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Renewable Energy for Africa

An overview of nine potential technologies

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May 2009

Renewable Energy For Africa
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Published May 2009
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Renewable Energy and Development

Fig. 1 "Earth at Night: Africa" A satellite image showing Africa's low level of electrification. *Source: nightskynation.com*

In 2009, Africa remains one of the least developed continents in the world. One billion Africans, though they are one sixth of the world populations, use a mere 4% of global electricity. Most African states continue to struggle to build their energy infrastructure leaving hundreds of thousands of people with no means of clean, safe and convenient energy. Instead many Africans must walk miles, spending hours to collect firewood to cook with, and most spend a large part of their income each month on costly fuels such as kerosene for dim, unclean light. Lacking access to clean and affordable energy has a tremendous socioeconomic impact on education, income, health, water, food and air quality. A quick look at Figure 1 "The Earth at Night" or Figure 2, the 2007 Human Development Index by country map (on pg.4), is enough to realize that Africa is home to most of the world's poorest and least developed countries.

Yet Africa as a continent is far from poor - that is, in terms of resources. Africa is rich in renewable resources that could power its development. From geothermal heat within its rift valleys, to the dozens of rivers and tributaries that could run microhydro systems; there is wind to be harvested on all its coasts and even possibly on the microscale within its interior, literally tons of biowaste that could be digested and utilized each day, and miles upon miles of deserts filled with some of the world's most potent solar radiation - enough to meet the entire world's current energy needs within a minor percentage of the Saharan desert.

Africa currently has the highest level of energy intensity in the world. Energy intensity is the ratio of a country's total domestic energy consumption to its GDP. Africa's high energy intensity ranking indicates that Africans are using energy but are doing so in such a way that is not aiding economic development. This is because of the nature of the energy the majority of people in Africa use - namely that which is imported, expensive, and environmentally degrading, such as coal, oil, firewood, and natural gases.[1]

In Sub-Saharan Africa 90% of the rural population and 74% of the overall population do not have access to electricity.[2] It has been shown that access to electricity can lead to improved education by improving the ease at which people can study or teach outside daylight hours. For farmers

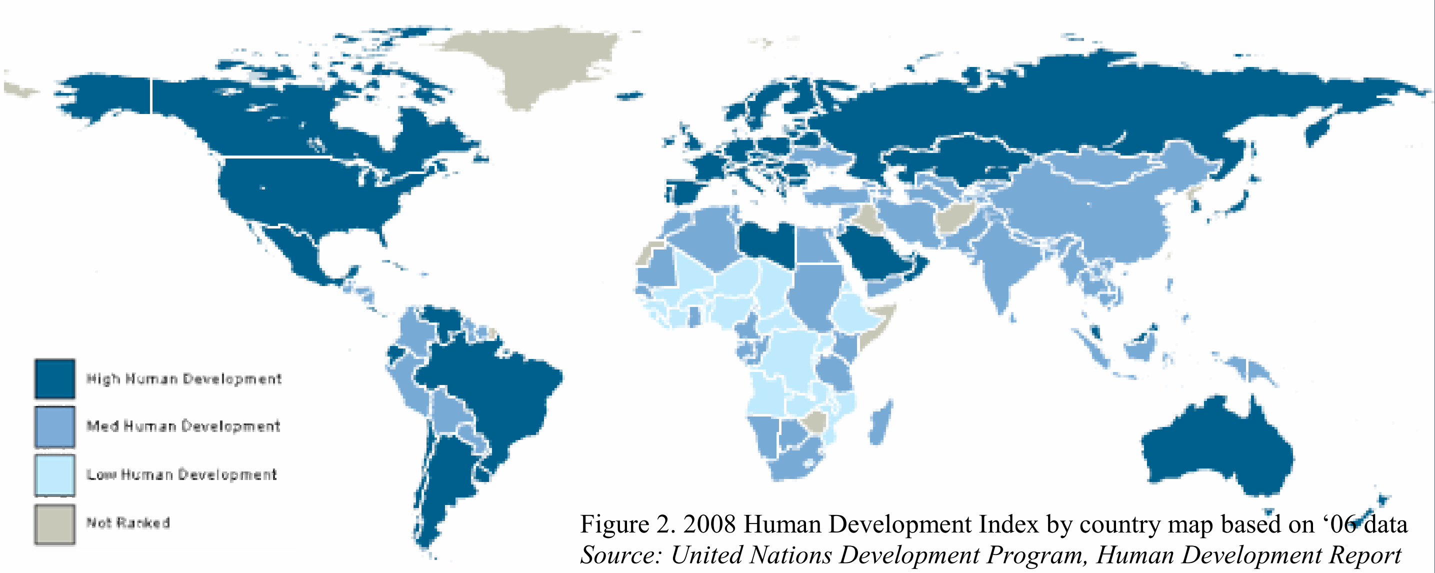


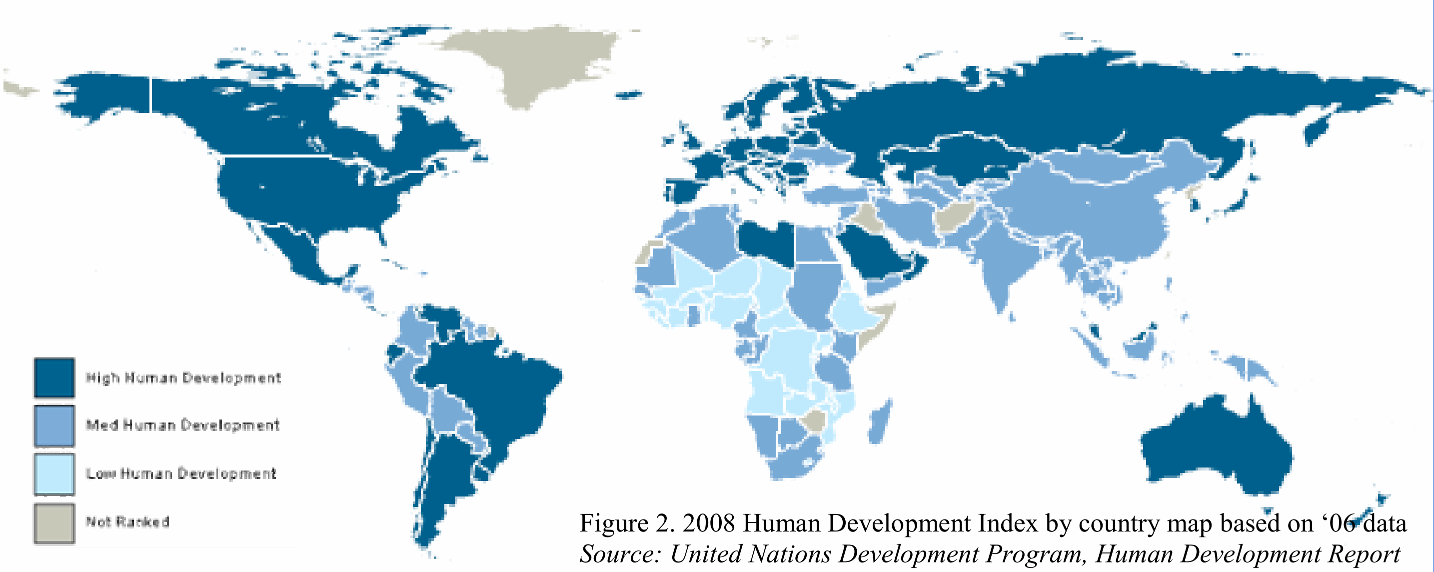
Figure 2. 2008 Human Development Index by country map based on '06 data
Source: United Nations Development Program, Human Development Report

and children who have to work during the day, this can make a large difference in their access to education. Electricity can also make running public works like hospitals and police stations more possible, while simple street lights can make communities safer. Access to electricity can increase the productive hours in the day for small entrepreneurs, and save women several hours every day usually spent collecting firewood for fuel, thus leading to improved gender equality. It can enable people to watch TV, listen to the radio, and use computers to be more informed of local and worldwide news, as well as for entertainment, and as a tool. Electricity and other clean sources of energy like solar cooking and biogas can improve health by replacing smoky kerosene lamps and firewood stoves. It is only logical that developing a state's energy sector will lead to economic and social development and an improved quality of life. Specifically, developing to use renewable, indigenous sources of energy and empowering rural communities to generate their own energy off the grid and at the microlevel will result in economic and social growth that is both rapid and simultaneously sustainable.

In this publication you will be exposed to 9 potential renewable energies for Africa using the abundant, non-polluting and non-depleting energy available from the earth, wind, sun, and water. For each energy I will briefly cover how the latest technology works, its benefits, costs, and challenges to its use, give examples of pilot projects and assess where in Africa it is most suitable for implementation.

Sources:

1. Renewable Energy in Africa Bulletin: A Summary Report of the International Conference on Renewable Energy in Africa. Published by the Int'l Institute for Sustainable Development (IISD) in collaboration with UNIDO. April 21, 2008. Volume 149, No. 1., Online at www.iisd.ca/ymb/sdrea/ p. 10
2. "Lighting Africa Year 1: Progress and Plans", The World Bank Group, 2008 Washington DC



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2. "Lighting Africa Year 1: Progress and Plans", The World Bank Group, 2008 Washington DC

Renewable Energy for Africa

GEOTHERMAL POWER Continued

Challenges/Constraints:

There are high initial costs for setting up a geothermal energy plant because you have to thoroughly survey the area and determine the most appropriate site to drill. Drilling to obtain geothermal heat is expensive and may require outside investment. Due to the nature of the resource there is always a level of geological uncertainty which may deter investors. Additionally, the amount of heat available at a particular site may decrease over time, if too much heat is extracted too quickly.

Costs:

Once geothermal plants are built, operating costs are low. The cost of electricity from a geothermal plant is currently in the range of 2-10 US¢/kWh. The cost for direct heat from geothermal energy is around 0.5–5 US¢/kWh. (FRIDLEIFSSON 2003). http://www.bgr.de/geotherm/energy.html

Figure 4. Fumaroles in the Kenya rift indicate a potential geothermal site. *Source: BGR.de*

Geothermal in Action:

Kenya currently has the most developed geothermal sector in Africa. This may be due to its enormous geothermal potential estimated at 3000 MW. The country is currently exploiting about 200 MW, and is hoping to boost its geothermal generation capacity to 500 MW by 2012. Most recently, in March 2009, KenGen (The Kenya Electricity Generating Company) received a $300 million loan from the French Development Agency to develop a geothermal energy unit that will add an additional 35 MW of electricity to the grid. KenGen is also receiving funding from the World Bank, European Investment Bank, among other sources.

Potential for Africa:

Kenya and Ethiopia are the only African countries currently using geothermal power for electricity. Algeria, Egypt, and Tunisia, currently have projects obtaining geothermal energy for direct heat. In some countries like Morroco the geothermal energy available is suitable for direct heat but not electricity.

However many countries in Africa have rift valleys with great potential to develop the generation of electricity from this resource. The East Africa Rift in Mozambique, and in Uganda is one rift system that has large potential for future development. Zambia, Tanzania, and Eritrea also have geothermal potential that needs to be further investigated and assessed.

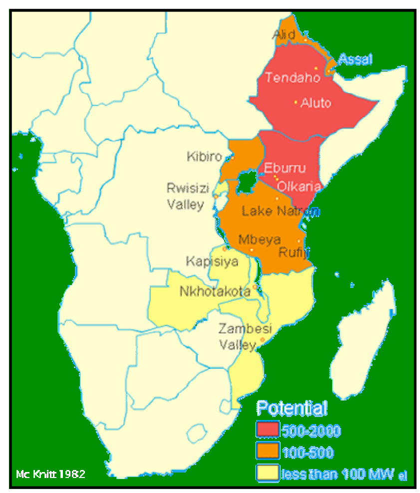

Figure 5. Map of the potential for geothermal energy in the East Africa Rift Valley; *Source: Bgr.de*

Sources

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Renewable Energy for Africa

MICROBIAL FUEL CELLS (MFCs)

How it Works:

Microbial fuel cells (MFCs) harness the small current that microbes in dirt naturally generate when they break down organic matter. Although it may sound crazy, this rather simple technology gets its energy from nothing but naturally occurring chemical reactions in dirt. No special microbes, or precise environmental conditions are needed; the soil simply must be moist enough for the microbes to do their work.

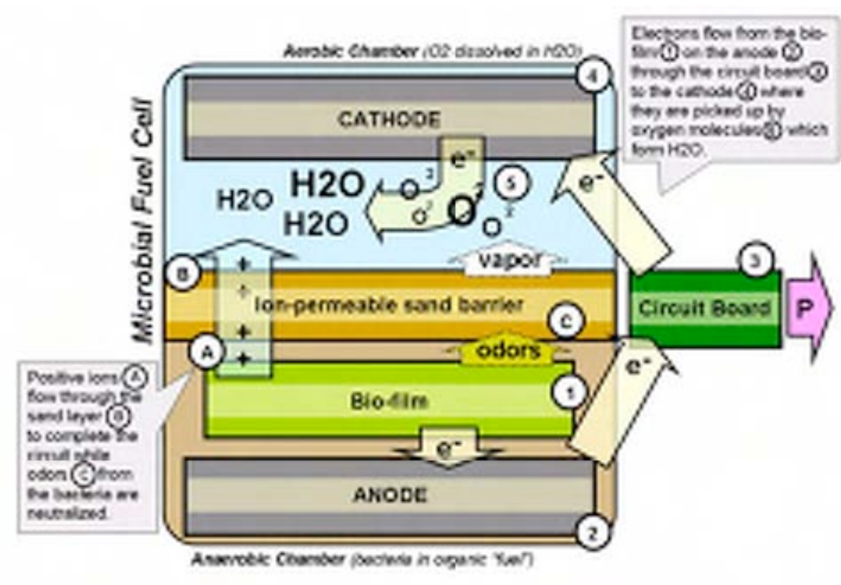

Figure 6. Microbial Fuel Cell; *Source: Inhabitat.com*

The basic way to build a MFC system is to dig a hole, layer an anode, soil, sand and a cathode, and connect the anode and cathode to a circuit board that is used to charge a battery to run a small LED (light emitting diode). MFC anodes and cathodes can be made of local and household materials such as scrap metal, and the whole system can be easily assembled locally with minimal training. MFC systems produce energy 24 hrs a day and run best on organic wastes like human or animal waste.

MFCs are still being tested and refined for use in developing countries. When the MFCs are ready for sale in 2011, they will likely use PLEDs (polymer organic light-emitting diodes) which are the next generation of LEDs. PLEDS can be as flat and flexible as a piece of paper. They are extremely malleable and adaptable to a variety of uses.

Advantages of MFCs

ENVIRONMENTALLY FRIENDLY: The resource used in this technology, energy from dirt, doesn't run out. Since MFCs run best on wastes they capture energy that would otherwise go unutilized.

LOCAL:

- Local power generation is advantageous because it is more stable, reliable and affordable than importing foreign sources of energy.
- There is a lot of dirt in Africa that could be used to power MFCs. Even in deserts that do not have soil, MFCs can run on human or animal wastes.
- MFCs are being developed by Lebônê Solutions Inc., an African company. Therefore it is specifically being developed to suit the needs and resources of rural Africa.

OFF THE GRID: Power from MFCs is generated and used locally, and can be produced for use in secluded rural areas that are not connected to the larger power grid.

INEXPENSIVE:

- Dirt and wastes used to power the system are free, and the rest of the materials to make an MFC are easily accessible and not expensive.
- Unlike other expensive renewable energies that are often subject to theft, MFCs are made of cheap materials and are implemented underground. For these reasons they will not require security measures to protect them from theft like PV does.
- Those who use MFCs will save the money that they normally spend on fuels because once they install the approximately $7-15 dollar system, it will run for years at no additional cost.

Renewable Energy for Africa

MICROBIAL FUEL CELLS (MFCs) Continued

Advantages (Continued from pg.7)

SAFE:

- MFCs do not emit smoke or any other pollutants that are harmful to health.
- Most people in rural villages burn fuel in oil lamps for light at night but doing can start fires; MFCs provide a safer alternative source of light.
- Adhering to basic sanitary practices like washing one's hands after handling soils and wastes will ensure health and safety while using MFCs.

EASY: MFCs are simple systems that can be made quickly and easily. The only component in an MFC system that requires more advanced knowledge and materials is the circuit board, and Lebônê Solutions Inc. is currently in the process of simplifying the circuit board.

EFFICIENT:

- According to Harvard biology Professor, Peter Girguis who helped develop the technology, just one trash barrel's worth of soil will provide enough energy to light two rooms for a decade –maybe more.
- Power from MFCs is generated 24 hours a day, unlike solar or wind power which relies on variable resources that are not available all day.

Figure 7. Soil - the source of energy behind MFCs; *Source: organicgardening365.com*

PROVEN: Lebônê Solutions Inc. has already run some successful trials using this technology. The company has gained international recognition for its work and received a grant from the International Finance Corporation, a part of the World Bank that helps build the private sector in developing nations.

RELIABLE: MFCs are robust systems that do not need require much maintenance and operate at all temperatures as long as there is moisture in the ground.

Challenges/ Constraints:

MFCs are still being tested and developed, and will not be on the market until (projected) 2011. Once they are available, the main constraint to MFC use is that each unit generates a limited amount of energy. According to Hugo Van Vuuren, founder and managing partner of Lebônê Solutions Inc., one cubic metre of soil will produce only enough power to light one high efficiency LED. However, units can be easily connected together to make ten to fifteen times more electricity.

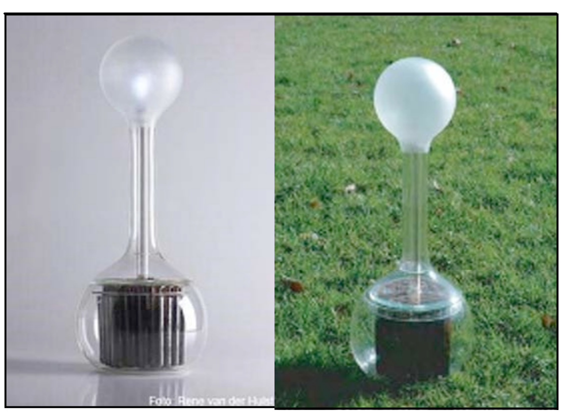

Figure 8. Soil powered LED lamp by Dutch designer Marieke Staps in two environments; *Source: dvice.com*

Costs:

An MFC currently costs about USD$50. Lebônê Solutions Inc. is working to increase efficiency and use even cheaper, more readily available materials such as chicken wire in the system. According to Mr. Van Vuuren, once the company scales up production in 2011, a MFC system including a MFC, battery, circuit board and some LED lights will cost less than 10 dollars.

MFCs in Action!:

- Dutch designer Marieke Staps created a LED lamp that runs on "dirt power" with a sleek design (See Fig.8 to the left). The lamp will continue to run as long as the soil is kept moist. However, the lamp is not yet on the market.
- MFCs for use in rural areas are also still being developed.

MICROBIAL FUEL CELLS (MFCs) Continued

Figure 9. Villagers in Tanzania are shown how to use a MFC by Stephen Lwendo, a Harvard electrical engineering student from Africa. *Source: nytimes.com*

Potential for Africa:

MFC technology was developed with Africa in mind, and was one of 16 winners of the "Lighting Africa 2008: Developing Marketplace" competition. Although each MFC only provides a small amount of power, this off-the grid technology could make a large difference in the lives of rural Africans who have no access to electricity. Many Africans walk miles to the local schools and other public places to use the electricity, for example, to charge cellphones that they need for communication and also use as a source of light.

MFC batteries could also be used to charge cellphones and run radios, which are an important medium for communication and information in Africa. Using MFCs to run LEDs is also extremely beneficial for a multitude of reasons. The quality of light from electricity is unparalleled. Students who work during the day and study at night by candlelight or kerosene lamps could greatly benefit from access to high quality LEDs that let off a bright white light. Similarly store owners, and craftspeople experience a better quality of life by being able to increase their production and income with out having to strain their eyes or inhale emissions.

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BIOGAS

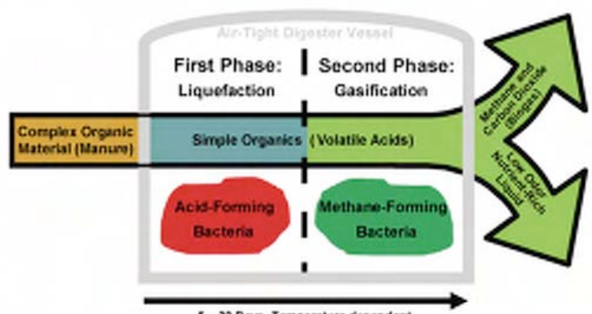

Figure 10. The process of biomass gassification; *Source: biogas.psu.edu*

How it Works:

Biogas is a combustible gas created by anaerobic digestion of biological material such as manure, sewage, green waste, abattoir waste or landfill wastes. Biogas is composed primarily of methane (60-70%), and carbon dioxide (20%-30%) which can be captured and used for cooking and heating.

Biogas is a type of biofuel because it generates energy from biological material. The process of obtaining biogas is relatively simple and inexpensive. First, waste material is fed into a biogas digester made up of one or more sealed reservoirs where various bacteria metabolize the waste and create a methane rich gas, and a nitrogen and odourless phosphorus sludge which is a great fertilizer. The gas can be connected to a kitchen stove, or a gas run light fixture or other appliances. Biogas can also be compressed and used for electricity but it is less efficient in this form, with an energy conversion efficiency (the ratio of energy created to energy used) of about 10% or less, while using biogas for a combination of heat and electricity can have an efficiency rate of about 88%. (For comparison non-renewable natural gas has an efficiency rate of 55%)

Small scale digesters for an individual household or farm are usually made out of metal, fiberglass, concrete, bricks or plastic. Larger biogas digesters for commercial are usually made up of bricks, mortar and steel. It takes from 6-25 days to process a batch of waste in a medium sized digester.

BIOGAS Continued

Advantages of Biogas:

ENVIRONMENTALLY FRIENDLY:

- Biogas technology captures the greenhouse gases methane and CO2 that naturally result from the decomposition of wastes, thus preventing them from entering the atmosphere. While CO2 is a known culprit of climate change, methane is also a harmful greenhouse gas, and is actually 23 times more potent that CO2.
- Biogas is a sustainable alternative to using firewood or charcoal for cooking and heating. Therefore its use can help decrease deforestation and the resulting environmental damage such as loss of ecosystems, species and poor air quality.

SIMPLE and INEXPENSIVE TECHNOLOGY: A small biodigester can cost as little as $45 USD and can be made using a variety of easily accessible materials.

SAFE FOR HEALTH:

- Using biogas decreases the use of indoor wood burning stoves and improves indoor air quality. Poor indoor air quality can cause respiratory conditions and many other health complications, such as low birth weight, asthma, ear infections, and other chronic diseases, especially for the women that cook over them and their children.
- Health risks associated with handling wastes used to make biogas are relatively minor with basic training on hygienic practices. The "slurry" (byproduct of biogas) used as fertilizer is free of the live pathogens found in untreated wastes, when wastes are digested by the bacteria in two separate steps - the acidifying and methanogenic stages.

IMPROVES SANITATION: Diverting wastes to use for biogas can lead to improved sanitation, especially in less developed countries.

FERTILIZATION: The process of making biogas results in a byproduct, bio-effulent or "slurry", which makes a better fertilizer and is less than unprocessed manure

BETTER THAN OTHER BIOFUELS: Biogas is simpler and cheaper to use than ethanol and other biofuels. Additionally while ethanol is often made by processing sugarcane, corn or other food crops, or uses other non-food crops grown on valuable agricultural land, biogas comes from waste materials and does not hinder the food supply in any way.

EFFICIENT and **TIME-SAVING:** Using biogas often saves several hours each day, time that would be spent on collecting fuel. Since women and children usually do this work, it empowers them to engage in income producing activities and to pursue an education.

Challenges and Constraints:

Small farmers in Africa usually let their animals roam so dung collection can be difficult and time consuming. Additionally, the very poorest people in Africa may not even have the small amount of capital needed to purchase and install a biodigester to start using biogas. Therefore this technology may be more suitable for use at a medium to large scale as by hospitals, schools etc. rather than by individuals.

It should also be considered that biogas is not that efficient to use for electricity, and is more suited to producing a combination of heat and electricity. Places with a mature electric grid in place may not

Costs:

Biodigesters can cost up to $1,700 depending on their size and the materials used. However this technology can be extremely affordable. There have been successful projects set up using plastic biodigesters that cost only USD $45 per unit.

Figure 11. A biogas digester in India. *Source: Ashden Awards*

Renewable Energy for Africa

BIOGAS Continued

Biogas in Action!:

Biogas projects in China, India and Nepal have all been successful using cattle dung as the waste product to supply biogas for cooking fuel for rural families. In China there are a reported 12 million working units, over 2 million units in India and 172,000 in Nepal (the most biogas units per capita in the world).

In Rwanda, the Kigali Institute of Science, Technology and Management (KIST), started a large scale biogas project in a prison in Rwanda using human wastes from prisoners to make energy for cooking and was able to cut their yearly firewood costs in half, saving about £12,500 a year by 2005. The project started in 2001, and has had no setbacks. The bio-effluent (or "slurry") left after the treatment has been used to fertilize gardens at the prisons. Prisoners also learn useful skills of gardening and maintaining biogas systems as a part of the project, skills they can use upon release. The project is so successful that KIST now has biogas plants in 6 prisons, with a combined population of 30,000 people and will be expanding, installing 3 more biogas plants every year.

Figure 12. A prison garden in Rwanda fertilized by the slurry byproducts of the biogas process. *Source: Ashden Awards*

Potential for Africa:

Since this technology is extremely affordable and does not run on a variable resource like sun, wind etc., it could easily be implemented throughout all of Africa. It could be especially useful on the medium scale at hospitals, jails, schools or other institutions where there are lots of people generating wastes, a need to dispose of it, and a need for energy. Studies show that a simple digester, made with a wooden trough, polyethylene sheet and PVC piping, that costs only about USD $45 is effective at disinfecting animal and human wastes of harmful microbes while producing biogas. There has also been success with simple plastic digesters costing only $50. Many Africans currently use firewood for cooking, but this practice is causing large amounts of deforestation as well as contributing to major respiratory conditions for the women and children that are the most around firewood stoves. Biogas is a cleaner source of energy that does not degrade the environment or human health. It is especially useful for development because its provides a great fertilizer that could be used to grow crops while simultaneously aiding in sanitation of wastes.

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Renewable Energy for Africa

Wind

WIND TURBINES

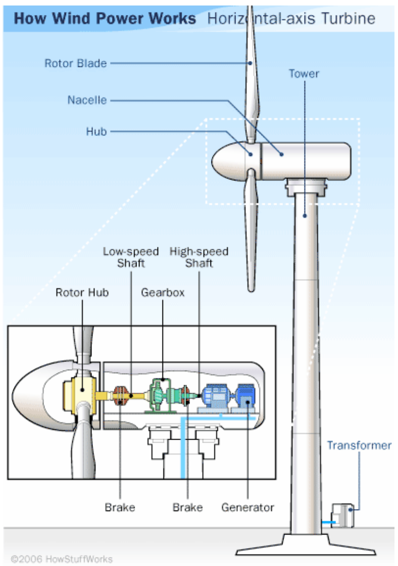

Fig.13 *Source: science.howstuffworks.com*

How it Works:

Wind power systems capture the kinetic energy of wind for use as mechanical energy or electricity. Wind turns the blades of a rotor or turbine. This movement rotates a shaft that is connected to a generator where it is converted to electricity. There are two basic kinds of turbines - vertical and horizontal systems. (see figure _. _) Vertical-axis turbines, also called "egg-beater" or "Darrieus" models, are less common. Horizontal-axis systems are the most commonly seen kind of wind power system. They usually have two or three blades that operate upwind (facing into the wind) and can vary in size and use.

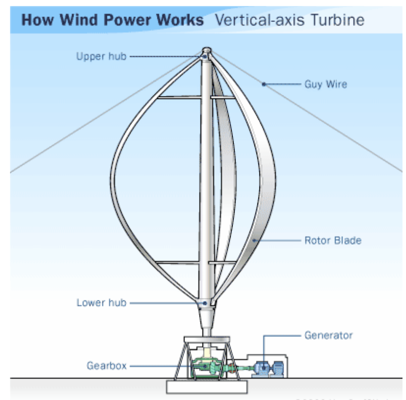

Fig. 14 *Source: science.howstuffworks.com*

Traditional wind turbines are not very big and are used mostly for mechanical energy on farms, usually to pump water, but also for other tasks like grinding grains. Modern utility wind turbines are lot bigger and can generate a lot more energy. Today, some people use small wind turbines (generating 100 kilowatts or less) for their individual homes or as part of hybrid systems with photovoltaic, battery or other energies in rural, off-the grid locations. Large utility turbines (generating from 100 kilowatts to several megawatts) are usually used for electricity and are often grouped together on wind farms that supply energy to the power grid in bulk.

Advantages of Using Turbine Wind Power:

ENVIRONMENTALLY FRIENDLY

- Wind power is a renewable energy, meaning it uses a resource that is naturally replenished.
- Generating power from wind energy does not emit greenhouse gases or pollution.
- Wind turbines cause minimal impact on their surrounding environments. Studies show that in general, birds can see and avoid turbines. In addition, recent innovations, like constructing turbines with smooth bases rather than a lattice base (where birds could perch), further decrease the chance of injury to birds.

EASY

- Small scale wind turbines do not take up much space, and can generally run alongside agriculture already in place.
- Wind systems can be set up relatively quickly, making it a good energy source for developing countries that lack infrastructure or capital for longer work.

RELIABLE:

- This is a proven and time tested technology.
- While energy that comes from foreign sources may be subject to political fluctuation, the availability and cost of wind power is more stable and reliable.

LOCAL: Wind power uses a source of energy that is captured and used locally. Therefore it brings jobs and income to the community, and encourages self reliance rather than dependence on foreign resources.

AFFORDABLE:

- Wind energy is one of the lowest costing renewable energies and as the market for wind power has been growing at a rapid rate over the last few decades, the cost has been continuously decreasing.
- There are no fuel costs to run a wind powered turbine, and only minor maintenance costs.

Renewable Energy for Africa

WIND TURBINES Continued

Challenges/Constraints: Wind is a highly variable resource; the strength of the wind at a given location can vary by time of day and season. However, it can be integrated into larger grids relatively easily using the existing mechanisms to deal with variable energy supply. When wind energy makes up 20% or more of the grid's energy, additional infrastructure may be needed to manage and forecast supply and demand. Having wind farms more dispersed will help ensure that somewhere wind energy is being captured and will aid integration.

Some people pose aesthetic concerns about the visual impact of large turbines on landscapes, or concerns about the noise of turbines. However technological advances that have greatly decreased noise, careful site selection, and a growing awareness of the need for renewable sources of energy should help negate these issues.

While generating wind energy is not costly once a system is operating, wind power does have higher initial capital costs, i.e. to build the turbine. It is even more costly to build off-shore wind farms which have the potential to capture the strongest winds and provide the most consistent and efficient energy.

Fig. 15 Photo from the 2006 opening of a hybrid wind and oil powered cell phone base in Nairobi. *Source: Bergey WInd-*

Costs: As a general rule, wind energy costs less using a larger turbine and where there are higher average wind speeds. At good sites, wind energy is cost competitive with plants run on coal or gas. In the US wind energy costs between 4 and 6 cents per kilowatt-hour, depending on the particular resource and project. The cost of building a wind turbine varies greatly by size and materials used, from $150 for a small turbine to $15,000 or more for an industrial one.

Wind Power in Action!: Wind power is becoming more attractive for developing countries. In 2008, South Africa's first wind farm was completed in the town of Darling, with the help of the Danish government. It consists of 4 turbines which are expected to generate about 12.9 GWh a year. The project also entails local wind power education and technical training with the goal of making South Africa leader in the wind energy industry.

Potential for Africa: Currently. due to slow wind speeds and high costs, the majority of wind power is used for water pumping not for electricity. Pumped water is for household use, irrigation and livestock. However there is potential for large scale wind power development along its coasts, in the north, and the extreme east, west and south. According to the Global Energy Network Institute the following 15 African countries, organized by region, have been identified as having the strongest wind resources in Africa.

North Africa: Algeria, Egypt, Morocco and Tunisia
East Africa: Djibouti, Eritrea, Seychelles and Somalia
West Africa: Cape Verde and Mauritania
Southern Africa: South Africa, Lesotho, Madagascar and Mauritius
Central Africa: Chad

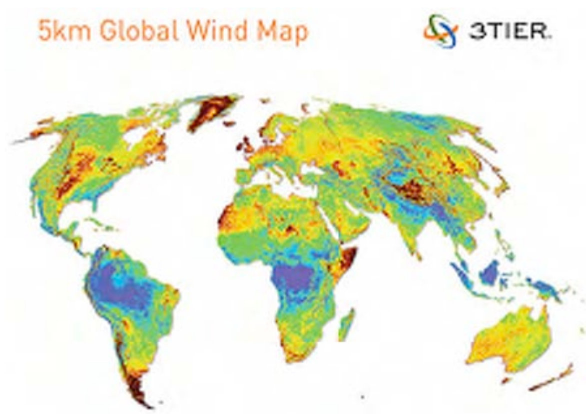

Figure. 16: 2009 World Wind map by 3Tier at 5 km
Source: Treehugger.com

Sources:

- American Wind Energy Association "Wind Energy Basics" http://www.awea.org/faq/wwt_basics.html
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- Greenpeace and Global Wind Energy Council. "Global wind energy outlook" Sep 20 2006. retrieved from http://www.greenpeace.org/international/press/reports/globalwindenergyoutlook
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- US Dept of Energy: Energy Efficiency and Renewable Energy, "How Wind Turbines Work", http://www1.eere.energy.gov/windandhydro/wind_how.html

Renewable Energy for Africa

WINDBELT™

How it works:

This new technology is the first ever to capture wind power with out using a turbine. It is very efficient and unlike turbine systems, it can operate effectively on the micro scale, and generate elctricity from very low wind speeds. The windbelt runs using the energy of aeroelastic flutter, an aerodynamic phenomenon that has been studied for its destructive power but has never before been captured as a useful source of energy. Windbelt technology uses a simple system that consists of a membrane held under tension, and a magnet mounted on one end of the membrane that moves perpendicular to a coil when the membrane vibrates. The movement of the magnet creates electricity in the coil. (see diagram) Humdinger Winder Energy LLC, the company that is developing this technology is working on making different sized units for various uses and energy output.

Fig.17

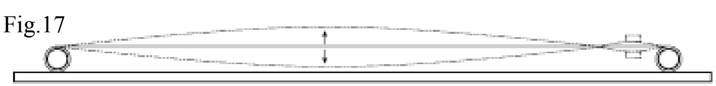
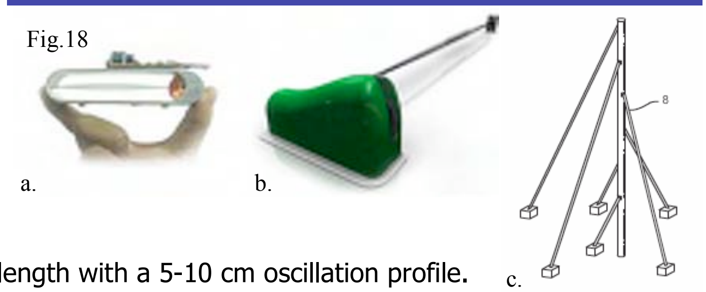


Figure 17. Oscillation profile of one variation of the Windbelt technology
Figure 18. a-b Micro, and medium windbelt prototypes c. sketch of a possible large-scale windbelt
Source: Humdingerwind.com

Fig.18



a. b. c.

Advantages of Using WindBelt Technology:

SCALABLE

- There are micro, medium and large scale versions of the Windbelt tm being developed.
- The micro version could be used to replace batteries and is operational at low speeds (5-20 mph, self-trimming in higher speeds) with a frequency of 70Hz.
- The medium Windbelt being developed is about 1-3 m in length with a 5-10 cm oscillation profile. Medium units generate 3-10W at a frequency of 50-60 Hz. It is important to note that these medium Windbelts, or windcells, can be used individually for smaller applications like powering a wifi router or as building blocks with as many other medium units as is desired for the specific energy needs.
- Larger scale windbelts are still being experimented with and therefore the details about their size, cost and energy capabilities have not yet been made available. Humdinger currently has a pilot large scale windbelt project running in Guatemala and we can expect to see this technology develop and on the market in a few years. (pic)

ENVIRONMENTALLY FRIENDLY:

- The Windbelt does not have any emissions.
- The Windbelt uses a renewable resource -wind.
- A single micro-Windbelt gathers as much energy as dozens to hundreds of AA batteries. If they are used as a substitute for disposable batteries, could greatly reduce waste, and potentially lower existing energy usage in buildings by 30-40%,

EFFICIENT: This turbine-less technology is significantly more efficient at capturing winds, especially for regions that experience lower wind speeds.

INEXPENSIVE: At a projected $2 per watt, medium Windbelts will provide energy for two to four times less than photovoltaic systems. Energy from medium Windbelts is also less costly that energy from MW-size wind turbines.

ACCESSIBLE: Originally developed to provide Haitian villagers with a low cost source of energy to run small LEDS instead of kerosene lamps, the Windbelt was designed with accessibility in mind. Aside from its low price and cheap power, the Windbelt's capacity to be used on the micro-scale brings a new potential for wind power to most of the world that do not experience high enough wind speeds to run turbine systems.

LOCAL + OFF the GRID: This technology uses a local resource that is therefore not subject to political instability to grid failures.

SOCIALLY BENEFICIAL: Windbelts could use local winds to provide enough energy for household and school lighting leading which has been shown to increase education and the success of micro and small enterprises, leading to further community development.

WINDBELT™ Continued

Challenges/ Constraints:

Since the innovative thinking behind Windbelt technology is so new, the technology is still being developed. Large scale Windbelt technology, in particular, is still being researched and tested (see but all prototypes are still being refined. As of April 2009 windbelt units are not yet for sale, however according to the Humdinger website currently, "Windbelt systems are being brought to market through technology transfer agreements in the energy and information industry". In addition, Humdinger has made available a technical brief to aid people in noncommerical educational endeavors to make their own Windbelt systems.

Figure19. A large scale windbelt being tested by Humdinger in Xela, Guatemala. (Photo: Ina Rommeck)
Source: Humdingerwind.com

Figure 20. The Tacoma's Narrow Bridge, which collapsed in 1940 due to the phenomenon of aeroelastic flutter.
Source: Humdingerwind.com

Costs:

Medium windbelt units have a projected cost of $2 per watt, and Humdinger expects that this cost will decrease over time. Micro and large windbelts are still being tested and developed, though we can expect energy costs will be lower than solar PV, and MW wind turbine power.

Potential for Africa:

Most of Africa does not have high enough wind speeds to be eligible for turbine wind power, however the entire continent could benefit from the use of micro-windbelt technology, since it can run on as little as 5 mph. Microscale solutions like the windbelt can help the communities that adopt them experience many positive effects of electrification, such as improved indoor air quality, and decreased energy costs.

Sources:

- Discover Magazine "Ten Everday Technologies that can Change the World", October 2008. by Karen Rowan , retrieved from discovermagazine.com/2008/oct/08-10-everyday-technologies-that-can-change-the-world
- Ecofriend, "Shawn Frayne Disclosing the Intricacies Behind his Ingenious Windbelt" Dec 3 2007, www.ecofriend.org/entry/shawn-frayne-disclosing-the-intricacies-behind-his-ingenious-windbelt/
- Humdinger Wind Energy. www.humdingerwind.com

Renewable Energy for Africa

Sun

CONCENTRATED SOLAR POWER (CSP)

How it works:

This technology, sometimes called solar thermal electric, has world record high solar-to-electricity efficiency rates. Concentrated Solar Power (CSP) uses the heat of sunlight to generate electricity and is distinct from photovoltaic technology. There are three main kinds of CSP systems, linear concentrator, dish/engine, and power tower systems, differentiated by how they collect sunlight. All kinds of CSP system use mirrors to reflect and concentrate sunlight onto a receiver that collects heat which is used to drive a turbine and generate electricity.

Figure 21. Parabolic trough system

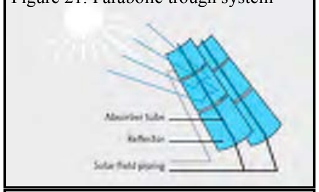


Figure 22. Dish system

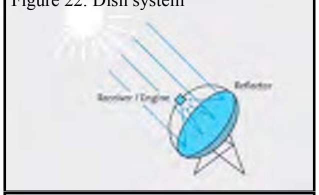


Figure 23. Power Tower system

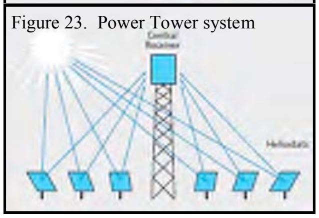


Fig. 21, 22, 23 *Source: GreenPeace*

Linear concentrators systems use long rectangular curved mirrors that face the sun to focus the sunlight onto receiver tubes. There are two type of linear concentrator systems, parabolic trough systems (see fig. 1) where the receiver tube runs along the focal point of each parabolic mirror, and linear Fresnel systems where the receiver tube is positioned above several mirrors. This is the most used and proven solar thermal system. The highest single unit solar capacity built to date is 80 MWe. (info from http://www.nrel.gov/learning/re_csp.html)

In **dish** or **engine systems**, sunlight is reflected onto a thermal receiver using a large mirrored dish that is usually mounted on a base that allows it to track the sun. The receiver absorbs the heat and transfers it to the generator. There are a few different ways to do so but he most common heat engine used in dish systems currently, is the Stirling engine which uses heat to move pistons, creating mechanical power that is used to run a generator. Dish systems typically produce between 3 to 25 megawatts, and are generally less productive than other kinds of CSP systems.

The **power tower system** uses many flat mirrors, called heliostats, to track and concentrate the sunlight to the top of the tower where the system's thermal receiver is located. The receiver's heat is used to run a turbine as explained above. The power tower system is very efficient and productive; individual commercial systems are projected to be able to produce 200 megawatts of electricity.

Advantages of Using CSP:

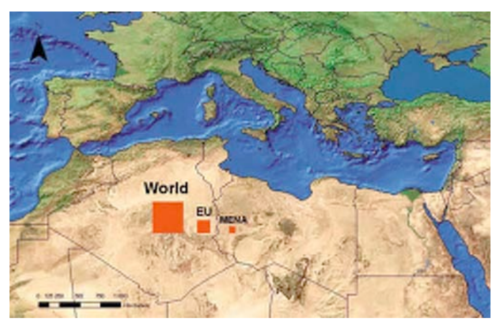


Figure 24. A map of the North African Saharan Desert, with squares indicating the amount of land that would be needed to power the World, the EU, and the Middle East and North African countries (MENA) based on current energy usage. *Source: Desertec-UK*

ENVIRONMENTALLY FRIENDLY:
- CSP uses a renewable resource (sunlight).
- CSP produces energy with out any emissions or pollution

EFFICIENT:
- CSP has the highest solar to electricity conversion efficiency.
- New technology allows for improved energy storage, so CSP electricity can be used efficiently at night.
- CSP systems are easy to integrate into existing grids, saving time and money.

PROVEN:
- CSP systems have been used for more than 30 years, and are a proven technology.

ABUNDANT:
- Where it is most applicable, in deserts, there is an abundance of unused sun energy, that CSP systems capture and capitalize on. See map of best CSP locations

INCOME PRODUCING:
- There is enough solar energy in African deserts to theoretically power the entire world with CSP. Those African countries rich in solar radiation could soon export CSP- produced electricity.

CONCENTRATED SOLAR POWER (CSP) Continued

Fig. 25 Southern view of Spain's Power Tower , PS10, in Seville; *source: beyondzeroemissions.org*

Challenges/ Constraints: There are a few challenges to the use of CSP. Firstly, CSP requires a lot of land, which should not be a large problem in Africa where it is most applicable in the sun-rich deserts. However this technology is still relatively expensive, and would probably require capital from outside sources to get started, although it is notable that CSP is cheaper than PV and CSP energy is easier to transport as well. Additionally, as time goes on, and CSP technology advances we can expect it to get more affordable and to improve its energy storage capabilities.

Costs: Costs vary based on what type of CSP system one is building. In the near term costs will be less than 15-20 cents/kWh, with varying costs depending on the solar resource. Trough plants will generate electricity from 7-8 euro cents per kilowatt in the medium term. Costs will be lower in the long term or in trough systems that are integrated with gas-fired plants. We can expect costs of electricity from "power-tower" systems to be 6-7 euro cents/kWh in the medium term and 5 euro cents/kWh in the long term. (According to a document by Greenpeace, "CSP now!")

CSP in Action!: California and Spain are the world's current leaders and both have large active CSP projects. The world's largest CSP plant is a power tower in Seville, Spain known as PS10 (See picture above). It is 115 meters (377 ft) high and uses 624 large mirrors placed around the tower that automatically track the sunlight east to west and reflect an intense light onto the thermal receiver. The tower produces 11 MW of electricity, enough to save about 18,000 tons of carbon emissions every year as reported by Abengoa, the company responsible for the project. Israel, France, Egypt, Austrailia, South Africa and Algeria are all looking into building CSP plants.

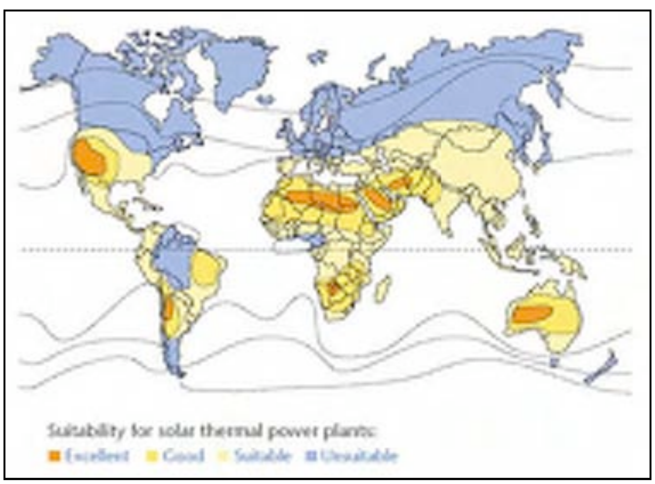


Figure 26. World Map indicating CSP suitability; *Source: Destertec*

Potential for Africa: The Saharan desert in the North and the Kalahari desert in the South have the best conditions in Africa for future CSP plants. Due to the vast amount of sun energy available in the Sahara desert and its location there is thepotential for energy trading between Europe and North Africa. Solar power could be exported using High Voltage Direct Current (HVDC) technology. Transporting CSP energy from North Africa to Europe would have transmission losses of at most 15% and therefore is still financially appealing. Such a trade would help meet high European demand for clean energy, while providing African countries with the investment capital to build the CSP plants and skilled jobs to maintain them. Once the plants are built they have the potential to produce enough energy to provide for domestic needs and provide profit by helping to meet European energy needs.

Sources

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PHOTOVOLTAIC (PV)

How it Works: Photovoltaic (PV), also known as solar electric, power converts sunlight energy into electricity using photovoltaic solar cells. Each PV cell is a small unit that typically produces about 1-2 Watts. To meet varying power needs, PV cells are grouped together into larger units called modules, and modules are groups together in larger units called arrays. The PV cell is made up of semiconductor materials that interact to create an electrical field. Photons of light are absorbed by the PV cells where they knock electrons in the cells into a higher state of energy so that they escape their normal position and create an electrical current in the cell. The electrical field created by the interaction of the semiconductor layers of the PV cell provides voltage to drive the electric current of the moving electrons through an external load such as a light bulb.

In addition to PV cells grouped in modules or arrays, a PV system also needs a structure to mount the cells on so that they face the sun, and a component to condition the direct current electricity produced by the cell so it is usable, usually by converting it into alternate-current electricity. Some PV systems that are not connected to a larger grid also use a battery that stores the electricity produced for later use.

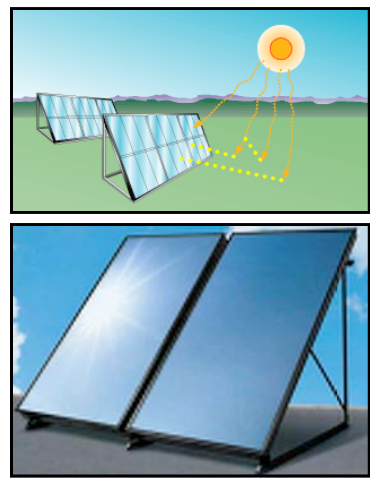

Fig. 27 + 28. PV Flat Plate Collectors
Sources: (top) US Dept of Energy (bottom) Sky Flair Ltd.

PV systems can be classified by their design as flat-plate systems or concentrator systems. **Flat-plate collectors** use a rigid flat surface to mount a large amount of solar cells and can absorb both direct and diffuse sunlight. Diffuse sunlight is sunlight reflected from clouds, the ground and other objects. On a partly sunny day up to half the radiation is diffuse, and on a cloudy day 100% of the radiation is diffuse, therefore it is an advantage of flat-plate systems that they can absorb diffuse sunlight. The simplest PV system is a stationary flat-plate system, which can often be found mounted on residential roofs.

PV systems can also be mounted on a tracking structure that tracks the sun daily route east to west. More sophisticated two-axis tracking systems track the sun's daily path as well as its seasonal course between the northern and southern hemispheres; these are most commonly used with concentrator systems.

Concentrator systems use lenses to focus sunlight onto fewer PV cells. A basic concentrator PV system uses an assembly of cells, a structure to hold them, a lens to focus the light onto them, a secondary concentrator to reflect off-center rays onto the cells, and a cooling device that dissipates the excess heat created by the concentrators. The advantage of this kind of system is that it uses less PV cells, which are often the most expensive part of a PV system, and that a cell's efficiency increases under concentrated light. However there are also some downsides to a concentrator PV system – concentrating optics can be expensive and the system requires a cooling mechanism to keep the cells from overheating under the concentrated light, as well as a tracking system. In addition concentrator systems do not utilize diffuse sunlight which can be up to 20% of the light even on a clear day.

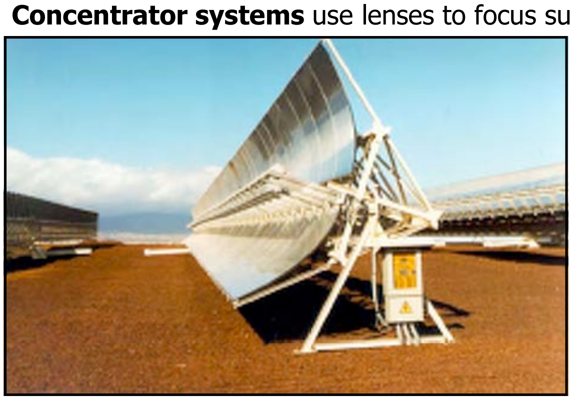

Fig.29 Example of a concentrator system. *Source: The European Commission Directorate– General Energy and Transport*

Advantages of using Solar Photovoltaic Power:

ENVIRONMENTALLY FRIENDLY: Solar PV relies on a renewable resource, and it is emission and pollutant free.
LOCAL: Solar PV uses a local resource which does not need to be transported to its place of use, is not subject to political fluctuation.
ABUNDANT: Africa is of the most sun rich region of the world.

PHOTOVOLTAIC (PV) Continued

ADAPTABLE: Solar PV can be used as a part of the energy mix in a grid system or on its own, off the grid.
Since solar PV is made of individual cells that can be combined in any number, each system can be easily customized to suit the resource availability and energy needs of a particular project.

POSITIVE SOCIAL IMPACT:

- Especially if the systems are produced locally, PV systems could provide skilled and technical jobs for local people.
- Rural electrification can lead to improved educational opportunities and economic development by increasing the working hours in the day. The quality of power from electricity is superior to other sources and

Fig.30. Rooftop PV modules in West Bengal, India used to power lights and refrigerators that contain vaccines and medicines. *Source: US Dept of Energy*

Challenges/ Constraints: Constructing a PV system can be prohibitively expensive, especially for the majority of communities in Africa that are most in need of electricity. Since PV cells are seen as a commodity, PV systems in poverty stricken areas are sometimes stolen for parts and PV Systems would require security measures like fences, locks or a security guard to protect them. Additionally, at this time most PV systems are not constructed locally, and must be imported meaning they may be subject to duties, and they lead to money leaving the local economy. Importation is difficult for small companies with out credit and capital available to them. The high quality batteries that are the best to store PV generated electricity in are also very costly. So far, PV systems can not be used to replace cooking fuels, therefore they do not address the indoor air quality issues that cause many respiratory diseases.

Costs: Costs are currently about $4 USD/ watt, although some experts say that in 2009 costs for PV cells will greatly decrease, possibly down to $2.6 USD/watt by the end of 2009 due to lower prices for solar grade silicon and thin-film market starting to grow to scale.

PV in Action!: Greenlight Planet, a commercial enterprise, is selling an efficient solar PV powered LED lantern in India, called the Sun King TM. On one day's worth of charge it can provide 16 hours of light on its lantern or torch mode, and 4 hours on its brightest setting. It is a complete unit that runs off the grid and pays for itself in a year by saving fuels costs. After a test run in India, it is now being scaled up in production and should soon be available for purchase around the world.

Fig.31.

Sun King TM Solar Lantern
Source: Greenlight Planet

Potential for Africa: Since PV runs on solar power, and Africa experiences some of the most intense solar radiation in the world, all of Africa could theoretically benefit from solar PV power. Some studies show that when PV has been brought to parts of Africa, only those people who have enough money to already have access to other energy sources can afford to use it, therefore it is not reaching the poorest people who have no access to electricity. Still, poorer people in the community may still benefit from having PV sources of power around, for instance because it could help local business and hospitals increase their opening hours, and could be used for outdoor lighting which everyone benefits from.

PV's greatest potential application in Africa is to be used in rural areas that are not very densely populated and do not have a demand for very large amounts of power – these are the places that it is not likely that the grid will extend to reach any time soon, and one of PV's greatest strong points is that it does not need to be connected to the larger power grid. However, even communities that have access to the grid may choose to invest in PV systems because in many places grid power is still rather unreliable.

PHOTOVOLTAIC (PV) Continued

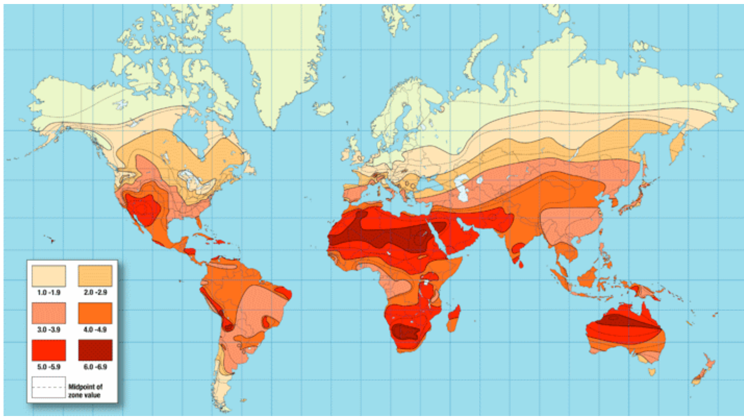

Figure 32. World map showing the amount of solar radiation (in kilowatt-hours per square meter), received each day on an optimally tilted surface during the worst month of the year. *Source: pysolar.wordpress.com*

As of now the potential for PV systems in Africa is limited by the costs involved. Local production of system components and government support for PV projects will be essential to the spread of this technology in Africa. The demand for electricity exists; people in rural areas are willing and many are surprisingly able to pay for their electricity.

Sources

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- Greenlight Planet at greenlightplanet.com
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SOLAR COOKING AND WATER PASTEURIZATION

How it Works: Solar cooking uses the heat of sunlight as a source of energy to cook food. It is a low cost and low technology alternative to using gas, charcoal or burning wood stoves. There are three general types of solar cookers: box cookers, parabolic (also called dish) cookers, and panel (combination) cookers. In all cookers, the food is placed in a pot that will absorb and retain the heat of the sun - "dark, shallow, thin metal pots with dark, tight-fitting lids" work best. (solar cookers international at http://www.solarcookers.org/basics/how.html) Solar cookers have reflective, conductive interior surfaces like sheet metal or aluminum foil covered panels, and insulated walls that aid the conveyance of heat to the pot placed inside the cooker. Some cookers use mirrors to reflect extra sunlight back towards the pot. The dark colored pot with food in it is either placed in a clear, sealed plastic bag and then into a solar cooker or into a cooker with a fitted transparent lid. The transparent bag or lid allows sunlight to reach the pot while it keeps the heat around the pot from escaping.

This technology is most commonly used for cooking food and pasteurizing water. It can be used for cooking most any food, including grains, beans, and even meat, although cooking time will be longer than using a conventional stove or oven. It is convenient for slow cooking foods like stews and can even be used for baking breads when the sun is high in the sky (from 11 am- 2 pm). Simple solar cookers typically reach temperatures from 82-135 degrees C (180-275 degrees F).

Figure 33. 3 Types of Solar Cookers

Box Cookers | Parabolic/ Dish | Panel Cookers

Source: Solar Cookers Int'l

SOLAR COOKING & WATER PASTEURIZATION Cont'd

Advantages:

INEXPENSIVE: Solar cookers can be made cheaply and easily (see Costs below)
ENVIRONMENTALLY FRIENDLY: Solar cooking does not degrade the environment in any way and can be used to replace alternative cooking fuels such as charcoal, wood and gas.
ABUNDANT: Africa is one of the most sun rich regions of the world. See solar distribution map (Fig.6 - on p. 6)
ACCESSIBLE: Sunlight reaches even the most underdeveloped, poverty stricken communities, or conflict zones where people have highly limited access to other sources of energy.
EFFICIENT:

- Solar cooking could saves time and effort and money currently spent on accumulating other sources of energy.
- Solar cooking cooks food with heat from all directions, unlike most stoves where the heat source in below the pot, solar cooking does not require stirring or monitoring. Ingredients can simply be placed in the pot in the morning and hot food will be ready in a couple hours for an afternoon or evening meal.

HEALTHY:

- Simple solar cookers reach temperatures that are high enough to kill harmful bacteria in food and water but low enough that food will retain its nutritional value and will never burn.
- Solar cookers can also be used to pasteurize water, and therefore can stop the spread of waterborne disease including . It is easy to make sure the water has reached a high enough temperature using simple devices like SCI's Water Pasteurization Indicator (WAPI), and a basic cooker can pasteurize one liter of water in about an hour.
- Using solar cookers decreases the household use of firewood and charcoal and therefore decreases smoke inhalation and resulting health complications.

SOCIALLY BENEFICIAL: Solar cooking can help foster female empowerment, by drastically reducing the time and energy women have to spend collecting fuel and cooking food. It has also been used to help keep women and children in war zones safe from rape or attack by rebels who often attack those who leave refugee camps in search for firewood.

Figure 34. Women outside a solar cooker shop in Kenya with two cookers. *Source: SCI*

Challenges/Constraints:
Solar cooking depends on strong, direct sunlight. One can not solar cook in the evening, night or early morning, when it is cloudy, raining or in regions where there is not enough sun (although all of Africa gets enough sun to be eligible for solar cooking).

Costs:
Panel solar cookers can be made for about USD $4-7 each. Other supplies needed to solar cook like black pots and heavy duty plastic bags are also rather inexpensive. For example, Solar Cooking International, an NGO that distributes solar cookers can provide a family with 2 cookers, 2 pots, enough bags for a year and training on how to solar cook for $30. Other kinds of cookers can be more expensive depending on the materials used for construction.

Solar Cooking in Action!:
Solar cooking is widespread in rural India, and other sun-rich places including countries in Africa. For example Solar Cooking International has humanitarian and development programs currently running in Kenya, Zimbabwe, Ethiopia and Chad. The program in Chad began in 2005 when SCI partnered with KoZon, a Dutch charity, to provide solar cooking training and materials to Darfur refugees living in the Irimidi refugee camp in Chad. By mid-2007, virtually all the 4,000 families living in the camp were successfully and consistently using solar cooking. Due to the success of the program the United Nations Commisioner for Refugees (UNHCR) has asked KoZon to expand CooKit training and distribution to other Refugee camps in Chad.

Potential for Africa:
All of Africa gets enough sun to be eligible for solar cooking. Distributing solar cookers and training could help with development and improve the quality of life for most Africans without another clean, easy, inexpensive way to cook food. Knowledge of how to construct solar cookers and how to solar cook could be passed on from person to person within communities.

Source: Solar Cookers International, solarcookers.org

Renewable Energy for Africa

Water

MICROHYDRO

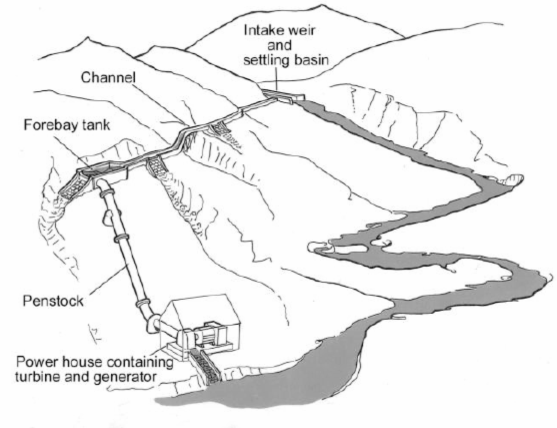

Figure 35. A typical run of the river micro-hydro system, *Source: Practicalaction.org*

How it works: Hydropower is the mechanical or electrical energy derived from the force of moving water. Micro-hydropower systems capture the energy of moving water on a relatively small scale (between 10kW and 200kW), and provide decentralized power (off the grid).

Micro-hydropower systems require a small turbine, which is turned as water flows through it, and civil works, to divert water into the turbine and return it to the stream after. Some also use a generator or alternator connected to the turbine that converts the mechanical energy produced by the moving turbine into electricity.

In general, to run a water turbine you need at least 2 feet of head (height from which water is falling) and at least 20 gallons per minute of flow. Alternatively, if you have more head, less flow is required (as little as two gallons per minute).1+2 There are different turbine designs to suit varying levels of head and flow. Mountainous or hilly areas are most popular for micro-hydro systems because they operate most effectively when water is flow is steep.

Advantages:

ENVIRONMENTALLY FRIENDLY:

- Microhydro systems are emissions free.
- Micro-Hydro power is "run of river", meaning it relies directly on the natural flow of a river or stream and does not utilize dams or reservoirs to control the movement of water. In micro-hydro systems, water flows through the system and is immediately returned to the stream it was captured from. Therefore micro-hydro systems are considered to have minimal impact on the surrounding eco-system.

LOCAL: This technology makes use of local water resources and microhydro systems can help a community develop self-reliance for their energy needs, and provide jobs for people in the community.

DECENTRALIZED: This technology is well suited for rural undeveloped areas that are "off the grid", and can be a source of power of a mini-grid that provides energy to a marginalized community, but can also be easily incorporated into a larger grid where one is available.

EASY: Since micro-hydro systems do not use dams or reservoirs they are relatively quick and easy to set up.

Challenges/Constraints:

There are initial capital costs to set up microhydro projects so these projects will probably need external funding to get off the ground. Once established, maintenance costs are relatively low. Those micro hydro programs that make energy available to poor people, or provide electricity only, are usually not financially self-sustaining and may require subsidies. On the other hand, when the generated power is used for income-creating projects (ex. Mechanical power used to run food-processing plants like mills), as well as to provide household electricity, the system is more financially viable.

The amount of water and rate of flow at a site may vary seasonally. Since micro hydro systems do not store water, the capacity for energy generation in the summer or dry season may be lowered. Additionally, expansion of a system to meet growing demand may not be possible in cases where the size and flow of a stream puts a limit on the amount of power that can be generated. Microhydro systems are only suitable where there is a reliable, source of moving water nearby (optimally no more than about a mile) from where the energy is needed.

Renewable Energy for Africa

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Costs: The capital costs can be high, and vary greatly from project to project. As a guide, every kilowatt of power generated costs about £800. Micro-hydro projects that supply mechanical energy for local industrial needs (ex. Milling, oil extraction, sawmills, carpentry workshops etc.) are less costly to initiate than those used only for electricity generation and are more profitable because they often create income. Once a system is built it is funded by payments from the families and companies that receive energy from it. Optimally, it should soon be able to pay for its own maintenance and operation.

In order to minimize costs it is essential to properly assess the water source and appropriateness of the site before beginning the project, observing flow levels for at least a year. Other ways to reduce the costliness of this technology include using local materials and workers for the system's construction. Local labor to build the civil works accounts for about 15% of the total cost of the system.3 Ideally, for both social and economic reasons, after a micro-hydro system is built, it should be locally owned, managed and maintained.

Microhydro In Action!: Small hydropower has been successfully implemented in Nepal and the Himalayas. There are also many small hydropower programs in South America, including Peru and Bolivia. There are already some successful micro-hydro projects in Africa – in Zimbabwe, Mozambique, Rwanda and Kenya.

The Tungu-Kabri micro-hydro power project in Kenya is one such project. The Mbuiru village is a typical Kenyan village, its people are generally poor farmers without access to electricity. Most families spend at least a third of their incomes on kerosene for light and cooking, or they resort to chopping trees for firewood. This micro-hydro project was organized by Practical Action East Africa and the Kenyan Ministry of Energy. Villagers worked once a week or more for 2 years to build it, and now it generates about 18 KW of electrical energy, enough to benefit 200 homes.

Figure 36. The Tungu-Kabri micro-hydro power project in Kenya run by Practical Action East Africa. *Source: Practicalaction.org*

Potential for Africa: According to President Mwai Kibaki of Kenya "The continent (of Africa) has some of the highest hydroelectricity potential in the world"4. As reported in a 2003 document for the UN, "Only about 7% of Africa's enormous hydro potential has been harnessed. Existing estimates of hydro potential do not include small, mini and micro hydro opportunities, which are also significant." Knowing as we do, that large scale hydropower plants that utilize massive dams and reservoirs can be quite detrimental to the surrounding ecosystem, small scale hydropower is a more environmentally friendly way of utilizing the great resource of water that is available in Africa, with the potential to provide the same amount of energy with less environmental degradation. And not only does micro-hydro power provide the potential for rural electrification, since energy generation is local and decentralized, it also increases self sufficiency of marginalized communities and can contribute to community empowerment and development. Africa has many rivers and tributaries that would be suitable for micro-hydro projects.

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