SAMSET brief on Other Renewable Energy Technologies

This briefing note has been designed for use by city officials and planners working in sub-Saharan Africa. It is a practical guide, which identifies easy to achieve energy interventions that will save money (for cities, businesses and households), promote local economic development, and enhance the sustainable profile of a city. This note is specifically aimed as a support tool to achieve the implementation of key interventions within municipalities across sub-Saharan Africa.

African municipalities need to be prepared to deal with an explosion in demand for services from burgeoning populations caused by two factors – high population growth in Africa as a whole, and rapid urbanisation. An interesting feature of population growth in sub-Saharan Africa is that it is expected to take place mostly in small and medium sized cities, rather than capitals (UN-Habitat, 2010). These changes are taking place at a time when many countries are devolving administrative powers to local governments, yet municipal authorities lack the skills and expertise to address challenges, to manage resources, and to implement and enforce policies.

Energy is only one of many services that municipalities need to address in the face of increasing urbanisation, but it is crucial to any form of urban development – planned or otherwise. People need energy as part of their every-day lives. The supply of energy is closely linked to economic development, health and individual wellbeing, as well as to local and global environmental sustainability.

Recognising the emerging role of municipalities, with limited capacity, in addressing energy provision in urban centres, the "Supporting African Municipalities in Sustainable Energy Transitions" (SAMSET) project seeks to build capacity and develop a practical and effective knowledge exchange framework for supporting actors involved with municipal energy planning. This note is an output of the SAMSET project.

The purpose of the note is to give planners an idea of the range of energy interventions that it is possible for them to implement at the municipality level. It provides enough information to give a basic understanding of different energy technologies – enough to start making enquiries and engage in discussion. More detailed technical expertise will, however, be needed in order to design a bankable project.

Full guide can be found at africancityenergy.org/uploads/resource_101.pdf

More info can be found at africancityenergy.org/

More project info can be found at samsetproject.net

Overview

Concentrated Solar Power (CSP)

Concentrated Solar Power (CSP) plants generate electricity by collecting incoming solar radiation and concentrating it onto a small area to generate high temperatures. The heat is then used to drive conventional steam generators. A CSP plant can be divided into two basic sections 1) the Collector, which collects the incoming solar radiation and converts it to heat and 2) the Generator, which converts the collected heat into electricity. There are three main collector technologies available as outlined below:

1. Solar Trough: A solar trough consists of a linear parabolic collector, which tracks the sun on a single axis to focus the light onto an absorber tube running along the focal length of the troughs. The collector holds a carrier fluid, which transfers the heat to the storage medium or generator.

2. Power Tower: The power tower uses an array of mirrors, which track the sun on multiple axes to focus sunlight onto a central receiver, placed on the apex of a tower. Like the solar trough, the collector holds a carrier fluid, which transfers the heat to a storage medium or directly to the generator.

3. Parabolic dish: This system consists of stand-alone parabolic dishes which focus sunlight onto a focal point. This can either hold a collector, which holds a carrier fluid, or a Stirling engine, which would generate electricity directly. Parabolic dish systems are known for their very high efficiencies in converting solar power to electricity.

The key variable for CSP projects is direct normal irradiance (DNI), i.e. the amount of radiation received by a surface always kept perpendicular to the sun's direct rays. The electrical energy generation of a CSP plant and thus electricity costs are directly dependant on the available DNI. The map below shows the annual DNI across Africa.

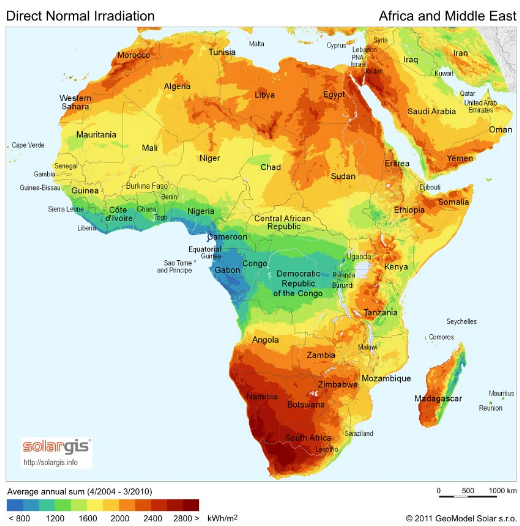
Total global installed CSP electrical generating capacity is 4.4 GW, so it is still a young technology, but installations have grown rapidly since 2010.

Wind Power

Wind energy is generated when the kinetic energy of the wind is harnessed by large wind turbines and converted into mechanical energy. To generate electricity, this mechanical energy is used to rotate generators situated in the hub of each turbine. Wind turbines can range in size from small home or boat based 50 W units to the large 6 MW commercial units which have an overall height of nearly 200m.

Wind turbines for commercial power generation are generally arranged in an array, collectively called a wind farm. Wind farms are typically located in areas where a consistently high level of wind is present. The performance of wind turbines increases exponentially with the linear increase in wind speed. Therefore consistent strong winds are critical to the financial viability of a wind farm. Wind speeds are stronger at higher elevation levels, and on top of smooth hills, which is why most wind turbines are mounted on high masts and on top of hills where possible.

Electricity generated from all the turbines in



Case Studies: Eskom's Solar Water Heater Rebate Programme

Eskom in South Africa has long been promoting a range of energy efficiency measures as Image © Cadbury they struggle to meet increasing demand for electricity. In 2008 they introduced the Solar Water Heater Rebate Programme. The South African government required Eskom to substitute 10,000 GWh of electricity with renewable energy. The rebate programme set a target of replacing electric geysers in 1,000,000 homes with SWHs, and was expected to achieve 23% of Eskom's overall target. Funds were made available for a five year period by the National Energy Regulator of South Africa (NESRA).

Image © Blue Carbon

In 2015, Eskom withdrew from the scheme, which was then suspended; by this time 425,000 solar systems had been installed. One of the reasons given for the underperformance of the programme was poor installation quality. As details of the scheme changed, subsidies were shifted in favour of locally manufactured systems, as a means of stimulating the South African SWH industry. Only systems with at least 70% local content became eligible for the scheme. This then ruled out the use of evacuated tube type systems, as these are not made in South Africa.

Despite these setbacks, the government remains convinced of the value of SWHs. The National Development Plan set a long term target of 5 million systems by 2030, and the government committed to a reviewed national SWH programme in 2015.

the wind farm is combined and modified to feed into the power transmission network in the area.

Global installed wind generating capacity is 430 GW. The market is dominated by China. South Africa and Ethiopia are the only sub-Saharan countries with substantial wind capacity (1,050 MW and 320 MW respectively at end 2015).

Solar Water Heaters

A solar water heater uses energy from the sun to heat water and works on two basic principles. Firstly, when water gets hot it rises due to density differences between hot and cold water (thermosiphon effect) and secondly, that black objects absorb heat.

A solar water heater comprises three main parts: the collector, the storage tank and an energy transfer fluid. Solar water heaters are classified as either active or passive and direct or indirect systems. They may make use of either flat plate collectors or evacuated tubes.

The global installed capacity at end 2014 was 410 GWth. Over 70% of this was installed in China, and only 0.3% in sub-Saharan Africa, and this was predominantly in South Africa. The dominant technology was evacuated tube collectors (71%). Roughly half of the capacity in sub-Saharan Africa was used for small scale domestic hot water systems (single household), and half for heating swimming pools (reflecting use in South Africa).

The Case

Concentrated Solar Power (CSP)

One of the main benefits of CSP, especially when compared with other renewable energy technologies such as wind and PV, is the relative ease of energy storage. As the concentrated solar energy is used to generate heat, this heat can be stored (often as molten salts) in insulated containers and then used to generate electricity on demand, even when there is no sunshine. This means that CSP can be used to meet transient peak loads in grid connected applications, and it can provide 24 a day power in off-grid applications.

CSP deployment in sub-Saharan Africa has only started in recent years, mainly driven by the Renewable Energy Independent Power Producer Program (REIPPP) in South Africa.

Wind Power

SSA's installed wind energy capacity increased 14-fold between 2003 and 2010. Due to wind speeds, the greatest potential for wind power exists in West Africa.

Countries such as South Africa, Morocco, Egypt, Cape Verde, Ethiopia, Kenya and Tanzania are currently developing wind farms. Somalia, Sudan, Madagascar, Kenya and Chad – have large on-shore wind energy potential. Five additional SSA countries – Mozambique, Tanzania, Angola, South Africa and Namibia – have potentially large off-shore wind energy resources.

The best wind potential in SSA is found in coastal regions whether in the East (Djibouti, Eritrea, Seychelles and Somalia), West (Cape Verde) or South (South Africa and Lesotho). With the exception of Chad and Ethiopia, whose topographies give rise to high speed winds in certain high altitude areas, the rest of landlocked Africa's wind intensity is too low to be harnessed for electric power generation.

Solar Water Heaters

It's difficult to argue a case for solar thermal water heating because little data is available from sub-Saharan countries on the energy expended on heating water. It is common practice to put a pot of water on a stove after cooking is finished in order extract heat from the embers. This makes it difficult to apportion energy consumption between cooking and water heating. A case for solar water heaters can only be made where people are paying for the energy used; this is why the market is biggest in South Africa, where households typically use electricity to heat water.

For households, a solar water heater (SWH) has several benefits:

Water heating accounts for 40-60% of total electricity consumption for a typical home in South Africa. Electric water heating costs can typically be reduced by 70% with a SWH. This amounts to about a 25 to 30% saving on an average monthly electricity bill. This presents a strong financial case for replacing electric geysers with solar water heaters.

Climate change mitigation. From an environmental perspective, water heated mostly by the sun will reduce a household's CO2 emissions by displacing the use of fossil fuels or unsustainably sourced biomass otherwise used to generate electricity; the amount will depend on the electric utility's generation mix (e.g. electricity in South Africa is generated mostly from coal, so CO2 savings will be high).

Energy security: In regions where there are limited natural resources, fuels for generating electricity are often imported at high cost. These technologies can improve energy security and reduce pressures on international energy markets.

Where SWHs displace dirty fuels, such as biomass, households will enjoy health benefits and improved quality of life.

Potential for Rollout

Concentrated Solar Power (CSP)

Most sub-Saharan countries receive solar radiation in the range of 6-8 kWh/m2/day, which counts among the highest amounts of solar radiation in the world. Until now, only a small fraction of Africa's vast renewable energy potential has been tapped.

There is substantial growth potential in the deployment of small-scale CSP for industrial process heat, offering significant benefits. In Africa this is by as much as a factor of 4,600 by 2050. According to the International Renewable Energy Agency (IRENA), total installed renewable capacity in sub-Saharan Africa is expected to grow from 28 GW in 2010 to around 800 GW by 2050, with wind accounting for 242 GW, and concentrated solar power for 94 GW.

CSP is attractive because its efficiency increases with irradiation level, which is not the case for solar PV where efficiency declines with rising collector temperatures. Given that the irradiation level corresponds also with the demand for air conditioning, solar CSP would reduce the need for peak capacity. This feature is attractive in desert countries where solar irradiation is particularly strong.

CSP systems offer the opportunity to store solar energy as heat, which can be used to generate electricity during periods of low or no sunshine. This attribute is a considerable advantage over solar PV when CSP is used for electricity generation, because a large-scale on-grid CSP plant can use the stored thermal energy to run its turbines and feed electricity into the grid for several hours after sunset (in many countries this may be a period of high demand). CSP systems with thermal storage have higher investment costs, but they allow higher capacity factor and dispatchability.

Wind

The theoretical potential for wind in Africa exceeds demand by orders of magnitude, and about 15% of the potential is characterised as a high-quality resource. This enormous capacity is not evenly distributed: East, North and Southern Africa have particularly excellent wind resources (ibid). The map below shows wind speeds across Africa.

Wind potential in Ghana is seen as marginal – average annual wind speeds are 4-6m/s at 50m above sea level along the coast and on some islands. However, some areas near the border with Togo have wind speeds above 8m/s. Currently, there are no wind energy installations in Ghana except for small off-grid ones installed for demonstration purposes. Three groups are currently undertaking wind resource data assessments; these are: the Energy Commission, Volta River Authority, and UP Wind Company.

According to the Alternative Energy Resource Assessment and Utilization Study carried out between June and September 2003, the wind energy resource in Uganda is insufficient for large scale electricity generation.

The continent's largest wind farm is currently being constructed in Kenya, by Lake Turkana, and will have in installed capacity of over 300 MW. The project is registered under the Clean Development Mechanism (CDM), which means it can generate revenue from selling carbon credits, and demonstrates the viability of large scale schemes in Africa.

However, as costs in Africa are expected to drop further with increased availability of locally manufactured components such as towers and blades, it is likely that wind farms will become more prevalent across sub-Saharan Africa in the future.

Solar Water Heaters

Domestic solar water heaters have been successfully introduced in Asia and in southern and northern Africa, with eastern African efforts recently starting in Kenya. Since 2009, the South African Government has supported this technology through schemes where a rebate is paid directly to consumers, provided the product, supplier and installers are registered in the programme. The rebate significantly reduces the cost of solar systems, making water heating more affordable for a large proportion of customers. Over 400,000 systems were installed under the programme, and it is currently being revised (see Case Studies).

A survey in Ghana found that the average daily hot water requirement for a household of 3 was estimated to be 80 litres per day. A cost-benefit analysis revealed that the payback period for a solar water heating system would be 8 years given a lifespan of 20-30 years. Future buildings should therefore include solar water heaters in their architectural designs. This will make installation of such systems much easier and cost effective.

Case Study: Lake Turkana Wind Farm, Kenya

Wind farms are a lucrative investment arena for the African Development Bank (AfDB), as shown by their commitment to the 300 MW Lake Turkana Wind Farm in Kenya. The Lake Turkana Wind Power (LWTP) consortium is constructing a wind farm consisting of 353 wind turbines, each with a capacity of 850 kW, in Northwest Kenya. LTWP can provide reliable and continuous clean power to satisfy up to about 30% of Kenya's current total installed power.

Image © KBC TV

Barriers to Implementation

Concentrated Solar Power (CSP)

The key barriers for small scale industrial applications are low awareness that CSP is a potential energy source for industrial process heat, lack of confidence that the technology works in local conditions and applications, and payback periods that are considered unattractive by potential customers. For rural/off-grid applications the critical barrier is the lack of an optimised and proven technology solution.

When compared to PV, CSP projects are more difficult to develop, finance and to implement. Given that significant economies of scale exist for CSP, projects should come from a techno-economic point of view. The large up-front investments, offering greater prospects for cost reductions, also make it more difficult for emerging CSP technologies to be commercialised.

Wind

The underdevelopment of wind markets reflects affordability issues as well as socio-political and technical considerations. It has been widely argued that renewable energy is not a priority for SSA given more basic issues that these countries are dealing with, such as high poverty rates, stagnant economic growth, and health crises, and that until renewable sources are cost-effective, African countries should not pay a high price due to past pollution from advanced economies.

Wind energy also poses negative effects on the environment through its effects on wildlife, visual impact and noise pollution. There is also substantial competition between wind and other well established renewable energy sources such as hydro, which have the capital cost advantage and favourable physical attributes such as the ability to store energy.

Solar Water Heaters

Issues affecting the uptake of domestic solar water heaters include the high up-front installation costs compared with gas and electric boilers, the complex process and associated costs to integrate solar thermal systems into existing housing, competition with heat pumps, and in some cases the competition with PV panels for rooftop space. Moreover in parts of Africa electricity and fossil fuel subsidies have acted as inhibitors to large-scale deployment.

Implementation

Clean Development Mechanism

Under the Kyoto Protocol, the Clean Development Mechanism (CDM) provides for emissions reduction projects which generate Certified Emissions Reductions units (CERs). These can be then be traded on the carbon market. The recent introduction of the programme of activities (PoA) under the CDM is expected to greatly enhance the opportunities for African countries to access the CDM. Examples of activities carried out in sub-Saharan Africa include the roll out of solar water heaters for domestic use.

Ghana's Renewable Energy Act

The Renewable Energy Act of 2011 provides for the development, management, utilization, sustainability and adequate supply of renewable energy for generation of heat and power for related matters. Key Provisions in the act include the feed-in-tariff scheme and the purchase obligation.

Feed in Tariffs

Both Ghana and Uganda have implemented Feed in Tariffs for the promotion of renewable energy use. CSP is not regarded as a sufficiently mature technology to be included in these arrangements. It is somewhat surprising that Uganda has no provision for electricity generated by solar PV but this is because, at the time the tariffs were last revised, PV was still regarded as too expensive. However, PV prices have since fallen dramatically.

Solar Bylaw

A city bylaw can enforce the installation of solar water heaters in:

all new buildings built in a city;

all additions to existing buildings in the city where extra water heating for sanitation purposes will be required.

Given that the financial case is clearly beneficial to the end user for all households that require a hot water system, this is a potentially very effective mechanism to drive implementation and stimulate the solar water heater industry. In order to allow for initial supply capacity deficits, a tiered introduction process can be adopted to ensure the industry keeps up with the new growth in demand.

Case Study: Namugoga Solar Power Station, Uganda

Namugoga Solar Power Station is a proposed 50 megawatt CSP plant in Uganda. The power generated will be sold directly to the Uganda Electricity Transmission Company Limited, the sole authorized purchaser. The electricity will be exported from the station to a substation in Kisubi for integration into the national electricity grid.

Image © Solar Africa

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SAMSET Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions