# Accounting Whole Life Cycle Bioenergy Emissions within the UNFCCC Emission Accounting Framework

## Key findings

- At each stage within biomass resource supply chains and bioenergy processes, there will be potential for flux of emissions to and from the atmosphere.
- Bioenergy can provide low-carbon energy where there is a close balance between carbon captured from the atmosphere during biomass growth and carbon released over different stages of a given bioenergy pathway.
- The United Nations Framework Convention on Climate Change (UNFCCC)'s emission accounting framework provides a comprehensive methodology to measure, report and verify emissions from bioenergy.
- Emissions are accounted and reported within a series of greenhouse gas (GHG) inventories that are divided into sectors grouped around key processes, sources and sinks: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and Other Land Use (AFOLU); Waste; and Other.
- In GHG accounting terms, bioenergy may provide an attractive option for countries producing fuels for bioenergy, with expansion of forestry providing a mechanism to capture carbon as accounted within the AFOLU GHG inventory, in addition to an attractive alternative for the country generating bioenergy where high GHG emitting fossil fuels are replaced, benefiting the Energy GHG inventory.

## Introduction

Bioenergy is an attractive renewable energy option for many countries as it is compatible with many elements of existing energy infrastructure, and can be easily transported and stored in the form of biomass and fuels. For bioenergy to be a viable low-carbon renewable energy option and replace fossil fuel generation, it is fundamental that the energy generated provides genuine reductions in greenhouse gas (GHG) emissions in line with the mitigation effort to stay well below 1.5°C.

The concept of bioenergy providing low-carbon energy revolves around the transfers of biogenic carbon between the atmosphere and terrestrial systems: the carbon cycle. Biogenic carbon is defined as the emissions related to the natural carbon cycle; these are separate from wider life cycle emissions such as those linked to use of fuel energy for harvesting or processing of biologically based materials.

Bioenergy will be low carbon providing there is a close balance between emissions released to the atmosphere and the carbon stored as biomass materials (plants) grow (Figure 1). Accounting whole life cycle emissions from bioenergy systems and demonstrating that they deliver energy with reduced GHG emissions compared with fossil fuels is crucial if we are to meet national and international emissions reduction targets.



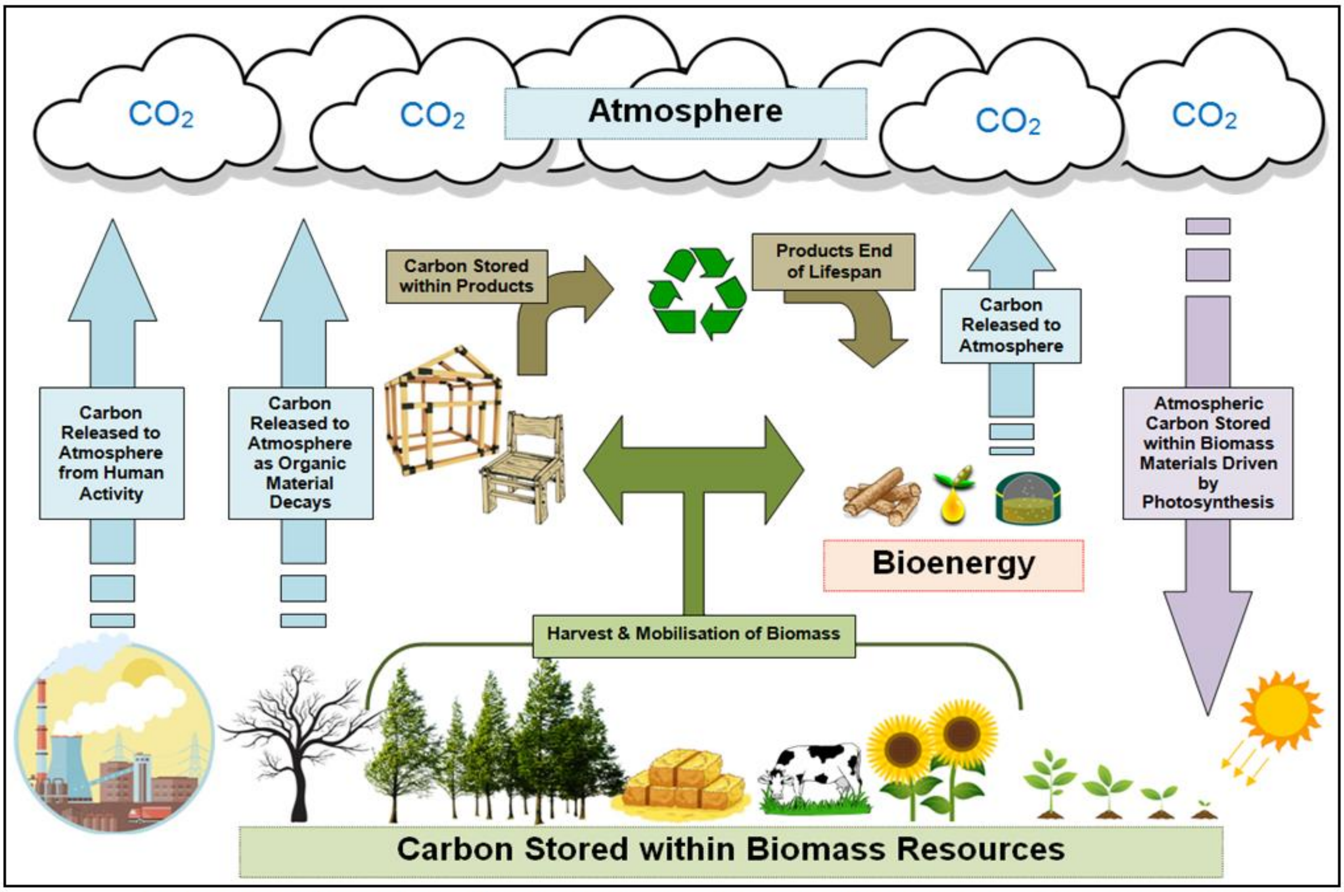


**Figure 1:** Biogenic Carbon Flows Key to Assessing the Overall Emissions of Bioenergy Systems & Supply Chains

## Bioenergy in the UK

The UK's GHG emission reduction and renewable energy generation targets have led to increased focus on low-carbon technologies to decarbonise the energy and transport sectors. Bioenergy with its vast array of feedstocks, conversion technologies and application pathways provides a major contribution to the UK's current renewable energy mix, and the UK government is targeting an increased role for bioenergy. UK government energy statistics for 2018 [1] showed that renewable energy contributed:

- 33% of total UK power generation (31.6% of total renewable power sourced from bioenergy)
- 11% of total UK heat generation (41% of total renewable heat sourced from bioenergy)
- Bio-diesel and bio-ethanol accounted for 3.7% and 4.6% of the UK's total transport fuels.

Large power stations fuelled by wood-based materials from the forestry sector are the predominant contributor of bioenergy currently generated in the UK, but there are targets to increase the role of bioenergy from many different sources of biomass to decarbonise both the UK's transport and heat sectors. The biomass feedstock demand for current and planned applications is large and in part supplied by a growing network of international supply chains importing biomass from different sources globally. Internationally sourcing is necessary to establish reliable and economic value chains to produce affordable and sustainable energy at the required scale. The UK bioenergy sector currently consumes about 20% of global forest-based wood pellet production, making it the largest consumer worldwide. Over 90% of these wood pellets are imported, making the UK the largest importer of wood pellets, reflecting one third of the globally traded feedstock [2].

**Table 1:** National Emission Measurement, Reporting & Verification Requirements [6]

| | Developed Countries (Annex I Parties) | Developing Countries (Non-Annex I Parties) |
|---|---|---|
| **Reporting** | • Annual GHG Inventory Submissions:<br>o Common Reporting Format (CRF) standardised data tables<br>o National Inventory Reporting (NIR) providing transparent and detailed information on the inventory<br>• National Communications (NCs)<br>• Biennial Update Report (BUR) | • GHG inventory reporting as part of: National Communications (NCs)<br>• Biennial Update Report (BUR) |
| **Third Party Review** | • International Assessment & Review (IAR) process, consisting a Multilateral Assessment (MA) of a country's submissions by International Expert Review Teams (ERTs). | • International Consultation & Analysis (ICA) process, consisting a technical review of BURs and Facilitative Sharing of Views (FSV) through a workshop. |
| **Technical Review & Analysis** | • In-depth review of NCs and BURs conducted by an international team of experts, coordinated by the UNFCCC secretariat. | • Technical Experts conduct a technical analysis of the BURs and any additional technical information that may be provided by the Party concerned. |
| **Multilateral Process** | • Multilateral Assessment (MA), where countries are assessed on their progress to meeting targets. | • Facilitative sharing of views to learn from experiences of other countries. |

## The UNFCCC Emission Accounting Framework

The Intergovernmental Panel on Climate Change (IPCC) oversaw the development of the universally adopted methodologies and guidelines for accounting GHG emissions [3,4]. Within this framework, nations are required to individually account and report all their emissions within a series of GHG inventories that are then submitted for assessment by the United Nations Framework Convention on Climate Change (UNFCCC). GHG emission and removal estimates for each inventory are divided into sectors grouped around the following related processes, sources and sinks [5]: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and Other Land Use (AFOLU); Waste; and Other (eg, indirect emissions from non-agriculture sources). Each sector comprises individual categories (eg, transport) and sub-categories (eg, cars).

A comprehensive framework has been developed to measure, report and verify (MRV) emissions with different reporting requirements for both Developed Countries (Annex I Parties) and Developing Countries (Non-Annex I Parties) (Table 1).

## Bioenergy Life Cycle Emissions and the UNFCCC Accounting Framework

At each life cycle step within a biomass resource supply chain and bioenergy process, there will be potential for flux of emissions to and from the atmosphere that will influence the overall GHG footprint of the 'bioenergy pathway'.

Figure 2 provides an example bioenergy pathway. At each life cycle step there will be processes that may result in a change of emissions in the atmosphere: carbon will be taken from the atmosphere during the growth of the biomass; emissions will result from harvesting/mobilisation of the resource; any land use change caused by biomass production may result in significant GHG fluxes; transportation and processing life cycle stages will require input of energy; release of biogenic carbon (stored within biomass material) and additional methane and nitrous oxide emissions will result from the bioenergy combustion stage; and energy will be used to manage the resulting post-combustion wastes (ash).

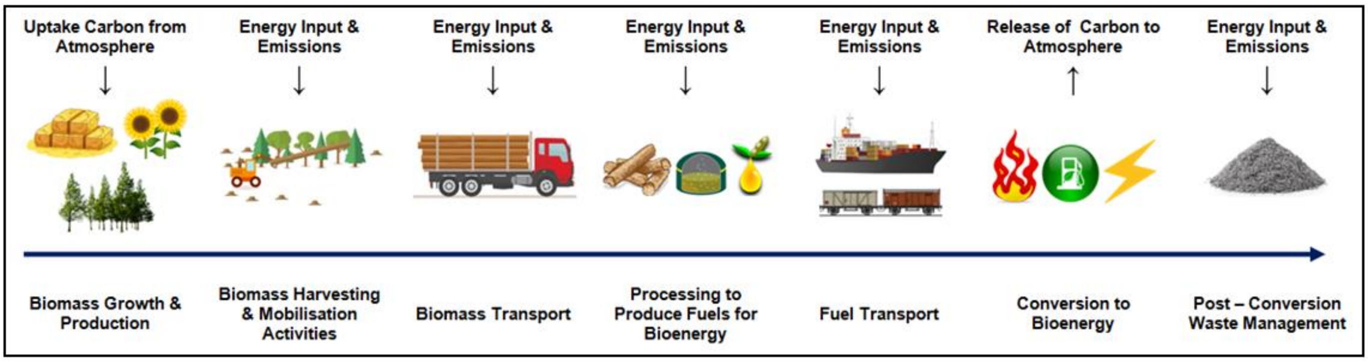


**Figure 2:** Example Life Cycle Steps for a Bioenergy Pathway

The IPCC approach for accounting GHG emissions from combustion of biomass or biomass-based products (eg, ethanol or wood pellets) allows complete coverage of emissions and removals across the sectors, particularly from Energy, AFOLU, and Waste [7]:

<u>AFOLU Sector GHG Inventory</u>

The $CO_2$ sequestered during biomass growth and released back to the atmosphere during energy conversion are not included in the sectoral total emissions in either the Energy or Waste sectors. These biogenic $CO_2$ emissions are captured within the $CO_2$ emissions in the AFOLU sector through the estimated changes in carbon stocks of forests and soils.

Where the production of biomass for bioenergy has resulted in land-use change, both directly through the conversion of land to bioenergy production, and indirectly by driving land-use changes elsewhere, GHG emissions and removals resulting from all the land-use changes in a country are reported in the AFOLU sector and can occur and may be reported within inventories for many years after the land-use change.

For annual crops, the IPCC guidelines assume that biomass carbon stock lost through harvest and mortality equal biomass carbon stock gained through regrowth in that same year, and so there are no net biogenic $CO_2$ emissions or removals from biomass carbon stock changes.

<u>Energy Sector GHG Inventory</u>

$CO_2$, $CH_4$ and $N_2O$ emissions from combustion of biomass or biomass-based products for energy are estimated, and $CO_2$ emissions are recorded as a memo item that is not included in the total emissions accounting for the Energy sector inventory. This provides a complete picture of a country’s energy system and avoids double accounting of these emissions with those reported in the AFOLU sector. The $CH_4$ and $N_2O$ emissions from the combustion of biomass or biomass-based products for energy are reported and included in the sectoral total emissions in the Energy sector, as these are not covered by the estimation methods in the AFOLU sector.

Emissions attributed to processes such as terrestrial transportation or fuel processing are accounted within the Energy sector inventory. Emissions attributed to international transport energy such as shipping taking place outside national boundaries are calculated but are excluded from national inventories and are reported separately as ‘international bunker fuel emissions’ [8].

<u>Waste Sector GHG Inventory</u>

Emissions attributed to the processing and management of post-combustion materials such as ash will be attributed to the Waste sector. When organic waste materials are incinerated for energy, the $CO_2$, $CH_4$ and $N_2O$ emissions from the biogenic part of waste are recorded as an information item within the Energy sector inventory.

When waste is burned without energy recovery, $CH_4$ and $N_2O$ emissions from the biogenic part of waste are estimated and included in the Waste sector inventory.

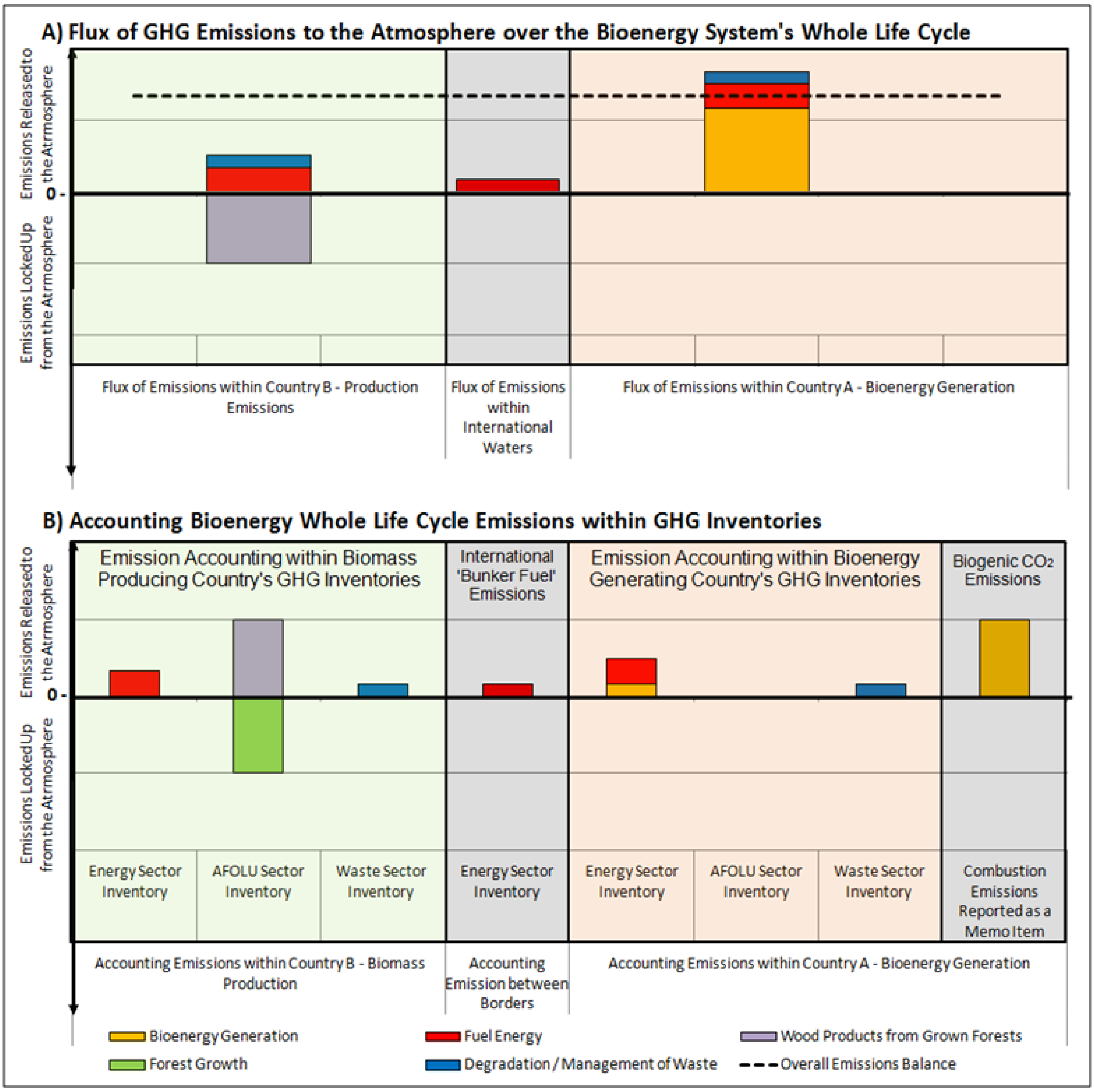


**Figure 3:** Stylised demonstration of A) the breakdown of whole life cycle GHG emissions resulting from the generation of bioenergy from imported forestry sourced biomass resources, and; B) How these life cycle emissions are accounted within GHG inventories across international borders under the IPCC's GHG reporting framework

## Accounting Bioenergy Pathway Emissions Across Borders

As the scale of traded biomass has increased and international supply chains have become more complex, GHG accounting frameworks have gained greater scrutiny as it has become a common scenario for biomass to be transported across national borders and to be converted to bioenergy in different countries. Further complexity is added if an activity results in land use taking place either locally or potentially across another international border. As a result, the emissions associated with different life cycle steps within an overall bioenergy pathway will likely be attributed to different sectors and GHG inventories in different countries, making assessment of the overall impact of a bioenergy pathway sometimes highly difficult.

Figure 3 has been developed to provide an example case study of a bioenergy pathway where Country A generates bioenergy from biomass pellets imported from Country B. Within the UNFCCC's accounting framework this bioenergy pathway will produce a GHG footprint across both countries, but also a different footprint across the GHG inventories of these countries.

Figure 3 presents a stylised demonstration[1] of: A) a breakdown of the source, scale and location of whole life cycle emissions that are generated as a result of generating bioenergy from imported forestry sourced biomass resources, and B) how these life cycle emissions are accounted within the different GHG inventories across international borders[2]. The stacked columns within the Figure 3 graphs each represent different activities and processes within the bioenergy pathway. Columns below the '0 line' reflect activities and processes that will result in $CO_2$ being captured from the atmosphere – resulting in 'negative' emissions being accounted within the GHG inventory. Columns above the '0 line' reflect activities and processes that will result in the release of emissions to the atmosphere – resulting in emissions being added to the different GHG inventories.

Graph A within Figure 3 demonstrates that for this given bioenergy pathway, there will be a net flux of emissions from the atmosphere taking place within Country B where the pellets are produced from grown forests. There will be an overall flux of emissions to the atmosphere taking place within Country A where the pellets are converted to bioenergy and the biogenic carbon is released. Graph B within Figure 3 demonstrates how these life cycle emissions would be accounted within the various GHG inventories across both Country A and B.

Within Country B's AFOLU sector GHG inventory, the growth of forestry will generate large-scale uptake of $CO_2$ from the atmosphere, which is accounted as negative emissions within the AFOLU GHG inventory. As it is assumed that the biogenic carbon stored within the biomass pellets (classified as 'Harvested Wood Products') will be released back to the atmosphere through bioenergy conversion, these biogenic emissions are also accounted within Country B's AFOLU GHG inventory. Where the overall size of the forest producing pellets for the bioenergy sector is maintained, there will be an overall neutral balance in emissions accounted within Country B's AFOLU GHG inventory. If Country B were to expand or reduce its forests dedicated to pellet production, there would be a corresponding net positive or negative influence of the AFOLU GHG inventory.

Any energy expended in Country B in producing, processing or transporting the biomass will generate GHG emissions accounted within Country B's Energy GHG inventory, and emissions released as a result of the degradation/management of wastes will be accounted within Country B's Waste GHG inventory. The biomass pellets may then be exported where any transport 'international bunker fuel' emissions are accounted but not attributed to any national GHG inventories.

Once landed in Country A, any further energy expended transporting or processing the pellets will generate emissions allocated to Country A's Energy GHG Inventory. Finally, the pellets are combusted to generate bioenergy, and in the process the stored carbon in the biomass is released back to the atmosphere. Non-$CO_2$ bioenergy combustion emissions will be allocated to Country A's Energy GHG inventory, while released $CO_2$ combustion emissions (assumed to balance those taken up during the growth of the biomass) are estimated but only recorded as a memo item within Country A's GHG inventory

[1] *The values presented in Figure 3 represent typical proportions of emissions that may be released to/taken from the atmosphere at each stage within a UK bioenergy pathway using North America pellets produced with best practice forestry processes.*

[2] *Graph B has been developed based on the 'Stock-Change' accounting approach for 'harvested wood products used directly as energy feedstocks' as described in the IPCC guidelines. The allocation of GHGs within the graph would change if different sources of biomass were used (eg, wastes/ residues) or where a different IPCC accounting approach was applied.*

reporting [9].

In GHG accounting terms, bioenergy may provide an attractive option for countries producing feedstocks for bioenergy as any expansion of forestry would result in emissions reductions as accounted within the AFOLU GHG inventory. Bioenergy is also an attractive alternative for countries generating bioenergy where high GHG emitting fossil fuels are replaced, resulting in emission reductions accounted within the Energy GHG inventory.

From a climate change perspective, the location of emissions and how and where they are accounted is irrelevant; the important calculation is assessing the overall GHG footprint of a given bioenergy system taking account of all life cycle steps and consequential impacts. Therefore implementing complementary analyses such as life cycle assessments (LCA) represents a well-developed and widely implemented technique for analysing the whole life cycle emissions of bioenergy pathways, which may be used to verify the overall GHG footprint of any given bioenergy pathway [10].

## Sustainability

For bioenergy to be truly sustainable, there are many factors beyond the emission performance of a given bioenergy pathway that need to be considered. Many bioenergy ‘sustainability indicators’ have been developed to assess the performance of bioenergy based on social, economic and environmental themes, for example: assessing how bioenergy may impact or benefit communities using indicators such as changing land ownership; how bioenergy may influence economic performance such as the level of employment that bioenergy may generate; and how bioenergy may impact or benefit environmental systems measured through indicators related to water, emissions or ecosystem biodiversity.

In general, criteria developed to assess the sustainability of bioenergy focus on performance of indicators related to: i) supply chains and the methods for sourcing bioenergy feedstocks; ii) characteristics of bioenergy deployment and the resulting scales, location and intensity of biomass resources that will be required; and iii) the overall GHG emission performance of a bioenergy pathway and levels of potential GHG savings that may be saved compared to alternative energy systems [11].

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