Sustainability

Sustainability can be defined as the ability of an activity to meet the needs of the present without compromising the ability of future generations to meet their own needs (Bruntland, 1987). The potential for bioenergy to be a more sustainable source of liquid fuel, electric power, and heat than current dominant sources is the major driver behind policies that support bioenergy research and development. Sustainability comprises overlapping environmental, economic, and social aspects. Tools to assess sustainability include indicators and life-cycle analyses. Sustainability of bioenergy can be assessed at scales ranging from individual operations (e.g., a farm or biorefinery) to industries (e.g., soybean biodiesel or mixed-feedstock cellulosic ethanol) of regional, national, or global extent. Assessments of sustainability must consider effects throughout the supply chain, even when focusing on a single operation within that chain. (For example, the concept of spatial footprints can be used to incorporate aspects of land-use efficiency in feedstock production when assessing the sustainability of biorefineries.)

Although usage of the term varies, the ability of a particular system to persist over time can be called “viability” and is one aspect of sustainability. Long-term profitability is the most obvious aspect of viability. However, viability has environmental and social as well as economic components. For example, viability of plant-based feedstock production requires the maintenance of soil quality, and bioenergy systems in general require acceptance from the public.

In addition to viability, sustainability encompasses the extent to which a particular system contributes to the ability of a broader system – a region, a country, or the globe – to meet its present and future needs. Environmental considerations for the sustainability of a bioenergy system include effects on soil quality, water quality and quantity, greenhouse gas (GHG) balance, air quality, biodiversity, and productivity. Social and economic considerations overlap and include employment, welfare, international trade, energy security, and natural resource accounts, in addition to profitability and social acceptability.

Indicators can be used to assess the sustainability of bioenergy systems. Sustainability indicators can be defined as any measurable quantity that provides information about potential or realized effects of human activities on environmental, social, or economic phenomena of concern. Indicators can relate to management practices (e.g., amount of fertilizer applied) or to their effects (e.g., nutrients in soil or in waterways). Indicators based on management practices can be useful in certification systems, such as those under development by the Roundtable for Sustainable Biofuels and the Council on Sustainable *Biomass* Production. Indicators that measure effects can be used to provide an empirical grounding for the interpretation of management-based indicators or to assess the overall sustainability of a bioenergy industry or pathway. To the extent possible, indicators should reflect the entire supply chain. Such indicators can provide guidance for decisions such as choosing a specific conversion technology or choosing locations that are both suitable for low-cost feedstock production as well as close to markets.

Life-cycle analyses (LCAs) are another tool used to assess bioenergy sustainability. An LCA typically considers one or more quantities of environmental significance (e.g., energy consumption, C_{eq} emissions, consumptive water use) and sums the contribution to that quantity (negative as well as positive) from each step of the entire supply chain ("cradle to grave"). LCAs can seem straightforward on the surface, but LCAs measuring similar quantities can give disparate results depending on how system boundaries, baseline conditions, and co-products are defined and dealt with.

More generally, different approaches to system boundaries, baseline conditions, and co-products pose challenges to any effort to assess the sustainability of bioenergy systems. The treatment of baseline conditions is particularly problematic. The term "baseline" can describe conditions that exist prior to the implementation of bioenergy production, or it can describe the most likely alternative uses of the land and resources. The former type of baselines can potentially be measured. In some cases, the latter type of baselines can be approximated by carefully selecting and monitoring land resources that are similar except lacking bioenergy systems. In other cases, especially when assessing effects that may be geographically dispersed (e.g., air pollution or energy security), suitable proxy sites may not exist for those latter baselines, and alternate scenarios must be projected through simulation modeling.

A full understanding of the relative sustainability of a bioenergy system requires comparing the effects of that system to the effects of displaced or alternative sources of energy. This comparison may or may not be considered an issue of baselines. Typically, bioenergy systems are compared against fossil fuel systems (such as production of electricity from coal or liquid fuels from petroleum). The sustainability of fossil fuel systems should be considered in sustainability assessments, including advantages such as pre-existing infrastructure and disadvantages such as non-renewability, high GHG emissions, adverse health impacts, and (in the case of oil) frequent location of resources in politically unstable regions. Comparisons between bioenergy and other renewable energy technologies are also appropriate in some situations, particularly when the desired end product is electricity.

A central controversy regarding the sustainability of bioenergy concerns the idea of indirect land-use change (iLUC). Given certain assumptions, economic models predict that bioenergy production could raise global agricultural commodity prices, inducing the conversion of forests and grasslands to bioenergy production. Researchers disagree about whether these models are sufficiently realistic, valid, and/or based on accurate input data for use in policymaking. This topic is explored more fully in "Indirect Land-Use Change – The Issues" found in the feedstock section.

Although researchers disagree about whether and to what extent current bioenergy systems are sustainable, there is relatively broad agreement that bioenergy has at least the potential to be more sustainable than currently dominant energy systems. For example, many researchers believe that the most pressing concerns about current bioenergy sustainability could be addressed by growing lignocellulosic biomass crops

such as switchgrass, Miscanthus, or hybrid poplar on land that is degraded, abandoned, or ill-suited to growing traditional crops. Such a plan will require advances both in technology (e.g., to overcome the recalcitrance of lignocellulose) and in policy (e.g., the widespread adoption of sound standards for sustainability). Despite daunting challenges, research progresses on both fronts.

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