COGENERATION

Modern Day Applications

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What is Cogeneration ?

- Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time.
- Trigeneration or combined cooling, heat and power (CCHP) refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or a solar heat collector.
- Cogeneration is a more efficient use of fuel because otherwise-wasted heat from electricity generation is put to some productive use.
- **Combined heat and power (CHP)** plants recover otherwise wasted thermal energy for heating. This is also called combined heat and power district heating. Small CHP plants are an example of decentralized energy. By-product heat at moderate temperatures (100–180 °C, 212–356 °F) can also be used in absorption refrigerators for cooling.

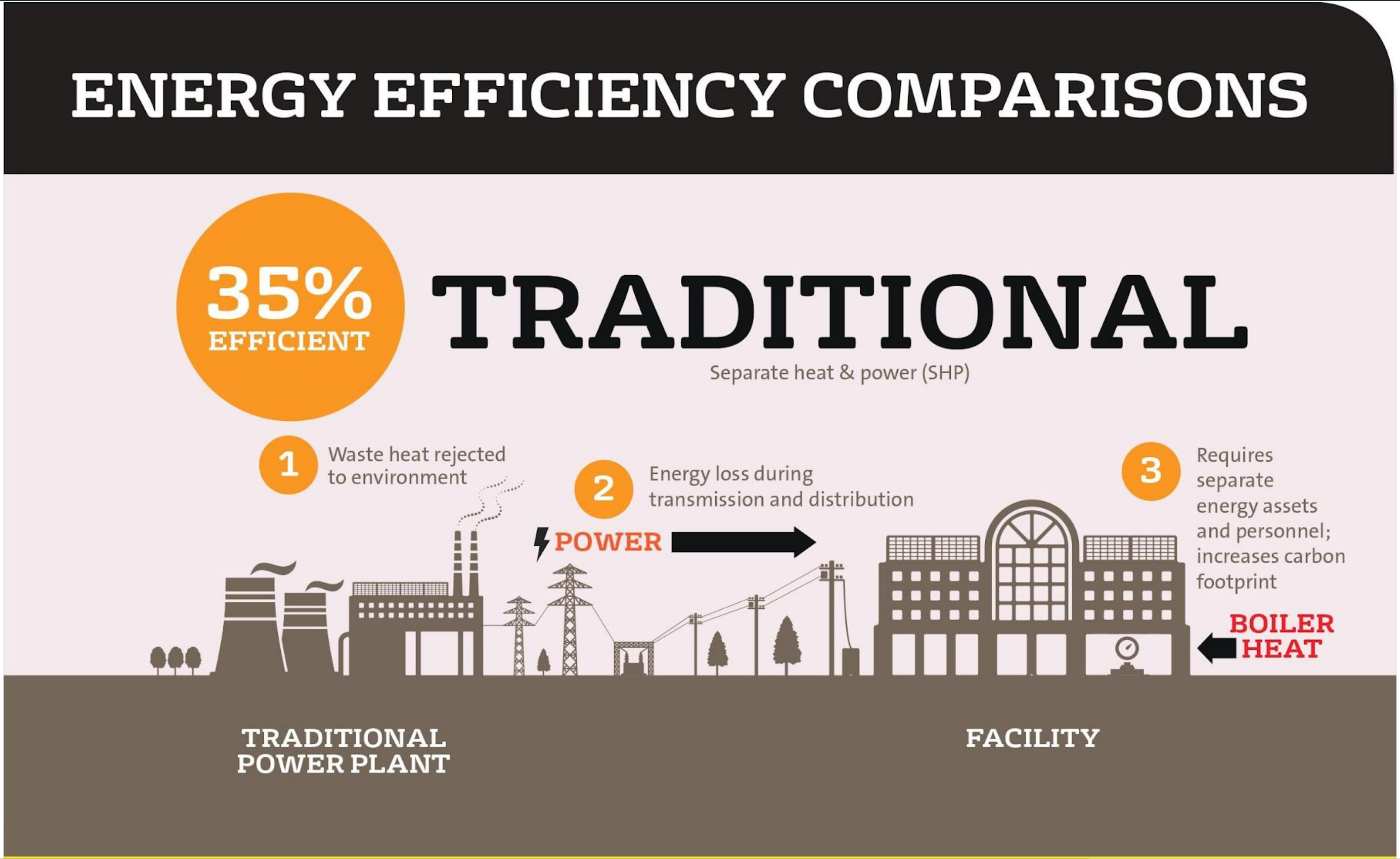
Why Cogeneration ?

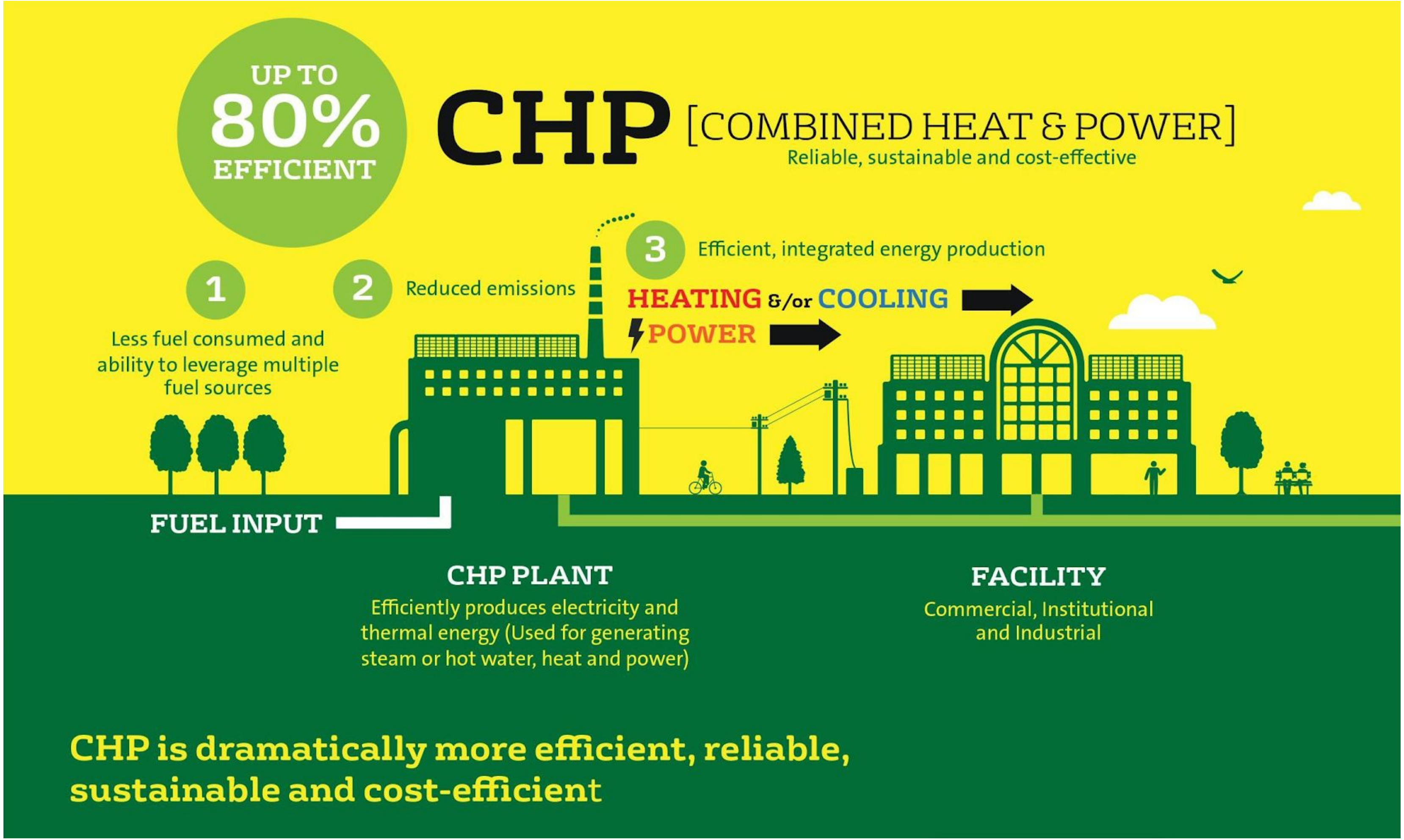
In the ever-evolving industries like energy generation and other heavy machinery production plants, increasing the efficiency has made a topic of research since the very inception.

A general idea of cogeneration introduces the following benefits even when applied even in its simplest form.

- Enhancing operational **efficiency** to lower overhead **costs**.
- Reducing **energy** waste, thereby increasing **energy efficiency**.
- Offering greater **energy** independence by moving a portion of the load off the grid.
- Allowing companies to replace aging infrastructure.

Modern-day Cogeneration plants have improved a lot in terms of energy efficiency gradually over the years. Almost half of the energy that was completely wasted before the idea of cogeneration can now be utilized in other applications by building sub-plants that can benefit from the waste energy of the main plant or the heat recovery systems can directly feed the main plant with the surplus energy creating an energy-efficient loop


ENERGY EFFICIENCY COMPARISONS
35%
EFFICIENT
TRADITIONAL
Separate heat & power (SHP)
1
Waste heat rejected to environment
2
Energy loss during transmission and distribution
3
Requires separate energy assets and personnel; increases carbon footprint
POWER
BOILER HEAT
TRADITIONAL POWER PLANT
FACILITY


UP TO 80% EFFICIENT
CHP [COMBINED HEAT & POWER]
Reliable, sustainable and cost-effective
1
Less fuel consumed and ability to leverage multiple fuel sources
2
Reduced emissions
3
Efficient, integrated energy production
HEATING &/or COOLING
POWER
FUEL INPUT
CHP PLANT
Efficiently produces electricity and thermal energy (Used for generating steam or hot water, heat and power)
FACILITY
Commercial, Institutional and Industrial
CHP is dramatically more efficient, reliable, sustainable and cost-efficient

Cogeneration on a Global Scale

Perhaps the first modern use of energy recycling was done by Thomas Edison. His 1882 Pearl Street Station, the world's first commercial power plant, was a combined heat and power plant, producing both electricity and thermal energy while using waste heat to warm neighboring buildings. Recycling allowed Edison's plant to achieve approximately 50 percent efficiency.

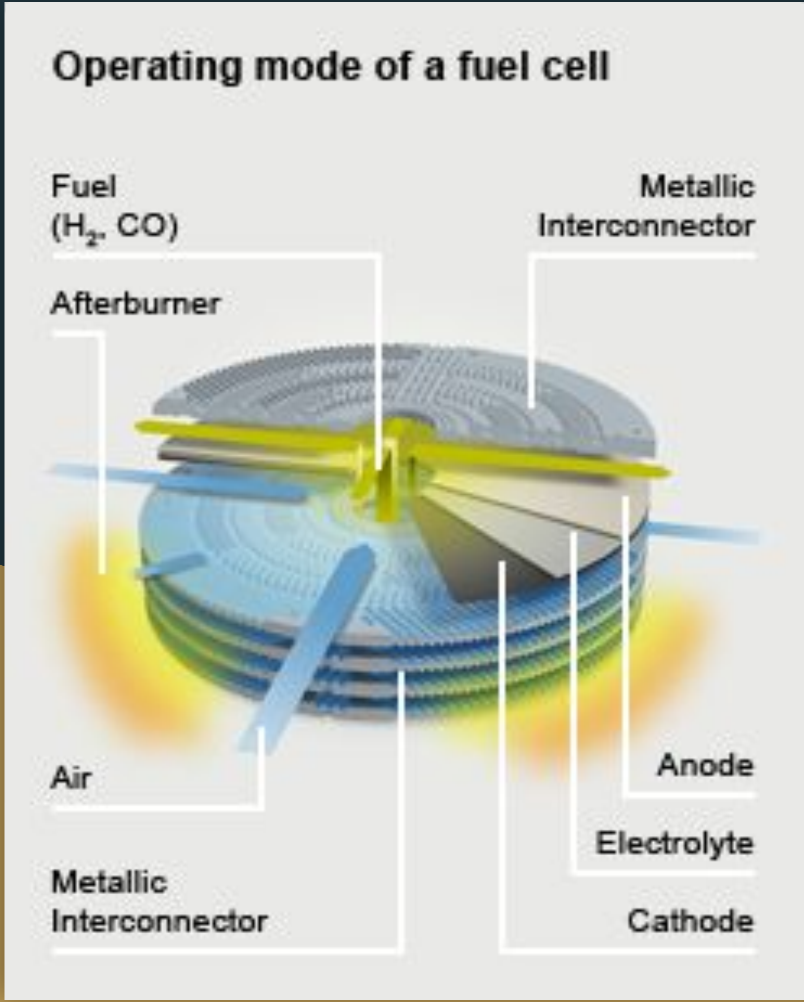
The United States Department of Energy has an aggressive goal of having CHP constitute 20% of generation capacity by the year 2030. Some Clean Energy Application Centers have been listed below:

- **Indian Cane Power Ltd,** Bagalkot, Karnataka
- **Kendall Cogeneration Station,** Cambridge
- **GM Sugars & Energy Limited,** Haveri, Karnataka
- **Midland Cogeneration Venture,** Midland, Michigan
- **Southeast Steam Plant**, formerly known as the **Twin City Rapid Transit Company Steam Power Plant**,Minneapolis, Minnesota

Modern Applications of Cogeneration

We will be discussing three application of cogeneration in the modern day scenario

- **Fuel-cell** based cogeneration
- **Solar thermal** based cogeneration
- **Bagasse** based cogeneration



Fuel cell based cogeneration

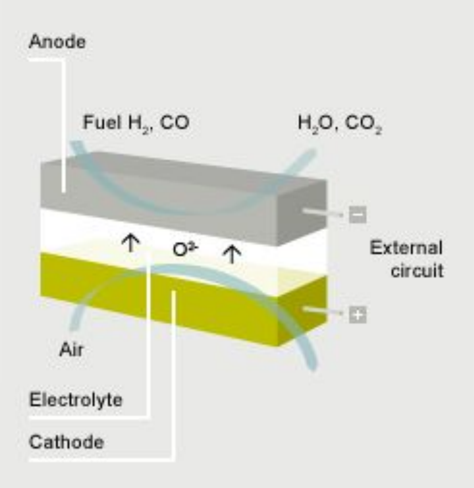
Fuel Cell micro-Cogeneration (also knowns as Stationary Fuel Cells, Fuel Cells micro-CHP, Fuel Cells Micro-Combined Heat and Power), is a technology that uses a single fuel (hydrogen, natural gas or LPG) to produce both **heat** and **electricity** for a building.

Compared to other micro-Cogeneration technologies the Fuel Cell micro-Cogeneration has a **low 'heat-to-power ratio'**(meaning it produces a relatively low amount of heat and a relatively high amount of electricity compared to other micro-Cogeneration technologies) – so is well suited to the evolving trend in buildings towards higher electricity use and low space heating demand.

How it works?

- The fuel cell works by **combining hydrogen** produced from the fuel and **oxygen** from the air to generate dc power, water, and heat.
- A system must be built around the fuel cells to supply air and clean fuel, convert the power to a more usable form such as grid quality ac power, and remove the depleted reactants and heat that are produced by the reactions in the cells.
- Water is created in the **electrochemical reaction**, and then pushed out of the cell with excess flow of oxygen.
- The net result of these simultaneous reactions is current of electrons through an external circuit-direct electrical current. The hydrogen side is negative and it is called the anode, whereas the oxygen side of the fuel cell is positive and it is called the cathode. Each cell generates about **1 V**, so more cells are needed in series to generate some practical voltages.

PEM Fuel Cells



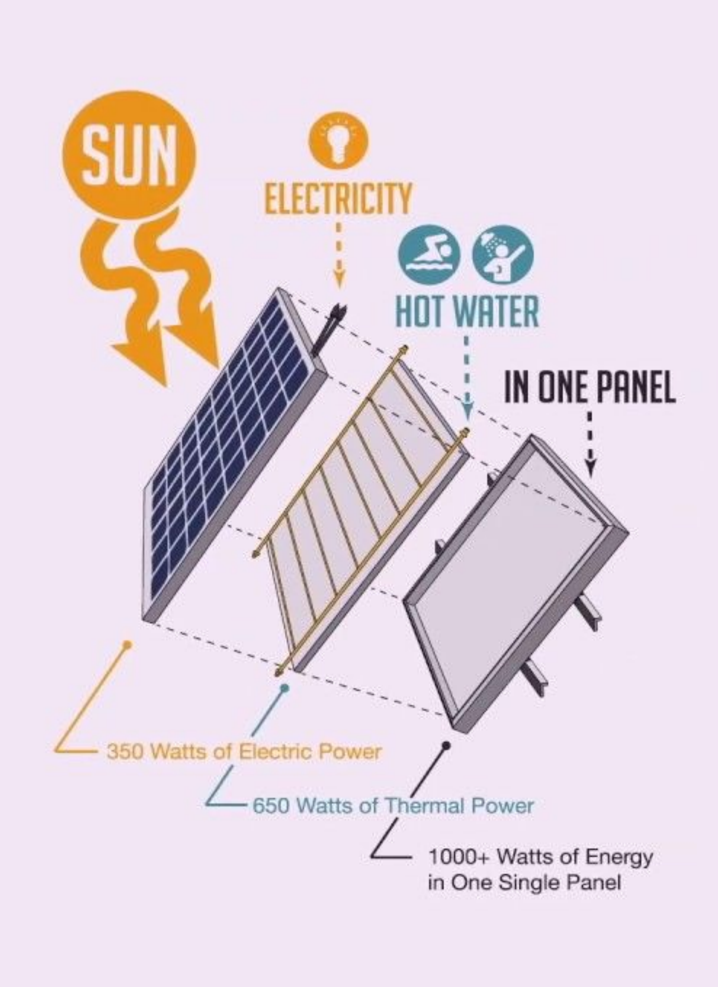
- At the heart of a PEM fuel cell, there is a **polymer membrane** that has some unique capabilities.
- It is impermeable to gases, but it **conducts protons** (hence the name, proton exchange membrane).
- At the interface between the porous electrode and the polymer membrane, there is a layer with catalyst particles, typically platinum supported on carbon electrochemical reactions happen at the surface of the catalyst at the interface between the electrolyte and the membrane.
- Hydrogen is split into its primary constituents – protons and electrons.
- Protons travel through the membrane, whereas the **electrons** travel through **electrically conductive electrodes**, through the outside circuit where they perform useful work and come back to the other side of the membrane.
- At the catalyst sites, they meet with the protons that went through the membrane and oxygen that is fed on that side of the membrane.

Solar-Thermal Cogeneration

Solar cogeneration modules consist of proven off-the-shelf components that can be quickly assembled on site and are designed to seamlessly integrate with existing hot water equipment.

Water is heated through a closed-loop heat exchanger to about 70°C. According to the facility's needs, the water is used immediately, fed into boilers to be heated to higher temperatures. The electricity generated feeds directly to the facility's existing power supply.

The most common applications include showers, laundry, cleaning, cooking and dishwashing.

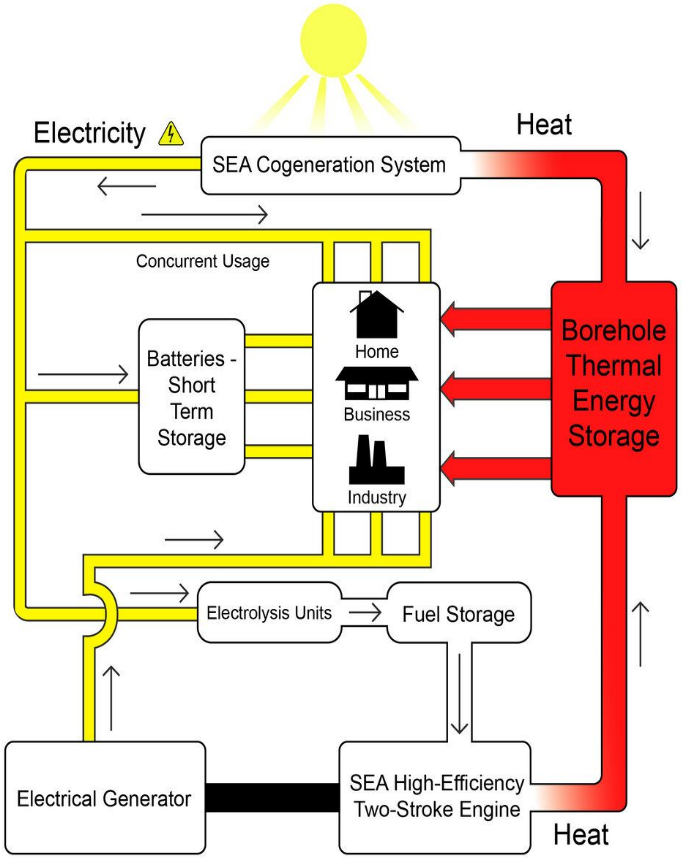


Advantages of Solar Cogen

Solar cogeneration – also known as **solar cogen** or **hybrid solar** – combines proven photovoltaic (PV) and solar thermal technologies in a single system to deliver both electricity and hot water.

- With solar cogeneration, this waste heat is used to heat water, **raising the efficiency of the system to as much as 75%.**
- By tapping into this lost resource, solar cogen **eliminates greenhouse gas emissions** at nearly three times the rate of traditional PV.
- Solar cogen also offers payback times that are typically one half to two thirds of those of standalone PV or SHW systems, ranging between three and five years.

Solar cogeneration advantages over traditional cogeneration are reduced greenhouse gas emissions and **stable energy prices**. The availability of solar energy also coincides with peak demand hours.

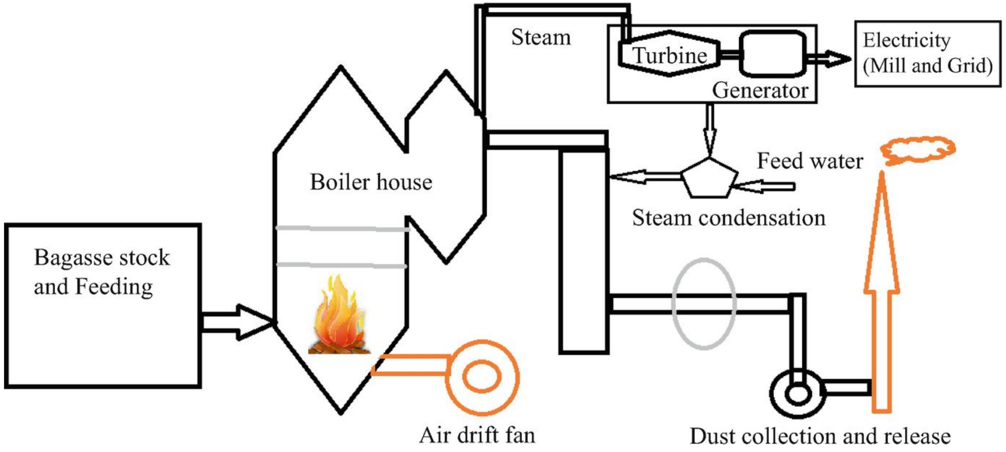


Applications at Industrial and Institutional Sites

- **The University of Arizona** recently decided to install **solar cogen arrays** on the rooftop of one of its dormitories to fuel **laundry** and **showers**.
- **Facebook** recently signed up to install a **rooftop solar cogen system** for the fitness centre at its new corporate campus in **Menlo Park, California**.

Bagasse based Cogeneration

Bagasse:
It is the **fibrous residue** obtained after sugarcane juice extraction which contains **45 to 50 % moisture and 1 % ash**. Bagasse **easily ignites and has free burning quality**. Its calorific value is 8022 kJ/kg and is **commonly used as a fuel** in boilers to generate steam and electricity through cogeneration. Other applications include use as a raw material in agro-residue based pulp and paper mills.

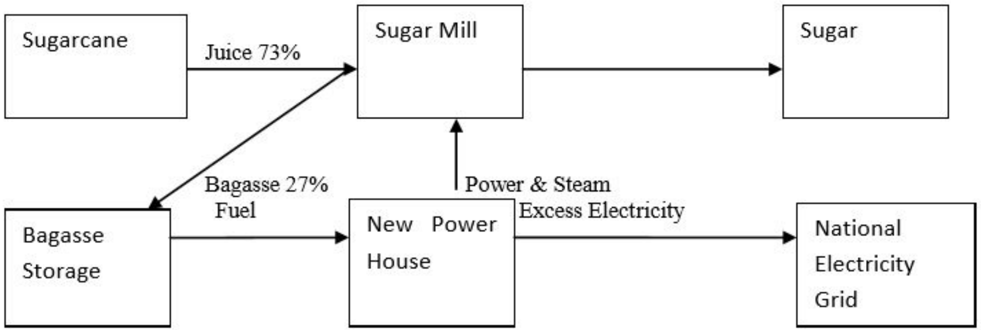


Combustion of bagasse in boilers for steam and electricity generation is commonly used in sugar mills. To improve energy recovery, a combination of bagasse and sugarcane trash has been investigated as a fuel in biomass integrated-gasifier/gas turbine combined cycle (GTCC) operations. This has been especially advocated in sugarcane producing countries like **Cuba** and **Brazil.**

Supplementing bagasse with trash is reported to enhance electricity generation by 500%; however, the **presence of alkali metals** (**Na** and **K**) in the resulting producer gas is detrimental to the turbine blades.

Energy-Flow Diagram

Cogeneration is defined as simultaneous generation of electricity and thermal power. Cogeneration in sugar mills have been explained by schematic diagram below ~



- In the sugarcane industry, cogeneration is **fuelled** by the **bagasse residue** of sugar refining, which is burned to **produce steam**. Some steam can be sent through a turbine that turns a **generator**, producing electric power.
- With the adoption of energy cogeneration in the sugar and alcohol sector, the sugarcane industries are able to supply the electric energy demand needed to operate, and generate a surplus that can be commercialized.
- During sugar production season electricity generated from the plant is used for the production process and surplus is fed into grid while during off season all electricity generated is fed into grid.

Bagasse based Cogeneration Plants in India

Grid connected surplus power generation from sugar industries gained momentum in India in 1993 consequent to a report submitted by a committee constituted by MNSE (Now known as MNRE).

In the eleventh five year plan (2007-2012) **1369.7 MW** of electricity against target of 1200 MW has been added from bagasse cogeneration.

As per MNRE database total installed capacity of bagasse cogeneration is 2393 MW as on 31st October 2013.

Maharashtra

Uttar Pradesh

ADVANTAGES

- In comparison with the electric power generation by means of fossil fuel-based thermoelectric plants, such as natural gas, the energy generation using sugarcane bagasse has environmental advantages due to the **reduction of Carbon emissions.**
- While in thermoelectric generation, part of the heat produced is lost, in cogeneration this heat has the possibility of being used in the production processes, **increasing the overall efficiency** of the process.

DISADVANTAGES

- In sugarcane cultivation, usually potassium sources containing high concentration of chlorine, such as potassium chloride (KCl) are used. Considering that **KCl** is applied in huge quantities, sugarcane ends up **absorbing high concentrations of chlorine**.
- Due to this absorption, when the sugarcane bagasse is burned in the power cogeneration, **dioxins** and **methyl chloride** ends up being emitted. In the case of dioxins, these substances are considered very **toxic** and **cancerous**.

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Thank you