



Biomass conversion technologies

Current and emerging technologies

There are a range of established and emerging technologies that produce heat, energy and biofuels from biomass, each suited to different feedstocks.

Production of liquid fuels from biomass are classified as first and second-generation processes. First generation processes use food crops such as canola to make biodiesel and sugar cane or grain crops to make ethanol. Second generation biofuels use ligno-cellulosic feedstocks such as cereal straw or plantation forestry residues and third generation biofuels are produced from photosynthetic microbial organisms such as cyanobacteria, algae and bacteria.¹

Anaerobic Digestion (AD)

The breakdown of moist organic matter by micro-organisms under low levels of oxygen to produce a biogas comprised of 40-70 per cent methane. This gas can be used as fuel for combustion to produce heat, power and electricity. It is one of the most widely used technologies with domestic and industrial systems available. The gas is very similar to natural gas extracted from the ground and can be upgraded by removing CO₂ and trace gases to meet the quality standards required for the natural gas grid. It can then be injected directly into the grid.

Although the biochemical pathways involved in anaerobic digestion are complex, the process can be simplified in a sequence of four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Different groups of micro-organisms are involved in each stage.

The tank used to make biogas is called a biodigester or anaerobic digester and these have been developed at scales ranging from domestic household to farm scale and through to industrial scale. As the scale increases more equipment is needed to handle the increasing volumes of feedstock

¹ Samanta, P., Senapati, T., Ghosh, A.R., Dey, S. (2025). Third-Generation Biofuels Using Green Algae. In: Baskar, C., Ramakrishna, S., Rosa, A.D.L. (eds) Encyclopedia of Green Materials. Springer, Singapore.

required to supply the digester and even greater volumes of liquid and solid by-product to be removed.

Anaerobic digestion is well suited for abattoirs and intensive animal production facilities as there is a demand for heat and/or electricity and an availability of putrescible (decaying). High carbon dry biomass such as straw digests slowly on its own, but when mixed with high nitrogen putrescibles the digestion of both is improved (as in backyard composting). Biogas digesters can be installed in homes, farms, towns, dairies, piggeries, sewage treatment plants and waste processing facilities.

In addition to biogas, a secondary product called digestate (the sludge left over after the energy has been removed as methane) can be used as a soil improver/fertiliser. However, the application of digestate as a fertiliser is dependent on the origin and composition of the feedstock to ensure it does not contain toxic substances and heavy metals. When the digestate is considered unsafe for application to farmland, it can be pyrolyzed to create an inert and safe biochar.

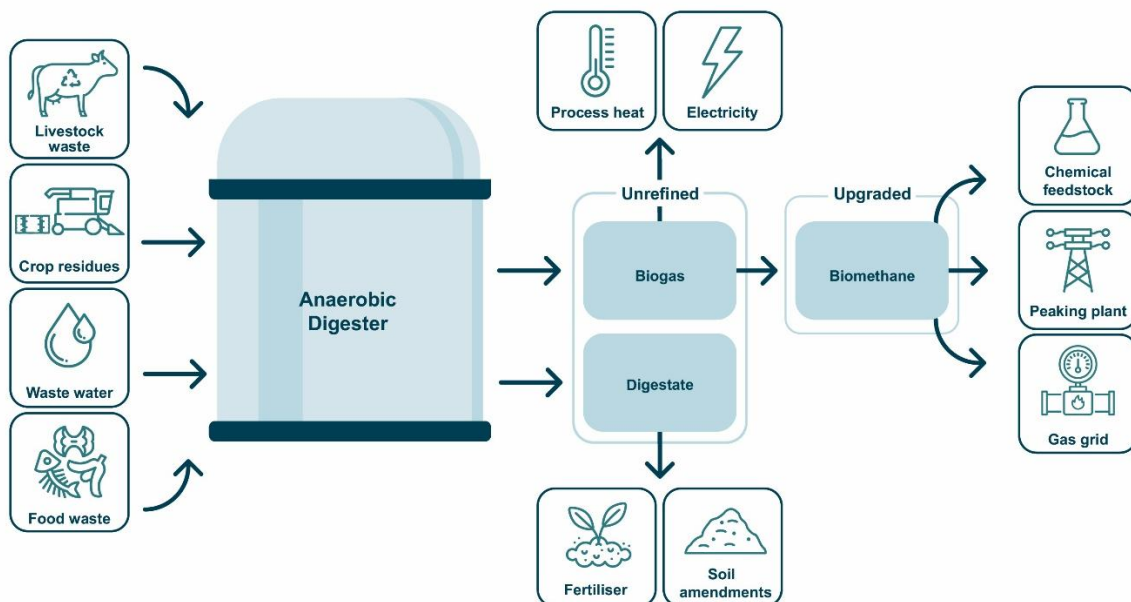


Figure 1: The process of anaerobic digestion

Cellulosic ethanol

Ethanol, or ethyl alcohol, can be used as a liquid fuel for transport, heating or electricity production. Up to 10 per cent can be blended with petrol and used in existing petrol engines and in vehicles with modification to their fuel system, up to 100 per cent ethanol can be used. Some engine manufacturers produce a 'flexi-fuel' vehicle which can run on any combination of petrol and ethanol. Conversion kits are available for many makes of petrol vehicles.

Fuel ethanol has traditionally been made from sugar- or starch-based crops (sometimes referred to as 'first generation ethanol'). There are crops suited for tropical/subtropical (sugar cane, sorghum) and temperate (corn, sugar beet) climates.

Fuel ethanol can also be made from ligno-cellulose, the fibrous part of plants and is referred to as 'second generation ethanol'. Cellulosic ethanol has been drawing increasing attention because it uses the non-food portion of food crops (cereal straw, sugar cane bagasse), other waste streams (paper, cardboard, woodchips, municipal solid waste) or non-food cellulosic crops (grasses, canes and trees). This can eliminate the need for additional land and fossil fuel inputs required to grow specialised sugar or starch crops. Ethanol can also be used to make aviation fuel.

Making ethanol from biomass is a biological process. Enzymes convert starches into sugars with limited oxygen, yeasts ferment sugars into ethanol and carbon dioxide.

The conversion processes vary according to feedstock but in general they include:

1. Pre-treatment: physical breakdown of biomass
2. Hydrolysis or saccharification: large starch or cellulose molecules are broken down into fermentable sugars using a combination of high temperatures and specialised micro-organisms or the enzymes obtained from them.
3. Fermentation: yeasts are added to the hydrolysed 'mash' and left to ferment for a few hours to a few days as they consume the sugars and produce ethanol.
4. Distillation: concentration of ethanol from 4-15 per cent (depending on feedstock) to over 95 percent using distillation columns.
5. Additional processing: Quality control, licensing or excise may dictate a higher purity than that obtainable by conventional distillation, which may require further treatment.

Combustion

Combustion is the burning of biomass such as wood chips and forest residues to produce heat, steam and electricity. It is perhaps the most proven technology with commercial, highly efficient biomass boilers readily available and may be useful for municipal waste. These systems are easily scalable and are the most common method for converting biomass to energy. However, it is the least efficient of the technologies for energy generation in terms of capturing all the energy stored within the biomass.

Gasification, Fischer-Tropsch and Pyrolysis

The heating of cellulosic biomass under low to nil oxygen levels. The gasification and Fischer-Tropsch process was developed in 1925 as a way of producing liquid fuel from coal, but recent work has established it as a pathway to produce liquid fuels from biomass. The gasification step reduces the feedstock to carbon monoxide and hydrogen, and the Fischer-Tropsch process converts these gases into liquid fuels.

Gasification is conducted in a low oxygen environment to produce syngas, whilst pyrolysis is under nil oxygen levels and is focused on the production of biochar and bio-oil. These processes produce syngas that can be directly burnt or converted to a liquid fuel. Distillation of the syngas produces a bio-oil that can also be processed into a range of liquid fuel types including diesel and aviation fuel. A by-product of pyrolysis is biochar that can be used as a soil ameliorant/conditioner, though the characteristic of the biochar depends on the type of biomass feedstock and the temperature of the process.

Dry to relatively dry combustible feedstock can be used including plantation and cropping residues and municipal, commercial and industrial waste. Systems are easily scalable and can be used for combustible fuel, heat generation and electricity production.

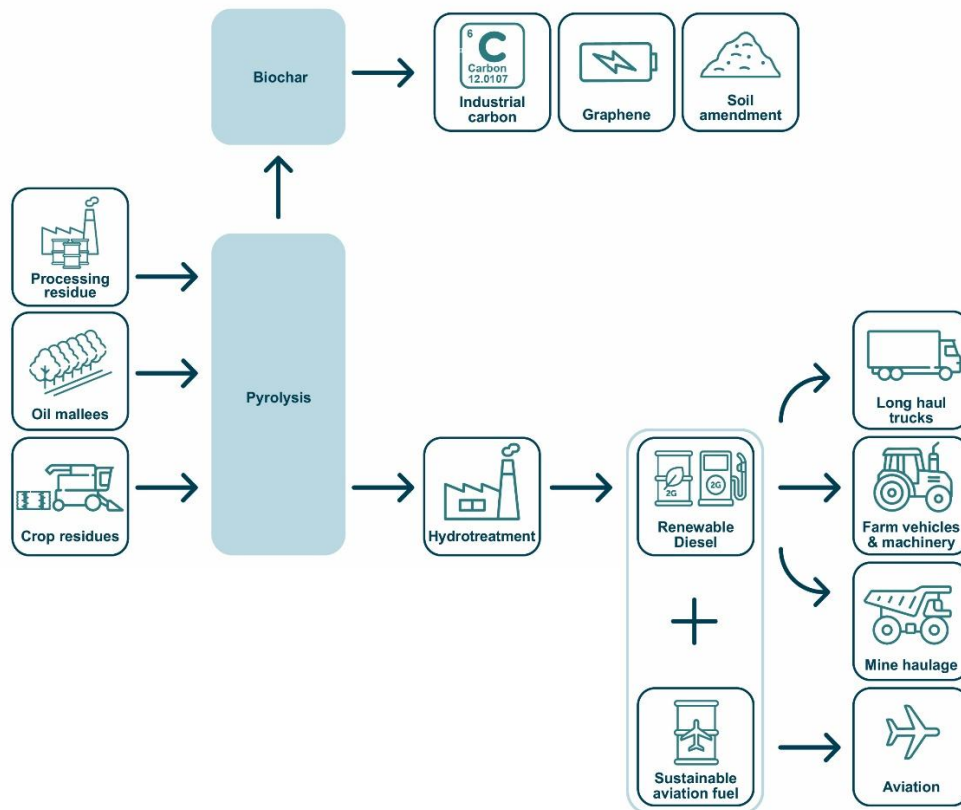


Figure 2: The process of pyrolysis

Hydrothermal Liquefaction (HTL)

A thermal depolymerisation process used to convert wet biomass into biocrude oil under moderate pressure and high temperature. The reaction involves alkaline catalysts to improve the quality and yield of products. Depending on the processing conditions, the fuel can be used as produced for heavy engines such as the ‘bunker oil’ used in shipping or upgraded to transport fuels such as diesel, petrol or jet fuels.

The oil produced through HTL has approximately twice the energy density of pyrolysis oil. HTL oil can contain up to 80 per cent of the feedstock carbon content. The HTL process can also be used to turn end of life plastic into new plastic. In addition to new plastics, the process can produce waxes, diesel, petrol and useful industrial gases like ethylene

Torrefaction

Torrefaction can be described as a mild version of pyrolysis which removes moisture and volatile chemicals from biomass feedstock and creates a kind of ‘bio-coal’ that can be used in existing coal fired power stations. During the process, the biomass typically loses 20 percent of its mass and 10 percent of its heating value with no appreciable change in volume. This 10 percent energy loss can be used as a heating fuel for torrefaction. The main advantage of this process is that it creates a very stable and easy to handle material.

Processes with potential in WA

Table 1. Summary of the Key Processes for biomass conversion

Process	Gasification/ pyrolysis	Cellulose ethanol	Anaerobic digestion	Combustion
Technology	Gasification boiler (heat), Cogeneration (heat + electricity)	Steam explosion, Enzymatic saccharification, Fermentation, Distillation, Cogeneration (heat + electricity)	Biogas digester, Gasholder biogas boiler (heat), Cogeneration (heat + electricity); Engine or turbine, Generator (heat exchangers)	Combustion boiler for steam production where heat or steam is need, or Closed cycle steam / Rankin cycle turbines for electricity
Feedstock	Cellulosic biomass: Wheat straw, oat husks, forestry products & waste from energy crops, municipal, commercial and industrial, construction and demolition waste (grasses, canes)	Cellulosic biomass: Wheat straw, oat husks, forestry products and waste from energy crops (grasses, canes); Waste/surplus grains, fruit & vegetables	Any organics (sewage, manure, municipal waste, waste/surplus grains, fruit & veg) can mix with cellulosic waste and abattoir waste	Cellulosic biomass: Wheat straw, oat husks, forestry products & waste from energy crops, municipal, commercial and industrial, construction and demolition waste (grasses, canes)
Energy products	Heat, Electricity, Bio oil and Syngas	Ethanol, Heat and Electricity	Biogas, Heat and Electricity	Heat, Steam and Electricity
Co-products	Biochar, Ash and Chemicals	Ash, Compost and Liquid fertiliser	Liquid and solid fertiliser	Ash
WA biomass projects	In Kalannie, Rainbow Bee Eater developed the ECHO2 system, a modular biomass pyrolysis and gasification technology used to produce biochar, pyrolygneous acid and syngas. Although the facility in Kalannie is now nonoperational, it led to production sites in South Australia and Victoria.	The Australis Biofuel Facility, to be developed in Esperance, will produce a range of products including cellulosic ethanol. A 50 MW biomass power plant will provide on-site energy with surplus electricity fed into the grid.	Richgro, based in Jandakot, uses a 2MW anerobic digestion plant to process more than 35,000 tonnes of solid and liquid commercial and industrial organic waste each year.	The Albany Leisure and Aquatic Centre transitioned to a biomass pool heating system which uses approximately 400–500 tonnes of locally sourced woodchips annually to heat the pool water and air handling units.

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