Evolution of Energy Sources from Fossil Fuels to Renewable Fuels: A review

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Abstract:
The world is witnessing a significant energy transition as renewable energy sources increasingly replace fossil fuels. Biomass to energy conversion is a crucial process that transforms organic materials into usable energy forms, such as electricity, heat, or biofuels.
Biofuels are produced using plants and animal waste as feedstocks and known as renewable source of energy. They serve as an alternative to fossil fuels, helps to decrease the greenhouse gas (GHG) emissions and encouraging energy sustainability. The current study explores the ongoing shift towards sustainable energy, highlighting the drivers, challenges, and implications of this transformation for global energy systems and climate change mitigation. This paper also discusses about various methods of biomass conversion, the types of biomass feedstocks available, and the environmental and economic implications of utilizing biomass as a renewable energy source. By understanding these aspects, we can appreciate the potential of biomass in contributing to sustainable energy solutions.

Keywords: Biofuels; Diesel Engine; Emission; Sustainable Development Goal; Transesterification Process

1.Introduction

The source of biomass is plants and animals which is organic material. It includes a wide range of feedstocks such as agricultural residues, forestry products, animal manure, and dedicated energy crops [1]. Because it can be regenerated naturally over time, biomass is regarded as a renewable energy source. From the first man-made fire to the use of pelletized wood as a feed for thermal plants, biomass has always been a dependable energy source. While the idea of using lignocellulosic feedstock as solid biofuel is widely recognized, turning biomass into liquid fuel is a significant challenge [2]. The more complex the biomass is in terms of its chemical makeup, the more difficult and costly the conversion process is overall. Although research on biofuels closely followed the price of petroleum for the majority of the 20th century, the depletion of oil supplies and the rise in global energy demand have led to a surge in interest in biofuels in the last ten to twenty years [3]. The reason behind shifting from fossil fuel to renewable fuel is depicted in figure 1.

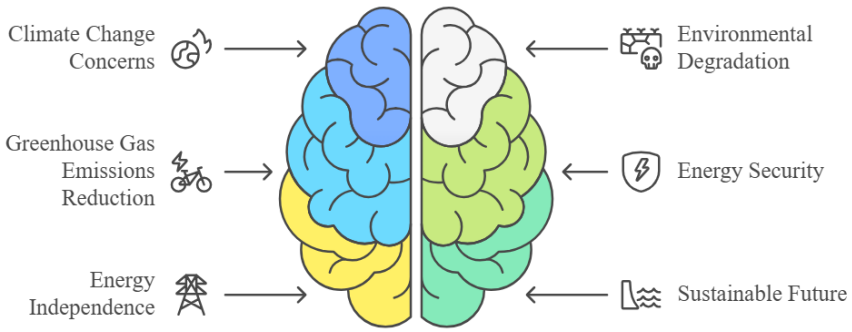

Figure 1. Sustainable path to a sustainable energy future

The transition from fossil fuels to renewable energy sources such as solar, wind, hydroelectric, and geothermal is gaining momentum [4][5]. Governments, businesses, and individuals are recognizing the need to reduce GHG emissions and combat climate change [6]. This shift is driven by several factors:

- **Climate Change Awareness**: The growing recognition of climate change and its impacts has led to increased advocacy for cleaner energy sources.
- **Technological Advancements**: Innovations in renewable energy technologies have made them more efficient and cost-effective, making them competitive with traditional fossil fuels.
- **Policy and Regulation**: Many countries are aiming to use 100% renewable fuels and to achive this they are framing attractive scheme such as tax incentive, subsidies related to renewable fuels.

- **Investment Trends**: There is a noticeable increase in investments in renewable energy projects, with both public and private sectors allocating funds to support sustainable energy initiatives.

Hence the current study explores the ongoing shift towards sustainable energy, highlighting the drivers, challenges, and implications of this transformation for global energy systems and climate change mitigation. This paper also discusses about various methods of biomass conversion, the types of biomass feedstocks available, and the environmental and economic implications of utilizing biomass as a renewable energy source. By understanding these aspects, we can appreciate the potential of biomass in contributing to sustainable energy solutions.

2. Methods of Biomass Conversion

Biomass has been recognized as potential feedstock for the production of renewable fuels [6]. Biomass feedstocks can be categorized into three main types:

- **Lignocellulosic Biomass**: This includes agricultural residues (e.g., straw, corn stover), forestry residues (e.g., wood chips, sawdust), and dedicated energy crops (e.g., switchgrass, miscanthus). Lignocellulosic biomass is abundant and has a high energy content [7].
- **Animal Manure**: Manure from livestock can be used as a biomass feedstock for anaerobic digestion, producing biogas while also managing waste [8].
- **Food and Yard Waste**: Organic waste from households and food processing can be converted into energy through anaerobic digestion or composting.

There are several methods to convert biomass into energy, each with its own advantages and applications:

i. Combustion

Combustion is the most straightforward method of biomass conversion. It involves burning biomass to produce heat, which can be used to generate steam for electricity production or for direct heating applications [9]. While combustion is efficient, it can produce greenhouse gases and other pollutants if not managed properly.

ii. Gasification

Gasification is a thermochemical process that converts biomass into syngas (a mixture of hydrogen and carbon monoxide) at high temperatures in an oxygen-limited environment [10]. Syngas can be used to generate electricity or can be further processed into biofuels and chemicals.

iii. Anaerobic Digestion

Anaerobic digestion involves the breakdown of organic matter by microorganisms in the absence of oxygen [11]. This process produces biogas, primarily composed of methane, which can be used for heating, electricity generation, or as a vehicle fuel. The residual material, known as digestate, can be used as a nutrient-rich fertilizer.

iv. Fermentation

Fermentation is a biological process that converts sugars from biomass into ethanol or other biofuels using yeast or bacteria[12]. This method is commonly used with crops like corn and sugarcane, and it can also be applied to cellulosic biomass through pre-treatment and enzymatic hydrolysis [13].

Despite the positive trends, the energy transition faces several challenges [14]. Existing energy infrastructure is predominantly built around fossil fuels, requiring significant investment to adapt or replace with renewable energy systems. Renewable energy sources like solar and wind are intermittent, necessitating advancements in energy storage technologies and grid management to ensure a reliable energy supply. The transition may disrupt traditional energy markets and economies reliant on fossil fuel production, leading to job losses and economic instability in certain regions[15]. There can be resistance to change from communities and industries accustomed to fossil fuel-based energy systems. Although each methods have their own advantages and challenges, the large-scale production of biofuels has many obstacles [16]. Some of the key points related with challenges of biomass to bioenergy process is shown in figure 2.

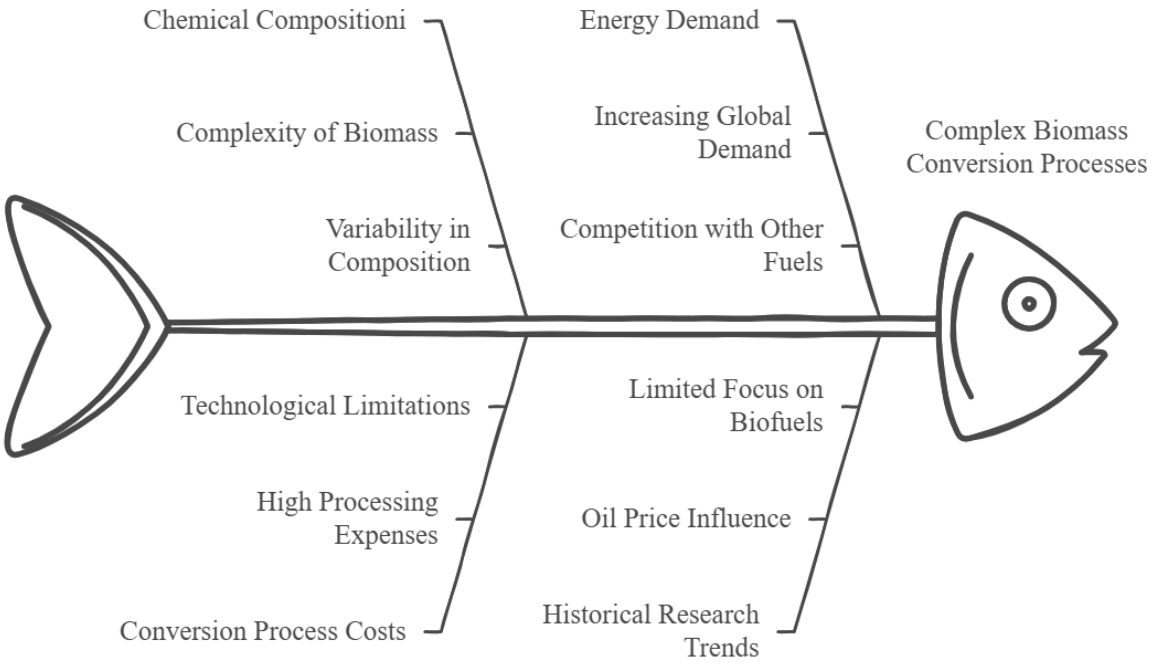

Figure 2. Challenges of biomass conversion process

3. Types of Biofuels

Burning of fossil fuels produced CO_2 which could be reduced with the use of biofuels made from renewable resources [17]. Biofuels made from biomass, such as plants or organic waste, may lessen the need for oil and the emission of CO_2. Because the plants that produce these biofuels use CO_2 during their growth, they have the potential to reduce CO_2 emissions [18]. The production of biofuels and bioproducts from plant biomass would help to slow down global warming. This could be because burning releases the same amount of CO_2 as the plant ties up during photosynthesis, so the net amount of CO_2 in the atmosphere does not rise. Furthermore, the production of biofuel and bioproducts can open up new job and revenue opportunities in rural areas. The 21st century is searching for replacement of petroleum fuels to renewable fuels and biofuels can become very attractive candidate [19] [20]. The different types of biofuels are discussed below:

i. Biodiesel

Biodiesel is produced through the transesterification of vegetable oils or animal fats. It can be used in its pure form (B100) or blended with petroleum diesel (e.g., B20, which is 20% biodiesel and 80% petroleum diesel) [21]. Biodiesel is known for its biodegradability and lower emissions of pollutants. Biodiesel, also referred to as vegetable oil-based fatty acid methyl esters (FAME), is becoming more and more popular as an environmentally friendly diesel fuel extender or replacement [22]. A homogeneous and heterogeneous catalyst is needed to chemically react oil or fat with alcohol to create biodiesel, an alternative to diesel, which is produced from renewable biological sources like vegetable and animal fats [23]. The reaction's end product is a blend of glycerol, a valuable byproduct, and methyl esters, commonly referred to as biodiesel.

ii. Bioethanol:

Bioethanol is an alcohol made from the fermentation of sugars found in crops like corn, sugarcane, and wheat. While primarily used in gasoline engines, it can also be blended with diesel in certain applications. Ethanol has been produced through fermentation using a wide range of raw materials containing carbohydrates. Grain alcohol is made from food crops like corn, wheat, barley, and sweet sorgum, whereas biomass ethanol or bioethanol is made from lingo-cellulosic biomass like agro residue (rice straw, wheat straw), grasses (switch grass), etc. A biochemical process is used to produce both of these alcohols [24].

iii. Biogas:

Biogas is produced through the anaerobic digestion of organic matter, such as agricultural waste, manure, and food scraps [25]. It primarily consists of methane and can be used to generate electricity or as a vehicle fuel, although its direct application in diesel engines is limited.

iv. Renewable Diesel:
Renewable diesel is produced through hydro processing of vegetable oils or animal fats, resulting in a fuel that is chemically similar to petroleum diesel. It can be used in diesel engines without modification and offers similar performance to conventional diesel.

v. Algal Biofuels:
- Algal biofuels are derived from algae, which can produce oils that are converted into biodiesel or renewable diesel. Algae have a high growth rate and can be cultivated on non-arable land, making them a promising source of biofuel[8].

Biofuels are also classified as first, second, third and fourth generation of biofuels as shown in figure 3.

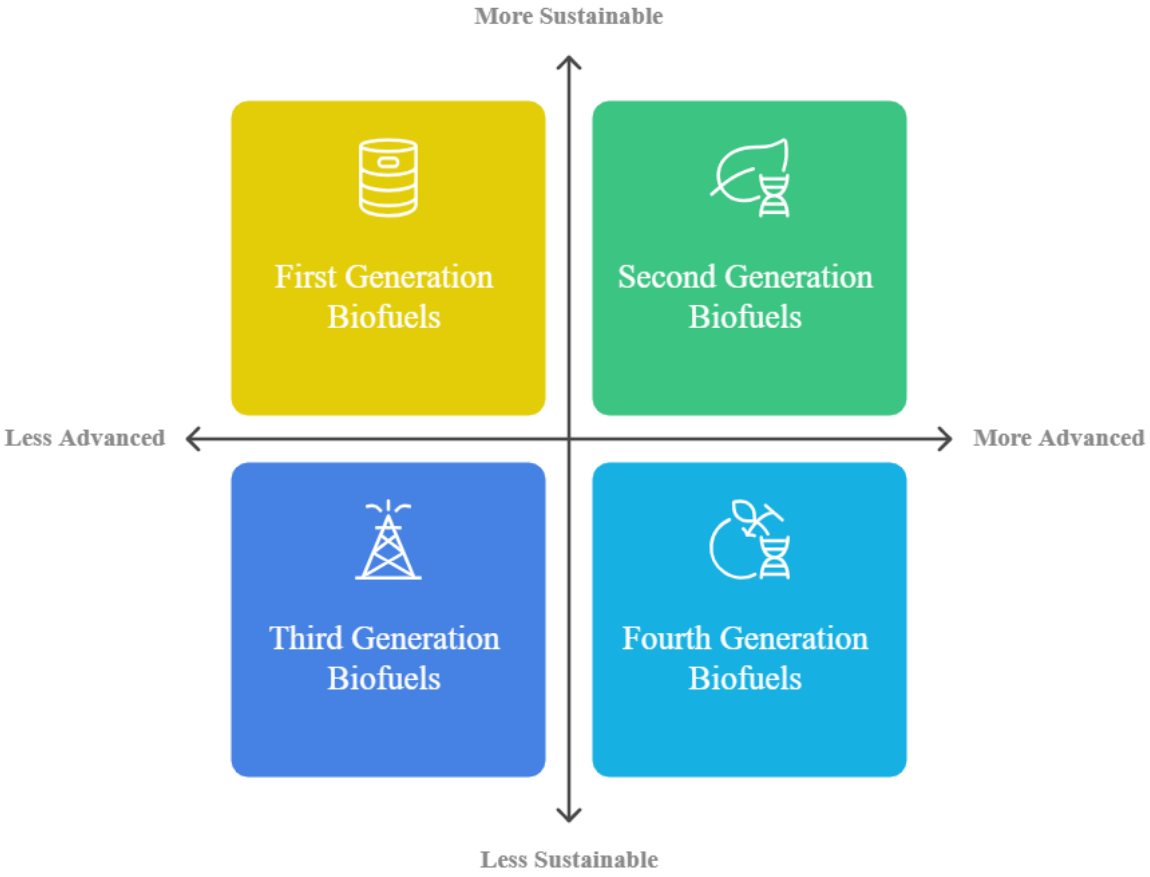

Figure 3. Types of biofuels

4. Implications for the Future

Biofuels, particularly biodiesel and renewable diesel, have significant applications in diesel engines. Biodiesel can be blended with petroleum diesel in various proportions without requiring engine modifications. This compatibility allows for a seamless transition to renewable fuels. Biodiesel has a higher cetane number than petroleum diesel, which can lead to improved combustion efficiency and reduced engine noise. It also has excellent lubricating properties, which can enhance engine longevity. The use of biofuels in diesel engines can significantly reduce emissions of carbon dioxide, particulate matter, and other harmful pollutants. This contributes to cleaner air and a lower carbon footprint. Utilizing biofuels helps diversify energy sources and reduces dependence on fossil fuels, contributing to energy security and sustainability. The production and use of biofuels can stimulate local economies, create jobs in agriculture and biofuel production, and promote rural development. The future of bioenergy is shown in figure 4.

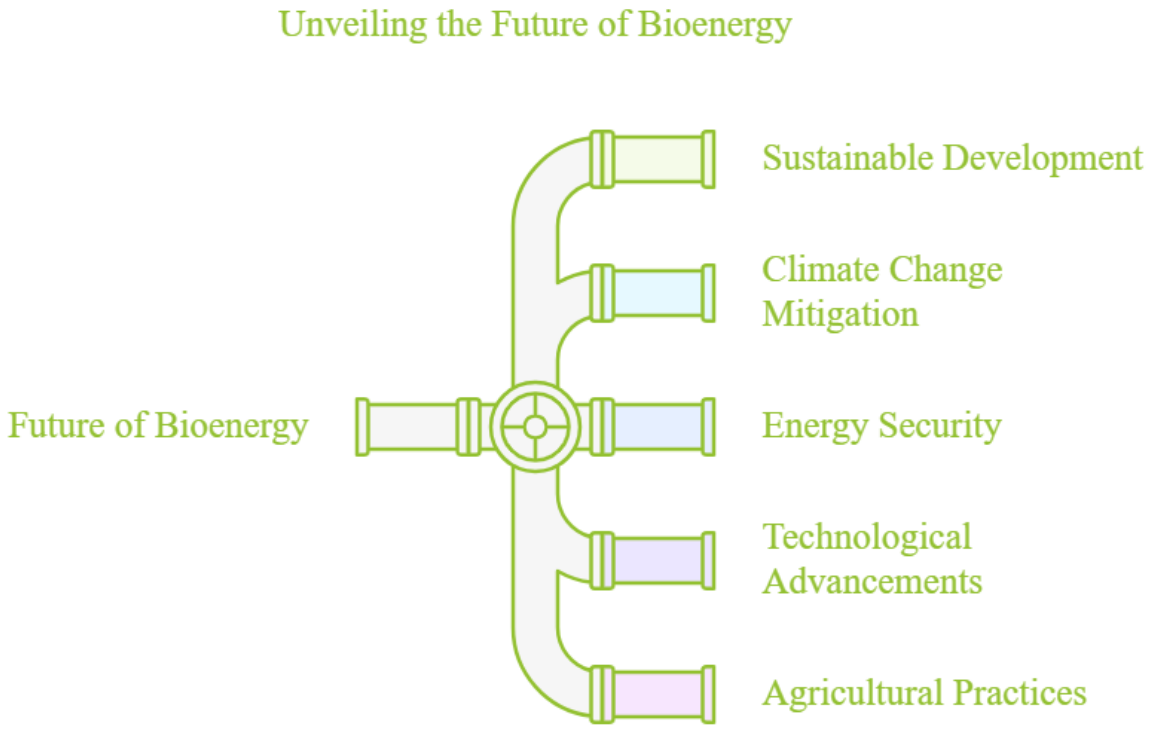

Figure 4. Future of bioenergy

The conversion of biomass to energy has several environmental benefits, including reducing greenhouse gas emissions, decreasing reliance on fossil fuels, and promoting sustainable land use. However, it is essential to consider the sustainability of biomass sourcing to avoid negative impacts on food production and biodiversity. Economically, biomass energy can create jobs in rural areas, stimulate local economies, and provide energy security. However, the initial investment for biomass conversion technologies can be significant, and ongoing research is needed to improve efficiency and reduce costs. The ongoing energy transition has profound implications for the global economy, environment, and society:

- **Environmental Benefits**: A shift to renewable energy can significantly reduce carbon emissions, contributing to global efforts to combat climate change and protect ecosystems.
- **Energy Security**: Diversifying energy sources enhances energy security by reducing dependence on imported fossil fuels and increasing resilience to geopolitical tensions.
- **Job Creation**: The renewable energy sector is expected to create millions of jobs in manufacturing, installation, and maintenance, providing new opportunities for workers.
- **Innovation and Growth**: The transition fosters innovation in energy technologies and services, driving economic growth and competitiveness in the global market.

5. Conclusion

Biomass to energy conversion presents a promising opportunity to harness renewable energy from organic materials. By utilizing various conversion methods and feedstocks, we can create a sustainable energy future while addressing environmental concerns. Continued advancements in technology and sustainable practices will be essential to maximize the potential of biomass as a key player in the global energy landscape. biofuels represent a vital component of the transition to sustainable energy systems. With various types available, their application in diesel engines not only enhances performance but also supports environmental goals and energy independence. As technology advances, the potential for biofuels to play an even larger role in the energy landscape continues to grow.

In conclusion, the energy transition towards renewable sources is not only in progress but is also essential for a sustainable future. While challenges remain, the collective efforts of governments, businesses, and individuals can pave the way for a cleaner, more resilient energy system that benefits both the planet and its inhabitants. The momentum for change is strong, and the path forward is filled with opportunities for innovation and growth in the renewable energy sector.

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