Energy from recently living matter

Biomass includes wood, crop residues, organic wastes and energy crops. Photosynthesis stores solar energy in organic molecules; people can use that stored chemical energy as fuel.

1. MATCH THE FEEDSTOCK TO THE CONVERSION

Solid biomass Wood or crop residues	Burn for heat; steam can drive a turbine and generator.
Liquid biofuels Sugars, starches, oils	Ferment sugars to ethanol; process oils or fats into biodiesel.
Biogas Manure or food waste	Anaerobic microbes produce methane-rich gas that can be burned.

Feedstock = the raw material used to make a fuel. Biogas and biodiesel are extension examples; the core focus here is biomass burning and ethanol.

2. RENEWABLE DEPENDS ON THE REPLACEMENT RATE

Biomass can be replenished on human time scales, unlike fossil fuels. But harvesting wood faster than trees regrow depletes the resource and can cause deforestation. Calling a fuel renewable describes its potential for replacement, not a guarantee that every harvest is sustainable or that burning it is pollution-free.

3. WHY USE IT, AND WHAT LIMITS IT?

Burning locally available biomass can supply useful heat at relatively low cost and reduce demand for fossil fuels. Waste materials may provide a fuel source without growing a dedicated crop. Collection, drying, transport and processing still use resources, and reliable supply matters. Compare the useful energy delivered, not simply the tonnes of material collected.

Feedstocks and conversion routes: US EIA, Biomass Explained.
Low-cost heat, emissions and overharvesting: College Board, ENG-3.I.1.
Wood use, regrowth and smoke: US EIA, Biomass and the Environment.

Scope: College Board AP Environmental Science CED, Topic 6.7, p. 127.

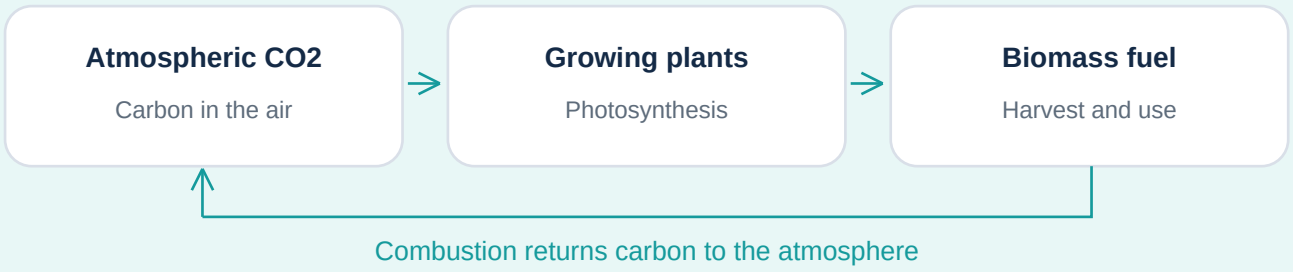
Renewable does not mean impact-free

Assess air pollution, land use and climate separately. A renewable feedstock may still produce harmful smoke, damage habitats or increase greenhouse-gas emissions over the period being studied.

1. BURNING BIOMASS STILL RELEASES POLLUTANTS

Combustion releases carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), particulates and volatile organic compounds (VOCs). CO_2 affects climate; smoke also damages air quality. Incomplete combustion increases products such as CO. Cleaner combustion and particle controls can reduce some pollutants, but do not make the fuel emission-free.

2. THE CARBON CYCLE IS NOT A ZERO-EMISSIONS CLAIM



Regrowth can take up released CO_2, but timing matters. Clearing forests can lose stored carbon and future uptake. Farming, processing and transport can add further emissions.

3. LAND AND WATER ALSO HAVE COSTS

Fuel crops can compete with food production and habitats for land and water. Fertilizer and pesticide use can affect water quality; land conversion can reduce biodiversity. A fuel made from plants is not automatically a low-impact fuel.

4. MATCH THE RESPONSE TO THE PROBLEM

Limit overharvesting, protect habitats and control smoke. Choose feedstocks and production methods using life-cycle evidence, rather than assuming all biomass has the same benefits.

Required combustion pollutants and deforestation: College Board, ENG-3.I.1.
Wood smoke and regrowth: US EIA, Biomass and the Environment.
Land, water and full-life-cycle impacts: US EPA, Biofuels and the Environment.

Scope: College Board AP Environmental Science CED, Topic 6.7, p. 127.

Ethanol: count carbon and energy

Ethanol is an alcohol biofuel that can replace part of gasoline use. It is commonly blended with gasoline; its environmental value depends on the feedstock and the entire production pathway.

1. FROM PLANT SUGARS TO LIQUID FUEL

Microbes ferment sugars into ethanol. Starch feedstocks such as corn must first be broken down into sugars; sugarcane supplies sugars directly. Separating and purifying the ethanol requires energy. Ethanol contains less energy per unit volume than gasoline, so equal volumes do not provide equal amounts of fuel energy.

2. RECYCLED CARBON IS NOT ABSENT CARBON

Ethanol combustion releases CO_2. The distinction from fossil gasoline is that its plant carbon was recently taken from the atmosphere, rather than extracted from a long-buried carbon store. This can reduce net fossil-carbon additions, but growing the crop, producing fertilizer, processing fuel and changing land use may add greenhouse gases. Carbon neutrality is not automatic.

3. ENERGY RETURN ON ENERGY INVESTMENT (EROI)

EROI = energy in the fuel produced / energy invested in producing it.

The syllabus highlights ethanol's low energy return: growing, processing and transporting feedstocks can consume a substantial share of the energy obtained. The ratio varies with feedstock, process and what the analysis counts; low return does not necessarily mean a negative energy balance.

Illustrative only: 5 MJ fuel output / 4 MJ invested = 1.25 : 1. Net gain = 5 - 4 = 1 MJ. These are invented values, not an industry average.

4. READ THE COMPARISON CAREFULLY

Use the same energy units and system boundary. EROI is not a price ratio, an engine-efficiency percentage or a carbon footprint. A positive energy balance alone does not prove low emissions. Feedstocks, production energy and land-use effects must be evaluated together.

Ethanol properties and energy balance: US DOE, Alternative Fuels Data Center.
Energy-input accounting: USDA, The Energy Balance of Corn Ethanol (method background).
Carbon accounting across production and use: US EPA, Lifecycle Analysis.

Scope: College Board AP Environmental Science CED, Topic 6.7, p. 127.