Chapter 2
Life Cycle Assessment of Biofuels:
Challenges and Opportunities

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ABSTRACT

To address energy security and climate-change concerns, substitutes are needed for petroleum-based transportation fuels. In addition to electricity and natural gas, biofuels are emerging as an important class of substitutes. The promotion of biofuels as energy is mainly driven by the perspective of oil depletion, concerns about energy security, and global warming. However, results published in the past few decades present conflicting pictures regarding the energy efficiency and sustainability of biofuels. To adequately address these real or apparent contradictions, a life cycle assessment (LCA) of biofuels is indispensable. "Life cycle" refers to all stages of a process: from the cradle, that is, raw material extraction through manufacturing, distribution, and use to ultimate disposal. This chapter discusses the benefits and limitations of biofuels from an LCA standpoint. The discrepancies and strengths in LCA of biofuels are critically analyzed and opportunities are highlighted. LCA of biofuels is shown to be critical to informing policy and for practical application.

INTRODUCTION

The rising demand for clean, affordable and ecofriendly energy, climate change and global warming concerns, political agitation among nations, and the depletion of fossil-based fuels has necessitated the search and development of alternative sustainable technologies focused on renewable raw materials. Biofuels are considered to curb most, if not all, the aforementioned issues because they serve as an

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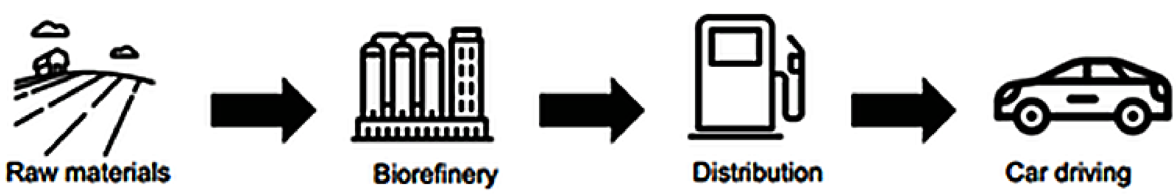
alternative clean fuel with supposed reduced greenhouse gas emissions, the drivers of global warming and climate change (Somerville, 2007). The link between biofuels and climate change is attributed to the fact that biofuels are supposed to be carbon-neutral alternative sources of energy. During photosynthesis, plants get sunlight energy and CO_2 from the atmosphere to form complex chemicals that constitute the plant body. When these plants are burnt, the resulting energy from oxidation is released as heat, CO_2 is given out as well and is recycled again (Somerville, 2007). Therefore, incident solar insolation can be harvested as biomass.

Bioenergy has the potential to offer a significant contribution to clean, low carbon, and secure energy. It is also referred to as a carbon-neutral process. Biofuels are also encouraged to mitigate anticipated shortages of fossil fuels resulting from anticipated depletion of natural resources or geopolitical instability. Despite the merits of biofuels, policy frameworks developed and incentives initiated, issues have been raised concerning other environmental impacts associated with biofuels and their energy efficiency sometimes with conflicting results. As such, sustainability assessment, before adoption, from an environmental, economic and social standpoint is very crucial and this can be achieved through a life cycle assessment (LCA). Life cycle assessment is a methodological tool used to evaluate the requirements and technological impacts, processes, and products to determine their propensity on resource consumption and pollution generation. It refers to all stages of a process that includes: from cradle, that is, raw material extraction, manufacturing, and distribution in the supply chain to grave, i.e. ultimate disposal (Mckone et al., 2011). Life Cycle Assessment is used within the framework of internationally accepted methods as explained in the ISO 14040 and ISO 14044. Figure 1 is a graphical sketch of the different steps in the life cycle of biofuel from the extraction of the raw materials to the end-user.

Figure 1. Graphical Representation of LCA of biofuels
(Hauschild et al., 2017)



LCA has been used in different fields of study such as wastewater treatment (Gallego-Schmid et al., 2019), solid waste management (Sebastian et al., 2022), the development of construction materials (Liu et al., 2022), food production systems (Lamnatou et al., 2022), and the environmental impacts of processes such as cement production (Ige et al., 2021) among other sectors. These studies underscore the usefulness of LCA in decision-making process and the need for comprehensive LCA of biofuels before adoption.

There are four types of activities that constitute the Life cycle assessment. The initial step entails defining the goal and scope of the assessment. The second activity is to collect life cycle inventory data on materials and energy flows emissions as well as wastes. The third activity entails conducting a life cycle impact assessment (LCIA), which serves to characterize the constituent process impacts. Lastly is the analysis and interpretation of the major findings alongside sensitivity and measurement of uncertainty to influence the decision-making processes (Mckone et al., 2011). Figure 2 is a schematic diagram of the four activities that define a life cycle assessment process.