KeSEBAE NEWS

Newsletter of the Kenya Society of Environmental, Biological and Agricultural Engineers

Volume 3.No. 9 15 September 2021

Co-generation In Industries

By: Amana Myrtle

Mumias Sugar Company, Co-generation power plant

1.0. INTRODUCTION

Co-generation is the simultaneous production of heat and electricity, which holds a possibility of generating 10% of Kenya's electricity requirement. Co-generation accounted for 0.7% of renewable energy sources in 2015. The current energy generation capacity of Kenya is 2,651MW. The projected Vision 2030 installed capacity is 64,700MW. In Mauritius, co-generation contributes to 50% of the country's energy. Borrowing from this, co-generation tables an opportunity for the country to reach its projected energy capacity.

In Kenya, co-generation has been predominantly implemented in the sugar industries. A good example is in Mumias Sugar Company with a co-generation plant capacity of 34 MW, with 26MW supplied to the national grid. The current capacity of sugar factories have is at an electricity export capacity of 586 GWhrs with a promising potential estimated to be 1,803 GWhrs. New adoptions of co-generation are being implemented in the tea industry such as the James Finlay tea Factory in Kericho with a capacity of 160kW and micro power productions; Cummins Co-generation Plant in Marigat Baringo proposed to generate 12 MW. The 58 Kenya Tea Development Agency (KTDA) factories have the potential of generating more than 30MW electrical power and over 264MW of thermal power if co-generation technology is embraced.

DEAR READER

Welcome to KeSEBAE Newsletter.

A fortnightly Newsletter touching on topical issues affecting our environment.

KeSEBAE NEWS is a Newsletter of the Kenya Society of Environmental, Biological and Agricultural Engineers (KeSEBAE)

Inside this Issue!

1.1 Definition

Co-generation is defined as sequential generation of two different forms of useful energy from a single and primary energy source. Co-generation is also known as **Combined Heat and Power (CHP)** or **distributed generation** or **recycled energy**.

In this process, a fuel is used to generate both heat and electricity with a single unit hence more efficient and more cost-effective than generating heat and electricity separately. Co-generation utilises fossil fuel combustion but can be carried out using other sources of thermal energy (e.g., some renewable energy resources, nuclear energy and burning wastes such as bagasse).

The electricity produced can be utilised on site, exported to the grid or both if the system is grid synchronized. The thermal energy can be used either for direct process application or indirectly for producing steam, hot water and hot air for dryer.

The principal advantage of co-generation is that the amount of fuel needed to produce both heat and electricity is way less than total fuel needed to produce electricity. The overall efficiency of energy use in co-generation can as high as 85%. Other advantages are lower emissions, reduced energy costs, reuse of waste among others. Co-generation increases energy efficiency by 40%over conventional power plants. This results in reduced energy costs.[1]

Figure 1: *Co-generation energy efficiency* **Source:** *Inoplex*

Co-generation is relevant for both macro and micro implementations. At the macro level, co-generation units form part of a distributed generation (DG) networks, according national electric utility companies an alternative to expensive systems capacity.

There are two types of CHP plants, micro-CHP plants and industrial CHP plants. Among the other types of plants closely related to co-generation plants are combined cycle power plants and trigeneration plants.

In Kenya, industrial co-generation has been put to use in the power production in sugar industries, tea industries and micro-CHP in micro power production. The sugar industry can generate surplus power over and above its internal requirements by burning bagasse.

[1] Cogen Europe (2021): What is Co-generation https://www.cogeneurope.eu/knowledge-centre/what-is-co-generation

2.0. History

Co-generation first appeared in the late 1880s in Europe and the early 20th century in the United States, when most industrial plants generated their own electricity using coal-fired boilers and steam-turbine generators. The exhaust steam in many of these plants is used for industrial processes. According to COGEN Europe, an advocacy group based in Belgium, co-generation produced 58% of the total power from on-site industrial power plants in the United States in the early 1900s. A few industries, such as pulp, paper and petroleum were the biggest adopters of co-generation.

In the mid-1900s, there arose a sudden shift as the central electric power plants and reliable utility grids, allowed industrial plants to begin purchasing lower cost electricity. This resulted in a decline in on-site industrial co-generation by 15% of total United States electrical generation capacity by 1950 and further 4% by 1974.

In the 1970s, it so happened that there was a substantial rise in fuel costs and uncertainty in the supply of fuel. This triggered led to the re-emergence of co-generation, expressly in large industrial applications that require large quantities of steam. In the recent years, smaller co-generation systems have begun to applied in the food, pharmaceutical and light manufacturing industries, commercial buildings and even university campuses.

2.1. How Did Traditional Power Plants Operate?

In conventional utilities, power production and steam production are independent of each other and separate fuel sources are used. Traditional power plant produces electricity by combustion of fossil fuel such as oil, coal or natural gas in a giant furnace to release heat energy. The steam is used to drive a turbine which in turn drives a generator and the generator produces electricity. These power plants have a large power producing capacity due to combustion of huge amounts of fuel.

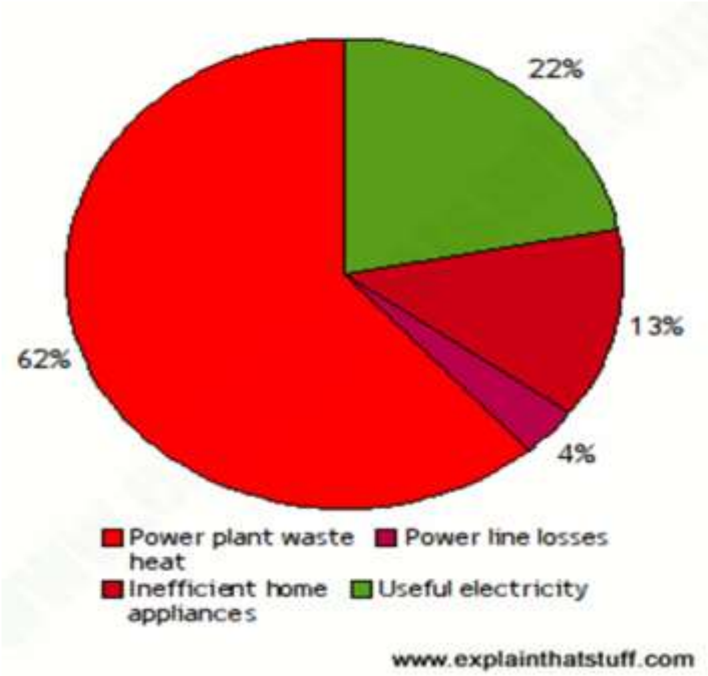


Figure 2.1: *Losses that are incurred during power production in a plant***. Source**: *Power Plants*

Most of these power plants are not duly efficient as only about a third of energy locked inside the fuel is converted to electricity while the rest is wasted. The wastage occurs in every step of the process. For example, water boiled to steam to drive the steam turbines has to be cooled using giant cooling towers in the open air, wasting huge amounts of energy into the air.

3.0. How Does Co-generation Power Work?

In co-generation, a fuel is used to drive the prime mover to generate electricity and produce heat. Co-generation entails the use of heat that would otherwise been wasted. The captured or trapped heat is utilised in producing further heat or electricity. The waste heat from the prime mover (i.e., Reciprocating engine) is used to heat water or create steam which can be utilised throughout the facility for a huge variety of purposes including hot water, cleaning, manufacturing, space heating, etc.

In a co-generation plant, electricity and heat is produced from a simple cycle gas turbine. The gas turbine exhaust energy is used to produce steam. The steam is therefore used without any portion routed to drive a steam turbine unlike the **combined power plant cycle**.

Co-generation is extremely energy efficient as it captures and utilises the heat that is expelled from the engine during electricity generation. The single fuel source provides both heat and electricity for the site. Grid transmission losses are avoided increasing the efficiency and lowering the carbon emissions.

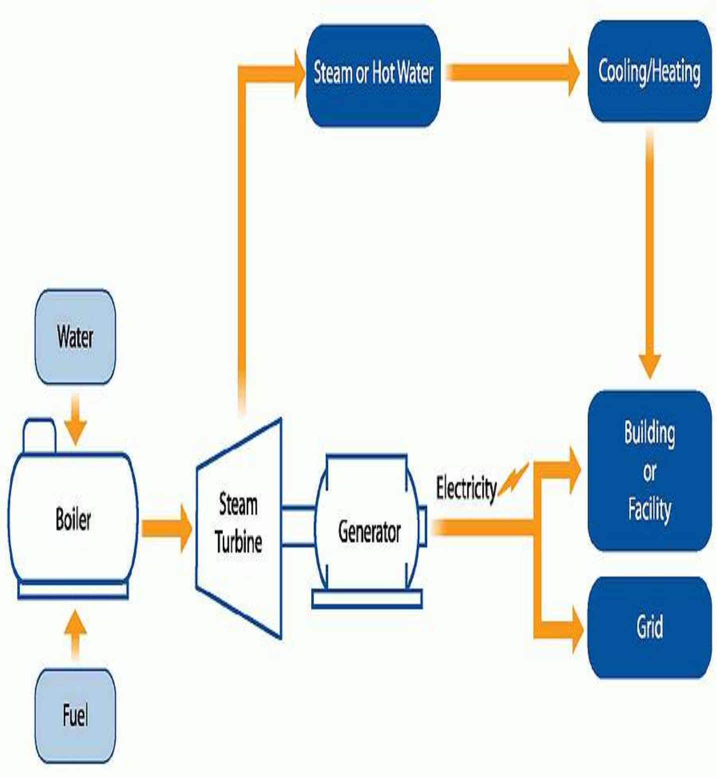


Figure 3: *An illustration of how co-generation works*
Source: *MIT news*

4.0 Types of CHP plants

Common types of CHP plants are: gas turbine CHP plant, gas engine CHP plant, biofuel engine CHP plants, molten-carbonate fuel cells and solid oxide fuel cells, steam turbine CHP plants and nuclear power CHP plants.

With reference to size, there are two types of co-generation systems; large CHP plants and small CHP plants. Large co-generation systems provide heating water and power for and industrial site or town.

Smaller co-generation units (i.e., micro-CHP) may use a reciprocating engine or Stirling engine. Here, the heat is removed from the exhaust and radiator. Co-generation power systems are more common in small sizes because small gas and diesel engines are less expensive than small gas oil-fired steam electric plants.

4.1. Industrial CHP

Co-generation is still common in pulp and paper mills, refineries and chemical plants. In industrial CHP, the heat is recovered at higher temperatures above 100 degrees Celsius and used for process steam or drying duties. The current focus on sustainability has made industrial CHP more attractive, as it substantially reduces carbon footprint.

4.2. Micro CHP

Also known as micro-co-generation or distribute energy resource (DER). Its installation is usually less than 5 kW in a house or small business. Instead of fuel being burned to heat space or water, some of the energy is converted to electricity while some to heat. The electricity can be used within the home or business or sold back to the electric grid if permitted by grid management.

Some co-generation plants are fuelled by biomass or industrial municipal waste. Some CHP utilise waste gas as the fuel for electricity and heat. Waste gases can be from animal waste, landfill gas, gas from coal mines, sewage gas and combustible industrial waste gas

5.0 Co-generation in Sugar Industries (Using *Bagasse)*

Biomass refers to any plant or animal matter which is possibly used as a source of heat or electricity. Examples of biomass include, sugarcane bagasse, vegetable oils, wood, organic waste and residues from the food or agricultural industries.

Biomass for sugar sector as a source of fuel is growing tremendously. The biomass residue; bagasse from the sugar production process is reused as a source of fuel. In the sugar producing factories, after the juice is squeezed out from the cane, about 30% - 40% residue of bagasse is generated as waste material.

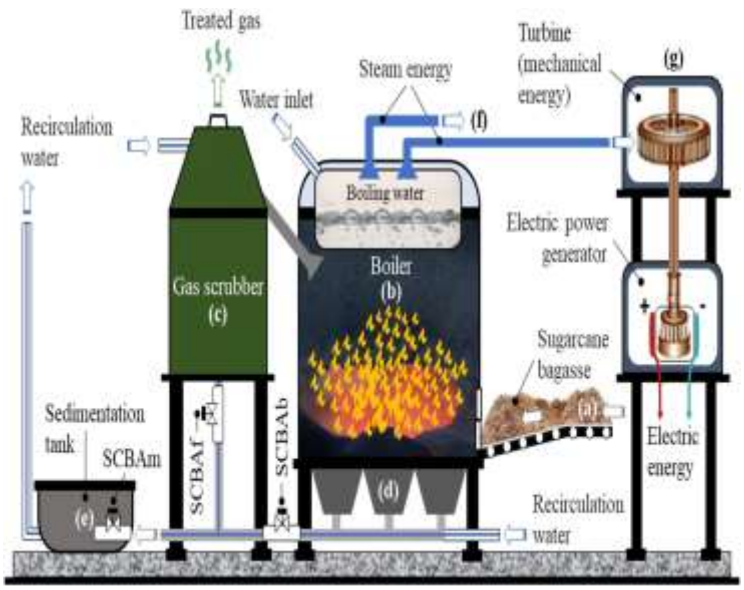


Figure 5: *Sugarcane bagasse for co-generation* **Source:** *Springerlink*

The power and process steam requirements in a sugar plant can be met in one of two ways: Conventional co-generation and integrated gasification co-generation with combined cycle. Conventional co-generation deploys a bagasse-fired boiler in conjunction with an extraction condensing and/or backpressure steam turbine coupled to an electrical generator, or a double extraction-condensing turbine coupled to an electrical generator. This is the predominant method currently used in Kenya with pressures of 20-25 bars.

In the past, due to limited technology and absence of regulatory framework that facilitates the sale of excess electricity to the grid, the sugar factories were designed to generate enough electricity and heat while the bagasse was taken into an incinerator. The recent development of more advanced turbines with high production of high pressure and high temperatures has given way for more power production from bagasse. The establishment of a regulatory framework that permits the private generators to sell their excess power to the grid has provided more opportunities for generation of cleaner power that is environmentally friendly while in tandem generating additional revenue stream for the sugar industry. Mauritius is country whereby co-generation by sugar industries is highly developed as co-generation meets 50% of the country's energy need. Recent data shows that half of the revenue for sugar factories is from the sale of sugar and the other half from the sale of electricity from co-generation

5.1. Current Status of Co-generation In Sugar Industries in Kenya

Co-generation is practiced in the western part of Kenya in sugar factories that use bagasse as a primary fuel source. The companies are reported to use co-generation. The current total installed cogeneration capacity in the Kenyan sugar industry is 36.5 MW, used exclusively within the industry. Sugar industry statistics show that in 2002 alone, sugar factories in western Kenya produced an average of 1.8 million tons of bagasse per annum. 60% of which is used as boiler fuel for steam generation and electricity production as a surplus while the remaining 40% is discarded. Huge volumes of bagasse are sometimes stored in the backyard of some factories. Studies done in the early 2000s show that in Chemelil sugar company, the bagasse posed to be a fire hazard as the bagasse dump adjacent to the factory caught fire, threatening the factory's premises.

Among the sugar companies, only Mumias sugar company is self-sufficient in electricity from its co-generation system producing 34 MW with a surplus capacity of 26MW for export to the national grid. In 2013 Mumias Sugar Company sold about 26 MW of electricity to Kenya Power and Lighting Company (KPLC), which distributes the power through the national grid. The remaining sugar companies due to the old equipment for energy generation, are net importers of electricity. The boilers in these sugar factories use inefficient low-pressure systems of 20 to 30 bar pressure. Muhoroni Sugar Company Ltd generates 89% of own power from the turbo-alternators and a diesel generator and imports 11% of the electricity demand. The current installed generation capacity for South Nyanza Sugar Company (Sony) is 7.2 MW and average generation is 4 MW to satisfy internal power demand. Chemelil Sugar Company Ltd. has Allen make turbine generators with a capacity of 3.5 MW but they generate an average of 2.8 MW against a demand of 4 MW. The balance is imported from the grid making the factory a net importer of electricity.

Most sugar factories in Kenya are in dire need of reinvestment to replace their co-generation equipment which are at the near end of their useful life. Most are currently are importing almost 100% of its power requirement from grid while their boilers merely supplying the steam requirements of the factory. The Institute of Research in Sustainable Energy and Development |(IRSEAD, 2004) reported that the production of bagasse is equivalent to a net capacity of over 300,000 tons of oil annually in Kenya. During the recent seminar in Nairobi, the **Ministry of Energy** reported that it intends to provide a framework and incentives to encourage sugar companies to invest in new co-generation technologies to generate more power from their bagasse and sell to the grid. The preliminary assessment of co-gen potential in selected sugar factories in Kenya were provided.

5.2 Potential Of Co-generation in The Kenyan Sugar Industries

Experience from Réunion, Mauritius, India, Brazil and Cuba confirm the practical potential for co-generation in Kenya, where it has hitherto been limited by the technology employed, financial and technical resource, availability, legal and regulatory frameworks.

Research shows that the current capacity and efficiency of the seven sugar factories have an export capacity of 586 GWhrs. Co-generation in sugar industries have been in use for long but export-based co-generation is a new concept yet to be well adopted. The capacity can improve to 972 GWhrs at factory overall efficiency of 90% for the current production capacity. The potential is estimated of 1,803 GWhrs based on planed factory capacities as per the strategic plans with 90% efficiency of operating factories.

6.0. Co-generation Application in the Tea Sector

Kenya is a leading country in the production and trade of black CTC tea in the world. The intense production of tea calls for huge supply of both thermal and electrical power to the tea factories. Of which, about 15% of the energy required is electrical and the remaining 85% thermal. Electrical power is sourced primarily from the national grid while heat from steam generation.

Successful operation of **Finlays Saosa tea** factory woodchip co-generation plant in Kericho since 2009, evidenced that biomass co-generation is applicable in the tea factories. Based on the current biomass present in the tea factories, the 58 Kenya Tea Development Agency (KTDA) factories have the potential to generate more than

30MW electrical power and over 264MW of thermal power. The co-generation plant is a commercial biogas production facility located near the **Finlays Tea Extracts Saosa** Factory. It has a substrate feeding capacity of about 28 tonnes per day with electrical installation of 160kW. The facility has capacity to expand to 70 tonnes per day with an electrical installation of about 600kW.

At the combined heat and power system (CHPS), a gas and diesel mixture are combusted in the engine coupled to an alternator producing 160 kW of electricity which is fed into the internal power grid. Configured for co-generation, the CHPS is equipped with an exhaust gas heat exchanger designed to combine both the heat available in the exhaust and the heat available in the engine's cooling circuit into a single heat stream of around 170 kWth.

Figure 6: *Biogas production unit* **Source:** *Finlays.net*

7.0. Co-generation using *Prosopis Juliflora* plant

Cummins Co-generation Kenya has been involved in the Marigat project in Baringo County of Kenya, which is proposed to generate 12 MW by making use of Prosopis Juliflora plant, a shrub, as feedstock.

8. Benefits of Co-generation

The benefits of implementing co-generation systems encompass the efficiency, economic and environmental aspects which governments, industries and businesses in Africa could gain if efficient co-generation is properly exploited.

8.1. Increased Energy Efficiency

A typical co-generation system converts 70% - 90% of the energy in the original fuel to useful energy.[2] This is unlike the conventional grid system with central power plants in which only a third of the fuel is converted to useful energy.

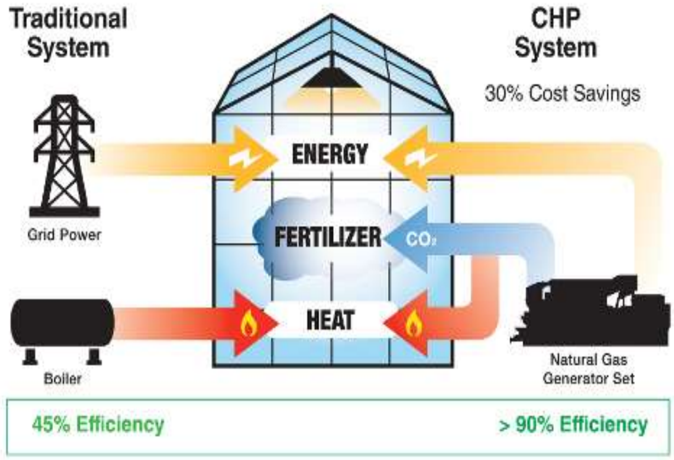


Figure 8.1. *Comparative energy efficiency of co-generation* **Source**: *Enertech*

8.2. Lower Emissions

Increased efficiency means less fuel is used. The world's electricity is primarily produced by fossil fuels. Less fuel reduces the carbon dioxide released to the atmosphere.

[2] Aytek Yuksel, June 2020. Energy IQ: What is co-generation, its benefits and how does co-generation work . https://www.cummins.com/news/2020/06/08/energy-iq-what-co-generation-its-benefits-and-how-does-co-generation-work

8.3. Energy Cost Savings

This is highly advantageous for industries. The energy cost savings come mainly from not having to purchase power from the grid or from not having to buy conventional fuel for generating power or for heat production, especially if using biomass as fuel. Co-generation system consume lower energy in comparison to a conventional separate heat and power generation.

8.4. Use of Indigenous, Cheap Renewable Fuel Source

Biomass residues suitable for co-generation can be found in abundant quantities Using these residues allows agro-industries to generate power and heat from what is considered as indigenous, cheap, environmentally friendly and renewable fuel.

8.5. Elimination of Disposal Problems

In sugar industries, using bagasse, which had been traditionally considered as a waste matter, as fuel for co-generation systems, the disposal costs and associated hazards of disposing them could be avoided.

Figure 4.5: *Sugarcane bagasse* **Source**: *afbd*

8.6. Improvement in Reliability of Supplies

In many countries in the African region, the power supply from the electric utility is not very reliable, propelling the industries to have their own back-up system in most cases diesel generators. For example, it is estimated that the Kenyan interconnected grid-system experiences over 10,000 recorded power interruptions every month. Co-generation therefore offers a stable alternative source of power.

8.7. Opportunity for Increasing Rural Electrification Levels

In many biomass-producing industries, a cluster of households develops due to the presence of workers in the industry. The added capacity from co-generation could be used to electrify the villages and rural community surrounding the industry hosting the co-generation system.

8.8. Reduction Of Transmission and Distribution Losses

In Africa, (i.e., Kenya) most agro-industries are found at the edge of the country's grid thus requiring an extensive transmission and distribution system. The introduction of embedded co-generation facilities significantly improves the power flow in these areas while reducing losses and costs associated with transmission of power from far-away centralized systems.

9.0 Conclusion

Co-generation implementation is of essence as it will assist the country to reach its expected potential in energy generation. This is expediently important as with the increase in population and economic development, comes an increase in energy demand of the country. Taking advantage of co-generation will enable the country to meet its energy demands in an environmentally friendly way.

CALL FOR ARTICLES TO KeSEBAE NEWS

KeSEBAE NEWS Editorial wishes to call for topical articles for publication in future editions of KeSEBAE NEWS.

Please transmit the same to the **Editor: Ezekiel Oranga** via Email: info@kesebae.or.ke

NOTE: A payment will be made to the author of each selected article

CALL FOR PAPERS TO THE NEXT EDITIONS OF JEAE

JEAE

Journal of Engineering in Agriculture and the Environment

The Journal of Engineering in Agriculture and the Environment (JEAE) is a Publication of the Kenya Society of Environmental, Biological and Agricultural Engineers (KeSEBAE) through which researchers in the fields of Environment, Agriculture and related fields share research information and findings with their peers from around the globe.

The JEAE Editorial Board wishes to invite interested researchers with complete work in any relevant topic, to submit their papers for publication in the next editions of the Journal.

Manuscripts may be submitted online or via email to:

Prof. Lawrence Gumbe, Chairperson, JEAE Editorial Board

Via Email: info@kesebae.or.ke or online via: https://www.kesebae.or.ke/journal/manuscript_submit.php

Criteria for Article Selection

Priority in the selection of articles for publication is that the articles:

a. Are written in the English language
b. Are relevant to the application of engineering and technology in agriculture, the environment and biological systems
c. Have not been previously published elsewhere, or, if previously published are supported by a copyright permission
d. Deals with theoretical, practical and adoptable innovations applicable to engineering and technology in agriculture, the environment and biological systems
e. Have a 150 to250 words abstract, preceding the main body of the article
f. The abstract should be followed by the list of 4 to 8 "Key Words"
g. Manuscript should be single-spaced, under 4,000 words (approximately equivalent to 5-6 pages of A4-size paper)
h. Should be submitted in both MS word (2010 or later versions) and pdf formats (i.e., authors submit the abstract and key words in MS Word and pdf after which author uploads the entire manuscript in MS word and pdf)
i. Are supported by authentic sources, references or bibliography

Our Expert Reviewers are Highly Regarded Globally and Provide Fast and Rigorous Review Services

For additional details and online support visit: https://www.kesebae.or.ke/journal/instructions.php or visit our JEAE website at: https://www.kesebae.or.ke/journal/

CALL FOR MEMBERSHIP

Be a KeSEBAE Member:

The annual subscription fees, admission fees and reinstatement fees for members of all grades (except Honorary and Life Members who shall pay no dues or fees) are indicated below: The annual dues are as follows:

Membership Category	**Annual Subscription (KES)**	**Admission Fees (KES)**	**Reinstatement Fees (KES)**
Fellow	5,000	1,000	2,000
Member	2,000	1,000	2,000
Ass.Member	1,000	1,000	2,000
Aff.Member	500	1,000	2,000
Student	300	100	-

Membership Renewal

Members of all grades are requested to renew their **2021 membership as follows.**

Membership Category	***Annual Subscription Fee (KES)***
Fellow	**5,000**
Member	**2,000**
Ass. Member	**1,000**
Aff. Member	**500**
Student Member	**300**

PAYMENT DETAILS

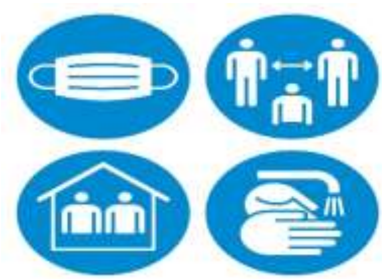
Bank	
Bank	**Absa Bank Kenya Plc**
Branch	**Nairobi University Express Branch**
Account Name	**Kenya Society of Env. Bio. & Agric. Engineers**
Account No.	**2038150696**
Swift Code	**BARCKENX**
Currency	**Kenya Shillings**

M-PESA PAYMENT DETAILS

Pay Bill No.: **4002575**

Account No: **Your Full Name**

M-PESA



ANNUAL KeSEBAE 2021 CONFERENCE

Theme: Engineering for Transformation

Date: 24-26 November 2021.

Attendance: *Mixed mode attendance: both virtual and in-person*

Submit abstract for conference to *info@kesebae.or.ke*

CONFERENCE SUB-THEMES

- Environment
- Irrigation and Water Resource
- Energy and Renewable Energy
- Engineering Education, Research and Practice
- Disaster Management
- Personal Professional Development
- Engineering The Blue Economy
- Emerging Issues
- Infrastructures and Structures
- Industries and Processing

Important Links

KeSEBAE	:	https://www.kesebae.or.ke/
JEAE	:	https://www.kesebae.or.ke/journal/
EBK	:	https://ebk.or.ke/
IEK	:	https://www.iekenya.org/
PASAE	:	http://www.pasae.org.za/

Follow Us on Social Media:

https://twitter.com/kesebae1

https://web.facebook.com/kesebae1/

Email: info@kesebae.or.ke

KeSEBAE NEWS EDITORIAL

The **KeSEBAE NEWS** is a Newsletter of the Kenya Society of Environmental, Biological and Agricultural Engineers

Contact: **Ezekiel Oranga**

The **Kenya Society of Environmental, Biological and Agricultural Engineers**
P.O Box 10677 - 00100
GPO
NAIROBI, KENYA

Visit our website at www.kesebae.or.ke

KeSEBAE: ***"Promoting Engineering and Research for Environmentally Sustainable Biological and Agricultural Systems***