INTRODUCTION

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"Biomass" collectively refers to large quantities of organic matter produced by biological action. The term seems to have appeared in open literature first in 1934 to express the amounts of plankton in bay water [1]. This literature further cites its origin as [2]:

> "By biomass (Demoll), we term the quantity of substances in living organisms per unit of surface or volume. The biomass may be considered at some particular moment, the average yearly, seasonal, monthly, etc. [2]."

Over the years, particularly after the worldwide oil crisis in the 1970s, the terminology started to include connotations of biological organic substances, dead or alive, that could be utilised as energy resources (excluding fossil organic resources such as petroleum and coal). In this context, the term biomass may be considered a collective designation of organic matters of biological origin that stored solar energy in the form of fixed carbon (excluding fossil resources) and could be utilised as an energy source and/or material resource.

While the attention given to biomass in the 1970s emphasised its role as a substitute for fossil fuels, recent attentions seem to put more emphasis on its carbon neutrality. The Paris Agreement – a legally binding international treaty on climate change, was adopted by 196 parties in December 2015, with a goal to limit global warming to below 2°C, preferably to below 1.5°C, compared to pre-industrial levels. Implementation of Paris Agreement has since added to the globally jointed commitment to reduce greenhouse gas emissions. Nonetheless, the Emission Gap Report 2020 released by United Nations Environmental Programme reported that the global mean temperature is still heading in the rising direction of 3.5°C by the Year 2100 [3].

In the Year 2020, a growing number of countries such as Japan, South Korea, and China are joining the bandwagon to pledge to achieve net zero carbon emission in the year 2050-2060. These countries, which have been relying heavily on fossil fuels, especially coal, for power, have revealed their ambition to scale up renewable energy. Large energy organisations, such as Exxon Mobil, Shell, BP and Petronas, have also publicised their commitment to energy transition to achieve carbon neutrality. While long-term strategies are essential, catalysing action from authorities and commitment from businesses and individuals are the keys to shaping a sustainable energy future.

The increasing demand and interest in renewable energy around the world made the total energy supply from biofuels and waste increase to 1,330 Mtoe in 2018, more than double from 640 Mtoe in 1973 [4]. However, ever-increasing world energy demand decreased the share of biofuels and waste in the world's total energy supply from 10.5% to 9.3% in the same period. In fact, modern renewable energy (solar, hydro, biofuels, etc.) only accounted for 11% of total final energy consumption in 2018 and less than one-third of energy demand growth between 2013-2018 [5]. Intensification of research and development efforts to replace fossil-based fuels and materials with renewables, including biomass, are increasingly important.

Biomass, in general, may be classified in Table 1.1 by location, mode of growth and usage. Close examination of the biomass examples listed in the table makes us realise that many of those biomasses overlap with those utilised as food by many terrestrial creatures. After all, photosynthesis is almost the only way to produce organic matter to be consumed as food by almost all the other creatures on earth.

Table 1.1 Biomass classification

Classifier	Breakdown	Examples
Location of growth	Land	Land crops, grasses, trees, land animals, soil microorganisms, etc.
	Aquatic	Aquatic plants, microalgae, planktons, aquatic animals, fishes, etc.
Mode of growth	Cultivated	Farm plants, plantations, farm animals, cultured fish, cultivated algae, etc.
	Naturally grown	Wild plants, wild animals, natural forests, grassland vegetation, etc.
Usage-based	Utilisable for specific purpose	Crops, grains, foodstuff, silage, timbers, etc.
	Waste from specific usage	Municipal waste (food waste, sewage sludge, etc.), animal manure, farm waste (rice husk, corncob, etc.), and industrial waste (pulp sludge, timber waste, etc.).

It would be natural, then, that using those biomasses as feedstock for fuel and materials would compete with their use as foodstuff for humans and other creatures such as domestic livestock. In view of this conflict between "food and fuel," fuels derived from biomass (biofuels) are often classified into three categories based on their feedstock relation to food, as listed in Table 1.2.

Table 1.2 Biofuel classification in terms of their feedstock relation to food

Biofuel categories	Relation of biofuel feedstock to food	Mode of competition with food
First generation	Biofuels derived from food sources (sugarcane, corn starch, canola oil, palm oil, etc.)	Direct competition as feedstock usage
Second generation	Biofuels derived from inedible biomass (jatropha, etc.)	Competition through land and water usage
Third generation	Biofuels derived from microalgae	Marginal competition

In order to utilise biomass of various kinds for fuel and other material sources, chemical constituents of biomass have to be converted into forms tailored to its objective usage. Three major conversion technologies are being practised presently, as found in Table 1.3. Those processes could be used as standalone for a specific product or combined and integrated to produce various products, and it is termed biorefinery in analogy to a petroleum refinery.

Table 1.3 Biomass conversion technologies

Technology classification	Representative processes	Representative products
Thermal conversion	Torrefaction, hydrothermal processing, pyrolysis, gasification, liquefaction, etc.	Synthesis gas, methane, hydrogen, pyrolysis gas, pyrolysis oil, char
Chemical conversion	Transesterification, cellulose acid digestion, etc.	Biodiesel, oligosaccharides
Biochemical conversion	Ethanol fermentation, acetone-butanol fermentation, hydrogen fermentation, methane fermentation, etc.	Bioethanol, biomethane, biohydrogen, biobutanol

The potential for global biomass production could be huge. A bioenergy annual report from International Energy Agency [6] predicts the technical biomass potential in 2050 to be as high as 1500 EJ/year, while it places sustainable biomass potential in 2050 to be between 200 and 500 EJ/year. In view of the prediction of world energy demand in 2050 to be between 600 to 1000 EJ/year, the future potential of biomass in the world's primary energy mix would be substantial.

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