Green Building Handbook for South Africa
Chapter: Energy Generation

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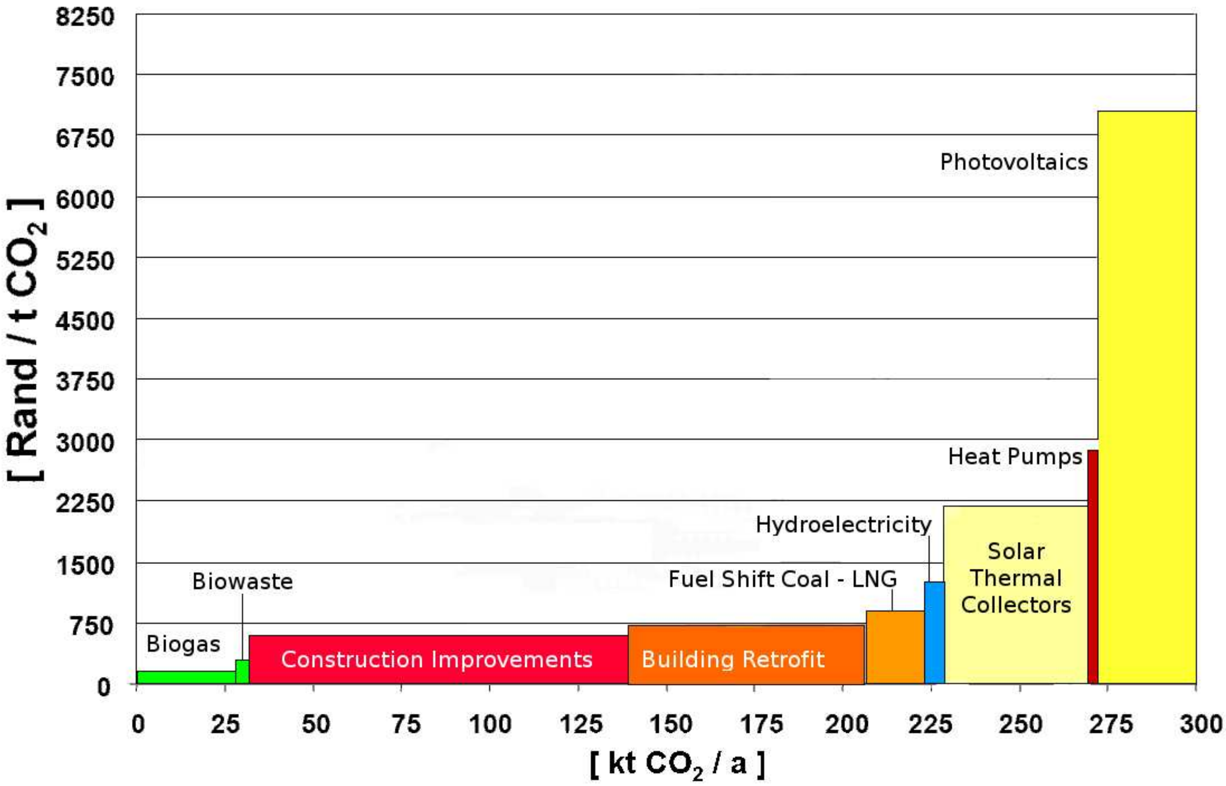
Current perceptions conjure images of photovoltaic panels and wind turbines when green building or sustainable development is discussed. How energy is used and how it is generated are core components of both green building and sustainable development. However, with current technologies and current South African building practise, on site building energy generation is highly ineffective and is a financially wasteful means of reducing CO_2 emissions.

Unfortunately, photovoltaic panels and wind turbines are images that the public at large associates with green building and oftentimes these measures are financed as they are clearly observable interventions and then the construction project will be perceived within the public domain as a green building.

Capital should first be used to upgrade the lighting and HVAC systems before energy generation options are considered. The graph below indicates the cost of mitigating CO_2 through a variety of different options and the overall potential of each strategy.



Cost of mitigating CO_2 and potential for reduction (Eltrop. L and Annegarn. H, 2008).

Biogas, Anaerobic Digester

Biomass, including human waste, can be biodegraded within an anaerobic digester for the purpose of producing biogas, which consists predominantly of methane. Biogas can be used as a clean, carbon-neutral fuel source for a myriad of applications. The raw material input for a digester can be a combination of different materials, usually plant matter, human waste, paper or waste food. Plant matter is also the raw material required for composting plants, so while it is often considered as waste, it has a value to another industry as a raw material.

In order to be an economically viable venture, the biogas should either be used as part of a cogeneration project, in which both electricity or steam can be sold or it should be sold as a fuel for vehicles. Both scenarios require the appropriate market to exist. Changes in government policy regarding renewable energy subsidies and fluctuations with the electricity price will affect the economics regarding the use of anaerobic digesters. Currently biogas cannot compete on an economic level as a replacement for coal.

Additionally appropriate economies of scale are required in order to make such a project viable. For anaerobic digestion in order to be more profitable than composting, about 30kt/a of waste is required. Approximately 145 000 people are required in order to produce this amount of waste. Economics improve further as the supply of waste increases.

Groenpunt Prison Farm Case Study

Groenpunt prison is located 60km south of Johannesburg and occupies 1064ha of land, of which 470ha is used to grow food for the prisoners and feedstock for the animals. The prison facility has 150 milks cows, 50 meat cattle and 2000 pigs.

With the raw materials available, a 250kW bio gas plant was considered; two digesters would be needed with a total volume of 2000m^3. In addition to the electricity, heat is also produced which could be used if a demand can be found for it. Also, 2900m^3 of fermented waste would also be produced that can be used as a fertiliser. Currently, under such a scenario, the electricity produced would cost €0.107/kWh which is roughly double the prevailing electricity price and the price of electricity would have to increase by €0.09/kWh in order to achieve an economically viable project.

Biogas as petrol replacement

Petrol has a significantly higher economic value per unit of energy than electricity does and biogas can be used to displace either electrical energy or petrol. However, in order to displace petrol, a market, which could use the biogas to power the vehicles, needs to exist or be created.

Under such a scenario, the economics of the plant could prove viable and would provide a stable, carbon-neutral fuel source.

Rural Family Sized Anaerobic Digester

Small anaerobic digesters can be successfully used in a rural environment to supply a family with enough biogas to fulfil their fuel requirements for cooking. Small anaerobic digesters have been successfully used in a number of capacity sizes ranging between, but not limited to, $1m^3$ to $6m^3$.

The capacity of a biogas plant is the quantity of biogas that can be produced on a daily basis. Per person, $0.34\text{-}0.42m^3$ of biogas is required for cooking food and 1kg of cattle dung can produce $0.04m^3$ of biogas. Thus, a $1m^3$ plant can serve between 2-3 people, will require roughly 25kg of dung daily and would rely on between 2-3 cattle for this supply.

As the size of the plant increases, the number of people that can be served, the amount of dung and the number of cattle required, all increase proportionately. However, as the size of the plant increases so does its economic viability and payback periods can range between 3 to 10 years, with the larger plants having a shorter payback periods.

The use of an anaerobic digester in such a rural environment has significant health benefits for the owners by providing a clean fuel that can be used for cooking. Traditionally within rural South Africa, paraffin and biomass is still often used for cooking and heating and has very significant detrimental effects on the health of the occupants, especially among women and small children. Such health benefits should not be underestimated and will also relieve some burden on local health services.

Conclusion

Biogas plants offer significant environmental benefits by displacing fossil fuels. The economics of the plants are dependant on whether a market can be found for the heat, which could then be sold alongside electricity, or whether biogas can be sold to displace petrol use. Each scenario requires that potential market to exist. The economics of such a plant are also dependant on electricity and petrol prices, each of which are highly volatile.

The applicability of such a plant in addition requires a large amount of biomass as waste to be used as raw material and are only applicable to very large institutions with high densities, on a community scale and/or to projects that have access to agricultural waste.

Photovoltaics

Photovoltaic panels (PV) can be used to produce electricity from the sun. However, PV panels remain one of the most expensive ways to reduce CO_2 emissions, due to their high cost and low power output.

Sizing Photovoltaic Panels

Photovoltaic panels are rated at their maximum output capacity that will only be achieved during high levels of solar illumination. A basic rule of thumb is to multiply the rating of the PV panel by 5.5 to get how much energy the panel can produce on an average summer's day. Therefore, a 150W panel can be expected to produce 825Wh per day. Using an electricity price of R0.36 per kWh, a 150W panel will produce, on average, R0.3 worth of electricity per day and R109 worth per annum.

It should also be noted that modern photovoltaic panels require between 2-3 years in order to produce as much energy that went into their fabrication. If PV panels are to be used, then they should also be used as an integral structural component, such as a roof or shading device.

Wind Turbines

Installation of wind turbines on or near buildings can be done in order to generate electricity to be used by those buildings or potentially to be fed back into the grid. Wind turbines rated between 600 and 3000 Watts are readily available within South Africa.

Wind turbines can produce clean renewable electricity with very low amounts of associated CO_2 emissions. The only CO_2 emitted over the life cycle of the wind turbine is during manufacture, installation and during maintenance operations.

Wind Turbine Location

Correctly locating a wind turbine is critically important for efficient operation. It should be placed high enough and far away enough from other obstacles that will cause turbulence within the air streams. Also, it should only be placed in areas of high average wind speeds in order to be as economical as possible.

Care should be taken so that the turbine is not placed in the flight paths of birds or bats as they have difficulty in detecting the rapidly moving blades and will be killed if they fly into it.

Power Output

The rated power of a wind turbine is the maximum amount of power it can produce and this will only occur at high wind speeds; at very high wind speeds the turbines shut down automatically in order to protect themselves from damage. Typically wind turbines will, when placed in good locations, have a capacity factor ranging between 20-40%. Each wind turbine has a different power curve that graphically displays the power output of the turbine at different wind speeds. Wind turbines generally start rotating at 2.5m/s (9km/h) and reach maximum output at about 12m/s (43km/h). Smaller wind turbines are more economically viable at lower wind speeds than larger turbines. A competent person should be consulted to select the appropriate wind turbine and to place it optimally.

Rough Port Elizabeth Case Study

This is a very rough estimation as to how much energy can be generated from the installation of a 1kW wind turbine in Port Elizabeth. Port Elizabeth has average monthly wind speeds ranging between 4.6m/s to 7.2m/s with an overall average of 6.2m/s. A typical 1kW wind turbine will produce 330Watts at 6.2m/s and this would correspond to a capacity factor of 33%. During a year this turbine will produce approximately 2900kWh. The value of this amount of electricity – using a price of R0.36 per kWh – is R1044.

This is a very rough estimation intended only to give the reader a reasonable expectation of what can be achieved using small scale wind turbines.

Electrical Storage

If the wind turbine is at times likely to produce more power than is required, then it may be required to install batteries to store the electrical energy so that it can be used at a later time. Installation of batteries will significantly increase the total cost of the installation of the wind turbine.

Cogeneration

Cogeneration is the use of both electricity and heat from a single fuel source. It is also known as combined heat and power and has found significant application within large buildings and industry. Typically, a gas turbine is installed in or near the actual building that can run off of a wide variety of different fuels and is used to run a generator that generates electricity for the use of the building. Alternatively, a boiler and a steam turbine can also be used. The hot exhaust gasses or steam can then either be used to heat the building or run an absorption chiller to cool the building as required. Cogeneration can achieve efficiencies in the order of 80% while a typical coal fired power plant has an efficiency of about 35-40%.

The environmental value of using cogeneration stems from its much higher efficient use of fuel than would otherwise be achieved. However, a use for the exhaust heat must be located nearby in order for the concept to work. The economics of cogeneration projects are dependent on the size of the project, heat and electricity demand, load factor, fuel availability, fuel cost and the cost of electricity. Consequently, significant analysis needs to be carried out in order to determine the financial feasibility of a cogeneration project; however, payback periods of about 2 years are achievable.

Cogeneration has a lot of potential, is being actively pursued and is being installed in many construction projects globally to achieve both environmental and economic goals.

Plant Sizing

The sizing of the cogeneration plant should be such that it achieves a very high capacity factor rather than aiming to meet the full load of the building. That is, that the plant is operating at 100% of capacity for as much as possible. Consequently, cogeneration is more suited to applications that have a flat power profile during operation.

Fuel Selection

Natural gas or ethanol are favoured fuels for cogeneration projects as they are relatively clean fuels and can easily be used within an urban environment. However, their scarcity within South Africa makes them an unlikely fuel choice. A wood-fired boiler operating off waste wood from nearby lumbering operations and a steam turbine could be the basis of a successful cogeneration project within South Africa.

South African Context

Many commercial businesses are installing back-up generation capacities at significant expense, a capacity which a cogeneration project while provide at no additional cost. Also, a cogeneration project will significantly reduce the amount electricity purchased from Eskom and relieve some load in that respect.

Solar Hot Water Heaters

Solar hot water heaters do not generate electricity but they do have the potential to significantly reduce the electrical demand within the domestic market. Furthermore, solar hot water heaters have acceptable simple payback periods, commonly reported in the range of 5 years.

Domestic Market

The electricity used to generate hot water within domestic homes is usually about 40% of the total domestic electrical load. Installation of a solar hot water heater can significantly reduce this load or even bring it to zero.

A 200ℓ solar hot water geyser is recommended for a family of four. This is a rough guideline only, as people's behaviour and hot water consumption can vary greatly. Any solar hot water geyser should come with an electrical heating element so that hot water will always be available in instances of high demand or poor weather conditions.

Commercial Market

The electrical demand to generate hot water within the commercial sector is very low and typically ranges between 0-5% of total electrical load. Although the load is small in comparison to the total electrical load, the economics to install solar hot water geysers does not change significantly. While the ability of solar hot water geysers to reduce the commercial electrical load is very limited, it is still a cost-effective means of doing so and is recommended.

Flat Panel Collectors

Flat panel collectors consist of a thermally absorptive base that is enclosed within an insulated casing with a glass cover. Pipes carry water or a heat exchange fluid through the casing where the heat is absorbed and is transfer to the geyser.

Flat panel collectors can only produce water at about 70-80℃, and some of these panels are manufactured within South Africa.

Evacuated Tubes

Evacuated tube collectors are more expensive than flat panel collectors; however, they are also significantly more effective. A heat exchange fluid is normally used and runs within a glass pipe that runs inside another glass pipe. All the air between the two glass casings has been evacuated and a vacuum exists in that space. Removing the air from that space greatly reduces the heat loss of the working fluid.

Evacuated-tube solar panels can produce water at 120℃. Unfortunately, all evacuated tubes are imported from China and no local manufacturing capabilities currently exist.

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