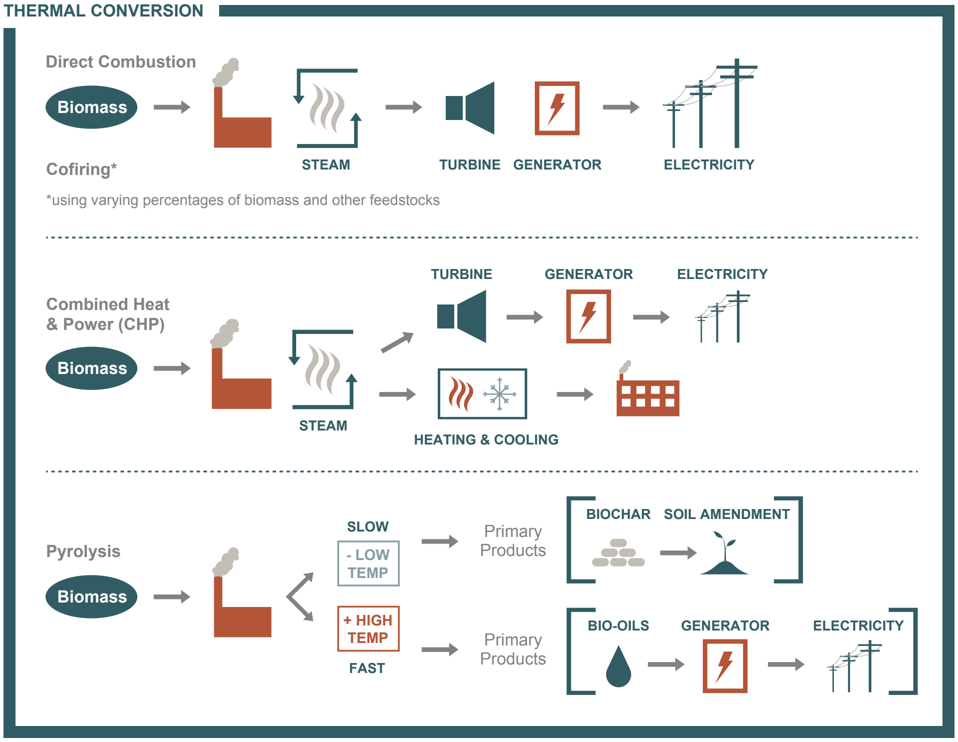
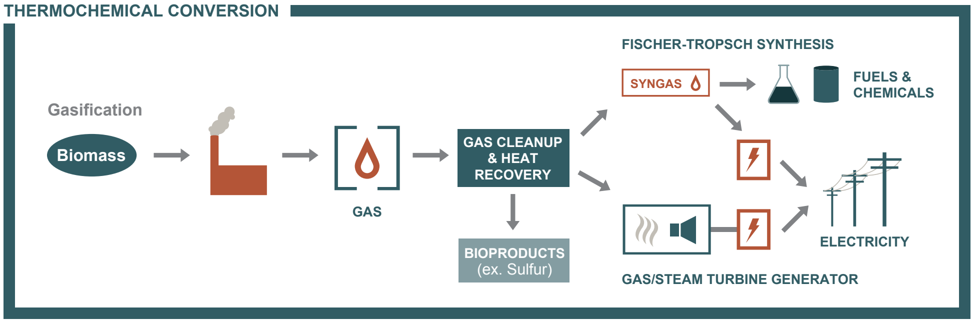
# Technologies that produce electricity, heat, and fuel from biomass feedstocks

**INTRODUCTION.** Utilizing biomass to meet our energy needs is nothing new and was the primary energy source in early America with the first steam engines using wood to power locomotives, riverboats, ships, and manufacturing facilities. Eventually coal surpassed wood as the primary energy source in the United States in 1885, but wood is still an important energy source for households, industries, and power production today. There are many conversion technologies that use biomass to produce heat, electricity, products, or fuel. This paper will explain the typical technologies used and the research underway to convert a wide variety of biomass feedstocks into useful forms of energy.

## Heat and Electricity Production (Thermal, thermochemical, and biochemical conversions)




**THERMAL CONVERSION.** Most of the heat and electricity that is produced from biomass is through a thermal combustion process. **Combustion** is simply the act or process of burning. Co-firing is another form of combustion and is used to describe a facility where biomass is combusted in varying proportions along with coal or other feedstocks such as tire-derived fuel. Facilities that produce only electricity **(Direct and co-firing combustion)** are the least efficient whereas **combined heat and power facilities (CHP)** utilize the simultaneous production of heat and electrical energy, thus increasing fuel efficiency. Small-scale CHP applications that utilize biomass feedstocks are typically industrial and manufacturing operations that require significant amounts of steam.

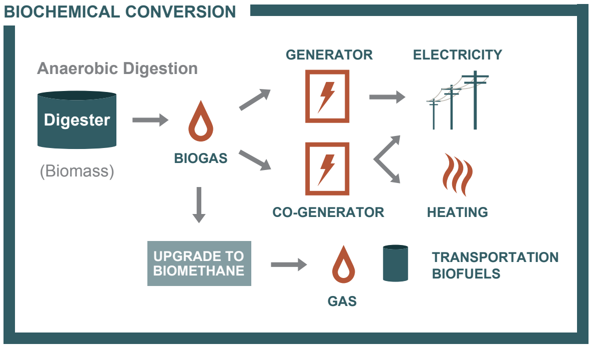



**Pyrolysis** technology involves heating organic material or **biomass** in the absence of oxygen. The biomass is converted into a solid or **biochar**, a liquid or **bio-oil**, and a **gas** through varied thermal temperatures and the absence of oxygen. At lower temperatures, called slow pyrolysis, primarily biochar is produced. At higher temperatures bio-oils produced through fast pyrolysis. The biochar produced can be used as a soil amendment to increase soil fertility and water retention or could be used to sequester carbon or produce energy. The bio-oil produced from fast pyrolysis can be used to fuel an engine generator thus creating electricity. It is unlikely that this oil will be used as a substitute for petroleum liquid fuels because it is unstable, contains char particles, and has half the heating value of traditional petroleum fuels. The pyrolysis of various biomass feedstocks are currently under research with many pilot scale facilities working towards commercializing the technology through academic and industry collaboration.

**THERMOCHEMICAL CONVERSION. Gasification** converts a solid fuel into a combustible gas in the presence of steam, which can be used to create heat or electricity. This technology is more efficient than *direct combustion* (by 40% or more) when used with advanced turbine designs and heat-recovery systems. Transportation fuels such as diesel and gasoline can be produced using gasification technology followed by **Fischer-Tropsch Synthesis** *(discussed in more detail under biofuels production)*.

*Biomass gasification demonstration plant at Oak Ridge National Laboratory, Knoxville, TN. Photo credit: NCSU Extension Forestry.*

**BIOCHEMICAL CONVERSION. Anaerobic** digestion is used to describe the process of microorganisms breaking down biomass to release energy (biogas) or to manage waste from landfills and animal operations. Biogas is composed of methane, carbon dioxide, and other trace gases. The gas can be used directly as a fuel, or used in gas engines to produce electricity, or may be upgraded to a higher-quality fuel called biomethane which is chemically identical to natural gas. Most biogas resources are rurally located, therefore, most renewable energy produced from these sources will be most likely be used to power facilities close to the production sites or electric power could be produced and delivered to the grid via a power-purchase agreement.




## Transportation Biofuels Production

Biofuels used for transportation are blended into traditional petroleum fuel sources such as gasoline and diesel. The primary crops that are used to produce biofuels are usually classified as sugar, starch, or oilseed feedstocks. Advanced biofuel feedstocks under research consist of fast-growing trees or **short-rotation woody crops** and perennial grasses such as switchgrass that are grown specifically for the production of fuel. There are many technologies available to produce a variety of fuels, but this paper will address the most viable technologies for producing gasoline and diesel fuels from biomass feedstocks. These include fermentation, transesterification, and gasification combined with Fischer-Tropsch synthesis.

### BIOCHEMICAL CONVERSION PROCESSES & TECHNOLOGIES.

**Biochemical processes** use chemicals, enzymes, and microorganisms to break down feedstocks into components. First-generation biofuels such as corn and sugarcane have readily-available sugars which can be fermented to produce biofuels. Advanced biofuel feedstocks such as fast-growing trees and switchgrass are fibrous or cellulosic and will need to be further broken down to isolate cellulose from other plant fibers.

Ethanol is the most widely used biofuel and is a fuel additive for petroleum gasoline†, the majority of which is produced using **fermentation**. **Biodiesel** can be produced in a process known as **transesterification**. The physical properties of biodiesel can vary depending on which feedstock is used and this is primarily due to the fatty composition of the feedstock. Standards are in place to ensure customers are fuelling their vehicles and equipment with a quality biodiesel blendstock.

**THERMOCHEMICAL CONVERSION.** A **thermochemical process** uses heat and chemicals to break down a variety of biomass feedstocks into a **syngas** or gas mixture that contains varying amounts of carbon monoxide and hydrogen. A catalyst is used to accelerate the chemical reaction of the syngas into a liquid fuel. The type of catalyst used determines whether the fuel will be an alcohol or hydrocarbon product. Diesel is the most commonly

*Biodiesel demonstration at the former Biofuels Center, Oxford, NC.*

*A combined heat and power operation using biomass feedstocks at the Perdue Rendering plant in Lewiston, NC. Photo credit: Courtesy of Gerald Cottrell, Wellons Energy.*

## Technologies that Produce Biofuels

### FERMENTATION

- *Process that creates a chemical change in sugar (i.e. sugarcane) and starchy (i.e. corn) plants by the action of bacteria that convert the sugars into ethanol.*
- *The feedstock then undergoes a distillation process in which alcohol is removed from water to produce ethanol. Cellulosic biomass (i.e. grass, corn stover, and wood) must undergo a process to convert the cellulose to sugar first, after which the sugar to ethanol process can then be used to produce cellulosic ethanol.*

### TRANSESTERIFICATION

- *Biodiesel can be produced from animal fats or plant oils through transesterification, by mixing an alcohol (methanol or ethanol) in the presence of a catalyst (alkali, acid, or enzyme).*
- *There are several steps involved in transesterification and the process essentially lowers the viscosity and oxygen content of the oil producing biodiesel and glycerol (byproduct used in soap).*

### FISCHER-TROPSCH SYNTHESIS

- *This process utilizes the syngas produced from gasifying biomass after impurities have been removed. Fischer-Tropsch synthesis produces hydrocarbons which are then refined to produce a wide variety of fuels and chemicals.*
- *Fuels produced include diesel, gasoline, kerosene, liquid petroleum gas, methane, and ethane.*

†The majority of gasoline in the United States contains up to 10% of ethanol (E10)

produced fuel, using a thermochemical conversion process.

**Gasification** technology along with **Fischer-Tropsch** synthesis can produce renewable diesel from many different carbon-containing feedstocks such as: coal, natural gas, and biomass. When biomass is placed in a **gasifier and partially oxidized or combined with oxygen**, a syngas is produced. The next step in the process recovers the heat from the syngas and sends it through a filter to remove the impurities. **Fischer-Tropsch** synthesis creates a chemical reaction that produces hydrocarbons or a petroleum-based substance from the syngas. The hydrocarbons are then refined to produce diesel, gasoline, kerosene, liquid petroleum gas, methane, ethane (light and heavy wax) and power. The renewable diesel produced is a cleaner fuel and is more compatible with existing infrastructure and transportation vehicles.

**CONCLUSION.** Technologies available for the production of heat and electricity include combustion, gasification, pyrolysis, and anaerobic digestion. For biofuels production, the technologies available include biochemical or thermochemical conversion processes to break down biomass feedstocks into transportation fuels. Research and innovation for biomass conversion technologies is still underway as the industry moves toward building commercial scale facilities that will use advanced bioenergy crops. Increasing the bioenergy market share is not only difficult in a mature fossil fuel energy sector but also challenging when competing against highly volatile market prices. Investing in the research and innovation for new technologies that will provide the renewable energy industry a competitive advantage against the fossil fuel sector is currently underway as society continues to demand cleaner renewable sources of energy. There has already been significant progress in the increase of renewables and in particular biomass used worldwide. The use of biomass for electricity, heat, and transportation fuels will continue to meet our energy needs with sufficient policy support, technological innovations, and continued research.

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