: URBAN POPULATION	RURAL POPULATION	TOTAL POPULATION	PER CAPITA CONSUMPTION OF FIRE WOOD - Kg	PER CAPITA CONSUMPTION OF CHAR COAL	TOTAL CONSUMPTION OF FIRE WOOD- MILLION TONS	TOTAL CONSUMPTION OF CHAR COAL - MILLION TONS	WOOD EQUIVALENT OF CHAR COAL - MILLION TONS	TOTAL CONSUMPTION OF WOOD FUEL - MILLION TONS	ALTERNATIVE FUEL SUBISTITUTION %	NET WOOD FUEL CONSUMPTION MILLION TONS	AREA OF NATURAL FORESTS MILLION HECTARS	POTENTIAL OF WOOD FUEL PRODUCTION FROM NATURAL FORESTS - MILLION TONS	AREA OF FORESTS PLANTATION - IN HECTARS	POTENTIAL OF WOOD FUEL PRODUCTION FROM PLANTATION IN MILLION TONS	TOTAL POTENTIAL WOOD FUEL PRODUCTION IN MILLION TONS	DEFICIT IN TOTAL WOOD FUEL NEEDED IN MILLION TONS	AREA OF PLANTATIONS REQUIRED IN MILLION HECTARS	PROGRAM OF ANNUAL PLANTATIONS - IN MILLION HECTARS
1979	2.5	15.0	17.5	594	29.7	10.4	0.52	3.0	13.4	-	13.4	40	17.2	135000	0.13	17.33	-	-	-
1981	2.7	16.8	18.5	589	31.3	10.9	0.58	3.3	14.2	-	14.2	39	16.8	148000	0.14	16.94	-	-	0.12
1985	3.0	19.2	22.2	548	27.5	12.2	0.61	3.5	15.7	-	15.7	37	15.9	161000	0.16	16.05	-	-	
1990	3.4	21.8	25.2	548	27.5	13.8	0.69	4.0	17.8	5	16.9	35	15.0	181000	0.17	15.17	2.63	0.66	
2000	4.5	28.0	32.5	549	27.0	17.7	0.88	5.0	22.7	10	19.4	30	12.9	206000	0.20	13.10	9.60	2.40	

Data Sources and main assumptions

1. Columns (1), (2) and (3) - Department of Statistics
2. Columns (4), (5), (6), (7), (8) and (9) - Forests Department
3. Column (10) an arbitrary assumption of the maximum likely subsitution of wood by other forms of renewable energy - estimated by (N.E.A.)
4. Column (11) estimated by National Energy Administration (N.E.A.)
5. Columns (12), (13), (14), (15) and (16) Forests Dept.
6. Columns (17), (18), and (19) estimated by (N.E.A.)

transport costs since these residues are scattered in enormous areas of the country. It is in the plans of the government to undertake feasibility studies for at least production of ethanol from molasses now produced in big quantities by the sugar industry for the purpose of blending with gasoline. Meanwhile bagasse is being used to generate electricity in the sugar factories. The quantity of electricity generated in 1979/80 by burning bagass was estimated to be 20 G.W.h.

Table V[illegible] shows the estimated quantities of crops residues that can be used as energy in the forms of solids, liquids and gaseous fuels.

3.3 Hydro Electrical - Power

Hydro energy is by far the best studied resource in the country and it accounts for more than 78% of the entire development of electrical energy. The potential hydro-energy sets cover all the reaches of the nile from southern boarders to the northern boarders. This can suffice for the high propulation densities along the Nile. This potential as estimated can allow for an installed power capacity of 3370 MW generating annually 21217GWH.

When comparing this to the present utilization of hydro electric power where only 249.7 MW power is installed i.e. 7.4% and generating 892 GWH i.e. 4.2%, the remaining potential to be developed is enormous.

According to the cost of installation of 80% hydro electric power to utilize this potential in 1978, the total sum of LS.3587.5 million is too large for the country to undertake at its present financial situation.

As the development of hydroelectric power will have after benefits to the country connected with the exploitation of surface water resources on national level, this program will have its due consideration as soon as the financial position improves.

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Table (VI): ENERGY FROM CROPS RESIDUES IN OIL EQUIVALENT IN SUDAN

CROP RESIDUE	Available Residue In 1000 Tons	POTENTIAL ENERGY					
		As Solid Fuel In Oil Equiva-lent 1000 Tons	AS LIQUID FUEL		AS GASEOUS FUEL		
			Million Gallons of Alcohol	In Oil Equiv-alent 1000 Tons	Biogas Million Cubic Feet	Low BTU GAS Mill-ion BTO	In Oil Equivalent 1000 Tons
COTTON	591.2	314	23.06	61.5	709.5	7095.0	78.8
MILLET	292.4	155	11.41	30.4	350.9	3509.3	39.0
WHEAT	270.3	111	10.54	28.1	324.5	3244.6	36.1
SORGUM	1071.8	542	41.80	111.5	1286.1	12861.0	142.9
RICE	582.3	309	22.71	60.2	698.8	6988.2	77.6
SUGAR CANE	281.8	149	10.99	29.3	338.2	3381.6	37.5
TOTAL	3039.8	1580	120.51	321.0	3708.0	37079.7	411.9

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Table VII : shows the potential capacity of hydroelectric power that can be installed, electricity that can be generated and the proposed sites of dams.

3.4 Solar Energy

3.4.1 INTRODUCTION

The earth receives daily from the Sun an amount of energy equivalent to 2.4×10^{12} barrels of oil which is equal to the known world reserves of oil. About 30 per cent of this energy is reflected and scattered to the outer space by the upper layers of the atmosphere. 17 per cent is absorbed by clouds and atmospheric constituents and emitted also to outer space as infra red rays. 22 per cent reaches the surface as diffuse sky radiation. Only 31 per cent reaches the earth's surface as direct-beam solar radiation.

Part of the incoming sunshine is absorbed during the photosynthesis process by green plants for the growth of organic matter. Though plants convert only one per cent of energy they receive, yet this energy converted annually is equivalent to about eight times the current oil consumption. Another part is absorbed by the atmosphere and earth's surface and converted into wind. Also evaporation of water absorbs some solar energy part. The remainder of solar radiation disperses into the heating of land and water masses resulting in low concentrations. Technical difficulties hinder the full utilization of solar energy on commercial basis. One problem has been collecting and concentrating the sun's energy due to its lower intensity. Another has been finding a means of storing the energy during sunny hours so that the power is available at night and cloudy spells. Nevertheless world wide research and development efforts are striving hard to overcome these difficulties.

3.4.2 SOLAR ENERGY IN SUDAN

Sudan is one of the most solar radiation-rich countries of the world. Geographically it is located between latitudes 4° & 22° north of the equator. Thus it is a suitable

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Table (VII). Shows the hydro electrical Potential, the proposed Site of dams and Costs based on 1978 Cost index.

Proposed dam Site	Location	Proposed Power M.W.	Average energy G.WH	Capital cost LS million.
1. Sabalcka	6th Chatarat	100	650	165
2. Sherick	5th "	240	1400	317.5
3. Shirri island	4th "	450	2600	535
4. Low Merowe	4th "	600	4800	668.75
5. High Merowe	"	750	3500	797.5
6. Dal	Dal	600	67	728.75
7. Rumela	Atbara River	30	2000	375
8. Bedin	Bedin Rapids	300	1600	n.a.
9. Fola	Fola	300		n.a.
		3370	21217	

Prices as at Jan. 1978 Exchange rate

$ US 2.0 = LS.1.0

excluding import duties

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place for utilizing such an important source of ever-lasting type of energy. Utilization of solar energy is not a new subject in Sudan. It has been used over many ages for the drying of agricultural products, timber, mud, bricks..etc. These applications of solar power, though primitive in nature, were the first steps to enter the solar era. Scientific research of Solar energy in Sudan started in 1955 at the Un. of Khartoum, where the department of physics was engaged in power generation and measurements of solar energy. In 1958 the Department of Mechanical Engineering began to conduct research on solar desalination, power generation, water heating and dehydration. The institute of Solar energy was established in 1970. In 1977 it has been renamed the institute of Energy Research (I.E.R.) The activities of this institute in Solar energy research include the following :-

i - Development of solar stills for large scale application.

ii- Low-cost water heaters

iii- Flat-plate steam generators

iv - Solar cooling systems

v - Solar drying

In May 1980 the National Energy Administration was created as an organ of the Ministry of Energy and Mining. Its major role is to control, coordinate utilize, and rationalize the energy sources in Sudan. Solar power research and development lie within the scope of its activities. The National energy Adm. will enable, through intensive research work, the solar energy to participate in the total share of energy needed in Sudan by the 1st quarter of the 21stcentury. The National Council for Research is undertaking the development of different solar power projects. A brief summary about these projects is given hereunder:-

(i) Solar water heaters

Five units are installed at the Faculty of Enging (Un. of Khartoum). Each unit is inclined 15^{o} to the South and comprises of galvanized steel tubes seated on galvanized corrugated steel plates or mesh wires. The tubes are covered

by glass plates. Out let temperatures upto 75°C are reached depending upon water flow rate inside the tubes. Such units may prove suitable in residential areas, hostels, and hospitals.

(ii) Solar stills

These units produce distilled water from tap water/ wells water. Each unit consists of a flat glass mounted on a basin. This basin is filled with water, and by the "green house" effect water evaporates and then condenses on the glass surface and the droplets are gathered on Troughs. One gallon of distilled water is produced per meter square flat plate per day.

Four units are installed near Khartoum area :-

Place	gal/day
Un. of Khartoum (Institute of Energy Research)	20
Suba (Institute of Energy Research)	40
Shambat (Food Research Centre)	16
Medani (Agricultural Research Corporation)	20

Petrol stations can utilize such units to produce distilled water for cars accumulators.

(iii) Solar Cooling unit.

This unit is a donation from Netherlands and is installed at the Faculty of Enging.(Un. of Khartoum). It is composed of steel tubes filled with solid calcium chloride. Ammonia is absorbed by $cacl_2$ during night and ejected during day. As a result of this process cooling occurs. This unit now produces about 16 kg of ice per day.

(iv) Solar Drying

Air is forced by means of fans to pass a series of cascades towards a cabinet where drying takes place. The cascades are composed of black tubes with flat glass plates mounted over them. Air absorbs heat as it passes

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through the cascades and the outlet temp reaches up to 70°C (158°F). Bricks are tested in the cabinet for drying and good results are obtained.

(v) Photovoltaic solar pumps

One type of such pumps is positioned at Butri (25 Km South of Khartoum). It is composed of a pannel of solar silicon cells which converts solar energy directly into electrical energy (D.C.) The panel has a design peak power of 660 watts with an average output of 400 to 500 Watts. A D.C. motor drives a centrifugal pump to pump water from a surface well with a capacity of 18 to 23 m^3 a day. Although the capital installed cost is comparatively high, the operating condition of the pump is now under investigation and recording to come to a final judgement.

(vi) Solar Thermal pump

This unit is under erection now at Suba (15 Km South of Khartoum). It consists of flat plate collectors which contain freon 13. A diaghram engine is pressed by heating freon and a reciprocating motion is created and transmitted to a hydraulic press which delivers water from an artesian well.

3.4.3. Potentials of Solar applications in Sudan

The potentials of harnessing solar energy in Sudan have good prospects due to more than one reason :-

(i) Sudan climate is very suitable for Solar utilization especially in middle and northern areas. Table VIII presents weather condition at Khartoum area in 1979 as an example. The average sunshine duration is about 1 hours and the Solar flux is about 80 Cal/hr/cm^2.

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TABLE NO. VIII

SHOWS WEATHER CONDITIONS IN KHARTOUM AREA IN 1979

MONTH	TEMPERATURE (C)			RADIATION (CAL/cm^2/day)						SUN-SHINE DDURATION (HRS)	WIND SPEED (MPH)	
	Mean	Max.	Min,	Total			Diffuse				Mean	Max.
				Mean	Max.	Min.	Mean	Max.	Min.			
JAN.	23.2	34.6	8,5	254	305	150	35	62	23	10 ½	8,1	33
FEB.	27,3	40.8	12.3	293	317	247	44	92	26	10	7.1	23
MARCH	27.4	41.8	13.4	325	358	281	55	102	35	10	8.6	31
APRIL	32.3	46.3	16	320	370	226	77	139	40	11	6.8	45
MAY	30.0	45.6	19	319	366	227	82	137	47	11	6.2	40
JUNE	33.8	44.5	21.7	310	338	229	105	135	50	11	8.9	64
JULY	32.2	42.0	21.5	203	233	131	94	126	61	7	8.7	51
AUG.	30.7	41.5	19.9	271	361	123	85	140	58	11	6.7	54
SEPT.	32.0	41.5	21.0	288	379	207	77	121	54	11	6.4	43
OCT.	32.1	42.2	22.4	276	311	121	56	98	15	11	5.5	30
NOV.	29	39.3	14	532	556	297	68	134	30	11	4.2	23
DEC.	22.1	32.9	11	456	517	425	83	129	51	11	10.5	32

(ii) Majority of population resides in rural areas which lack conventional sources of energy (mainly electricity). Solar energy can be utilized with reasonable cost to promote the development in these remote areas. Water pumping, irrigation, and cooking are suitable fields of Solar applications.

(iii) Needless to say that Solar energy environmentally is cleanest source of energy, besides that it needs less operating and maintenance costs once the equipment is erected.

In fact Sudan lacks the technology of Solar energy, like many other developing countries, but would like to step forward into such zone through research and by the help of other developed nations, because Sudan enjoys a lot of Solar energy and there is no reason to miss a technology that would convert the enormous amounts of heat into useful applications.

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3.5 WIND ENERGY IN SUDAN

The application of wind energy in Sudan as a source of power dated back to 1950, where windmills were erected in Gazira Province to deliver water for drinking from artesian wells for the scattered small communities which inhabitted that area.

About 250 units brought from Australia were installed throughout the Province during 1950-1952. At that time the 900 gph discharge rate of wind mills served these small communities satisfactorily (500 people each community). As time progressed, diesel-driven engines, and later electrical-driven motors, began to replace wind mills. In 1965 the last wind mill had been dismantled. Three main reasons led to the shift from wind mills operations :-

i- The increase in population of the small communities from 500 to 2500 people needed a corresponding increase in water off-take, thus making the output of wind mills lag behind. Also urbanization increased the consumption of water per capita (The current consumption has reached now 10 gal/day/capita)

ii- The scarcity of spare parts led to the local manufacture of these parts. The local parts being not precise decreased the life time of the Wind Mills. The improper repairing deviated the dynamic balance of the Shaft, thus increasing its fatigue and decreasing the life time of wind mills also.

iii- During the period from March up to May, annually, people usually suffers from acute water-shortages due to the windless period that occures within these months. These communities complained to authorities accordingly.

Wind mills were replaced firstly by force pumps with capacity of 1200gph, and later with centrifugal pumps with capacity of 5000 gph. In fact the poor old design, and the

bad maintenance and repair of wind mills contributed vigorously to the above replacement. Table (1x) gives wind speeds at the Gazira Province during 1960 - 1970 which shows clearly that climate favours wind mills operations.

The emergence of energy crisis in early seventieth put wind mills again to the surface as a means to conserve energy.

In Sudan an Australian team from Australian Development Assistance Bureau (ADAB) visited Sudan last year and went to western part of Sudan to invistigate the possibility of installing new wind mills at that area.

According to the team, the project was justified on the basis of :-

i) apparently adequate wind
ii) Fuel/Cost/transport savings, and
iii) Minimal maintenance costs.

The total cost of the project amounted to about 100,000 Australian dollars to provide installed costs of 3 wind mills. The equipments are expected to arrive by the end of this year.

The potential of wind energy in Sudan seems to be promising due to the favourable climate conditions and the shortage in petroleum fuels to operate diesel engines. Although the capital cost of windmills is comparatively higher yet the running costs are almost negligible.

3.6 Geothermal Energy in Sudan

Geothermal energy is one of the renewable energy resources receiving now some attention in Sudan. There are indications of available resources in the volcanic areas of Sudan e.g. Gabal Mara, Rejaf, Meidob, Gadarif & along the Rift valley. As the primary cost of utilising this resource is considered to be low compared with other resources, its development will be encouraged. The N.E.A. is planning to identify geothermal sites in the near future.

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TABLE (IX) : Average Wind Speed in Gezira Province from 1960 to 1970

MONTH	AVERAGE OF WIND SPEED IN MILES PER HOUR
JANUARY	8
FEBRUARY	9
MARCH	8
APRIL	7
MAY	8
JUNE	10
JULY	10
AUGUST	9
SEPTEMBER	7
OCTOBER	5
NOVEMBER	7
DECEMBER	8

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4. Obstacles Preventing Maximum Use of New and Renewable Resources of Energy in Sudan

According to the present trend of consumption of commercial energy at an annual rate of increase of 6.3% of petroleum products and 10.5% of electricity, coupled with 0.5% decrease in non commercial energy use, the country's requirement of commercial energy will be double the present requirement by the year 1995. Until the development of new and renewable energies we have to use petroleum products with the difficulties of shortages and rising prices. As the petroleum products prices keep rising, the balance of payment will be worsened further and unstable world economy will always aggravate our financial position and hinder any appreciable development. This situation reflects on the considerable magnitude of the energy problem, and calls for urgent viable solutions. The development of all new and renewable energy resources, should go together to achieve the overall social goals of national income growth, better balanced income distribution, environmental quality, institutional stability, public health and regional development. Our planning should focuss on more than one energy resource and for a long term rather than short term policy and to cover larger areas and include broader technical aspects and allow for multisectorial development. As we embark on the development of new and renewable energy resources we face the following obstacles :-

4.I Financing

The activities to be financed has been summerized as follows :-

- Research on biomass, wind, solar and hydroenergies.
- Development of alcohol and gaseous energy from sugar residues and other agricultural crops residues.
- Improvement on charcoal production techniques and on stoves using charcoal.
- Establishment of wood fuel plantations.
- Combination of wind and solar energy for water pumping

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in rural areas.

- Development of hydroelectric power-larger, medium and mini-technologies.

Great and cost intensive effort has to be made to develop these activities which require large capital and take many years before projects based on them come into production which accelerates capital interest rate, and tie the capital for a long time without any pay back dividends. As our foreign currency situation does not allow at present to undertake all of these projects, we depend partly on bilateral aids and some help from the international financial institutions for small share of the capital needed. The problem of procuring larger funds for bigger investments still exists.

4.2 Transfer of technology

There are certain difficulties hindering the transfer of the appropriate technology which can be suited to our conditions. In the first place we depend on imported technology whether in the form of machinery, equipment or experties. This is also aided by the absence of such important infra-structures in the country as consultancy in development and planning, contracting enterprises, engineering, metallurgical and chemical industries. Difficulties are encountered in the selection of suitable technology particularly medium and small types which are not easily available in the market. In addition suppliers attitudes frequently tend to impose both type and place of machinery to be provided. Moreover, no evaluation or appraisal of the existing technology in the country have been made to ascertain the best methodology to be adapted in the future.

4.3 Research, education and training

In this field, the institutions of education, research and training are inadequate and lack the most important infra-structures of equipment, personnel and needed funds to achieve their goals. There is no planning for the priorities of

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research regarding basic applied research particularly in connection with the rural areas need of clean water supply, electricity etc. In the field of education and training there is a need to improve on the present means to the effect that technology adaptation can be feasible. Construction of proto types and pilot plants and demonstrating systems of the new and renewable technologies will surely help the promotion of education and training.

4.4. Information flow

In this field the obstacles are very clear. First, the important data regarding energy use in all economical sectors is not easily available; there is no system in the country to guarantee access to and use of information. Public information to promote awareness, and alert the public to energy problems does not exist. So, there is a need for the establishment of an effective information system in the country, Although highly advanced technology information flows to the country from the industrialized areas, yet the information from neighbouring countries or from countries which have difficulties like ours is very scarce.

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5. How to overcome difficulties and enhance the development of new and renewable energy resources in Sudan

To develop new and renewable energy resources and to overcome difficulties in this respect and to enhance the development to ease the energy crises at present and to cater for the near and far future needs of energy, Sudan Government is undertaking the following measures :-

5.1. Organization of energy sector :

With a view towards identifying energy problems as well as other problems connected with energy supply, the Sudan Government created in 1977 a new ministery, the Ministery of Energy and Minning. Under the umbrella of this ministery are almost all energy institutions e.g. General Petroleum Corporation, Sudan Pipe Line and the Nile Import and Trdaing Company for petroleum products distribution. In May 1980, the National Energy Administration was created within the Ministery of Energy and Minning to undertake the tasks of the assessments of energy resources, current energy production and consumption, identification of suitable energy projects and the overall planning and policy making of the energy sector in the country. The N.E.A. have to work in coordination, cooperation and harmony with all the institutions of energy and energy using sectors in the country.

5.2 Energy strategies and planning :

To develop sound energy strategies and planning, integrated with the development of different economical sectors, Sudan is embarking now on a project for the assessment of the energy situation in the country. The U.S.A. and Sudan Government have agreed on an aid to Sudan by U.S.A.I.D. to undertake this assessment for a period of two years ending in Sept. 1982. Based on results of this assessment, the Country will formulate the plans and strategies that will focus on the development of the energy sector including that of new and renewable energies.

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5.3. Energy conservation :

Different measures to secure rational utilization of the various energy resources are being studied. In the field of wood fuel, improvement of charcoal stoves is being worked on by the Energy Institute. The Forest Administration is preparing plans, to improve on charcoal production and to secure future demands of fire wood for rural areas through afforestation programs and protection of the natural forests. The development of mollasses as a substitute source of energy is being thought of seriously. In the case of petroleum products, improvement in the transport sector to increase efficiency of use is being worked on particularly the improvements of roads and railways. The establishments of the pipe Line between Port Sudan, and Khartoum is a step forward in energy conservation. Cpntinueous efforts are going on to improve on electricity generation, transmission and consumption and power III project is the latest of these efforts.

5.4. International Cooperation and Bilateral agreements.

The Sudan has gone into several agreements with international institutions and bilaterally, with individual developed countries, to promote and enhance energy sector particularly in new & renewable energy resources. These agreements include financing, training and information flow facilities to promote research in wind, solar and biomass fields. These agreements satisfy only small percentage of our requirements, and a greater help in the fields of research, development and demonstration equipment is required from industralized countries, especially for the development of biomass, solar and wind resources.

In the case of co-operation with similar developing countries we look forward to a closer cooperation and participation with our African brother countries in the following fields :-

I- The use of wind and solar energy in water pumping from surface and underground reservoirs for water supply and irrigation of rural areas.

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II- Generation of electricity from mini-hydro power stations and by the use of solar energy.

III- Development of cold storage systems for agricultural crops, especially in areas where transport is primitive, using solar energy.

IV- Development of ethanol from molasses and other crop residues

V- Establishment of wood fuel plantations particularly in arid zones, using fast grown and drought resisting species.

VI- Improvement of cooking stoves using charcoal.

VII- Improvement of charcoal production methods for better qualities and less waste; the gradual introduction of modern Kilns. In this field joint projects with neighbouring countries could be fruitful.

VIII- Development of Biogas taking into consideration the widely spread animal and crops residues.

IX - The creation of regional and sub regional centres within Africa for collection and analysis of information related to the fields of research, development & training in new and renewable resources of energy and passing such information to where it is needed in Africa, could be a helping step in integrated regional co-operation.

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