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WORKING TOGETHER FOR SUSTAINABLE DEVELOPMENT

Global Bioenergy Partnership Sustainability Indicators for Bioenergy: Implementation Guide

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Executive Summary

The *Implementation Guide for the Global Bioenergy Partnership Sustainability Indicators for Bioenergy* has been developed to complement and enhance the first edition of *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, published in 2011. It includes guidance that is based on the implementation of the Global Bioenergy Partnership (GBEP) Sustainability Indicators in fourteen countries, spanning four continents. On the basis of the lessons learnt from this implementation of the GBEP Sustainability Indicators (GSI) at national and local level, guidance has been provided on methodological and practical issues that were not addressed in the original report. This includes both cross-cutting issues that concern the implementation of the set of GSIs (Section 1), as well as methodological guidance for each of the 24 GSIs (Section 2).

Section 1 on cross-cutting issues addresses: the integration of definitions and methodologies; ensuring an effective implementation of the indicators; and enhancing the practicality of the indicators. In order to address these issues, the Guide provides the following guidance:

- Definitions of modern bioenergy
- Attribution of the impacts to bioenergy production and consumption
- Relevant good practices and practical proxies
- Stepwise approach for the effective implementation of a GSI project

In Section 2, guidance is provided on the methodology for each individual indicator under the three pillars (environmental, social and economic). For each indicator, this Section addresses clarifications to the original GSI report, suggests proxy approaches to indicator measurement, provides further data sources and guidance on data collection, and presents guidance on attribution.

This Guide is to be used by practitioners, in conjunction with the first edition of *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy,* to ensure an effective and successful implementation of the GSIs in their country. The Guide is a 'living document' that will be updated as new lessons learnt emerge and further guidance can be provided.

Introduction

The Global Bioenergy Partnership (GBEP) considers that bioenergy production and use can make a valuable contribution to the sustainable development agenda. With careful management, various forms of bioenergy can help countries meet growing energy demand while concomitantly realizing carbon emissions reductions, climate change mitigation and adaptation efforts and improvements to citizens' livelihoods. These benefits are best obtained through effective monitoring, research and information sharing as they support the development of comprehensive national sustainable bioenergy policies. To that end, in June 2008, GBEP established the Task Force on Sustainability (TFS). Its initial goal was to develop a set of common, voluntary and science-based indicators and methodologies to assess the environmental, social and economic impacts of bioenergy production and use, with a view to inform policy-makers and other stakeholders in countries seeking to develop their bioenergy sector to help meet national goals of sustainable development.

The GBEP TFS published the first edition of "The Global Bioenergy Partnership Sustainability Indicators for Bioenergy" in 2011 (FAO, 2011a). Each of the 24 indicators (See Table 1) includes a short description and a multi-page methodology sheet that outlines the approach for collecting and analysing data, highlights data limitations and provides additional references to other well-documented processes. The TFS recognized that bioenergy development does not occur in a vacuum and therefore must be consistent with a country's overall policies and strategies, which is why the format of the indicators allows users to tailor them to their particular circumstances. It also means that they do not provide users with the answers to what the correct values for sustainability should be but rather they present the right questions to ask.

Since the establishment of the TFS, eleven countries have tested the indicators at the national level and another three countries have applied them at the local level. These experiences have generated a number of relevant lessons learned and recommendations to further develop the methodological guidance and increase the practicality of the indicators. In June 2014, members of the GBEP Activity Group 2 (AG2) of the Working Group on Capacity Building (WGCB) met in Bonn, Germany, to share some of the key enabling factors and challenges encountered during their implementation of the GBEP Sustainability Indicators (GSI). At the workshop, participants suggested that an Implementation Guide would be a valuable and appropriate way to capture the knowledge gained and facilitate future users' measurement of the GSIs as

it could provide them with additional guidance on practical and methodological issues. The GBEP Steering Committee approved this proposal in November 2014 and charged the TFS with its development, as it was the GBEP entity that originally elaborated the GSIs.

This Implementation Guide intends to clarify issues identified within the methodology sheets of the first edition report as well as enable future users to take advantage of relevant lessons learned. As such, it does not aim to open a discussion or revise the GSIs agreed upon by GBEP Partners and Observers in 2011; it complements – rather than replaces – the first edition of "The Global Bioenergy Partnership Sustainability Indicators for Bioenergy" report.

Through additional discussions and meetings, AG2 Members identified the major practical and methodological challenges associated with the measurement of each of the 24 indicators (see Annex 1: Lessons learned and recommendations emerging from testing). They also recorded information on data availability and appropriateness as well as the relevance of capacity building. In general, the lack of data, skills and/or resources, particularly in developing countries, were identified as presenting some of the biggest challenges, which, consequently, is why capacity building was found to be relevant for almost all of the GSIs. The variations in data availability and appropriateness throughout the eleven countries' experiences also highlights the need for future users to be very clear when communicating how their results were achieved. Additionally, the countries that carried out assessments using the indicators were asked to complete a template that included the key results, lessons learned and recommendations. In addition to sessions held during the regular GBEP meetings of the TFS, workshops specifically for the development of the Implementation Guide were undertaken. All of the information gathered through these exercises has helped to greatly inform and enrich the work of the TFS on the Implementation Guide.

In the development of the Implementation Guide, priority was given to those issues that affected the measurement of all or most of the indicators. These cross-cutting issues were grouped into three categories: integration of definitions and methodologies; ensuring an effective implementation of the indicators; and enhancing the practicality of the indicators. Once those were addressed, discussions related to the guidance to be provided for individual indicators took place under the TFS sustainability pillar sub-groups (i.e. environmental, social and economic). This guide is separated into two parts to reflect this division between general, cross-cutting issues (Section 1: Cross-cutting issues) and specific guidance for individual indicators (Section 2 – Guidance on individual indicators).

Table 1 - GBEP Sustainability Indicators

PILLARS GBEP's work on sustainability indicators was developed under the following three pillars, noting interlinkages between them:		
Environmental	**Social**	**Economic**
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under these pillars:		
Greenhouse gas emissions, Productive capacity of the land and ecosystems, Air quality, Water availability, use efficiency and quality, Biological diversity, Land-use change, including indirect effects.	Price and supply of a national food basket, Access to land, water and other natural resources, Labour conditions, Rural and social development, Access to energy, Human health and safety.	Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use, Economic development, Economic viability and competitiveness of bioenergy, Access to technology and technological capabilities, Energy security/Diversification of sources and supply, Energy security/Infrastructure and logistics for distribution and use.
INDICATORS		
1. Lifecycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and re-qualification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

1. Section 1: Cross-cutting issues

This section will examine and provide guidance for three categories of cross-cutting issues: integration of definitions and methodologies; ensuring an effective implementation of the indicators; and enhancing the practicality of the indicators.

1.1. Integration of definitions and methodologies

For this category of cross-cutting issues, the objective is to address shortcomings found in the GSI methodology sheets by:

- creating a clearer definition of modern bioenergy;
- clarifying the issue of attribution of impacts to bioenergy production and use; and
- providing a compilation of relevant good practices to help overcome data constraints.

Addressing these deficiencies will help reduce the number of uncertainties that arise when implementing the indicators. Future users will benefit from previous experiences by having a range of approaches available to them that will allow them to choose a strategy that best suits their needs.

1.1.1. Definition of modern bioenergy

Bioenergy is energy derived from the conversion of biomass, where biomass may be used directly as fuel, or processed into liquids and gases. Biomass is any organic, i.e. decomposable, matter derived from plants or animals available on a renewable basis. Biomass includes wood and agricultural crops, herbaceous and woody energy crops, municipal organic wastes, as well as manure (IEA and FAO, 2017).

The "Global Bioenergy Partnership Sustainability Indicators for Bioenergy" first edition report states that, "*modern bioenergy* is used to describe energy, for example when we need to quantify it or use the term in an abstract sense, which delivers *modern bioenergy services".* It then goes on to define modern bioenergy services as "relying on biomass as their primary energy source" (FAO, 2011a, p.209). "Modern bioenergy services include electricity delivered to the final user through a grid from biomass power plants; district heating; district cooling; improved cookstoves (including such stoves used for heating) at the household and business level; stand-alone or grid-connected generation systems for household or businesses; domestic and industrial biomass heating systems; domestic and industrial biomass cooling systems, biomass-powered machinery for agricultural activities or businesses; and biofuel-powered tractors and other vehicles, grinding and milling machinery. Modern bioenergy services do not include

biomass used for cooking or heating purposes in open stoves or fires with no chimney or hood or any other energy systems that release flue gases indoors or release high concentrations of air pollutants, irrespective of the feedstock or biofuel employed" (FAO, 2011a, p.209).

The lack of a clear distinction between traditional and modern bioenergy in these definitions led previous users to have various interpretations of modern bioenergy, given the different contexts in which the GSIs were applied.

One recommendation to overcome this was to develop a more precise definition of modern bioenergy, illustrated with concrete, detailed examples to eliminate any further confusion. In an attempt to find a benchmark, the TFS looked at various definitions of modern bioenergy used by other relevant international organizations and initiatives (See Table 2). This research showed that there is no internationally recognized definition of modern bioenergy and that the term is frequently defined by what it is not. This discord between the organizations and initiatives speaks to the complexity and politically sensitive nature of the issue, and because of this, the TFS found it difficult to align its definition with any particular group.

Therefore, instead of updating the first edition report's definition, the guidance to users of the GSIs is to ***clearly outline the definition of modern bioenergy being used and provide a solid justification for why that particular one was chosen***. This will provide clarity for those wishing to interpret the findings of GSI measurement, as well as ensure consistency for future monitoring.

Table 2 - Definitions of modern bioenergy

Organization/ Initiative	Source	Definition
Clean Cooking Alliance (CCA)	CCA, 2019	CCA does not explicitly define modern bioenergy. The term modern bioenergy is used as an alternative to the traditional burning of biomass.
International Energy Agency (IEA)	IEA, 2019	The IEA does not explicitly define modern bioenergy. The agency refers to it as the opposite of traditional use of biomass, which is "the use of local solid biomass resources by low-income households that do not have access to modern cooking and heating fuels or technologies. Solid biomass, such as wood, charcoal, agricultural residues and animal dung, is converted into energy through basic

Organization/ Initiative	Source	Definition
		techniques, such as a three-stone fire, for heating and cooking in the residential sector".
International Panel on Climate Change (IPCC)	Chum, H. et al. 2011.	The IPCC does not explicitly define modern bioenergy. However, it does differentiate between highly efficient modern bioenergy and industrial bioenergy applications. "High-efficiency modern bioenergy uses more convenient solids, liquids and gases as secondary energy carriers to generate heat, electricity, combined heat and power (CHP) and transport fuels for various sectors".
International Renewable Energy Agency (IRENA)	IRENA, 2018	IRENA affirms that "Bioenergy use falls into two main categories: "traditional" and "modern". Traditional use refers to the combustion of biomass in such forms as wood, animal waste and traditional charcoal. Modern bioenergy technologies include liquid biofuels produced from bagasse and other plants; bio-refineries; biogas produced through anaerobic digestion of residues; wood pellet heating systems; and other technologies".
Renewable Energy Policy Network for the 21st Century (REN21)	REN21, 2013 REN21, 2018	REN21 refers to modern bioenergy as "Energy derived efficiently from solid, liquid, and gaseous biomass fuels for modern applications, such as space heating, electricity generation, combined heat and power, and transport (as opposed to traditional bioenergy)". REN21 also defines modern biomass as "Includes technologies other than those defined for traditional biomass, such as biomass cogeneration for power and heat, biomass gasification, biogas anaerobic digesters, and liquid biofuels for vehicles".
Sustainable Energy for All Initiative (SE4ALL)	SE4ALL, 2013	SE4ALL does not explicitly define modern bioenergy. It states that, as opposed to traditional use "biomass can also be used to produce household-level energy more efficiently via improved cooking and heating appliances. It can also be used to produce heat efficiently for commercial and industrial needs, as well as electricity and transport fuels. Ambitious renewable energy scenarios rely heavily on these "modern" forms of bioenergy use to meet their goals, but some also recognize that traditional uses of biomass will continue to be an important energy source for many people for some time to come."

Organization/ Initiative	Source	Definition
	AGECC, 2010	SE4ALL's predecessor, Advisory Group on Energy and Climate Change, gave examples of 'modern energy' in which biodiesel and ethanol were included.
United Nations Development Programme (UNDP)	UNDP, 2000	UNDP does not explicitly define modern bioenergy. It does highlight the need to promote sustainable biomass energy production through modern bioenergy technologies, including biogas, combined heat power and ethanol. It states "Biomass energy has the potential to be "modernised" worldwide, i.e., produced and converted efficiently and cost-competitively into more convenient forms such as gases, liquids, or electricity.
United Nations Environment Programme (UNEP)	UNEP, 2009	UNEP does not define modern bioenergy but refers to "«modern biomass use» for energetic purposes, such as biomass used for (co-) generation of heat and power and liquid biofuels for transport".
United Nations Industrial Development Organization (UNIDO)	UNIDO, 2013	UNIDO does not explicitly define modern bioenergy. It describes modern energy systems as being based on locally available renewable sources (biomass, solar, wind, mini-hydro). The concept of biofuels is used to define energy carriers derived from the conversion of biomass to provide sustainable inputs for heat, power, and transport applications and can be liquid, solid or gaseous.

1.1.2. Attribution of impacts of bioenergy production and use

Previous users of the GSIs experienced difficulties determining how best to attribute the impacts of bioenergy production and use. This is because the generation and use of bioenergy cuts across multiple sectors and parts of the entire economy. Focusing on a specific subsector always means to separate it from the whole economy and specify its role within the entire economic system of a country. The isolation of one subsector requires clearly defined procedures, rules and conventions about how to draw the line between the sector of interest and the remainder. Some overarching considerations for tackling attribution are dealt with in Box 1.

Attribution issues can arise due in various scenarios. It can be the case that the parameters needed to calculate the indicators are regularly monitored and measured but not specifically for bioenergy purposes, particularly in the case of those indicators associated with general agricultural and forestry feedstock production (e.g. soil quality, water use and efficiency, water quality and land use/land use change, productivity) as well as social and economic indicators that are calculated using national statistics (e.g. jobs or health and safety). Further attribution issues include uncertainties regarding how to deal with general co-product allocation as well as the allocation of impacts to wastes, residues and when there are multiple bioenergy products from the same crop or farm.

Therefore, three main types of attribution can be identified for the measurement concepts of the 24 GSIs and their implementation:

(1) Statistical separation of impacts of the bioenergy sector from other economic activities;
(2) Allocation of impacts from production activities (coupled processes) that are simultaneously related to bioenergy products and other products (e.g. food products); and
(3) Partial assignment of general effects to the bioenergy sector.

Box 1 - Overarching considerations for tackling attribution

Obeying overarching criteria

The most important criteria that should be respected when tackling an attribution issue are as follows:

- Plausibility – needed to understand the rationale behind an attribution issue
- Transparency – supports the reproducibility of results
- Practicability – ensures the feasibility of an assignment under given circumstance
- Consistency – ensures that the same methods or procedures are applied to the same kind of attribution issue

Practicality as the main challenge

Practicability is connected to the availability of data and therefore directly linked to the economic effort required to produce data for sector-specific attribution. Therefore, the guidelines here often propose a TIER approach that supports the needs and possibilities for the use of indicators under different circumstances, with varying availability of resources. The TIER approach suggested is drawn from the IPCC Inventory Guidelines, where a tier represents a level of methodological complexity. Usually three tiers are provided:

- Tier 1 is the basic method;
- Tier 2 intermediate; and
- Tier 3 is most demanding in terms of complexity and data requirements.

Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.

Respecting the objective of an indicator

Every indicator has a purpose. This purpose is formulated in the GSI Report (FAO, 2011) under the heading “How the indicator will help assess the sustainability of bioenergy at the national level”. The solution of an attribution issue must be in line with the text given under this heading.

For instance, the objective of an indicator may set the system boundaries. According to the objective, the system boundaries related to an indicator could be:

- the entire life cycle (e.g. Indicator 1 – the GHG balance for a bioenergy product)
- the national situation (e.g. Indicator 12 – jobs in the bioenergy sector)
- the national territory (e.g. Indicator 2 – soil quality for bioenergy crops)

The attribution methodology must respect the underlying system boundaries.

1.1.2.1. Statistical separation of bioenergy from other activities

Often it is necessary to separate bioenergy from other economic activities in the larger economic system. Many indicators of the GSIs address bioenergy as part of the total national economy. An attribution issue arises if no detailed information about the bioenergy share as a subsystem exists. In these cases, rules are needed to deal with the isolation of bioenergy as a subsystem in a feasible, transparent, and reasonable manner where a clear and unambiguous demarcation line between the bioenergy system and other applications is not obvious from available data. Consistency is also important so that results can be tracked and compared over time or to other bioenergy applications. Furthermore, indicators lose their value if arbitrariness causes doubts in the results or changes them according to a modification in the underlying methodology.

To attribute impacts to bioenergy, the activities in the bioenergy system must first be separated by their end use. For instance, besides its application as renewable energy, biomass could be harvested for other uses within the bioeconomy, such as food, animal feed or as material, e.g. in the building sector. Therefore, an attribution of the harvest activities of a certain biomass has to be split according to its later use. This may be difficult because often the final uses of biomass are not defined in advance and its final assignment depends on many factors (i.e. seasonal weather conditions, biomass quality, market price, etc.), which are linked to spatial and temporal circumstances.

This statistical attribution issue can generally be solved by efforts to collect more specific data or use simple methods of allocating available figures to the sector, as described below.

It can be argued that an attribution issue would not arise if sufficient statistical data exists but reality shows that the collection of data can be connected with institutional and cost constraints within a country. Consequently, indicators may not always be available as desired. In principle, sufficient financial resources, as well as favourable legal and institutional conditions, may allow the generation of primary data that are directly related to bioenergy. Furthermore, statistical data available from national statistical offices may have been aggregated to produce a national figure and perhaps could easily be separated again for the purpose of the bioenergy sector. Additionally, Systems of National Accounting (SNA) may exist to be used for the statistical separation of the bioenergy sector.

In the case of insufficient existing statistical data, the separation of bioenergy from other sectors can be applied by a:

- Top-Down-Approach, or a
- Bottom-Up-Approach.

The **Top-Down Approach** works with auxiliary information that is available on a national scale for bioenergy as well as for other economic sectors. The relationship between the bioenergy subsector and other economic sectors for this auxiliary information can then be assumed to hold for the attribution of impacts to bioenergy for a specific indicator. For example, the total revenues for bioenergy may be known in relation to the total revenues from agriculture. If this auxiliary information is assumed to be appropriate for the attribution of, for example, the occupation of agricultural land, it can be used to calculate the bioenergy indicator result about land tenure.

In other cases, information may exist for a single unit of the bioenergy sector but not for all bioenergy activities of a country. Then a **Bottom-Up-Approach** can be used to extrapolate from a unit or a multitude of single units to the totality of the bioenergy sector. The emissions of, for instance, biofuel production can be extrapolated from one representative production plant to the overall emissions of the sector by scaling up the production figure of the specific plant to the production of the whole country. For example, Indonesia had 608 registered palm oil mills in the year 2012. During the implementation of the GSIs, specific information from some representative palm oil mills was used to extrapolate to the situation of all palm oil mills in the country. One precaution for this approach is to assure that a representative sample is used before upscaling.

1.1.2.2. Allocation of indicator results from coupled production activities

It is not always the lack of information that causes difficulties in attributing information to the bioenergy system. A different attribution issue arises when a certain process generates two or more products that serve not only the production of bioenergy but also the production of biomass for non-energy purposes. Then the fundamental question arises about the proportion of the impacts of a process that can be attributed to bioenergy.

Examples of these coupled processes are manifold. For example, the procedure of growing and harvesting of a crop like wheat, which is meant to produce flour, also produces straw as a by-product that is burned for heating purposes. Then questions arise such as “does the occupation of land belong entirely to alimentation or also partly to bioenergy” or “is the use of fertilizer or pesticide only caused by the production of grains”? Other examples also occur in processes like sugar production, which yields sugar

as the main product and bagasse as a by-product. If sugar is used for food purposes and bagasse for bioenergy then the process itself, and its related upstream activities (sugar cane growing, transportation, etc.) must be assigned to the bioenergy sector and the non-bioenergy sector. A similar issue also arises if sugar from sugar cane is used partly for food and partly to produce ethanol for fuel purposes.

This issue is a common challenge in the assessment method of Life Cycle Assessment (LCA) where environmental impacts have to be allocated to different products from a coupled production process. This attribution issue in LCA is referred to as *allocation*. An extended discussion of the allocation of environmental impacts to coupled products exists in the LCA community, and principles for dealing with allocation of this type can be found in international standards (ISO 14040, ISO 14044) and many academic publications. However, it must be noted that scientific or technical solutions do not necessarily exist to clearly separate bioenergy from other end products. Therefore, attribution rules are needed to avoid arbitrariness in using the GSIs, and conventions have to be agreed upon when no straightforward way exists to address attribution.

Solutions to the allocation problem are not always straightforward and depend to a large extent on the goal and scope of an underlying question. In the case of the GSIs, the objective is to describe the performance of a bioenergy system at a national scale. Therefore, a solution to co-product allocation is needed at the basis of single processes, which then could be used for an upscaling to the national inventory.

Due to the complex nature of bioenergy systems, choices about allocation need to be made thoughtfully, following the general criteria mentioned in Box 1, and should be clearly documented. Once an allocation method is selected for an indicator of the GSI, it should be applied consistently if comparisons are to be made over time, or among project options.

Allocation of environmental impacts in LCA – but also other indicator values – for coupled processes can be made by:

- Physical properties, or
- Economic properties.

Physical properties include flows of mass, chemical energy content, exergy values, stoichiometric relations, etc. Economic properties are typically costs or prices to be used for allocation. An allocation of an indicator result of coupled processes always sums up to 100 percent, only the distribution of the share

of the result is subject of the chosen allocation factor. The advantage of using physical properties is their inherent value that does not change over time and regions. Nevertheless, they sometimes do not represent the rationale behind a subdivision of an indicator. For instance, mass flows between grains and straw of wheat does not reflect the purpose of cultivating this crop.

An allocation by economic values is more in line with the purpose of running a process that provides coupled products. However, the disadvantage is the fluctuation of the economic property in time that leads to different indicator results for a specific co-product. Therefore, the indicator result may change not because of a change in environmental or technical performance but due to fluctuation in the underlying economic value.

Concerning the GSIs, plausible allocation conventions should be applied that allow the comparison of indicator results over time. As their main purpose is to monitor the indicators of bioenergy systems over time, physical properties should be applied as a first choice. That does not exclude economic allocation factors *per se* but their application must be handled with care especially while monitoring the development of an indicator over time.

When dealing with energy systems the following conventions are suggested:

- Allocation by energy content should be the default method when different energy products originate from a coupled production.
- Allocation by energy content should be the default method when energy products and products for other purposes (e.g. food, animal feed, and material use) share the same production processes and have to be allocated. A sensitivity analysis should be performed using the economic values of the co-products to detect any implausible conclusion for the GSI.
- Provide full transparency and traceability of underlying assumptions and results if co-product allocation has been used in the context of the GSI measurement.

It should be noted that for the context of comparing systems on a macroeconomic scale, the method to calculate a marginal substitution could also be chosen. Therefore, the comparison of a system with bioenergy production to a reference scenario or counterfactual system without bioenergy production can be an approach to avoid allocation (e.g., Kopoenen et al., 2018; Efroymson et al., 2016).

1.1.2.3. Assignment of general effects to bioenergy

Another attribution problem arises if an indicator result may have different causes. Some GSIs refer to general effects that may partly be caused by the bioenergy sector. Examples are a change of water quality in rivers or the change in mortality and health effects due to indoor smoke. In these cases, the impact measured by an indicator – to what extent this can be assigned to the production and use of bioenergy – must be related to the different underlying activities by analysing cause-effect-chains.

For example, indicator 15 ("change in mortality and burden of disease attributable to indoor smoke") is based on total mortality and disease figures. In this example, all other reasons that lead to mortality and disease have to be taken into account and be separated from the cause "indoor smoke".

The use of proxy indicators along the cause-effect-chain is a pragmatic approach to avoid more complex indicators at the effect level. However, the measurement is then shifted from effects to its causes with a consequent loss of accuracy of the desired indicator objective.

1.1.3. Relevant good practices

Poor data availability and quality due to either lack of information, skills or willingness to share information were another common set of issues. The suggested methods for calculating/measuring the GSIs outlined in the report are rigorous. Most indicators, particularly the environmental ones, have large data requirements that can be difficult to meet, which led many users to design their own data gathering approaches. Typically, they involved extended literature reviews, interviews and/or expert estimations. For instance, in Colombia and Indonesia the intention was to establish a typology of national production systems, to measure the indicators for a sample of each of the typology classes and then scale up the values to national context. However, difficulty accessing production sites led to a shift towards using more secondary and tertiary national level studies (themselves undertaken partly through collecting data in a bottom-up manner).

When indicators cannot be measured due to a lack of data, skills and/or resources, and when appropriate as a complement to the measurement of the current quantitative indicators, practical proxies for the indicators might help countries to implement the GSIs and to propose bioenergy actions that would likely prove sustainable. These will help in the formation of consistent and simple approximations for indicators where there is poor data availability and/or quality.

The Bioenergy Roadmap issued by IEA (2017) states: “A number of sensible land management steps should be promoted even without a need to improve the prospects for bioenergy or biomaterial production. They include measures to increase the potential for food production and to ensure that resources are used as efficiently as possible.” Similarly, in 2017, a brief on Bioenergy for Sustainable Development was jointly prepared by IRENA (International Renewable Energy Agency), the Bioenergy Technology Collaboration Programme of the International Energy Agency (IEA Bioenergy) and the Food and Agricultural Organization (FAO) (IRENA, IEA Bioenergy and FAO, 2017). The brief discusses how bioenergy can be produced whilst simultaneously supporting the Sustainable Development Goals (SDGs) around energy access, nutrition and climate change. The examples given below range from improving productivity for agricultural and forestry sectors to reducing waste and losses in the food chain. Bioenergy production systems can also be integrated into rural development strategies to restore previously degraded land and mitigate further land degradation. These are examples of what some consider “no regrets” approaches to bioenergy:

- **Improving food crop yields** through improved crop varieties and management practices, but especially by narrowing the “yield gap” between best practice and achieved food production, thus enabling more to be produced on less land.
- **Raising the land efficiency of animal husbandry.** (Nearly half of all high-quality “good” and “prime” agricultural land is used for meat and dairy products, although it provides a much smaller share of protein and calories consumed than the land used for food crops.).
- **Reducing food waste and losses**. Imperfect markets and policies that result in localized over-production can lead to large volumes of food being left in fields unharvested. In developing and emerging economies, a large share of food is lost in production and distribution, for example due to deficiencies in cold chains to bring food to market in good condition. In more developed economies, a large share of food is wasted by consumers after it is purchased.)
- **Improving the efficiency with which biomass is used for energy.** (Modern cook stoves can use wood much more cleanly and efficiently than traditional ones.)
- **Afforestation of derelict and abandoned land**, which could provide significant resources for local food and energy use. (The Bonn Challenge and New York Declaration on Forests seek pledges from countries to restore 350 million hectares of degraded land to productive use. The African Forest

Landscape Restoration initiative, launched at COP21 in Paris, aims to restore 100 million hectares, and this initiative has already been joined by 21 African nations.)

Accordingly, some possible no-regret strategies or agreed good practices might be endorsed:

- **better use of farm and forest residues**;
- **boosting yields of food crops**;
- **sustainable intensification of pastureland,** provided it enhances biodiversity;
- **reducing waste and losses in the food chain;** and
- **restoring degraded land** pursuant to the Bonn Initiative and associated Africa Forest Restoration initiative (AFR-100).

However, these strategies may come with some caveats and specifications. For instance:

- The increased collection of farm and forest residues needs to take into consideration the requirements for leaving a share of these residues to maintain soil quality.
- Boosting of food crop yields needs to consider what restrictions should be suggested on artificial fertilizers, monocultures, etc. and which specific activities should be promoted for this end, e.g. building smallholder capacity for agroforestry approaches or investing in solar irrigation.
- Reducing waste and losses in the food chain requires multiple strategies for the many different types and locations of waste. It may involve, for example, better storage and transport systems, better food labelling and consumer education, and better market forecasts for producers, as well as flex-crops where excess production can be absorbed in non-food markets.
- In restoring degraded land, care should be taken to preserve indigenous food and land rights.

Annex 2 – Use of proxies and best practices - gathers relevant studies to provide guidance on the use of proxies and best practices that can give an indication of the sustainability of bioenergy at national level, to be used by implementing nations who lack the data or capacity to use the agreed GSI methodologies.

1.2. Ensuring an effective implementation of the indicators – a stepwise approach

Box 2 - Overarching practices for effective implementation

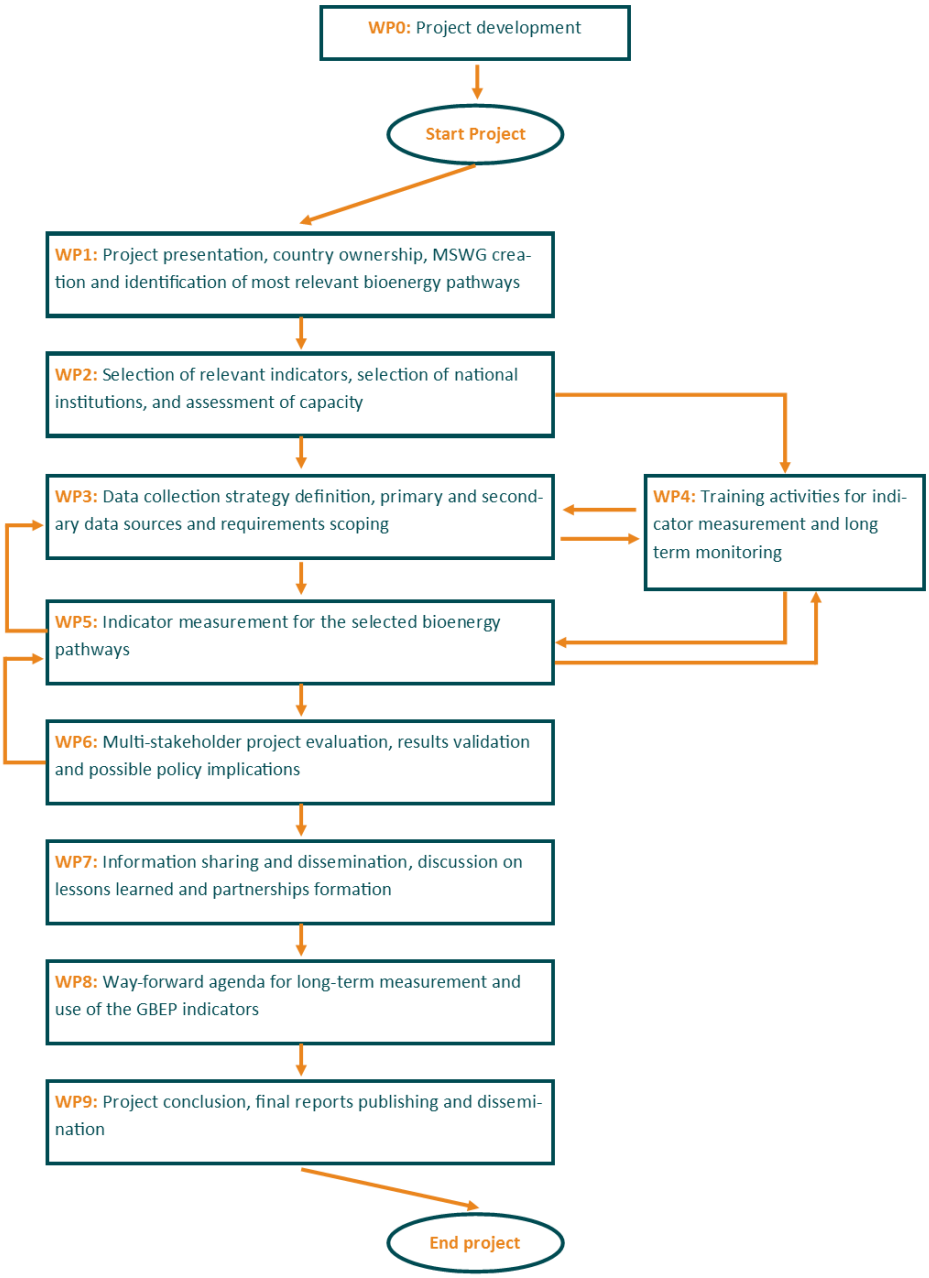
Overarching practices for effective implementation

To ensure an effective implementation of the GSI, users should seek to:

- Employ a multidisciplinary team of experts with in-depth knowledge of the national context and domestic bioenergy sector;
- Encourage the proactive engagement of all relevant stakeholders including government agencies, private sector organizations and civil society organizations;
- Utilize empirical information rather than model estimates; and
- Carefully define the spatial extent of the assessment needs.

The following section provides practical guidance on the steps for carrying out a project on the implementation of the GBEP Sustainability Indicators (GSI). This 'stepwise approach' for the implementation of the GBEP indicators is based on the experiences of FAO in Colombia, Indonesia, Vietnam and Paraguay, as well as experiences from other countries that have also implemented the GSIs. It includes nine working packages (WPs). For each WP, the project results chain, the details of the activities and the actors involved are stated. It is estimated that the project duration is approximately 24 months, from presentation of the project to dissemination of results. A Gantt chart is provided in *Annex 3 – Gantt Chart* to show the project timeline

1.2.1. Overview of stepwise approach



1.2.2. Working Package 0: Project development

Activities:

The project development involves three main activities:

a) Self-assess readiness

This involves a preliminary self-assessment of the country's readiness to apply the GSI, including: actual presence of bioenergy value chain(s) in the country; the importance of bioenergy in the country energy framework; the potential for further development; and the political willingness to develop the sector.

b) Define modern bioenergy and assess the extent to which traditional and modern bioenergy are produced and used in the country

Section 1.1.1 of this guide provides an overview of the various definitions of modern bioenergy. Where modern bioenergy is not used in the country, a baseline scenario with traditional bioenergy can be assessed in order to allow the long-term monitoring of the energy scenario development.

c) Carefully define assessment needs

Some users of the indicators opted for a national scope, others focused on specific case studies, others focused on specific cases which are then scaled up to the national level. The selection of one or other scope dictates the overall approach used. Pilots using case studies opted for a bottom-up approach, i.e. aiming to collect project-specific data from the different parts of the bioenergy supply chain. In Indonesia, for example, the aim was to establish a typology of national production systems, measure the indicators for a sample of each of the typology classes, and then scale up the values to give the national result. The pilots that opted for a national scope used a more top-down oriented approach. Because there is such spatial variability in the indicator values, the spatial extent of the assessment needs to be carefully defined and care needs to be taken in extrapolating site-level information to national-level indicators.

Project results chain:

This stage is preliminary to the project WPs, as it ensures country readiness to measure the GSI. It also defines key terms to avoid confusion in later stages of the project.

1.2.3. Working Package 1: Project presentation, country ownership, multi-stakeholder working group creation and identification of most relevant bioenergy pathways

Timeframe:

1 to 3 months

Activities:

a) Identify and engage the relevant experts from national institutions, academia, the private sector and civil society

Box 3 - The importance of a multidisciplinary team

The GSI cover a broad range of complex topics and are often data and skill intensive, which is why employing a multidisciplinary team with extensive knowledge of the domestic bioenergy context is recommended. Without such a team, it will be difficult to gather nationally appropriate information as well as integrate the results from the environmental, social and economic pillars into a comprehensive and balanced analysis.

If it is not possible to find a local expert, then the TFS recommends finding external support. However, it is important to remember that this should not come at the expense of capacity building. The focus of GSI implementation should be on creating or improving the capacity of national institutions to conduct the calculation and monitoring of indicators. External support is generally useful in facilitating the process, but the aim should be to enable local institutions to carry out the calculation by themselves, as they will be the ones measuring the indicators in the future.

Multiple representatives/experts belonging to different components of the society, including public administration, private sector and civil society members who have a relevant role in the context of bioenergy and bioenergy sustainability in the country (i.e. stakeholders), should be identified. The proactive engagement of all relevant stakeholders in the bioenergy value chain, including government agencies, private sector and civil society organizations, is key to the effective implementation of the indicators and the proper interpretation and use of results. Measuring the GSI brings together organizations that have not previously worked together but that each have a role to play. The establishment of a Multi-Stakeholder Working Group (MSWG) ensures that these actors are involved and

take ownership of the entire process from the calculation of the indicator baseline to monitoring, bringing continuity to the implementation process. Stakeholder engagement and ownership of the process are also critical for gaining access to the necessary data, receiving inputs and feedback.

A stakeholder map, such as the one in Box 4, could be useful to facilitate this process, and should be treated as a starting point for the establishment of the MSWG.

Box 4 - example of a stakeholder map, showing the three main groups (public, private and multilateral) and the various types of stakeholders that should form the MSWG.

b) Establish a MSWG that will be in charge of identifying the most relevant bioenergy pathways, defining the most relevant indicators, and providing *in itinere* project evaluation and validation of final project results.

The experts identified should be contacted and briefly introduced to the project.

c) Introduce the MSWG to the project and stimulate institutional coordination

Once the stakeholders have been identified, an initial meeting should be held in the country with the aim of formally presenting the GBEP indicators and the specific project to the MSWG, highlighting the relevance of the topic for the country, and enhancing the stakeholder ownership of the project.

Roles and responsibilities of each member of the MSWG should be discussed and agreed upon at this initial meeting. If not already established, a national representative should be selected to act as local project coordinator, to assure effective and timely communication between the local authorities, the broad number of experts and stakeholders, and project implementers. Institutional coordination should be stimulated wherever possible.

d) Identify and select the relevant bioenergy pathways

The MSWG should identify the most relevant bioenergy pathways in the country for further measurement. A description of the potential criteria for identifying relevant bioenergy pathways is detailed in Box 5. This will depend on national context and priorities.

Box 5 - Criteria for the identification and selection of bioenergy pathways

Identification and selection of relevant bioenergy pathways
•Relevance, i.e. economic value or share in energy mix •Development priorities •Strategic national importance, i.e. for renewable energy targets such as biofuel mandates •Sustainability concerns, i.e. in terms of the impact of the pathway on the environment or on social equality and human development •Bioenergy pathways for comparison, i.e. to compare bioenergy production from different feedstocks

Note that the composition of the stakeholder map (and the MSWG) should be discussed and, if necessary, amended in light of the selected bioenergy pathways, in order to obtain efficient representativeness and maximum inclusiveness of the experts to be involved in the project.

e) Describe in detail the bioenergy value chains and the related regulatory framework

The bioenergy value chains should be described in detail at this stage, although this may need to be updated and built upon in subsequent WPs as the measurement occurs (see Box 6).

Box 6 - Actions to be carried out in order to describe bioenergy pathways

Describing bioenergy pathways and relevant institutional context

- A **detailed description of the bioenergy pathways** in the country should be compiled. This should include: the main feedstocks and technologies utilised; the volume of production and use of the different types of bioenergy/biofuels considered; the scale of use (i.e. industrial, household, etc.); the steps in the value chain; the system boundaries of the value chain; and the roles of the different actors along the value chain.
- The **baseline situation**, such as fossil fuels or traditional biomass, that the modern bioenergy value chain is replacing should also be described as this will determine which indicators are relevant to be measured, and will be used for defining the baseline situation for comparison.
- **Consideration of institutional context**. A detailed description of the regulatory framework in agriculture, forestry, energy, environment/climate change, etc. should be developed. It is also important to refer to international instruments and agreements (such as the Sustainable Development Goals -SDGs- and the Nationally Determined Contributions - NDCs- under the UNFCCC), and the relationship between the domestic bioenergy sector and related policies and such instruments.

Project results chain:

WP1 is the foundation for the other WPs, creating a broad support base and building ownership in the country through the establishment of a MSWG.

Actors:

WP1 should be led by the project coordinator, in consultation with members of the MSWG, once established.

1.2.4. Working Package 2: Selection of relevant indicators, selection of national institutions, and assessment of capacity and need of trainings for the measurement of the GBEP indicators

Timeframe:

3 months

Activities:

a) Determine which GBEP indicators are relevant and feasible for the selected bioenergy pathways

After the bioenergy pathways have been prioritised in WP1, the MSWG should choose the most relevant indicators for each selected bioenergy pathway. Relevance in this case should be based on the development priorities within the country, should be aligned with other national policies (identified in *WP1d*) and will depend on the bioenergy pathways. The international standard ISO 13065:2015 "Sustainability criteria for bioenergy" could also be consulted[1].

b) Formally engage and contract relevant national experts and researchers for the measurement campaign

The main national universities and research institutions in the project country should be chosen based on transparent and standardised methodology (see Box 7).

[1] https://www.iso.org/standard/52528.html

Box 7 - Selection of national experts and institutions

Choosing national experts and institutions

- The selection of national institutions is of particular importance because they will receive the capacity development and know-how to monitor the indicators in the future. These institutions will become the leaders for the continuous monitoring of the indicators in the country so it is important to prioritize public institutions that have a greater time and space horizons and could act as trainers for other implementers (for knowledge transfer).
- The selection should therefore be as standardised and transparent as possible. Criteria for the choice of national institutions could include:
  - Ranking by the number and impact of relevant papers published in international journals;
  - Interviews with scientists/researchers; and
  - Auto-evaluation of capacity to measure the GSI.

Based on the capacity and the data availability assessment, the tasks of the national institutions recruited should be defined and they should be formally contracted. The team of national researchers within the selected national institutions for the actual measurement of the GSI can then be decided.

c) Identify priority areas for human and institutional capacity development

From the selection process of the local research institutions, a preliminary assessment of the technical capacity to measure the GSI is obtained, both through auto-evaluation and interviews. The preliminary capacity gaps should be carefully noted for future consideration and preparation of training material.

Room for human and technical capacity development may be observed and the need for further international expert contributions individuated, which may take the form of trainings on specific indicators or methodologies. The project coordinator should collaborate with the institutions and engage technical experts in order to identify the priority areas for human and institutional capacity development given the capacity required to measure the GSI.

Although this activity is initiated in WP2, it should be continuous throughout all stages of the project in order to determine future needs for capacity development that are required for monitoring of the indicators over time (see WP4).

Project results chain:

WP2 builds upon the outcomes of WP1 as the possibility to assess data availability and human and institutional capacity is strictly dependent upon the presence of the best-available experts and relevant representatives of the interested components of the society in the country (the MSWG). The building of

country ownership is therefore fundamental in order to obtain the government's collaboration and active participation in informing and engaging national stakeholders.

The identification of the capacity gaps and capacity development requirements in the WP2 are essential for the identification of appropriate trainings to be carried out in WP4.

Actors:

The activity should be led by the project coordinator, in collaboration with the MSWG. Outside of the MSWG, it may be beneficial to involve officials from relevant ministries and the national institute of statistics, as well as representatives of the bioenergy sector and researchers collecting relevant data in the field.

1.2.5. Working Package 3: Data collection strategy definition, primary and secondary data sources and requirements scoping

Timeframe:

3 months

Activities:

a) Identify existing data sources and data gaps in the country

When possible, empirical data is preferred over model estimates. Primary data can provide a better picture of what the actual situation is like when the data is gathered in a comprehensive or representative way. Estimations from models, on the other hand, can vary widely based on the assumptions used and may not accurately reflect the situation on the ground.

b) Screen the data sources available, in consultation and synergy with the national experts and researchers, as well as with the MSWG (including the private sector and civil society representatives)

The MSWG and the national researchers should discuss data requirements for each of the selected relevant GSI and assess the country data availability and gaps.

The need for data consistency among indicator measurements should be taken into consideration at this stage, by ensuring that primary and secondary data is the same for all institutions. The common data required are explained further in Annex 4.

The main data sources for secondary data should be established, and a hierarchy of these sources should be agreed between all implementers.

c) Define a strategy for the collection of required data for both primary and secondary data sources, including addressing major data gaps encountered

The data collection strategy should be formulated accounting for time and financial constraints, and should consider national priorities for each pillar of sustainable development. It should balance desk research of secondary data available, editing, calculation and possible modelling of the information on the one hand, and the verification in the field of representative samples of bioenergy supply chains (primary data) on the other hand.

The methodological approach for each indicator should be tailored to the country's specific conditions in order to maximise the practicality, representativeness and efficiency Annex 4 provides some proposals on how to approach the indicators in a systematic way and displays indicative rational sequencings of indicator measurement based on previous experience of GSI implementation. The tailored methodological approaches should be discussed within the MSWG and agreed upon for future monitoring of the indicators.

This activity may have to be returned to after WP4 is initiated if it becomes apparent that data barriers are present that were not foreseen in the initial strategy.

Project results chain:

WP3 builds upon the outcomes of WP2 as the data collection strategy and methodological approach is defined according to the actual data availability, presence of trained staff, and human and institutional capacity in the country, in addition to time and financial constraints. The needs for data collection and analysis should be shaped according to the possibility to obtain maximum representativeness of the research given the outcomes of WP2.

There is a constant feedback between WP3 and WP4 as the strategy is redefined based on the experience of the measurement of the indicators.

Actors:

The activity should be led by the national experts/researchers in the chosen institutions. The members of the MSWG (including bioenergy industry representatives and civil society) play an important role for data scoping and supply.

1.2.6. Working Package 4: Training activities for indicator measurement and long-term monitoring

Timeframe:

11 months

The timeframe for the WP is highly dependent on the outcomes of previous working packages, especially activity WP2 (d) that determines the human and institutional capacity required for indicator measurement.

Activities: (As required)

a) Train government officials and scientists to measure and interpret the indicators

This should be carried out concurrently with WP3 and WP5 as identification of the data sources and strategies for primary data collection are defined and the subsequent measurement takes place.

Training activities to build and/or enhance the capacity of local government officials and scientists to measure and interpret the indicators should be delivered, if necessary.

b) Produce practical recommendations and training material that could be of utility to other potential users in terms of capacity development

Based on the lessons learned from the technical implementation of the GBEP indicators in the country (after WP5), recommendations for enhancing the practicality of the tool in the country's context could be produced. These recommendations should be developed starting from discussions and considerations related to the benefits and limitations of the methodological approach tailored to the country's specific conditions (WP3) and during their measurement (WP5). Training and training material aimed at the potential national users could be delivered during workshops and webinars.

Project results chain:

WP4 recognises the need for human or institutional capacity development identified in WP2 and provides training to ensure the smooth measurement of the indicators during WP3 and WP5.

Furthermore, WP4 builds upon the lessons learned during the measurement of the indicators (WP3 and WP5) to train local scientists and government officials in order to put them in the position to measure the GBEP indicators in the future.

Actors:

Training material should be developed and delivered by national and international experts and scientists, including members of the GBEP Task Force on Sustainability, in particular sub-group leader teams, in order to transfer the know-how from the experts, who originally developed the GBEP indicators, to users in the country.

1.2.7. Working Package 5: Indicator measurement for the selected bioenergy pathways

Timeframe:

10 months

Activities:

a) **Collect available data** from primary and secondary sources as identified in WP3.
b) **Elaborate and analyse the dataset** according to the methodology chosen in order to define the current status for the selected relevant GBEP indicators for the selected bioenergy pathways.
c) **Evaluate the implementation strategy** foreseen in WP3 in light of measurements on the ground and modify, if necessary.

Project results chain:

WP5, the measurement of the indicators, is the direct consequence of a sound and effective data collection strategy (WP3). Indicator measurements start from primary, secondary, as well as tertiary (from modelling) data sources and may begin as soon as the strategy is defined; possibly identified data gaps (during WP2) and the strategy for their fulfilment (WP3) may be applied during this activity. Where barriers to measurement are experienced, it may be necessary to adapt the strategy defined in WP3; there is therefore continuous feedback and recalibration between these two WPs.

Actors:

The activities should be led by the selected national institutions and researchers under the supervision of the project coordinators, who will supervise the national institutions as they ensure consistency among the different indicators. In addition, the host country government officials responsible for data collection should be involved and national researchers could lead further primary data collection efforts.

1.2.8. Working Package 6: Multi-stakeholder project evaluation, results validation and possible policy implications

Timeframe:

8 months

Activity:

This WP should include:

a) *In itinere* project evaluation that could imply the revision of the implementation strategy.

This should be carried out in parallel with the measurement of the indicator values in WP5. It could include a mid-term meeting with the MSWG for evaluation of preliminary results.

b) A validation of final results before finalizing the final report and disseminating it.

Facilitation of multi-stakeholder validation of indicator values and their implications for policy objectives over the coming years. This could occur through meetings and workshops in the country and regular information exchange through the development of teleconferences and webinars.

Project results chain:

The multi-stakeholder *in itinere* project evaluation in activity (a) is carried out in parallel with WP5.

The validation of measurement values and the methodology used for their definition is directly dependent on the measurement and definition of indicator values (WP5) and therefore activity (b) builds strictly upon the previous WP with linear consequentiality.

Actors:

The activity would be led by the project coordinator, and the discussions would be led by the national experts and the representatives of the MSWG.

1.2.9. Working Package 7: Information sharing and dissemination, discussion on lessons learned and partnerships formation

Timeframe:

3 months

Activity:

This activity involves exchange of experiences and lessons learned. The indicator values and their implication for policy (from WP5 and WP6) should be discussed with government officials from the region and international experts in order to disseminate the results of the project and form partnerships for the future development of sustainable bioenergy in the region.

This could be carried out through the organization of workshops in the country (and at regional and international level) aimed at disseminating information and forming partnerships within the country (and with neighbouring countries during organized Regional Forums). The forums can be helpful for acquiring experience from other countries for solving critical issues pinpointed during GSI measurement and related to the selected bioenergy pathways. They can also be useful for developing considerations on concrete challenges of illustrating sustainable bioenergy potentials and policies that can help to overcome the identified challenges, thanks to regional dialogue.

Project results chain:

This activity builds upon the work done by presenting the lessons learned from the previous WPs to regional government officials invited to the final workshop.

Actors:

This activity should be coordinated by the project coordinator and led by the host government. The workshops involve host country government officials and representative of governments in the region in addition to those involved in measuring the indicators, as well as representatives of the MSWG.

1.2.10. Working Package 8: Way-forward agenda for long-term measurement and use of the GBEP indicators

Timeframe:

2 months

Activities:

a) **Identify objectives for the next 5-10 years** regarding areas for improvement and suitable policies and practices to help meet these objectives.

b) **Evaluate requirements for the long-term measurement** and use of the GSI according to the country context (including actual and proposed policies) and in light of the discussions and achievements of the capacity enhancements developed during the project.

Project results chain:

In light of the outcomes of the project and their implications for policymaking and capacity development (WPs 1 – 7), the MSWG, with the support of project coordinator, can discuss and identify objectives for the medium to long term enhancement of their bioenergy sector. In order to be successful, this activity needs to build upon the lessons learned in all previous WPs.

Actors:

This activity should be coordinated by the project coordinator and led by the host government. The MSWG should participate and contribute to the production of a national *way-forward agenda*.

1.2.11. Working Package 9: Project conclusion, final reports publishing and dissemination

Timeframe:

3 months

Activities:

a) **Draw conclusions concerning the assessment of bioenergy sustainability in the country and about whether and how the GBEP indicators need to be amended to increase their practicality.**
b) **Write, edit, and publish the final report.**

The conclusions should be shared with the GBEP Activity Group 2 of the Working Group on Capacity Building to contribute towards the building of a collection of lessons learned on implementation of the indicators; this will aid in the development of future guidance material. The material produced should also be presented to the international community through GBEP networks.

c) **Outline possible means for presenting and interpreting the indicator values in order to be relevant and useful to policymakers.**

Dissemination activities should include sharing the results within the country and with the global scientific communities, by participating in conferences/meetings specifically focused on the bioenergy pathways analysed. This could give an important contribution to improve the introduction/application strategies of bioenergy technologies.

Project results chain:

WP9 is the conclusion, final reporting and dissemination of the project and by definition builds upon information from all previous activities and WPs.

Actors:

This activity should be coordinated by the project coordinator and national researchers. Furthermore, all those involved in the project implementation should be involved in the discussion under this activity.

1.3. Enhancing the practicality of the indicators

The following suggestions were put forth to enhance the practicality of the indicators:

- An excel and/or web interface based on a computerized model could be developed to significantly reduce the time, skills and cost required to measure the GBEP indicators.
- Mechanisms to facilitate the systematic flow of data and information from the private sector to the organizations/agencies measuring the GBEP indicators could be identified and exploited.
- Given the global nature of the GBEP indicators, the report containing the methodology sheets could be translated into other official languages of the UN. This would greatly facilitate the dissemination and implementation of the indicators in developing countries around the world.

The TFS has acknowledged these suggestions and it is hoped that with adequate resources they could be taken up as future activities of the TFS (and GBEP as a whole).

2. Section 2 – Guidance on individual indicators

2.1. Environmental Pillar

Indicator 1: Lifecycle GHG emissions

Main Implementation Challenges

The fundamental challenges identified for this Indicator are the following:

- The issue of the scope of the Life Cycle Analysis (LCA);
- Assembling adequate data for equivalence when considering energy carrier(s) displaced
- Accounting for potential climate feedbacks; and
- Issues surrounding the inclusion of potential soil organic carbon (SOC) storage.

Guidance

Scope of Life Cycle Analysis

For GHG emissions based on LCA, the definition of the analytical scope and related boundaries is extremely important in order to obtain transparent and comparable results. As such, the GBEP Common Methodological Framework for GHG LCA of Bioenergy[2] provides an approach for countries to define the methodology applied in their case. Although the methodology should be clearly illustrated, the Framework provides flexibility for national determination of boundaries, pathways, GHG gases, etc.

However, it should be noted that the results of LCA for bioenergy are calculated in order to be compared with the LCA for non-biomass energy carriers or traditional biomass alternatives. Therefore, the boundaries of both analyses need equivalence (i.e. same scope) in order to be able to compare the GHG emissions and, thus, to determine the differences when a proposed bioenergy system displaces another energy source.

The IPCC Guidelines for national GHG emission inventories[3] use the **non-LCA** approach of territorial annual accounting (see Box 1 for definition). Yet, the inventory data can be used for LCAs at the national level, e.g. for emissions from agricultural production, or fossil fuel systems. The LCA then needs further data

[2] GBEP (2010) The Global Bioenergy Partnership Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy. Version one. Rome
http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/GHG_clearing_house/GBEP_Meth_Framework_V_1.pdf
[3] IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories https://www.ipcc-nggip.iges.or.jp/public/2006gl/

(e.g. lifetime of bioenergy systems), and data processing (e.g. adding emissions from upstream[4] and auxiliary energy).

For many countries, bioenergy value chains are not located entirely within the national territory. Raw feedstock and converted feedstock, as well as the final bioenergy carrier can be traded between nations.

Box: The IPCC Guidelines for National GHG Inventories

The coverage of the IPCC Guidelines comprises 'national territory', which "include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction" (Vol. 1, p.1.4).

When defining the system boundaries for the LCA approach, there are a number of potential methods for dealing with imported or exported biomass or bioenergy carriers, and the choice of method depends on the defined purpose and scope of the assessment. As previously mentioned, an LCA approach requires that the boundaries of the analysis be consistent when comparing bioenergy to non-bioenergy alternatives, including in cases where the bioenergy value chain is not entirely located within the national territory. Data on the part of biomass value chains that occurs **outside** of territorial boundaries - such as quantities of imports, respective types (e.g. biodiesel, ethanol, vegetable oil, wood pellets) and feedstocks (e.g. rapeseed, soybeans) - are available from international (e.g. FAOSTAT, UN Comtrade), regional (e.g. EUROSTAT), and national statistical databases. In addition, national/global lifecycle models, e.g., BIOGRACE[5] (for the EU), GREET[6] (for the US), GHGenius[7] (for Canada), RenovaCalc[8] (for Brazil) or more global life-cycle databases such as GEMIS[9] can help considering transboundary bioenergy flow. The analysis should clearly indicate whether emissions of biomass or bioenergy carriers (i.e. those from production or conversion of feedstock) that occur **outside** of the national boundary are included or excluded.

[4] Typically, a life cycle starts with primary energy/material extraction, followed by transport and conversion steps, and auxiliary energy/material inputs. The end-use conversion (e.g. wood heating, or sawmill delivering construction wood) sees these processes as "upstream", while waste management would be "downstream".

[5] www.biograce.net

[6] https://greet.es.anl.gov/

[7] https://www.ghgenius.ca/

[8] http://www.anp.gov.br/producao-de-biocombustiveis/renovabio/renovacalc

[9] **G**lobal **E**missions **M**odel for **i**ntegrated **S**ystems), a life-cycle and model and database provided freely by IINAS, see http://iinas.org/gemis.html

Attribution of impacts to bioenergy

1. Where there are multi-output processes with different (energy) products, co-product allocation using LCA methodology can be an issue. The following tier approach is proposed in this case:
    - TIER 1: Use pre-set default methods and values imbedded in specific data sources with a consistent allocation approach
    - TIER 2: Use energy content of products and apply other solutions such as exergy or economic allocation factors where appropriate.
    - TIER 3: Use energy content of material flows as allocation factor or appropriate other well-defined allocation factors with original data
2. Another attribution issue that may arise if statistical data is not satisfactory, is *how to separate the aggregated GHG impact of bioenergy at a national level from the overall GHG impact of the country?* The LCA approach applies the definition of a functional unit, which is related to the use phase (e.g. MJ of used energy). Accordingly, the functional unit can be defined as the total of all energy products (electricity, heat, biofuels) consumed in the respective country in GWh.
    - TIER 1: Estimate the share of energy products from bioenergy against the overall consumption of energy products in a country and combine them with default values for the respective products' life cycle.
    - TIER 2: Use statistical national consumption data for bioenergy products and combine them with default values for the respective products life cycle.
    - TIER 3: Combine all energy products on a one-by-one basis from original national data with statistical national bioenergy consumption data to achieve the national GHG bioenergy level.
3. Another attribution issue arises for GHG balances if land use of bioenergy products has to be set into perspective to the total land use of a country[10], i.e. *How can GHG emissions from land use and land use change be attributed to specific bioenergy products?*
    - TIER 1: In cases where the role of bioenergy for the area of land use change is not known, it shall be assumed that the land use change for bioenergy relates to the same share of land

[10] This also applies for other indicators like indicator 2 (soil quality), indicator 8 (land use and land use change) and indicator 9 (land tenure).

occupation between different uses as it was before the change. Carbon change data should be used from reports of the Intergovernmental Panel on Climate Change (IPCC).

- TIER 2: Apply original area data of land use change from a land use category into land use for bioenergy products and use the most adequate data for biogenic carbon change from IPCC.
- TIER 3: Apply original data from national administrations or statistical offices regarding land use change from an IPCC land use category to land use for bioenergy for area and biogenic carbon on this land before and after the change (reference date, period of time to be defined).

Accounting for other potential climate change drivers

The IPCC-listed GHG emissions represent one set among many drivers of climate change. Other factors such as earth's surface reflectance (albedo), aerosols, and black carbon, are increasingly recognized as important drivers of global climate. Accounting for potential climate effects from these drivers may be important but is outside of the scope of this indicator, as it deals with GHG emissions, rather than all other impacts on the climate system.

Inclusion of potential soil organic carbon (SOC) storage

Given the nature of the Attributional LCA analysis, the sinks and the emissions in the soil are important to include in the analysis but SOC storage per se that does not represent a flow within the carbon system, should not be considered as part of the analysis. Net changes in SOC stocks are relevant. Inclusion of SOC changes makes LCA consistent with IPCC guidelines where SOC changes are allowed in national GHG inventory estimation.

Indicator 2: Soil Quality

Main Implementation Challenges

Major challenges identified when measuring this indicator:

- Data availability on soil organic carbon (SOC) content and its development;
- data availability regarding the amount and distribution of soil improvement measures; and
- attribution to bioenergy production (a cross-cutting issue).

Data availability on SOC content and its development

Data on SOC content in both topsoil and subsoil is limited in many countries, and primary data collection campaigns tend to be complex, and both time and resource intense. The IPCC 2006 Guidelines for GHG inventories in the land sector[11] give very rough national default data for SOC. In many cases, there is no regular long-term SOC monitoring available which would be necessary to detect the influence of bioenergy production because SOC typically reacts slowly to changes in cultivation practices and may require deeper soil sampling and more costly analysis than normal – and as modern bioenergy production is a relatively recent development, respective impacts to soils may not be easy to detect.

However, this strongly depends on the soil type, soil management (incl. fertilization), and climate conditions.

Data availability regarding the amount and distribution of soil improvement measures

Where primary data on soil quality and SOC is not available, most implementing countries have focused on soil improving measures as a proxy. However, guidance is required on soil improving measures, as there is often a tendency to think only in terms of biophysical measurements (such as no-tillage, application of organic matter, crop rotation, and cover crops).

Attribution to bioenergy production

The attribution of SOC content and/or soil improvement measures to bioenergy production is difficult, as many crops are grown mostly for non-energy purposes.

[11] http://www.ipccnggip.iges.or.jp/public/2006gl/vol4.html

Guidance

Data availability on SOC content and its development

Key questions include: how does management change under the bioenergy system compare to the reference scenario, and how do changes in management affect SOC over time? Experiments done in the past may provide useful data on expected changes associated with different management practices. The fact that SOC changes are very slow means that even old data (10 years old) may be useful in some instances, and that assessments should focus on change over the long-term rather than short-term changes.

Given that multiple alternative (competitive) methods are available to measure SOC and that results can be very sensitive to the method selected, it is crucial to define reference conditions and methods in order to compare results at different scales (local vs. national vs. global). Additionally, a good knowledge of soil quality properties and its measurements is needed. While conventional soil sampling methods continue to be used for SOC measurements, new measurement methods based on in-situ sensors and near-ground aero measurements provide great potential to measure SOC and other soil parameters extensively and inexpensively.

Improvements in national data can be expected in the coming years due to the need to provide data for SDG Indicator 15.3.1 "*Proportion of land that is degraded over total land area*", which consists of three sub-indicators (land cover, land productivity, and carbon stocks above and below ground). The carbon stock change sub-indicator refers to SOC. The change in Net Primary Productivity (NPP) is also measured under this indicator and could be used as a proxy when paired with data on crop characteristics.

Data availability regarding the amount and distribution of soil improvement measures

The following approaches could be applied:

- General application of **soil improving measures** countrywide or related to bioenergy plantations (e.g. no-till; manure application, organic farming);
- Identification of **high-risk areas** (erosion risk, salinization/sodification, acidification, water logging, mechanical disturbance); and
- Definition of bioenergy crop properties and its risk potential/identification of **high-risk crops** (high risk of erosion, carbon storage rates/humus balances).

There is often a tendency to think only in terms of biophysical measurements (such as no-tillage, application of organic matter, crop rotation). Chemical and biological components also need to be taken into consideration, e.g. biological activity such as bioturbation[12].

Attribution to bioenergy production

Potential methods for attribution include:

- A causal analysis approach[13] could be applied to determine what factors are responsible for the effect being measured, in this case, for example, to allocate cause among potential factors for a documented change in SOC. One method of causal analysis that helps to resolve attribution is to perform longitudinal analysis of SOC change for similar (neighbouring) land areas with and without bioenergy production, before and following the bioenergy production.
- If maps on SOC contents and/or high-risk areas are available, they can be combined with maps of bioenergy production, if available, to get an estimate of risk to SOC stocks (e.g. SEEMLA approach[14]).
- As a *proxy*, the distribution of crop production that could potentially be used for bioenergy production (e.g. palm oil, sugarcane) could be used.
- Alternatively, information on the indicator can be attributed based on share of the area covered by bioenergy production.
- Also, the share of application of good practices could be used as a proxy.

Based on these potential methods, the following solutions (using the TIER approach) are given to questions of attribution that may arise:

(1) How can the soil management and the share of maintained or improved soil quality be attributed unambiguously to the production of bioenergy if the same biomass product is used for food, fodder or non-energy products?

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[12] An example is the EU index for soil biodiversity: https://esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-atlas

[13] Efroymson et al. (2016 A causal analysis framework for land-use change and the potential role of bioenergy. Land Use Policy 59: 516–527 http://dx.doi.org/10.1016/j.landusepol.2016.09.009

[14] http://www.seemla.eu/en/home/

- TIER 1: Via humus balancing, spatial or similar approaches, shares of degrading, maintaining and improving of soil carbon content can be determined but without differentiating between the final uses of the biomass. Then soil qualities shall be attributed to bioenergy according to its share of the total production of the respective cultivation.

- TIER 2: A clear assignment of agricultural land to bioenergy production can be made (see above) and the change in soil organic content will be estimated via humus balancing for this land with a sufficient spatial differentiation of bioenergy feedstock production.

- TIER 3: Due to a clear assignment of agricultural area to bioenergy feedstock e.g. because of fiscal reasons or unambiguous regional practice, the land for bioenergy can be identified. Furthermore, soil organic content is analysed and monitored over a sufficient time period and with sufficient soil sampling in the respective area.

(2) *How can soil quality be attributed to bioenergy feedstock management if this material is derived as a co-product from biomass for various purposes (e.g. straw) or as a separate co-product of continuous rotation farming?*

It is a prerequisite to have information on the amount and type of production of biomass for energy and the other products from combined production, by measurement or statistics.

- TIER 1: With the knowledge of SOC or humus balances of a certain combined agricultural production, but without the evidence that it relates to a specific product of the combined production, a simple allocation shall be performed. The allocation factor can be the economic value of the by-products or their energy content (mass * lower heating value).

- TIER 2: Humus balance can be calculated for the combined production of energy biomass and be attributed to bioenergy with the knowledge of management options.

- TIER 3: Soil organic content is measured over a sufficient time period and with sufficient soil sampling in the respective area and findings can be attributed directly to the management of the different parts of biomass (e.g. high yield of straw) or to the bioenergy cultivation in rotation farming (in that case if a net SOC degradation of the overall rotation can be attributed to the bioenergy cultivation only).

Indicator 3: Harvest levels of wood resources

Main Implementation Challenges

Major implementation challenges encountered are:

- Data availability in some countries;
- determination of the share of woodfuel coming from forests; and
- aggregated national data – possibly misleading as it can mask important regional differences in harvest levels.

Data availability

Data on net growth and harvesting is scarce in many (developing) countries. In many countries, statistics rely on information from forest operation data, although FAOSTAT provides indicative figures on harvesting for most countries, which could be used as defaults, or at least as benchmarks. Data on harvest may include large uncertainties due the harvesting of woodfuels being primarily informal in many countries.

Determination of the share of woodfuel coming from forests

Wood for modern bioenergy (e.g. wood pellets, chips) usually comes from primary or secondary residues (e.g. sawmills, wood industry) and in some countries tertiary residues (post-consumer or demolition wood). Harvests specifically for bioenergy production may be occurring to some extent, but the relative magnitude of this material stream is unknown.

In many countries, standard inventory and harvest measures are given in volume units (cubic feet or meters) and are applied to the merchantable portion of the tree stem. These measures implicitly include residues from processing (e.g., saw dust and other mill residues) but not residues produced at the harvest site (e.g., branches or tops). The actual volume of these processing residues, however, will vary considerably depending on the end products produced and the technologies used to produce them. Moreover, certain volume measures (e.g. within-bark or board-foot measures) discount non-usable material from standing or harvest volume estimates. As a result, residue or waste-wood streams present challenges when trying to map these streams into forest stocking and harvest data depending on the specific measures and processing technologies used.

Yet, there are countries in which forests are (over-)used to provide woodfuel for traditional uses (e.g., cooking), and these practices are very different from the forest operations described above, as small trees

and/or branches may be collected which are not accounted for in forest inventories – especially if those inventories are based on remote sensing or areal mapping using default data. Furthermore, trees outside of forests may play a relevant role as feedstock providers for traditional biomass uses.

Problems with aggregated national data

An aggregated national figure may not adequately account for diversity in landscapes, forest management and harvest of biomass; this may mean that important differences could be missed across regions within countries that are heterogeneous in this regard (e.g. information on deforestation in areas with higher local woodfuel demands that surpass forest increment may be lost in aggregated national figures). Furthermore, cyclic market cycles are evident in forestry sectors and periods of high demand where net stocks temporarily decline can be important to provide incentives for landowners to retain land in forest or to plant more land in forest. Haiti is a recent example of investment in forests and forest areas finally rebounding in large part due to bioenergy markets.

In general, aggregate national harvest rates, and available wood supply are influenced more by weather events (e.g. drought, flood, hurricane, etc.), disease and pests, and the predominant forestry markets for lumber and fibre, than by bioenergy use. Thus, aggregate national data are only useful if there has been adequate analysis to allocate any observed changes accurately among the many different causal forces.

The differences in landscape variability for forestry-related analyses should not be underestimated in many countries, particularly those characterized by large forested areas, high altitude, or ecosystem variability. This is the case e.g. in Colombia, where the south-eastern part of the territory is covered by the rainforest of the Amazon basin, and the north-east is characterized by a dry tropical landscape. In between, there are high plateaus where forests have been converted to agriculture and a mosaic of native forest types still remain. The national mean annual growth value in Colombia accounts for the contribution of the vast rainforest, where scarce utilization for woodfuel is recorded, due to low population density. The areas where there is a much lower forest growth rate, as well as the areas of the country where the forests and woodlands are more scattered, have in turn the highest wood harvest levels. However, disaggregation is problematic because, although there is disaggregated data on net growth in some cases, there is usually no disaggregated data on woodfuel harvest and/or use, and there is great uncertainty at national level (many countries model woodfuel use in the residential sector, which implies uncertainty); data would have to be obtained from bottom-up data collection (e.g. Colombia and Indonesia used questionnaires to obtain information on woodfuel harvesting in different regions).

Guidance

Use best available data, ideally including forest inventories that measure actual growth rates, volume changes, forest type and age composition, and other forest characteristics.

Modern woody biomass value chains

When trying to map residue or waste-wood streams into forest stocking and harvest data, care must be taken when choosing measurement units, conversion factors, and materials' accounting stances. Therefore, when measuring Indicator 3 in a given country, emphasis needs to be given to the description of the modern woody biomass value chains studied, including the origin of the raw material. This will help discern the provenance of the feedstock as a component of (or outside the amount considered in) the statistics of net growth. Harvest levels should then be calculated to be consistent with the definition of net growth being applied.

Data Disaggregation

Forest inventories are common in most countries, including developing countries. Many research institutes collect and analyse data on mean annual growth of forests, standing volumes, regeneration rates and more. These parameters may be very homogenous in some situations (where little or no climatic gradient is found, e.g. small countries) but much more frequent are the cases of significantly heterogeneous forest forms that may be due to climatic differences (north-south gradient, as well as altitude gradient, distance from bodies of water, presence of natural barriers like mountain chains, precipitation regimes, etc.) or ecological differences (e.g. soil type, species composition, etc.) found within the same country. In these cases, a single aggregate value of forest growth would be misleading. It is therefore important to assess data relevant to the area and specific forest type involved in bioenergy production. The individual forest types analysed comprise the blocks to build up the analysis. The net growth values of these forests should be treated individually in relation to harvest levels specific to the forest type, and that forest type only.

Similarly, the analysis of the demand of wood from these forests should be carried out on the basis of local statistics and, where unavailable, through purpose-built questionnaires. It should include a bottom-up analysis carried out by local research centres with in-depth knowledge of local conditions of demographics, landscape variability, and disaggregated values by forest type. Local forestry institutions, including academia, may have necessary data and knowledge on disaggregated information that is well classified and distinct from nation-wide figures. Yet, such bottom-up analyses typically require significant

resources in terms of expert's time, data sourcing and handling as well as interpretation, and may have to be carried out for several regions to adequately reflect different consumption patterns, especially in larger countries, or wood-using regions[15]. Some countries address this problem through extensive modelling, calibrated with bottom-up data collected from e.g. chimney-sweeping registries, heating demand data for building types, and respective time series.

Another important aspect of the disaggregated analysis is the consideration of domestic trade and logistics. In fact, in countries where domestic trade of woodfuels is prominent, harvest levels should be accounted for starting from the supply side (forest companies, harvest permits, forest management institutions, academia) rather than from the demand side (questionnaires) because the geographical links may or may not be obvious.

[15] For several Sub-Saharan African countries, IRENA is working together with regional development banks and stakeholders to establish better data for bioenergy resources, including forest biomass. Results are expected in the near future.

Indicator 4: Emissions of non-GHG air pollutants, including air toxics

Main Implementation Challenges

The following major challenges were identified when measuring this indicator:

- Measurement of this indicator is quite burdensome; and
- This indicator is very skill intensive and requires the involvement of a team of expert chemists and engineers.

Guidance

Scope of Life Cycle Analysis

The scope of the LCA for air emissions should reflect the considerations for Indicator 1 (GHG emissions).

For a 1st order proxy analysis, it could be sufficient to start with the **direct** emissions of bioenergy-using processes (e.g. cookstoves, boilers, busses/cars, diesel engines for electricity, etc.) for which some default data are available (e.g. EEA 2016; US-EPA; as well as data from models such as GEMIS and GREET). However, for crop-based bioenergy this would neglect the primary production, processing and distribution which all represent significant sources of air emissions (e.g. fertilization, trucks, etc.). Thus, it is highly recommended to expand the scope to at least a simplified LCA approach. Default data for "upstream" air emissions are available for selected countries in the literature (e.g. Franke et al. 2013), and in several models (e.g., GEMIS, GREET).

With regard to air toxics (e.g. heavy metals, PAH), the 1st order proxy analysis for "hot spots" in the bioenergy supply chains could be sufficient, considering again only the **direct** emissions of bioenergy-using processes (e.g. cookstoves, boilers, busses/cars, diesel engines for electricity, etc.) for which some default data are available.

Indicator 5: Water use and efficiency

Main Implementation Challenges

The primary implementation challenges were found in determining the correct level and timeframe for analysis, and in ensuring that reference values are available for comparison of data.

Guidance

Level of analysis

Level of analysis depends on country context. Watersheds can be used as the level of analysis and then watershed-level data can then be aggregated to give national values. However, it is extremely important to have a reference base from which to compare watersheds. In some countries the use of watersheds is not applicable, given that they may be very large in comparison with country area and transcend national boundaries. Reservoirs are another level of analysis that could be useful for some feedstocks.

Timeframe

It would worthwhile to take measurements from an average year and a dry year in order to obtain an average.

Indicator 6: Water quality

Main Implementation Challenges

Attribution

At national level there is generally good data on pollutant loading as contributions per sector but bioenergy is not one of the specified sectors (its impact transcends sectors).

Specifically, for sub-indicator 6.1, the methodology includes two approaches. Pollutant loadings to waterways and bodies of water from bioenergy shall be measured:

- in kg of N, P and active ingredient per ha per year, and
- as percentages of total N, P and pesticide active ingredient loadings from agriculture in the watershed.

The first measurement can be carried out based on the bioenergy feedstock management and is not connected to an attribution issue. The second measurement, however, has a double attribution issue because it is related to an indicator about the state of the environment (total N, P and pesticides in the watershed) and an impact indicator (N, P and pesticides loadings from agriculture). Not only do the loadings of the water body have to be known, but also the share attributable to agriculture has to be derived as well as the share of the cultivation of bioenergy crops within this.

Guidance

Attribution

For attributing impacts to the bioenergy sector, first, one must separate agricultural from non-agricultural contributions to loadings and then the bioenergy cultivation from the agricultural sector using a TIER approach:

- TIER 1: Possible emission sources for water pollutants shall be identified and the contribution of agriculture to the loadings of the water body shall be estimated with available information. Then the share of the bioenergy sector shall be attributed to the loadings according to the percentage of land for bioenergy to the total agricultural land.
- TIER 2: Total emissions and share of agricultural management emissions shall be assessed with the help of an environmental effluent model. As in Tier 1, the share of bioenergy shall be estimated with the share of land for bioenergy to the total agricultural land.

- TIER 3: An effluent model for pollutants from agriculture as a total and with a separate sub-model for types and location of bioenergy crops shall be used.

Models and Software

The Soil and Water Assessment Tool (SWAT) of the University of Texas[16] and the Climate, Land, Energy & Water Strategies (CLEWs)[17] of the UN DESA could be useful tools to model watersheds for numerous applications. Specifically, for indicator 6, SWAT is effective for assessing water resource and nonpoint-source pollution problems, and can also be used to predict the impact of management on water, sediment and agricultural chemical yields[18]. The inputs to the model include climate and weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens and land management. The Hydrologic and Water Quality System (HAWQS) is a 'web-based interactive water quantity and quality modelling system that employs SWAT'[19] as its core modelling engine. These tools are accompanied by substantial global support and capacity training, online community support, webinars and workshops.

[16] More information available at: http://swat.tamu.edu/software/arcswat/

[17] https://unite.un.org/sites/unite.un.org/files/app-globalclews-v-1-0/landingpage.html

[18] Gassman, P. et al. (2007) The soil and water assessment tool: historical development, applications, and future research directions. *American Society of Agricultural and Biological Engineers*. Vol. 50(4): 1211-1250. https://www.card.iastate.edu/research/resource-and-environmental/items/asabe_swat.pdf

[19] Hydrologic and Water Quality System (HAWQS). Information available at: https://epahawqs.tamu.edu/

Indicator 7: Biological diversity in the landscape

Main Implementation Challenges

Data Availability

An official definition and map of areas of high biodiversity value or critical ecosystems does not exist for all countries. However, when the areas concerned are either protected by national law or tracked by national programmes, data should be available.

Problem with concept of 'nationally recognized areas'

The concept of 'nationally recognized areas' is problematic because land cover/land use change in these areas is usually prohibited by law and thus the official value of land use change typically approaches zero, even though illegal land use may occur due to many factors. Furthermore, areas of high biodiversity value or critical ecosystems are not always nationally recognized; this reflects on data appropriateness.

When countries measure this indicator, it may be worth considering areas of high biodiversity value or critical ecosystems that are not (yet) officially recognized and protected in the country, referring to e.g. inventories of such areas maintained by international bodies (e.g. IUCN).

Habitat corridors

The importance of habitat corridors between areas of high biodiversity value or critical ecosystems could be considered when measuring this indicator. Although this is an interesting qualitative addition, this issue of 'connectedness' cannot currently be integrated with the measures of area already included in the indicator methodology.

Guidance

Proxies

A potential proxy for the impact on biodiversity is the *change in the number of endangered and vulnerable species* in key bioenergy production areas, especially in the case where there is a lack of an official definition and map of nationally recognized areas of high biodiversity value or critical ecosystems. However, attribution of these changes in endangered and vulnerable species to bioenergy production is approximate as, in general, actual causes of species decline may not be known.

An example of a similar approach comes from the US Department of Energy Bioenergy Technologies Office (BETO)[20]. This program developed a biodiversity indicator around the concept of 'species of concern'. These species are plants, animals, insects or other species identified as important in the location of bioenergy production. The species may be valued for recreation, hunting, their threatened status, or due to concerns about pests, noxious weeds, invasive species, etc. They are selected based on local regulations or publications from local governmental agencies. If recommendations on management practices exist for these species of concern, then they can be compared with bioenergy production management plans to determine if they include specific consideration of the requirements of these species.

Two further proxies[21] might be helpful:

- percentage of remaining area of native vegetation; and
- percentage of land managed with wildlife-friendly agri- or silvicultural techniques.

The former should be defined spatially explicit in political (e.g., municipalities, provinces, countries) or geographical units (e.g., river basins, ecosystems, biomes). The latter should be based on wildlife-friendly management techniques widely accepted by recognized international organizations and conventions. Species of concern, as proposed in the text, might complement these indicators above.

[20] https://www.energy.gov/eere/bioenergy/sustainability

[21] Example from PY: For a sugarcane-based EtOH plant, maize is considered to be cultivated using conservation agricultural practice as a bottom-up proxy. This may be a helpful approach if not enough data is available for the whole country (see chapter "stepwise approach").

Indicator 8: Land use and land-use change related to bioenergy feedstock production

Main Implementation Challenges

The main issues for this indicator are:

- Attribution (a cross-cutting issue);
- The time component of land-use change;
- Land typologies and their categorization; and
- Availability of data – given that often data from remote sensing (especially satellites) is used, land-use change may not be easily detectable from space.
- No consistent, clear, measurable definition of what "land use change" signifies.

Attribution

For this indicator, there are multiple attribution issues.

The first issue is the lack of information on what "land use change" is, where it occurs, how much, when and why. A minor issue is bioenergy feedstock distribution, i.e. exactly where crops for bioenergy are grown in the country. In some cases, bioenergy-related land-use change has been allocated using an artificial overlay based on the use of bioenergy production from various crops. This assumption can be used when it is not deemed feasible to determine where land conversion occurs specifically for bioenergy.

Another difficulty with measuring land use and/or land cover change occurs when the crop used for producing the bioenergy carrier is a secondary crop only used in rotation with the primary crop (and so the attribution of land-use change to the crop grown for bioenergy is complicated by this issue). Plus, the bioenergy share of a crop may vary seasonally and may not be determined until long after the harvest, in response to relative market values.

Where multiple crops are used for the same bioenergy carrier (for example, both sugar cane and cassava for ethanol production in Paraguay) and the ratio of the crops is not available, calculating the land area required using data from mills on quantity of ethanol produced and conversion efficiency is very difficult.

Time component

Sub-indicator 8.3a (yield increase) was mentioned specifically as being difficult to measure because yields can vary greatly from year to year due to weather. Therefore, long-term trends need to be considered and caution needs to be taken if making any assumptions about yield and land-use change.

Guidance

Attribution

For the issue of feedstock distribution, i.e. *how can land use and land use change be attributed to specific bioenergy products?* the following Tier approach is suggested:

- TIER 1: In cases where the role of bioenergy for land use change is not known, it shall be attributed with the same share as its share of the total land occupation.
- TIER 2: In cases where the role of bioenergy for land use change can be estimated it shall be applied using different estimated shares (lower or higher) as the numerical share of total land occupation suggests.
- TIER 3: Original data of land use change from a land use category into land use for bioenergy products shall be applied.

For the issue of how to attribute land use change for rotation cropping, conventionally, LUC is either observed (direct LUC), or determined within models to attribute changes in the area dedicated to specific crops that are used in rotation with other crops. To understand changes in crop rotations and areas relative to market signals requires longer-term trend analysis. For the attribution of land-use change to perennial crops (such as palm oil), one needs to first understand what is driving the initial changes in land cover, prior to the planting of the crop. To understand drivers, it is important to measure all changes in land cover and in management over time.

Definition of wastes and residues

It was noted that for this indicator, wastes and residues are used as separate concepts (a waste is something that needs to be treated and disposed of whereas a residue is something that is co-produced but not used). However, in some countries/situations these terms are used interchangeably and this may create a problem of definition. Therefore, it is important to be transparent and explicit in their use. In terms of land use change, wastes and residues are both considered to have zero land use change (under the European definition).

2.2. Social Pillar

Indicator 9: Allocation and tenure of land for new bioenergy production

Main Implementation Challenges

As already foreseen in the methodology sheet of Indicator 9, the assessment of this indicator may be challenging, especially regarding the need to measure changes related to informal situations (e.g. traditional land authority) and/or processes (e.g. informal land transfers), since land held or used informally by local poor populations could be difficult to measure.

As explained in more detail in the sections below, the main challenges experienced by the countries and organizations that have applied this indicator relate mainly to:

- Data availability, in terms of both quantity and quality;
- The definition and identification of 'new bioenergy production', and the separation of the effects (on land tenure) of bioenergy activities from other factors; and
- The sensitivity of tenure-related issues and information, and the consequent risks of not being able to access relevant information or of getting distorted data, especially where regulations are weakly enforced.

Data

The definition of land tenure may be very complex due to the existence of different land tenure systems/regimes, sometimes even within the same country. Furthermore, the availability of sufficient data of adequate quality may affect the practicality of this indicator in some countries, creating the need for proxies.

Relevant evidence for Indicator 9 can be provided by formal reporting regimes, including national and local land registries, publication of land transfers through a digest or record, and/or publication of court records and cases. However, as already highlighted in the methodology sheet of this indicator, this approach may face a few challenges in developing nations (see FAO, 2011a, p.109).

The method may be very time consuming as data is often not systematized or aggregated, so it may require manual searches of original land tenure documents, and/or searching through different registries or court publications one by one. This may be even more difficult in federal countries where administration is decentralized.

Furthermore, information regarding land transfers in protected areas, reserves and/or forest concessions might not be available or collected by the relevant government authority.

Finally, the sensitivity of tenure-related issues might lead to the use of distorted data. Tenure-related issues and information tend to be highly sensitive, both politically and from a commercial perspective, especially in some countries. As a result, challenges may emerge in the application of this indicator, such as the impossibility of obtaining relevant information and the risk of getting distorted information.

Capacity

Given the high complexity of tenure-related issues, dedicated experts/specialists are needed in order to collect and analyse the data and information required for this indicator and to interpret its results. In particular, an in-depth knowledge of the legal instruments, practices and procedures for the determination of land titles and related changes is necessary, combined with a good understanding of the local bioenergy sector.

Attribution

For the measurement of Indicator 9, it is necessary to define what constitutes 'new bioenergy production' based on the specific local circumstances (e.g. features of the local bioenergy sector) and on the objectives of the analysis.

Regardless of how a country/user defines the aforementioned term, it is very difficult to identify the specific land/areas used to grow the feedstock for the production of such 'new' bioenergy as compared to land where the same feedstock is grown for non-bioenergy purposes. Furthermore, as already mentioned in the methodology sheet of Indicator 9, it might be challenging to establish and monitor the link between land tenure and bioenergy activities, especially in the case of informal transactions, due to the difficulties in separating the effect of bioenergy activities from other factors.

Scope

Another issue pertains to the scope of Indicator 9. Tenure-related issues may arise on land where bioenergy feedstock is grown, but also in relation to the informal harvest/collection of wood for cooking and heating. These activities, which oftentimes take place on communal lands, may affect the access to/use of land and natural resources by forest-dependent communities, including indigenous ones. Even though these issues are relevant to the theme under which Indicator 9 was developed (i.e. 'Access to land, water and other natural resources'), in its current formulation this indicator is not suitable for capturing

these impacts and the effect of a possible shift from traditional biomass harvest/use to modern bioenergy options.

Guidance

Proxies/Best Practices

A method for monitoring this indicator over time is to look at good practices in land tenure and their evolution. Although a consensus on international good practices for land tenure has not been reached, the use of good practices identified nationally, and maintained over time for monitoring and reporting, will provide country trends. Recognized good practices for modern bioenergy production could be used to guide site selection at the national level[22].

Another possible proxy is represented by evidence of land claims/disputes/conflicts. In the case of formal land claims/disputes, while their presence would be a sign of tensions related to land tenure, it would also indicate the existence of a recognized 'due process' and of a formal complaint system.

Data Collection Strategies

Additional data sources

As described in Section 1.1, relying exclusively on formal reporting regimes (where available) to obtain the information required for the measurement of Indicator 9 can give rise to challenges. For this reason, additional data sources and data collection strategies should be considered, in addition to formal reporting regimes.

For instance, as suggested in the methodology sheet of Indicator 9, some of the necessary information could be collected for a sample of land transfers for new bioenergy production through interviews of those involved in and affected by such transfers. Regarding informal/unrecorded structures and processes related to both 9.1 and 9.2, interviews with relevant households and communities (i.e. those with the most stake in the land transfers in question), key informants, and relevant traditional land authorities (e.g. customary authorities, village councils, etc.) could be used as measuring methods if data are not readily available. Finally, if appropriate, sample household surveys could also be used.

[22] For example, the FAO 'Good Socio-economic Practices in Modern Bioenergy Production' could provide the basis for the selection of good practices (FAO, 2011b). Further documents that could provide a basis for the selection of good practices are: Zakout et al., 2006; FAO, 2015; and FAO, IFAD, UNCTAD and the World Bank Group, 2010.

Contested land transfers can be used for data collection in order to identify deviations from the implementation of fair and effective processes. The data sources should be interpreted critically as they may be biased towards good practices and therefore bad practices may be less likely to be recorded where provisions for dealing with such cases are considered weak.

Sensitivity of data

Tenure-related issues and information may be politically and commercially sensitive, especially in some countries. This may give rise to difficulties in obtaining relevant and truthful information. Means to mitigate this risk could include a domestic, transparent multi-stakeholder process involving relevant government authorities, private sector representatives and civil society representatives to inform and complement a formal process.

Attribution

As regards the attribution issue, one pragmatic approach could be to focus on areas of recent expansion in the production of the main crops/feedstock used to produce bioenergy in the country where Indicator 9 is applied. If relevant and appropriate, the share of the aforementioned crops/feedstock used for bioenergy (vs. other uses) should then be considered, in order to attribute the measured impacts to bioenergy. Regarding sub-indicator 9.2, if part of the crops/feedstock cultivated in the aforementioned areas are certified according to sustainability standards that address land tenure in a manner consistent with the scope and approach of Indicator 9, it could be assumed that the established procedures for determining legal title have been followed.

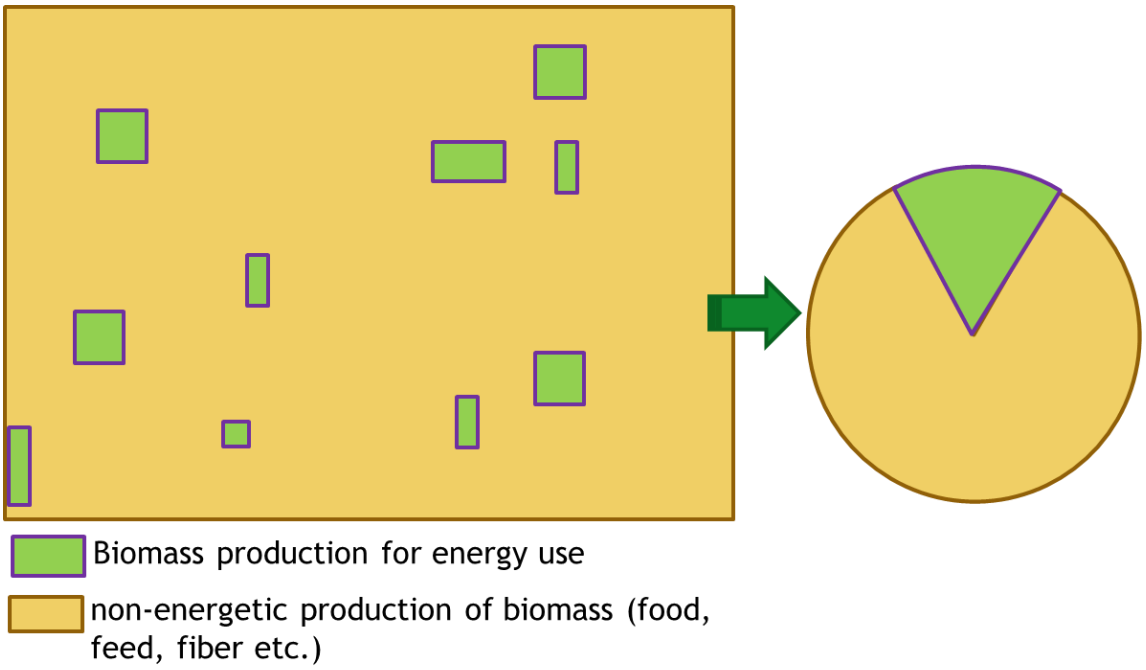
The following TIER approach could be applied for these questions:

(1) How can tenure of land be attributed to production of "new bioenergy"?

- TIER 1: With general data about tenure of land and production figures of new bioenergy, the percentage of land where new bioenergy exists should be estimated. Then as a first approximation, the related production can be regarded as equally distributed to the tenure of land (see Figure 1). This should be supplemented by interviews with experts or a literature review to confirm the hypothesis that the advance of bioenergy is uniformly distributed on all forms of land tenure, and if not, identify processes where the advance of land use for bioenergy tends to take place on certain forms of land tenure more than others.

- TIER 2: With the help of general data about the distribution of land-ownership and general data about farm sizes, business models and production figures of new bioenergy, an aggregate of this information can be used as a proxy.
- TIER 3: Original data on tenure of land should be related to original production figures of new bioenergy. This should be a constant feature of national statistics.

Figure 1 - Scheme of the attribution issue about how to attribute land tenure to the bioenergy sector



Capacity Building

As mentioned above, given the high complexity of tenure-related issues, dedicated national experts/specialists are needed in order to collect and analyse the data and information required for this indicator and to interpret its results. Therefore, strengthening the expertise of relevant local institutions would be key in order to ensure that this indicator can be measured over time and used to inform decision-making.

More generally, in order to create an enabling environment for sustainable bioenergy development, the awareness and capacity of relevant national stakeholders in relation to land tenure issues should be strengthened. FAO's Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (FAO, 2012), which are based on an inclusive process of consultations and which were endorsed by the Committee on Food Security (CFS) in May 2012, would represent a valuable resource for this awareness raising and capacity building effort.

Indicator 10: Price and supply of a national basket

Main Implementation Challenges

The main implementation challenges for Indicator 10 relate to the knowledge, skills and resources (capacity) required to implement the Indicator. A large amount of capacity is required to carry out the Tier II and Tier III analysis because they require expert judgement and modelling, respectively:

- Tier II relies on expert judgement on the links between bioenergy and observed changes in price and/or supply of national food basket.
- The Tier III analysis requires sophisticated modelling, and practical information on where help can be found on these modelling techniques would be useful.

Guidance

Based on the implementation challenges identified, the guidance primarily focuses on three main areas:

- Some considerations on Tier 1;
- A clearer diagram to aid in the implementation of the Causal Descriptive Assessment of Tier II;
- Some indications regarding Tier II, including a detailed description of the Systems Dynamic Approach for carrying out a modelling approach; and
- Background and practical information on models that can be used to aid in the implementation of Tier III.

Tier 1 analysis

Tier I aims at providing a preliminary indication on the influence of bioenergy production on the price and supply of food. However, it cannot provide precise information on the relevant factors. Therefore, where effects are identified during Tier 1, this result should ideally be complemented with Tier II and, if needed, Tier III analysis.

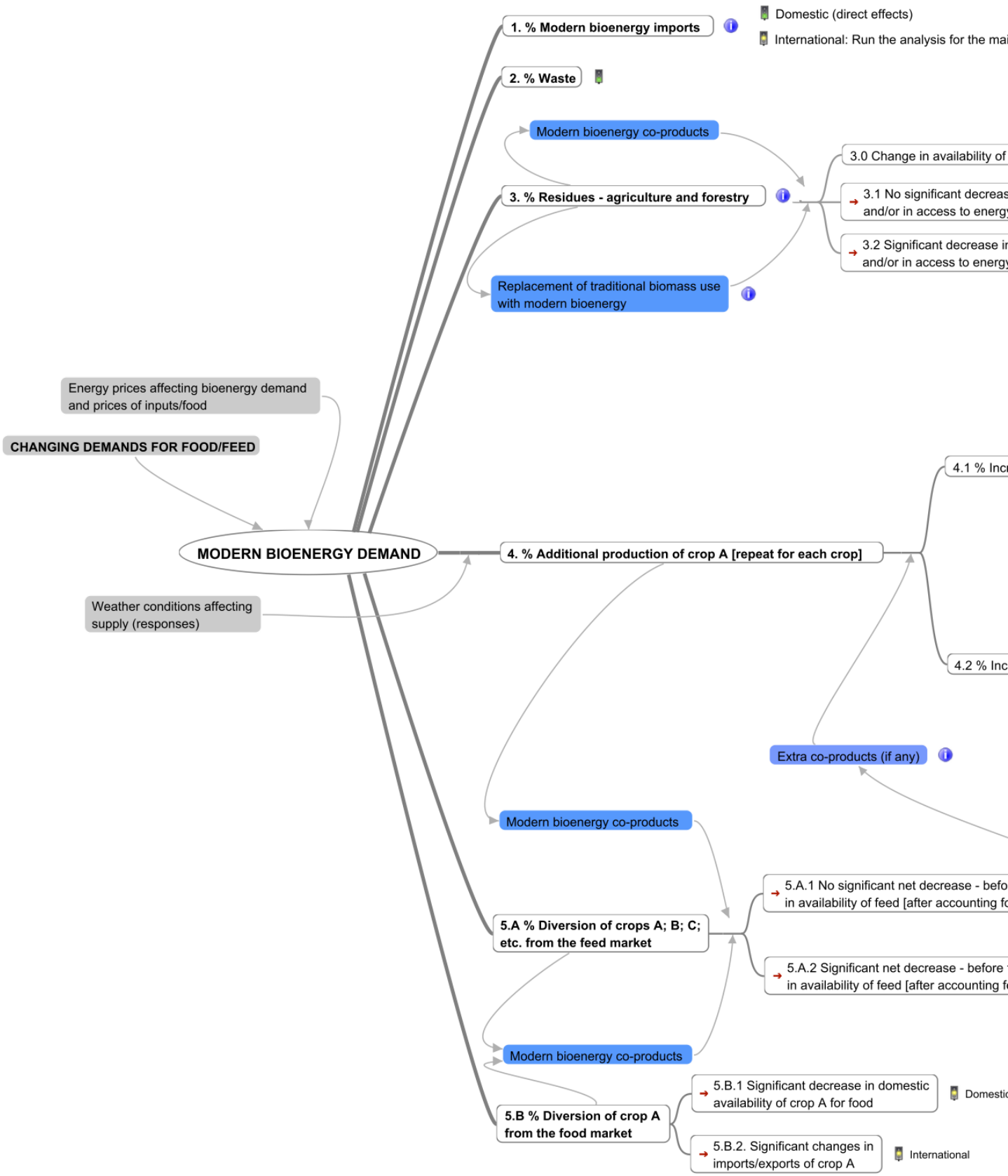
Causal Descriptive Assessment (CDA)

Figure 2 provides a diagram that is supplementary to that on Page 132 of the GSI Report (FAO, 2011a), and that can be used to inform the Tier II CDA.

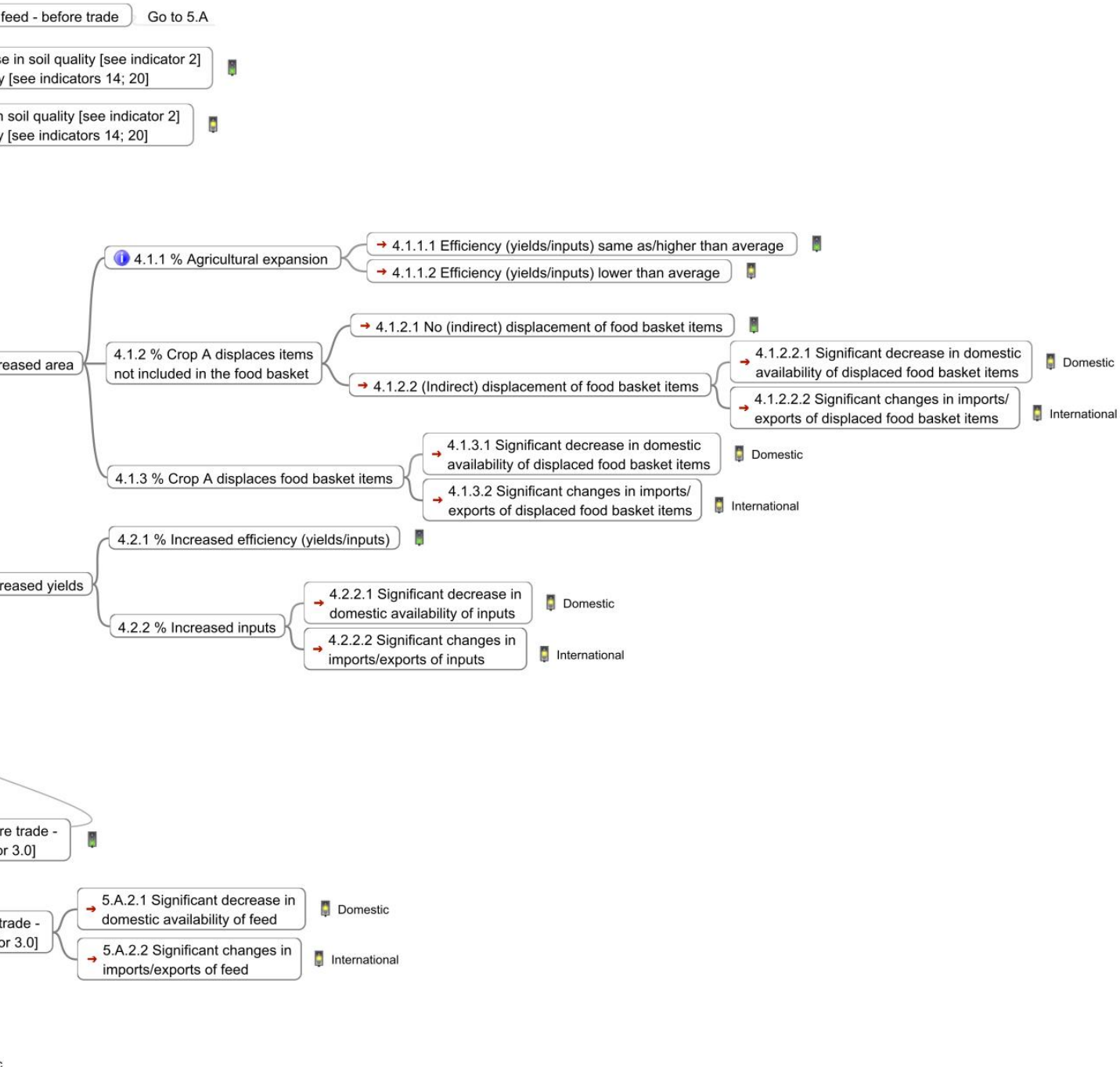
The Tier II CDA provides an understanding of causal relationships and potential local/global, short/long term effects. It is based on interdisciplinary and participatory analysis by national experts, in collaboration with international ones, as appropriate. It requires deep knowledge of the different options included in the pathway. This knowledge can be of a qualitative nature but ideally should be backed by robust,

harmonised and up-to-date data. Experts' opinions should be the first option to undertake Tier II analysis. If it is not sufficient or faces strong challenges, then one could use a system dynamics approach, which is described below. This latter approach can represent a good way to assess the indicator in a quantitative way but still requires quite some knowledge and expertise, as well as data. It can be seen as a 'hybrid' approach between Tier II and Tier III.

Figure 3 - Causal Descriptive Assessment



in countries of origin using the four options below



System dynamics simulation approach to Tier II (Causal Descriptive Assessment)

Overview

The Tier II Simulation Approach can be used in addition to the qualitative component of Tier II, to supplement the insights provided by the multidisciplinary team of experts. It provides a simulation-based assessment of the probability that the demand for modern bioenergy in a given country led to a downward pressure on supply – and to an upward pressure on prices – of the relevant food basket(s) and/or of its components.

A System Dynamics (SD) generic model at the country level is developed to assess this probability. The model covers all the components of the Causal Descriptive Assessment (CDA), represented in Figure 2, accounting for the demand for modern bioenergy (in the context of other relevant factors) and the five different strategies to supply modern bioenergy.

System dynamics is a simulation technique governed by the passage of time where the evolution of the system depends on the behaviour of the system components and their interaction (Sterman, 2000). Mathematically, it is a set of differential and integral equations that represent changes in slopes (rates) and area (accumulation), respectively. Internal feedbacks and the effect of external factors determine evolution patterns of the system over time. The model is designed and constructed through stock and flows that define the rate of change and accumulation.

The CDA is represented in the system dynamics approach through a "Causal Loop Diagram" (CLD), identifying the main feedback interactions as closed loop causal relations (see Figure 3). These relations are then specified in a set of equations and modelled with simulation software. Based on available data and expert knowledge, reference and alternative scenarios and feedstock supply strategies can be defined to explore the system behaviour. The appropriate identification and representation of the CLD relations is the key factor in assessing the effects of modern bioenergy on the price/supply of food basket items. The country-specific refinement of the generic model requires expert judgment and analysis of evidence data to avoid missing important relations. This type of analysis can be carried out through participative discussions on each of the components of the CLD by a multidisciplinary team of experts; preferably covering all the stakeholders involved in the bioenergy, agricultural, land-use and energy sectors.

Depending on the values assigned to scenario variables (combinations of other relevant factors) and strategies (shares of supply pathways for modern bioenergy feedstock), the model determines the probability that the demand for modern bioenergy in a given country led to a downward pressure on

supply – and to an upward pressure on prices. The model can be set to analyse this probability using actual data or trend lines to simulate historic/future behaviour (measured in tons/year, USD/ton, or percentage variation between model runs), or in strict probability terms (likelihood that this pressure will occur, measured in numbers between 0 and 1). These results may be used to determine maximum/minimum levels of pressure, to identify points for further analysis and to find the combination that result on the lower impacts on food security.

Main features of system dynamics simulation in the context of Tier II approach

- **Time-dependent analysis:** SD simulations allow management of time, accounting for short- or long-term effects and delays in the supply for good or production factors, providing a more real and holistic representation of the structure of the system and possible effects at different time horizons.
- **Relation between variables (in the context of other relevant factors):** The bioenergy sector link agricultural and energy markets, with their own specific dynamics, including socio-economic, biological, technological, agricultural and energy components which relation was less evident prior to modern bioenergy. Several complex interactions can be formalized and tested especially when feedstock for bioenergy comes from additional crop production.
- **Alternative scenarios/strategies:** Alternative scenarios for other relevant factors and bioenergy supply strategies can be tested, according to the effective or desired levels. Based on a reference scenario, simulation experiments can be easily run to analyse the effect of changes in external factors and supply strategies in price/supply of food basket items.
- **Recommendations:** Assessing alternative (uncertain, typical, default) values can provide a better understanding of the level of pressure (in the context of other relevant factors) of bioenergy demand on price/supply of food basket items. It can show which factors have the greatest influence and which actions may be recommended from a policy perspective. The analysis of simulation results may help identifying points (“magnifying glass”) for further analysis (Tier III).

Methodology

A generic quantitative model is constructed and implemented through system dynamics (SD) simulation, to assess CDA interactions. The generic simulation approach can be applied to any country, feedstock type or competing food-basket crop, and focuses on the description of the feedstock supply strategies and effects on the price and supply of food basket items. It includes four components:

- **A conceptual model** specifies relations for each component of the CDA that are translated into a generic CLD. Specifically, it defines reinforcing or balancing effects relating price and quantity of the food basket crop, demand for modern bioenergy, and other relevant factors (including biophysical parameters, such as land productivity and additional demands for other uses of the feedstock).
- **A specification model** translates the CLD into a set of equations describing the interaction between endogenous and exogenous variables and parameters. Model specifications include:
    - **Strategic variables:** quantity supplied /price of feedstock under each supply strategy for modern bioenergy and quantity supplied /price of food basket crop.
    - **Scenario variables:** market evolution (domestic demand, exports and imports), technology change (energy, industrial and agricultural yields), biophysical factors (land productivity, total suitable agricultural land, weather), land-use patterns (expansion into non-agricultural land).
    - **Conditions:** (non)equilibrium condition, resources availability.
- **A simulation model** simulates the main market and land-use dynamics between:
    - A representative bioenergy sector, including feedstock (e.g. crude palm oil);
    - A representative food basket crop (FBC) sector (e.g. rice);
    - A representative competing non-FBC (e.g. rubber); and
    - A representative inputs sector (e.g. NPK fertilizer).

  The model assesses changes in the availability (price/supply) of food at the country level between two situations: a reference and alternative scenario. The model can be calibrated for any time step (time between two simulations) and time period (length of the simulation).
- **Designed simulation experiments:** The ultimate objective of simulation experiments is to describe the past effects of bioenergy demand in food security and understand 1) the implication of alternative feedstock supply strategies and 2) the effect of other relevant factors. Four types of simulation experiments are designed:
    1. **Reference scenario:** Set the base line situation without modern bioenergy demand.
    2. **Reference strategy:** Find impact on food security with modern bioenergy demand and current combination of supply strategies.
    3. **Alternative scenario:** Find best/word case scenario with alternative values of other relevant factors.

4. **Alternative strategy:** Find best/worst strategy based on alternative shares of bioenergy supply strategies.

The main advantage of SD simulation is that once the structure of the CLD is well defined and understood, it is easy to develop and construct a tailored simulation model specific for the country context. The country-specific model can be as complex as desired, adding other relevant sectors for the country, multiple competing land and product uses, uncertainty analysis and probability distributions. However, the added value of this complexity should be measured against the understating of the CLD.

Pilot testing in Indonesia – case study

The generic model was developed and tested using the demand for palm-oil-based biodiesel in Indonesia as a case study.

The model implementation for the Indonesian case assesses relative changes in the price/supply of crude palm oil (CPO), a representative FBC (i.e. rice) and a representative non-FBC (i.e. rubber), due to an increase in domestic (and export) demand for CPO as feedstock for biodiesel. The changes are assessed between two points in time: a reference situation (calibrated to 2001, without biodiesel demand); and an alternative situation (set at 2012, with biodiesel demand). The model allows the extension of model horizon for a projected time (i.e. 2025), assessing possible future effects on food security. The model simulated the evolution of oil palm land area and fresh fruit bunches (FFB) agricultural yield and its effects on price and supply of CPO, the FBC and the non-FBC. By comparing model runs, the change in price/supply of the FBC and the CPO was determined. Alternative CPO supply strategies and evolution of external factors were tested to provide policy recommendations for increasing biodiesel supply while reducing undesired effects on price/supply of food and on natural ecosystems.

Figure 3 - Causal loop diagram

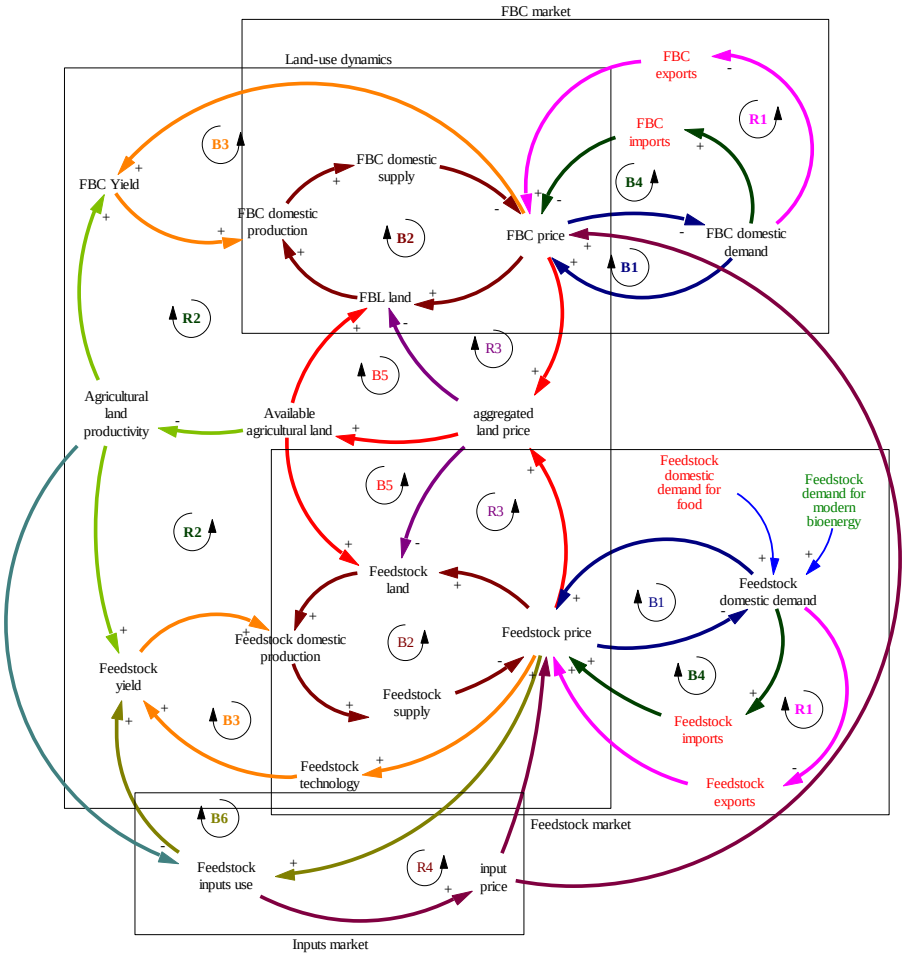


Table 3 - Feedback loops of Tier II Simulation approach

Balancing (B) loops	Reinforcing (R) loops
B1: FBC/Feedstock domestic demand	R1: FBC/Feedstock exports
B2: FBC/Feedstock land	R2: FBC/Feedstock land productivity
B3: FBC/Feedstock yield (technology)	R3: FBC/Feedstock land supply (competition)
B4: FBC/Feedstock imports	R4: Feedstock/FBC costs (inputs)
B5: Agricultural land supply	
B6: FBC/Feedstock yield (inputs)	

Information on Tier 3 modelling approaches

Aglink-Cosimo Model

The Aglink-Cosimo Model is a recursive-dynamic partial equilibrium model of world agricultural markets. It is managed by the Secretariats of the OECD and Food and Agriculture Organization of the United Nations (FAO). The model is used to simulate developments of annual markets balances and prices for the main agricultural commodities produced, consumed and traded globally. It is a partial equilibrium model in that non-agricultural markets are not included and are treated as exogenous variables. The Model is used to generate the *OECD-FAO Agricultural Outlook* and policy scenario analysis.

Both biofuel production and use are incorporated as part of the Aglink-Cosimo Model. Biodiesel and bioethanol production are modelled using both an exogenous and endogenous component. The exogenous component is based on mandates and the endogenous part is a function of lagged production, the relation between output prices and feedstock costs and a trend component. The use of biofuels is separated into a use of biofuel feedstocks (which includes a technical time component to account for advances in technology) and the direct use of biodiesel and bioethanol (with two main components: a market-driven part and a mandate-driven part).

Further information and documentation on the Aglink-Cosimo Model can be found on the website[23]. There is also the opportunity for countries to collaborate on the use of the Model for biofuels at country level and the Secretariats are available for capacity development activities in this respect.

[23] www.agri-outlook.org

Indicator 11: Change in Income

Main Implementation Challenges

The main implementation challenges relate to the cross-cutting issues of data availability and attribution.

Data

Availability of - and access to - detailed data related to wages and prices might be an issue in a number of countries, due, among other things, to the commercially sensitive nature of part of this information.

In some cases, the compensation received by wage workers includes goods (e.g. food, sugar, etc.) and services. The available data might not always properly account for this.

Disaggregated data for bioenergy specifically is often not available. Data on wages, in particular, tend to be available by broader sectors, e.g. agriculture and industry. This is also an attribution issue (addressed below).

Attribution

There are two main attribution issues:

1. The first, as mentioned above, is that disaggregated data for the bioenergy sector is often not available. Therefore, for sub-indicator 11.1 (wages paid for employment in the bioenergy sector in relation to comparable sectors), the wages in the bioenergy sector are subsumed by other sectors, making comparison difficult or impossible.
2. The second issue arises where there are multiple co-products within one value chain. The income should be attributable to bioenergy and distinct from other non-bioenergy-related income. Especially for complementary products of the same value chain, it is difficult to attribute changes in income to the bioenergy pathway. This is a very specific question that is related to research activities; it is difficult to observe the incomes based on different crops/feedstocks or even the same crops/feedstocks for bioenergy and non-bioenergy on a regular basis.

Guidance

When this indicator is measured, inflation-adjusted figures should be used and the effect of feed-in tariffs (if any) should be considered.

Data Collection Strategies

Cooperatives and associations of workers and producers may represent good sources of data.

For sub-indicator 11.2, data are required on the income from the sale, barter and/or own-consumption of bioenergy products, which could be collected through household surveys. Some guidance on the collection of these data with a Woodfuel Supplementary Module to be incorporated into existing household surveys can be found in *Annex 5 – Further resources*. The collection of primary data through household surveys is quite resource intensive. Therefore, the feasibility of undertaking it during the assessment of GSIs should be carefully pondered during such type of work. The GSI assessment team may use part of the questions of the survey, as appropriate, to ease its own work. However, beyond the assessment of GSIs, the inclusion of these questions in national surveys can represent an efficient and effective method for institutionalising data collection for long term monitoring, not only for the GSIs but also other national and international processes for which these data are required.

Attribution

The two attribution issues noted above may be approached as follows:

1. The first question is not an attribution issue *per se* but a matter of lack of sufficient data, i.e. *How can wages paid for employment in the bioenergy sector be assessed in relation to comparable sectors?* The following tier approach could be used:
    - TIER 1: An estimation could be done by analysing market prices for other agricultural goods (e.g. foodstuff) in comparison to bioenergy products based on typical annual yields of farms.
    - TIER 2: If information exists for the agricultural sector in total, a special (representative) survey could be launched for bioenergy production only and compared to the entire agricultural sector.
    - TIER 3: Established statistical data is available and collected frequently with a specific survey about employment in bioenergy.
2. For multiple co-products within one value chain, the question is: How should the income from multiple co-products be attributed to bioenergy and non-bioenergy related income? Especially how can complementary products of the same value chain be attributed to different income levels? The following tier approach could be used:
    - TIER 1: An estimation could be done by comparing market prices for products for bioenergy uses to market prices for non-bioenergy uses. This could be a proxy indication for the income situation of people working in the sector.

- TIER 2: National statistics about the income situation of different employments comparable to the bioenergy and non-bioenergy farms and industries could be analysed and used.
- TIER 3: A representative survey about the income of employees from respective farms and industries could be conducted with different share of bioenergy and non-bioenergy products.

Indicator 12: Jobs in the bioenergy sector

Main Implementation Challenges

The main implementation challenges relate to the cross-cutting issues of data availability and attribution.

Data

Given the relative novelty of the bioenergy sector, data may be scarce. In particular, disaggregated data for bioenergy production specifically is often not available, neither on the feedstock side nor on the processing side. Bioenergy-specific data disaggregated into skilled/unskilled and temporary/indefinite jobs are even rarer.

Markets are changing dynamically, which changes the situation of jobs. This means that extremely up-to-date data needs to be collected to be relevant for the measurement of the indicators.

Attribution

It may be difficult to determine the exact number of jobs created and lost/displaced as a result of bioenergy production and use (to give net job creation figure).

Guidance

Data Collection Strategies

Primary data may need to be collected from surveys, extrapolated, and verified with results found from secondary sources.

Attribution

This attribution issue is a matter of existing statistical figures.

When determining the answer to the question: *What is the exact number of jobs created and lost/displaced as a result of bioenergy production and use?*, the following tier approach could be used:

- TIER 1: Estimations can be made by observing the number of total jobs in the agricultural sector compared to the production figures of conventional products and bioenergy products. (This does not include the whole value chain.)
- TIER 2: Surveys about the job creation in bioenergy can be made on an individual basis for research purposes.
- TIER 3: Established statistical data about jobs in the bioenergy sector is available and collected on a regular basis.

Indicator 13: Change in unpaid time spent by women and children collecting biomass

Main Implementation Challenges

Data

Data availability might be an issue in some developing countries, for instance, data was not available in the pilot countries, due mainly to the fact that woodfuel is often collected/traded in the informal market.

Given the lack of secondary data, this indicator relies heavily on surveys and thus may be resource intensive. Furthermore, there is a need for representative surveys (large sample over several months where seasonality exists).

Gender neutrality

Experiences in Indonesia and Paraguay have shown that, in some cultures, it is the male family members who typically collect biomass (rather than the women or children).

Guidance

Data

As mentioned above, in many cases, data needs to be collected through household surveys. Where questions are not already incorporated into existing household surveys, The Global Strategy for Improving Agricultural and Rural Statistics (GSARS) provides some guidance on the collection of these data with a Woodfuel Supplementary Module; information can be found in *Annex 5 – Further resources*. The collection of primary data through household surveys is quite resource intensive. Therefore, the feasibility of undertaking it during the assessment of GSIs should be carefully pondered during such type of work. The GSI assessment team may use part of the questions of the survey, as appropriate, to ease its own work. However, beyond the assessment of GSIs, the inclusion of these questions in national surveys can represent an efficient and effective method for institutionalising data collection for long term monitoring, not only for the GSIs but also other national and international processes for which these data are required.

Gender Neutrality

This indicator was initially developed to investigate unpaid time of women and children collecting biomass, as they are traditionally the members of the household responsible for this task. However, it is recognised that this is not the case in all countries. Therefore, when implementation of this indicator is carried out, the local contexts should be taken into account and, if necessary, a gender-neutral version of

this indicator could be adopted, for instance “Change in unpaid time spent collecting biomass per household”. Gender disaggregation of data can be used in order to understand these aspects.

Potential extensions of the Indicator

Potential extensions of this indicator will depend on national context and priorities.

A further dimension to this indicator was raised from experience of its measurement in Paraguay (FAO, 2018). Overexploitation of forest resources can lead to deforestation, which, in turn, can lead to increases in the time required for collecting biomass. However, at a certain point biomass becomes so scarce that it then has to be purchased, rather than gathered. This represents an interesting trend of increasing time for collection until a tipping point past which the time taken reduces to zero but the *cost* of biomass increases to substitute this saved time. Therefore, as an extension to this indicator, the *opportunity cost* of traditional biomass (rather than just time) could be considered.

This indicator could also be extended to include the time saved in cooking and cleaning compared with traditional biomass use, which are also important for households.

Indicator 14: Bioenergy used to expand access to modern energy services

Main Implementation Challenges

Definition of modern bioenergy

This indicator is problematic because of the necessity to distinguish between traditional and modern bioenergy. For different energy pathways, 'modern' may have varying definitions that depend on feedstock, energy efficiency, emissions and technology used. It is very difficult to provide indicative ranges or cut-offs for modern bioenergy for each bioenergy technology as it may be dependent on the local contexts.

Attribution

Excluding the case of decentralized energy production from biomass sources, in all other cases attributing an increase in access to modern energy services to bioenergy poses challenges both in terms of data requirements and methodology.

Guidance

Definition of modern bioenergy

As mentioned in Section 1.1.1, modern bioenergy can have many definitions, therefore it is important to clearly outline the definition of modern bioenergy being used and provide a solid justification for why that particular one was chosen.

Where there are difficulties in distinguishing between traditional and modern bioenergy, local stakeholders may be charged with deciding the definitions used for the measurement. This includes decisions on 'modern' technology, efficiency levels that constitute 'modern' levels and amounts of acceptable emissions (both greenhouse gas and non-greenhouse gas). These decisions, and the reasoning, should be made explicit in the project report.

Proxies

In the case that it is not possible to carry out an exact quantitative measurement, it would still be useful to attempt a semi-quantitative or qualitative estimate (based on expert judgement, supplemented by qualifying case studies) of the contribution, over time, of bioenergy to access to modern energy services. The impacts of this improved access are then captured under other indicators (e.g. health captured under Indicator 15).

Attribution

After analysing the implementation of this indicator already carried out at the national level, only in Vietnam were calculations carried out for this indicator. The case of Vietnam shows that specific information is needed to make estimations for the measurement of the indicator. It can be concluded that the possible attribution issue can be addressed by conducting studies that use the basic information available in a country.

Indicator 15: Change in mortality and burden of disease attributable to indoor smoke

Main Implementation Challenges

The main implementation challenges relate to the cross-cutting issues of data availability and attribution.

Data

In order to measure a change, reliable statistics based on sound epidemiological studies and covering an adequate period of time are needed, i.e. statistics or surveys that cover a time window sufficient to describe the development of chronic diseases caused by household air pollution from cooking (thus targeting the family members more exposed).

Attribution

The measurement of this Indicator has proved problematic during Implementation because of the difficulty of attributing health impacts to indoor smoke. It is very resource intensive to carry out interviews or studies to quantitatively measure this Indicator.

Guidance

Data

As mentioned above, reliable statistics are required to measure this indicator. The Global Strategy for Improving Agricultural and Rural Statistics (GSARS) provides some guidance on the collection of data on health problems from the use of woodfuel. This Woodfuel Supplementary Module can be incorporated into existing household surveys in order to capture reliable and comparable data on the impacts of the production and consumption of woodfuel in the informal sector; information can be found in *Annex 5 – Further resources*. The collection of primary data through household surveys is quite resource intensive. Therefore, the feasibility of undertaking it during the assessment of GSIs should be carefully pondered during such type of work. The GSI assessment team may use part of the questions of the survey, as appropriate, to ease its own work. However, beyond the assessment of GSIs, the inclusion of these questions in national surveys can represent an efficient and effective method for institutionalising data collection for long term monitoring, not only for the GSIs but also other national and international processes for which these data are required.

Attribution

The “change in mortality and burden of disease attributable to indoor smoke” is an effect at the very end of the cause-effect-chain starting from living conditions to final health effects. That makes it difficult to

link the measurement of the final effect (change in mortality, change of burden of disease) to one specific aspect of the change of living conditions – amongst many others – like the "decrease of indoor smoke by using increased deployment of modern bioenergy services".

The measurement of the indicator includes two components. In the first place, change in mortality and burden of disease have to be measured by statistics, which should be available in most countries at a general level. The challenge is then to separate health risks of individuals in order to reach conclusions for a population and a specific risk, which is made with the help of epidemiological studies. Further to this, statistical data is needed about what has changed in households and to what extent. The deployment of modern bioenergy services is one factor of many.

It is possible to implement a measurement of this indicator with the help of primary statistics and supporting scientific knowledge. The attribution issue is mixture of having access to statistics and applying scientific evidence to the cause-effect-chain.

Instead of proposing a TIER approach, it should be considered if the content of this indicator could be addressed by a proxy indicator, e.g. "number of households with indoor cooking stoves" or "change in number of households with indoor cooking stoves" (see below).

Proxies

Where causal attribution of health impacts to indoor smoke is difficult to obtain, there are a number of potential proxies for this Indicator, which are described below.

Number of homes relying on combustion of solid cookfuels

Simple proxy of the number of homes relying on indoor combustion of solid cookfuels, with or without "ventilation" (which may be hard to determine easily without inspection). Many dozen health studies have found this a reasonable indicator of ill-health (Smith et al., 2014).

This proxy would not include gas or liquid fuels, however, even with no ventilation. The exception being kerosene, which studies have shown to be a bad actor (e.g. Apple et al., 2010). Most countries, however, are now discouraging or regulating its use for cooking and lighting.

The HAPIT model, developed by University of Berkeley[24], could be used to obtain conservative default values for four broad classes of household energy interventions based on the available literature - liquid fuels, chimney stoves, rocket stoves, and advanced combustion stoves. It could therefore be used to determine the changes in burden of disease from shifts from solid cookfuel use to these more modern alternatives.

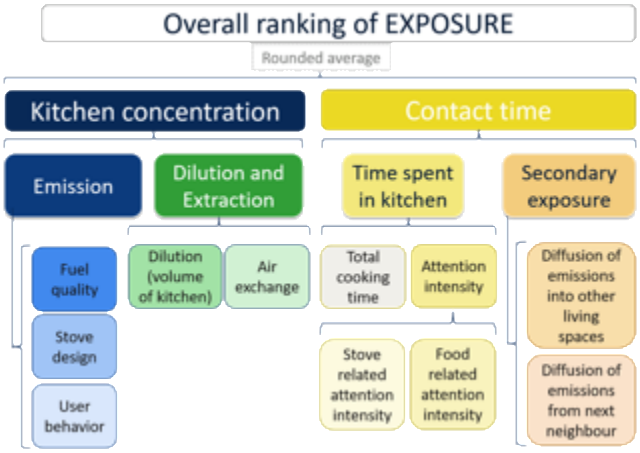
Risk Assessment approach

Risk assessment of exposure to indoor smoke (including time spent cooking, technology used, etc.). This provides a qualitative assessment of the risk of health impacts, based on the ranking of exposure and frequency.

The Cooking Energy System (CES) Evaluation by Energising Development (EnDev) provides this type of risk assessment, within the framework of the Multi-Tier Framework (MTF) revision of the Global Tracking Framework (GTF) to measure progress towards access to modern energy services under the SDGs (Bhatia & Angelou, 2015). EnDev evaluates quality and effects of access to cooking energy, based on field-based approximations and household surveys. It considers the most important factors of many dimensions of the cooking context and the interaction of factors determining the impact experienced by beneficiaries: fuel, stove, user and kitchen (Energising Development (EnDev), 2017a). The CES has models based on both calculated exposure (based on lab test results) and an exposure assessment by proxy indicators. The set of factors for both the modelling and proxy assessment of exposure levels can be seen in Figure 4.

[24] HAPIT 2.0. is available as an online tool: https://hapit.shinyapps.io/HAPIT/

Figure 4 - Factors considered for ranking of exposure. Credit: EnDev, 2017b



Proxy linked with Indicator 4

A proxy linked to the results of Indicator 4 on non-GHG emissions at household level, used to indicate quantities of smoke and, by linking with epidemiological studies, the potential health impacts.

Indicator 16: Incidence of occupational injury, illness and fatalities

Main Implementation Challenges

Data

The data for occupational injury, illness and fatalities is owned mainly by the private sector, having no incentive for reporting/sharing such data.

There is also a lack of availability of adequate data with the level of disaggregation required in order to conduct a specific analysis for the bioenergy sector.

Capacity

It is fundamental, as in the case of any other indicator on which information is held primarily by the private sector, to partner with relevant organizations and strengthen the capacity to produce relevant statistics in order to monitor this indicator. It is also important to develop the capacity of national policymakers to design policies that discourage informal jobs in bioenergy and require mandatory insurance regimes.

Attribution

As mentioned above, better disaggregation of data is required to conduct this analysis specifically for the bioenergy sector.

Other

In addition to understand baseline conditions, if possible, conditions under a bioeconomy should also be assessed.

Guidance

Data

In general, agro-industries have data on occupational injury, illness and fatalities (e.g. in Brazil). Insurance companies have these data as well, but only for insured workers, which generally represent a relatively small share of total workers, especially in the agricultural sector of developing countries. The data owned by agro-industries and insurance companies, however, may not be publicly available.

Capacity

It is fundamental, as in the case of any other indicator on which information is held primarily by the private sector, to partner with relevant organizations and strengthen the capacity to produce relevant statistics in order to monitor this indicator. It is also important to develop the capacity of national policymakers to design policies that discourage informal jobs in bioenergy and require mandatory insurance regimes.

Attribution

The availability of satisfactory statistical data is the main shortcoming concerning this indicator. Hence, the attribution issue is a secondary problem if data about occupational injury, illness and fatalities are collected at a general level and have to be assigned to bioenergy activities.

The question then becomes: *How can occupational injuries, illness and fatalities be assigned to the bioenergy sector?* The following tier approach could be used:

- TIER 1: Use existing occupational health statistic and use given subdivisions such as agricultural operations, forestry, etc. for a first estimate for the bioenergy sector.
- TIER 2: A specific stand-alone survey will give a picture of the situation. It can be combined with the approach described in TIER 1.
- TIER 3: Establish occupational health statistics with a subdivision for workers in the bioenergy sector and collect this information on a regular basis.

2.3. Economic Pillar

Indicator 17: Productivity

Main Implementation Challenges

Data

Lack of data has been recognized as a problem for the calculation of sub-indicators 17.1 and 17.4.

With regard to sub-indicator 17.1, problems may arise for many dedicated energy crops (e.g. Jatropha *spp*., Miscanthus *spp)*, for which official statistics have not yet been developed.

Data on production costs (sub-indicator 17.4) are, by their nature, "confidential" since they belong to the private sector. Therefore, they are not available in official statistics and refer only to the firm level.

Scale and representativeness of plant-level data

When data are not available in official statistics, there is the need to validate and upscale results from research studies or obtained by the private sector at a plant level, also taking into account the rapid changes in the technology.

Attribution

For productivity, there are a number of attribution issues to be considered. The main aspect is co-product allocation within a production process providing several products. For instance:

- where a feedstock input (e.g. soybean, sugarcane, etc.) has a number of different uses outside of the bioenergy value chain; and
- where co-products from the production process are used together with the main feedstock (as with sugarcane bagasse and molasses both used for ethanol production).

However, two other considerations also complicate the attribution issue for the productivity indicator. First, as it is defined in the GSI Report, Indicator 17 relates to two different types of productivity:

- productivity per area of land (indicator 17.1 and 17.3); and
- productivity related to the energy output of the feedstock (indicator 17.2 – MJ output per tonne input; indicator 17.4 – USD revenue per MJ output).

Furthermore, Indicator 17 may be used at different spatial levels:

- at the farm level;
- at the level of a landscape or region; or
- at the national level.

Guidance

Data Collection Strategies

When data from official statistics are available, they should be utilized. In the case of indicator 17.1 this may be challenging for dedicated energy crops as data are not available in most cases. When not available, a representative farm approach can be utilized.

For sub-indicator 17.4, where data on production costs are needed, in most cases data are available only at plant level. These data are, by their nature, "confidential" since they belong to the private sector. For this reason, these data may often need to be collected through questionnaires and interviews with stakeholders and sometimes this requires a confidential agreement with the interviewed company/industry. Where data is available, the measurement of sub-indicator 17.4 can typically be carried out using an LCA approach, calculating all cost components along the value chain. However, where this is not feasible, a 'black box' approach can be used, where the final cost of one unit of energy is provided by bioenergy producer.

Scale and representativeness of plant-level data

Overall, the guidance is to use the best available data in terms of being representative of the process being assessed, and in terms of robustness (quality, validity, sample size).

When using plant-level data, a sufficient number of plants should be surveyed to ensure robustness, and the representativeness of the data collected should be ensured through validation. For well-established, large-scale value chains, the processing technologies and productivity are typically standardized regionally or nationally and average figures therefore exist for these pathways. In the case of small-scale production pathways, average figures may not provide a good overview of the pathway, given the broad differences in plant technologies and management, feedstocks and production costs.

At the farm level, productivity of bioenergy feedstock can range widely due to a number of factors, including geography and cultivation system (intensive/extensive systems, large/small scale farms, management practices, etc.). It may be necessary to distinguish different scenarios for feedstock production and calculate the indicator separately for each scenario.

In order to ensure representativeness of data gathered at plant-level, different scenarios may need to be considered, on the basis of plant scale (small/large scale), geography or other variables that can affect production efficiency due to differences in technologies and plant management capability. A desk analysis

of existing relevant studies can provide information on plant size and technology (e.g. plant scale, maximum working potential, amount of feedstock processed per hour, number of hours worked in a year, actual amount of feedstock processed per hour and number of hours actually worked in a year, etc.), which can be used directly as a substitute for primary data collection or utilized for subsequent verification of the coherence of collected data and explanation of causes of relevant divergences. It should be noted that in large countries, agricultural and industrial productivity may vary according to region and therefore regional statistics will need to be obtained.

Attribution

According to the aspects discussed above, different attribution issues may arise. The following tier approaches can be used when tackling co-product allocation, bearing in mind the two types of productivity of the indicator:

1. Multi-output processes with different amounts of (bioenergy) products or co-products have an influence on the productivity. The productivity indicators (17.1) and (17.3) refer to a productivity per area (feedstock productivity). How can the hectare-productivity be assigned to a given bioenergy feedstock at farm level?
    - TIER 1: Use allocation factors determined for a specific case e.g. nutrition content, carbon content, etc. as specifically determined for a country and a type of plant production.
    - TIER 2: Use economic value of products with original data from a farm (value of products at the point of sale from the farm).
    - TIER 3: Use energy content (lower heating value) of material flows as allocation factor with original data from a farm.
2. Multi-output processes with different amounts of (bioenergy) products or co-products have an influence on the productivity. The productivity indicator (17.2 MJ/Tonne) refers to energy input to produce feedstock output. How can this productivity be assigned to an amount of a specific feedstock output at farm level?
    - TIER 1: Avoid allocation by measuring the energy input related to the output of total biomass (gives no specific information for bioenergy feedstock but for the efficiency of total biomass production).
    - TIER 2: Use economic value of products with original data.
    - TIER 3: Use energy content (lower heating value) of material flows as allocation factor with original data.

The GSI report provides further guidance on the attribution issues under “Scientific Basis” and “Methodological Approach”.

Indicator 18: Net energy balance

Main Implementation Challenges

Main implementation challenges for this indicator are:

- Data – sub-indicators are data intensive and collection of plant-level data may be complicated by confidentiality issues;
- Defining system boundaries of *Sub-indicator 18.4 – Lifecycle analysis (LCA)*;
- Capacity building for computing the LCA; and
- Aggregation of different pathways.

Guidance

Data

Sub-indicator 18.2 – processing of feedstock into bioenergy requires collection of data at the plant level, aggregation/extrapolation and then validation through expert consultation. Where there are confidentiality issues related to data collected at plant level, a 'black box' approach can be used: collecting from technology providers energy input and output without detailing energy flows. Although this method requires trust with technology holders, it is an option when disaggregation is not possible. It may also be cheaper and faster as it is less data intensive.

With regard to *Sub-indicator 18.3 – bioenergy use,* several hypotheses need to be made as the ratio depends on the technology for end use (e.g. electricity generator, transport vehicle, etc.). These data are usually not available in national statistics, therefore, it is essential to refer to studies and validate them with stakeholders.

Defining system boundaries

In approaching this indicator, the first step is the definition of the system boundaries of the supply chain to be examined, as this will determine which of the sub-indicators are relevant for the analysis. For example, when the feedstock is waste (in the case of biogas produced from manure), sub-indicator 18.1 is not relevant. It is recommended to estimate all sub-indicators that are relevant to the supply chain in order to identify where efficiency gains can be pursued.

System boundaries are essential for Sub-indicator 18.4, as it utilizes an LCA approach, and boundaries are required to facilitate comparison across years and countries. It is important that the boundaries of energy inputs and outputs for the analysis are clearly stated when reporting the methodology used for this indicator. Three main considerations should be taken into account when making the decision about which

steps in the value chain to include: delineation between the system being considered and the natural environment (e.g. lifecycle analysis for fossil fuels usually starts from the extraction phase); geographical area; and time horizon (EC, 2006). Where by-products are used (for example, the use of bagasse during ethanol processing), the treatment of these data needs to be made clear.

In addition to the supply chain segments defined for the other sub-indicators, Sub-indicator 18.4 should also consider the amount of energy spent in collecting, transporting, storing and distributing both the feedstock and the bioenergy products and co-products. The LCA could incorporate the same system boundaries as those used for other LCAs, for example those used for Indicator 1 (Lifecycle GHG emissions), 4 and 17. This ensures consistency between indicators and may increase efficiency during implementation.

Aggregation

This issue arises in all case where different feedstock types, cultivation systems and technology paths are present in a country for the production of the same kind of bioenergy. Aggregation should use weights based on the relative share of total bioenergy production. For example, where two types of feedstock (e.g. maize and sugarcane) are used to produce ethanol, their relative shares should be used as weights when aggregating values for the indicator.

Energy ratio

The energy input depends heavily on the cultivation system and technology in place. An example of alternative feedstock cultivation practices is the use of vinasse instead of chemical fertilizer in feedstock production (Sub-indicator 18.1) or an example of an alternative technology is the use of bagasse in sugar mills to produce ethanol (Sub-indicator 18.2). The estimation of energy ratios as described in the GBEP methodology is in any case required in order to evaluate the energy efficiency of each value chain.

It may be an interesting *additional analysis* to express energy ratio as 'input of non-renewable/output of renewable', for sub-indicators 18.1, 18.2 and 18.4 in order to measure the extent to which bioenergy is displacing fossil fuels, thus contributing to sustainable development.

Indicator 19: Gross value added

Main Implementation Challenges

Main challenges for this indicator come from:

- Data availability – the availability of sufficiently detailed and up-to-date information (e.g. with regard to the value of intermediate inputs) might be an issue in some countries. Data can be estimated at plant level and inferred at the national level, although validation of representativeness is required, and there may be confidentiality issues.
- Attribution – the bioenergy sector is not included as a single economic sector in the System of National Accounts (SNA), and gross value added (GVA) data for the sector is not available in some countries.
- Representativeness of plant-level data – as data are not available in official statistics in some countries, there is the need to validate and upscale results from research studies or obtained from the private sector at a plant level.

Guidance

Attribution

The indicator can be measured at both plant and national level. In the latter case, the utilization of official statistics should be considered. The SNA is the most anticipated data source at national level. GVA can be broken down by industry. However, the bioenergy sector is not always disaggregated as a single sector in the SNA. In this case, attribution issues should be considered; they arise and may be solved with the help of economic allocation because this is the underlying attribution principle for SNA. However, this work can only be done by national statistical offices.

Where national statistical offices cannot analyse the bioenergy sector separately within the SNA, proxies provide an alternative approach to handle these data constraints. For example, investment and economic turnover can be used as a proxy for GVA as these data may be more readily available from national statistics.

In the absence of national level statistics, as well as information regarding the GVA generated by the production of a certain biofuel at national level, the estimated gross profit per unit of energy of a representative plant producing such biofuel could be used as a proxy. For example, proxies can be estimated by subtracting intermediate inputs from total output value or from gross profit per unit of energy using data of representative companies. When measuring the indicator at plant level, one has to consider the representativeness of the plant or company selected as a case. GVA depends heavily on the operation system (e.g. feedstock, scale, conversion technology, etc.) applied to the plant. The reason why

the plant represents the whole national bioenergy sector should be clearly explained, for example, that the production of the plant represents a high percentage of total production in the country.

The following tier approach could be used for Indicator 19 when determining the gross value added per unit of bioenergy:

- TIER 1: Conduct case studies and extrapolate to the national level.
- TIER 2: As a proxy for this indicator, investments and annual turnover for bioenergy can be used, as these are the monetary inputs to economic sectors that generate additional value.
- TIER 3: The System of National Accounting should be used for a sub-division of bioenergy. SNA applies economic allocation of the sector.

Data Collection Strategies

Following the above tier approach, the following data collection strategy could be followed:

(1) Consider obtaining national data from official statistics

In the SNA (UN, 2009), gross value added is defined as:

GVA = Total output value – intermediate inputs

Indicator 19 also applies this definition. The SNA is a well-organized and internationally-standardized set of data on economic activities. Normally, GVA data is obtained from the SNA. In addition, not only national statistics, but also international databases of the World Bank, International Monetary Fund, and the United Nations can be data sources.

As the indicator is intended to show the size of the contribution of the bioenergy sector to the national economy and GDP per unit of bioenergy, the indicator should be assessed explicitly for the bioenergy sector. However, where the bioenergy sector is not disaggregated as a single sector in the SNA, a different data collection strategy must be followed.

(2) Look for a proxy at national level

- Disaggregation of SNA

If no disaggregated data on the bioenergy sector are available from the SNA, a good alternative proxy for the indicator would be data at industrial level or by energy type. Disaggregation of the SNA data using certain coefficients could be another option for a proxy. For example, GDP of bioenergy sector can be estimated by multiplying the share of bioenergy by GDP of all energy sectors.

- Use of national input-output table

Use of national input-output table (IOT) is also an option. IOT is compiled along with the SNA as national economic statistics, and both total output value and intermediate inputs are recorded. Since it is generally more disaggregated into subsectors compared to SNA, data for bioenergy might be obtained more easily.

(3) Look for a proxy at plant level

If no data are available at national level, the second option is to use proxies of a representative plant. At plant level, GVA generally equals gross profit (GP) and it is estimated using the following formula:

$$GP = \text{net sales} - \text{cost of goods sold}$$

Where:

$$\text{Net sales} = \text{gross sales} - \text{customer discounts} - \text{returns} - \text{allowances}$$

In this case, data is obtained from research studies or obtained from the private sector. This data is collected for the calculation of sub-indicator 17.4. Where a black box approach has been used for indicator 17, one should ensure that the costs do not include depreciation or amortization so as to obtain the gross profit for the calculation of indicator 19.

Confidentiality of the data is still a concern. Normally GP is highly confidential, particularly for private companies. In addition, when measuring the indicator at plant level, there is the need to validate and upscale results obtained. In this case, the reason why the plant represents the whole national bioenergy sector should clearly be explained. Aggregation and average of multiple plants is one of the solutions for representativeness problem. Indicating the share of the representative plants among bioenergy sector is also a measure to confirm the representativeness.

Indicator 20: Change in the consumption of fossil fuels and traditional use of biomass

Main Implementation Challenges

Main challenges for this indicator come from data availability in developing countries, mainly when domestic use of traditional biomass is concerned.

Guidance

When measuring the indicator at national level, the utilization of official statistics should first be considered. Data are usually collected at national level with the purpose of monitoring national energy strategies and they are divided between different uses (transport, electricity, thermal power). Data needed for sub-indicator 20.2 are never available in official statistical but can be collected in surveys on household consumption. Some guidance on the collection of these data with a Woodfuel Supplementary Module to be incorporated into existing household surveys can be found in *Annex 5 – Further resources*.

In some cases, data from Indicator 11 can be used on change in income from savings due to self-consumption of fossil fuels (e.g. LPG) or traditional biomass (e.g. charcoal).

Scope of indicator

As the main focus of the indicator is the contribution of domestic bioenergy production to energy security and to the balance of payments, consumption of imported bioenergy should not be considered. For the same reason, exports of bioenergy produced in the country should be considered when estimating indicator 20.1b (annual savings – or earnings – from reduced purchased of fossil fuels or increased sales of bioenergy).

In measuring the substitution of fossil fuel with domestic bioenergy, four scenarios are possible:

- All bioenergy used in the country is produced domestically: estimation of indicators 20.1a and 20.1.b is straightforward;
- All (or part) of bioenergy is imported: only the domestic production of bioenergy is considered;
- Biomass is imported and is processed to produce bioenergy: Indicator 20.1a: the bioenergy produced is accounted for the substitution of fossil fuels (indicator 20.1a) but in terms of saving (20.1.b) only the net value added is considered (i.e. savings = expenditure for fossil fuels – (purchases of imported biomass - sales of modern bioenergy).

Indicator 21: Training and re-qualification of the workforce

Main Implementation Challenges

Data

Data are generally not available but they might become available if the country puts in place a national strategy on bioenergy that includes training of workers.

Guidance

Data

If national data are not available, a specific survey at a representative plant level can be performed. This kind of data is usually not considered sensitive and it should be available in large companies, or from industry organisations/unions. Results could be inferred at the national level, subject to validation from experts.

Indicator 22: Energy diversity

Main Implementation Challenges

The definition of the indicator is clear, but there may be some issues on data availability.

Data

In some countries there may be data availability issues. To assess the indicator, data for energy sources (not only bioenergy but also all other types of energy including fossil fuels) is required. Some countries have well-organized databases for energy, but others might not. In addition, data for traditional bioenergy that is used without commercial transactions (e.g. self-consumption or informal trading) like woodfuels (including charcoal) is also difficult to obtain at national level.

Aggregation level

In countries where the share of bioenergy is very small, this indicator may be difficult to measure.

As mentioned in the GSI Report, (dis)aggregation of different categories of energy supply impacts the results of the HI calculation and requires expert judgement. This entails specific knowledge of the country context in order to understand what types of energy bioenergy has replaced/is replacing in the country and calculate the change in the energy diversity.

Guidance

Data Collection Strategies and valuation

(1) Obtain the data on Total Primary Energy Supply (TPES)

Data on TPES from each source and domestic bioenergy production should be collected. These data can be obtained from international databases (e.g. IEA energy statistics) as well as national databases.

(2) Calculate the shares of energy source

Once TPES data is obtained, the share of each source in TPES should be calculated. These figures are indicated in percentage. As mentioned above, the indicator values heavily depend on the level of aggregation, therefore, users should disaggregate the energy source as much as possible, based on data availability.

(3) Calculate the Herfindahl Indices (HIs)

Based on the share of TPES, HIs for both with/without bioenergy should be estimated using the following equation:

$$\mathrm{HI} = \sum (ES_1^2 + ES_2^2 + ES_3^2 + \cdots + ES_n^2)$$

Where, ES_i is the energy share supplied by from energy source *i*. To estimate HI without bioenergy, users should simply exclude bioenergy sources from the calculation. In this case, the share belonging to bioenergy should be attributed to its assumed most direct substitute. Expert knowledge of the country context should be used for this assumption. For measuring HI with bioenergy, all energy sources including bioenergy sources should be taken into account. Note that a higher energy diversity is represented by a lower HI value (a value closer to 0). Therefore, a lower indicator value indicates higher energy diversity and would suggest greater sustainability of bioenergy (energy diversity). For the examples of HI estimation, see tables in Page 196 of the GSI report (FAO, 2011a).

The indicator is defined as "change in diversity of total primary energy supply". To calculate the change in energy diversity (difference between with and without biomass), the HI values for the two scenarios are compared. The contribution of bioenergy to energy diversity ($HI_{No\ bioenergy} - HI_{Bioenergy}$) is shown as a negative value as the indicator decreases along with higher energy diversity.

(4) State the level of aggregation clearly

Finally, users should mention at which level the sources are aggregated as well as indicating the HI. This can validate the results of assessment. As the unit is common (TPES) to each energy source, the aggregation itself is straightforward. However, the degree of aggregation affects the result of assessment of the indicator. If the energy portfolios are aggregated to smaller number (e.g. fossil energy and bioenergy), the value of the indicator becomes higher which means lower energy diversity. On the other hand, if energy portfolios are aggregated less (e.g. wood, methane, petroleum, coal, hydro, solar, wind, etc.), the indicator value becomes lower which leads to the result of higher energy diversity, even if the share of each energy source is the same (see Table 4).

Table 4 - Effects of (dis)aggregation

Aggregation and HI	Disaggregated	Aggregated
Oil	20%	50%
Coal	10%	
Gas	20%	
Nuclear	0%	0%
Wood chips - Region A	5%	5%
Wood pellets - Region B	5%	10%
Straw pellets - Region C	5%	
Biodiesel - Region D	5%	10%
Biodiesel - Region E	5%	
Bioethanol - Region F	5%	15%
Bioethanol - Region G	5%	
Bioethanol - Region H	5%	
Hydro	5%	5%
Other RE	5%	5%
HI	**0.115**	**0.300**

Source: The GSI report p.196 with modification.

Traditional and modern bioenergy

The statistics on the share of bioenergy also includes traditional biomass. According to the GSI Report, traditional biomass should be included in the indicator. However, the users should disaggregate this where possible because it is important to distinguish between modern and traditional bioenergy as they may have different implications for energy security.

Indicator 23: Infrastructure and logistics of bioenergy

Main Implementation Challenges

Data

Main challenges for this indicator come from data availability. In many cases, the Indicator has only been measured qualitatively as data was not available for quantitative measurement.

Capacity

For measuring this Indicator, a GIS approach has been suggested, given the geographical nature of the data. This was the methodology used for implementation in some countries. However, technical knowledge and skills might be required for the use of a GIS application.

Guidance

Measures of energy supply routes are amongst the most commonly used indicators for energy security. Various forms of disaggregation with respect to fuels and regions are possible. For example, it might be most convenient to consider solid biomass, liquid biofuels and gaseous biofuels separately, along with the upstream capacity of the electricity grid in the case where bioenergy is used for power generation. In general, the disaggregation should separate categories which have differing risk profiles – for example produced in different regions and so subject to different climatic and other risks. It might be more informative, though, to calculate national values for transport fuels and for heat and power separately. In many cases, it might be easy to attribute biomass and biofuels to a sector on the basis of their physical state and other basic properties, based on knowledge of conversion processes used within a country or region.

System boundaries

The indicator covers from feedstock transportation and storage to bioenergy delivery and storage. This includes the capacity of the electricity grid in the case where bioenergy is used for power generation. If the feedstock and bioenergy are imported, it is also taken into account for the measurement of the indicator but only in terms of its transport *within* the country of measurement. Therefore, international pipelines would not be considered as part of the analysis but transport from international ports within the country to bioenergy facilities or end users might be considered as critical distribution systems.

Data collection and measurement strategies

(1) Identify critical distribution systems

To measure this indicator, the critical distribution systems in a country should be identified. Critical routes are defined as those which are subject to significant risk of disruption and which could not easily or quickly be replaced, such as pipelines or port facilities, or where the distribution system is composed of only one route. It should be noted that 'quickly replaced' in this context could depend on the timespan of analysis for risk. These data can be collected through interviews and surveys at the national level.

Once the critical distribution systems are identified, its number would be sub-indicator 23.1.

(2) Determine the capacity values for each of the distribution systems to measure sub-indicator 23.2

Bioenergy feedstock distribution

It would be useful to convert measurements in units of mass or volume into the energy value that they will ultimately deliver in order to facilitate comparison and an indication. The necessary conversion factors will depend on the nature of the feedstock, its water content and other factors. It is likely that the conversion factors will have to be determined empirically.

- Bioenergy for heat and power – Feedstock transportation to plants could be assessed in units of mass or volume and also converted to the corresponding value of generation capacity (in MW) or energy delivered (in kWh).
- Biofuels for transport – Feedstock transportation could be measured in units of mass or volume and also converted to the corresponding value energy delivered by the biofuel (in MJ). Fuel distribution should be measured in terms of the energy delivered (in MJ).

(3) Measure the proportion of bioenergy that relies upon each distribution system

It is instructive to compare the capacity of these critical infrastructure components with the actual capacity required, and to consider what proportion of the required bioenergy resources uses each (sub-indicator 23.3). It is defined by the proportion of a country's bioenergy that relies upon each distribution system.

(4) Identify the national risks and weak points

In addition to the identified critical components of the distribution infrastructure, an identification of risks and weak points in national distribution systems is recommended. This analysis should take into account the various transport modes used and their characteristics.

Indicator 24: Capacity and flexibility of use of bioenergy

Main Implementation Challenges

Data

In some countries there may be data availability issues. Although some national and international databases are available, some data need to be collected at plant level. These may cause confidentiality issues. Data availability is especially difficult in case of sub-indicator 24.2 (flexibility of use). A specific example for biofuels for transport is that there may not be reliable information on the number of Flex Fuel Vehicles (FFV) actually present in the country, and no traceability of the actual amount of biofuel they use (FFV have the capacity to use 100% hydrous ethanol but they may also use other blends such as E-85).

Definitions

The definitions of capacity ratio and flexible capacity ratio have caused some confusion and an erroneous example on how to calculate sub-indicator 24.2 was mentioned in the initial GSI Report.

Expansion of indicator to other value chains

This indicator was designed with biofuels for transport in mind and its application to other value chains might not be straightforward.

Guidance

Definition of capacity ratio (sub-indicator 24.1)

The definition of this sub-indicator has caused some misunderstanding; it should read: *Ratio of actual use of bioenergy compared with total capacity for using bioenergy, for each significant utilization route*. The right formula to be used is, therefore:

Capacity ratio = actual bioenergy use/total capacity for bioenergy use

Definition of flexible capacity ratio (sub-indicator 24.2)

The flexible capacity of bioenergy is defined as the capacity within the system that can use both bioenergy and other fuel sources. The flexible capacity ratio is therefore the ratio of this flexible capacity to total capacity for bioenergy use, *for each significant utilization route*. An example of FFV is mentioned in the GSI report.

Flexible capacity ratio = flexible capacity/total capacity for bioenergy use

Data Collection Strategies and implementation

The three components required for the implementation of the indicator are: the actual bioenergy use; the flexible capacity; and the total capacity for bioenergy use. The process is as follows:

(1) Estimate current bioenergy use

Once the relevant supply chains are identified, the actual current level of use is assessed (for example the volume of ethanol currently being used in the transport sector, or the amount of syngas used in electricity generation). National statistics and international database (e.g. IEA energy statistics) can be used as data sources.

(2) Estimate the total capacity of bioenergy use

The current bioenergy use can then be compared with the total capacity to use the fuel within the country. For example, the capacity of the vehicle fleet to use ethanol or biodiesel, or of the power generation plant to use syngas or biogas.

(3) Estimate the flexible capacity

The proportion of the capacity which is flexible can be assessed, for example the proportion of FFV in the fleet and their fuel using capacity, or the proportion of power generation systems which can operate in a fuel flexible mode.

Application of indicator to different value chains

Indicator 24 was developed with FFV in mind but there are other aspects/pathways to which the methodology can be applied. Below are three pathways with the components of each sub-indicator explained for the specific pathway.

Biofuels for transport

Actual use	Total capacity of bioenergy use	Flexible capacity
Data from statistics are obtained and/or estimations are made for: consumption of FFV (e.g. hydrous ethanol or E85); and consumption of biofuels by conventional vehicles	Estimates are made for: the maximum capacity of consumption of biofuels by FFV; and the maximum blending level of biofuels with conventional	For FFV, this is the maximum capacity of consumption of biofuels, and for conventional vehicles, it is the difference between the maximum blending level (known as 'blending wall')

(estimated by using total fuel use and the current blending mandate).	fuels without retrofitting of engines.	and the minimum blending rate established by law.

Decentralized biogas

For decentralized biogas used at household level for cooking, there are two potential types of cookstoves: biogas cookstoves (that run solely on biogas) and flexible cookstoves (that can use both biogas and LPG).

Actual use	Total capacity of bioenergy use	Flexible capacity
Estimates are made for: the amount of biogas used in the biogas cookstoves; and the amount of LPG replaced by biogas in flexible cookstoves.	Maximum capacity of use of biogas of all biogas cookstoves and flexible cookstoves.	Capacity of biogas use of flexible cookstoves.

Biogas/syngas for electricity generation

For centralized biogas/syngas used for power generation, there are two potential scenarios: generators that run solely on biogas/syngas; and generators that have flexibility to use either biogas/syngas (GIZ, 2011) or diesel.

Actual use	Total capacity of bioenergy use	Flexible capacity
Estimates are made for: the amount of biogas used in the biogas generators; and the amount of conventional fuel (e.g. diesel) replaced by biogas in flexible generators.	Maximum capacity of use of biogas of all biogas generators and flexible generators.	Capacity of use of biogas of flexible generators.

Correction to the report

In the example described in the scientific basis section of this indicator in the report, the numerators and denominators for the calculation of the capacity ratios of countries A and B were mistakenly inverted. The corrected example is presented below and the electronic version of the Report on the website has been updated.

Here we present an example of calculating the capacity ratio and the flexibility ratio of bioenergy use.

Capacity ratio = Bioenergy use / Bioenergy capacity

Flexibility ratio = Flexible bioenergy capacity / Bioenergy capacity.

Consider the transportation sector in countries A and B:

	Country A		Country B	
Annual Transport bioenergy use MTOE/y	100		100	
Transport bioenergy capacity MTOE/y	300		120	
Flexible transport capacity MTOE/y	250		40	

Capacity ratio for country A = 100/300 = 33%; Capacity ratio for country B = 100/120 = 83%

Potential Further analysis

This sub-indicator, together with information reported in Indicator 22, gives information on the country's ability to cope with unexpected incidents with bioenergy supply (e.g. shortage of bioenergy and/or bioenergy feedstock due to adverse conditions or political implications).

A further analysis could consider what kind of risks could occur and what alternative measures would be taken. Most bioenergy plants have some strategies when they face risks such as unexpected events. For example, fuel wholesalers might reduce mixture volume of gasoline when they face ethanol shortage. All these strategies can be regarded as flexible capacity of bioenergy supply chain.

Business continuity plans (BCPs) of each bioenergy enterprise might be helpful if available. Generally, a BCP states fundamental functions of a business, identifies which systems and processes must be sustained, and details how to maintain their services and supply of products. Any possible business disruptions are taken into account as well. Therefore, it might be useful to identify what kind of risks are supposed by a bioenergy supplier.

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Annex 1: Lessons learned and recommendations emerging from testing

ENVIRONMENTAL PILLAR

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
1. Lifecycle GHG emissions	1. Selection of attributional LCA (ALCA) vs consequential LCA approaches (CLCA) depending on whether direct and indirect land use changes are being accounted for. 2. The Common Methodological Framework does not offer sufficient guidance on the definition of LCA boundaries and the selection of the relevant timeframe and cut-off criteria. 3. The need to define an average national figure for GHG emissions related to the production of bioenergy is another methodological challenge, as site-specific or operator-specific assessments may vary greatly	1. Primary data should be used when available (this is generally the case). It would be important to specify when it is appropriate to use default values. 2. Biograce, GREET, GHGenius and other models are useful tools to be used, because methodologies and background data are already included. 3. Relevant data (GHG as well as other data) are collected or will be collected by countries as part of the UNFCCC	Relevant: For training on methodology; and For generation of country specific data.	1. The issue of imported/exported biomass for energy has to be solved. IPCC GHG accounting good practice guidance could be used. 2. Accounting for potential climate feedbacks. 3. Inclusion of potential soil organic carbon (SOC) storage - is this temporary storage? To what soil depth should SOC storage be evaluated? How does this affect timeframe allocation and future land use?	1. Need to distinguish between the attributional and consequential LCAs. Most indirect land use change effects are really part of consequential LCAs and should not be used in attributional LCAs for individual farms/industrial facilities etc. 2. When this indicator is measured, it is recommended to take into account relevant national policies/programmes/standards and international processes (e.g. UNFCCC) and methodologies (e.g. IPCC).

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
	within the same country. The intrinsic diversity and variability of bioenergy production pathways that exist in some countries requires the formulation of assumptions and the production of scenarios in order to come up with nationally representative results.	inventory process. That UNFCCC process provides an opportunity for coupling with GBEP data collection. Coupling those efforts as much as possible should be explored.			
2. Soil quality	1. More guidance needed on the type of measurement, e.g. soil depth. 2. Data availability might be an issue in some developing countries.	1. In some countries there might be a lack of adequate data. Data on soil organic carbon is particularly limited and primary data campaigns tend to be complex and both time and resource intensive. 2. Where data bases exist, data are often under privacy protection. In these cases, confidentiality agreements may be necessary.	1. Relevant, for field assessments and processing of soil samples.	1. Sampling and having the capacity to process samples are the main limiting factors.	1. When this indicator is measured, it is crucial to define reference conditions in order to compare results at different scales (local vs. national vs. global). 2. The real key is to objectively evaluate soil biological, chemical, and physical properties and processes in a timely and routine manner. Soil quality assessments are not needed every year but only every 5 years or so to measure the direction and magnitude of the trend lines. Is the soil aggrading, degrading, or at least remaining stable? 3. Techniques for measuring soil quality need to be consistent across different systems (including soil type, soil depth and feedstock

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
					type). For example, the appropriate depth of measurement for soil indicators depends on depth of soil layers and cultivation practices on a given site and should remain constant over time. Soil organic carbon, pH, electrical conductivity, bulk density, N, P, K, and selected soil enzymes are frequently considered to be important components for a minimum data set. 4. The question of whether the GBEP indicator or its methodological approach might be adapted to take account of the impacts on soil quality of the application of vinasse, biocompost and perhaps residues from the bioenergy production process arose in one of the pilot countries. 5. Soil quality could be mapped, in order to identify - and focus on - hot spots. 6. A proxy that could be considered is the level of uptake of nationally/locally defined good soil management practices.
3. Harvest levels of wood resources	1. Data availability might be an issue in some developing countries.	1. Lack of forest inventories.	1. Relevant.		1. Connecting with REDD reports. 2. The counterfactual reality needs to be considered in analyses that attempt to evaluate forest harvest rates. For example, the

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
	2. In some cases it might be challenging to determine the share of woodfuel coming from forests.	2. Possible lack of data on net growth or sustained yield. 3. Usually woodfuel is informally harvested and thus official data might not be available. 4. The quality of data on woodfuel consumption could be improved by conducting surveys to determine household and commercial woodfuel consumption and production at district level and transportation of woodfuel outside the district.			alternative of leaving large debris piles in the woods or of burning those piles needs to be considered. 3. Among the natural phenomena affecting forest productivity and causing fluctuations in annual harvest levels, fires should be considered as well in addition to adverse weather and outbreaks of pests. 4. Harvest of wood and its use for bioenergy under programmes aimed at eradicating invasive alien plants (e.g. the 'Working for Water' programme in South Africa) should be accounted for separately. 5. In the lack of information about net growth or sustained yield, a possible alternative would be to undertake surveys (which, however, could be costly) and a literature review regarding the state of a country's managed forests to determine if over-harvesting is considered to have occurred and, if so, where. This information could then be overlaid with the information on sources of wood for modern energy purposes.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
					6. In order to understand the way in which woodfuel use affects the sustainability of wood harvesting, it would be useful to gather information on the end use and, in particular, the use efficiency. 7. The indicator could be improved by developing a methodology to determine the impact of bioenergy production on the traditional uses of biomass.
4. Emissions of non- GHG air pollutants, including air toxics	1. Overall, the measurement of this indicator is quite burdensome. 2. This indicator is very skill intensive and requires the involvement of a team of expert chemists and engineers.	1. Datasets and default values are available, but there is a need to improve data quality. Moreover, emission factors may be missing for some activity levels and practices. 2. With regard to air toxics, there is a lack of data and default values tend to be pretty rough.		1. Distinguishing between particulates derived within a locality vs those that have migrated in from elsewhere.	1. In the methodological approach it is suggested that, where feasible, a full lifecycle analysis should be conducted. This approach might not be ideal, in light of the fact that the impacts of non-GHG air pollutants are mainly local and that large differences exist in terms of emissions and exposure to air toxics throughout bioenergy supply chains. 2. When this indicator is measured, it is recommended to take into account relevant national policies/programmes/standards and international processes (e.g. Gothenburg Protocol) and methodologies (e.g. IPCC).

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
5. Water use and efficiency	1. Data availability might be an issue in some developing countries.	1. Maps about water availability are there → hot spots detectable → need ground truthing. 2. It is suggested to use watershed level data as opposed to average national-level data and to present results at the same scale/level. 3. Possible lack of data on the share of renewable vs. non-renewable water sources, especially for feedstock production. 4. Watershed boundaries may not coincide with those of the administrative units for which data on production of bioenergy feedstocks and products are available, making it difficult to determine the amount of			1. When this indicator is measured, it is crucial to define reference conditions in order to compare results at different scales (local vs. national vs. global). 2. When this indicator is measured, it is crucial to take into account environmental, social and economic parameters that may affect the levels of water use and efficiency. 3. In addition to withdrawals, evapotranspiration could be considered as well. 4. It would be useful to measure this indicator for both average years and dry years, as the TARWR and thus the share of it used for bioenergy production might change significantly in a watershed. 5. This indicator has already been measured in several countries, however it would be interesting to see the results of the measurement of this indicator in more vulnerable countries from a water use and efficiency point of view.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
		water withdrawn in a specific watershed for bioenergy production.			
6. Water quality	1. The indicator requires the measurement of nutrients/pesticides that reach a water body. This measurement may be pretty complicated and burdensome.	1. While data on the application of fertilizers and pesticides in bioenergy feedstock production is generally available, there might be less data about pollution of water bodies. Finally, data on the runoff of chemical inputs to water bodies is very rare. However, hot spots are detectable. 2. There are some models that can be used to trace water pollution back to the land use but they require a lot of entry data that oftentimes is not available. 3. Environmental data is needed to define and			1. When this indicator is measured, it is crucial to define reference conditions in order to compare results at different scales (local vs. national vs. global). 2. When this indicator is measured, it is crucial to take into account relevant environmental, social and economic parameters. 3. Lesson could be learned from areas where within a watershed only one type of crop/feedstock is grown.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
		simulate reference conditions.			
7. Biological diversity in the landscape	1. An official definition and map of areas of high biodiversity value or critical ecosystems might not exist in some countries.	1. When the areas concerned are either protected by law or tracked by national programmes, data should be available. 2. The concept of "nationally recognized areas" is not enough. Areas of high biodiversity value or critical ecosystems are not always nationally recognized. This reflects on data appropriateness.	1. Need to strengthen capacity at local level.		1. When this indicator is measured, it is recommended to consider as well the areas of high biodiversity value or critical ecosystems that are not officially recognized and protected in the country. 2. The importance of habitat corridors between areas of high biodiversity value or critical ecosystems should be considered when measuring this indicator. 3. A potential proxy for the impact on biodiversity is the change in the number of endangered and vulnerable species in key bioenergy production areas, especially in the lack of an official definition and map of nationally recognized areas of high biodiversity value or critical ecosystems.
8. Land use and land-use change related to bioenergy	1. It may be difficult to measure the conversion between land-use types caused by bioenergy feedstock production. 3) A consistent time frame is important.	1. Most land use is now categorized through remote sensing/satellite inventory. This may be complemented with ground truthing, also in	1. Relevant.		1. Mapping technologies may help with this indicator. 2. Data to be used as a 'baseline' would be very useful.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
feedstock production	4) Consistency in the categorization of land types and management practices is critical.	order to capture land management practices.			

SOCIAL PILLAR

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
9. Allocation and tenure of land for new bioenergy production	1. Concept of "new" bioenergy production is complex to define because in many cases bioenergy is produced from feedstocks that are not dedicated solely to energy purposes (e.g. sugarcane, oil palm, soybean, etc.). 2. Data availability might be an issue in some developing countries.	1. Lack of data, especially in the case of areas recently converted to the production of bioenergy feedstocks.	1. Relevant, given the complexity of tenure-related issues.		1. If the required data is not available, a pragmatic approach that may be used is to analyse key variables closely related to land allocation and tenure, such as the structure of land ownership, the size and distribution of farms, and the various types of business models found along the bioenergy supply chain.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
10. Price and supply of a national food basket	1. For some countries the measurement of this indicator might be quite burdensome and external support might be needed. In particular, the 'Causal descriptive assessment' (i.e. Step 2, tier II) requires the active engagement of a broad range of experts and stakeholders, while the 'Quantitative assessment' (i.e. Step 2, tier III) entails sophisticated modelling and analysis.	1. This indicator is very data intensive. However, in most cases data is available (e.g. from FAOSTAT, National Statistics Office and Ministry of Agriculture).	1. Given the complexity of this indicator and of the issues addressed by it, specific training at both policy and technical level is fundamental, e.g. on the Causal Descriptive Assessment, on the AGLINK COSIMO model, and on the analysis and interpretation of the results of both.		
11. Change in income	1. It may be difficult to attribute changes in income to bioenergy production. 2. Data availability might be an issue in some developing countries.	1. Availability of - and access to - detailed data related to wages and prices might be an issue in a number of countries, due among other things to the commercially sensitive nature of part of this information. Cooperatives and associations of workers and producers may represent good sources of data. 2. Disaggregated data for bioenergy specifically is often not available. Data			1. Household income of those employed in the bioenergy industry is a useful indicator of well-being and is measured as financial compensation received by workers for their labour. As with other indicators, the income should be attributable to biofuels and distinct from

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
		on wages, in particular, tend to be available by broader sectors, e.g. agriculture and industry. 3. In some cases, the compensation received by wage workers includes goods (e.g. food, sugar, etc.) and services. The available data might not always properly account for this.			other non-bioenergy-related income. 2. When this indicator is measured, inflation-adjusted figures should be used and the effect of feed-in tariffs (if any) should be considered.
12. Jobs in the bioenergy sector	1. It may be difficult to determine the exact number of jobs created and lost/displaced as a result of bioenergy production and use. 2. Data availability might be an issue in some developing countries.	1. Given the relative novelty of the bioenergy sector, data may be scarce. In particular, disaggregated data for bioenergy production specifically is often not available, neither on the feedstock side nor on the processing side. Bioenergy-specific data disaggregated into skilled/unskilled and temporary/indefinite jobs is even more rare.	1. Relevant.	1. Markets are changing dynamically → changes situation of jobs.	1. Further guidance would be useful on the measurement and estimation of jobs lost/displaced as a result of bioenergy production and use (to give net job creation figure).
13. Change in unpaid time spent by women and	1. This indicator relies heavily on surveys and thus may be resource intensive.	1. Data was not available in the pilot countries, due mainly to the fact that woodfuel is often collected/traded in the informal market; need for			1. In some countries, men (as opposed to women and children) are responsible for collecting biomass. Where

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
children collecting biomass	2. Data availability might be an issue in some developing countries.	representative surveys (large sample over several months where seasonality exists).			this is the case, this should be reflected in the indicator measurement. 2. Apparently UNDP is carrying out surveys in Africa on this matter. It is advisable that GBEP liaises with UNDP in order to find out whether the survey could help measuring this indicator.
14. Bioenergy used to expand access to modern energy services	1. Excluding the case of decentralized energy production from biomass sources, in all other cases attributing an increase in access to modern energy services to bioenergy poses challenges both in terms of data requirements and methodology. 2. The issue of a more clear definition and demarcation of traditional vs. modern bioenergy is particularly important in the case of this indicator.		1. Relevant.		1. In the few countries where this indicator has been implemented so far, the focus is on other types of bioenergy technologies. Therefore, additional evidence is needed from other countries on the relevance and practicality of the indicator.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
15. Change in mortality and burden of disease attributable to indoor smoke	1. The limited statistics available are the result of the aggregation of DALYs lost due to upper respiratory disease, thus including multiple possible causes such as cigarette smoke, etc. 2. In order to measure a change, reliable statistics based on sound epidemiological studies and covering an adequate period of time are needed.	1. Limited data available.			1. Statistics or surveys that cover a time window sufficient to describe the development of chronic diseases caused by indoor pollution from cooking (thus targeting the family members more exposed) may lead to the identification of the role of traditional bioenergy use.
16. Incidence of occupational injury, illness and fatalities	1. Data owned mainly by the private sector, having no incentive for reporting/sharing such data.	1. Lack of availability of adequate data with the level of disaggregation required in order to conduct a specific analysis for the bioenergy sector. 2. In general, agro-industries have data on occupational injury, illness and fatalities (e.g. in Brazil). Insurance companies have these data as well, but only for insured workers, which generally represent a relatively small share of total workers, especially in the agricultural sector of developing	1. It is fundamental, as in the case of any other indicator on which information is held primarily by the private sector, to partner with relevant organizations and strengthen the capacity to produce relevant statistics in order to monitor this indicator. It is also important to develop the capacity of national policymakers to design policies that discourage informal jobs in bioenergy and		1. In addition to baseline conditions, if possible conditions under a bioeconomy should be assessed as well.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
		countries. The data owned by agro-industries and insurance companies, however, may not be publicly available.	require mandatory insurance regimes.		

ECONOMIC PILLAR

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
17. Productivity	1. In the countries where the GBEP indicators have been implemented so far, the measurement of this indicator has been relatively straightforward. 2. Availability of part of the required data might be an issue in some developing countries.	1. Most of the data required under this indicator is generally available in national statistics. However, getting hold of the information required for indicator component 17.4 might be challenging, in light of the commercially sensitive nature of production cost data.			1. Further guidance on how to account for co-products and by-products under the various components of this indicator would be useful.
18. Net energy balance		1. Limited data available.	1. Relevant.		1. Energy balance should be evaluated on LCA basis, using data similar to those used for indicator 1.
19. Gross value added	1. Data availability might be an issue in some developing countries.	1. The availability of sufficiently detailed and up to date information (e.g. with regard to the value of intermediate inputs) might be an issue in some developing countries.			1. In the lack of information regarding the gross value added generated by the production of a certain biofuel, the estimated gross profit per unit of energy of a representative plant producing such biofuel could be used as a proxy

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
20. Change in the consumption of fossil fuels and traditional use of biomass	1. Data availability might be an issue in some developing countries.	1. In some countries, most of the required data is likely to come from one-off reports. Data may be particularly scarce with regard to the replacement of traditional biomass use with modern bioenergy.	1. Relevant, in order to support data collection and analysis.		1. The wording of indicator component 20.1b appears to be tailored mainly to oil importing countries. In the case of oil exporting countries, it is more appropriate to assess the increase in oil exports rather than the import savings associated with the substitution of fossil fuels with biofuels.
21. Training and re-qualification of the workforce	1. Data availability might be an issue in some developing countries.	1. Data on the skill level of workers (i.e. indicator component 21.1) might be limited in some developing countries, especially with regard to feedstock production, where high rates of informal labour are found.			1. Indicator component 21.2 appears to have a pretty narrow scope, as it seems to be applicable mainly (if not exclusively) to requalification programmes for sugarcane cutters who lost their jobs as a result of a switch to mechanical harvest.
22. Energy diversity					1. No particular issues arose in the implementation of this indicator so far.
23. Infrastructure and logistics for distribution of bioenergy	1. Data availability might be an issue in some developing countries.	1. Sufficiently detailed data for a quantitative assessment of this indicator might not be available in some developing countries.	1. Relevant.		1. Further guidance would be useful on how to measure the actual capacity of critical distribution systems for bioenergy and above all on how to attribute to bioenergy its share and disaggregate the results by commodities transported along the same routes and distributed by the same multi-purposes infrastructures.

INDICATOR NAME	1) Which are the major challenges when measuring this indicator?	2) Data availability? Data appropriateness?	3) How relevant is capacity building?	4) Any other fundamental obstacle?	5) Comments.
24. Capacity and flexibility of use of bioenergy					1. In the example described in the scientific basis section of this indicator in the report, the numerators and denominators for the calculation of the capacity ratios of countries A and B were mistakenly inverted. This might confuse users.

Annex 2 – Use of proxies and best practices

This Annex gathers relevant studies to provide guidance on the use of proxies and best practices that can give an indication of the sustainability of bioenergy at national level, to be used by implementing nations who lack the data or capacity to use the agreed GSI methodologies.

Overview

IRENA (2016) ***Boosting biofuels: sustainable paths to greater energy security*****. IRENA, Abu Dhabi.** http://www.irena.org/documentdownloads/publications/irena_boosting_biofuels_2016.pdf

This paper explores sustainable biofuel pathways, and examines policies and measures for promoting these pathways.

IINAS (2015) ***Global sustainable land use: concept and examples for systemic indicators*****. GLOBALANDS working paper 3.3.** http://iinas.org/tl_files/iinas/downloads/land/IINAS_2014_GLOBALANDS_WP_33_Systemic-Indicators.pdf

This paper discusses indicators for global sustainable land use and how systemic indicators can be used. It suggests a screening process for land use practices to be used as systemic indicators. It can be used to guide a bottom-up approach to identifying sustainable land use practices in specific regions/contexts.

FAO (2012) ***Good environmental practices in bioenergy feedstock production: Making bioenergy work for climate and food security*****. Environment and Natural Resources Management Working Paper 49. FAO, Rome.**

http://www.fao.org/docs/up/easypol/944/good-environmental-practices-bioenergy-feedstock_136en.pdf

This paper describes a set of criteria, indicators, good practices and policy options to ensure that modern bioenergy development is sustainable and that it safeguards food security. It was developed to help policy-makers understand and manage the risks and opportunities for food security associated with various bioenergy development pathways.

FAO (2011) ***Good Socio-economic Practices in Modern Bioenergy Production*****. FAO, Rome.** http://www.fao.org/docrep/015/i2507e/i2507e00.pdf

This paper explores good socio-economic practices under a number of dimensions, including: access to land; employment, wages and labour conditions; income generation and inclusion of smallholders;

local food security; community development; energy security and local access to energy; and gender equity.

Global Database on Sustainable Land Management (WOCAT). https://qcat.wocat.net/en/wocat/

A data repository for sustainable land management (SLM) practices.

Farm and forest residues

IEA Bioenergy (2017) ***Mobilisation of agricultural residues for bioenergy and higher value bio-products: Resources, barriers and sustainability.*** **IEA Bioenergy: Task 43.** http://task43.ieabioenergy.com/wp-content/uploads/2017/06/TR2017-01-F.pdf

The paper uses and reviews several frameworks to understand the sustainable potential of agricultural crop residues for bioenergy and concludes that further opportunities for sustainable use of agricultural residues exist.

Daioglou, V. et al. (2016) Projections of the availability and cost of residues from agriculture and forestry. ***Gcb Bioenergy.*** **8 (2), 456-470.** https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12285

This study projects long-term global supply curves of by-products of agricultural and forestry processes, and the available potential using consistent scenarios of agriculture, fuel use, forestry and livestock production.

Gregg, J. and Smith, S. (2010) Global and regional potential for bioenergy from agricultural and forestry residue biomass. ***Mitigation and Adaptation Strategies for Global Change.*** **15 (3), 241-262.** https://link.springer.com/article/10.1007/s11027-010-9215-4

In this study the authors developed a method for estimating the maximum sustainable amount of energy potentially available from agricultural and forestry residues by converting crop production statistics into associated residue, while allocating some of this resource to remain on the field to mitigate erosion and maintain soil nutrients.

Boosting yields of food crops

Fischer R.A., Byerlee D. and Edmeades G.O. (2014) Crop yields and global food security: will yield increase continue to feed the world? ***ACIAR Monograph No. 158. Australian Centre for International Agricultural Research: Canberra*****. xxii + 634 pp.** https://www.aciar.gov.au/node/12101

This study suggests to aim for a higher future rate of yield progress to better protect against unanticipated shocks that are likely to disadvantage people of lower socioeconomic status through food prices rises and to ensure food (and energy) security for most people on this planet.

Sustainable intensification of pastureland

Pretty, J. et al. (2018) Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability.* 1(8), 441. https://www.nature.com/articles/s41893-018-0114-0

This paper discusses the challenges and possible solutions of a sustainable intensification of agricultural systems.

Berndes, G., Chum, H., Leal, M.R.L.V., Sparovek, G. and Walter, A. (2016) *Bioenergy Feedstock Production on Grasslands and Pastures: Brazilian Experiences and Global Outlook*. IEA Bioenergy: Task 43. http://task43.ieabioenergy.com/wp-content/uploads/2017/06/IEA-Bioenergy-Task-43-TR2016-06.pdf

This report concerns the bioenergy feedstock cultivation on pastures and grasslands. It describes sugarcane ethanol production conditions and prospects for expansion, governance, and factors affecting market demand.

Foley, J.A. et al. (2011) Solutions for a cultivated planet. *Nature.* 478 (7369), 337. https://www.nature.com/articles/nature10452

This Nature paper discusses the problems humanity is facing in terms of climate, land, water and biodiversity loss including possible solutions for the tasks of food security, sustainability needs and food production. Analysed in the paper are the progresses concerning halting agricultural expansion, closing 'yield gaps' on underperforming lands, increasing cropping efficiency, shifting diets and reducing waste.

Fischer, G. et al. (2010) Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures. Part I: Land productivity potentials. *Biomass and Bioenergy.* 34 (2), 159-172. https://www.sciencedirect.com/science/article/pii/S0961953409001482

Fischer, G. et al. (2010) Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures, Part II: Land use scenarios. *Biomass and bioenergy.* 34 (2), 173-187. https://www.sciencedirect.com/science/article/pii/S0961953409001470

These two papers discuss the spatial distribution of suitability of biofuel feedstocks and possible land conversion scenarios in Europe.

Reducing waste and losses in the food chain

Papargyropoulou, E. et al. (2014) The food waste hierarchy as a framework for the management of food surplus and food waste. ***Journal of Cleaner Production.*** **76, 106-115.** https://www.sciencedirect.com/science/article/pii/S0959652614003680

This study discusses first steps towards a more sustainable resolution of the food waste issue by adopting a sustainable production and consumption approach.

Lipinski, B. et al. (2013) Reducing food loss and waste. ***World Resources Institute Working Paper.*** http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.360.951&rep=rep1&type=pdf

This paper discusses the causes, problems and possible solutions of global food loss and waste to create a sustainable 'food future'.

Kummu, M. et al. (2012) Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. ***Science of the total environment.*** **438, 477-489.** https://www.sciencedirect.com/science/article/pii/S0048969712011862

In this paper the authors estimate the global food supply losses due to lost and wasted food crops, and the resources used to produce them. Furthermore, they quantify the potential food supply and resource savings that could be made by reducing food losses and waste.

FAO (2011) ***Global food losses and food waste – Extent, causes and prevention*****. FAO, Rome.** http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

These studies conducted by FAO focused on the extent and effects as well as causes and prevention of food losses and food waste.

Restoring degraded land

IRENA (2017) ***Bioenergy from degraded land in Africa: Sustainable and technical potential under Bonn Challenge pledges*****. International Renewable Energy Agency, Abu Dhabi.** http://www.irena.org/publications/2017/Dec/Bioenergy-from-degraded-land-in-Africa

The study presents a methodology to estimate the sustainable energy potential from land restoration in line with the Bonn Challenge, particularly as it relates to African countries, and suggests that bioenergy can strengthen the economic incentive to undertake restoration efforts.

Edrisi, S.A. and Abhilash, P.C. (2016) Exploring marginal and degraded lands for biomass and bioenergy production: an Indian scenario. ***Renewable and Sustainable Energy Reviews.*** **54, 1537-1551.** https://www.sciencedirect.com/science/article/pii/S1364032115011296

Here the authors propose (in a scenario for India) that the sustainable intensification of bioenergy production from degraded land is a viable solution to solve the conflict between food and fuel production and offer a sustainable solution to meet the energy requirements of the society.

Nijsen, M. et al. (2012) An evaluation of the global potential of bioenergy production on degraded lands. ***Gcb Bioenergy.*** **4 (2), 130-147.** https://onlinelibrary.wiley.com/doi/full/10.1111/j.1757-1707.2011.01121.x

In this article the authors estimate the global potential of energy crop production on degraded lands.

Campbell, J.E. et al. (2008) The global potential of bioenergy on abandoned agriculture lands. ***Environmental science & technology.*** **42 (15), 5791-5794.** https://pubs.acs.org/doi/abs/10.1021/es800052w

This study discusses the problems of converting forest lands into bioenergy agriculture as it could accelerate climate change while converting food agriculture lands into bioenergy agriculture could threaten food security. As a solution the authors highlight the potential of using abandoned agriculture lands for bioenergy agriculture.

Wiegmann, K., Hennenberg, K.J., and Fritsche, U.R. (2008) Degraded land and sustainable bioenergy feedstock production. ***Joint international workshop on high nature value criteria and potential for sustainable use of degraded lands*****.** http://np-net.pbworks.com/f/OEKO,%20RSB,%20UNEP%20et%20al%20(2008)%20Degraded%20land%20and%20sustainable%20bioenergy%20feedstock%20production.pdf

This paper defines and identifies degraded land and abandoned farmland as an important step towards a potential sustainable use of such lands as prior bioenergy feedstock production areas.

Annex 3 – Gantt Chart

Working Packages	Year 1 Months												Year 2 Months											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP1: Project presentation, country ownership, MSWG creation and identification of most relevant bioenergy pathways																								
WP2: Selection of relevant indicators, selection of national institutions, and assessment of capacity																								
WP3: Data collection strategy definition, primary and secondary data sources and requirements scoping																								
WP4: Training activities for indicator measurement and long term monitoring																								
WP5: Indicator measurement for the selected bioenergy pathways																								
WP6: Multi-stakeholder project evaluation, results validation and possible policy implications																								
WP7: Information sharing and dissemination, discussion on lessons learned and partnerships formation																								
WP8: Way-forward agenda for long-term measurement and use of the GBEP indicators																								
WP9: Project conclusion, and final reports publishing and dissemination																								

Annex 4 – Information Flow and data consistency

The GSI mutually inform each other to provide a comprehensive and coherent overview. However, this coherent overview can only be achieved when data is used consistently across the measurement of the indicators. There are many interactions among all the indicators; this includes the cases where indicators use similar data inputs and where one indicator gives results to be used as input in other indicators. In the interest of ensuring data consistency across the measurement of the GSI, a systemic approach is preferable.

The following guidance provides information on how to approach the indicators in a systematic way and how to ensure data consistency during implementation; it is based on the lessons learnt from previous implementation of the GSIs.

Information Flow

As mentioned above, a systematic approach is preferable when implementing the GSI. This is because some indicators may produce results that can serve as inputs in the measurement of other indicators, or lead to the collection of data that will be used in other indicators. By implementing the indicators in a rational sequence, efficiency of the process is improved and data consistency can be ensured. This is especially important where a multidisciplinary team of experts is taking care of different indicators.

Approaches to indicator measurement may differ depending on methodological approach. Therefore the following document provides two potential approaches based on the previous implementation of the GSI, one that takes the bioenergy pathway as a starting point (Figure 5) and the other that starts from the national level (Figure 6).

The flowchart in Figure 5 is intended to display an indicative rational sequencing of indicator measurement based on previous experience of GSI implementation by FAO in Paraguay, Viet Nam, Colombia and Indonesia. This approach is based on the analysis of a generic bioenergy pathway within a country. The arrangement of the GSI within the flowchart demonstrates a potential way to order their measurement and signals the flow of information; it does not provide an exhaustive overview of all potential linkages between the indicators (an overview of common data is provided in Table 5).

The flowchart in Figure 5 flows from left to right and is split into six conceptual steps that represent the sequence of indicator measurement and are not a reflection of the importance of any one indicator over another. The indicators can be measured following the flowchart from left to right, whilst those indicators in the same ‘step’ can be measured concurrently. Arrows between indicators signal where

it is preferable to measure one indicator before another, either because an output value from first indicator is then used as an input for the following indicator or because input values collected primarily for the first indicator are also used for the following indicator. It should be noted that the exact data requirements for an indicator might depend on the bioenergy pathway under analysis, and scale and depth of measurement.

Not all indicators are always relevant for certain pathways or contexts. For instance, if there is no significant traditional use of biomass in the country at household level, some social indicators (e.g. 13, 15 and 20.2) will not be required for the sustainability assessment. In this case, the indicators not to be measured are skipped but the flow remains.

Figure 5 - Flowchart of indicator measurement based on implementation of GSI by FAO

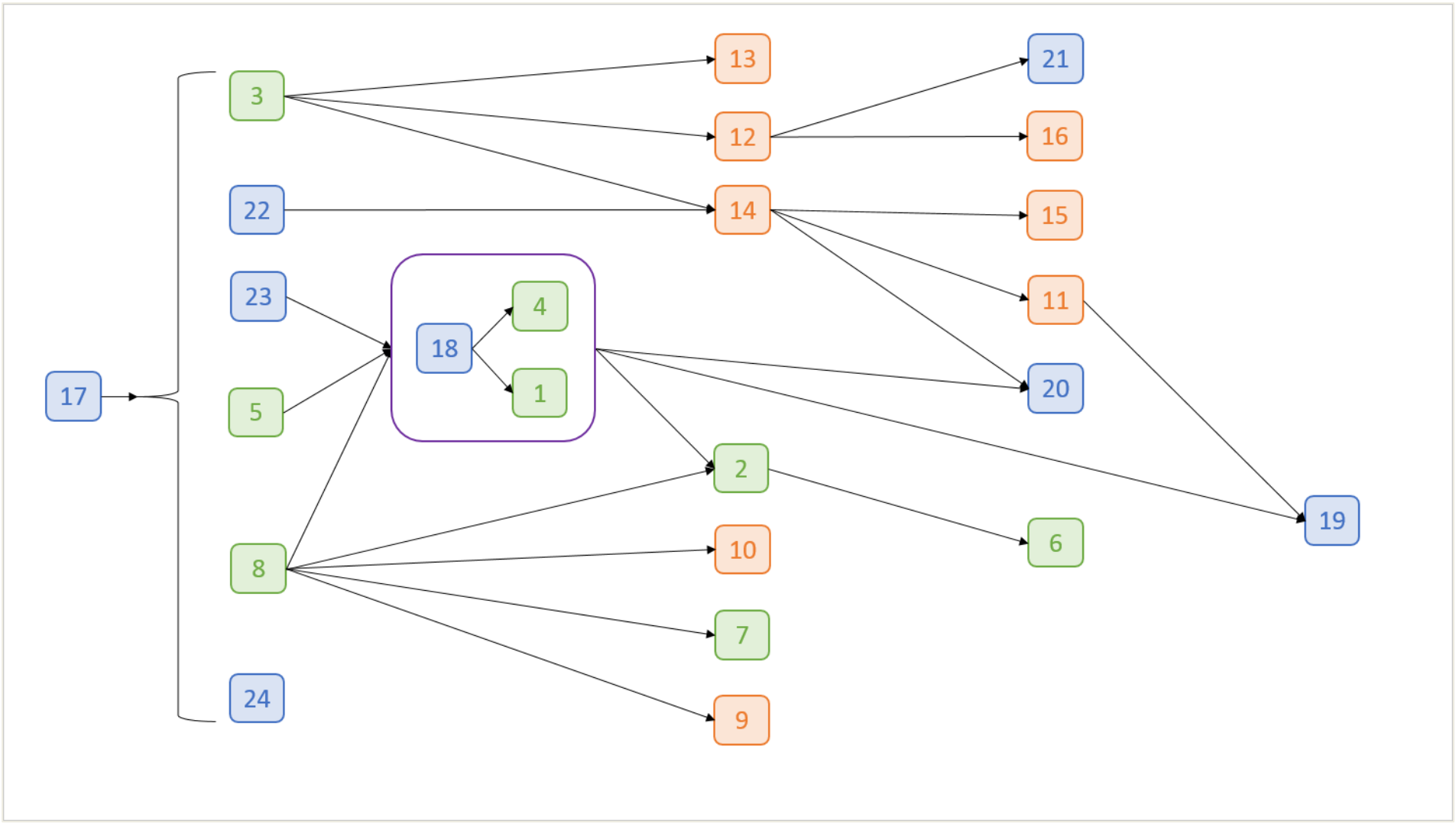
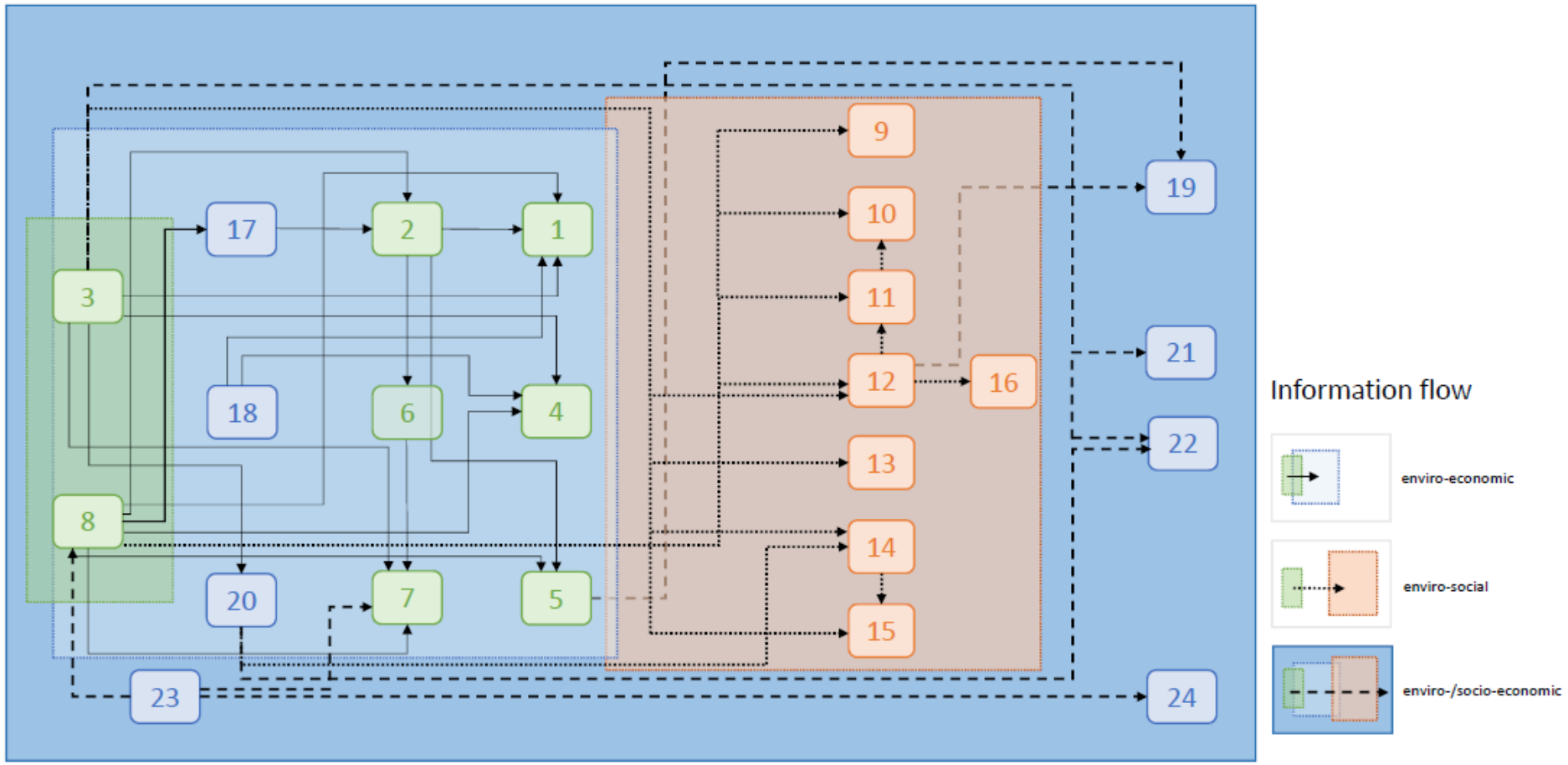


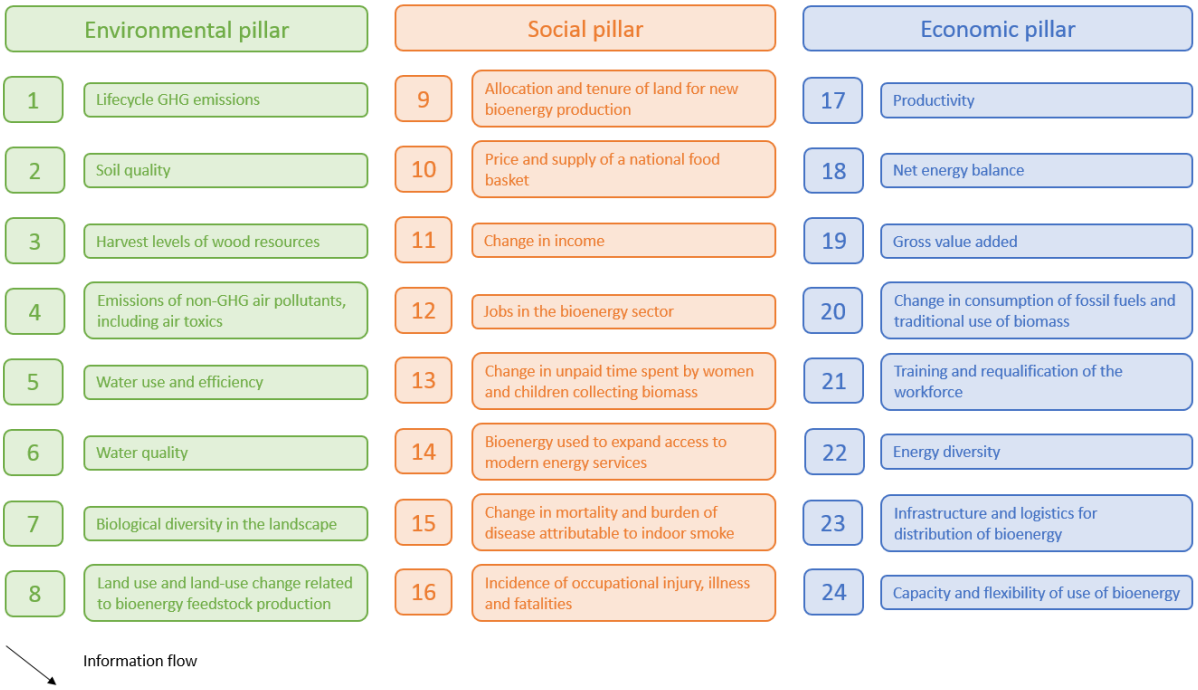
Figure 6 presents another indicative approach to implementation and a proposed sequence of the GSI measurement based on the experience of the implementation of the GSIs in Germany, based on implementation of the indicators starting from the entire bioenergy sector national level.

The flowchart can be read from left to right; as an essential part, the three pillars of GSI indicators remain in groups, indicated by colours corresponding to the legend. However, all indicators are intertwined, but their significance varies from region to region on an international scale. Push and pull factors, i.e. significance of indicators and pillars, are different from country to country, depending on e.g. policy frameworks and state of (circular bio)economy development. The flow chart given in Figure 6 includes three levels of interaction between the three pillars “environmental”, “economic” and “social”, resulting in “enviro-economic, enviro-social, and enviro-economic-social interactions (cf. signature in Figure 6). Thus, overarching aspects and interactions are represented. Arrows function as connectors and represent the *main connections* between single indicators, e.g. “soil quality” towards “water quality”, or “GHG emissions”.

Figure 6 - Flowchart based on implementation of the GSI in Germany



Legend for Figure 5 and Figure 6:



Data consistency

Where data are common between indicators, the same data source should be used to ensure consistency. This is particularly important when the implementation of the GSI is developed by a multidisciplinary team of experts focusing on different indicators.

Table 5 gives an overview of the common data required for the implementation of the indicators. As mentioned above, the exact data requirements for an indicator might depend on the bioenergy pathway under analysis, and scale and depth of measurement. Data that are required for just one indicator are not included in this table.

Some data in the table are calculated as an output of one indicator and then used as inputs in one or more other indicators. For example, bioenergy production costs can be calculated as part of the measurement of indicator 17 and may be used then used as input data for the measurement of indicator 19. In this case, where data represent an output, it is marked in red.

Table 5 - Common data

Data \ Indicators	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Feedstock yield	x			x	x			x									x	x						
Product processing yield	x				x			x									x	x						
Land area for agriculture						x		x																
Harvested area for bioenergy	x	x	x	x	x	x	x	x			x					x	x	x						
Bioenergy per hectare	x			x				x									x	x						
Bioenergy production costs																	x		x					
Land Use	x			x			x	x	x															
Land use change	x			x			x	x	x	x														
% of bioenergy from yield increases, residues and wastes								x		x														
Fertiliser and agrochemical use	x	x		x		x											x	x						
Net Energy Ratios (NERs)	x																	x	x	x				
Installed bioenergy capacity																x								x
Capacity for distribution	x																						x	
Harvest levels of wood resources for bioenergy			x									x	x								x			
Number of workers in bioenergy sector												x				x					x			
Number of households using traditional bio-mass											x			x	x									
Number of households using modern energy services to replace traditional biomass											x			x	x					x				
Primary Energy Supply from each energy source														x								x		

Annex 5 – Further resources

Guidance on collection of data on woodfuel from household surveys

Description

In response to the lack of reliable data available on woodfuel production and consumption, the Global Strategy for Improving Agricultural and Rural Statistics (GSARS), together with FAO, has developed guidelines for the incorporation of a woodfuel supplementary module (WSM) into existing household surveys in developing countries. These guidelines provide guidance for countries on developing a WSM, to be incorporated into existing national household surveys in order to capture reliable and comparable data on the production and consumption of woodfuel in the informal sector. By incorporating the WSM into existing surveys at the national level, data can be collected in a cost-efficient way.

Through its four topic sections (fuelwood use, collection and sales; charcoal use, production and sales; cooking and heating; and health problems), the WSM provides a picture of a number of elements of woodfuel consumption and production, namely:

(i) the amount of woodfuel used by the household sector;
(ii) the amount of time and money spent to acquire woodfuel;
(iii) the amount of energy obtained from woodfuel by the household sector;
(iv) the penetration of clean cooking and heating fuels and devices;
(v) the seasons of the year when there is more scarcity of woodfuel; and
(vi) the amount of fuelwood obtained from forests.

When it can be used:

These guidelines could be used by implementers of the GSIs, either as a tool to strengthen the monitoring of woodfuel statistics in the long term (through the incorporation of this WSM in existing household surveys) or as the basis for stand-alone primary data collection to be carried out as part of a GSI project.

When the informal wood energy sector is analysed using the GSIs, the data collected through the WSM will be useful for all GSIs. Even when the wood energy sector is not analysed specifically as a priority bioenergy pathway, data on production and consumption of woodfuel by the informal sector are required for many of the GSIs, including:

- Indicator 3 – Harvest levels of wood resources
- Indicator 11 – Change in income
- Indicator 13 – Change in unpaid time spent by women and children collecting biomass
- Indicator 15 – Change in mortality and burden of disease attributable to indoor smoke
- Indicator 20 – Change in consumption of fossil fuels and traditional use of biomass

Resources:

GSARS, 2018. Guidelines for the Incorporation of a Woodfuel Supplementary Module into Existing Household Surveys in Developing Countries. Available at: http://gsars.org/wp-content/uploads/2018/10/GS-WOODFUEL-GUIDELINES-EN-10.pdf

Borlizzi, A. 2017. *How to Include the Woodfuel Supplementary Module into Existing Surveys and Derive Woodfuel Indicators*. Technical Report no. 26. Global Strategy Technical Report: Rome. Available at: http://gsars.org/wp-content/uploads/2017/08/TR-02.08.2017-How-to-Include-the-Woodfuel-Supplementary-Module-into-Existing-Surveys-and-Derive-Woodfuel-Indicators.pdf

Bioenergy and Food Security (BEFS) Approach

Description

The BEFS Approach has been developed by FAO to support countries in understanding the linkages between food security, agriculture and energy in order to design and implement sustainable bioenergy policies and strategies.

The BEFS Approach can be used to undertake Sustainable Bioenergy Assessment, based on the BEFS Analytical Framework (BEFS AF), which is comprised of a number of tools. These tools include step-by-step online manuals and the modules run using Microsoft Excel software. One of these tools is the BEFS Rapid Appraisal, which provides a preliminary indication of the sustainable bioenergy potential of the country. The Natural Resources module of the BEFS Rapid Appraisal (RA) can be used in conjunction with the techno-economic component of the Energy End Use Option module to determine the costs of production. The Natural Resources module calculates the costs of bioenergy feedstock, which can then be used in the Energy End Use Option module to determine the production costs of various solid, liquid and gaseous biofuels. This module includes sections on Intermediate or Final Products, Heating and Cooking, Rural Electrification, Heat and Power, and Transport, so that the user can tailor the use of various sections to the selected bioenergy pathways under the GSI analysis.

Another tool within the BEFS AF is the BEFS Detailed Analysis, which provides more accurate results to inform policy making, including an in-depth analysis of the potential environmental and socio-economic impacts of bioenergy development.

When it can be used:

Sub-indicator 17.4: Where collection of primary data is not possible due to its confidential nature. If there is capacity to do so, the techno-economic component of the BEFS Detailed Analysis can be used to calculate the production costs for different biofuels.

Resources:

More information (along with detailed user manuals) can be found on the website:

- BEFS rapid appraisal: www.fao.org/energy/befs/rapid-appraisal/en/
- BEFS Detailed analysis: http://www.fao.org/energy/bioenergy/befs/assessment/befs-analysis/en/

Indicator-specific resources

Indicator 1

GREET (The Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model)

Indicator 2

Soil quality rating tools, such as the Muencheberg Soil Quality Rating in Germany[25].

The state of knowledge on SOC measurements and data availability, as summarized in FAO (2017)[26].

The Global Soil Organic Carbon map (GSOC map)[27] of the Global Soil Partnership (GSP) released on Dec 5, 2017 at World Soil Day.

Mello, F. et al. (2014) Payback time for soil carbon and sugar-cane ethanol. *Nature Climate Change 4* (7): 605

The Brazilian National Institute for Space Research (INPE) Database on Soils - Mapa Digital de Solos do Brasil https://www.embrapa.br/solos/sibcs/solos-do-brasil

LEAP+ programme (Livestock Environmental Assessment and Performance Partnership). Guidelines are being developed on accounting for soil carbon stock changes. More information: http://www.fao.org/partnerships/leap/activities/leap/en/

Indicator 3

The Brazilian Association of Forest Plantation Producers (ABRAF) publishes annual reports (statistical yearbooks) on planted forests in Brazil that may be useful:

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[25] The maps are available here: https://geoviewer.bgr.de/mapapps/resources/apps/geoviewer/index.html?lang=en

The field manual is available here:
http://www.zalf.de/de/forschung_lehre/publikationen/Documents/Publikation_Mueller_L/field_mueller.pdf

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ABRAF (2013) ABRAF Anuário Estatístico da ABRAF 2013 ano base 2012. Associação Brasileira de Produtores de Florestas Plantadas 146. Brasilia (Statistical data of forests in Brazil in 2012, including natural and planted forests, eucalyptus, pinus, and use of wood - see also statistical yearbook 2011) http://www.ipef.br/estatisticas/relatorios/anuario-ABRAF13-EN.pdf

Indicator 4

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GEMIS: http://iinas.org/gemis.html; GREET: https://greet.es.anl.gov/

Indicator 7

Relevant "general" material and data for biodiversity mapping:

- UN CBD website (https://www.cbd.int/)
- GBIF (Global Biodiversity Information Facility, see https://www.gbif.org/)
- IUCN's Key Biodiversity Areas (https://www.iucn.org/resources/conservation-tools/world-database-on-key-biodiversity-areas) and its "Red list of Ecosystems" (https://iucnrle.org)
- WWF (http://wwf.panda.org/about_our_earth/biodiversity/), although these data do not give high resolution
- IPBES (The intergovernmental science-policy-Platform on Biodiversity and Ecosystem Service) (https://www.ipbes.net/)

There are excellent regional biodiversity mapping activities, e.g. in Brazil, the EU, and the USA. Examples of useful data sources include:

- Landscape Conservation Cooperative Network (https://lccnetwork.org/)
- USA Protected Areas Data Portal (https://gapanalysis.usgs.gov/padus/)

- USA National Conservation Easement Database (https://www.conservationeasement.us/about/)