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Use of biofuel in the present day energy crisis: a sustainable management from plant resources in the grip of climate change

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Sustainable management of plant resources and its profitable exploitation is an urgent need in the present day world. Management of plant derived, economically viable elements ensure that these resources are used sustainably. Plant resource management is potentially applicable for the modern vegetation that includes wide array of organisms ranging from microbes to flowering plants. However, fossilized plants preserved in earth as sedimentary rocks also can be commercially used in various applications.

In the present day scenario, the biosphere realm of the earth is being adversely affected owing to climatic change. Most of the climate models for the next couple of decades predict unusual spike in the atmospheric temperature. According to the recent report of Berkeley Earth (California), during the year 2025 the earth experienced the 3rd hottest year since 1850. Analysis of Berkeley Earth revealed that the global annual average temperature of 2026 will be more or less similar to 2025. In all probabilities, the year 2026 has been predicted to be the 4th warmest year since 1850. Most of the European countries like France, Spain, Germany, Croatia, Albania, and Belgium alongside United Kingdom are experiencing record breaking heat. All these countries experience prolonged cold season and are not well equipped for extreme heat waves. As a consequence of heat waves, multiple wildfires have been recorded in most of these countries. Specifically in France, six nuclear reactors have been shut owing to extreme heat. Residents from the potential regions of wildfire have been evacuated to safe locations. Levitan *et al.* (2014) commented that combustion of petroleum and other fossil fuels are mainly responsible for long-term global climate change, and there is an urgency to explore sustainable, carbon-neutral and economically feasible alternatives that can be used as a substitute.

The latest report of Intergovernmental Panel on Climate Change (IPCC), *i.e.*, the Sixth Assessment Report published in March 2023 provides a conclusive scientific overview on global warming. The panel report clearly states that human activities, primarily combustion of fossil fuels are unambiguously the cause of global warming.

Before 1859, humans used whale blabber as a fire source. Discovery of first major oil well by Edwin Drake in 1859 was a breakthrough, that led to the supply of cheap fuel for igniting of kerosene lamps (Levitan *et al*., 2014) and reduced the demand of whale blabber. Subsequently, there was a high demand for gasoline after the invention of internal combustion engines. In the first few decades of 20th century, the fossil fuel became a trademark of economic upswing in industrially developing countries. According to Rodrigue *et al*. (2013), fossil fuel, *i.e*., petroleum is exploited in more than 96% of all transportation processes. It has been predicted that the global reserves of fossil fuels are capable of fulfilling the demand for several future decades.

With reference to IPCC report, there is an urgent need for replacing of fossil fuel by renewable alternative, such as plant based biofuel that can reduce their use. Basically, biofuels are directly obtained from plants and organic wastes. Ethanol and biodiesel are two basic types of biofuels. Ethanol is derived from sugars and starches, whereas, biodiesel is derived from plant oils. Biofuels can effectively lower the net greenhouse gas emissions, however, there are several hurdles like land use, energy efficiency, and overall scale for the absolute replacement of fossil fuels. Methane-rich gas, *i.e*., biogas or biomethane is produce by the anaerobic breakdown of organic and agricultural wastes. More advanced and second generation biofuels are derived from rice straw, wheat straw, wood chips, non-edible oil trees like *Jatropha* or *Pongamia* and algae that can reduce the greenhouse gas emission.

Algae based biofuels, considered as third and fourth generation in this category, have attained attention during the last ~50 years (Levitan *et al*., 2014). Amongst the algae, the green, planktonic microalga *Botryococcus braunii* yields around 75% of its dry mass as hydrocarbons and after non-destructive extraction it produces biofuel that can be converted into gasoline, kerosene and biodiesel. Hence, *Botryococcus braunii* can be considered as a renewable source of valuable hydrocarbon; however, further research should be focused on efficient cultivation for sustainable energy and high-value products. Diatoms are planktonic algae that belong to family Bacillariophyceae are also potential source of biofuels. Diatoms are capable of fixing ~20% carbon through photosynthesis and play a major role in global carbon cycling. A substantial portion of superior quality petroleum is derived from sediments rich in fossil diatoms. The source of diatoms can be tracked by analyzing lipids that act as biomarkers. Diatoms remain stable for millions of years in the petroleum reservoirs. The fossilized diatoms that form diatomaceous earth as sedimentary rocks are commercially used in filtration, pest control, thermal insulation, micro-abrasion and various other applications. The overwhelming dominance of diatoms over the last ~34 million years is owing to their elevated photosynthetic energy transformation efficacy and quick absorption of nutrients. More than three decads ago based on the study of Neogene (23.04 to 2.58 million years ago) diatomaceous deposits from Japan, Aoyagi and Omokawa (1992) opined that owing to presence of excellent organic components preserved in diatoms and high biological productivity, diatoms might be one of the most significant sources of petroleum. Though, diatoms are considered as major contributors to crude oil, the overall estimation of worldwide petroleum reserves contributed by diatoms are still lacking (Ramachandra *et al*., 2009). Based on the assessment of Lisitzin (1972), Shukla and Mohan (2012) identified three major belts of diatomaceous sediments in the modern oceans. The Neogene marine sediments of Andaman and Nicobar Basin are also rich in diatoms (Ghosh *et al*., 2025). In order to overcome the present day world energy crisis, intensive research on petroliferous basins alongside alternate methods for crude oil generation is crucial. Future researches on the third or fourth generation biofuel should mainly focus on the study of biochemical pathways using molecular and genetic tools for the generation of algal strains with high lipid yield. Only very few studies on the diatom species *Cyclotella cryptica, Phaeodactylum tricornutum, Thallasiosira psuedonana, Navicula pelliculosa, Nitzschia longissima* etc. carried out earlier (Orcutt and Patterson, 1975; Roessler, 1988) on genetic manipulation for enhancing their biomass or lipid content (Levitan *et al.,* 2014). It would be meaningful to take the edge of natural selection of diatoms that possess high photosynthetic energy conversation efficiency with lipids as their primary storage product. Culture of diatoms as feedstock for biofuel production may be the main substitute for all petroleum consumption in future.

Specifically in India, biofuel must be considered as an alternative renewable energy source for future, and diatoms may be the future of energy source as India imports nearly 89% of its crude oil needs, making it the world's third largest oil importer. According to the assessment of Ministry of Power, Government of India, bio energy only contributes 5.4% of the installed capacity of renewable energy. In future, though diatoms can be considered as a third or fourth generation biofuel, their global market perception is almost negligible. Considering the present day energy crisis and unusual extreme climatic conditions, a critical assessment is necessary to validate its potential as a source of biofuel not only for mitigating the energy crisis, but also for safe, carbon neutral climatic condition. Recently, thirty nine countries (China, Japan, New Zealand, Canada, USA, Brazil and number of European countries) have shared a collaborative programme “International Energy Agency (IEA) Bioenergy Task 39” to decarbonize their transport sectors with biofuels and it has provided an international forum to assess the biofuel policy of these countries (Mohammadi and Saddler, 2025). Fatima *et al*. (2025) systematically reviewed the government policies of India, such as the National Policy on Biofuel, Bharat Stage Emission Standards, ethanol blending programme and their recent challenges as well as implementations to explicate biofuel landscape. However, commercialization and entrepreneurship is needed at different levels for its success.

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