Sustainable Energy Options and Planning For South Sudan

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Introduction

The country of South Sudan has ample natural resources. Both conventional mineral, agricultural, and petroleum resources are being developed to provide for a growing economy.

In addition, South Sudan has ample renewable energy resources in the form of solar, wind, and biomass. Developing these vast resources with modern alternative energy technologies could place South Sudan at the forefront of sustainable energy infrastructure development worldwide. This can be done for electrification, motor vehicle biofuels, and for rural home cooking fuel needs.

Whereas the United States, Europe, and other developed nations have invested hundreds of billions of dollars over the past century to install fossil fuel burning power plants, electric transmission lines, and distribution systems, South Sudan has the remarkable opportunity to design a master plan that can will outline a leap over this old technology into the next generation of clean, self sufficient, renewable energies.

This concept is similar to telecommunications development. Instead of investing millions of dollars in copper wiring and land based communications infrastructure, developing nations are installing wireless communications networks which are cheaper, more advanced, and more adaptable to a growing economy's changing needs. The same holds true for energy infrastructure.

Distributed generation from a mix of solar, wind, biomass, hydro, and conventional diesel can provide a robust, reliable, and self sufficient infrastructure to power South Sudan well into the next century. The following paper will discuss options, obstacles to overcome, and the need for an energy master plan for the country to move forward.

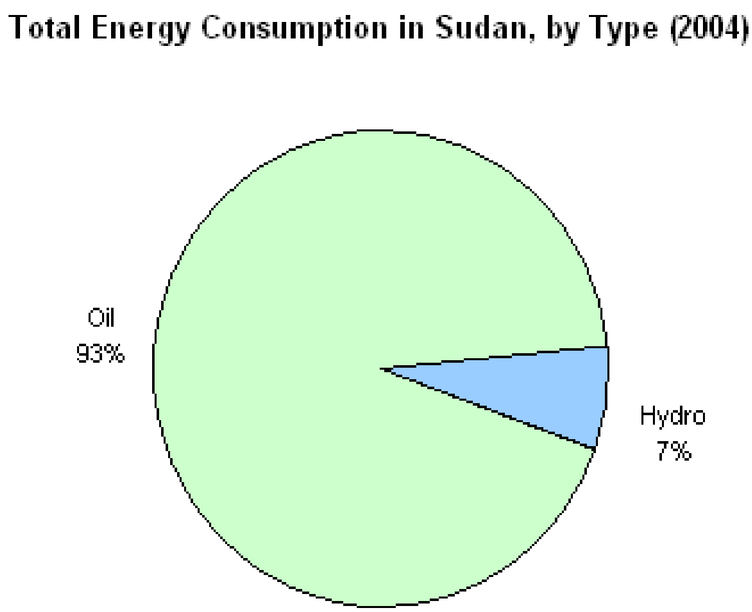
Sudan Energy Background

Source: US Department of Energy, Energy Information Administration, 2004

Revenues from Sudan's increasing hydrocarbon (petroleum) exports represent 70 percent of the country's total export revenues.

Sudan is developing its significant hydrocarbon resources. The country's oil exports, which have increased sharply since the completion of a major oil-export pipeline in 1999, account for 70 percent of total export revenues. Additional growth in Sudan's hydrocarbon sector will likely occur with a refurbished infrastructure, which has seen little improvement since the beginning of the country's civil conflicts in 1955. As of January 2007, according to the Sudanese Minister of State for Energy and Mines, Sudan is considering joining the Organization of Petroleum Exporting Countries (OPEC) at some point in the future.

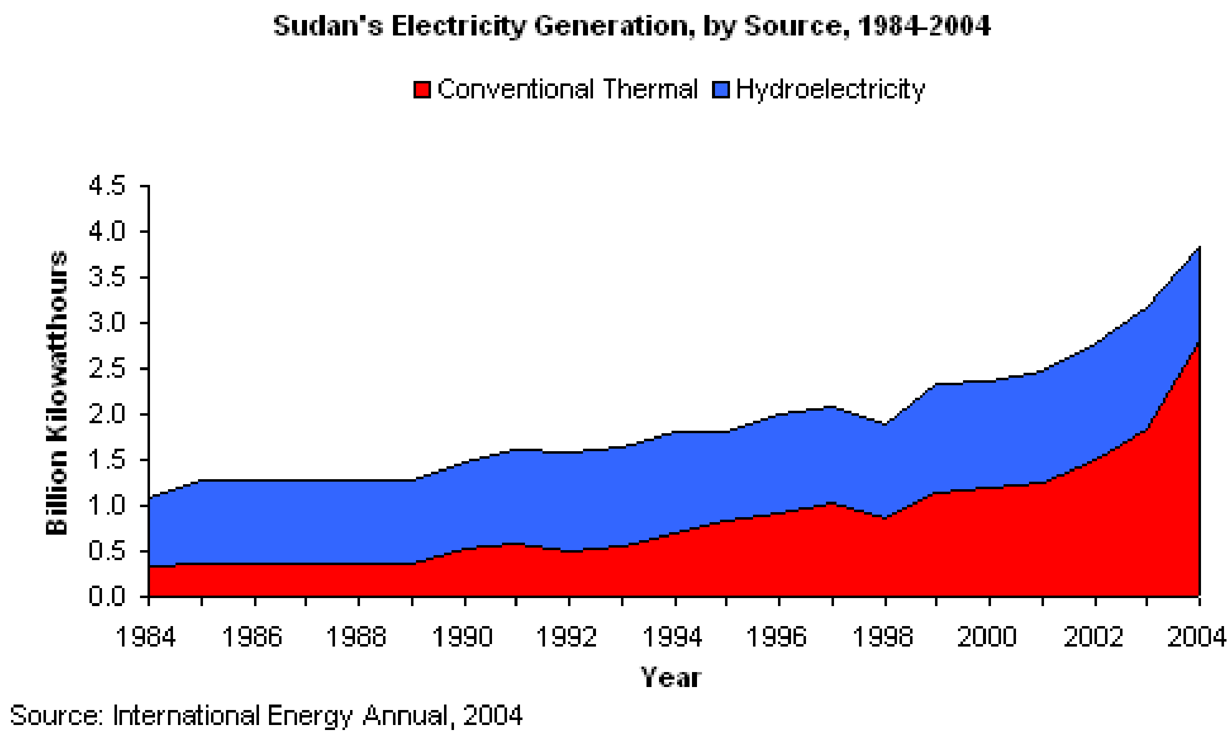
In January 2005, the Sudanese government in Khartoum and the Sudan People's Liberation Army (SPLA) in the south signed the Comprehensive Peace Agreement (CPA), which ended 21-years of civil war. Prior to the signing, several important issues were agreed upon by the two parties including the sharing of oil revenues (50:50). Also in 2005, President Bashir formed a border commission tasked with defining the border between northern and southern Sudan, in accordance to the CPA. Much of Sudan's oil producing region lies in the disputed border area.



In 2004, Sudan's energy consumption mix was dominated by oil (93 percent), with the remainder coming from hydro-electricity (7 percent). Natural gas, coal, nuclear and other renewables are currently not part of the country's energy consumption mix. Between 1984 and 2004, the share of oil in Sudan's energy mix increased from 86 percent to 93 percent. Hydroelectricity consumption experienced a decrease, during the same time period, from 14 percent to 7 percent.

Electricity

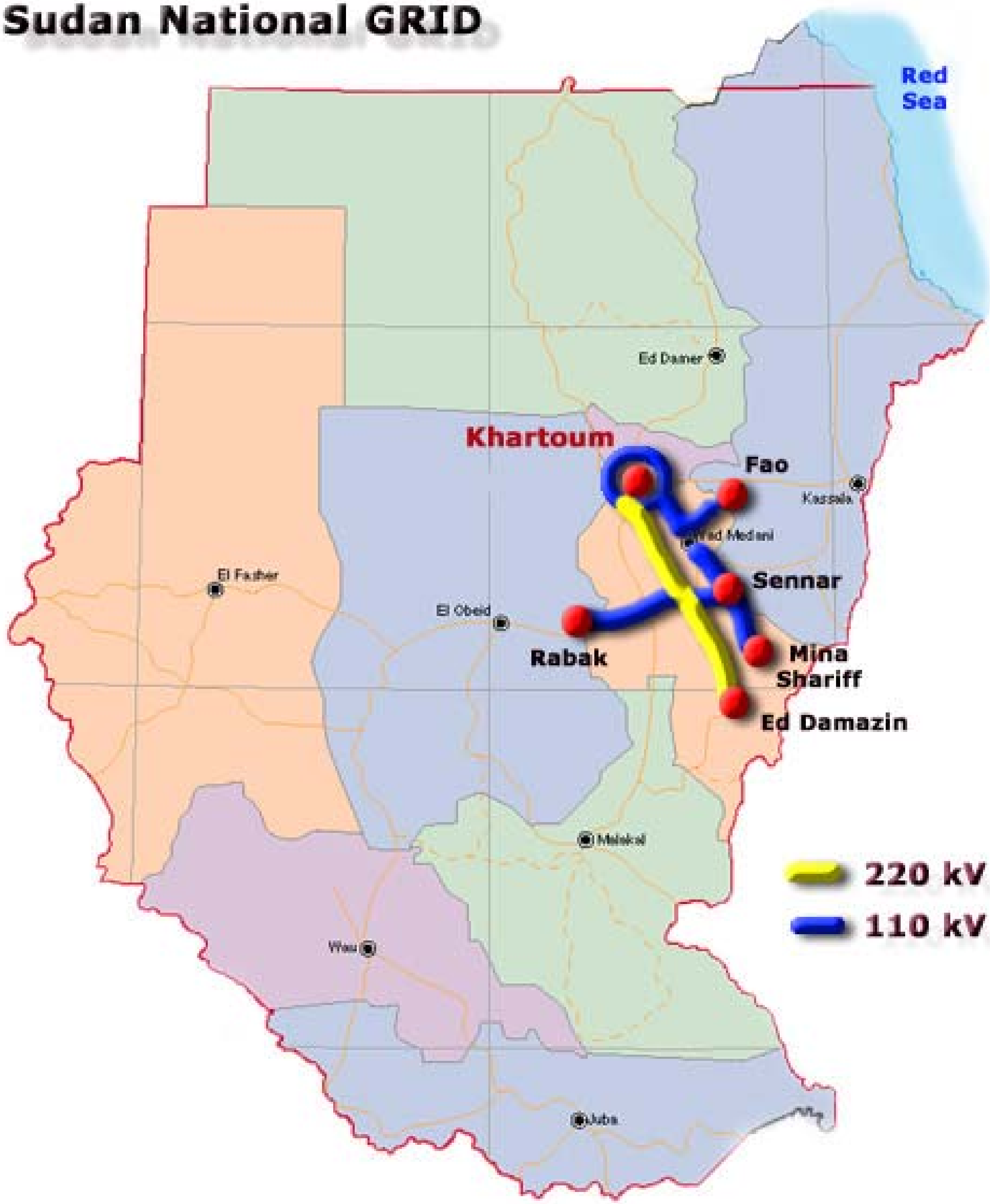
Sudan generates the majority of electricity by conventional thermal sources.
In 2004, Sudan had 760 megawatts (MW) of electricity generation capacity. Sudan generated 3.8 billion kW hours of electricity in 2004, and consumed 3.6 billion kW hours. The majority of electricity in Sudan is generated by conventional thermal sources (76 percent), with the remainder coming from hydroelectricity (24 percent). The country's main hydroelectricity generating facility is the 280 MW Roseires dam located on the Blue Nile river basin, approximately 315 miles southeast of Khartoum. The facility has frequently been attacked by rebel groups, and low water levels often cause its capacity to fall to 100 MW.



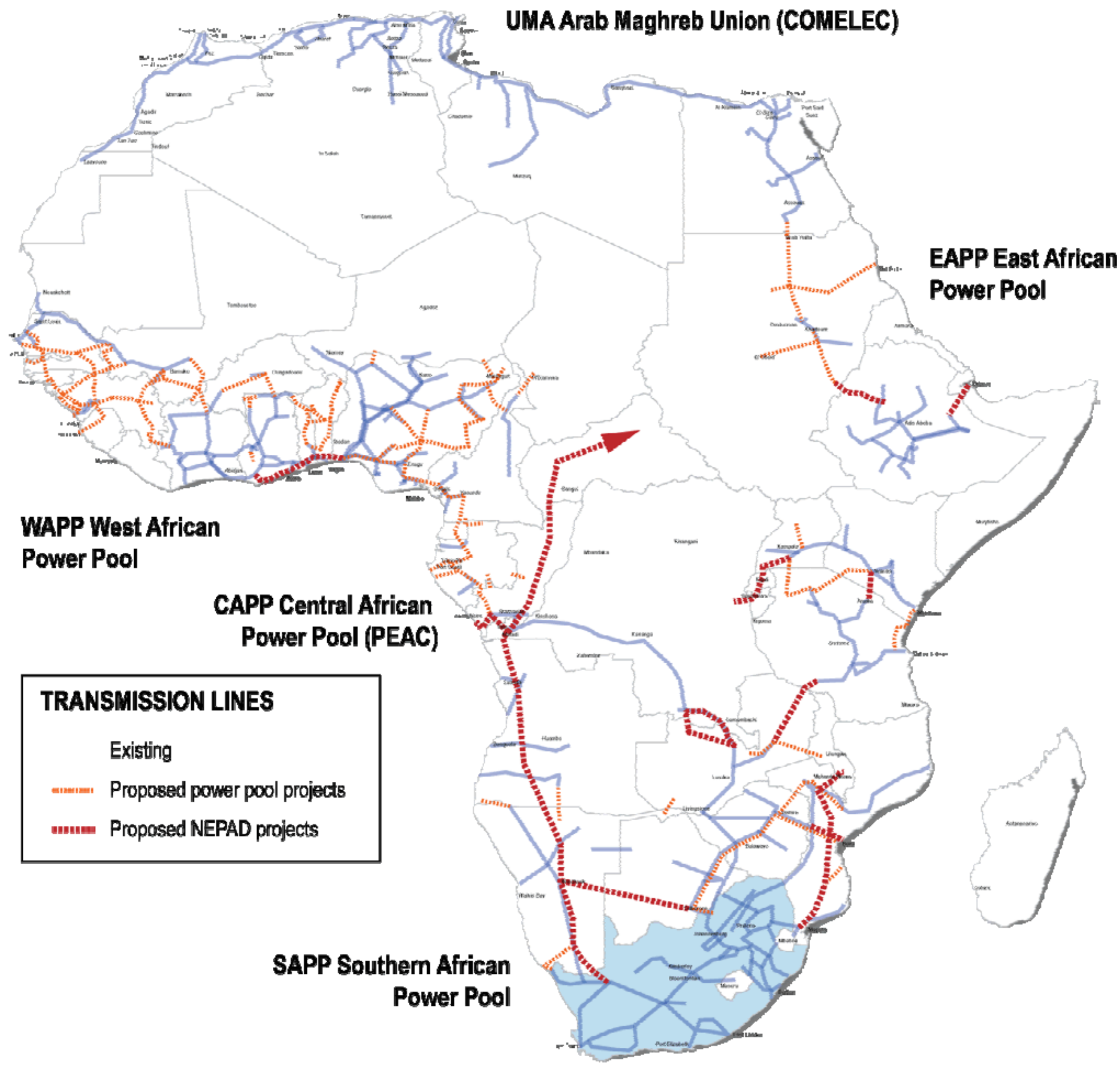
Sector Organization

The north Sudan, state-owned National Electricity Corporation (NEC) is responsible for electricity generation, transmission and distribution around the capitol city of Khartoum. NEC transmits electricity through two interconnected electrical grids, the Blue Nile Grid and the Western grid, which cover only a small portion of the north Sudan. Regions not covered by the grid often rely on small diesel-fired generators for power.

Sudan National GRID



African Continent Electric Transmission Grid System



Possible Types of Systems Needed

The table below lists a number of energy supply applications, from small to large size. The rural home has needs for lighting, communications, and cooking at a minimum. Solar and biomass resources would be most appropriate for these applications.

Street lighting, individual buildings of all sizes, and entire village power systems can be designed to utilize clean, sustainable energy systems with solar, wind, biomass, and diesel.

Larger cities will most likely be powered by a mix of distributed and central station power sources. Also, the production of ethanol and biodiesel transportation fuels is possible from locally grown crops such as sugar cane and Jatropha.

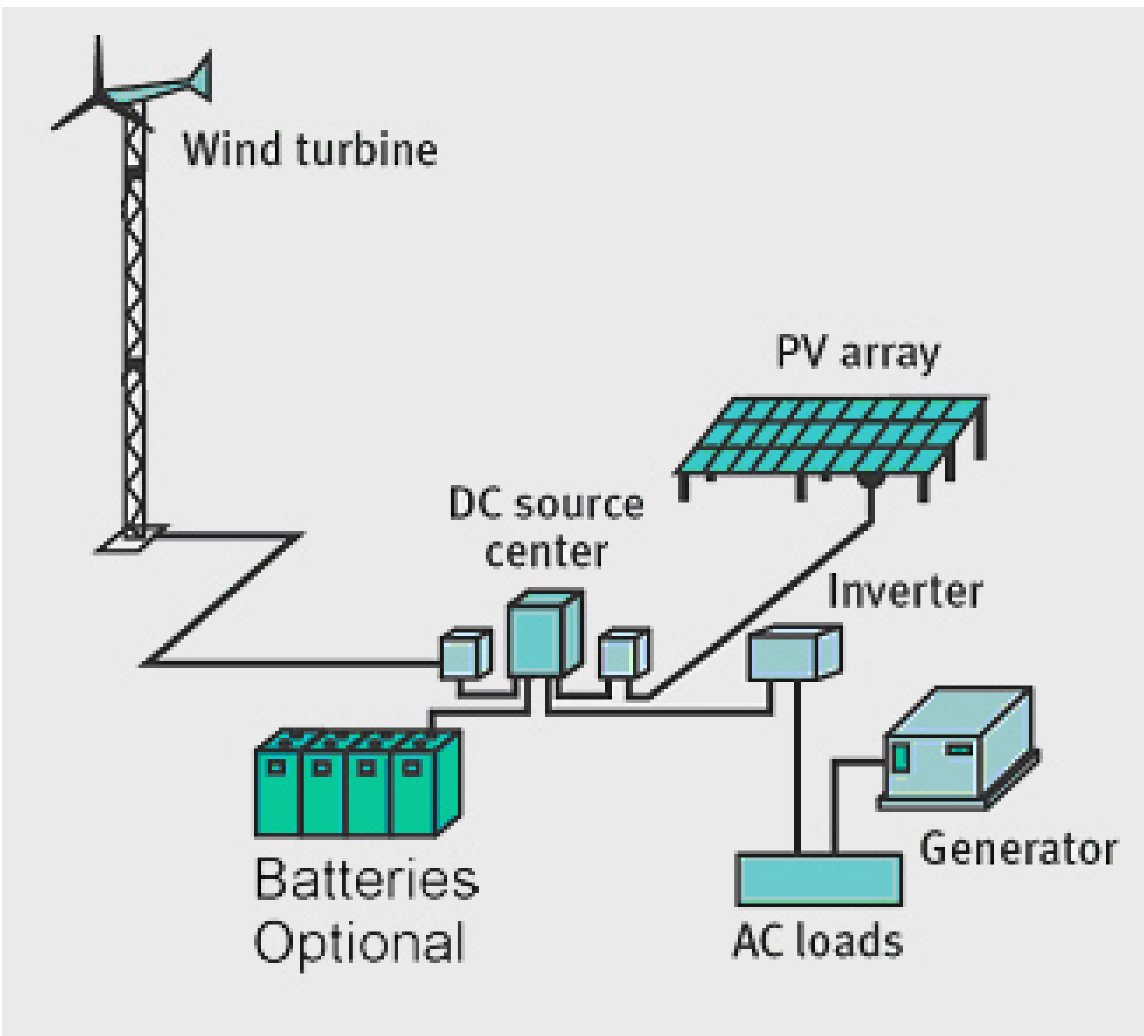
Application	Grid	Energy Source	Equipment	Size
Portable lighting	off grid	solar	LED lantern	5-10 W
Rural home	off grid	solar	lighting and communications	50-100 W
Rural home cookstove	off grid	biomass briquette, bottled gas, solar	cookstove	
Solar street lighting	off grid	solar	LED lighting	50-100 W
School, church, or small building	off grid	solar, wind, diesel	lighting, communications, computers	1-5 kW
Office or other larger building	off grid	solar, wind, diesel	lighting, communications, computers	5-25 kW
Rural village	off grid	solar, wind, hydro, diesel, biomass	lighting, communications, computers, refrigeration	25-250 kW
Larger city	ON GRID	solar, wind, hydro, diesel, biomass	lighting, communications, computers, refrigeration, air conditioning, industry	multiple MW
Transportation fuel	ON GRID	Jatropha or sugar cane	Biodiesel or ethanol plant	millions of gallons per year

Rural Village Power

The United States Renewable Energy Laboratory, located in Golden, Colorado, has done extensive work on renewable energies for complete village power systems. These village power systems can supply energy to rural communities in a clean, cost-competitive way without the need for costly transmission lines and central power stations.

Their work has shown that social issues dominate over technical issues in the development of rural energy systems. Some important issues are:

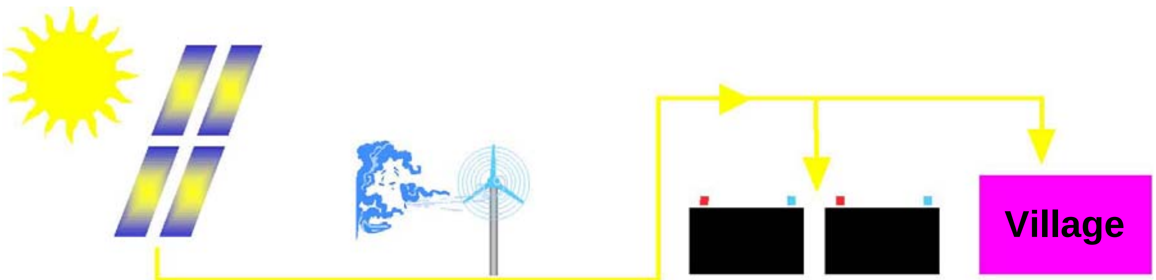
- Master planning
- Individual project planning
- Ownership of equipment
- Metering and billing
- Tariffs
- Responsibilities of maintenance, operation, etc…



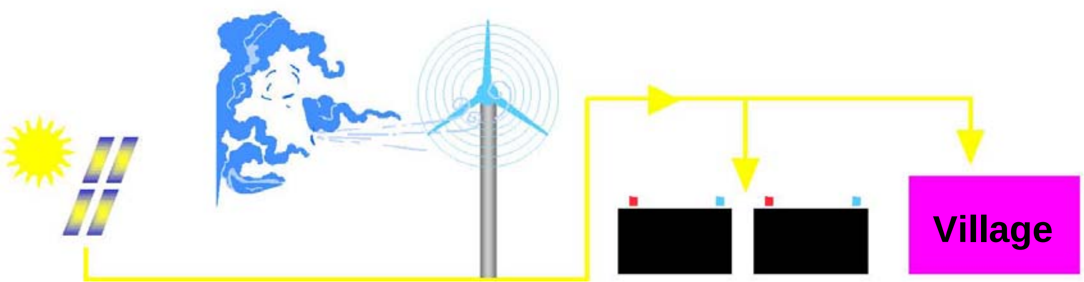
Schematic of hybrid power system schematic uses wind, solar, and diesel

The Benefit of Hybrid Solar, Wind, Diesel Systems

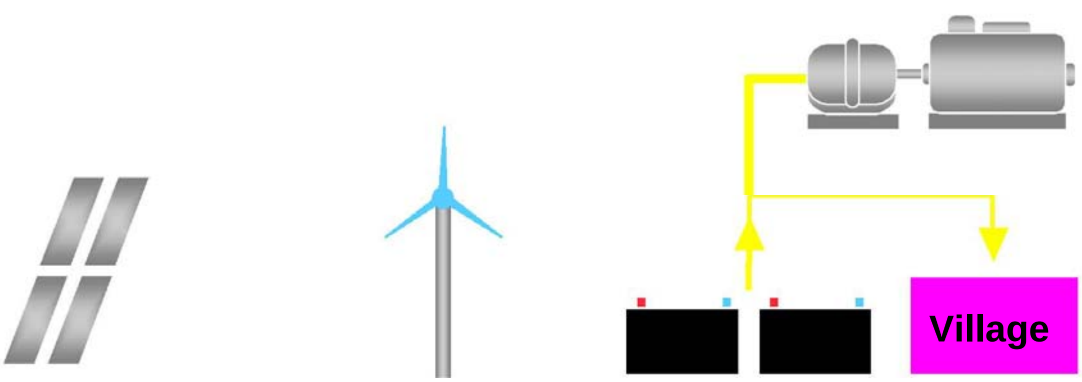
In the design of a remote energy system, not connected to a central grid system, the design for maximum reliability is very important. Multiple energy sources are a necessity. The sun and wind compliment each other very well. The wind often blows on a cloudy day, and sunny days are often less windy. Batteries and diesel generators carry the system through cloudy, still days and times of peak power needs. The level of reliability added by the multiple energy sources provides a very robust and self sufficient system with out connection to a central grid system.



Sunny days produce energy from the solar arrays.



Windy days produce energy predominantly from the wind turbines.



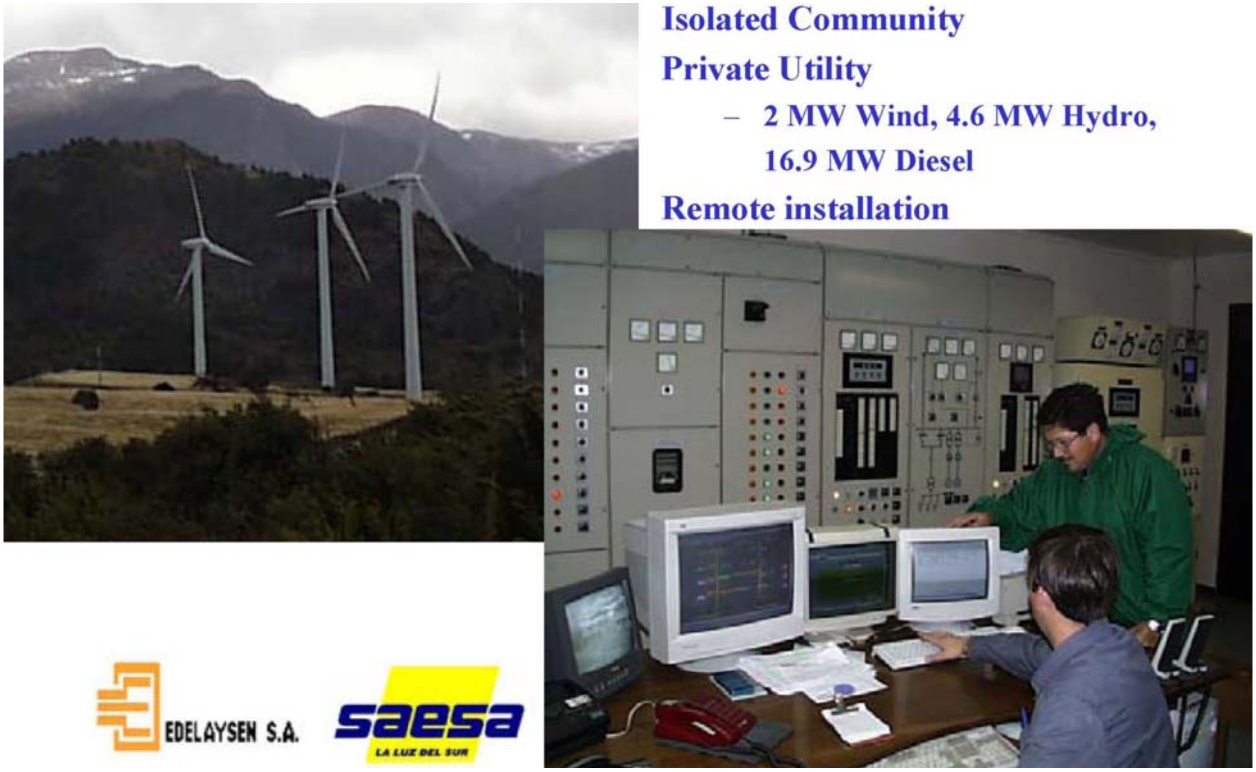
On still, cloudy days the batteries or diesel backup will serve the village power load.

Examples of Hybrid Village Power Installations

San Juanico, Mexico is a remote fishing & tourism community of 400 people

<u>Power System</u>

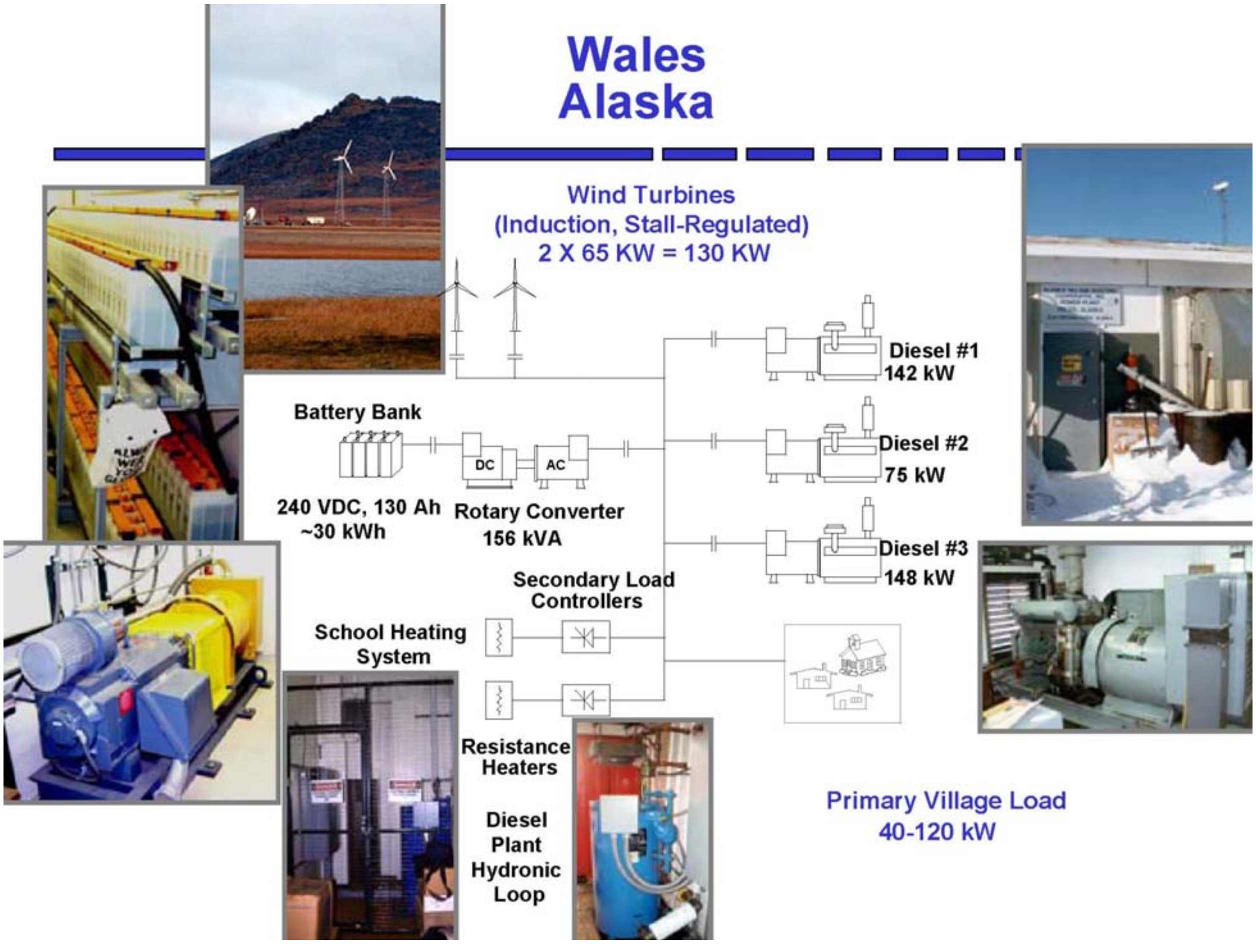
- 17 kW solar electric
- 70 kW wind (seven 10kW wind turbines as shown here)
- 80 kW diesel generator
- 100 kW power converter/controller
- Advanced monitoring system



Coyaique, Chille system using wind, hydro, and diesel at a remote utility installation

<u>Power System</u>

- 2,000 kW wind
- 4,600 kW hydro
- 16,900 kW diesel generator



Wales, Alaska, USA is a remote village power system.

<u>Power System</u>

- 130 kW wind
- 365 kW diesel generator
- Small battery storage
- 40 to 120 kW village load

Village Power Challenges

A number of challenges are present with any energy or utility company operations. Many of the following are common to any utility operation, centralized or remote.

- Higher installation costs (offset by lower operation costs)
- Operation, performance and reliability issues
- Operation & maintenance
- Payment for kWh
- Manufacturer technical and sales support
- Regional infrastructure
- Lack of institutional oversight
- Non payments
- Illegal connections
- Inadequate or non-existent tariffs
- Unmanaged load growth
- Maintenance ignored
- Corrosion
- Battery maintenance
- Long response time to component failures
- Remote site – difficult access
- Institutional issues -availability of qualified personnel

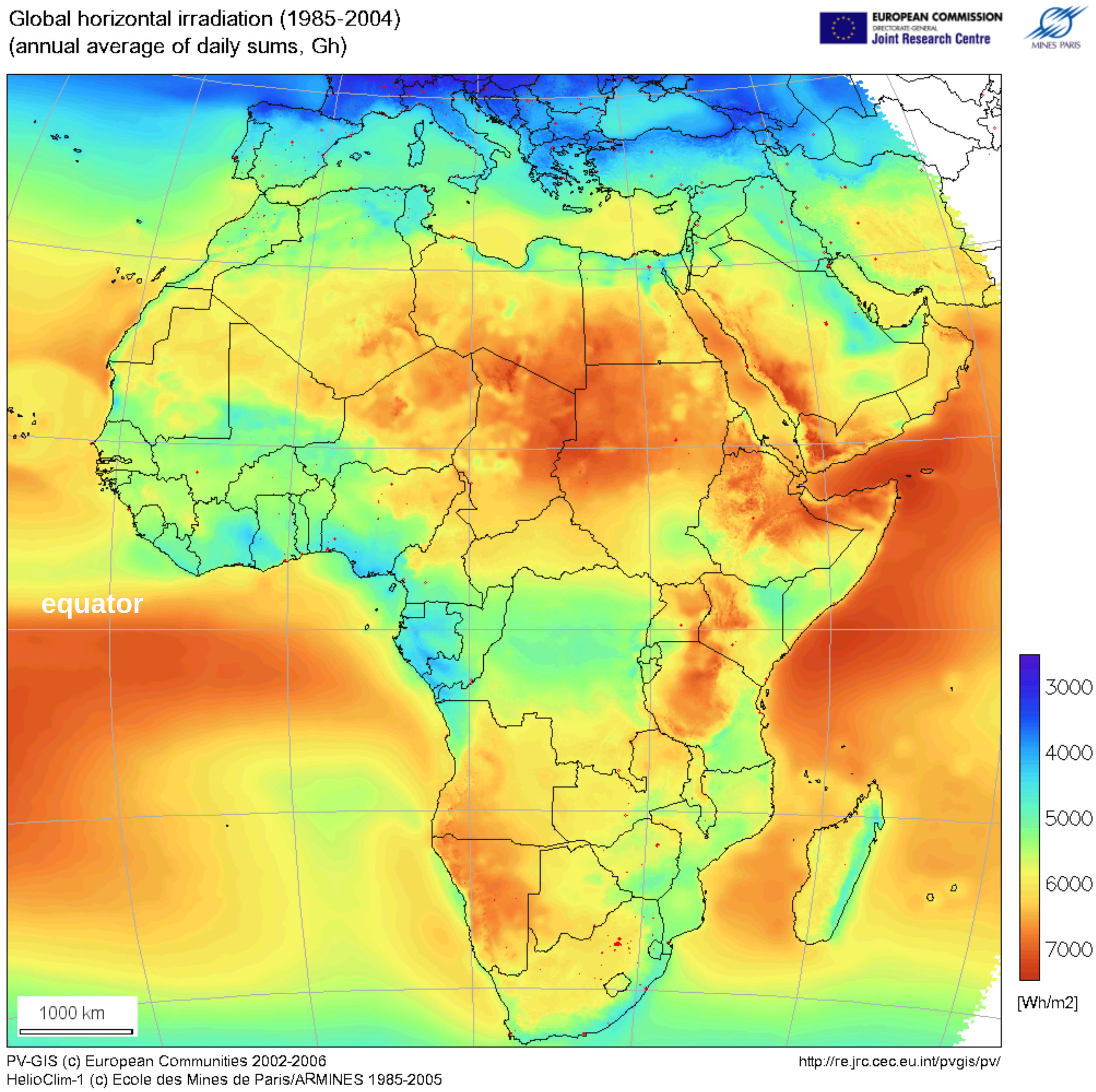
Potential methods to deliver and maintain Village Power

- Retailers and individual entrepreneurs
- "McWind" (franchise model)
- Traditional rural electric cooperatives (member owned)
- Local or municipal power association
- Rural energy service companies (very small to very large)
  National utility company
- Non-government and private voluntary organizations

The following pages will provide an introduction to the African and South Sudan renewable energy resources: solar, wind, and biomass.

Solar Energy Resource

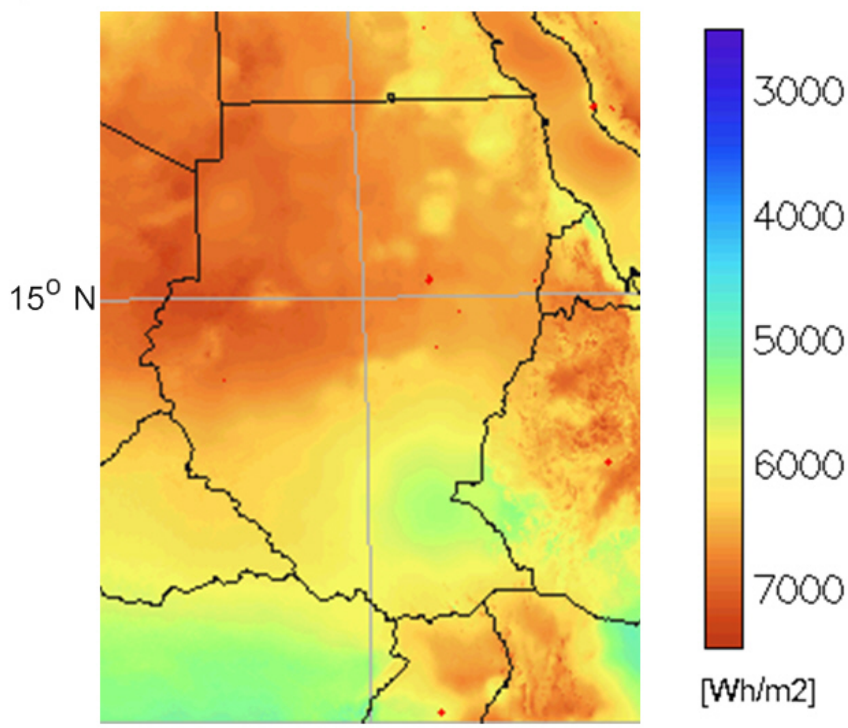
Below is a solar radiation map of the African continent. The solar resource available varies from about 4 to 7 kilowatt hours per day per square meter (annual average).



Throughout South Sudan, the annual average solar energy received is between 5 and 6 kW hours per square meter, each day.

Therefore, each 1 kW of installed photovoltaics will produce approximately 5-6 kW hours per day of energy.(on average throughout the year).

The amount of solar radiation received by the full 2.5 million square kilometers of the old Sudan is over 18,000 quadrillion BTU. This is over 170 times the total annual energy consumption of the United States (oil, natural gas, coal, and nuclear combined).



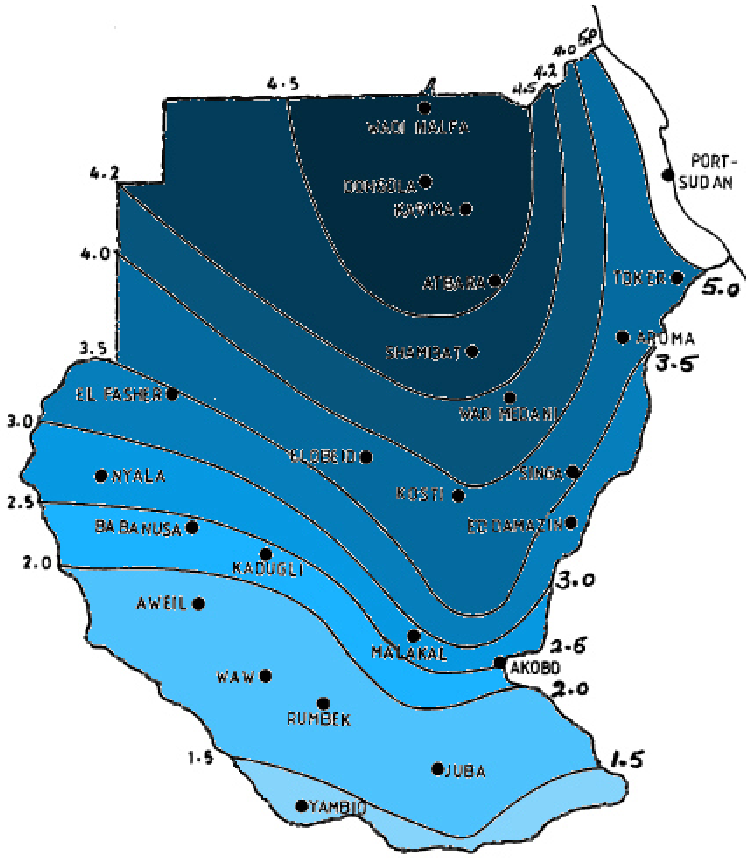
Solar is the most “democratic” of energy resources. A solar panel located anywhere in the country, either on the roof of a rural home or in a megawatt sized central station, will receive the same amount of clean, free, and sustainable solar energy. Unfortunately, solar is the most expensive energy technology. It is very reliable and rather low maintenance, but very costly.

Wind Energy Resource

Wind energy is more site specific. It varies across the country and is also affected by local issues such as elevation, vegetation, terrain, etc… Shown here are the average wind speeds (meters per second) at a 10 meter height. Wind speeds at typical wind turbine hub heights of 30 to 100 meters will be much higher.

Individual microclimates and site terrain require site by site assessments to determine the viability of installing wind power. However, the general prevailing winds and regional wind resource availability will remain constant.

When wind power is available at a given site, it is much more economical than solar energy.



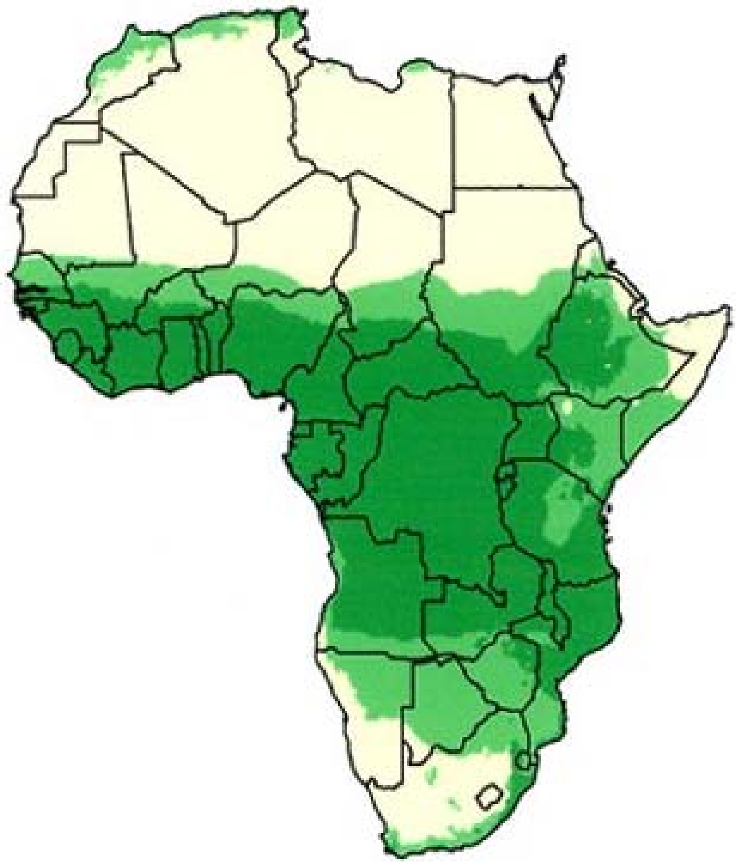
Source: Abdeen M. Omer, "On Wind Energy Resources in Sudan", Renewable & Sustainable Energy Reviews, 12 (2008) pgs. 2117 – 2139.

Table of Wind Energy Stations in Sudan

Station	Altitude (m)	Annual wind speed (V) ms^{-1}	Shape factor (k)	Number of years of observation
Wadi Halfa	190	4.6	1.8	4
Port Sudan	5	5.0	1.6	10
Karima	250	4.7	1.7	10
Atbara	345	4.2	1.75	10
Shambat	380	4.8	2.1	10
Khartoum	380	4.8	1.9	10
Kassala	500	4.0	1.95	10
Wad Madani	405	4.8	1.8	10
El Fasher	733	3.4	1.15	10
El Geneina	805	3.1	1.9	10
El Obeid	570	3.4	1.9	10
Kosti	380	4.0	1.8	10
Abu Na'ama	445	3.1	2.2	10
Malakal	387	2.8	1.2	10
Wau	435	1.7	1.2	10
Juba	460	1.5	1.4	10

Source: Abdeen M. Omer, "On Wind Energy Resources in Sudan", Renewable & Sustainable Energy Reviews, 12 (2008) pgs. 2117 – 2139.

Biomass Energy Resource



There is a vast abundance of bioenergy resources in the African continent as shown here. South Sudan has more than enough bioenergy resources to fuel this growing country's fuel and electricity needs.

The following sections are adapted from an except from a 2005 analysis of the Sudan bioenergy potential by Abdeen M. Omer, "Biomass energy potential and future prospect in Sudan", Renewable & Sustainalbe Energy Reviews, 9 (2005) pages 1-27.

Biomass technologies

Biomass resources play a significant role in energy supply in Sudan. Biomass resources should be divided into residues or dedicated resources, the latter including firewood and charcoal can also be produced from forest residues.

There exists a variety of readily available sources in Sudan, including agricultural residues such as sugar cane bagasse, molasses, cotton stalks, groundnut shells, tree/forest residues, aquatic weeds, and various animal wastes.

The most promising agricultural residues which have high availability factor and high potential for energy production, are cotton stalks and groundnut shells.

The use of biomass through direct combustion has long been, and still is, the most common mode of biomass utilization. Biomass technologies include: biogas, briquetting, gasification, improved charcoal, carbonization, and improved stoves.

Briquetting

Briquetting is the formation of a char (an energy dense solid fuel source) from otherwise wasted agricultural and forestry residues. One of the disadvantages of wood fuel is that it is bulky with a low energy density and is therefore expensive to transport. Briquette formation allows for a more energy-dense fuel to be delivered, thus reducing the transportation cost and making the resource more competitive. It also adds some uniformity, which makes the fuel more compatible with systems that are sensitive to the specific fuel.

Briquetting of agricultural residues in Sudan started in 1980, where a small entrepreneur constructed a briquetting plant using groundnut shells in Khartoum. The second plant was introduced in Kordofan (western Sudan), and the plant had a capacity of 2 tonnes per hour with a maximum 2,000 tonnes per season. Another prototype unit was worked in Nyala with a capacity of 0.5 tonnes per hour (600 tonnes per season). In central Sudan, a briquetting plant of cotton stalks was installed at Wad El Shafie with a capacity of 2 tonnes per hour (2,000 tonnes per season). The ongoing project in New Halfa is being constructed to produce 1,200 tonnes per season of bagasse briquettes. A number of factories have been built for the carbonisation of agricultural residues, namely cotton stalks. The products are now commercialized. More than 2,000 families have been trained to produce their cooking charcoal from the cotton stalks.

Improved cook stoves

In Sudan, most urban households burn charcoals on traditional square 'Canun' stove that have very low fuel-to-heat conversion efficiencies. The following prototypes were all tried and tested in Sudan:

- The metal clad Kenyan Jiko
- The vermiculite lined traditional Kenyan Jiko
- The all-ceramic Jiko in square metal box
- The open draft Dugga stoves
- The controlled draft Dugga stoves
- The Umeme Jiko 'Canun Al Jadeed'

Several, local traditional stoves were tested, improved, and commercially used in Sudan.

- Traditional muddy stoves
- Bucket stoves
- Tin stoves

Gasification

Gasification is based on the formation of a fuel gas (mostly CO and H2) by partially oxidizing raw solid fuel at high temperatures in the presence of steam or air. The technology can use wood chips, groundnut shells, sugar cane bagasse, and other similar fuels.

Biogas

Presently, Sudan uses a significant amount of kerosene, diesel, fire wood, and charcoal for cooking in many rural areas. Biogas technology was introduced to Sudan in the mid seventies when GTZ designed a unit as part of a project for water hyacinth control in central Sudan. Anaerobic digesters producing biogas (methane) offer a sustainable alternative fuel for cooking and lighting that is appropriate and economic in rural areas. In Sudan, there are currently over 200 installed biogas units, covering a wide range of scales appropriate to family, community, or industrial uses. The agricultural residues and animal wastes are the main sources of feedstock for larger scale biogas plants.

Sugar cane biomass

Residuals from the sugar cane industry represent by far the most important source of current and potential biomass resources in Sudan. The sugar industry in Sudan goes back fifty years and Sudan has been one of the world's leading sugar producers. Sugar cane plantations cover one-fifth of the arable land in Sudan. In addition to raw sugar, Sudanese enterprises produce and utilize many valuable cane co-products for feed, food, energy and fibre. In 2005, there were 5 sugar factories.

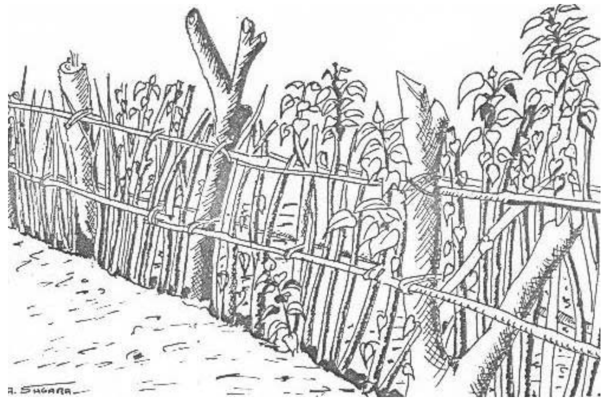
Sugar cane bagasse and sugar cane trash already provide a significant amount of biomass for electricity production, but the potential is much higher with advanced cogeneration technologies. Most sugar factories in Sudan can produce about 15–30 kWh per tonne of cane. If all factories were fitted with biomass gasifier-combined cycle systems, 400–800 kWh of electricity could be produced per tonne of cane, enough to satisfy all of Sudan's current electricity demand.

In Sudan there are no alcohol distilleries. The three factories were closed with Islamic Laws in 1983. The current circumstances suggest that Sudan should consider expanding production for use as transportation fuel, but this option has not yet been pursued. The alcohol was used for a variety of applications, mainly for medical purposes and rum production. Blending with gasoline would also have direct environmental advantages by substituting for lead as an octane enhancer.

Jatropha for Bio-Oil

Whereas sugar cane has the potential to fuel an alcohol fuel program in South Sudan, various oil seed crops have the potential to provide the feedstock for a biodiesel industry.

Jatropha curcas is not an indigenous plant to Sudan, but it is known in the country. It grows in arid areas without attention. Since the plant is not browsed by animals, Jatropha is used by the farmers to protect their gardens against roaming animals. It seems that the plant was introduced to Zambia from Angola and Mozambique, where the plant is widespread.



The Jatropha System is an integrated rural development approach. By planting Jatropha hedges to protect gardens and fields against roaming animals, the oil from the seeds can be used for soap production and as fuel in special diesel engines. In this way the Jatropha System covers four aspects of rural development:

- promotion of women (local soap production);
- poverty reduction (protecting crops and selling seeds).
- erosion control (planting hedges);
- energy supply for lighting and stationary engines in the rural area;

Plantations and/or rural production of Jatropha seeds could supply large scale biodiesel plants that could provide a local biofuel for stationary and on-road diesel engines for Sudan.

NOTES:

Make a list of types of jobs that will be needed

NRECA International Programs

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www.nrecainternational.org/news/Publications/TAGs.htm

www.nrecainternational.org/news/video/Sudan/Sudan.htm

Rural Electrification Technical Assistance Guidebooks

NRECA International has initiated the development of a comprehensive series of Technical Assistance Guidebooks (TAGs) that will provide a combination of "best practices" and "how to" guidelines for the design, development, implementation and monitoring of rural electrification systems.

The TAGs are designed for a wide audience, including domestic and international rural electrification policy makers and field practitioners (engineers, economists, project managers, etc.) and will include written guidebooks for each module, select case studies highlighting successful experiences in developing countries, and practical tools, such as economic analysis models and engineering design applications that will be useful to program implementation personnel.

The TAGs are comprised of twelve modules, including:

1. Feasibility Analysis of Peri-Urban Projects
2. Project Engineering Design & Cost Estimation
3. Feasibility Analysis of Grid-Extension & Renewables
4. Project Monitoring & Electric Co-op Performance
5. Material Acquisition & Bidding Procedures
6. Creating an Electric Cooperative
7. Functions of the Board of Directors of ECs
8. Preparation of a Business Plan for ECs
9. Construction Standards for Rural Electrification
10. Construction Standards for PV Systems
11. Analysis of Productive Uses
12. Project Economic Analysis

NRECA International has completed initial drafts of all of these modules and is in the process of revising and editing them for publication.

If you are interested in the TAGs, please contact NRECA International.

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Mr. Manon is NRECA International's Engineer and Operation Manager for Nigeria project. Mr. Manon has over 35 years of experience in supervising and managing rural electrification assignments for government and private clients. Mr. Manon has managed USAID -funded programs in Southern Sudan, El Salvador, Dominican Republic, Bolivia, and Nicaragua that encompass rural line design, construction and supervision; utility organizational development, privatization analysis, and training support.

Mr. Manon has developed work plans, coordinated task assignments with multiple subcontractors, provided overall substantive administrative and logistical support to short term and long term teams in developing countries focusing on donor agencies' strategic objectives and targets and indicators. Mr. Manon has a strong cooperative sector background in promoting rural electrification projects utilizing innovative technology in developing countries.

Mr. Manon received his M.S. and B.S. University of California, Davis.