THE GLOBAL BIOENERGY PARTNERSHIP SUSTAINABILITY INDICATORS FOR BIOENERGY

FIRST EDITION

Global Bioenergy Partnership

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Dear readers,

Modern bioenergy presents great opportunities for sustainable development and climate change mitigation, but it brings challenges too, some of international relevance. In light of this, international cooperation is essential for building consensus on how to measure success in bioenergy and building capacity to help implement successful solutions. The Global Bioenergy Partnership (GBEP) has proved that a voluntary partnership of developed and developing countries and international organizations, informal enough to allow open discussion yet formal enough to yield meaningful results, is an effective and innovative vehicle for coordinated progress towards low-carbon, sustainable development. This report is the result of the hard work and dedication of many individuals and experts from GBEP Partners and Observers, working with and supported by the GBEP Secretariat. We would like to take this opportunity to recognize the efforts made by all those who have contributed to the successful completion of this report and to thank them for their commitment in preparing an invaluable tool for officials and scientists to use.

In developing countries, switching from traditional to modern bioenergy can reduce death and disease from indoor air pollution, free women and children from collecting fuelwood and reduce deforestation. It can also cut dependence on imported fossil fuels, improving countries' foreign exchange balances and energy security. Furthermore, bioenergy can expand access to modern energy services and bring infrastructure such as roads, telecommunications, schools and health centres to poor rural areas. In such areas, bioenergy can increase the income of small-scale farmers, alleviating poverty and decreasing the gap between rich and poor. In urban centres, using biofuels in transport can improve air quality.

For developed countries, where the focus is on reviving economic growth and mitigating climate change, bioenergy can stimulate a green recovery, generating more jobs and fewer greenhouse gas emissions than fossil fuels. It can breathe life into rural economies and diversify energy supply.

However, if not sustainably produced, bioenergy can place extra pressure on biodiversity, scarce water resources and food security. If land use is not well planned and enforced, increased deforestation, loss of peatlands and land degradation can occur and lead to an overall negative impact on climate change. Where land tenure is insecure, communities can be displaced and lose access to land and other natural resources.

The 24 sustainability indicators for bioenergy and their methodology sheets presented in this report are intended to provide policy-makers and other stakeholders with a tool that can inform the development of national bioenergy policies and programmes, monitor the impact of these policies and programmes, as well as interpret and respond to the environmental, social and economic impacts of their bioenergy production and use.

We believe this is a fundamental tool to facilitate sustainable development and climate change mitigation. We encourage you to use it.

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Italy

Mariangela Rebuá
GBEP Co-Chair
Brazil

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Chair of the GBEP
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Acknowledgements

In June 2008, the Global Bioenergy Partnership (GBEP) established the GBEP Task Force on Sustainability to promote sustainable production and use of bioenergy. The Task Force, under the leadership of the United Kingdom until October 2010 and of Sweden after that, has developed a relevant, practical, science-based set of measurements and indicators that can inform policy-makers and other stakeholders in countries seeking to develop their bioenergy sector to help meet national goals of sustainable development.

This report was developed by the Partners and Observers of GBEP, under the able chairmanship of Kieran Power (United Kingdom) and Sven-Olov Ericson (Sweden) supported by the GBEP Secretariat (Maria Michela Morese, Jonathan Reeves, Alessandro Flammini, Ylenia Curci and Marco Colangeli), and with the valuable contribution of the Task Force sub-group leaders – Environmental sub-group co-led by Germany and UNEP; Social sub-group led by FAO; and Economic sub-group co-led by IEA and UN Foundation.

GBEP would also like to express its appreciation to all the experts that actively and generously contributed to the development of this report.

Preface

On 11 May 2006, 10 nations and 7 international organizations signed the Terms of Reference to create the Global Bioenergy Partnership (GBEP) and begin to implement the wish expressed by G8 Leaders in the 2005 Gleneagles Summit Action Plan to support “biomass and biofuels deployment, particularly in developing countries where biomass use is prevalent.” As of December 2011, GBEP includes 23 Partner countries and 13 Partner international organizations, along with 23 countries and 11 international organizations that participate as Observers.

Partner countries: Argentina, Brazil, Canada, China, Colombia, Fiji, France, Germany, Ghana, Italy, Japan, Mauritania, Mexico, Netherlands, Paraguay, Russian Federation, Spain, Sudan, Sweden, Switzerland, United Rep of Tanzania, United Kingdom and United States of America.

Partner international organizations: Economic Community of West African States (ECOWAS), European Commission, Food and Agriculture Organization of the United Nations (FAO), Inter-American Development Bank (IDB), International Energy Agency (IEA), United Nations Conference on Trade and Development (UNCTAD), United Nations Department of Economic and Social Affairs (UN DESA), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO), United Nations Foundation, World Council for Renewable Energy (WCRE) and European Biomass Industry Association (EUBIA).

Observer countries: Angola, Australia, Austria, Cambodia, Chile, Egypt, El Salvador, Gambia, India, Indonesia, Kenya, Lao People’s Dem Rep, Madagascar, Malaysia, Morocco, Mozambique, Norway, Peru, Rwanda, South Africa, Thailand, Tunisia and Viet Nam.

Observer international organizations: African Development Bank (AfDB), Asian Development Bank (ADB), Economic Commission for Latin America and the Caribbean (ECLAC), European Environment Agency (EEA), Global Environment Facility (GEF), International Fund for Agricultural Development (IFAD), International Renewable Energy Agency (IRENA), Organization of American States (OAS), West African Economic and Monetary Union (UEMOA), World Bank and World Business Council on Sustainable Development (WBCSD).

The Partnership is currently chaired by Corrado Clini, Minister for the Environment Land and Sea, Italy, and co-chaired by Mariangela Rebuá, Director of the Department of Energy, Ministry of External Relations, Brazil. They are supported by the GBEP Secretariat, hosted at FAO Headquarters in Rome.

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Executive summary

The Global Bioenergy Partnership (GBEP) has a clearly defined mission: to promote the wider production and use of modern bioenergy, particularly in the developing world where traditional use of biomass is prevalent. Exactly how modern bioenergy is developed, deployed, and used is a decision that individual countries will make according to their domestic needs and circumstances. The Partnership established the Task Force on Sustainability to promote the sustainable production and use of bioenergy. The Task Force has developed a science-based, technically sound, and highly relevant set of measurements and indicators that can inform policy-makers and other stakeholders in countries seeking to develop their bioenergy sector to help meet national goals of sustainable development.

This report presents 24 indicators of sustainability regarding the production and use of modern bioenergy, broadly defined. These indicators were developed to provide policy-makers and other stakeholders a set of analytical tools that can inform the development of national bioenergy policies and programmes and monitor the impact of these policies and programmes. The indicators were developed by the Partners and Observers of GBEP and provide a framework for assessing the relationship between production and use of modern bioenergy and sustainable development. The indicators were intentionally crafted to report on the environmental, social and economic aspects of sustainable development.

The GBEP indicators are unique in that they are a product of the only multilateral initiative that has built consensus on the sustainable production and use of bioenergy among a wide range of national governments and international organizations. The indicators are meant to guide analysis at the domestic level and to inform decision-making that encourages the sustainable production and use of bioenergy as a means towards meeting national goals of sustainable development. Measured over time, the indicators will show progress towards or away from a nationally defined sustainable development path. The indicators are value-neutral, do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding. The indicators are intended to inform policy-making and facilitate the sustainable development of bioenergy, and shall not be applied so as to limit trade in bioenergy in a manner inconsistent with multilateral trade obligations.

The benefits and challenges of bioenergy

The production and use of bioenergy is growing in many parts of the world as countries seek to diversify their energy sources in a manner that helps promote economic development, energy security and environmental quality. Modern bioenergy can provide multiple benefits, including promoting rural economic development, increasing household income, mitigating climate change, and providing access to modern energy services. On the other hand, bioenergy can also be associated with risks, such as biodiversity loss, deforestation, additional pressure on water resources, and increased demand for agricultural inputs, land, and commodities. The evaluation of the benefits and challenges of bioenergy production and use should reflect the national context.

Encouraging all stakeholders to use the sustainability indicators

Policy-makers and other stakeholders require information in order to develop and evaluate policy decisions. GBEP encourages all stakeholders, including public officials, technical experts, farmers, producers, and civil society, to use this set of indicators in a holistic and inclusive manner as a framework for planning the sustainable production and use of bioenergy. This set of indicators can empower policy-makers and other stakeholders to take into account the economic, environmental, and social aspects of modern bioenergy that are the most relevant for their domestic needs and circumstances. The indicators are objective, technically sound, value-neutral metrics that inform the policy-making process and report on the impact of policies. The indicators presented here are not themselves instruments of policy. The indicators are written so as to encourage and assist stakeholders to undertake the necessary analytical work of implementing these indicators immediately without the need for developing separate additional metrics of sustainability.

Using the indicators

GBEP prepared this report to present a set of sustainability-related themes and indicators important to consider when developing a modern bioenergy sector. The report provides relevant background in Chapter 2 on how the indicators were developed and describes the three pillars of sustainable development – economic, environmental, and social – in the context of bioenergy.

Each indicator was developed with three parts: a name, a short description, and a multi-page methodology sheet that provides in-depth information needed to evaluate the indicator. The methodology sheet describes how the indicator relates to relevant themes of sustainability and how the indicator contributes towards assessing sustainability at the national level. The methodology sheets outline the approach for collecting and analyzing the data needed to evaluate the indicator and for making relevant comparisons to other energy options or agricultural systems. The methodology sheet also provides information on data limitations and highlights potential bottlenecks to data acquisition. Further the methodology sheets highlight relevant international and national processes with links to publicly available data sources in an extensive reference section. This reference section gives stakeholders, scientists and policy-makers access to a breadth of resources with which they can tailor these indicators to be domestically relevant.

The indicators are starting points from which policy-makers and other stakeholders can identify and develop measurements and domestic data sources that are relevant to their nationally defined needs and circumstances. The GBEP indicators do not provide answers or correct values of sustainability, but rather present the right questions to ask in assessing the effect of modern bioenergy production and use in meeting nationally defined goals of sustainable development.

The following summary table presents the pillars, themes and indicator names.

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 requalification 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

Acronyms

BEFSCI Bioenergy and Food Security Criteria and Indicators

BOD Biochemical oxygen demand

CBD Convention on Biological Diversity

CBO Congressional Budget Office

CDM Clean Development Mechanism

CGE Computable general equilibrium

COD Chemical oxygen demand

CONCAWE Conservation of Clean Air and Water in Europe

CSD Commission on Sustainable Development

COP Conference of the Parties

Defra Department for Environment, Food and Rural Affairs (UK)

EC European Commission

EEA European Environment Agency

EMEP European Monitoring and Evaluation Programme

ELCD European Reference Life Cycle Database

EU European Union

EUCAR European Council for Automotive R&D

FAO Food and Agriculture Organization of the United Nations

FRA Forest Resource Assessment

FTE Full-time equivalent

GBEP Global Bioenergy Partnership

GDP Gross domestic product

GHG Greenhouse gas

GIEWS Global Information and Early Warning System

GIS Geographic information system

GISP Global Invasive Species Programme

GREET Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation

GTZ Deutsche Gesellschaft für Internationale Zusammenarbeit

GVA Gross value added

GWP Global warming potential

HAIR Harmonised environmental indicators for pesticide risk

IAEA International Atomic Energy Agency

ICID International Commission on Irrigation and Drainage

ICLS International Conference of Labour Statisticians

IEA International Energy Agency

IFEU Institut für Energie und Umweltforschung

IIASA International Institute for Applied Systems Analysis

ILO International Labour Organization

ILUC Indirect land-use change

INTA Instituto Nacional de Tecnología Agropecuaria

IPCC Intergovernmental Panel on Climate Change

IRENA International Renewable Energy Agency

ISIC International Standard Industrial Classification

ISO International Organization for Standardization

IUFRO International Union of Forest Research Organizations

IWMI International Water Management Institute

JPOI Johannesburg Plan of Implementation

JRC Joint Research Centre

LADA Land Degradation Assessment in Drylands

LCA Lifecycle analysis

LCI Lifecycle inventory

LSMS Living Standard Measurement Survey

LUC Land-use change

MDGs Millennium Development Goals

NASS National Agricultural Statistics Service (USDA)

NGO Non-governmental organization

NRCS Natural Resources Conservation Service (USDA)

NREL National Renewable Energy Laboratory (US DOE)

NVA Net value added

OECD Organisation for Economic Co-operation and Development

PE Partial equilibrium

PM Particulate matter

POPs Persistent organic pollutants

PPP Purchasing power parity

REDD Reducing Emissions from Deforestation and Forest Degradation

R&D Research and development

RD&D Research, development and demonstration

RSB Roundtable on Sustainable Biofuels

SADC Southern African Development Cooperation

SFU Solid fuel use

SME Small or medium-sized enterprise

SLU Sveriges lantbruksuniversitet

SOC Soil organic carbon

SOM Soil organic matter

TARWR Total actual renewable water resources

TAWW Total annual water withdrawals

TPES Total primary energy supply

TREMOD Transport Emission Estimation Model

UN CCD United Nations Convention to Combat Desertification

UN DESA United Nations Department of Economic and Social Affairs

UNCTAD United Nations Conference on Trade and Development

UNDP United Nations Development Programme

UNECE United Nations Economic Commission for Europe

UNCED United Nations Conference on Environment and Development

UNED United Nations Environment and Development

UNEP United Nations Environment Programme

UNESCO United Nations Educational, Scientific and Cultural Organization

UNFCCC United Nations Framework Convention on Climate Change

UNFF United Nations Forum on Forests

UNICA União da Indústria de Cana-de-açúcar

US DOE United States Department of Energy

US EPA United States Environmental Protection Agency

USDA United States Department of Agriculture

USGS United States Geological Survey

VCS Verified Carbon Standard

VSA Visual Soil Assessment

WHO World Health Organization

WISDOM Woodfuel Integrated Supply/Demand Overview Mapping

WRA Weed Risk Assessment

WSSD World Summit on Sustainable Development

WWDR World Water Development Report

PART I

Chapter 1: The history and purpose of the GBEP work on sustainability

§1.1 Background: an overview of the Global Bioenergy Partnership

The Global Bioenergy Partnership (GBEP) builds its activities upon three strategic areas: sustainable development, climate change, and food and energy security. It is a forum where national governments, international organizations and other partners engage in a dialogue on effective policy frameworks, identifying ways and means to facilitate investment and encouraging the sharing of good practices and experiences through capacity building. It also enhances collaborative project development and implementation, with a view to optimizing the contribution of bioenergy to sustainable development, taking account of environmental, social and economic factors.

GBEP was established to implement the commitments taken by the G8 in the 2005 Gleneagles Plan of Action to support "biomass and biofuels deployment, particularly in developing countries where biomass use is prevalent." The G8 welcomed the establishment of GBEP at the St Petersburg Summit of 2006 and the work of GBEP has been supported at subsequent meetings of the G8. The work on indicators of sustainable bioenergy production and use was raised in the 2008 G8 Hokkaido Toyako Summit, when G8 members specifically invited GBEP to "work with other relevant stakeholders to develop science-based benchmarks and indicators for biofuel production and use." At the 2009 L'Aquila Summit, the 2010 Muskoka Summit and the 2011 Deauville Summit, the G8 reinforced its support for the work of GBEP, including on a set of sustainability indicators. Furthermore, the G20 Ministers of Agriculture in 2011 stated in their Paris meeting Declaration: "We continue to support the work of the Global Bioenergy Partnership (GBEP) [...]. In particular we support its set of sustainability indicators for bioenergy and we welcome the future GBEP work on capacity building for sustainable bioenergy."

In January 2007, GBEP was registered with the Commission on Sustainable Development (CSD) as a Partnership for Sustainable Development.[1] CSD Partnerships are voluntary multi-stakeholder initiatives contributing to the implementation of intergovernmental commitments in Agenda 21, the Programme for the Further Implementation of Agenda 21 and the Johannesburg Plan of Implementation.[2]

GBEP is a forum where voluntary cooperation works towards consensus amongst governments, intergovernmental organizations and other partners in the areas of the sustainability of bioenergy and its contribution to climate change mitigation. It also provides a platform for sharing information and examples of good practice.

[1] See http://www.un.org/esa/dsd/dsd_aofw_par/par_index.shtml for further information on CSD Partnerships for Sustainable Development.
[2] These three documents are available at http://www.un.org/esa/dsd/resources/res_docukeyconf.shtml.

GBEP's main objectives are to:

- promote global high-level dialogue on bioenergy policy-related issues and facilitate international cooperation;
- support national and regional bioenergy policy discussions and market development;
- favour the transformation of biomass use towards more efficient and sustainable practices;
- foster exchange of information and skills through bilateral and multilateral collaboration; and
- facilitate bioenergy integration into energy markets by tackling barriers in the supply chain.

The current GBEP priority areas are:

- facilitating the sustainable development of bioenergy;
- testing and disseminating a common methodological framework on the measurement of GHG emissions reduction from the use of bioenergy;[3] and
- raising awareness and facilitating information exchange on bioenergy.

In order to achieve progress in these priority areas, GBEP established two Task Forces, one on GHG Methodologies in October 2007 and one on Sustainability in June 2008, of which all GBEP Partners and Observers are members. In May 2011, GBEP also decided to start work through a new working group to facilitate capacity building for sustainable bioenergy. This report represents an outcome of the work of the Task Force on Sustainability.

§1.2 The GBEP Task Force on Sustainability

It is generally acknowledged that bioenergy can make a significant contribution to meeting energy security and economic development goals, as well as helping to reduce GHG emissions. There is also widespread recognition that if bioenergy is to have a viable long-term future, it must be produced and used in a sustainable way, taking into consideration the economic, environmental and social pillars of sustainability. GBEP believes that it can play a valuable role in helping to build an international consensus on practical and effective ways of achieving this important and widely shared goal. To that end, in June 2008 GBEP established, in accordance with the declarations made by G8 Leaders, a Task Force on Sustainability, initially under the leadership of the United Kingdom and then of Sweden, to develop:

[3] The GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy, Version One, was published in January 2011 and is available online at http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/GHG_clearing_house/GBEP_Meth_Framework_V_1.pdf

- an inventory of existing initiatives on sustainable bioenergy, with a view to identifying and discussing commonalities and differences in approaches as well as issues requiring further consideration;
- a set of global science-based criteria[4] and indicators[5] regarding the sustainability of bioenergy;
- a final report summarizing the work and conclusions of the Task Force as well as any recommendations to the GBEP Steering Committee for further work.

GBEP Partners and Observers focused the work within the Task Force on developing criteria, now known as themes, and indicators regarding the sustainability of bioenergy in all its forms. This work is intended to provide relevant, practical, science-based, voluntary sustainability indicators to guide any analysis undertaken of bioenergy at the domestic level. The indicators themselves, when made part of such analysis, should be used with a view to informing decision-making and facilitating the sustainable development of bioenergy and, accordingly, shall not be applied so as to limit trade in bioenergy in a manner inconsistent with multilateral trade obligations.

Even though several national and regional initiatives[6] either have defined or are in the process of defining their own sustainability criteria for bioenergy (mainly focused on liquid biofuels), the uniqueness of the Task Force lies in the fact that it is currently the only initiative that has built consensus among a broad range of national governments and international organizations on the sustainability of bioenergy and in the fact that the emphasis is on providing measurements useful for informing national-level policy analysis and development. The GBEP work addresses all forms of bioenergy. The GBEP sustainability indicators do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding on GBEP Partners. Measured over time, the indicators will show progress towards or away from a sustainable development path as determined nationally.

[4] For the purpose of this work criteria are defined as categories of sustainability factors, capacities or processes that are used to evaluate the environmental, economic or social performance of bioenergy production and use.
[5] For the purpose of this work indicators are defined as measurable outcomes of a criterion regarding bioenergy production and use; a means for measuring or describing various aspects of the criterion.
[6] Detailed overviews of a number of these initiatives can be found in the Compilation of Bioenergy Sustainability Initiatives that was prepared by the FAO's Bioenergy and Food Security Criteria and Indicators (BEFSCI) project. This compilation, which is updated on a regular basis, is available at http://www.fao.org/bioenergy/foodsecurity/befsci/62379/en/

Chapter 2: The GBEP work on sustainability indicators

§2.1 The GBEP work as a contribution to sustainable development

The Global Bioenergy Partnership considers that bioenergy can make a valuable contribution to sustainable development. To realize and enhance this contribution, the development and deployment of modern bioenergy should be based on the principles reflected in a common set of sustainability indicators that can be applied by individual countries or communities to meet today's needs, including the needs of the poor, without compromising the ability of a society to meet its future needs. An assessment of the sustainability of bioenergy integrates economic, environmental and social considerations within the context of relevant and practical data that can inform national decision-making.

Since the Rio Earth Summit of 1992, sustainable development has been variously defined and interpreted. Agenda 21, the Johannesburg Plan of Implementation and CSD Decisions build a picture of the value of sustainable development as a unifying and useful agenda for the twenty-first century.

The World Commission on Environment and Development (or "the Brundtland Commission") defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[7] Various principles of great relevance to any global framework intended to measure sustainability are established in the Brundtland Commission's report, Agenda 21, the Rio Declaration, the Johannesburg Plan of Implementation and CSD Decisions:

- As a general guiding principle, sustainable development is a process of technological progress and social organization that meets the needs of society (and particularly those of the poor) in a manner that does not damage the environment to the extent that future generations cannot meet their own needs.
- The environmental limits set by this last condition are not absolute, but can be adjusted by human innovation in technology and social organization.
- Sustainable development implies social equity between generations and within each generation. Social equity and eradication of poverty are essential to sustainable development.
- Sustainable development requires integration of economic, social and environmental considerations. The Johannesburg Plan of Implementation refers to "the three components of sustainable development — economic development, social development and environmental protection — as interdependent and mutually reinforcing pillars." In addition to these three pillars, institutional aspects should also be considered. CSD-3

[7] The Report of the World Commission on Environment and Development is available at http://www.un-documents.net/wced-ocf.htm

Decision refers to the economic, social, institutional and environmental elements of sustainable development.

- Sustainable development is a process in which changes are made consistent with future as well as present needs.
- Trade-offs among different elements of sustainability are inevitable and must be assessed with one eye on the present and one eye on the future, based on nationally determined circumstances.
- The basic concept of sustainable development and the broad strategic framework for achieving it should be common, though interpretations will vary among countries, taking into account their unique social, physical, economic and political characteristics.

Therefore, an assessment of the sustainability of bioenergy needs to integrate economic, social, environmental and institutional considerations. It is on the basis of the above principles that a common set of sustainability indicators can be applied by countries to such a multi-faceted subject as bioenergy. Concerted efforts to improve access to reliable, affordable, efficient and clean energy services, preferably from renewable sources, are essential for sustainable development. The goal is to foster economic growth through more efficient use of energy and wider utilization of renewable energy resources, including bioenergy. Effective choices of energy solutions that take into account national circumstances are important and can benefit from the creation and application of tools to guide decision-makers.

The GBEP indicators and food security

Food and energy security are among the most serious challenges faced by developing countries. Sustainable modern bioenergy can promote agricultural, social and economic development that will help address these challenges. While seeking to promote the positive effects that sustainable modern bioenergy can have on food and energy security, GBEP recognizes that there is a complex, multi-faceted relationship between bioenergy and food security. Investing in and improving agricultural systems could lead to increased production of food, feed, and fibre, and the residues that can provide feedstock for bioenergy, which in turn could promote rural development and improve household welfare. Modern bioenergy development can lead to an increase in household income, especially in rural areas, by stimulating both employment creation and enterprise development. At the same time, bioenergy can create increased demand for certain agricultural commodities, which can increase their price. Moreover, because many of the resources and inputs – such as land, water and fertilizers – that will be used to produce bioenergy are also required for food and feed production, bioenergy projects should be developed in a rational and well-thought-out manner. These factors, along with many other factors described in this report, can have a positive or negative effect on countries and households, depending on local needs and circumstances. When there is a significant change in global, regional and/or national food prices, the resulting welfare impact should be assessed, regardless of any bioenergy production or use. In the 2008 Hokkaido Toyako Summit Declaration on Global Food Security, G8 leaders acknowledged this relationship and explicitly asked that countries “ensure the compatibility of policies for the sustainable production and use of biofuels and food security”. In response, GBEP Partners and Observers have developed a comprehensive set of science-based sustainability indicators that seeks to measure, among other things, the effects of bioenergy production and use on food and energy security. Through these indicators, GBEP Partners and Observers aim to clarify possible misconceptions and improve the understanding of the complex relationship between bioenergy and food security in order to show that the sustainable production and use of bioenergy can contribute to both food and energy security.

“Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (World Food Summit, 1996). The four internationally agreed dimensions of food security are: availability, access, stability and utilization. These dimensions are related to, *inter alia*: land use; land access; household income; access to energy; nutrition; and, last but not least, food supply and prices, which are affected by a number of factors in addition to bioenergy production and use, such as the demand for food, feed and fibre; imports and exports of foodstuffs; weather conditions; and the prices of energy and agricultural inputs. As such, food security is a broad, multi-faceted issue that has multiple economic, environmental and social dimensions; there is no single measurement or indicator that can determine its presence or absence. GBEP developed a number of indicators that monitor most of these key elements and when measured in concert, will permit an evaluation of the impacts of bioenergy on food security at the national, regional and household levels.

The core GBEP indicators relevant to food security are 1) Price and supply of a national food basket, 2) Land use and land-use change related to bioenergy feedstock production, 3) Allocation and tenure of land for new bioenergy production, 4) Change in income, 5) Bioenergy used to expand access to modern energy services, and 6) Infrastructure and logistics for distribution of bioenergy. The price and supply of a national food basket indicator is a technically sound approach to assessing the effects of bioenergy on a nationally determined collection of representative foodstuffs, including main staple crops. This indicator seeks to account for the main factors that influence the price and supply of food in relation to bioenergy use and domestic production, taking into consideration changes in the demand for agricultural products, changes in the cost of agricultural inputs including the impact of energy prices, weather conditions, and food imports and exports. It also considers the influence of changes in food prices on national, regional and/or household welfare levels. The core set of indicators relevant to food security are complemented by additional indicators that monitor the economic, environmental and social factors that affect food security, including jobs in the bioenergy sector, biological diversity in the landscape, soil quality, water use and efficiency, and productivity. The aggregate evaluation of these indicators will provide the knowledge necessary to meet the goal enunciated by the G8 Leaders – a goal further highlighted in a recent study on “Making

Integrated Food-Energy Systems work for People and Climate" (FAO, 2011). The study finds that the sustainable production of food and energy side-by-side may offer an effective means to enhance a country's food and energy security while simultaneously reducing poverty and mitigating climate change.

§2.2 How the indicators were developed

The Task Force sought to develop a holistic set of science-based and technically sound indicators for a national evaluation of the domestic production and use of modern bioenergy. All Partners and Observers were invited to contribute their respective experiences and technical expertise to the development and refinement of the indicators.

The Task Force first developed and provisionally agreed on a list of criteria, and then established three sub-groups: (1) Environmental – co-led by Germany and UNEP; (2) Social – led by FAO; and (3) Economic and Energy Security – co-led by IEA and UN Foundation. These sub-groups undertook the detailed work on indicators for these criteria, which were equally divided between the three sub-group headings. Decisions – as for all decisions in GBEP – were taken by consensus among Partners. Furthermore, the Task Force agreed to change the term "criteria" to "themes", noting that this better represented the nature of the eighteen agreed category headings under which the indicators had been developed.

During the process of developing the indicators and their underlying methodology sheets, GBEP Partners and Observers took into account and used the work of relevant organizations and international processes related to environmental quality, social welfare and sustainable economic development. Examples of some of the relevant international organizations whose work has informed the development of indicators include the International Energy Agency (IEA), the International Labour Organization (ILO), the UN Development Programme (UNDP), the UN Environment Programme (UNEP), the UN Food and Agriculture Organization (FAO), the UN Industrial Development Organization (UNIDO) and the World Health Organization (WHO).

The development of the indicators made use of existing guidance documents on sustainable development as discussed in the global community, especially taking into account the Millennium Development Goals (MDGs), the Commission on Sustainable Development (CSD), and Agenda 21. Although the MDGs do not have a specific goal for energy access and energy security, the MDGs provide concrete numerical benchmarks for tackling extreme poverty within the context of sustainable development in its many dimensions. The Task Force developed themes that are connected to the social impact of access to modern energy services, notably human health and safety and rural and social development. Access to modern energy services from bioenergy for households and businesses can promote social development and poverty reduction and as such can contribute to achieving various MDGs, including those related to health, education and gender equality.

The Task Force developed indicators relevant to the economic themes of sustainability, including those that cover the concepts of economic development, energy security, resource availability and efficiency of use, infrastructure development, and access to technology. Indicators related to these themes were informed by the work of the CSD, UN agencies (e.g. FAO, UNDP, UNEP and UNIDO), IEA, and the work of agencies and ministries within the governments of Task Force Partners and Observers.

Within the environmental pillar, a number of central themes were considered as part of the discussion of the GBEP sustainability indicators, including those related to greenhouse gas emissions, productive capacity of the land and ecosystems, water and air quality, biological diversity, and land-use change. Within these themes, mitigating greenhouse gas emissions and protecting biological diversity are two of the important aspects that were discussed and incorporated within relevant indicators and their underlying methodologies. Therefore, the development of the indicators was informed by relevant international processes also focusing on these themes, including the Convention on Biological Diversity (CBD), the Intergovernmental Panel on Climate Change (IPCC) and the UN Framework Convention on Climate Change (UNFCCC).

The Convention on Biological Diversity has informed several GBEP themes such as those related to productive capacity of the land and the ecosystem, water availability and quality, and land-use change. The UN Framework Convention on Climate Change (UNFCCC) acknowledges that the adverse effects of climate change are a common concern, including human activities that have been increasing the atmospheric concentrations of greenhouse gases, which may adversely affect natural ecosystems and humankind. Measurement and reporting of GHG emissions from bioenergy production follow the Intergovernmental Panel on Climate Change (IPCC) Guidelines and Good Practice Guidance (2000 and 2003), which consider these emissions in the Land use, land-use change and forestry (LULUCF), Agriculture, and Industrial processes sectors. Among the themes defined by GBEP, the theme on greenhouse gas emissions is the one that most directly and comprehensively addresses issues related to climate change – specifically the role of bioenergy in mitigating climate change. Other themes relevant to assessing the mitigation potential of bioenergy include concepts associated with productive capacity of the land and land-use change.

Selection criteria for the indicators

The selection criteria for the indicators were relevance, practicality and scientific basis. Additionally, the geographic scale was to be considered, as well as whether the full set of indicators was balanced and sufficiently comprehensive while still practical. Information relating to these selection criteria for the GBEP indicators was collected in order to inform the decision-making process. Much of this supporting information is presented in the methodology sheets in Chapter 3 of this report. The criteria for selecting the indicators are set out below.

Relevance: An indicator must be relevant inasmuch as it must measure as closely as possible the trend of a theme or a component of a theme. The indicators should provide policy-makers with targeted information that will help them to decide where current policies are successful and where new policy responses are required, as well as potentially providing information of use to other bioenergy stakeholders. The sustainability of bioenergy is to be considered, where relevant and meaningful, in an energy context and therefore, where possible, indicators should be identified that allow for comparison with the fossil fuel equivalent (or alternative energy sources or policy options). However, this should not be to the detriment or exclusion of non-fossil fuel comparators desirable to demonstrate the sustainability of bioenergy.

The degree of relevance of each indicator to policy-makers might differ locally, and this is likely to be reflected in the choice of indicators that countries or organizations choose to use to inform their own analysis. However a set of general, universally relevant indicators, applicable to all sources of bioenergy, was (and is) the primary objective of the Task Force.

Practicality: The practicality of the indicators will contribute to the extent of their (voluntary) use. The Task Force strove to learn from relevant previous and ongoing indicator processes. Adopting, where appropriate, identical or similar indicators to those that are already being measured, and methodologies that are already in use, would make measuring the GBEP indicators less burdensome, but care had to be taken to ensure that these indicators and methodologies disaggregated the effect of bioenergy from all other factors as well as possible.

The practicality of indicators depends on data availability and the ability to collect the data. For example, some or all data required to produce a value for the indicator may already be available from existing sources. When the relevant data is not already being collected, the level of complexity (time, cost, technology) of the process required to measure the indicators (e.g. statistical survey, modelling and physical measurement) needed to be considered prior to selecting the indicator. The selected indicators were deemed to be measurable within a reasonable period of time and with reasonable effort. The ability to measure the indicators will depend on a country's capacity, and the Task Force adopted the approach that if an indicator could be practically measured in some Partner countries, but others lacked the capacity to do so, then the indicator should still be considered practical since the required capacity could be developed through technical cooperation. Where quantitative indicators could be found, they were to be preferred to qualitative indicators, but it was decided that this latter class should be included where appropriate, especially where methodologies for quantitative indicators did not exist and needed to be developed. Qualitative data may be preferred in some instances so as not to give a false sense of accuracy, such as in surveys or reporting of interview results.

Scientific basis: The scientific basis of the indicators is crucial to the operationality, objectivity, transparency and credibility of the GBEP Task Force product. The Task Force aimed to have a well-established scientific relationship between the indicator and the aspect of sustainability that it is desired to measure or inform, as expressed by a theme or a component of a theme.

The key to the indicators being science-based is having a methodical approach to proving the link between the values or changes in values over time and bioenergy production and use, as well as principles to guide the establishment of accurate answers, taking into account resource constraints. General agreement on the methodological approach and the level of certainty attached to its results was necessary for the final selection of a GBEP indicator. The indicator methodological approaches encompass techniques from the full range of sciences (e.g. natural, social, behavioural), including modelling, interviews and direct physical measurement. A physical measurement, for all its precision, may in fact be subject to uncertainties related to the baseline, interference of external factors, natural (e.g. seasonal) variation of the environment, etc. of a comparable or greater level than uncertainties from interview or model-based results. Since an important part of science is peer review of research findings, the existence of peer-reviewed documentation of the use of an indicator to demonstrate an impact of bioenergy production and use was one important factor in support of the scientific basis of an indicator.

In light of this agreed process, the Task Force agreed on a list of 24 sustainability indicators developed under three pillars (environmental, social and economic) to reflect common usage in international discussion on sustainable development.

§2.3 Contextual information and cross-cutting issues to support analysis using the GBEP indicators

As previously stated, the GBEP work on sustainability indicators is intended to guide any analysis undertaken of bioenergy at the domestic level and to be used with a view to informing decision-making and facilitating the sustainable development of bioenergy. To this end, the measurements of the indicators will be more relevant to stakeholders if they are placed within the proper domestic context, including information on legal, policy and institutional frameworks. For example, it could be useful for governments to interpret the indicator values in light of national policy objectives and targets in place regarding bioenergy or related to bioenergy. Specifically, a government might ask whether there is a legal, policy and institutional framework in place to assess, monitor and address the sustainability issues relating to bioenergy production and/or use addressed by the indicators. It could also be useful to take into consideration the level of government support offered for bioenergy production and/or use, in order to perform a cost-benefit analysis of a national bioenergy programme. This approach may also allow the user to understand the extent to which different practices used in their country are aligned with their overall policy objectives. In this way it enables governments to collect information on sustainability issues related to bioenergy, analyse the information and use this for the design, development, and implementation of policies related to sustainable bioenergy production and use.

To make the analysis more informative for decision-makers, it is important to collect information on the types of practices applied (including management practices for feedstock production, conversion technologies and the scale of these operations). Although GBEP indicators are generally presented as national aggregates, data for the GBEP indicators may often be collected at the level of economic operators (e.g. farmer, processor, distributor, and end user).

While the focus of the indicators is at the national level, disaggregated analysis of these data could also be performed – where relevant and appropriate – to augment the analysis of data aggregated at the national level.

The measurement of the indicators, including determining which areas and population groups within a country should be looked at in greater detail, will be enhanced by the availability and use of maps of natural and human resources, including socio-economic conditions. This would include: soil surveys; maps of water resources; maps of areas recognized nationally as being of high biodiversity value or as ecosystems of national importance; and mapping and assessment of food insecurity and vulnerability. However, gaps in such information should not prevent attempts to start measuring the GBEP sustainability indicators in a country.

Just as the values of the GBEP sustainability indicators for bioenergy would benefit from being interpreted in the context of relevant policy objectives, so might bioenergy policy benefit from being developed in the context of various cross-cutting issues. These issues have an influence on how bioenergy policies can be developed in a sustainable way and ideally provide relevant information and policy context on a broader scale. The following is a non-comprehensive list of such relevant issues, which mainly relate to institutional and policy aspects and others that are broader than and outside the scope of the agreed GBEP indicators:

- Good governance
    - Good governance, in particular a sound legal and policy framework and adequate institutional capacity and coordination, and public institutions conducting public affairs and managing public resources in order to guarantee the realization of human rights, provides an enabling environment for achieving the objectives of bioenergy policies as well as measuring the indicators in a transparent way;[8]
- Integrated policy-making, with the institutional structure to support it
    - It is important that the environmental, social and economic implications of bioenergy policy be considered in a holistic manner and reflected in institutional arrangements;
    - Given how cross-cutting a policy area bioenergy is, coordination among ministries and agencies responsible for agriculture (including forestry), energy, environment, climate change, trade, poverty eradication, research and development, industry, finance and other areas is invaluable in order to ensure that bioenergy policy objectives and implementation are aligned with those of other policy areas, with synergies and trade-offs assessed;
- Regular policy monitoring and review to ensure quality in policy implementation
    - It is always good practice to monitor and evaluate implemented policies and review the policies in light of this evaluation. Bioenergy policy is no exception. A well planned and thought-out modern bioenergy programme can have important benefits; however, a

[8] UN Millennium Declaration stresses that good governance at both the national and international level is essential to meeting development objectives.

    programme that is scaled up quickly without being well-thought-out may pose some potential challenges that are currently poorly understood due to their complexity and novelty;
  - Such monitoring and review could inform adjustments of government plans, programmes and budgets to help ensure bioenergy policies meet their goals;
- Monitoring, implementation of and adherence to national bioenergy policies, goals and legislation
  - Adequate data collection, observation and analysis can contribute to successful implementation of the bioenergy policies;
  - National bioenergy legislation should be supported by effective enforcement by relevant domestic authorities;
  - Strengthening institutional capacity for monitoring the effects of bioenergy production and use may encourage compliance with national policy and legislation pertaining to bioenergy production;
  - Including relevant stakeholders in the planning and design of policies can enhance their efficacy and improve data collection and monitoring of the effects of a particular policy;
- Decentralized, participatory decision-making processes
  - Recognized and established decision-making processes and the involvement of all relevant stakeholders (including private sector, public sector, civil society, women, and local and indigenous communities, as appropriate) at different levels in bioenergy decision-making processes is central to sustainable development and contributes to the acceptance of sustainable bioenergy policies;
  - This may also help national-level bioenergy policy-making factor in locally specific considerations in their design and implementation;
- Public-private partnerships with a view to advancing energy for sustainable development;
- Environmental, social, and economic impact assessments of bioenergy projects and national bioenergy programmes;
- Codes of business practice and responsible investment approaches to achieve the sustainable production and use of modern bioenergy;
- Integrated physical and land-use planning and management
  - A well organized system for physical land use planning can contribute to the selection of suitable areas for bioenergy production and use and sustainable management and can prevent undesired developments in e.g. vulnerable ecological areas or protected areas;
- Integrated water resources management
  - As bioenergy crops and processing plants require water, while other water demands for other functions (drinking water, cooling water for power plants, agriculture, etc.) exist as

well, integrated water management in watersheds could help guide sustainable supply and demand;

- Policies and laws that guarantee well defined land and water use rights and promote legal security of tenure;
- Education and awareness-raising about bioenergy and its contribution to sustainable development;
- Stable regulatory framework and an enabling environment for the bioenergy sector;
- Open, equitable, secure, non-discriminatory and predictable multilateral trading system consistent with sustainable development; and
- Improved market access for developing countries.

§2.4 The GBEP sustainability indicators for bioenergy

In the following table, the set of twenty-four GBEP bioenergy sustainability indicators is set out under the three pillars, with the relevant themes listed at the top of each pillar. The order in which the indicators are presented has no significance. Full supporting information relating to the relevance, practicality and scientific basis of each indicator, including suggested approaches for their measurement, is set out in the methodology sheets in Part II.

ENVIRONMENTAL PILLAR	
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar: 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[9]	
INDICATOR NAME	INDICATOR DESCRIPTION
1. Lifecycle GHG emissions	Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology chosen nationally or at community level, and reported using the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'
2. Soil quality	Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested
3. Harvest levels of wood resources	Annual harvest of wood resources by volume and as a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy
4. Emissions of non-GHG air pollutants, including air toxics	Emissions of non-GHG air pollutants, including air toxics, from bioenergy feedstock production, processing, transport of feedstocks, intermediate products and end products, and use; and in comparison with other energy sources
5. Water use and efficiency	▪ Water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstocks, expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and non-renewable water sources ▪ Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of bioenergy output, disaggregated into renewable and non-renewable water sources
6. Water quality	▪ Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock cultivation, and expressed as a percentage of pollutant loadings from total agricultural production in the watershed ▪ Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents, and expressed as a percentage of pollutant loadings from total agricultural processing effluents in the watershed
7. Biological diversity in the landscape	▪ Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production ▪ Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated ▪ Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used

8. Land use and land-use change related to bioenergy feedstock production	▪ Total area of land for bioenergy feedstock production, and as compared to total national surface and agricultural and managed forest land area
	▪ Percentages of bioenergy from yield increases, residues, wastes and degraded or contaminated land
	▪ Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production, including the following (amongst others):
	  o arable land and permanent crops, permanent meadows and pastures, and managed forests;
	  o natural forests and grasslands (including savannah, excluding natural permanent meadows and pastures), peatlands, and wetlands

[9] In light of discussions on the issue and considering the state of the science on quantifying possible indirect land-use change (ILUC) impacts of bioenergy, it has not yet been possible to include an indicator on ILUC. GBEP notes that further work is required to improve our understanding of and ability to measure indirect effects of bioenergy such as ILUC and indirect impacts on prices of agricultural commodities. GBEP will continue to work in order to consolidate and discuss the implications of the current science on these indirect effects, develop a transparent, science-based framework for their measurement, and identify and discuss options for policy responses to mitigate potential negative and promote potential positive indirect effects of bioenergy.

SOCIAL PILLAR	
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar: 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	
INDICATOR NAME	INDICATOR DESCRIPTION
9. Allocation and tenure of land for new bioenergy production	Percentage of land – total and by land-use type – used for new bioenergy production where: ▪ a legal instrument or domestic authority establishes title and procedures for change of title; and ▪ the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title
10. Price and supply of a national food basket	Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration: ▪ changes in demand for foodstuffs for food, feed and fibre; ▪ changes in the import and export of foodstuffs; ▪ changes in agricultural production due to weather conditions; ▪ changes in agricultural costs from petroleum and other energy prices; and ▪ the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally determined
11. Change in income	Contribution of the following to change in income due to bioenergy production: ▪ wages paid for employment in the bioenergy sector in relation to comparable sectors ▪ net income from the sale, barter and/or own consumption of bioenergy products, including feedstocks, by self-employed households/individuals
12. Jobs in the bioenergy sector	▪ Net job creation as a result of bioenergy production and use, total and disaggregated (if possible) as follows: o skilled/unskilled o temporary/indefinite ▪ Total number of jobs in the bioenergy sector and percentage adhering to nationally recognized labour standards consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work, in relation to comparable sectors
13. Change in unpaid time spent by women and children collecting biomass	Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services
14. Bioenergy used to expand access to modern energy services	▪ Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of energy and numbers of households and businesses ▪ Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass
15. Change in mortality and burden of disease attributable to indoor smoke	Change in mortality and burden of disease attributable to indoor smoke from solid fuel use, and changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves
16. Incidence of occupational injury, illness and fatalities	Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors

ECONOMIC PILLAR	
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar: 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	
INDICATOR NAME	INDICATOR DESCRIPTION
17. Productivity	▪ Productivity of bioenergy feedstocks by feedstock or by farm/plantation ▪ Processing efficiencies by technology and feedstock ▪ Amount of bioenergy end product by mass, volume or energy content per hectare per year ▪ Production cost per unit of bioenergy
18. Net energy balance	Energy ratio of the bioenergy value chain with comparison with other energy sources, including energy ratios of feedstock production, processing of feedstock into bioenergy, bioenergy use; and/or lifecycle analysis
19. Gross value added	Gross value added per unit of bioenergy produced and as a percentage of gross domestic product
20. Change in the consumption of fossil fuels and traditional use of biomass	▪ Substitution of fossil fuels with domestic bioenergy measured by energy content and in annual savings of convertible currency from reduced purchases of fossil fuels ▪ Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content
21. Training and re-qualification of the workforce	Percentage of trained workers in the bioenergy sector out of total bioenergy workforce, and percentage of re-qualified workers out of the total number of jobs lost in the bioenergy sector
22. Energy diversity	Change in diversity of total primary energy supply due to bioenergy
23. Infrastructure and logistics for distribution of bioenergy	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each
24. Capacity and flexibility of use of bioenergy	▪ Ratio of capacity for using bioenergy compared with actual use for each significant utilization route ▪ Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity

Chapter 3: Methodology sheets for the GBEP sustainability indicators

The methodology sheets for the GBEP sustainability indicators, which include supporting information relating to the relevance, practicality and scientific basis of the indicators, are presented in Part II of this report. They were developed through a transparent, concerted, collaborative and science-based effort. They reflect the combined expertise and experience of GBEP Partners and Observers.

§ The structure and content of the methodology sheets

The following content is included for each indicator.

Indicator name:

A short name is used for ease of communication.

Description:

This is what the indicator actually measures.

Measurement unit(s):

SI units are suggested, though countries may use other units, depending on national data availability.

Application of the indicator:

Here it is stated whether the indicator applies to the production and/or use phases and whether it applies to all bioenergy feedstocks, end-uses and pathways or just some specified categories.

Relation to themes:

- Here it is stated how the indicator is related to the sustainability themes selected by GBEP, trends in aspects of which the indicator is intended to measure;
- Note that an indicator can inform more than one theme and more than pillar of sustainability.

How the indicator will help assess the sustainability of bioenergy at the national level: Here it is explained how the indicator values should be interpreted in order to assess the sustainability of bioenergy and inform national-level decision-making.

Comparison with other energy options:

- While the indicators can be used to assess the sustainability of bioenergy (including comparison of different types of bioenergy used within a country) without reference to other energy sources, it is also deemed extremely useful to be able to relate the contribution (positive or negative) of bioenergy to sustainable development to that of the fossil fuels or other energy sources they might displace or compete with;

- It is therefore stated in this section to which other energy sources the indicator can be applied;
- If the indicator cannot be applied to other energy sources, alternative means of including the issue in a full comparative analysis are suggested.

Methodological approach:

- This section includes a description of how the methodological approach allows one to determine the impact of bioenergy production and/or use, separate it from other possible impacts, and build an aggregate national level indicator; [10]
- The indicators are intended to measure the effects of bioenergy on various elements of environment, social and economic sustainability and to report these effects primarily as national averages or aggregated values; however, it can be challenging to attribute effects specifically to bioenergy in the overall context of agricultural and economic activity. The effects of bioenergy production and use will typically depend upon the geographic location of feedstock production and processing. Many of the methodology sheets present options for attributing the effects from the cultivation and processing of potential feedstocks (e.g. crops, wood, residues and wastes) for bioenergy production and use. The choice of methods for data collection, aggregation and analysis will depend upon country-specific circumstances and knowledge of the national agriculture and bioenergy sectors. The same applies to the methods used for attribution to bioenergy. Data for bioenergy feedstock production can be collected at the national (or regional) level if assessment of agricultural performance exists, otherwise through sampling (or surveys) at the field level or at bioenergy processing facilities. Data on the sources and extent of bioenergy feedstock production and processing will permit attribution to bioenergy. In some cases, the distance of the crop production or residue/waste collection site from bioenergy processing facilities can be used to estimate whether a crop, residue or waste is used for bioenergy. Similarly, data for the processing phase can be collected at the national (or regional) level if reporting from biofuel production plants exists, otherwise through data collection at the processing plant level. Strategies for data collection should take into consideration the degree of geographic variation of feedstock production. Where supply chains are more complex, it might be necessary to adopt a simpler approximation based on the percentage of the crop produced in the country that is used for bioenergy production.

[10] Note that “impacts” in this context does not carry the same meaning as it does in the context of the driving force-pressure-state-impact-response (DPSIR) indicator framework. (See for example “Environmental Indicators: Typology and Use in Reporting”, European Environment Agency, 2003: http://eea.eionet.europa.eu/Public/irc/eionet-circle/core_set/library?l=/management_documentation/indicator_typology/_EN_1.0_&a=d)

Anticipated limitations:

A key part of science is knowing the main sources of uncertainties in a methodology – some possible means to reduce these uncertainties are also suggested in some cases.

Data requirements:

- These are the basic data that are required to build the indicator, in accordance with the methodological approach described above;
- Measurement types and scales are also indicated.

Data sources (international and national):

A non-exhaustive list of available sources of the data required for the indicator.

Known data gaps:

Known data gaps and suggested strategies for filling these gaps are highlighted.

Relevant international processes:

International processes that involve similar measurements could mean that data is being collected or that new data collection would serve more than the GBEP indicators and could also imply a broader policy relevance.

References:

A non-exhaustive list of useful references, some of which might be essential to a full understanding of the methodological approach suggested.

PART II

The methodology sheets

The GBEP sustainability indicators and their methodologies are presented below. The order in which the indicators are presented has no significance. The summary table of pillars, themes and indicator names is followed, for the environmental, social and economic pillars in turn, by a more detailed table showing the themes, indicator names and indicator descriptions, and then the respective methodology sheets. These methodology sheets set out supporting information relating to the relevance, practicality and scientific basis of each indicator, including suggested approaches for their measurement.

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

ENVIRONMENTAL PILLAR

THEMES

GBEP considers the following themes relevant, and these guided the development of indicators under this pillar:

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[11]

INDICATOR NAME	INDICATOR DESCRIPTION
1. Lifecycle GHG emissions	Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology chosen nationally or at community level, and reported using the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'
2. Soil quality	Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested
3. Harvest levels of wood resources	Annual harvest of wood resources by volume and as a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy
4. Emissions of non-GHG air pollutants, including air toxics	Emissions of non-GHG air pollutants, including air toxics, from bioenergy feedstock production, processing, transport of feedstocks, intermediate products and end products, and use; and in comparison with other energy sources
5. Water use and efficiency	▪ Water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstocks, expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and non-renewable water sources ▪ Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of bioenergy output, disaggregated into renewable and non-renewable water sources
6. Water quality	▪ Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock cultivation, and expressed as a percentage of pollutant loadings from total agricultural production in the watershed ▪ Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents, and expressed as a percentage of pollutant loadings from total agricultural processing effluents in the watershed
7. Biological diversity in the landscape	▪ Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production ▪ Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated ▪ Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used
8. Land use and land-use change related to bioenergy feedstock production	▪ Total area of land for bioenergy feedstock production, and as compared to total national surface and agricultural and managed forest land area ▪ Percentages of bioenergy from yield increases, residues, wastes and degraded or contaminated land ▪ Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production, including the following (amongst others): ○ arable land and permanent crops, permanent meadows and pastures, and managed forests; ○ natural forests and grasslands (including savannah, excluding natural permanent meadows and pastures), peatlands, and wetlands

[11] In light of discussions on the issue and considering the state of the science on quantifying possible indirect land-use change (ILUC) impacts of bioenergy, it has not yet been possible to include an indicator on ILUC. GBEP notes that further work is required to improve our understanding of and ability to measure indirect effects of bioenergy such as ILUC and indirect impacts on prices of agricultural commodities. GBEP will continue to work in order to consolidate and discuss the implications of the current science on these indirect effects, develop a transparent, science-based framework for their measurement, and identify and discuss options for policy responses to mitigate potential negative and promote potential positive indirect effects of bioenergy.

Indicator 1 Lifecycle GHG emissions

Description:

Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology chosen nationally or at community level, and reported using the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'

Measurement unit(s):

Grams of CO_2 equivalent per megajoule

Relevance

Application of the indicator:

The indicator applies to bioenergy production and use and to all bioenergy feedstocks, end-uses or pathways.

Relation to themes:

The Life Cycle Assessment (LCA) provides an estimate of the GHGs emitted by the production and processing of bioenergy feedstock, transport and distribution of feedstock and biofuel, and the end use of bioenergy/biofuel.

The methodological framework developed by the GBEP GHG Task Force aims to provide a flexible tool for communicating and comparing methodologies used in GHG LCA of bioenergy systems.

In addition to the theme of *Greenhouse gas emissions*, this indicator is related to *Productive capacity of the land and ecosystems, Air quality, Land-use change, including indirect effects, Human health and safety,* and *Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use.*

How the indicator will help assess the sustainability of bioenergy at the national level:

One reason for pursuing increased use of bioenergy worldwide is its potential to reduce greenhouse gas (GHG) emissions compared to the fossil fuels it would replace. Life Cycle Assessment (LCA) is an important tool for estimating GHG emissions and comparing the GHG emissions from different energy sources at the national level.

Providing a detailed explanation of the methodology used along with the outcome of the measurement and analysis by means of the GBEP Common Methodological Framework for GHG LCA of Bioenergy, ensures that transparent and comparable results when performing LCA analysis of GHG emissions from different energy sources.

GHG LCA analysis that has been aggregated to the national level provides a straightforward metric of the impact of bioenergy on GHG emissions. This aggregated value would be most accurate and useful when regional or local differences in emissions are accounted for in each step of the LCA, including the use of region-specific emission factors (if applicable). In addition, separate aggregated figures for bioenergy for transport, heat and power might be useful for informing national policy-making, as might more specific national average figures for biodiesel, bioethanol, biogas, etc. Likewise, figures for GHG emissions savings due to national programmes such as energy efficiency measures in the use of biomass for heating and cooking might also be relevant.

In some cases it will not be fossil fuel use but rather the traditional use of biomass for energy (e.g. combustion of fuelwood on open fires) that could be substituted for by modern bioenergy (see Glossary). In these cases the equivalency of the compared options in terms of the energy services they provide have to be assessed with careful consideration (see Methodological approach section below).

Comparison with other energy options:

Comparisons can be done with GHG emissions of the fossil fuel equivalent and any other energy source. A comparison calculating lifecycle GHG emissions from bioenergy as a percentage of lifecycle GHG emissions of the replaced fossil fuel could give additional information.

Scientific Basis

Methodological approach:

The GHG LCA of bioenergy approach using the GBEP Common Methodological Framework allows identification of how the different steps contribute to the total emissions. The framework consists of 10 "Steps" of analysis. Steps 1 and 2 are simple checkboxes in which the user identifies the GHGs included in the LCA and the source of the biomass feedstock. In cases where the feedstock is waste material, further explanation is requested. Steps 3-9 walk the user through a full LCA appropriate for bioenergy production and use, including emissions due to land-use change, biomass feedstock production, manufacture and use of fertilizers, co-products and by-products, transport of biomass, processing into fuel, transport of fuel, and fuel use (where applicable and nationally appropriate). For each Step the framework presents a series of yes/no questions and checkboxes, with requests for further explanation where appropriate. Step 10 is the comparison with the replaced fuel. In this Step the framework includes options for reporting LCA of fossil transport fuels and LCA of fossil stationary heat and electricity production systems.

Thus the description of the methodological approach applied to determine the lifecycle GHG emissions and to separate these from other sources of emissions emerges through answering the questions in the Methodological Framework.

In cases where traditional use of biomass for energy (e.g. combustion of fuelwood on open fires for cooking or heating) is to be compared with use of modern bioenergy (such as improved cookstoves or electricity) the GHG emissions per unit energy should be made per unit of useful energy output (see Glossary), taking into account the end-use technology. A comparison between total GHG emissions from traditional use of biomass and those from the modern bioenergy that has replaced this traditional use of biomass could also be undertaken as part of a holistic evaluation of the two scenarios, taking into consideration the fact that household activities such as cooking and heating may alter in both quality and quantity as a consequence of such a change in energy access. (Indicator 14, *Bioenergy used to expand access to modern energy services, measures some of these changes*.) Emission factors for open burning, fireplaces and various categories of stoves are available from Akagi et al. (2010) and updated at BAI[12] website, from IPCC (2000; 2006), the IPCC NGGIP emissions factor database and the US-EPA Compilation of Air Pollutant Emission Factors.

An aggregate national level indicator value could be formed by classifying bioenergy production (and consumption, where end-use is considered in the LCA calculation) in the country into categories according to various parameters such as feedstock, land-use change, soil type, cultivation practice, conversion technology, transportation distance and method, end use, etc. and determining a representative lifecycle GHG emissions value per unit of energy for each category, in accordance with a methodology presented by means of the GBEP Common Methodological Framework. Where possible, emission factors for different regions and types of processes should be included in the calculations. These values, together with the quantity of energy produced according to each category of production and consumption, could then be used to form a national average for GHG emissions per unit energy, as well as a total absolute value for GHG emissions from bioenergy production and use in the country.

Alternatively, bioenergy producers could be asked to submit GHG values for their bioenergy to a national authority, each using a nationally recognised methodology or using the GBEP Common Methodological Framework to demonstrate the methodology applied. These could then be aggregated as desired, taking into account any variations in methodologies applied.

[12] See electronic sources section.

Anticipated limitations:

Uncertainty in the estimates from LCA, specifically in regards to the boundaries of LCA, and data gaps in the lifecycle inventories are important issues to consider. Numerous studies have been performed worldwide on biofuels looking at this issue with differing results, strongly depending on the assumptions made for the calculations. Therefore, to improve the usefulness of LCA results and foster transparency, GBEP's Task Force on GHG Methodologies developed a common methodological framework that could be applied to the lifecycle analysis of bioenergy production and use as compared to the full lifecycle of its fossil fuel equivalent. The framework was developed with the expectation that it would be continually informed and improved by users' experience.

Specific significant methodological uncertainties and methodological choices that can significantly affect the indicator values refer to:

- indirect land-use change;
- base year to measure land use change;
- multi-purpose crops;
- N_2O emissions;
- how to treat different timescales of emission sources and possible sinks as well as permanence of carbon stored in unburnt products.

Practicality

Data requirements:

Detailed data requirements will depend upon the choice of methodology, but in general will include information about:

- GHGs covered;
- source of biomass (feedstock);
- information about land use change (direct and/or indirect);
- biomass feedstock production including GHG sources and sinks;
- transport of biomass feedstock (calculation method, transport means);
- processing into fuel;
- by-products and co-products produced;
- transport of fuel (e.g. calculation method, transport means);
- information about fuel use;
- comparison with replaced fuel using the same framework.

These data can be gathered through national/international statistical accounts, calculation/computation of (existing) data or physical, biological or chemical measurements at the national, regional, field (farming) or site (processing plant) level.

Data sources (international and national)[13]:

Possible data sources include:

- default values of the German biofuel legislation;
- ECOINVENT;
- ELCD;
- Energy Information Administration (US DOE);

[13] See references and electronic sources section.

- GEMIS;
- International Energy Agency (IEA);
- IPCC Guidelines for National Greenhouse Gas Inventories, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories;
- IPCC NGGIP Emissions Factor Database;
- JEC Well-to-Wheels Analyses (JRC, EUCAR and CONCAWE);
- National Center for Atmospheric Research Fire Emission Factors and Emission Inventories;
- UNEP-SETAC (Society for Environmental Toxicology and Chemistry) LCI Initiative;
- US EPA and California *low-carbon fuel standard* studies: Rules for calculating the greenhouse gas impact of biofuels, bioliquids and their fossil fuel comparators;
- US EPA: Emission factors and AP 42, Compilation of Air Pollutant Emissions Factors;
- US DOE NREL Life Cycle Inventory Database.

Known data gaps:

The context and protocols for the US DOE NREL Life Cycle Inventory database[14] can provide some insight to overcome data gaps. Also the EU LCI Database has a similar approach.

Relevant international processes:

- IPCC
- UNFCCC
- The Montreal Process
- EU directives 2009/28/EC and 2009/30/EC
- UN Millennium Development Goals (MDGs) indicator 7.2 - CO_2 emissions, total, per capita and per $1 GDP (PPP) [14]

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[14] See electronic sources section.

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Indicator 2 Soil quality

Description:

Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested.

Measurement unit(s):

Percentage

Relevance

Application of the indicator:

The indicator applies to bioenergy production from all bioenergy feedstocks.

Relation to themes:

This indicator is primarily related to the theme of *Productive capacity of the land and ecosystems*. Soils are an essential determinant of the productive capacity of the land. Soil degradation, which can be caused by climatic factors, poor agricultural practices and their interactions, can lower the productive capacity of the land. Appropriate agricultural and soil management practices can help to maintain or improve soil quality, and therefore have a positive effect on the productive capacity of the land. The development and use of technologies for soil conservation and management are also key.

To maintain or improve soil quality on land used for bioenergy feedstock production, it is necessary to address the effects of soil and crop management, and in some cases forest and woody vegetation management, on five key factors that contribute to soil degradation:

1. loss of soil organic matter, leading to decreased carbon and soil fertility;
2. soil erosion, leading to soil loss (especially of fertile topsoil);
3. accumulation in soils of mineral salts (salinization) from irrigation water and/or inadequate drainage, with possible adverse effects on plant growth;
4. soil compaction, reducing water flow and storage, and limiting root growth;
5. loss of plant nutrients, e.g. through intensive harvest.

These factors are often interlinked. For example, erosion removes surface, the soil fraction in which most organic matter is found, which affects soil water retention, and soil compaction in the surface layer can increase surface runoff, thereby further increasing soil and water losses.

Organic matter within the soil serves several functions. From a practical agricultural standpoint, it is important especially to (i) maintain nutrient capital, providing plant-available nutrients such as nitrogen, phosphorus, sulphur and iron; (ii) improve soil structure and minimize erosion; and (iii) aid water infiltration and retention. It therefore serves as a useful proxy for other aspects of soil quality and productivity.

Soil organic carbon (SOC) is the total organic carbon of a soil excluding carbon from undecayed plants and animal residues, and is the major component of soil organic matter (SOM). The amount of SOM directly affects several aspects of soil function, so SOC is commonly used both to measure organic matter content in soils and as an indicator to assess soil quality and productivity. Soil organic carbon is affected by changes in production management systems. For example, removal or burning of plant residues typically left on the ground following (agricultural or forestry) harvest leaves the soil without adequate protection, causing the loss of soil organic matter through surface erosion by rainfall and wind. Moreover, plant residues also contribute to restoration of soil organic matter through decay.

This indicator also informs the following themes: *Greenhouse gas emissions; Water availability,* *use efficiency and quality; Biological diversity* (if the measured changes in soil quality can reveal changes in soil biodiversity); and *Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use*.

How the indicator will help assess the sustainability of bioenergy at the national level:

This indicator aims to monitor the influence of bioenergy production on soil quality. The higher the percentage of land used for producing bioenergy feedstocks where soil quality is maintained or increased, the more sustainable is the production. If this percentage is low or declines, it may indicate a need to review policy and practice in order to identify ways of making bioenergy feedstock production more sustainable. For example, should soil organic carbon levels decline, it might be useful to investigate the extent to which extraction of primary agricultural or forestry residues for bioenergy production could have been responsible.

Comparison with other energy options:

Maintenance of soil quality is an important factor in sustainable development. However, direct comparison of impacts on soil quality with other energy options is relevant in some cases. Other energy options may occupy potentially productive land and in some cases may affect soil productivity. Assessing impacts in these cases would require consideration of the total amount of land involved as well as the percentage where productive capacity is maintained or enhanced. Fossil fuel production results in depletion of natural resources through mineral extraction (rather than degradation or improvement of the land). Therefore a meaningful comparison of bioenergy and fossil fuels under this criterion would need to use a metric that shows the effective footprint on a country’s natural capital of other energy forms. However, there is not yet a high degree of agreement on appropriate methodologies for such a metric.

When evaluating this indicator it may be useful and relevant to compare the results for bioenergy feedstock production with similar assessments for other types of agriculture or with national and/or regional averages for agricultural lands. When making such comparisons it is important to take into account the differences between various biomass production systems. Different agriculture systems, forestry systems and aquatic biomass production systems are based on different practices, often requiring different inputs, and can have different impacts on soil quality.

Scientific basis

Methodological approach:

Due to the interlinkages between the key factors affecting soil quality (soil organic matter decline, soil erosion, salinization, compaction and nutrient loss), assessing trends in soil organic carbon can provide much of the information needed. Declines in soil carbon content may also be indicative of soil erosion, and soil that is low in organic carbon may be more vulnerable to compaction. Consequently, soil organic carbon content is suggested as the principal parameter to assess in relation to soil quality and productive capacity (but this may be less relevant in carbon-rich soils, such as peats).

Ideally, compiling the indicator would require repeated measurement of soil organic carbon content from each production area, following established methods, such as the Soil Sampling Protocol[15] for Soil Organic Matter of the EU or the USDA Natural Resources Conservation Service Soil Survey Laboratory Methods Manual (USDA, 2004), and taking care to ensure that methods and sampling are consistent over time.

According to the Terrestrial Ecosystem Monitoring Sites database of the FAO Global Terrestrial Observing System, both laboratory and in situ methods can be used to measure soil organic carbon levels (see Soil Survey Staff, 2009):

- Laboratory methods: dry combustion analysis usually used with wet combustion methods playing a minor role. The International Standards Organization (ISO) specifies a method for determining the total carbon content in soil after dry combustion in ISO-10694 a detailed presentation of which can be found at the ISO catalogue[15] webpage. The organic carbon content is calculated from this content after correcting for carbonates present in the sample. If carbonates are removed beforehand, then the organic carbon content is measured directly. A description of the analytical methodology can also be found in USDA (2004). Measurements can also be obtained through laboratories using infrared spectroscopy (see Sensing Soil Quality [16]).

- In situ methods: usually by estimating the organic matter content using colour tables and then calculating carbon as a percentage (commonly 58%) of organic matter. The FAO Visual Soil Assessment (FAO, 2008, 2010) for example is used to carry out local level land degradation assessment in drylands (see LADA). It uses a field test to assess soil labile carbon in which a dilute solution of potassium permanganate ($KMnO_4$) is used to oxidize organic carbon and the extent of loss of colour (absorbance) indicates the amount of oxidisable carbon in the soil. The FAO Visual Soil Assessment uses both a Soil Carbon Index and a composite Soil Quality Index, which may provide useful basis for compiling relevant data.

Determining whether soil quality is maintained (or improved) requires a baseline against which successive measurements can be compared. The baseline measurement for each bioenergy production area should include a measure of soil carbon content based on a sampling intensity that is appropriate both to available resources and to the *in situ* variability of SOC. Successive measurements should be taken at intervals that are relevant to the rotation cycle of the energy crop – e.g. annual crops or forest rotations. Because of both natural variability of SOC in time and space and limitations in the accuracy of measurement techniques, it will be necessary to define ‘maintenance’ of SOC for national circumstances, i.e. to decide how large a difference in soil carbon content between successive measurements should be considered a ‘real’ change.

Data needed for this indicator could be gathered either directly by the responsible national agency or by producers, who would be requested to report the findings to the national government. At national scale, the total land areas used for bioenergy production on which soil quality is maintained or improving will be divided by the total land area used for bioenergy production to calculate the percentage of the total bioenergy production area where soil quality is maintained or enhanced. These data can also be aggregated by feedstock and/or land management practice.

The natural variability of SOC means that effective *in situ* measurement requires intensive and carefully designed sampling, which may be infeasible due to limitations in the capacity and resources available. At least two approaches can be used to reduce measurement burdens: (a) limiting monitoring to areas at high risk of soil quality decline, and (b) focusing on the use of practices that help to maintain or enhance soil quality are in place.

To focus on areas at high risk of soil quality decline, monitoring can potentially be limited to the areas of most intensive production (where nutrient losses could be a problem) and those identified using a simple risk assessment based on evaluating conditions contributing to risk in each production area. For example:

- if the cultivation of bioenergy feedstocks takes place on land with slopes higher than 5% or open exposure to high or persistent winds, there is a particular risk of soil erosion;
- if the cultivation of bioenergy feedstocks entails changes from dryland pasture to irrigated cropping, and/or poor quality water is used for irrigation, there is a risk of salinization;
- where cultivation is heavily mechanised or the movement of heavy machinery is otherwise a factor, there is a risk of soil compaction.

These assessments can potentially be based on datasets available at broad geographical (national/regional/global) scales that will indicate where more in-depth study and sampling are needed. Additional approaches for assessing risk can be found in Stocking and Murnaghan

[15] See electronic sources section.
[16] See electronic sources section.

(2001).

An alternative approach to reducing the monitoring burden, and potentially a complementary indicator that would also help to assess whether soils are being appropriately managed before degradation occurs, would be to compile information on the percentage of the land used for bioenergy production where practices that help to maintain or enhance soil quality are in place. The practices that are relevant will vary between countries and production systems, and might include low till, or no till agriculture, various means of limiting erosion, management of crop residues and compost; use of green manures and cover crops, and less intensive harvest of perennial energy crops, among others. Bioenergy producers could be requested to provide information the measures employed to maintain or enhance soil quality in their bioenergy feedstock production and on the area over which these measures are implemented. This would permit aggregation (using a similar approach to that recommended for Indicator 7.3) to produce an estimate of the percentage of bioenergy production where such practices are employed.

Under certain circumstances, where specific risks are involved, additional measures may be needed to assess the maintenance of soil quality more effectively. A simple assessment of conditions in each production area, as described above, could help identify such risks, and areas where additional monitoring is required. In principle, monitoring should include baseline and repeated measures of parameters relevant to specific risks, e.g.:

- Ideally, where there is a particular risk of soil erosion, soil loss should be measured, but direct measurement of actual soil loss from erosion may not be practical, but modelling based on broader scale datasets may be helpful, as may other approaches given by Stocking & Murnaghan (2001). Michigan State University maintains an online version of the Revised Universal Soil Loss Equation (RUSLE), which can be used to predict the effects of bioenergy production and removal of residues (USDA and NRCS, 2006). Therefore, it is suggested that information on soil stabilizing measures in place (e.g. those listed at the Washington State Department of Ecology[17] website) be used as an indication of where erosion is likely to be minimized (see indicative list below).
- Where soil salinization is a risk, soil electrical conductivity (EC) should be measured, e.g. according to USDA’s Electrical Conductivity Test (USDA, 2001; chapter 5).
- Where there is a particular risk of soil compaction, bulk density should be measured, e.g. according to USDA’s Bulk Density Test (USDA, 2001; chapter 4).

To describe soil nutrient balances, ideally inputs by weathering, deposition and fertilization (including ash recycling) should be compared to outputs such as harvests and leaching. A simpler estimation of the balances can be done by comparing losses by harvests to inputs by fertilization. This simple estimation may be sufficient in many cases.

The soil quality indicator should be re-measured at appropriate intervals (e.g. every 1 to 5 years, to be determined in relation to the soil type, crops grown, likely impacts and rates of impact) and compared to the baseline and/or previous measurements to identify the bioenergy production areas where they are stable or improving. In cases where some parameters are stable or improving while others are in decline (e.g. soil organic matter content is maintained or improved while soil compaction increases), it is recommended to conduct further analysis of the trends in overall productivity of the land. For example, this could be done by comparing the agricultural input that is necessary for the maintenance of the agricultural productivity (while taking into account the potential impact of further external factors).

Anticipated limitations:

Capacity and resources for conducting risk assessments and subsequent measurements may not be always available. As for other indicators it may be difficult to distinguish areas used for bioenergy production from areas where the same crops are grown for other purposes. Crop rotations may also make it difficult to identify where trends need to be monitored and to attribute emerging patterns to bioenergy cultivation.

[17] See electronic sources section.

Practicality

Data requirements:

For this indicator to inform about the sustainability of bioenergy production, data from measurements repeated over several years should be compared against baseline data (ideally also collected over several years), meaning that measurements are needed from multiple points in time. The baseline year(s) can be the year in which the production area was first used for cultivation of bioenergy feedstocks, or the one before current bioenergy feedstock production started, or, if data do not exist from those years, the first year for which they are available.

The specific information needs are as follows:

- total land on which bioenergy feedstock is cultivated or harvested (in hectares or square kilometres);
- soil organic carbon content for each bioenergy production site (mg of organic carbon per g of soil sample);
- where focus is to be limited to areas at high risk of soil quality decline data are needed on risk factors for nutrient loss, erosion, soil compaction or salinization based on site scale assessments and/or mapped information. These can usefully be summarized by area (e.g. “X square kilometres of the production area are on slopes higher than 5 degrees”);
- depending on the risk assessment:
    - in case of increased erosion risk: Information on soil stabilizing measures in place by production site;
    - in case of increased soil salinization risk: Data on electric conductivity of the soil by production site;
    - in case of increased soil compaction risk: Data on bulk density of the soil by production site.

Where adequate field measurement of carbon content and other soil parameters is not feasible (e.g. due to lack of resources), it may be possible to develop an approach analogous to that used in Indicator 7.3 (*Biological diversity in the landscape*), in which the extent of likely improvement in soil quality is indicated by the area where measures to maintain or improve soil quality are employed. Some of the measures included under Indicator 7.3 are relevant to maintaining soil quality, but others addressing the specific soil properties mentioned here would need to be included.

Due to the key role of soil management practices in maintaining soil quality, it is also important for assessments of bioenergy sustainability to take into account efforts to promote implementation of best practices in soil management (including through training courses, technical assistance, investments in research, etc). Identifying and sharing best practices and information on management techniques aimed at maintaining or enhancing soil organic carbon and other aspects of soil quality can contribute to sustainability. Best practices in soil quality management could further be encouraged by evaluating this indicator and by assessing the area of bioenergy production in which these practices are implemented in relation to the total area being used for bioenergy production.

Data sources (international and national)[18]:

This indicator requires field measurements within bioenergy production areas. Soil legacy data (soil profiles and maps) are available in many countries (in agricultural departments of national governments and national research institutions) and in institutions like FAO, and may prove useful sources of data. A Global Soil Partnership (GSP) is being created to mobilize such soil information, in which countries are to be active participants. Soil legacy data and international datasets are likely to be especially relevant for risk assessment and possibly for establishing baselines. Other potentially relevant sources include:

[18] See reference and electronic sources section.

- the Global Soil Map project will generate thematic digital layers globally using satellite multispectral analyses and legacy soil data (ground truthing data), including soil carbon, to produce data on soil properties at 90 x 90m resolution. Initial work is focusing on sub-Saharan Africa, data are available at the Global Soil Map website;
- in the US, soil carbon and other soil properties are beginning to be collected under the “Dynamic Soil Property (DSP)” data collection effort. This is primarily being done in conjunction with soil survey activities and Ecological Site Description data collection. Not a monitoring project, DSP’s, including carbon, are collected on major (benchmark) soils, on different land use/management systems using a “substitution of space for time” concept thereby allowing the comparison of properties such as soil carbon by land use/management practice in the near future;
- European Digital Archive of Soil Maps (EuDASM);
- Soil Organic Carbon Content in Europe (EU-JRC resources);
- map of the natural susceptibility of the soil to Compaction in Europe.

Known data gaps:

Due to the fairly rapid and highly variable changes that can occur in topsoils as a result of land use and soil management practices, this indicator depends in principle on site-level measurements associated with individual bioenergy production areas. Therefore, existing global or national datasets on e.g. soil organic carbon content are unlikely to be useful as a baseline, but they may be very helpful as a basis for risk assessment and modelling.

In addition, actual soil loss from erosion is difficult to measure, which is why reporting on established soil stabilization measures is suggested as a proxy indicator for erosion or avoidance of erosion.

If it is financially and logistically challenging to take measurements as frequently as ideally recommended, but stratifying the sampling and establishing standard protocols could reduce the total burden of maintaining the indicators.

Relevant international processes[19]:

- European Commission’s Thematic Strategy for Soil Protection (Communication (COM(2006) 231).
- Roundtable on Sustainable Palm Oil Principles and Criteria (RSPO, 2007): Criterion 4.2 requires that cultivation “practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimized and sustained yield” and Criterion 4.3 requires that “practices minimise and control erosion and degradation of soils”.
- Better Sugar Cane Initiative (Bonsucro, 2011): Criterion 5.2 requires practices “to continuously improve the status of soil and water resources”, which includes to “ensure the continuous improvement of soil organic carbon”.
- Roundtable on Sustainable Biofuels (RSB, 2010): Principle 8 asks for biofuel operations to “implement practices that seek to reverse soil degradation and/or maintain soil health”. Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests(Montréal Process, 2007).
- Stockholm Convention on Persistent Organic Pollutants.
- UN Convention to combat desertification.
- UNEP on POPs. UNEP's Chemicals Branch is developing global guidance for POPs analysis and is undertaking training and capacity building for laboratories, governments, and other institutions to provide high quality information on the presence of POPs in all media (UNEP on POPs)
- OECD Theme: Soil quality provides soil quality statistics for OECD countries (OECD data

[19] See reference and electronic sources section.

compendium).

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Indicator 3 Harvest levels of wood resources

Description:

Annual harvest of wood resources by volume and as a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy

Measurement unit(s):

m^3/ha/year, tonnes/ha/year, m^3/year or tonnes/year

percentage

Relevance

Application of the indicator:

The indicator applies to bioenergy production from wood resources and forestry residues, according to nationally defined forest type.

Relation to themes:

This indicator relates primarily to the theme *Productive capacity of land and ecosystems*. The indicator aims to monitor the harvest of trees, wood resources and the removal of wood harvest residues for bioenergy. Unsustainable forestry practices may disrupt nutrient cycles and deplete soil of organic matter, which would have negative impacts on both continued wood production and for the moisture holding capacity of the soil and overall hydrological function of the land. As such, this indicator relates to Indicator 1 (*Lifecycle GHG emissions*), Indicator 2 (*Soil quality*), Indicator 5 (*Water use and efficiency*) and Indicator 6 (*Water quality*).

Wood energy is the dominant source of energy for over two billion people, particularly in households in developing countries (FAO, 2011). Traditional use of biomass, especially fuelwood and charcoal, currently provides nearly 10 percent of the world's total primary energy (IPCC, 2011). Social and economic scenarios indicate a continuous growth in the demand for woodfuels that is expected to continue for several decades (Schlag and Zuzarte, 2008). In developing countries, the dependence on such fuels is much greater; they provide about one-third of the total energy in these countries, and as much as 80 percent of energy is derived from biomass in some sub-regions of Africa. Particularly in poor rural and urban households wood and charcoal from wood are the most commonly used fuels. In addition to being used for domestic cooking and heating, they are often essential in food processing industries for baking, brewing, smoking, curing and producing electricity.

In sub-Saharan Africa and other parts of the developing world deforestation is a major concern. Harvesting wood for use as cooking fuel contributes to this problem. Transitioning away from this traditional source of biomass and towards sustainable modern bioenergy has the potential to reduce deforestation. Data collected in the process of evaluating this indicator can be used to understand the potentially beneficial role that this indicator has in reducing demand for woody biomass and as such reducing pressure on forests. Evaluating this indicator together with Indicators 8 (*Land use and land-use change related to bioenergy feedstock production*) and 20 (*Change in consumption of fossil fuels and traditional biomass*) can provide data that highlights the potential benefits that modern bioenergy use can have on forest ecosystems and forest management practices.

To the extent that forest productivity is reduced or that residues are normally used for other purposes (e.g. fuel and feed for local use), it may relate to the themes of *Access to land, water and other natural resources* and to *Resource availability and use efficiencies in bioenergy production*. Assessing extraction intensity in relation to estimates of growth or sustained yield should provide an indication of the sustainability of the practice.

How the indicator will help assess the sustainability of bioenergy at the national level:

GBEP indicator 3 is based upon the Montréal Process Criterion 2 (Maintenance of productive capacity of forest ecosystems), Indicator 2.d: Annual harvest of wood products by volume and as a percentage of net growth or sustained yield (Montréal Process, 2007). This indicator is intended to assess whether forests are being harvested beyond their ability to renew themselves and how much of the harvested wood and harvest residues are being used for energy purposes. Monitoring the volume of wood and non-wood forest products annually removed relative to the amount which could be removed sustainably provides an indication of a forest's ability to provide a continuing supply of forest products and economic and forest management opportunities, and therefore provides a basis for identifying the degree to which bioenergy production is part of sound forest management. The use of biomass for bioenergy creates a demand for woody harvest residues, such as low-quality trees, branches, and stumps, which could increase the off-take of nutrients that would otherwise contribute to forest soil nutrient cycling. While the impact of bioenergy production on soil quality is dealt with explicitly in Indicator 2 (*Soil quality*), the issues raised by the removal of woody harvest residues are considered in this indicator as well.

Comparison with other energy options:

The bioenergy produced from the harvest of wood resources can be compared to energy produced from fossil fuels or other energy sources including solar and wind.

Scientific basis

Methodological approach:

This indicator requires the measurement and analysis of extraction levels as well as sustainable levels of extraction including net growth and/or sustained yield. These data are most easily assessed by wood product type (sawlogs, fuelwood, residues, etc.) at the region or country geographic scale. The indicator should be evaluated over nationally defined timescales relevant to the Forest Management Unit (FMU) of interest. While the indicator specifies that the levels of wood should be evaluated annually, the indicator should also be evaluated for longer periods of time in order to account for fluctuations in annual harvest levels resulting from temporary declines in forest productivity due to natural phenomena such as adverse weather and outbreaks of pests. The relevant timescales should be established taking into account national, regional and local forest characteristics and conditions.

Factors determining (and used in calculating) sustainable harvest levels include forest type, climate and soils as well as management regime, and methods are country-specific. They can be calculated by forest management authorities and private landowners for particular management areas and forest types, using growth functions and simulation models, most commonly in terms of industrial roundwood. Few models are available that account for fuelwood harvest and small-scale extraction or for residue use; here again it may be necessary to use models or factors that calculate this as a function of timber harvest. Similar information is needed for the calculation of 'non-renewable biomass' (NRB) in relation to project scale interventions under the UN Framework Convention on Climate Change Clean Development Mechanism (CDM, 2009) or the Verified Carbon Standard (VCS 2010, 2011) methodologies.

Extraction levels should, in theory, be available from harvest records, but these are likely to be less effective for locations where informal harvesting, for example of firewood, or illegal extraction is a major factor. The UN FAO Global Forest Resource Assessment (FRA) has created a network of National Correspondents that have reported on the management of forest resources in their country. In addition, FRA maintains an electronic repository of its Working Paper Series (FRA Working Paper List[20]) that provides numerous case studies in effective forestry management and best practices for the collection and analysis of forest management data. Data on forests are now being collected by a combination of remote sensing using satellites and ground sampling, aka ground truthing (FRA, 2010[20]). In formal forest management

[20] See electronic sources section.

or harvesting arrangements there are requirements to measure harvest yields by volume or weight; however, in many locations there is both illegal and informal harvesting of wood, fibre, fuel where records are not available. Accounting for this class of harvest will be a challenge. A goal of GBEP is to promote the transition away from traditional biomass consumption and use and towards the production and use of modern bioenergy. Adoption of modern bioenergy could lead to a decrease in informal harvest of wood resources.

In principle, it will be possible to identify at a national scale the total wood resource extraction relative to net growth or sustained yield. This is done by a number of countries for reporting under the Montréal Process, but resources extracted for use other than timber is included to varying degrees (see for example Forestry Agency of Japan, 2009; Montréal Process Implementation Group for Australia, 2008; USDA, 2010). For each area for which extraction data and net growth or sustained yield values are available, comparison of harvest levels with net growth or estimated sustainable yield will make it possible to determine the relative harvest level utilized. Identifying the proportion of the extracted wood resources used for bioenergy will make it possible to identify the amount/percent of harvested wood used for bioenergy. This is in itself challenging, but it may be possible to draw on resources such as FAO's Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM[21]) method to map the supply of, and the demand for, woodfuel as well as national forest inventory and use data.

The possible impact of wood resource extraction for bioenergy will be of concern wherever total extraction exceeds net growth or sustained yield, and especially where the share of extraction used for bioenergy is equal to or greater than any over-utilization of the forest. In addition, how the woods resources are extracted is of great concern. Harvest levels less than net growth or sustainable yield do not guarantee sustainable forestry. If total wood resource harvest exceeds net growth, then care must be taken when attributing the excess to bioenergy. For example, if total extraction of wood products represents 125% of net growth or sustained yield for a forest, and bioenergy use is responsible for extraction amounting to 25% of net growth or sustained yield, then further analysis would be required to determine how the extraction level of wood resources could be brought back to the level of sustained yield, taking into account priority demands for wood extraction from this forest, including bioenergy. (Such analysis might take into consideration the net benefits of the competing demands and the possibility for substituting the wood required with other raw materials). These volumes can be tracked over time to determine the relationships between net growth and wood harvest levels including for energy use.

Ultimately, it should be possible to identify trends in the share of harvested wood resources used for energy. The FAO "Wood Energy Today for Tomorrow" studies constituted an important mechanism for data collection on wood-based fuels and related energy aspects at the national level, including the production, consumption and trade of different wood-based fuels. The series covered Africa, Asia and the Pacific, Latin America and the Caribbean, the Near East and Eastern Europe, as well as countries of the Organisation for Economic Co-operation and Development (OECD). Additional country information was produced by national wood energy experts in the framework of the FAO-EC Partnership Programme on sustainable forest management in Africa. These studies have identified shortcomings and gaps in the main wood energy databases and have helped to diagnose the main constraints in national wood energy planning. Analysis can be used in country-specific circumstances to determine the effectiveness of existing policies and inform any potential policy changes of wood-based bioenergy derived from forests where resource extraction (including for bioenergy) is at sustainable levels. Ideally, the share of forests with sustainable practices would increase over time.

An important aspect of the harvest of wood resources for bioenergy and bioenergy feedstock is the removal of wood harvest residues. Potentially, harvest of residues could be estimated and reported as a function of the harvest and known removal of legal sawlogs. Accounting for the off-take of residues in the case of illegal or informal harvest will be particularly difficult. In order to fully understand the impact that the removal of wood harvest residues will have on soils, it will be necessary to directly monitor soil quality using the methods described in Indicator 2 (*Soil quality*).

[21] See electronic sources section.

Anticipated limitations:

Significant data collection and research are required to develop and maintain a database of net growth or sustained yield for forests for those countries without a forest inventory system.

Practicality

Data requirements:

At the country level, the following data are needed:

- total tonnes of wood resources harvested, including fuelwood and forestry residues collected per year;
- estimates of net growth or sustained yields. These may be available in national forest inventories, or collected in forest management plans. Where no such calculations exist, it may be possible to derive coarse estimates from standard references on forest growth and inventory (see for example the collection of references relating to observations and measurements in FAO-IUFRO-SLU);
- total tonnes of harvested wood products and forestry residues used for bioenergy production per year;
- forest soil analysis (see Indicator 2, *Soil quality*).

Data sources (international and national[22]):

- national forest inventories;
- FAO Forestry, e.g. trends in wood removal (disaggregated into industrial roundwood and woodfuel), from the Global Forest Resources Assessment 2010.

Known data gaps:

Some national forest inventories are outdated. To overcome this, inventories may be updated. Alternatively, harvest levels could be estimated from national statistics. Similarly, for many countries there will be limited data available on net growth (or mean annual increment) or sustained yield. As specified above, it may be possible to obtain a rough estimate using methods outlined in FAO and other forest inventory documentation.

Relevant international processes[22]:

- Montréal Process indicator 2.d (Annual harvest of wood products by volume and as a percentage of net growth or sustained yield);
- Pan-European Criteria and Indicators for Sustainable Forest Management, Indicator 3.1 (Balance between growth and removals of wood over the past 10 years);
- International Tropical Timber Organization: ITTO's Annual Review and Assessment of the World Timber Situation provides information on trends in forest area, forest management and the economies of ITTO member countries;
- United Nations Forum on Forests (UNFF). MAR (monitoring assessment and reporting) supports the production of information on progress in implementation of national forest programmes, progress towards sustainable management of all types of forests according with UNFF criteria;
- FAO Forestat collects annually data on forestry products (import, export, production – quantity and value);
- FAO National Forest Monitoring and Assessment: upon request, FAO supports countries in their efforts to close knowledge gaps by implementing field inventories and establishing forest information services.

[22] See reference and electronic sources section.

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

Description:

Emissions of non-GHG air pollutants, including air toxics, from

(4.1) bioenergy feedstock production,

(4.2) processing,

(4.3) transport of feedstocks, intermediate products and end products, and

(4.4) use;

and in comparison with other energy sources

Measurement unit(s):

Emissions of $PM_{2.5}$, PM_{10}, NO_X, SO_2 and other pollutants can be measured and reported in the following ways as is most relevant to the feedstock, mode of processing, transportation and use.

4.1 mg/ha, mg/MJ, and as a percentage

4.2 mg/m^3 or ppm

4.3 mg/MJ

4.4 mg/MJ

Relevance

Application of the indicator:

The indicator is applicable to bioenergy production and use. In general it applies to all feedstocks, end-uses and pathways. If the feedstock is not derived from land-based cultivation, then part 4.1 that reports on emissions from cultivation, land clearing and crop burning will by definition have a value of zero.

Relation to themes

This indicator is primarily related to the themes of *Air quality* and *Human health and safety*. The four components of the indicator refer to different aspects of air quality.

4.1: The use of agricultural equipment in bioenergy feedstock productions emits non-GHG pollutants. In addition, field burning, if performed, can be a significant component of the pollutants affecting air quality within the lifecycle of bioenergy production. In particular, field burning generates significant quantities of particulate matter that are reported as 2.5 and 10 micron particles, i.e. $PM_{2.5}$ and PM_{10}.

4.2: Bioenergy processing facilities can contribute significantly to the whole lifecycle balance of non-GHG pollutants. In addition, such facilities can have a significant impact on local airsheds, depending on plant size and location.

4.3: Transportation is one of the key sectors releasing air pollutants (Gorham, 2002). Because bioenergy feedstocks have a low density, the requirement to transport these feedstocks to processing plants could result in a significant increase in transportation. As such, transportation of bioenergy feedstocks and of bioenergy products has the potential to impact air quality.

4.4: The use of bioenergy is a major phase in the whole life-cycle balance of non-GHG pollutants. In most countries, energy use and transport cause the major portion of national pollution inventories. Tailpipe pollution from transport is the dominant factor affecting air quality in most cities of the world. The use of biofuels can reduce non-GHG air pollution relative to fossil fuels with the decrease in particulate matter being quite significant (US EPA, 2002). Similarly, low efficient traditional bioenergy (e.g., fuelwood) leads to significant air pollution in many rural areas, especially in developing countries.

How the indicator will help assess the sustainability of bioenergy at the national level:

This indicator will help to identify whether the production, conversion and use of bioenergy are weak or strong contributors to air pollution. If applied as a comparison with fossil fuels, specific advantages or disadvantages per energy unit will be expressed.

4.1: The extent of practice of land clearing by field burning within a country can be regarded as information about the performance of biomass production in the country with regard to air quality. The lower the level of land clearing and crop burning, the lower the negative impact on air quality and the better the performance against this criterion.

4.2: Bioenergy production and processing can involve air pollutant emissions. Low-emission conversion excludes this potentially negative impact of bioenergy production. Monitoring emissions from bioenergy production and processing can support the demonstration and uptake of best available technologies.

4.3: Short transportation distances reduce potentially negative impacts of bioenergy production. Measurement of emissions from this phase of the lifecycle could inform decisions on location of processing plants and choice of transportation method and fuel use.

4.4: A significant shift from fossil fuel to biofuel is likely to cause changes concerning urban air quality. Some changes might be positive, some might be adverse. This indicator shall describe such changes.

The evaluation of 4.1, 4.2, 4.3 and 4.4 should provide a comprehensive analysis of relevant hot-spot areas for non-GHG air pollutant emissions in relation to bioenergy production and use. The detection of hot-spots will encourage the monitoring of trends in national bioenergy production and use and comparison with other energy sources.

Comparison with other energy options:

This indicator can be used to make comparisons of pollutant emissions with other energy options for the conversion, transport and use of different sources of energy. From the data collected a full life-cycle assessment of emissions is possible.

Scientific Basis

Methodological approach:

4.1: The methods for evaluating the emissions of non-GHG air pollutants due to bioenergy feedstock production will vary as a function of the pollutant of interest. Data on the emissions from farm equipment, such as particulates, NO_x, and SO_2, can be generated following standard evaluations of modern agriculture (see USDA Natural Resources Conservation Service Agricultural Air Quality Task Force for data sources and best practices[23]). The data on pollution from farm equipment can be reported as the mass of pollution per land area cultivated (mg/ha) or the mass of emission per energy produced (mg/MJ).

A major source of non-GHG air pollution is burning of biomass associated with land clearing and crop residue burning. The emissions associated with these practices could be presented as mass emissions per area cultivated or per unit of energy produced. An alternative representation could be the percentage of land area burned per area of land used for bioenergy. The area of land (in ha) used for bioenergy feedstock cultivation where land clearing by burning and (separately) bioenergy feedstock crop residue burning has occurred should be measured, and the indicator expressed as a percentage of total land area used for bioenergy feedstock production in the country.

In general there will be national data for crop production and for crop production based on field burning, and at farm level the information on burning or non-burning will be available and can be collected and aggregated.

Estimates of the mass of emissions of non-GHG air pollutants can be generated by measuring

[23] See electronic sources section.

the mass of biomass burnt and using emissions factors for biomass burning (e.g. IPCC default factors for CO and NO_x).

4.2: Processing: this will need further specification as a function of location, feedstock processed and processing technology used which will lead to different methodological approaches:

- Emissions of pollutants per unit of useful energy in absolute terms. This is a standard measurement (in the worst case, allowed emission levels could be used). For the comparison with the replaced fossil fuel. A fossil comparative baseline and clear system boundaries are needed.
- Change in ambient concentrations of pollutants per unit of useful energy. This needs a standard dispersion model and background ambient air quality to be measured (or estimated). For the comparison with replaced fossil fuel. This needs the same data set requested in b) also for the fossil system. It would be unlikely to work without high expertise and intensive review from third parties.

Estimations are possible: several databases (see below) could provide baselines (e.g. for a non-bioenergy scenario or for background ambient air quality) for specific plants as well as for aggregating to the national level.

4.3: Transport: this sub-indicator covers only transport processes within the bioenergy production chain. These transport processes could be assessed separately (e.g. the same way as 4.2 a) above) or aggregated with conversion.

Estimations are possible: several databases (see below) could provide baseline (for a non-bioenergy scenario) for transport emissions as well as for aggregating to the national level.

4.4: Bioenergy use: First, an analysis of substituted energy systems/transport fuels has to be carried out, i.e. describing the situation with modern and traditional bioenergy, respectively, and a reference case without bioenergy. In the case of biofuels for transport, emission sources shall refer to urban areas, and the overall difference between the reference case and the biofuel scenario can be expressed as a change. In the case of other bioenergy use, rural areas might be more relevant (scope has to be substantiated case by case). In both cases, referring to a percentage of improvement (or worsening) might not inform about the relevance and the effectiveness.

Default emission values referring to “typical technical standards” presumed to be appropriate within a certain country can be defined.

Categorization of pollutants: it is presumed useful to make a distinction between (see, for example, the US EPA’s “Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards[24]”):

- criteria (or “classical”) air pollutants including CO, $PM_{2.5}$, PM_{10}, NO_x, SO_x, and VOC;
- air toxics (i.e. hazardous air pollutants, including 1,3-butadiene, acetaldehyde, acrolein benzene, and formaldehyde).

Where feasible, a full lifecycle analysis should be conducted to calculate emissions of non-GHG pollutants integrating the number stages (4.1 to 4.4) and analysing the most significant parameters.

Anticipated limitations:

4.1: Field burnings:

- specific necessities of farmer to burn crops (or use residues for energy purpose) should be acknowledged.

4.2: Processing:

- measurement of air pollutants might not be always available;
- it is necessary to limit the number of pollutant to those for which data is available;

[24] See electronic sources section.

- Impact assessments on ambient air will be complex and supposed to work only on an abstract level.

4.3: Transport: assigning model data to actual transport situation requires assumptions and generalizations.

4.4: Bioenergy use:

- generalized tailpipe emission factors for biofuel and fossil fuel are crucial since the actual bandwidths are very large and overlapping. These are strongly dependent on fuel quality, vehicle type and driving mode;
- working out the right reference systems will need good databases from existing assessments.

Practicality

Data requirements:

- ha of land on which land clearing and crop burning occur (from national spatial and land use inventories, remote sensing if possible);
- emissions factors from biomass burning (e.g. IPCC default factors for CO and NO_x);
- emission factors from the conversion plants and plants for energy supply for conversion processes;
- emission factors from transport processes (vehicle types) and distances;
- specific tailpipe gas emission from vehicles once fuelled with biofuel and once fuelled with fossil fuel;
- specific off-gas emission from energy plants once fuelled with biofuel and once fuelled with fossil fuel.

These data can be gathered through statistical measurement (national/international accounts), calculation/computation of (existing) data, physical, biological or chemical measurements and, interviews and surveys at the national, regional, field, site and urban area level.

Data sources (international and national)[25]:

- international databases that are used in LCA;
- US EPA Compilation of Air Pollutant Emission Factors;
- UNECE emission data;
- German TREMOD database;
- GEMIS;
- European Reference Life Cycle Database (ELCD);
- further general databases for specific tailpipe gas emission and chimney stack emissions are available.

Known data gaps:

Owing to the number of existing databases the majority of required data should be available. However data gaps might occur when assessments focus on specific cases representing specific technical standards (e.g. engines, machinery) or local side-conditions (e.g. field burning).

Local Authority and Environmental Agency Permitting Data can be used to fill key gaps in the available data.

[25] See reference and electronic sources section.

Relevant international processes[26]:

- UNFCCC CDM calculation method available at the CDM website
- Bonsucro: Better Sugarcane Initiative

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[26] See electronic sources section.

Indicator 5 Water use and efficiency

Description:

(5.1) Water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstocks, expressed

(5.1a) as the percentage of total actual renewable water resources (TARWR) and

(5.1b) as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and non-renewable water sources;

(5.2) Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of bioenergy output, disaggregated into renewable and non-renewable water sources

Measurement unit(s):

(5.1a) percentage

(5.1b) percentage

(5.2) m^3/MJ or m^3/kWh; m^3/ha or m^3/tonne for feedstock production phase if considered separately

Relevance

Application of the indicator:

The indicator applies to bioenergy production and to all bioenergy feedstocks, end-uses and pathways.

Relation to themes:

This indicator is primarily related to the theme of *Water availability, use efficiency and quality*. The production and processing of bioenergy feedstocks can require significant quantities of water.[27] In regions featuring competing demands on surface or groundwater, the change in withdrawals for feedstock and fuel or energy production can alter the use of available water resources. Potential impacts of increased water use in a watershed include degradation of water quality, groundwater subsidence and modification of subsurface geochemistry, seasonal reduction of in-stream flows, and effects on water supply reliability with a range of adverse impacts, including on agricultural yields and on availability of water for domestic use. Access to sufficient water supplies is critical to ensuring long-term capacity of bioenergy feedstock production and processing.

5.1: Bioenergy development requires water use. For areas in which overall agricultural production does not change, overall water use may not change. However, some bioenergy developments could lead to additional water demand that may apply pressure to existing water resources. This indicator measures the amount of water used for the two phases of bioenergy production that require most water and places this amount in the context of available water within one or more watersheds, given the cumulative demands for water resources; disaggregated into renewable and non-renewable water.

5.2: This indicator seeks to provide information on the efficiency of water use in bioenergy production: i.e. the volume of water used to produce a unit of energy, disaggregated into renewable and non-renewable water.

The indicator will also inform the following themes: *Greenhouse gas emissions*, since, for example, some GHG emissions from bioenergy production are due to water use in bioenergy feedstock production (e.g. energy used to power irrigation equipment); *Productive capacity of*

[27] As a global average, around 3,000 litres of water are consumed in the production of one litre of biofuel but regional variation is wide (Fraiture, et. al. 2008).

the land and ecosystems, since over-withdrawal of water can affect land and soil quality; *Biological diversity*, since, for example, agriculture can compete for water with natural vegetation in a watershed; *Price and supply of a national food basket*, since bioenergy can compete with food production for water use; *Resource availability and use efficiencies in bioenergy production, conversion, distribution and end use*, since water is an important natural resource, whose availability and use efficiency should be considered in conjunction with those of other resources, such as land; *Economic viability and competitiveness of bioenergy*, since bioenergy production will not be viable if its water requirements cannot be met economically; and *Energy security/Diversification of sources and supply*, since water scarcity could disrupt energy supply if there is a strong dependence on bioenergy feedstocks with high water requirements.

How the indicator will help assess the sustainability of bioenergy at the national level:

The appropriate scale for evaluating this indicator is at the level of the watershed and it is suggested that, if possible, national and decentralized decision-making regarding bioenergy be informed by an assessment of water use at the watershed (i.e. catchment or river basin) level, the most commonly used unit for water resource management, rather than a single national average. However, in some cases other units of analysis may be more appropriate (e.g. polders or aquifers). Where countries share a watershed, cooperation between the countries involved will be needed to evaluate this indicator properly. If a country or region manages its water resources (and data) within administrative units other than the watershed level, then it is likely to be more practical for this indicator to be measured in accordance with management units. Considering both large basins and their sub-basins is necessary for understanding how changes in one part of a basin affect both water availability and environmental health in other parts of the basin.

5.1: This indicator gives information about the extent of water demand from the bioenergy sector and how it compares to water availability and other competing uses. If water is being withdrawn for the production and processing of bioenergy feedstocks in a watershed (or other management unit) in a state of medium-high or high water stress (see Table 1 in Methodological approach section), then a more detailed analysis is warranted that takes into account 1) the different competing uses for water resources, 2) the priority given to them locally, and 3) the existence of problems regarding access to water for certain sections of the population. It is important to bear in mind that using less than 100% of TARWR does not indicate sustainability from the water use perspective, even if all water used is from a renewable source.

Note that the ratio of TAWW to TARWR that indicates a problem of water scarcity will depend upon the country and in many cases the potentially utilizable water resources make up only a relatively small share of the TARWR. Furthermore, for countries or regions dependent upon non-renewable water sources, an evaluation of the use of these resources for bioenergy production would require consideration of the rate of their depletion – TARWR is not an applicable concept in such cases.

If projections of future changes in water demand (e.g. due to population growth, climate change and changes in consumption patterns) are factored in, the indicator can inform an assessment of the sustainability of national plans regarding bioenergy.

5.2: This indicator is specifically aimed at efficient water use in biomass production and processing. It provides a tool to monitor current water use efficiency and compare it with best practice data, so as to optimize the use of water resources for bioenergy production. It may also be informative to evaluate the water use efficiency of feedstock production separately from that of the feedstock processing phase. This is especially relevant in those cases in which only one phase takes place in the watershed, and should be straightforward because the data on production and processing are likely to be collected independently. This would lead to three possible metrics:

5.2a water use for feedstock production in the watershed(s) per tonne of feedstock produced in the watershed(s);

5.2b water use for feedstock processing in the watershed(s) per unit of bioenergy produced; and

5.2c water use for feedstock production and processing in the watershed(s) per unit of bioenergy produced, where both feedstock production and processing occur in the determined watershed(s).

In this case, the metric for the feedstock production phase could be m^3/ha or m^3/tonne of feedstock (with a specified moisture content), and comparison with the average water use efficiency in agriculture in the watershed(s) would be possible. Calculating the metric in this way requires data on the total feedstock production in the watershed, which are collected for the evaluation of Indicator 17 (*Productivity*). The water use per production ratio described here demonstrates the importance of treating the 24 indicators as a coherent, holistic set and argues for coordinating the data collection across the indicator set.

This indicator and the cross-cutting analysis of water use per production unit can be used as tools to identify the most water-efficient ways to produce bioenergy among a given set of options. In water deficit regions and nations, this indicator could be used to assess the appropriateness of certain feedstocks or promote the development of alternative water management strategies.

Looking at 5.1 and 5.2 together, it is important to note that 5.1 provides more useful information for understanding the impact on local water scarcity due to bioenergy, whereas 5.2 provides more useful information regarding water use efficiency of specific technologies or bioenergy production pathways. Since the cumulative impacts over time and across projects are the critical issue for water use in bioenergy development, care is required when using 5.2 to inform policy-making. For example, a more efficient use of water for irrigation of bioenergy feedstocks may result in farmers irrigating more of their land or in less water being available for groundwater recharge or downstream users. Likewise, a very low value of process water per unit of biofuel produced might still result in strain on water resources within a watershed in the case of a very large processing plant. Hence high or improved water use efficiency (i.e. low values for 5.2) should not be interpreted as indicating there is adequate (or improved) water availability within a watershed. Therefore, the values provided by the water use efficiency part of this indicator (5.2) should be interpreted in the context of the water use and availability part (5.1), and other water uses should also be considered as part of this context.

Comparison with other energy options:

This indicator can be compared to total water use for the extraction and processing of any fossil fuel or alternative energy source. A comparison can be made with conventional petroleum, heavy oil, oil sands, coal to liquids (CTL), coal, as well as with non- fossil equivalents (such as solar, wind, geothermal and others), contingent on available datasets or methods of estimation. However, care must be taken to apply the same system boundaries and methodology to the lifecycle analysis of water use across different energy sources. This is especially significant since the metric used in the methodology is withdrawal and not consumption. Water withdrawn for hydroelectricity production, for example, consumes only a small fraction of the withdrawal and the vast majority of water removed is returned to the river basin.

When evaluating this indicator it may be useful and relevant to compare the results for bioenergy feedstock production with similar assessments for other types of agriculture, or with national and/or regional averages for agricultural lands. When making such comparisons it is important to take into account the differences between various biomass production systems. Different agriculture systems, forestry systems and aquatic biomass production systems are based on different practices, often requiring different inputs, and can have different impacts on water use and efficiency.

Scientific Basis

Methodological approach:

The indicators are based on the following definitions[28]:

- Water use: Withdrawal of water for specific sectoral purposes, i.e. industrial, agricultural or domestic (UNESCO - World Water Development Report.).

[28] See electronic sources section.

- Water withdrawal: Abstraction of water from surface or ground water, for consumptive purposes (UNESCO World Water Development Report.).
- Water consumption: Proportion of water withdrawal that is not returned to surface waters after use, as it is lost via evaporation, or incorporated into a finished industrial product, by-products or solid waste (UNESCO World Water Development Report.). (Note that water consumption is not measured by this indicator, but is dealt with in the 'anticipated limitations' section).
- Non-renewable water resources: Groundwater bodies (deep aquifers) that have a negligible rate of recharge on the human time-scale and thus can be considered to be non-renewable. While renewable water resources are expressed in flows, non-renewable water resources have to be expressed in quantity (stock) (FAO AQUASTAT).
- Renewable water resources: Water resources that, after use, can return to their previous stock levels by natural processes of replenishment (FAO AQUASTAT).

5.1: The intent of this component of the indicator is to evaluate the water used for the production of bioenergy feedstocks and for their processing, expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW). If water can be disaggregated into renewable and non-renewable sources in 5.1a, then it would be preferable to compare renewable water use to TARWR – which does not include non-renewable water resources – and to compare non-renewable water use with the available fossil/non-renewable water stocks in the groundwater bodies (deep aquifers), since it is the rate of depletion of these stocks that is most relevant.

The water use aspect of this indicator can be expressed mathematically as:

5.1a % of TARWR = $(W_{bioenergy\_ren}/TARWR) \times 100\%$

5.1b % of TAWW = $(W_{bioenergy}/TAWW) \times 100\%$,

in which, for all bioenergy production within one or more nationally determined watersheds,

$W_{bioenergy\_ren} = W_{feedstock\_ren} + W_{processing\_ren}$, and

$W_{bioenergy} = (W_{feedstock\_ren} + W_{feedstock\_nonren}) + (W_{processing\_ren} + W_{processing\_nonren})$,

where

- $W_{feedstock\_ren}$ is the renewable water used for producing bioenergy feedstocks (e.g. crop irrigation)
- $W_{feedstock\_nonren}$ is the non-renewable water used for producing bioenergy feedstocks (e.g. crop irrigation)
- $W_{processing\_ren}$ is the renewable water used for bioenergy processing
- $W_{processing\_nonren}$ is the non-renewable water used for bioenergy processing

TARWR is the maximum theoretical amount of renewable water actually available for a country (watershed), which is calculated from:

- sources of water within a country (watershed);
- water flowing into a country (watershed); and
- water flowing out of a country (watershed) (taking into account treaty commitments).

TAWW is the total annual water withdrawals, which is calculated from all human water uses including industrial, agricultural and domestic.

It may also be informative to look separately at the water used in the feedstock production and processing phases to allow for a comparison of water withdrawn for feedstock production with water withdrawn for agricultural production in general in the watershed(s):

i) water withdrawn for feedstock production in the watershed(s) ($W_{feedstock}$) as a percentage of TARWR and TAWW; and

ii) water withdrawn for feedstock processing in the watershed(s) ($W_{processing}$) as a percentage of TARWR and TAWW,

where:

$W_{feedstock} = W_{feedstock\_ren} + W_{feedstock\_nonren}$; and

$W_{processing} = W_{processing\_ren} + W_{processing\_nonren}$.

As the production and processing data will be collected separately dividing the analysis according to how the water is used is straightforward.

TARWR and TAWW are evaluated by national and international organizations. For example, FAO, through its global information system on water and agriculture, AQUASTAT collects, analyses and disseminates information on water resources, water uses, and agricultural water management with an emphasis on countries in Africa, Asia, Latin America and the Caribbean.

In many instances, the agricultural practices for producing bioenergy feedstocks will not differ from general agricultural practices, in which case calculating the water used to irrigate bioenergy feedstocks can be calculated based on the fraction of agricultural output that is used for bioenergy production. In some cases specific data for bioenergy feedstock production will have to be generated. Studies for water use in bioenergy production at the farm level could be used to build aggregate levels of water requirements at the watershed level. Water withdrawal data collected through state or local agencies could be used to determine the value of this indicator. Furthermore, water use for the processing of biomass could be estimated from knowledge of the typical water usage of a biorefinery and subsequent extrapolation to the number of biorefineries in the watershed.

Data collection requirements could be reduced by establishing representative values for categories of bioenergy production pathways employed in a country or region. Particularly for larger countries that contain several large river basins and many watersheds with significant variations in climate, soil, and water resources, aggregating to a single national value will not be appropriate. Instead data should be aggregated at the closest spatial scale to the watershed taking into account data availability. National decision-making could be usefully informed by either stating the numbers of watersheds in a country where bioenergy production takes place that fall into the categories of low, moderate, medium-high and high water stress mentioned above or stating the percentage of TARWR and TAWW used for bioenergy production in watersheds that are highly water stressed (see Table 1 below). Providing this information in mapped form may also be helpful.

Table 1: UN Definitions of Water Stress Levels (UN, 1997; Raskin et al., 1997; Alcamo et al., 2003); these thresholds can be applied at both watershed and national levels

TAWW in relation to TARWR	Water stress
<10%	Low
10-20%	Moderate
20-40%	Medium-high
>40%	High

Water scarcity or water stress can also be measured in terms of annual per capita water availability. Under this approach, water stressed and water scarce (or highly water-stressed) areas have been defined as those where water availability is less than 1700 and 1000 m^3 per year per capita, respectively. In this regard, see Falkenmark and Widstrand (1992), Hinrichsen et al. (1998) and UNEP (1999); see also IPCC (2007) and Algamal (2011), though these authors use water stress to mean less than 1000 m^3 per capita per year. Physical availability of water is just one aspect of water scarcity. The multiple dimensions of water scarcity are described in UN Water (2007), where a general definition of water scarcity is given as "the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully."

5.2: This indicator is intended to evaluate the efficiency of water use in biomass production and processing for energy purposes. It provides a tool to monitor current water use efficiency and compare it with best practice data, so as to encourage the optimized use of water resources per unit of bioenergy production.

Water use per unit of bioenergy = $W_{bioenergy} / E_{total}$,

where

$W_{bioenergy} = (W_{feedstock\_ren} + W_{feedstock\_nonren}) + (W_{processing\_ren} + W_{processing\_nonren})$

and

- $W_{feedstock\ ren}$ is the renewable water used for producing bioenergy feedstocks (e.g. crop irrigation)
- $W_{feedstock\ nonren}$ is the non-renewable water used for producing bioenergy feedstocks (e.g. crop irrigation)
- $W_{processing\ ren}$ is the renewable water used for bioenergy processing
- $W_{processing\ nonren}$ is the non-renewable water used for bioenergy processing
- E_{total} is the total amount of bioenergy produced

If necessary, then water use efficiency data for different crops, regions and processes collected at the field or watershed level can be aggregated in a national database. It is suggested that it might be informative to aggregate results to the level of distinct bioenergy production pathways, which might be distinguished by feedstock, agricultural practice, processing technology and sub-national region (e.g. agro-ecological zone). If desired, an average figure for a country could then be aggregated up by using these average or typical values for different pathways to form a weighted average representative of the country's bioenergy production.

It should be borne in mind that whilst 5.1 measures water withdrawn for all bioenergy feedstock production and processing activities (whether related or not) within one or more watersheds (or the country as a whole), 5.2 measures the efficiency of water use for these two phases of the bioenergy production lifecycle and therefore the feedstock production and the processing must be part of the same bioenergy production pathway.

If a country produces bioenergy feedstock and exports some of it unprocessed, or imports some bioenergy feedstock and processes it, then a misleading value for water use efficiency will be obtained unless the water used for production and processing of bioenergy feedstocks into a particular (significant) batch of biofuels partly produced in the country are either both included or both excluded. In other words, either values for production water in the countries where the imported feedstock is produced or for process water in the countries where the exported feedstock is processed should be included or values for water use where only one of the production or process phases takes place in the country should be excluded from the national average figure. Calculating national average figures for feedstock production (in m^3/ha) and processing (in m^3/MJ or m^3/kWh) separately would be informative in such cases:

5.2a water use for feedstock production in the watershed(s) per tonne of feedstock produced in the watershed(s);

5.2b water use for feedstock processing in the watershed(s) per unit of bioenergy produced; and

5.2c water use for feedstock production and processing in the watershed(s) per unit of bioenergy produced, where both feedstock production and processing occur in the determined watershed(s).

In this case a comparison of water use efficiency of the production stage with average water use efficiency in agriculture in the watershed(s) would be possible.

In the case that both feedstock production and processing take place in the same watershed or other area used in 5.1 for all bioenergy production in that area, the value of $W_{bioenergy}$ calculated for 5.1 will be the same as the value required for 5.2, and the average water use efficiency for the area is given simply by $W_{bioenergy}/E_{total}$, where E_{total} is the amount of bioenergy produced in the area.

The amount of water withdrawn per unit of bioenergy produced could be converted to the amount of water withdrawn per unit of bioenergy output (see glossary) if information about the technology for final use of the bioenergy is available or can be estimated. In such a case, the latter value could be obtained by dividing the former by the fraction of bioenergy actually available to the consumer after final conversion of the bioenergy into its useful form (for instance, light, mechanical energy or heat).

Anticipated limitations:

5.1 and 5.2:

Lifecycle analysis:

The indicator does not involve a full lifecycle analysis of water use, but rather focuses on the feedstock production and processing phases. Therefore if water use for other phases of the lifecycle such as feedstock and fuel transportation is significant for a particular fuel production pathway, this should be taken into account in any analysis, including comparisons. However, in most cases, the vast majority of water used for bioenergy (or fossil fuel) production will be used in the feedstock production (extraction) and processing (refining) phases.

Water use vs. consumption:

The indicator measures water use (i.e. withdrawal) for bioenergy production, not water consumption. By looking at the amount of water withdrawn for the production of bioenergy feedstocks, the indicator does not give an entirely accurate picture of the effect of water use for bioenergy feedstock production on the availability of water for other users in the watershed. For example, many irrigation systems return a large amount of water to the system after use. Some countries may therefore wish to attempt to identify how much water is consumed by bioenergy feedstock – in addition to measuring water withdrawals. Water consumed from local surface or groundwater resources during the feedstock production stage is limited to the portion of water that is either evapotranspired or incorporated into the crop. Water consumption does not include runoff to ground or surface water.

Water consumption can be measured. Information on consumptive use of water for agriculture can be calculated in different ways. Using data cropping seasons and yields for various crops at different locations or agroclimatic regions could be used with precipitation data to calculate water consumption. This can also be conducted through using models which incorporate the Penman Montieth method for established crop and feedstock parameters. FAO has established crop parameters for several regions of the world. However, the crop parameters in the current FAO database are aggregated to large regions, which may not be sufficiently representative of a specific watershed or river basin. Use of inappropriate crop parameters would skew estimates of the water use. Therefore, watershed specific parameters should be used whenever they are available to improve the accuracy of the estimate. Water withdrawal data collected through state or local agencies is often a good source for model validation. If data is unavailable for potential feedstock production areas, then it is recommended to evaluate these parameters to insure the use of proper crop parameters. An approach that removes the need for detailed statistical data collection uses remote sensing (e.g. geographic information systems (GIS). This approach has been demonstrated to robustly assess water consumption of crops (Perry, 2007). In order to use this information to assess the impacts of bioenergy water use at the watershed level, a complementary on-site assessment would likely be needed.

Furthermore, the IWMI World Water and Climate Atlas[29] gives irrigation and agricultural planners rapid access to accurate data on climate and moisture availability for agriculture. The Atlas includes monthly and annual summaries for precipitation, temperature, humidity, hours of sunshine, evaporation estimates, wind speed, total number of days with and without rainfall, days without frost and Penman-Montieth reference evapotranspiration rates. If one had a data

[29] See electronic sources section.

base that gives the cropping seasons and yields for various crops at different locations or, better, agroclimatic region, around the world, then this could be used with the climate atlas to calculate water consumption by crop and location.

Water requirements of rainfed alien species:

It is not suggested that water used in rainfed bioenergy feedstock production is considered in this indicator, since rainfall is not normally subject to competition from other sectors and in most cases the amount of evapotranspiration from rainfed agriculture will be similar or less than that from natural vegetation, and will have negligible impacts on groundwater recharge and downstream water availability. However, when alien species not adapted to the local conditions are used for bioenergy feedstocks, attention should be paid to the possibility that they might withdraw significantly higher amounts of rainwater from the soil than natural vegetation or native crops. Knowledge of the relative levels of evapotranspiration for rainfed production of various bioenergy feedstock crops could inform comparisons of the suitability of land for different crops.

Disaggregation into renewable and non-renewable water sources:

Disaggregation into renewable and non-renewable water sources might be difficult to implement as this process depends on the availability and accessibility of spatial data on water resources.

There are anticipated limitations due to insufficient or inconsistent available data on water requirements and price. In the datasets that do exist, e.g. the International Groundwater Resource Assessment Centre (IGRAC) and AQUASTAT, there are limitations in applicability to bioenergy productions. Not all relevant datasets include bioenergy crops or disaggregate the share of dual-use bioenergy/food crops in a way that is immediately useful for analysing the water use of bioenergy production.

While it may be possible, particularly for the production of liquid biofuels in the later stages of the supply chain, to collect data directly at bioenergy processing plants, linking crop production and some of the earlier stages of processing to bioenergy may be challenging in practice, because the end use of a given crop may not be known at these earlier stages. See the section of this report “On the attribution of impacts to bioenergy production and use when using the GBEP indicators”.

5.1:

Calculation of evapotranspiration (TARWR):

Calculating evapotranspiration of natural and managed land for the calculation of TARWR is difficult. Satellite remote sensing has advanced, but ground monitoring and confirmation of remote sensing data will always be necessary. Most water balance models assess actual evapotranspiration by comparing reference evapotranspiration to available soil moisture. Currently the FAO Penman Monteith method is the standard method to assess reference evapotranspiration. Given the strong relationship between feedstock production (e.g. irrigation) and loss of water due to evaporation and evapotranspiration care must be taken in evaluating Indicator 5.1a.

Linkage between ground and surface waters:

The linkage between ground and surface waters (and groundwater usage in general) is understudied and can impact renewable water calculations. Efforts should be made to incorporate locally produced data for ground and surface water sources and the linkages between them.

According to the UNESCO World Water Development Report (Second Edition), monitoring use of groundwater at the national, sub-national and aquifer levels is particularly important since exploitation, for example of more than 50 percent of recharge, will likely result in particular stress on the aquifer sustainability of groundwater systems.

Environmental flows:

Environmental flows – the amount and timing of water flows required maintaining the species, functions, and resilience of freshwater ecosystems and the livelihoods of human communities that depend on those healthy ecosystems – are not yet taken into account. The ELOHA[30] (Ecological Limits of Hydrologic Alteration) Toolbox can help in assessing and managing environmental flows across large regions.

Practicality

Data requirements:

- water withdrawn for production and processing of bioenergy feedstocks (at the watershed level);
- amount of bioenergy production (at the watershed level);
- total actual renewable water resources (TARWR);
- total annual water withdrawals (TAWW);
- data/maps of water resources covering e.g. rivers, watershed boundaries and identifying water stressed areas.

These data can be gathered through national/international statistical accounts, calculation/computation of (existing) data at the regional or watershed level. TARWR can be estimated by using satellite imagery (e.g. Normalized Difference Vegetation Index) or modelling (data on e.g. rainfall, rates of evaporation and evapotranspiration for crops and groundcover and runoff is needed).

Data sources (international and national[31]):

Available data sources include:

- International Water Management Institute
    - Water scarcity map
    - Water and Climate Atlas (and watersim model)
    - IWMIDSP is an award winning pathfinder pioneered by IWMI for providing state-of-the-art global public good (GPG) spatial data on water and land resources for river basins, nations, regions, and the world.
- AQUASTAT
    - FAO's global information system on water and agriculture
- UNESCO World Water Development Report
- FAO Geonetwork
    - Provides data on watershed boundaries
- World Hydrological Cycle Observing System (WHYCOS)
    - Provides data on surface water levels (rivers, lakes, etc.)
- International Groundwater Resource Assessment Centre (IGRAC)
    - Provides international data on groundwater
- UNEP Collaborating Centre on Water and Environment
- EUROSTAT
- National data sources for the United States
    - USGS National Water Information System
    - USGS National Hydrography Data Set

[30] See electronic sources section.
[31] See reference and electronic sources section.

- USDA Agricultural Research Service (ARS) Water Database
- USDA NASS Farm and Ranch Irrigation Survey

Known data gaps:

As discussed above, sources of data on water use and efficiency are not always complete, which is especially true in the developing world. However, numerous international efforts at monitoring water are in progress and improving over time.

TARWR and TAWW: Water use data resources at the watershed level are often limited. In some cases data is only available at the national level or may not be available at all. TARWR has no regular update except when new country data are available. As such, TARWR is only currently suitable for averaging over longer multi-year timescales. For the countries for which it is available, TARWR is the most complete source available today and is updated ideally every five years, but occasionally up to ten years may pass between updates depending on the resources available.

TARWR uses a generic water resource balance sheet that was established on the basis of available information in 2003 at country level for the world. Since then, the country water balance sheet is sent to each country together with the AQUASTAT questionnaire. Countries are requested to verify the information and correct it if data have changed. Data quality is a concern for UN-Water (2006), who concluded that data quality is and remains a major issue in assessing the reliability of monitoring systems.

Some countries, especially developing countries, might have difficulties in measuring their domestic TARWR and total annual water withdrawals (TAWW) due to lack of data and uniform measurement resulting in uncertainties in estimates.

Relevant international processes[32]:

- International Water Management Institute has developed water resource assessment methodology at a basin level (see for example Water for Food, Water for Life issue brief 4);
- UN Water uses "Total use (of water) as share of total actual renewable water resources" which is the MDG water indicator ; Available at: http://webworld.unesco.org/water/wwap/wwdr/indicators/pdf/WWDR3_appendix_1.pdf
- UNESCO World Water Development Report (WWDR); Available at: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/
- RSB Principle 9. “Biofuel production shall optimize surface and groundwater resource use, including minimizing contamination or depletion of these resources, and shall not violate existing formal and customary water rights” (RSB, 2011).

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Indicator 6 Water quality

Description:

(6.1) Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock production, and expressed as a percentage of pollutant loadings from total agricultural production in the watershed

(6.2) Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents, and expressed as a percentage of pollutant loadings from total agricultural processing effluents in the watershed

Measurement unit(s):

(6.1) Annual nitrogen (N) and phosphorus (P) loadings from fertilizer and pesticide active ingredient loadings attributable to bioenergy feedstock production (per watershed area):

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

(6.2) Pollutant loadings attributable to bioenergy processing effluent:

- pollutant levels in bioenergy processing effluents in mg/l (for pollutant concentrations and biochemical and chemical oxygen demand – BOD and COD), and (if also measured) ºC (for temperature), µS/m (for electrical conductivity) and pH
- total annual pollutant loadings in kg/year or (per watershed area) in kg/ha/year
- as a percentage of total pollutant loadings from agricultural processing in the watershed

Relevance

Application of the indicator:

The indicator applies to production of those bioenergy feedstocks that use fertilizer (including manure) and pesticide, and to effluents from processing plants for all bioenergy feedstocks, end-uses and pathways.

Relation to themes:

This indicator is primarily related to the theme of *Water availability, use efficiency and quality*. It aims to measure and monitor the impact of bioenergy feedstock production and processing on water quality. For example, nitrogen (N) and phosphorous (P) fertilizers and pesticide used for bioenergy feedstock production and effluents from bioenergy processing facilities could add to the pollution of waterways and bodies of water such that water quality may suffer significant decline.

The most significant impact of feedstock production and processing on water quality results from the use of N and P in fertilizers and pesticides. N is a critical nutrient for plants and animals. Terrestrial ecosystems and headwater streams have a considerable ability to capture it (through fixation) and to reduce it to N_2 gas through the processes of nitrification and de-nitrification. N cycling and retention is thus one of the most important functions of ecosystems (Vitousek et al., 2002). When loads of N from fertilizer, septic tanks, and atmospheric deposition exceed the capacity of terrestrial systems (including croplands) to hold and cycle it, the excess may enter surface waters, where it may create “cascading” harmful effects as it moves downstream to coastal ecosystems (Galloway and Cowling, 2002).

P is a critical nutrient for all forms of life, but like N, P that enters the environment may exceed the needs and capacity of the terrestrial ecosystem. As a result, excess P may enter lakes and streams. Because phosphate is often the limiting nutrient in these waterways and bodies of water, an excess may contribute to algal blooms and exponential growth of cyano bacteria, which cause taste and odour problems and deplete oxygen needed by aquatic organisms. In some cases, excess phosphate can combine with excess nitrates to exacerbate algal blooms (i.e. in situations where algal growth is co-limited by both nutrients), although excess nitrates usually have a larger downstream effect in coastal waters. The most common sources of P in rivers are fertilizer and wastewater, including storm water and treated wastewater discharged directly into the river.

Pesticide residues carried to ponds, rivers and lakes by surface runoff, leaching or spray drift can cause acute poisoning (e.g. fish kills) and also chronic poisoning, when wildlife is exposed to pesticide levels not immediately lethal. There are also risks of secondary poisoning when predators consume prey that contain pesticides. This can be particularly a concern in relation to persistent chemicals that accumulate and move in food chains. Indirect effects can also occur when habitats or food chains are modified, for instance when insecticides diminish insect populations fed on by fish and other aquatic animals. However, it should be noted that best management practices adapted to soil properties can significantly reduce the pollutant loading into downstream waters. Furthermore, the cultivation of perennial energy crops can contribute to a lower leakage of plant nutrients from the agricultural landscape to the waterways. Also some energy crops are capable of removing heavy metals from the soils.

(6.1) ***Fertilizer and pesticide loadings***: N and P fertilizers (including manure) and pesticides applied to increase agricultural yields can result in excess nutrients and pesticides flowing into waterways and bodies of water via surface runoff, infiltration to groundwater as well as volatilization and vapour transport. Nutrient pollution and pesticide contamination of fresh and marine water bodies can impact water quality and subsequently, the aquatic ecosystem functioning and human health (where the water is used for drinking).

The amount of a fertilizer nutrient or pesticide that is captured in a crop depends on the crop, the amount, timing, and method of application, the methods of soil cultivation, and other variables. Fertilizer and pesticide applications exceeding plant uptake and soil retention capacity can lead to water pollution. A certain amount of fertilizer nutrients and pesticides inevitably moves offsite by various pathways. For example, N in forms such as nitrate (NO_3^-) is highly soluble, and along with some pesticides infiltrates downwards toward the water table. From there it can migrate to drinking water wells, or slowly find its way to rivers and streams. Another pathway is surface runoff, which transports N, P and pesticides to surface water either in solution or attached to eroding soil particles. A third pathway is wind erosion, or volatilization to the atmosphere in the case of N, followed by atmospheric transport and deposition over a potentially broad area downwind. Surface runoff and infiltration to groundwater can both have significant impacts on water quality (Committee on Water Implications of Biofuels Production in the United States 2008, Bonnet et al. 2009). Pesticides can also reach water bodies through spray drift (Strassemeyer et al., 2007).

The comparison of the N, P and pesticides loadings due to bioenergy feedstock production with the total N, P and pesticide loadings from agriculture in the watershed gives information on the relative contribution of bioenergy feedstock production to pollutant loadings in the watershed with respect to the whole agricultural sector. (Comparing the N, P and pesticide loadings for bioenergy feedstock production, with the total loadings from agriculture in the watershed can be facilitated by expressing these data on a per hectare or per tonne of biomass basis (see the section below on comparisons).

(6.2) ***Effluents from processing plants***: Wastewater from bioenergy production facilities is potentially high in nitrogen (N) and phosphorus (P) that contribute to biochemical oxygen demand (BOD). Discharge of high-BOD water to waterways and bodies of water is problematic because decomposition can consume all of the dissolved oxygen, suffocating aquatic animals (Committee on Water Implications of Biofuels Production in the United States, 2008).

Additional pollutants in effluents from bioenergy processing plants that could affect water quality will vary as a function of the feedstock and process. For example, in the case of palm oil mill effluent (POME), information on the following are relevant to water quality: temperature, pH, BOD, COD, total solids, total suspended solids, total volatile solids, oil and grease, ammonia-nitrate, total Kjeldahl nitrogen (Rupani et al., 2010; Wu et al., 2010; Department of Industrial Works and GTZ, 1997).

Some processing effluents may be acidic, while others may be alkaline (Rupani et al., 2010; Atadashi et al., 2011). Changes in pH, both acidic and alkaline, can negatively affect aquatic life and use of the water, but the effects of effluent will depend on properties of the watershed. For example, ammonia is much more toxic in alkaline water than acidic. Importantly, for human health, a decrease in pH could also decrease the solubility of essential elements including selenium, while increasing the solubility of potentially dangerous elements such as aluminium, cadmium and mercury (Morrison et al., 2003).

Some effluents may be high in temperature. From bioenergy refineries in general there is heat pollution from cooling systems. Changes in temperature of water bodies due to effluents may affect the populations of aquatic life, including fish, all of which have a preferred temperature range. Warm water holds less oxygen than cool water; it may therefore be saturated with oxygen yet still not contain enough for the survival of aquatic life.

Some bioenergy processing plants produce brine effluents. For example, from ethanol plants there are brine effluents from the reverse osmosis step of the refining process and wastewater from periodic salt blowdown operations performed on cooling towers. Build up of salts can interfere with water reuse by municipalities, industries manufacturing textiles, paper and food products, and agriculture for irrigation. High salt concentrations in water bodies may result in adverse ecological effects on aquatic biota, and a very high salt concentration (over 1000 mg/l) imparts a brackish, salty taste to water and is discouraged because of the potential health hazard (Morrison et al., 2003).

Biodiesel plants' wastewater discharges may also contain high amounts of greases and oils (Committee on Water Implications of Biofuels Production in the United States 2008), as may discharges from other bioenergy feedstock processing.

It should be noted that the effluents covered by this indicator include wastewater from biomass-fired power plants and from plants that process raw materials into intermediate products later processed into biofuels, as well as that from liquid biofuel processing plants. Where wastewater from other sources is treated to produce bioenergy (e.g. through biogasification, anaerobic digestion, thermal oxidation or thermal drying) or reused for cooling in bioenergy plants, the net impact on pollutant loadings to water bodies could be evaluated,

The indicator also informs the following themes: *Greenhouse gas emissions*, *Productive capacity of the land and ecosystems*, *Biological diversity*, *Price and supply of a national food basket*, *Human health and safety* and *Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use*.

How the indicator will help assess the sustainability of bioenergy at the national level:

The maintenance of water quality is an important aspect of sustainable development. This indicator aims to measure and monitor the impact of bioenergy feedstock production and processing on water quality and will inform national policy development and implementation.

(6.1) Tracking of N, P and pesticide loadings to waterways and bodies of waters from bioenergy feedstock production, together with information on the relative contribution of bioenergy to the total pollutant loadings from agricultural production, will enable policy-makers to understand at the watershed level the impact bioenergy production can have on water quality.

(6.2) Tracking of pollutant loadings from the effluents of bioenergy feedstock processing facilities, together with information on the relative contribution of bioenergy to the total pollutant loadings of agricultural processing, will enable policy-makers to understand at a broad level the impact bioenergy production facilities can have on water quality.

Monitoring pollutant concentrations in the water bodies will enable policy-makers to gain insight into the actual consequences of the tracked pollutant loadings for a specific water system. The impact of a certain level of pollutant loading will depend on the type of water body and the interpretation of values for 6.1 and 6.2 will be enhanced by contextual information about the overall health of water bodies in the watershed.

Comparison with other energy options:

6.1: When evaluating this component of the indicator it could be useful and relevant to compare the results for bioenergy feedstock production with similar assessments for other types of agriculture evaluated as national and/or regional averages for agricultural lands on a per hectare of cultivated land or per tonne of produced biomass basis. When making such comparisons, it is important to take into account the differences between various biomass production systems. Different agriculture systems, forestry systems and aquatic biomass production systems are based on different practices and require different inputs. As such, agriculture, including forestry and aquatic biomass, can have different impacts on soil quality, water quality, water use and efficiency, etc.

Comparison on a per MJ basis with some other energy options whose raw material production/extraction can pollute water (e.g. coal mining, oil drilling) basis would also be possible. If the raw material production/extraction and processing phases cannot be separated, the water pollution measured in 6.1 and 6.2 could be summed and compared with total water pollution from other energy sources. Metrics such as the value of lost ecosystem services or reparation costs could be explored as means to facilitate such comparisons.

6.2: Effluents from processing plants can be compared with effluent discharges from oil refineries and (heat and) power plants on a per MJ of energy produced basis or with effluent discharges from (average) agricultural processing on a per tonne of processed biomass basis.

Scientific Basis

Methodological approach:

In this section, a range of options for measuring the components of this indicator are set out. The approach taken will depend upon factors such as the availability of data, technical expertise and time, and the complexity of the situation to be analysed (e.g. the diversity of activities in the watershed that contribute to pollutant loadings and the extent to which soil characteristics, hydrology and management practices vary across the areas in which these activities take place). It is common to estimate N, P and pesticide loadings through the use of well-established modelling techniques. In situations where appropriate modelling is not feasible, N and P balances can provide an initial indication of the pressure on water pollution caused by the application of fertilizers and pesticides for bioenergy feedstock production.

6.1: Annual N, P and pesticide active ingredient loadings to water bodies as a result of bioenergy feedstock production and of all agricultural production in the watershed will generally need to be estimated through modelling techniques, due to the complex interactions between agricultural management practices, soil and climate characteristics and water nutrient status. However, in some cases water quality monitoring data or values taken from the literature can be used to estimate these loadings, particularly where the range of agricultural activities in the watershed is limited and the watershed has been well studied. Furthermore, where detailed analysis of the pathways by which excess nutrients and pesticides can reach ground and surface waters is not feasible or accessible, a range of risk indicators has been developed and applied. Such indicators allow countries to determine the nutrient and pesticide pressures from agriculture and combine this information with a subset of the remaining factors that determine the extent to which these pressures will result in water pollution.

Watershed modelling techniques for diffuse N, P and/or pesticide pollution

Two distinct categories of watershed modelling approaches can be identified: those using detailed physically based hydrological models, which predict changes in water quality in real time, and those based on export coefficient models, which predict annual nutrient loading at any site in the surface water drainage network of a watershed as a function of the export of nutrients from each source in the watershed above that site. The former category tend to work well in the watershed in which they were originally constructed, but – particularly for large watersheds – tend also to be expensive to construct and difficult to calibrate due to their large data requirements. Some of these models can be used to assess nutrient loadings and pesticide loadings, as well as other pollutants such as sediment and metals (Johnes, 1995; US EPA, 2008). It is desirable to ensure that ammonia N is considered in addition to nitrate N (some models consider only the latter). In oxygen-poor environments ammonia can be a significant cause of decreased oxygen availability, increased algal blooms, eutrophication and at high concentrations is toxic to in some aquatic organisms (Bell, 1998 and Antweiler, 1995).

The **export coefficient models** used in the latter category tend to be simpler to construct and use, but do rely on the availability of export coefficients in the literature that are applicable in the watershed under analysis. They generally only apply to nutrient loadings. Export coefficients are defined as the rate, in kilograms per hectare per year, at which nutrients are lost from land under a specified use. The models are used to find the most appropriate value for a given watershed within a range found in the literature. For further information on an export coefficient modelling approach, adapted to be more sensitive to the spatial heterogeneity of land use and management practices than traditional approaches, see Johnes (1995). Export coefficients, when available in the literature, can also be used very simply by multiplying the area of land under each use by the relevant coefficient and summing the resulting loadings. See US EPA (2008) for more information on this and another simple model (the Simple Method) using empirical relationships established in the literature. North Carolina State University's WATER, Soil, and Hydro-Environmental Decision Support System (WATERSHEDSS)[33] provides a decision support system to help land managers to evaluate non-point source pollution and use the results to implement good agriculture management practices. A tool for calculating loadings using export coefficients can be downloaded from www.water.ncsu.edu/watershedss.

Hydrological diffuse-pollution models are designed to simulate the movements of water and pollutants in watersheds and thereby aid in assessing water quality. Various models for predicting nutrient and/or pesticide concentrations in river water have been proposed and applied. For example, the SWAT model is used to estimate N and P loadings in two river basins and the contribution of agriculture to the total measured loadings at the outlet of the two river basins by Bouraoui (2003) and Schilling et al. (2003) apply and compare the three models SWAT 2000, DIFGA 2000 and MONERIS. The Hydrologic Simulation Program-FORTRAN (HSPF) (Johanson et al., 1983, 1997) is another comprehensive model of watershed hydrology and water quality that enables integrated simulations of runoff, sediments, and nutrient transport (Moore et al., 1988, Laroche et al., 1996, Dabrowski et al., 2002). For further information on the models available, how to select the most appropriate one, and a detailed discussion of seven watershed models (AGNPS, STEPL, GWLF, HSPF, SWMM, P8-UCM, and SWAT), see US EPA (2008).

The risk of excess N, P and pesticides loading to water bodies can be mitigated by best management practices, which some models can take into account. For example, Evans et al. (2003) describe a software application developed to estimate the effect of the following agricultural best management practice systems on reducing such loadings: permanent vegetative cover; strip-cropping and contour farming; terraces and diversions; grazing land management; cropland protection; conservation tillage; stream protection; nutrient management.

The application of these models for predicting nutrient and pesticide movements in watersheds requires accurate agricultural as well as hydrological, meteorological, and geographical data as input. Data should be collected regarding fertilizer and pesticide application for bioenergy feedstock(s) and other crops cultivated in the watershed, livestock production and other activities that result in N and P reaching groundwater (by infiltration) or surface water (by runoff), including human waste. These data can be measured directly through questionnaires (e.g. fertilizer and pesticide application) or possibly calculated with the use of local default values by crop, soil types, etc.

Models will be calibrated by measurements of total N, P and pesticide active ingredient concentrations in water bodies and various other points of interest in the watershed. (Some such direct measurement techniques are described in Inoue (2003). Monitoring data recording instream pollutant concentrations and flow rates sampled at various points in the water bodies can be used to estimate total pollutant loadings in a watershed, and these estimates can be improved using regression analysis (US EPA, 2008; Evans and Miller, 2009).

Data on the proportion (and location, in spatially sensitive models) of fertilizers and pesticides applied in the watershed for bioenergy production, along with an assessment of N fixation by crops and N and P from livestock waste in the watershed, will be used to help determine the quantity of pollutant loadings attributable to bioenergy feedstock production and the percentage of loadings from agricultural production these represent.

Pesticide models: Some of the previously mentioned models can be used to estimate pesticide loadings in addition to nutrient loadings. However, there has also been work focused solely on

[33] See electronic sources section.

modelling pesticide flows in the environment. In Europe, the Forum for the co-ordination of pesticide fate models and their use (FOCUS) produced guidance for calculating pesticide leaching to groundwater (FOCUS; 1995, 2000), for pesticide persistence in soil (FOCUS, 1996) and for pesticide loss to surface water (FOCUS, 1997; EU IRENA indicator 20[33]) This was followed by the research project on Harmonised environmental indicators for pesticide risk[33] (HAIR), which developed an extensive set of indicators to evaluate trends in the aggregated risk of the agricultural use of use of pesticides, including aquatic indicators that take into account the three pathways for pesticide loadings of spray drift, surface runoff (for both dissolved and adsorbed active ingredients) and drainage into the surface water: for more information, see RIVM[33], van der Linden et al. (2007) and Strassemeyer et al. (2007). In 2010, the HAIR Repair Project/HARP constructed a new, user-friendly version of the instrument with a restricted set of robust and well documented risk indicators. This resulted in the HAIR2010 software package, which is available for download from HAIR website.

For large watersheds, however, acquisition of precise data on farming schedules, including the amounts of fertilizers and pesticides used and the dates of application, is impossible; the data acquired invariably involves substantial uncertainty. Moreover, many factors affect the processes of adsorption and decomposition of pesticides in soil and water. A lack of information on the reaction environment, however, makes it impossible to quantify specific reaction rates. Generally, reported values are subject to various kinds of uncertainties and, given this uncertainty, the Monte Carlo method can be applied to help assess likely pollutant concentrations in rivers due to agriculture (Matsui et al., 2003).

N and P balances: The gross N and P balances estimate the potential surplus of N and P on agricultural land (kg/ha/year). They are estimated by calculating the difference between the quantities of these nutrients added to an agricultural system and the quantities removed from the system per hectare per year. The gross N balance accounts for all inputs and outputs from the farm, and includes all residual emissions of nitrogen from agriculture into soil, water and air. The volatilisation of ammonia is therefore included. N inputs include i) N as mineral and organic fertilizers, including manure; ii) biological N fixation by legumes; iii) N input through animal feeds; and iv) atmospheric deposition (e.g. through rainfall). The atmospheric deposition component of the balance can also come from non-agricultural sectors. N outputs include i) N taken out by harvested crops and grass/fodder eaten by livestock; ii) N lost through soil organic carbon loss and erosion; and iii) N emitted as N_2O (OECD, 2007a; EU IRENA indicator 18.1; INTA; Defra, 2010; EEA nitrogen balance)[34].

P inputs include i) P mineral and organic fertilizers, including manure; ii) other inputs, such as supplementary feeds for cattle, seeds and planting material; and iii) atmospheric deposition (e.g. through rainfall). P outputs include i) P taken out by harvested crops and grass/fodder eaten by livestock; and ii) P lost through soil organic carbon loss and erosion (OECD, 2007b; Defra, 2010; INTA). N and P losses through soil organic carbon loss can be estimated assuming a constant C:N:P ratio.

AgroEcoIndex N and P pollution risk indicators: The N and P balances are used as inputs to calculate the N and P pollution risk indicators of the AgroEcoIndex model of Argentina's Instituto Nacional de la Tecnología Agropecuaria (INTA). These indicators require as additional inputs the balance between precipitation and evaporation and the capacity of the soil to retain water. In accordance with McRae et al. (2000), it is assumed that there is N or P pollution risk only when N and/or P excesses (based on N and P balances) coexist with water excesses. A water excess exists when the difference between rainfall and evapotranspiration values exceeds the water retention capacity of the soil. If this is the case, the nutrient excesses are diluted in the water excess, and the results are expressed in mg/l of runoff/infiltration water (INTA). It should be noted that the value of this indicator is relative and does not in itself allow an indication of the absolute loadings of pesticide active ingredients to water bodies. It should therefore be used to monitor trends in performance, preferably in concert with monitoring of trends in the overall health of the water bodies receiving the pesticide loadings.

FAO Visual Soil Assessment Potential Nutrient Loss Index: A relatively simple assessment of the susceptibility of soils under crops for bioenergy production to lose nutrients into the groundwater and waterways can be performed by following the guidance in the FAO Visual Soil

[34] See reference and electronic sources section.

Assessment to calculate the Potential Nutrient Loss Index (FAO, 2011). This involves assigning visual scores for soil texture, soil structure, potential rooting depth and root development and combining these with a ranking score for the amount and solubility of fertilizer and nitrogenous products applied per annum. Whether the land is susceptible to leaching (i.e. flat land with little or no runoff) or runoff (i.e. gently undulating to rolling land) must also be assessed. The outcome is a numerical score for the Index, where a score below 11 indicates a high potential for nutrient loss, 11-20 indicates moderate potential and a score above 20 indicates low potential. The procedure could be combined with an assessment of the overall level of water quality in waterways in the watershed (i.e. without attribution to specific causal factors), in order to determine the significance of nutrient loss from bioenergy feedstock production into these waterways.

As mentioned above in the description of modelling approaches, agricultural best management practices can mitigate the risk of excess N and P reaching water bodies. The above risk indicators could therefore be complemented by an evaluation of the extent to which such practices are implemented.

Time series data using any of the above approaches will enable the detection of trends in nutrient loadings as bioenergy production changes in a given area. National analysis could rely on results generated from major watersheds of the country, or those identified as most vulnerable to nutrient and/or pesticide pollution.

Use of risk indicators for pesticide water pollution

Amongst the EU IRENA project indicators there is one indicator on pesticide levels in the water. This indicator determines pesticide levels in water by measuring annual trends in the concentrations (μg/l) of selected pesticide compounds in ground and surface waters (EU IRENA indicator 30.2[35]). There are fewer potential sources of pesticides than of N and P in water bodies, and these potential sources can be narrowed down further by considering only the specific active ingredients known to be used for bioenergy feedstock production in a region or watershed. Therefore direct monitoring observations of pesticide active ingredient concentrations in water bodies could be evaluated in conjunction with surveys on pesticide use in the watershed to determine the impact of bioenergy feedstock production on pesticide water contamination or, with appropriate flow measurements, on annual pesticide loadings attributable to bioenergy feedstock production. At the other end of the scale, risk indicators based on complex modelling are described in the above-mentioned HAIR documents.

AgroEcoIndex pesticide pollution risk indicator: An intermediate option with respect to the IRENA and HAIR indicators, in terms of practicality and precision, is the pesticide pollution risk indicator from the AgroEcoIndex model of Argentina's INTA, which depends upon pesticide application rate, formulation, characteristics (solubility, adsorption, half life), and toxicity (INTA). The pollution risk, PR , is given by the following formula:

$$PR = \frac{1000}{DL50}\left[\frac{Ksp + R}{2} + Koc + T_{1/2}\right] \times Dose \times Area$$

In this formula, for any given pesticide, $DL50$ is the oral lethal dose for rodents of commercial pesticides, Ksp is an index of solubility in water, R is the water recharge capacity of soils (infiltration), Koc is a soil adsorption coefficient, and $T_{1/2}$ is the half-life.

A further option for pesticide risk indicators is the Swedish approach described by Bergkvist (2005).

In the evaluation of the risk of pesticide loadings to water bodies and their impacts on aquatic life (including through indicators based on modelling, risk indicators such as the above, or more qualitative assessments), it is useful to distinguish between different categories of pesticides on the basis of their toxicity, persistence (measured through the half-life or mean lifetime) and type (fungicide, insecticide, herbicide, etc.). The persistence of the pesticides is particularly important with regard to their accumulation at the bottom of water bodies.

[35] See electronic sources section.

Since different types of pesticides impact upon different functional groups in the ecosystem, looking at different functional organism groups (performing counts and comparing these to a reference) could complement other pesticide pollution measurement approaches, including more expensive chemical analysis. Using biological indicators is time-consuming and therefore not always less costly. However this approach gives more insight into the pressure on the aquatic system over a longer period. Chemical analysis of the water layer only gives information on the pressure in the short term (pesticides can only be chemically detected over a short period), while the “pollution signal” can be detected for longer in organisms.

Monitoring of management practices

There could be value in obtaining information regarding trends in the extent to which certain management practices and regulations restricting the use of certain agrochemicals are implemented. For example, the percentage of land area used for bioenergy feedstock production where pesticides are not used or where regulations regarding the use of pesticides are adhered to could inform policy-making, particularly in vulnerable watersheds or critical ecosystems, as nationally determined, and in the absence of more sophisticated analysis, such as the watershed modelling or risk indicator approaches outlined above.

6.2: One key measurement of pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents and pollutant loadings from total agricultural processing effluents in the watershed is the BOD. This measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. It also measures the chemical oxidation of inorganic matter (i.e. the extraction of oxygen from water via chemical reaction). BOD from the discharged effluents of biorefineries and other agri-processing plants will be measured directly at their discharge points. Methods for doing this are described, for example, by US EPA water monitoring & assessment[36]. In order to inform national-level decision-making, these data could be presented as a graph with standard deviation of the pollution per unit of energy produced by the various processing plants of the country. The impact of these pollutants on the watershed can be evaluated by sampling water quality at various points downstream of the discharge point – see Morrison et al. (2003). Daily or annual pollutant loadings from a processing plant can be calculated by multiplying the pollutant concentrations in its effluent by its discharge flow rate. Daily loadings could be compared with any established total maximum daily load values. An annual value for these pollutant loadings in kg/year can be summed over all watersheds in a country to give a national total. Alternatively, the annual pollutant loading for each watershed can be divided by the watershed area to give a value in kg/ha/year that may be used to form a national average figure for all watersheds analysed. The same approach could be taken for measurement of COD (which measures the equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant) and the nutrients N and P.

As discussed above in the *Relation to themes* section, other pollutant measurements could be appropriate in a given context. In some cases, temperature and pH could be added to the measurements of water quality described above. Where processing plants discharge brine effluents, electrical conductivity, measured using a simple conductivity meter, can serve as a useful salinity indicator when considered with other factors and when a natural geological origin does not apply in terms of the source of dissolved salts (Morrison et al., 2001). In the case of processing plants whose discharges contain high amounts of greases and oils, the oil and grease concentrations could also be monitored as indicators of pollution.

Anticipated limitations:

6.1:

The methodological approach described above indicates a range of options, whose selection will depend upon data and resource availability. The extent of the data requirements for the more complex, model-based approaches are mentioned above. On the other hand, if simpler risk indicator approaches are chosen, it should be born in mind that such calculations do not measure the impact of bioenergy on water quality as such. Water pollution is difficult to allocate precisely to bioenergy production, since N and P fertilizers and pesticides are used throughout

[36] See electronic sources section.

agricultural production and the extent to which they enter surface water depends on a wide range of additional variables (methods and times of application, slopes, distances from recipient water bodies, etc.). The presence of nitrates in surface water comes mainly from agriculture application, but also from discharges from communities and industry. Inaccuracies in data collection regarding N and P applications will add uncertainty at each step of the analysis. Further, the variation in N balances as a function of differences in agricultural practices generates several classes of methodological challenges including:

- difficulty in determining residual N in soils due to previous crops; and
- sensitivity to data heterogeneities (e.g. composition and soil depth) and variability (e.g. inter-annual variability of climate).

As an example of the importance of context, as noted previously, through the application of best management practices adapted to soil properties and the cultivation of perennial energy crops one can get lower pollution rates at higher application rates than in, for example, less sustainable production systems. The effects of some of these practices on pollutant loadings can be estimated through the tool described in Evans et al. (2003), but at the national level such analysis would be challenging. Also some energy crops are capable of removing heavy metals from the soils, a potential positive impact that is not addressed in this indicator. This impact may be partially addressed through measurement of the use of contaminated land for bioenergy feedstock production for Indicator 8 (*Land use and land-use change related to bioenergy feedstock production*).

Since there are many different active ingredients used in pesticides, it will be difficult to arrive at an aggregate national figure for the pollutant loadings attributable to pesticide application and to compare values obtained across different practices and analyse trends over time.

6.2:

Although the concentrations of pollutants and other pollutant characteristics (such as BOD, COD, temperature, electrical conductivity and pH) of discharge effluents are relatively simple to measure, estimating the total annual loadings of relevant pollutants to the water bodies of the watershed requires more data and modelling. However, as described above, analyzing discharge effluent and water quality sampled at various points of interest in the watershed downstream of the discharge point may often provide a sufficient indication of the role of bioenergy feedstock processing in contributing to water pollution. Where there are various point and non-point sources in the watershed of the pollutants present in the discharge from bioenergy processing plants, detailed modelling may be required to attribute pollutant loadings to bioenergy.

Practicality

Data requirements:

Detailed data requirements will depend on the methodological approach adopted (just as the choice of methodological approach will depend on data availability). See Methodological approach section above and references for more details.

6.1: Total amounts of N and P fertilizer and pesticide applied per hectare for total agricultural production in the watershed. In addition to quantities of N and P applied as fertilizer per hectare per year, solubility of fertilizers applied is also useful information. Sufficient information is required about pesticides applied to enable the active ingredient, toxicity, half-life, solubility and soil adsorption coefficient to be identified. Timing and method of application of fertilizers and pesticides is also required for some modelling approaches.

6.1: Data on the proportion of fertilizer applied in the watershed for bioenergy production. These data can be derived from knowledge of the fraction of agricultural output used as a bioenergy feedstock, if agricultural practice is relatively homogenous within the watershed. Preferable to this data requirement would be geospatially referenced data (gained through surveys of farmers) on fertilizer and pesticide application, since some models derive different pollutant loadings to water bodies depending on the connectedness of the farm to the hydrological system.

6.1: In addition to N and P inputs through fertilizer application, data on all other significant inputs and outputs are required to calculate N and P balances (see above).

6.1: The previous data requirements include precipitation rates. Watershed models also tend to require other climate and soil data and may also require information on agricultural practices (including any management practices adopted to mitigate the risk of excess nutrients reaching water bodies).

6.1: Total N, P and pesticide concentrations in waterways and bodies of water.

6.1: The calculation of the Visual Soil Assessment Potential Nutrient Loss Index requires Potential Nutrient Loss Index scores for a suitable sample of land under bioenergy crops. This requires a visual assessment of the soil and land in addition to the above-mentioned data on fertilizer application.

6.1 and 6.2: Watershed area.

6.2: Pollutant concentrations (including BOD and others as required – see Methodological approach section above) of effluents from bioenergy feedstock processing and other agri-processing facilities and their discharge flow rates.

6.2: Amounts of bioenergy produced in bioenergy feedstock processing facilities, should per MJ values be required.

6.1 and 6.2: Area of land used for bioenergy feedstock/agricultural production (or tonnes of biomass produced), should per hectare (or per tonne) values be required for comparison.

These data can be gathered through national and international bodies such as Ministries of Agriculture, Ministries of the Environment, the U.S. Department of Agriculture, the UN Environment Programme and the Food and Agriculture Organization of the UN. Physical, biological and chemical measurements as well as interviews and surveys at the watershed, field or processing plant site may be taken as necessary.

Data sources (international and national[37]):

- AQUASTAT
    - FAO's global information system on water and agriculture
- GEMS - Water
    - UNEP’s global information system on water and agriculture
- NAWQA
    - U.S. water quality assessment program

6.1:

- typical fertilizer and pesticide amounts applied as a function of crop, soil type and agro-climactic conditions;
- U.S. Geological Survey (USGS) SPARROW model;
- annual measures of water quality at local level.

6.2:

- routine pollution monitoring of effluents discharged by any industrial facility depending on applicable national regulation.

Known data gaps:

6.1:

- Farm level statistics of fertilizer and pesticide applications by crops and fields. A representative sampling of such statistics in a given area may suffice to model area-wide fertilizer and pesticide applied amounts.

[37] See electronic sources section.

- Additional modelling and/or measurements, particularly in the area of estimating the proportion of fertilizer attributable to bioenergy production.
- Uncertainties associated with measuring and modelling outputs of multiple agricultural, industrial and waste systems on a landscape and within a watershed.

6.2:

- Continuous BOD and flow rate monitoring of bioenergy processing facilities effluents.

Relevant international processes[38]:

- UN Water
- Bonsucro principle 4
- AQUASTAT
  - FAO's global information system on water and agriculture
- GEMS - Water
  - UNEP’s global information system on water and agriculture
- USDA Water Quality Information Center (National Agricultural Library)
  - U.S. Department of Agriculture database of water quality information and expertise
- UN Human Rights Council Resolution on Human Rights and Access to Safe Drinking Water and Sanitation, A/HRC/15/L.1 (UN, 2010)
- EU IRENA indicators on pesticides in soil and water:
  - EU IRENA indicator 18.1
  - EU IRENA indicator 20
  - EU IRENA indicator 30.1
  - EU IRENA indicator 30.2

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Indicator 7 Biological diversity in the landscape

Description:

(7.1) Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production;

(7.2) Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated;

(7.3) Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used.

Measurement unit(s):

Absolute areas in hectares or km^2 for each component and for total area used for bioenergy production. Percentages of bioenergy production area can be calculated from these, and given either separately for each relevant category (i.e. different types of priority areas for 7.1 and specific methods for 7.3) or as a combined total across such categories.

Relevance

Application of the indicator:

7.1 and 7.3 apply to bioenergy production and to all bioenergy feedstocks.

7.2 applies to bioenergy production from those feedstocks that are known to be potentially invasive, such as *Amelanchier candensis* (Serviceberry), *Artocarpus communis* and *A. altilis* (Breadfruit), *Arundo donax* (Giant reed/elephant grass), *Azadirachta indica* (Neem), *Brassica napus* (Rapeseed/canola), *Camelina sativa* (False flax), *Cocos nucifera* (Coconut), *Crataegus spp.* (Hawthorn), *Diospyros virginiana* (Persimmon), *Elaeis guineensis* (African oil palm), *Gleditsia triacanthos* (Honeylocust), *Jatropha curcas* (Physic nut) and others (see list of species invasive in different regions provided in GISP (2008) (more sources cited under 'available data').

Relation to themes:

This indicator is primarily related to the theme of *Biological diversity*. Bioenergy production can pose several different risks for biological diversity. Conversion of land within areas recognized nationally as important for biodiversity and critical ecosystems to bioenergy feedstock production may have negative impacts on biodiversity. Another risk is the potential of some species cultivated as bioenergy feedstocks to become invasive and displace or adversely affect native species. Some agricultural and forest management practices involved in feedstock production can have adverse impacts on biodiversity, ranging from direct mortality of invertebrates and their predators caused by pesticide use to reduction in resources available to pollinators and suppression of soil fauna, but others can limit adverse impacts and may have positive impacts on biodiversity.

Identification and monitoring of areas converted for bioenergy production and of potentially invasive species used as bioenergy feedstocks are the first steps towards preventing loss of biodiversity. Employment of nationally recognized conservation methods (aimed at limiting adverse impacts on biodiversity from agriculture and forestry) in and around biofuel production areas can help reduce negative and promote positive impacts on biodiversity of the cultivation of biofuel feedstocks.

The three components of this indicator capture area conversion, cultivation of nationally recognized invasive species and the application of nationally recognized conservation methods and thus address a range of potential negative and positive impacts of bioenergy production on biological diversity.

The indicator will also inform the themes of *Land-use change, including indirect effects*, *Productive capacity of the land and ecosystems, Water availability, use efficiency and quality*, as well as *Human health and safety*, and *Economic development*.

How the indicator will help assess the sustainability of bioenergy at the national level:

The maintenance of biological diversity and ecosystem services is crucial for achieving sustainable development. This is reflected in the Millennium Development Goals as well as in the results of The Economics of Ecosystems and Biodiversity[39] (TEEB) initiative. Bioenergy production can adversely affect biological diversity and thus interfere with a country's efforts to develop in a sustainable way. The Convention on Biological Diversity has recognized these linkages in decision X/37 Biofuels and Biodiversity of its Conference of the Parties (COP 10, 2010), which "invites Parties to (a) develop, national inventories so as to identify areas of high biodiversity value, critical ecosystems, and areas important to indigenous and local communities; and (b) assess and identify areas and, where appropriate, ecosystems that could be used in, or exempted from, the production of biofuels; so as to assist policy-makers in applying appropriate conservation measures and identifying areas deemed inappropriate for biofuel feedstock production, to promote the positive and minimize or avoid the negative impacts of biofuel production and use on biodiversity ...".

Furthermore, biological diversity plays a key role in sustainable agricultural production, so minimizing adverse impacts on biodiversity is also important in ensuring that bioenergy production is itself sustainable.

7.1: Land use change, including deforestation, is a major cause of the loss of biological diversity and is in most cases related to agricultural expansion. Agricultural areas are projected to expand further in the future as a response to the globally increasing demand for food, and the cultivation of bioenergy feedstocks represents an additional demand for land suitable for agriculture.

Because biodiversity is unequally distributed across space, impacts on biodiversity from the conversion of land depend on where conversion takes place. The conversion of areas of high biodiversity value or critical ecosystems can have significant negative impacts on species and ecosystems, including through fragmentation and landscape change. Assessing the annual conversion rates of areas of high biodiversity importance and of critical ecosystems due to bioenergy feedstock production can inform national policy development and implementation.

7.2: Invasive species can threaten biodiversity, food security, human health, trade, transport and economic development. Globally, they pose a significant threat to biodiversity, and in certain ecosystems (notably islands), they represent the greatest threat to biodiversity (Biodiversity Indicators Partnership, 2010[40]). There is evidence that the magnitude of this threat is increasing globally (Hulme, 2009).

Invasive alien species alter ecosystem processes (Raizada et al., 2008), decrease native species abundance and richness via competition, predation, hybridization and indirect effects (Blackburn et al., 2004; Gaertner et al., 2009), change community structure (Hejda et al., 2009) and alter genetic diversity (Ellstrand & Schierenbeck, 2000). (Extract from McGeoch et al., 2009; see references)

The global total cost per year of damage caused by invasive species has been estimated at US$ 1.4 trillion per annum (around 5% of GDP, Pimentel et al. 2001), indicating a potential for significant impact on economic development.

The Global Invasive Species Program's report Biofuels run the risk of becoming invasive species. Biofuel crops and the use of non-native species: mitigating the risk of invasion (GISP, 2008) states that "some of the most commonly recommended species for biofuel production, particularly for biodiesel, are also major invasive alien species in many parts of the world. […]. Some of these species are spread by birds, small mammals and other animals, making their control difficult or impossible, with impacts increasing over time and long-term production prone to greater financial losses than gains." For a brief summary on the issue of invasive species in the bioenergy context, see UNEP Bioenergy Issue Paper No. 3. [40]

[39] See electronic sources section.
[40] See electronic sources section.

This component of the indicator will provide an indication of the scale of the risk presented by using invasive alien species as bioenergy feedstocks. Since invasive alien species can cause transboundary environmental harm, this indicator could also help assess the risk of such harm as a result of trade in bioenergy feedstocks. For each species cultivated as biofuel feedstocks and known to be (potentially) invasive, the area on which it is cultivated provides an assessment of its potential impact on biodiversity; the total area where such species are cultivated indicates the overall potential for adverse impact on biodiversity from this aspect of bioenergy production; the larger the area they cover, the larger the potential risk.

7.3: Specific cultivation, management and harvest practices can reduce negative and promote positive impacts on biodiversity within and around feedstock production sites (e.g. Buck et al. 2004, Scherr and McNeely, 2008) and can thus be considered an important contribution to sustainable bioenergy production. Conservation methods currently exist, or are in development for many different crops, landscapes, and national contexts (e.g. Bennett and Mulongoy, 2006, e.g. Perrow and Davy, 2008a and 2008b). These methods range from those related to cultivation practice (e.g. no-till, integrated nutrient management) to those that focus on the wider agricultural landscape (e.g. maintenance of corridors and buffer zones). These and other measures may be implemented by individual producers and/or explicitly promoted by government policies.

An indicative list of such measures that may be used to help conserve biodiversity within and around biofuel production areas is included under Methodological approach. It is likely that negative impacts on biodiversity decrease with an increasing proportion of the total production area on which such measures are employed.

This component of the indicator reflects:

- producers' awareness of, and willingness to address biodiversity concerns;
- the policies in place; and
- the magnitude of likely reductions in negative impacts on biodiversity from bioenergy production.

Direct assessment of the magnitude of positive or negative impacts of bioenergy production employing or not employing biodiversity friendly measures would require intensive monitoring of trends in species populations and in ecosystem condition using careful sampling designs.

Comparison with other energy options:

7.1: Comparison could be made with areas of conversion for, or direct impact of, extraction and processing of fossil energy sources in areas of high biodiversity importance and critical ecosystems (measurement: ha/yr converted for fossil fuel production). Land-use related biodiversity impacts can also arise from energy options such as land-based photovoltaics (PV), concentrating solar power (CSP), inundated areas caused by hydropower, and impacts from on- and offshore wind energy installations. For nuclear energy, land use from conversion, storage, and final repository facilities and their respective infrastructures could be considered (measurement: ha/yr converted for non-fossil energy production).

7.2: It may be possible to estimate the cost to society due to invasive alien species, which could potentially contribute to a comparison of net (monetizable) impacts of bioenergy production with those of fossil fuel and alternative energy production).

7.3: Comparison could be made with the employment of analogous measures within and around extraction and processing sites for fossil fuels, as well as within and around production sites for other types of renewable energy. Where information on the implementation of nationally recognized conservation methods is lacking, countries could consider the relative value of acquiring that information, and may decide to assess the coverage of such methods in government policies and/or in sustainability standards of companies.

Also of potential interest is comparison of all three components with the same assessments for other types of agriculture.

Scientific Basis

Methodological approach:

7.1: Spatial information on areas nationally recognized as being of high biodiversity importance or as critical ecosystems should form the basis for this indicator. Ideally such areas should be monitored annually to detect any conversion (but less frequent monitoring may be more feasible). In the case of biofuel crops, conversion happens where land that was not used for agriculture or grazing is converted into agricultural land used for bioenergy crop cultivation. In forestry, conversion might be either from natural ecosystems to plantation forest or from unmanaged forest to forest managed for bioenergy production. The latter is much more difficult to detect and also has different implications for biodiversity. Where conversion is detected, information is needed on the purpose for which the conversion took place and whether there is a direct causal link between the conversion and the expansion of bioenergy feedstock production in that region.

Where such monitoring is not feasible, reports from producers on the location and extent of areas converted to production of bioenergy feedstocks can be compared with the spatial information on areas of high biodiversity importance and critical ecosystems. Countries may wish to establish a national database including all areas identified through global, regional or national level approaches that are nationally accepted as of high biodiversity importance and as critical ecosystems to facilitate this. Clarity on the definitions governments use to identify nationally recognized areas of high biodiversity value or critical ecosystems is an important starting point for the analysis. When new areas are identified, or the boundaries of existing areas revised, the updated dataset should be used as the baseline.

7.2: The data are to be collected at the national level through surveys of agricultural practices. Countries may wish to present the data as hectares of cultivation by species or aggregated by risk category (e.g. X hectares planted with species in risk category 3). The risk category can be developed by applying the following assessment process:

1. List species used for biofuel production and area they cover.
2. Check information sources listed under ‘data sources’ to identify the potential for invasiveness of each species.
3. If no information exists on the potential risk of invasiveness, assess according to the Weed Risk Assessment (WRA, see ‘data sources’), by using the WRA question sheet and the WRA scoring sheet (substituting “low risk”, “medium risk” and “high risk” for “accept”, “evaluate” and “reject”).
4. If the species is known to be invasive or has a medium or high risk for being invasive according to results from the WRA, review existing information on biodiversity impacts in the country and in adjacent countries (e.g. by checking the databases listed, running online searches), and checking with government departments and country level research institutions.
5. Based on this review species could be classified as follows:

The species is known to be invasive or has potential for invasiveness,…

- …but no information exists on impacts on biodiversity in the focal country, adjacent countries or any other countries = category 1
- …and impacts on biodiversity are reported from other countries, but not from the focal country or adjacent ones = category 2 (information sources should be referenced)
- …and impacts on biodiversity are reported from the focal country and/or adjacent ones = category 3 (information sources should be referenced).

After these evaluations the indicator can be presented as hectares of cultivation by species or aggregated by risk category).

7.3: The data are to be collected at the national level through surveys of agricultural practices. Bioenergy producers can be asked to provide information on their implementation of nationally recognized conservation methods in relation to bioenergy feedstock production areas. This should include information on the size of the area on which these conservation methods are implemented and the type of method. Relevant conservation methods can include the following:

- no-till or low-till agriculture;
- integrated pest management;
- integrated nutrient management;
- maintenance or enhancement of agrobiodiversity;
- agroforestry/intercropping, and low impact harvesting;
- low impact forest management and wood harvest;
- maintenance and/or enhancement of ecological corridors and/or buffer zones;
- restoration or conservation of areas within and around production areas for biodiversity and ecosystems;
- monitoring populations of flagship and/or indicator species;
- other nationally recognized methods.

Countries may wish to compile a database including spatial data on which measures have been implemented where. Such a database will not only inform assessments of the sustainability of bioenergy production, but could also support national conservation planning. One example of such a survey is the USDA Census of Agriculture that provides essential monitoring of conservation practices in the U.S. agricultural sector[41].

Anticipated limitations:

The necessary information may be difficult to obtain from land under certain land tenure arrangements, such as private lands.

As for other indicators it may be difficult to distinguish areas used for bioenergy production from areas where the same crops are grown for other purposes. Crop rotations may also make it difficult to identify where trends need to be monitored and to attribute emerging patterns to bioenergy feedstock production.

7.1:

- Some areas of high biodiversity importance or critical ecosystems may not be identified and their possible conversion to bioenergy feedstock production could then go unnoticed.
- A solid causal link between the conversion of areas of high biodiversity importance and ecosystems of national importance and bioenergy feedstock production will have to be established. Differentiation between land conversion for agricultural crops relating to food production or to crops used for bioenergy production can be difficult, and in some cases the land is used for multiple purposes, including bioenergy feedstock production. If the newly established crop is not a bioenergy crop it nonetheless may (or may not) indicate indirect land use change due to bioenergy production elsewhere (See Indicator 8, *Land use and land-use change related to bioenergy feedstock production*).
- Data collection is likely to rely on information provided by producers to their national government or other relevant data collection body about the crops that they are growing on the converted land, including the purpose for which they are grown. Smallholders and farmers in remote areas might find it difficult to provide this information.

7.2: Whilst there are no anticipated difficulties in measuring the number of invasive species used for bioenergy production and area covered by these within a country (other than perhaps where field trials are being conducted by private firms), this measure has been proposed precisely because there is currently inadequate information in many countries for trends in invasive species (i.e. whether they continue to spread or ways have been found to halt their

See electronic sources section.

spread or reduce the populations).

Information on the impacts on biodiversity of individual invasive species used in bioenergy production may be incomplete. It is difficult to trace changes back to one driver only, e.g. one invasive bioenergy crop that is spreading. This is why a very simple classification system is suggested above.

7.3: Mapping areas on which conservation methods are being implemented can be time-intensive and may not be realistic in some countries' circumstances. However, while such spatial information is useful to understand how these conservation methods relate to plans for the use of land and contribute to country-wide conservation measures, the indicator is also applicable without spatial information.

None of the components of the indicator addresses directly the trends and changes in species abundance that may result from bioenergy. Where particular species are of interest, these may be addressed with targeted studies. Approaches that address a wider range of species trends have been developed in other contexts - e.g. those reviewed by Croezen et al. (2011) - but tend to be very data-demanding and to require the application of sophisticated modeling approaches.

Practicality

Data requirements:

7.1:

- A list and accurate maps (at the most highly resolved scale available) of areas of high biodiversity importance, updated as new areas are identified;
- A list and accurate maps of critical ecosystems, updated as new areas are identified;
- Annual monitoring data on conversion rates of those areas, including information on the newly established crops; or country-wide maps showing conversion for energy crops, which can be overlaid with areas of high biodiversity importance and ecosystems of national importance to assess impact.

These data can be collected through remote sensing, aerial photography and field surveys, or interviews and surveys, or a combination of methods, at the national, regional or natural and agro-ecosystem level.

7.2:

- List of species used as bioenergy feedstocks in the country in question and size of area on which they are cultivated;
- Information on which of these species are nationally recognized as invasive;
- Survey and synthesis of available information on the impact of these species on biodiversity.

These data can be gathered through compilation of (existing) data at the national level, through interviews and surveys, and/or through review of publications on impacts on biodiversity and impact classification of species known to be invasive or considered potentially invasive (as described in methodological approach).

Local studies on the impacts on biodiversity of invasive species used in bioenergy production could help assess the indicator but are not a pre-requisite for measuring it.

7.3:

- Nationally agreed set of measures to protect biodiversity should be chosen to fit the circumstances (see example list under 'methodological approach'). New methods can be devised through research and development activities;
- Number and size of production areas;
- Information on which conservation methods are employed and size of area on which they are employed and by production area.

These data can be gathered through compilation of (existing) data or interviews and surveys at the national, field or management unit level.

To reduce the difficulty of data collection, one or more components of this indicator could be restricted to production sites above a threshold size to be determined in relation to necessary survey effort (i.e. to include only medium and large scale producers). This would also help deal with issues around different types of tenure and 'traditional' and 'modern' bioenergy.

Data sources (international and national)[42]:

7.1:

- Maps of areas recognized nationally as being of high biodiversity value;
- Maps of areas recognized nationally as critical ecosystems;
- National or regional ecological gap analyses. CDB provides a list of places where such analyses have already been conducted;
- Information from other national and sub-global ecosystem assessment processes (e.g. EURECA);
- Important Plant Areas (IPAs) that have been identified for a number of countries;
- Important Bird Areas (IBAs) that have been identified for many countries in the world.

If nationally agreed areas do not exist, the following may be useful sources:

- national maps on the distribution of (threatened and/or endemic) species to identify new areas of high biodiversity importance;
- information on the conversion of different ecosystems in the past to identify which ecosystems may be important to maintain;
- Integrated Biodiversity Assessment Tool (iBAT), which includes Key Biodiversity Areas, consisting of Important Bird Areas, Important Plant Areas, Important Sites for Freshwater Biodiversity, and Alliance for Zero Extinction Sites;
- World Database on Protected Areas (WDPA);
- databases for sites designated under regional conventions, such as Natura 2000 sites in the European Union;
- Global Forest Protected Area Gap Analysis (UNEP and WCMC, 2009);
- Intact Forest Landscapes;
- Global Lakes and Wetlands Database;
- Ramsar Wetlands of International Importance(but a large number of the currently 1888 Ramsar sites are also included in the WDPA).

For monitoring the conversion, remote sensing data can be useful, e.g. as provided by:

- Google forest monitoring tool;
- Landsat data, e.g. from the U.S. Geological Survey website;
- in part, the EU monitoring of NATURA2000/FFH areas, and the EU indicator system for agriculture cover some of the data.

7.2:

- national lists of species used for biofuel production and area in which they are cultivated;
- lists of species used or being considered for biofuel production and countries where they are invasive. Sources include:
    - Biofuels run the risk of becoming invasive species. Biofuel crops and the use of

[42] See references and electronic sources section.

non-native species: mitigating the risk of invasion (GISP, 2008);

- Assessing the risk of invasive alien species promoted for biofuels (GISP, n.d.);
- other relevant databases, potentially containing information about invasiveness of species and their impacts on biodiversity:
    - Global Invasive Species Database (GISD);
    - IUCN Red List;
    - IABIN Invasive Species Information Network and related country specific databases;
    - Delivering Alien Invasive Species Inventories for Europe;
    - NOBANIS European Network on Invasive Alien Species;
- database selection from the Invasive Alien Species section of the CBD website;
- country level information where available, such as:
    - UK: https://secure.fera.defra.gov.uk/nonnativespecies/home/index.cfm
    - Ireland: http://www.invasivespeciesireland.com/sighting/
    - Mexico: http://www.conabio.gob.mx/invasoras/index.php/Portada
    - Brazil: http://i3n.cria.org.br/
    - United States of America (U.S. National Invasive Species Information Center): www.invasivespeciesinfo.gov/.

Information provided in National Reports to the CBD might be useful and a list of related documents from different countries and regions is provided at the CDB Experiences, Case Study, and Assessments webpage.

7.3:

- national lists of bioenergy feedstock producers and production areas (e.g. from the agricultural department of the government);
- national and regional literature and agricultural extension manuals on biodiversity-friendly practices in agriculture and forestry.

Known data gaps:

7.1:

Data gaps can be filled by mapping areas of high biodiversity value and of critical ecosystems using the above information sources as well as national and sub-global relevant datasets and following existing methods, e.g. for identification of KBAs and ecological gap analyses:

- on-site mapping of areas of high biodiversity value (field surveys) following existing methods (e.g. Conservation International's Rapid Assessment Method, see McCullough et al. 2007, 2008, Richards 2007);
- measuring of the conversion of areas through analyses of remote sensing data and ground-truthing;
- measuring of the conversion of areas through analyses of aerial photography (and ground-truthing).

7.2:

The only key gaps in available information for this indicator concern the risk of invasiveness of a species and its impact on biodiversity.

These may be filled as above mentioned databases are updated when new information becomes available. Risk of invasiveness can also be assessed using the approach given in the Weed Risk Assessment (WRA), i.e. the WRA question sheet and the WRA scoring sheet, substituting “low risk”, “medium risk” and “high risk” for “accept”, “evaluate” and “reject”(Weed risk assessment system website)[43]. Additionally, site-level studies can help understand invasiveness and impacts.

7.3:

In order to fill data gaps, surveys at the level of producers and collection of outcomes on national level can be undertaken.

Relevant international processes[44]:

- Convention on Biological Diversity and its Cartagena Protocol on Biosafety
- Convention on the Conservation of Migratory Species of Wild Animals
- UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention)
- The World Conservation Union (IUCN) provides statistics and reports
- Natura 2000 (Natura 2000 barometer provides statistics twice a year for European countries)

7.1:

- RSB indicators “conversion shall not occur prior to the land use impact assessment” Criterion 7.a
- EU Renewable Energy Directive – no production on land with “high biodiversity value”
- UN Millennium Development Goals (MDGs) indicators 7.6 (Proportion of terrestrial and marine areas protected) and 7.7 (Proportion of species threatened with extinction)
- U.S. Energy Independence and Security Act – no harvest of biomass from forests or forestlands with a global or state ranking

7.2:

- The Global Invasive Species Program has developed four indicators, upon which the GBEP indicators are based, in order to track progress towards the goals of the Convention on Biological Diversity to ‘control threats from invasive alien species’ and its two targets to (1) control pathways for major potential alien invasive species and to (2) have management plans in place for major alien species that threaten ecosystems, habitats or species (see COP 8, 2006). The indicators have been measured and analysed for a sample of 57 countries (McGeoch et al. 2010).
- The Standards of the Better Sugarcane Initiative include an indicator on the existence and implementation of an environmental management plan that, among others, also refers to alien invader plant and animal control.
- IDB Biofuels Sustainability Scorecard requests information on whether the species used are invasive or not.
- The RSB includes a criterion that requires assessing the invasiveness of species used for biofuel production and rejection of those that are considered as alien invasive species under local conditions.

7.3:

- RSB’s Principles and Criteria include criteria referring to protection, restoration or creation of buffer zones (criterion 7c) and ecological corridors (criterion 7d).
- The International Finance Corporation (IFC) in its ‘Environmental, Health and Safety Guidelines for Plantation Crop Production’, asks for:

[43] See electronic sources section.
[44] See references and electronic sources section.

- utilization of field borders to provide wildlife corridors around fields used for plantation crop production;
- provision of buffer zones on farmland bordering wildland;
- reduction of soil preparation to maintain the structure of soil ecosystems (e.g., promote low-till and no-till strategies);
- provision for minimum disturbance to surrounding areas when harvesting or gathering crops.

- The Basel Criteria for Responsible Soy Production, require that a plan to maintain and increase biodiversity in and around the farm should be developed and implemented, and that this plan includes, among others, measures to enhance habitats, particularly riparian strips, corridors to link areas of natural vegetation, and enlargement of existing areas of natural vegetation.
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Indicator 8 Land use and land-use change related to bioenergy feedstock production

Description:

(8.1) Total area of land for bioenergy feedstock production, and as compared to total national surface and (8.2) agricultural land and managed forest area

(8.3) Percentages of bioenergy from:

(8.3a) yield increases,

(8.3b) residues,

(8.3c) wastes,

(8.3d) degraded or contaminated land

(8.4) Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production, including the following (amongst others):

- arable land and permanent crops, permanent meadows and pastures, and managed forests
- natural forests and grasslands (including savannah, excluding natural permanent meadows and pastures), peatlands, and wetlands

Measurement unit(s):

(8.1-2) hectares and percentages

(8.3) percentages

(8.4) hectares per year

Relevance

Application of the indicator:

This indicator applies to bioenergy production from all cropping systems.

Relation to themes:

The indicator is related to the theme of *Land-use change, including indirect effects*. Bioenergy feedstock production could lead to land-use change, which can have both negative and positive environmental (and social) impacts.

Indicator components 8.1 and 8.2 place the amount of land being used for bioenergy feedstock production into the contexts of total agricultural land and managed forest area and total national surface area. This analysis is done to provide a sense of the size of the role of bioenergy in national land use.

8.3 relates to the share of bioenergy production which does not have a direct impact on land-use change (LUC) as described in 8.4.

8.4 relates to bioenergy feedstock production causing LUC, describing in detail the patterns in LUC arising from bioenergy feedstock production, including conversion of unmanaged lands to managed lands and also conversion of one kind of managed land to another kind.

The indicator does not attempt to measure indirect effects of bioenergy – such as indirect LUC – but partially addresses indirect effects by measuring
i) the contribution made by certain bioenergy production pathways that pose a low risk of displacing other uses of the same feedstock or land (8.3); and
ii) certain forms of direct land-use change due to bioenergy that pose a high risk of displacing other agricultural activities (8.4).

The yield increases described in 8.3a need to be evaluated in such a way as to indicate the contribution of bioenergy to the increase. Since yield increases may depend on increased water consumption, this indicator should be evaluated in concert with indicator 5 Water use and efficiency.

The percentage of bioenergy produced from residues (8.3b) and/or wastes (8.3c) refers to potential bioenergy feedstocks for which the impact on land use can be minimal depending on the volume and means of harvest. Agricultural residues and wastes contribute significantly to soil organic carbon and soil quality, and so this indicator should be evaluated in concert with Indicators 1 (*Lifecycle GHG emissions*) and 2 (*Soil quality*). In addition, the harvest of forestry residues can impact the productivity of forest soils and so this indicator should be evaluated in concert with Indicator 3 (*Harvest levels of wood*).

The indicator will also inform the themes of *Greenhouse gas emissions, Productive capacity of the land and ecosystems, Price and supply of a national food basket, Access to land, water and other natural resources, Rural and social development, Economic viability and competitiveness of bioenergy, Economic development* and *Energy security/Diversification of sources and supply*.

How the indicator will help assess the sustainability of bioenergy at the national level:

Evaluating this indicator will provide basic information on the role bioenergy production and use plays in land use and land-use change. Increasing bioenergy production could require either extensification of agriculture (i.e. increased land use) or changes in cropping patterns. Land use and land-use change data are fundamental to understanding many of the environmental, social and economic effects due to bioenergy production and use. Land use and land-use change data are a prerequisite to measuring many of the GBEP indicators, such as Indicator 2 (*Soil quality*) and Indicator 7 (*Biological diversity in the landscape*), which report their data in terms of percentage of land used for bioenergy. The measurements given by this indicator inform the assessment of the demand for agricultural land from the bioenergy sector, which might be interpreted in light of total availability and other competing uses. The interpretation of this indicator is significantly improved if it is considered simultaneously with land quality and suitability, for example some bioenergy feedstocks can exploit unused degraded or contaminated land. If the measurement of the share of land used for bioenergy feedstock production that has been subject to some land suitability assessment (approved by the relevant domestic authority) is added to the above measurements, this will inform an evaluation of the degree to which bioenergy expansion is part of official land use planning. An example for such a procedure for assessing land suitability is given by Manzatto et al. (2009); this was approved by the Brazilian President Lula da Silva (Presidência da República, 2009) for use as the basis for concession of credit for sugarcane production and industrialization (Brazilian Government, 2010). For further information on land suitability assessments see FAO (1996, 2010a) and Venema and Vargas (2007).

The indicator also helps to distinguish between the land-use change implications of different bioenergy feedstocks.

The impacts of land-use change on sustainable development are complicated and will depend strongly on the country context. The effects of such land-use changes should be carefully considered in conjunction with, amongst other factors, indicators 1, 7, 9 and 10, and – particularly in countries with availability of land suitable for agriculture – can in some cases reveal a positive impact on sustainable development. Particularly for countries with limited high quality agricultural land, lower amounts of land-use change can be promoted through actions that generate bioenergy from increased productivity and/or biomass sources not requiring additional land (8.3) and by lowering rates of land-use conversion (8.4).

Comparison with other energy options:

Land use from other energy sources such as coal, gas, oil and uranium mining/extraction and conversion can be measured and be compared to those of bioenergy. Land use for coal-to-liquids is one example of a particularly direct and highly relevant comparison. With regard to suitability and land-use planning, specific land-use requirements (e.g. for biodiversity) are also applicable to fossil or non-fossil extraction and conversion systems due to upstream processes (e.g. mining, milling, impacts from respective waste sites), and siting of conversion systems (e.g. concentrating solar power, onshore wind parks, hydropower reservoirs). There are also land-use considerations that should be taken into account for wind energy production either on- or offshore.

For biomass used for electricity, comparison can possibly be made with land used for other renewables, such as the footprint for solar and wind equipment or the balance of agricultural land flooded/made available through increased irrigation systems with dams for (small) hydropower systems.

Comparison with traditional use of biomass for energy may be possible when it is displaced by modern bioenergy. The rate of avoided deforestation and forest degradation e.g. due to gathering wood for fuelwood and charcoal would be measured in this case.

Scientific Basis

Methodological approach:

This indicator will enable the land use for bioenergy feedstock production to be put into perspective at the national level. National statistics at the farm level or data from analysis of satellite images will be aggregated to give national total figures for land use and land-use changes.

The indicator is based on point estimates derived from data collected in periodic agricultural censuses and surveys as well as terrestrial observation.

To calculate the values of 8.1 and 8.2, the total land area in a country used for bioenergy feedstock production is required. This can be derived from spatial data or estimated from data on bioenergy production (disaggregated by production pathway – e.g. feedstock and processing technology) and productivity (e.g. from Indicator 17). Total agricultural land and managed forest area is defined above.

8.1 and 8.2 give a broad indication of the role of bioenergy in national land use. In order to improve the relevance of these indicator values, countries that conduct land suitability assessments can calculate the share of land assessed as suitable for agriculture or forestry that is used for bioenergy feedstock production, and possibly disaggregate the results by groups of crops or by geographic regions. Such land suitability assessments take into account climate, hydrological and soil conditions. Land suitability assessments can use categories that are different from the FAOSTAT categories presented below in section 8.4, because these assessments are meant to provide information on land for potentially new agricultural production.

8.3) Calculating the total amount of bioenergy produced from various feedstocks

Calculating 8.3 requires data for the total amounts of bioenergy produced from each of the four feedstock categories defined above. These data can be derived from surveys of bioenergy feedstock processors (for quantities of each feedstock and of residues and wastes used for bioenergy production) combined with data on crop yield increases from farmers or trends reported in the literature. The percentages should be calculated on the basis of the energy content of the bioenergy end product. If this is not feasible, the calculation could be done on the basis of the mass of the feedstock, though in addition to the processing efficiency, the varying moisture content in the different types of feedstock would affect the accuracy and consistency of the results.

With regard to 8.3a, an attempt should be made, to the extent feasible, to evaluate the additional yield increase induced by bioenergy, as distinct from general trends in yield increases. Note this analysis is also suggested with regard to Indicator 10 (*Price and supply of a national food basket*). For a discussion of how to do this at the national and project levels, see JRC (2010) and Ecofys (2011), respectively. A general increase in agricultural yield might also include an increase in the availability of land due to increases in livestock productivity that would indicate higher production using less land. The integration of bioenergy feedstock production into a food production system (e.g. through new intercropping or agroforestry) or vice versa (e.g. the integration of livestock into a sugarcane ethanol production system) could result in a bioenergy-induced yield (or productivity) increase for the system as a whole (FAO, 2011; Sparovek et al., 2007; Ecofys, 2011).

When altering the use of residues or the fate of wastes (see Glossary), then the prior uses of these residues and fates of these wastes can be taken into account. For example, crop residues can be incorporated into soil or used for energy in traditional and modern ways, and tallow can be processed into biodiesel, burned to provide process heat in rendering plants, used to produce soap and cosmetics and for various other applications. For cases such as these, the use of residues for bioenergy production cannot necessarily be considered to be free of land use or land-use change or other impacts addressed by GBEP indicators, such as Lifecycle GHG emissions and Soil quality. Similarly, the use for bioenergy of wastes that would otherwise have gone to landfill, for example, can result in the avoidance of GHG emissions and other impacts. Precise, functional definitions of residues and wastes need to be nationally defined.

Evaluating the percentage of bioenergy feedstock from the use of degraded or contaminated lands (8.3d) will require national definitions and interpretation in a way that reflects specific national context and circumstances. For the purpose of this indicator, the definition of land degradation as a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided, from UNEP (2007), may be useful. The level of current use (mostly low level if at all) and the current land productivity potential should be taken into account.

8.4) Calculating rates of land use conversion due to bioenergy feedstock production

Part 4 of this indicator seeks to provide data on changes in land use. As such, users of this indicator must first define the categories of land that are relevant to their regional, national and local context. The categories of land include, but are not limited to, arable land, land under permanent crops, permanent meadows and pastures, managed forests, natural forests and grasslands (including savannah, excluding natural permanent meadows and pastures), peatlands, and wetlands. The users of this indicator are encouraged to clearly define these land use categories in a manner relevant to their domestic and/or regional context. For the purpose of clarity and transparency, the land use definitions are to be provided to relevant stakeholders when the data resulting from the evaluation of this indicator are shared.

If relevant and applicable to a given area of bioenergy production, the users of the indicator may choose to use the following FAO definitions (see below and glossary; the full FAOSTAT glossary is available at FAOSTAT glossary[45] webpage).

Arable land, permanent crops and permanent meadows and pastures are land use categories defined by FAOSTAT, which together make up the agricultural area of a country. The following FAOSTAT definitions may therefore be applicable:

- Arable land is the land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for “Arable land” are not meant to indicate the amount of land that is potentially cultivable. As an alternative, data based on land suitability categories meant to identify land for potentially new agricultural production could be used if applicable (see subsections 8.1-8.2). In that case, the respective definitions of land use categories should be reported.
- Land under permanent crops is the land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under "forest"). Permanent meadows and pastures are excluded from land under permanent crops.
- Permanent meadows and pastures is the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

Furthermore, forest area is defined as the land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use. (For full definition, see FAOSTAT glossary.) For example, tree stands in agricultural

[45] See electronic sources section.

production systems, such as in fruit plantations and agroforestry systems would be included under permanent crops, not forest area.

For the purposes of this indicator, a distinction between “managed forest” and “natural forest” is made. The first bullet point of land categories under 8.4 includes land in productive use (which could be displaced if this use were to change to bioenergy feedstock production) and the second bullet point contains other land types without a productive function – or provisioning service (Millennium Ecosystem Assessment, 2005) – that could potentially be converted to bioenergy feedstock production. On the basis of categories of primary designated forest functions used in the Global Forest Resources Assessment 2010 (FRA2010) (FAO, 2010b), “managed forest areas” comprise forests whose designated function is production – either as the primary designated function or as one function among multiple uses. Countries often use their own forest function classes. These nationally defined classes can be used to determine if forest classified as “multiple use”, “other” or “unknown” can be considered as part of the category “managed forest”, depending on the likelihood of there being productive activities on the land. In the absence of further information, forest designated in these three categories can be included in the “managed forest” category for this indicator. All other forest area should be considered “natural forest” for the purpose of this indicator (even if some of this forest might be managed for conservation purposes or to provide social services). This category will include “primary forests” (defined in FRA2010 as naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed), but also other naturally regenerated forests that are not used to produce wood or non-wood forest products.

This indicator requires a definition of “natural grasslands (including savannah)”. This class does not include naturally grown permanent meadows or pastures (i.e. land used as permanent meadows or pastures that is not being controlled, such as wild prairie or grazing land), where permanent meadows and pastures are defined above, since such lands have a productive function.

In order to calculate 8.4 (which asks for net land-use change rates), the number of hectares of land where a change from bioenergy feedstock production to a specified land-use category is observed should be subtracted from the number of hectares of land where a change from the specified land-use category to bioenergy feedstock production is observed and the resulting area should be divided by the time period, in years, between the two land-use observations. The first time that the indicator is evaluated, either a simple reference land-use observation for use in determining a LUC rate at the next observation point can be made, or, if suitable historical data are available, these can be used to produce a LUC rate between a chosen time in the past and the present.

Anticipated limitations:

Land attribution uncertainty associated with multi-purposes feedstock (bioenergy and other uses) can be a limitation as data may not be always reliable and would need to be cross checked against yields in the relevant areas.

Other limitations include:

- restricted availability and uncertainty of statistical data on bioenergy feedstocks from residues and wastes;
- non-availability of annual land monitoring, especially for degraded and contaminated land, and limitations in how representative low-resolution remote sensing data are for smaller areas;
- data errors in interpretation of land cover changes;
- missing definition and monitoring of forest degradation.

Practicality

Data requirements:

Land areas by categories

8.1:

- total area of land for bioenergy feedstock production
- total national surface

8.2:

- total agricultural land and managed forest area

8.3:

- annual energy crop yields
- annual amount of residues and wastes used as bioenergy feedstocks
- annual amount of bioenergy feedstocks from degraded or contaminated land

8.4:

- annual rate of conversion of arable land and/or
- annual rate of conversion of permanent crops and/or
- annual rate of conversion of permanent meadows and pastures and/or
- annual rate of conversion of managed forests and/or
- annual rate of conversion of natural forests and/or
- annual rate of conversion of grasslands and/or
- annual rate of conversion of peatlands and/or
- annual rate of conversion of wetlands (drained)

These data can be collected from national/international statistical accounts when available or through remote sensing, aerial photographs, GPS-based surveys or interviews, at the national, regional or field level.

Data sources (international and national):

- national statistics usually centralized within agriculture ministries and specialized institutes (geographic data and national statistics);
- FAO data on crops yield;
- national statistics on bioenergy feedstocks;
- land cover and land cover change data from remote sensing and census data in forestry and agriculture (including those submitted to the Global Forest Resources Assessments and FAOSTAT).

Known data gaps:

Data gaps can be filled through remote sensing or aerial photographs, bottom-up data collection, or survey through agricultural extension services, for shares of a same feedstock used for energy and other purposes (food, feed).

Land use at a local level can be monitored by spatial planning documents, (GPS-supported) on-site inspections and surveys.

Relevant international processes[46]*:*

- UN REDD and UN REDD plus schemes, and respective monitoring and project-level evaluations, including smallholder aggregates;
- UN Millennium Development Goals (MDGs) indicator 7.1 (Proportion of land area covered by forest);
- Convention on Biological Diversity, especially Nagoya Decision on biofuels and biodiversity (COP X/37, 2010);
- United Nations Framework Convention on Climate Change;
- United Nations Convention on Combating Desertification;
- chapter 10 of Agenda 21 on “Integrated Approach to the Planning and Management of Land Resources” and related CSD indicator of Sustainable Development, “land use change”;
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SOCIAL PILLAR	
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar: 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	
INDICATOR NAME	**INDICATOR DESCRIPTION**
9. Allocation and tenure of land for new bioenergy production	Percentage of land – total and by land-use type – used for new bioenergy production where: ▪ a legal instrument or domestic authority establishes title and procedures for change of title; and ▪ the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title
10. Price and supply of a national food basket	Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration: ▪ changes in demand for foodstuffs for food, feed and fibre; ▪ changes in the import and export of foodstuffs; ▪ changes in agricultural production due to weather conditions; ▪ changes in agricultural costs from petroleum and other energy prices; and ▪ the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally determined
11. Change in income	Contribution of the following to change in income due to bioenergy production: ▪ wages paid for employment in the bioenergy sector in relation to comparable sectors ▪ net income from the sale, barter and/or own consumption of bioenergy products, including feedstocks, by self-employed households/individuals
12. Jobs in the bioenergy sector	▪ Net job creation as a result of bioenergy production and use, total and disaggregated (if possible) as follows: ○ skilled/unskilled ○ temporary/indefinite ▪ Total number of jobs in the bioenergy sector and percentage adhering to nationally recognized labour standards consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work, in relation to comparable sectors
13. Change in unpaid time spent by women and children collecting biomass	Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services
14. Bioenergy used to expand access to modern energy services	▪ Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of energy and numbers of households and businesses ▪ Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass
15. Change in mortality and burden of disease attributable to indoor smoke	Change in mortality and burden of disease attributable to indoor smoke from solid fuel use, and changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves
16. Incidence of occupational injury, illness and fatalities	Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors

Indicator 9 Allocation and tenure of land for new bioenergy production

Description:

Percentage of land – total and by land-use type – used for new bioenergy production where:

(9.1) a legal instrument or domestic authority establishes title and procedures for change of title; and

(9.2) the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title.

Measurement unit(s):

Percentages.

Relevance

Application of the indicator:

The indicator applies to new bioenergy production and to all bioenergy feedstocks/end uses/pathways.

Relation to themes:

This indicator is primarily related to the theme of *Access to land, water and other natural resources*. Access to land is a consequence of land tenure.

Access to arable lands and lands under permanent crop, permanent meadows and pastures, and forest areas[47] is essential to sustainable development. Respect for land tenure rights, whether customary rights or rights derived from formal legal mechanisms, is essential to the fair and equitable allocation of land resources. Evaluating this indicator can help promote sustainable economic growth and improvements in social welfare among all stakeholders including smallholders, subsistence farmers, forest-dependent communities, and entrepreneurial and other businesses, by providing relevant data on the extent to which land tenure rights are recognized. The data required for the evaluation of this indicator can provide the social and legal context in which improvements in economic development and energy security, which can result from new bioenergy feedstock production, can take place. These data are important for evaluating the effect of new bioenergy production on the livelihoods of communities that depend on land and other natural resources.

The indicator will also inform the following themes: *Land-use change, including indirect effects; Price and supply of a national food basket; Rural and social development; Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use;* and *Economic viability and competitiveness*.

How the indicator will help assess the sustainability of bioenergy at the national level:

This indicator aims to measure the percentage of land – total and by the land-use types defined in Indicator 8 (*Land use and land-use change related to bioenergy feedstock production*) – used for new bioenergy production for which a domestic authority or legal instrument has established title and due process and established practices are followed for establishing title. Sustainable economic and social development will be encouraged if land owners and/or users have a recognized mechanism, e.g. a legal or socially accepted instrument that secures rights to new land. This instrument can be a formal certificate of use, certificate of occupancy, or in appropriate cases a title (or joint title as needed). This indicator can serve as a way to assess how new bioenergy production influences the allocation and tenure of land. Measuring changes

[47] In the rest of the methodology sheet, the term "land" refers to "arable land and land under permanent crops, permanent meadows and pastures, and forest area", according to FAOSTAT terminology.

in land tenure can help assess how new bioenergy activities influence the social sustainability and livelihoods of various populations in developing countries.

Allocation and tenure of land has both local and national considerations. The local land allocation and tenure system typically determines which community members have the rights to use and control different resources. Local land tenure systems may function through customary or formal mechanisms. Local land tenure systems can interact with the formal national system, which may provide protection and the means of enforcing land rights, to create incentives or disincentives for the production of bioenergy feedstocks. If communities are to benefit from new bioenergy feedstock production, then the local, regional and national land tenure systems will need to work jointly to record and enforce land tenure rights.

From a social sustainability perspective, establishing and following proper land access and tenure procedures can be an important element of promoting energy access and agricultural and economic development. Access to land can be a proxy for access to other natural resources. A transparent and accountable land tenure system can help create an enabling environment that allows farmers and enterprises, including entrepreneurial ventures, to grow and flourish. However, if land is expropriated, i.e. taken without providing due process or following established procedures, then communities, farmers, and enterprises might have little or no access to lands that they had previously used through customary or formal mechanisms. In many developing countries land rights and land transfer markets have not been established. The local poorer segments of the population may grow agro-products (food and feed mainly) on land for which legal title has not been established. Similarly, common permanent meadows and pasture lands are essential to the livelihoods of pastoral communities, as are common forest areas for forest-dependent communities. Approximately 75% of the world's poor live in rural areas, and the majority of these people are smallholders, subsistence farmers and pastoralists that depend on land access for their production of food, feed and fibre (Morton, 2007; Quan, 2010). In addition, access to agricultural land, pastures and forests, is important to many communities, including the rural poor, for access to a diverse array of goods, including fuelwood, medicinal plants, and subsistence income from wild resources and forest products. If land is expropriated without providing due process or following established procedures, then this may reduce access to food, feedstock and livestock feed, and more generally to ecosystem goods and services for communities, farmers, and enterprises, which may put them at risk of losing their livelihood.

Where competing claims for land exist among land users, governments, and new bioenergy producers, and where legal protections through due process are not in place, the rapid spread of commercial activity, including new bioenergy production, may result in land users losing access to the land on which their livelihoods depend (FAO, 2008; Sulle and Nelson, 2009).

Increasing values of this indicator – i.e. increasing area or percentage of land, previously collectively or privately owned or used, which was transferred according to a formal or socially accepted procedure that allows for it to be challenged in the case of competing claims – will show a positive trend in the quality of land transfer processes related to new bioenergy investments – hence a likely reduction of the risk that land access by communities, and therefore the livelihood of local communities, will be hampered. The quality of the land allocation process is likely to be negatively affected where differences exist between local, regional, and national procedures.

Comparison with other energy options:

The same approach can be followed to assess the impacts on land tenure of any other energy option that requires land in the production process.

It is also possible to compare the changes of this indicator with those caused by other land uses such as agriculture, forestry and the extraction of natural resources.

Scientific Basis

Methodological approach:

Land tenure is the relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land and associated natural resources (water, trees, minerals, wildlife, etc.). Rules of tenure define how property rights in land are to be allocated within societies. They define how access is granted to rights to use, control, and transfer land, as well as associated responsibilities and restraints. Land tenure systems determine who can use what resources for how long, and under what conditions.

Access to land is the ability to use land and other natural resources (e.g., use rights for grazing, growing subsistence crops, gathering minor forestry products, etc.), to control the resources (e.g., control rights for making decisions on how the resources should be used, and for benefiting financially from the sale of crops, etc.), and to transfer tenure rights for the sake of social and/or economic benefit (e.g. transfer rights for selling the land or using it as collateral for loans, conveying the land through intra-communal reallocations, transmitting the land to heirs through inheritance, etc.) (FAO, 2002b).

The indicator aims at measuring two aspects of the allocation and tenure of land used for new bioenergy production:

- First, in relation to 9.1, whether the title and procedures for the subsequent change of title for land for new bioenergy production are established either by legal instrument, such as a contract, or by a domestic authority, such as a government agency or socially accepted tribal authority.
- Second, in relation to 9.2, the extent to which due process is provided in the determination of new title. Providing due process with regard to the transfer of land in the context of this indicator entails that all established procedures are followed, including those related to the assessment and recognition of the rights of current owners and users under the national legal framework and/or socially accepted customary practices. Where customary practices are recognized and followed, those practices would provide the governing legal and procedural framework. In addition, laws and procedural requirements related to compensation measures should be followed, taking into account the assessment results.

Disaggregation by land-use type (where feasible) is a simple means of supplementing this indicator with information on the type of natural resources where due process for land transfers is followed. Ideally, the same land-use types used for Indicator 8 (*Land use and land-use change related to bioenergy feedstock production*) would be used for this indicator. However, for both these indicators, the choice of terms and level of disaggregation used in a country may depend on data availability.

This indicator should take into consideration the national-level elements such as the policy and legal framework, and national practices related to informal authorities and processes. Regarding the latter, local-level information might help the measurement of the indicator by providing examples and empirical information on the positive and negative effects of bioenergy on social sustainability and land tenure.

9.1: One approach to measurement would be to refer to documents of land rights or land registry records. This approach has the advantage of being straightforward and reasonably objective but it has limitations. Land registries are not necessarily the sole source of information on rights relating to a parcel of land. The situation is made more complex in developing nations where:

- few documents or registers exist;
- registers may not be up-to-date or complete;
- registers and documents may not reflect the de facto situation;
- documents and registers often only list one name (de jure head of household); and
- documents and registers probably do not reflect the variety of formal and informal rights

that exist through custom and tradition.

For these reasons, while analysis of records may play a useful role in measurement of this indicator, it might also be beneficial for domestic authorities to seek some of the necessary information for a sample of land transfers for new bioenergy production through interviews of those involved in and affected by the land transfer.

9.2: This part of the indicator aims to measure the percentage of land for which due process and established procedures are followed to determine the transfer of tenure rights for new bioenergy production. In particular, it would measure the extent to which all transaction processes have been free and voluntary, all agreements have been appropriately negotiated with holders of ownership and/or other tenure rights both from formal and customary ownership, and other stakeholders, as appropriate, and have included a “willing seller/willing buyer”, and there is a formal or socially accepted informal procedure through which the transaction can be challenged by the “seller” or “buyer”. If communal land is leased to a private party for new bioenergy production, the indicator can show if the agreements have been reached with all accepted community representatives, and if lease agreements provide use of land for a stipulated period of time, not ownership of the land itself.[48]

9.1 and 9.2: Regarding informal/unrecorded structures and processes related to both 9.1 and 9.2, interviews of relevant households (i.e. those with most stake in the land transfers in question), key informants, relevant groups, and relevant traditional land authorities (e.g. customary authorities, village councils, etc.) will be used as measuring methods if data are not readily available. In addition, if appropriate, sample household surveys could also be used.

Furthermore, relevant evidence can be provided by formal reporting regimes, at the local and/or national level. Formal reporting regimes can include, but are not limited to, national and local land registries, publication of land transfers through a digest or record, and/or publication of court records and cases. In some cases examining contested land transfers for relevant data can be a practical means of identifying deviations from the implementation of fair and effective processes; however, care should be taken when interpreting such data sources. Voluntary and/or mandatory reporting regimes may be biased towards good practices and contested cases would be expected to highlight bad practices. Bad practices may be less likely to be recorded where provisions for dealing with such cases are considered weak.

Anticipated limitations:

The assessment of this indicator is 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 might be difficult to measure. Yet, such informal features must be included because they form a significant proportion of land tenure structures and mechanisms in many developing countries. Most of the least developed countries have not established a market where land tenure has been completely organized and registered. Thus, the main assumption of this indicator is that by combining information on formal and informal aspects of land transfer authority and processes related to new bioenergy operations, it will show a picture of the effect of bioenergy on land tenure changes in a country. Nevertheless, the link between land tenure and bioenergy activities might be difficult to monitor and to measure since it might be difficult to separate the effect of bioenergy activities from other factors, in particular in the case of informal transactions.

In addition, access to land is a sensitive matter in some countries. Where regulations are weakly enforced, a risk of getting distorted data could arise. 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.

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

[48] RSB Land Rights Assessment Guidelines, version 1.0

Practicality

Data requirements:

The indicator will be based on the following data collection:

- Land area (ha and percentage of total country land area) used as common or open access land by local population, and land privately owned by the local population, to be given in concession to new bioenergy investments in bioenergy production areas (BEPA). Special relevance should be given to the overlap of BEPA and community forests and indigenous or poor communities as these are often most dependent on forest resources.
- Titles, contracts and any other formal registration of land tenure held by bioenergy investors and companies that have been registered in a national or local registry/cadastre.
- Existence of community/local population rights to lands, amount (ha and %) of lands legally recognized as community/common lands
- Information about qualitative aspects of the issuing of new bioenergy concessions, in particular whether:
  a) land rights are granted by constitutions, statutes and official tribunals;
  b) land rights are granted by other laws – customary, informal, secondary, tertiary;
  c) there is security of the aforementioned rights in terms of enforcement and application;
  d) there are land-related or subsidiary rights that women are free to exercise without specific mention in formal or informal laws;
  e) there is effective access to fair adjudication, including the court system or other dispute resolution processes (FAO, 2002a);
  f) the public land allocation procedure has followed due process and, where applicable, provided due compensation, and was also consistent with applicable national and international obligations and commitments regarding the rights of indigenous peoples and relevant human rights;[49]
  g) land rental and sales contracts including contracts for temporary use agreements are accessible to all;
  h) periodic monitoring is carried out to assess the impacts of bioenergy on changes in access to and use of natural resources by local communities.
- If the land used for new bioenergy production is recognized as community/common land it is important to gather information regarding mechanisms of participation or consultation carried out by the new owner with the local community. If the land is recognized as land with secure rights by national legislation, it is important to gather the evidence of the negotiation agreement for any contingent compensation between the new owner or other

[49] Relevant international obligations and commitments may include, as appropriate, the International Covenant on Civil and Political Rights (ICCPR, see electronic sources section) and the UN Declaration on the Rights of Indigenous Peoples (UNDRIP, 2008) and its concept of free, prior and informed consent (FPIC, see electronic sources section).
The ICCPR states in Article 1 (2): “All peoples may, for their own ends, freely dispose of their natural wealth and resources without prejudice to any obligations arising out of international economic co-operation, based upon the principle of mutual benefit, and international law. In no case may a people be deprived of its own means of subsistence.” Article 18 of the UNDRIP states that “Indigenous peoples have the right to participate in decision-making in matters which would affect their rights, through representatives chosen by themselves in accordance with their own procedures, as well as to maintain and develop their own indigenous decision-making institutions.” Article 19 states that “States shall consult and cooperate in good faith with the indigenous peoples concerned through their own representative institutions in order to obtain their free, prior and informed consent before adopting and implementing legislative or administrative measures that may affect them.” The FPIC framework can also be a useful tool in working with other communities who have traditional rights to land.

tenure right holder and the local community.

These data can be gathered at the national level through national/international accounts if available, or through interviews and surveys at the household, villages or local government units (districts or regions) level, since these resources tend to stretch beyond administrative boundaries.

Data sources (international and national):

Possible data sources include local, regional or national government registers of rights and deeds[50] (where titles, contracts and any other formal registration of land tenure held by bioenergy investors and companies might be found).

Baseline information needs to be first obtained (or derived) to know the number of people dependent on arable land and land under permanent crops, permanent meadows and pastures, and forest area and for what, the existing rights for access and how these are exercised. Sources of information on different types of land use are similar to those considered for Indicator 8 (Land use and land-use change related to bioenergy feedstock production).

If titles, contracts and management agreements are not available, surveys and household interviews should be conducted to assess the change in land tenure and access as a consequence of bioenergy activities.

More specifically regarding 9.2 – the quality of the transaction process – possible sources of information are formal laws, evidence of practice (including written records of land transfer processes and interviews), and records of court cases related to land transactions. Since court cases concern only cases where the transaction has been challenged – hence are biased towards cases where the procedure has not been correctly implemented or fair – they could be used to identify deviations from legal requirements. Furthermore, for a case to arrive at court requires not only a certain quality of evidence but also a certain quality of governance. As such, a lack of court cases cannot always be interpreted as an indication of the full provision of due process and following of established procedures.

Known data gaps:

Data gaps might be found in formal registers of rights and deeds that are not updated at the time of the indicator assessment. However, most data gaps are likely to be found concerning informal transactions that have not been registered.

Relevant international processes[51]:

Issues related to land transactions have been the subject of several international processes such as:

- FAO Voluntary Guidelines on Land Tenure Governance
- Responsible Agro-Investment Initiative (RAI)
- Round Table on Sustainable Biofuels, in particular their Land Rights Guidelines (RSB, 2011)
- UN Declaration on the Rights of Indigenous Peoples (in particular the section on Free Prior Informed Consent)
- Bonsucro Production Standard, including Bonsucro EU Production Standard

References:

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[50] A deed is a written instrument recording a transaction affecting, or purporting to affect, a right. A deed is only executed when there is some change in the possession of a right and a register of deeds is a record of transactions in rights and not of the rights themselves (FAO, 1995)
[51] See references and electronic sources section.

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- ICCPR. International Coventant on Civil and Political rights. http://www2.ohchr.org/english/law/ccpr.htm . [Accessed November 2011].
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Indicator 10 Price and supply of a national food basket

Description:

Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration:

- changes in demand for foodstuffs for food, feed, and fibre;
- changes in the import and export of foodstuffs;
- changes in agricultural production due to weather conditions;
- changes in agricultural costs from petroleum and other energy prices; and
- the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally determined.

Measurement unit(s):

Tonnes; USD; national currencies; and percentage

Relevance

Application of the indicator:

This indicator applies to bioenergy production and use and to all bioenergy feedstocks, end-uses and pathways.

Relation to themes:

In addition to bioenergy use and domestic production, numerous other factors may affect the price and supply of a food basket, including the demand for foodstuffs for food, feed and fibre; imports and exports of foodstuffs; weather conditions; energy prices; and inflation. This indicator aims to measure the impact of bioenergy use and domestic production on the price and supply of a food basket in the context of other relevant factors.

The food basket is defined on a regional and/or national level and includes staple crops, i.e. the crops that constitute the dominant part of the diet and supply a major proportion of the energy and nutrient needs of the individuals in a given country. In addition, the indicator aims to assess the impact of changes in the prices of the food basket components on the national, regional and household welfare levels.

This indicator is strongly inter-related with numerous issues of sustainability including land use, income and infrastructure. As such, this indicator is also related to the themes of *Land-use change, including indirect effects*, *Rural and social development* (and in particular the Indicator 12.1 (*Net job creation)* and Indicator 11 (*Change in income*) and *Energy security/Infrastructure and logistics for distribution and use*.

How the indicator will help assess the sustainability of bioenergy at the national level:

This indicator aims to measure, through the methodologies described in the Scientific Basis section, the impact of bioenergy production and use (in the context of other relevant factors) on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level. In addition, this indicator aims to assess the welfare impacts of the measured price changes at the national, regional and household levels.

Bioenergy production may contribute to an increase in agricultural production (Diaz-Chavez, 2010), resulting in an increase in the domestic supply of staple crops for food depending on the share of them used for feed, fibre, fuel and/or export. On the other hand, bioenergy production could lead to a reduction in the domestic supply of staple crops available for food due to a reduction in the availability of these crops and/or to an increase in the share of them used for feed, fibre and/or fuel, unless the gap between domestic supply and demand is met through imports.

In addition, bioenergy feedstock production may alter demand for inputs, such as land, water and fertilizers that are used in the production of main staple crops. This can lead to a change in the demand for these inputs, which could influence their prices. Part of this price change can be transmitted to the final price of foodstuffs, including main staple crops.

Changes in the prices of main staple crops (due to bioenergy production) will have both an international and a national/local dimension. In the case of non-traded crops such as cassava in Africa, domestic prices would reflect, at least in part, changes in the domestic supply and demand (including for food and fuel) for these crops. In the case of internationally traded commodities. However, it would be necessary to look at additional factors. Much of the variations in the domestic prices of these crops can be linked to international price variations due to external factors and thus domestic bioenergy production may have a limited impact (Minot, 2010, Robles, 2011).

Comparison with other energy options:

A comparison can be made with any energy source that may compete for land or other inputs used in food production (e.g. other land-based renewables such as solar and wind). Similarly, a comparison can be made with fossil fuels, which are themselves an input for food production and whose demand-induced price changes will be transmitted to food prices. Note that certain elements of the methodological approach described below would have to be slightly adapted to permit comparison to other energy sources.

Scientific basis

Methodological approach:

Summary

The measurement of this indicator consists of two main steps, the second of which includes three tiers, which provide a range of increasingly complex approaches for the evaluation of the effects of bioenergy production and domestic use (in the context of other relevant factors) on the price and supply of nationally determined food basket(s):

Step 1: Determine the relevant food basket(s) and its components; and

Step 2: Assessing the links between bioenergy use and domestic production and changes in the supply and/or prices of relevant components of food basket(s):

- **Tier I: "Preliminary indication"** of changes in the price and/or supply of the food basket(s) and/or of its components in the context of bioenergy developments resulting from collecting data on price and supply;
- **Tier II: "Causal descriptive assessment"** of the role of bioenergy (in the context of other factors) in the observed changes in price and/or supply; and
- **Tier III: "Quantitative assessment"** using approaches such as time-series techniques and Computable General Equilibrium (CGE) or Partial Equilibrium (PE) modeling.

Collecting and analyzing data on the price and supply of food provides the basis for understanding the impact of bioenergy on food and commodity markets, but does not provide information on the impact of price and supply changes on welfare at the national, regional and household level. In order to translate the data collection and analysis described in the aforementioned steps and tiers, additional methodologies for **assessing the welfare impacts** of food price inflation and volatility at national, regional and household levels are provided. Making the connection between the economic data and welfare impacts is of fundamental importance and users of the indicator are encouraged to use these welfare impact tools in conjunction with any of the tiers listed above and/or in a standalone way in response to food price inflation and volatility.

Step 1, “Determining the relevant food basket(s) and its components”, is a prerequisite to evaluating the entire indicator. In this step the relevant food basket(s) and its components are identified.

Step 2, with its three tiers, provides a range of approaches – from the simplest to the most complex – to evaluate the effects of bioenergy use and domestic production. For each of them, different types of data are to be to be collected and analysed.

Users of this indicator are encouraged to evaluate the indicator to the fullest extent that they can. Depending on their needs, as well as on data and resource availability; however, such users could decide to use any one (or more) of these tiers. If, in the context of increasing levels of bioenergy production and/or use, the “preliminary indication” (step two, tier I;) detects a decrease in the supply of the food basket(s) and/or of its components for food and/or an increase in the “real” prices of such basket(s) and/or components, a “causal descriptive assessment” (Step two, tier II of the role of bioenergy (in the context of other relevant factors) in the observed supply decreases and/or price increases can be conducted. If this assessment indicates that there is a high 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, then the “quantitative assessment” (i.e. step 2, tier III), such as time-series techniques, Computable general equilibrium (CGE) and/or Partial equilibrium (PE) modeling, can be used to quantify these impacts of bioenergy in the context of other factors (step 2, tier III).

Welfare impacts at both national and household levels have to be assessed whichever tiers is chosen in step two. Specific methodologies to assess these impacts at the national and household levels (i.e. respectively the so-called “terms-of-trade-effect” and “net benefit ratio”) are described below in the step 3 section.

Users of the indicator are encouraged to pay particular attention to local food basket price and supply variations in food insecure and vulnerable areas and the impacts that these variations have on household welfare. Mapping these areas and identifying the most vulnerable groups would be quite useful in this context, as it would help countries target the analysis of the domestic impacts of bioenergy, and increase cost-effectiveness of the analysis by starting with these most vulnerable groups and/or areas.

The data and analyses that compare the behaviour of food basket price and supply across different locations and population groups create the opportunity for cross-cutting analyses and for connecting this indicator to themes such as Land-use change including indirect effects, Rural and social development, Economic development and Energy security/Infrastructure and logistics for distribution and use.

Domestic production and use of bioenergy from agricultural commodities may influence prices at the international level. For countries and regions that are well connected to international markets, these international effects can loop back and impact the price and supply of food in their national food basket(s). This feedback effect will be limited to countries or regions that use major commodities as feedstocks for bioenergy and are major importers or exporters of those same feedstocks. In these cases, evaluating the indicator would entail assessing the effects of domestic production and use of bioenergy on international markets and how this feeds back on domestic prices of relevant components of the national food basket. This can be achieved through quantitative approaches of varying degrees of complexity such as time-series techniques and modelling; techniques which are described in Section 3. Measurements of impacts of domestic bioenergy use and production on international prices are not relevant for countries which do not play a significant role in the international market of those commodities used in the domestic bioenergy sector. On the other hand, in order to disaggregate the effects of domestic bioenergy production and use on the price and supply of the elements of the food basket in price-taking countries, some methodological approaches require analysis of those international factors that substantively affect domestic food prices and supply. Linked to the above, when relevant, one should consider not only the crop of interest but also all the elements of the national food baskets whose supply and prices might be influenced by that crop, in order to account for possible ripple effects (see for example CBO, 2009). In other words this should be considered when there is a possible displacement from a production (i.e. concerning land) or consumption (i.e. concerning food) point of view. The causal descriptive assessment – i.e. step 2, tier II – allows one to do this from a qualitative point of view; and step 2, tier III presents quantitative approaches to carry out this analysis.

Much of the data required to measure this indicator is available in international, national and/or local statistics. If deemed necessary by the relevant domestic authority, then market surveys can also be used to complement and integrate data for evaluating the indicator. Finally, in order to fill any remaining gaps in the data and analysis, the relevant domestic authority can seek inputs from experts with an in-depth understanding of the relevant national and/or local agricultural commodity market (including its links to the international market) and of the food, feed and fuel sectors. These experts could include, among others, economists, scientists and analysts drawn from different stakeholder groups, as deemed relevant and appropriate by the relevant domestic authority.[52]

Detailed methodology.

Step 1: Determination of the relevant food basket(s) and of its components.

The first step in the measurement of this indicator is the identification of the “representative” food basket or baskets (Flores and Bent, 1980). These baskets, which reflect current food consumption patterns, may be determined, for instance, by ranking foodstuffs based on their contribution to the average per capita calorie in-take (either through direct consumption or via the foods that these crops are processed into), with the ‘main staple crops’ likely providing the highest share in developing countries. Certainly, the most significant food items in people’s diets are to be included in the food basket.

It would be informative for countries to define a representative “low-income food basket”, which would include the main crops and foodstuffs consumed by households in the bottom household income quintile(s) that are particularly vulnerable to food insecurity (Meade and Rosen, 2002). Large countries with significant differences in diets across regions and/or segments of the population may consider specifying regional/local food baskets. In addition, if a country is interested in assessing the effects of its domestic bioenergy demand/use on the international market, it might also consider how its demand/use affect the price and supply of the main internationally traded agricultural commodities and/or of the main regional staple crops (e.g. maize and cassava in sub-Saharan Africa).

Generally, food consumption patterns are not subject to rapid variations, especially in developing countries. If such changes do occur, then the composition of the food basket can be adjusted accordingly. In the event that changes do occur, then it would be important to identify and analyse the main drivers of these changes, in order to assess the role (if any) played by bioenergy.

Evaluators of the indicator are encouraged to monitor the effects of bioenergy use and domestic production on the nutritional quality of the food basket over time. In order to do this, the “representative” food basket and its development over time would need to be compared with a “nutritious” food basket, which fulfils basic nutritional guidelines while reflecting the range of foods typically eaten in a country. This “nutritious” food basket should contain a sufficient amount of food per day and contain specific food and nutrient groups that are typical of a country’s food consumption patterns. There are numerous sources of data for these food patterns, including a compilation of food-based dietary guidelines from different countries maintained by FAO[53] and standards from various US government agencies, such as USAID and USDA (IOM, 2002 and 2004).

[52] The definition of “experts” provided in this paragraph applies to the entire indicator.
[53]The compilation of food guidelines by country available at the FAO Food Guidelines by Country (see electronic sources section). The International Network of Food Data Systems maintains Food Composition Tables (see electronic sources section) that could provide essential data to evaluating the nutritional composition of a food basket.

Step 2. Assessing the links between bioenergy use and domestic production and changes in the supply and/or prices of relevant components of food basket(s).

After defining the relevant food basket(s), the next step is to assess whether bioenergy production and/or use has increased significantly in the country (since the last time the indicator was measured[54]) and whether this has been accompanied by significant changes in the price and/or supply of the identified food basket(s) and/or of its components. Three ways to carry out this assessment, hereafter referred to as tiers, are proposed, from simple (tier I) to more complex (tier III).

Tier I: "Preliminary indication" of changes in the price and/or supply of the food basket(s) and/or of its components in the context of bioenergy developments.

Data on the following factors are needed:

- levels of bioenergy use and domestic production;
- supply of the food basket(s) and its components disaggregated by end-use (food; feed, fibre; and fuel); and
- "real" (i.e. inflation adjusted) prices of the food basket(s) and its components.

Domestic supply of a given crop is the sum of domestic production and imports minus exports. If a crop is stockpiled, then domestic stocks should be considered as well, as they might reduce - if part of the production is stocked – or increase – if stocks from a previous year are released into the market – the supply of a crop for a given period of time. Estimates of crop production are usually made at the district level and then combined to give the overall national picture, while data on imports, exports, stocks and use are generally available at the national level. In addition, FAOSTAT provides time-series and cross sectional data on production and trade of main staple crops for some 200 countries.

Once the domestic supply of a given crop has been determined, data should be gathered from national statistics on the share of this supply that is used for feed, fibre and fuel and the share of it that is available for food. If deemed necessary, market surveys could be used in order to complement and integrate this data. Finally, in order to fill any remaining gaps in the data, input could be sought from the relevant experts convened by the relevant domestic authorities. This approach would provide a preliminary, qualitative indication of the potential role played by bioenergy production and use, should a decrease in the supply or an increase in the prices of food basket components be observed.

With regard to prices of the food basket(s) and its components, detailed data is available in official statistics in the majority of countries, both nationally and, in most cases, locally as well. USAID's Famine Early Warning Systems Network[55] (FEWS NET) and FAO's Global Information and Early Warning System[55] (GIEWS) can provide detailed, up-to-date data on food prices for countries for which market data are not readily available. Further, market surveys may be conducted to fill any additional gaps in the data.

If bioenergy production is distributed across the country in proportion to the production patterns of main staple crops, then a national focus should suffice. However, if bioenergy is produced in localised regions, then local price levels – and variations – should be considered as well. For instance, prices of the food basket(s) and its components might be distinguished between rural and urban areas. This split would also implicitly capture differences in the import-content of urban households' food baskets and transaction costs associated with moving foods from rural to urban areas. In the case of rural areas, it would be especially important to focus on those areas where food production is displaced. Finally, as already mentioned particular attention should be given to local food basket price and supply variations in food insecure and vulnerable areas.

If there is a significant increase in the price of the identified food basket(s) and/or of its components, it is important to also get an initial indication of the resulting welfare implications at both the national and the household levels. In order to do so and identify countries and

[54]The first time the indicator is measured, price changes occurred during the last year – if the indicator is measured on an annual basis – or the last x number of years – if the indicator is measured every x years – should be considered.
[55] See electronic sources section.

population groups that are likely to benefit and those that are likely to be worse off, the net trading position of both the country as a whole (i.e. whether the country is a net exporter or importer) and of households (i.e. whether these households are net producers or consumers of food products) should be determined with respect to the food basket components that experienced a price increase. As explained in detail in the welfare impact section, an increase in the price of a certain commodity will have positive welfare effects on countries that are net exporters and households that are net producers of that commodity. On the other hand, countries that are net importers of food commodities and households that are net consumers will be negatively affected by this price increase. In line with the “quick and simple” character of this tier, the estimate of household and national welfare impacts should be based on inputs from experts convened by the relevant domestic authority. A more quantitative estimate of these features would require the use of methodologies such as terms of trade regarding the national level welfare and net benefit ratio for the household level welfare.[56] These are described in the welfare section below.

If, in the context of increasing levels of bioenergy production and/or use, the “Preliminary indication” detects a decrease in the supply of the food basket(s) and/or of its most relevant components for food and/or an increase in the “real” prices of such basket(s) and/or components, then a “Causal descriptive assessment” (step 2, tier II) of the role of bioenergy (in the context of other relevant factors) in the observed supply decreases and/or price increases can be conducted. This assessment would also be useful in case of significant variations in the composition of the food basket(s), especially when the diversity of the latter is reduced.

Tier II: “Causal descriptive assessment” of the role of bioenergy (in the context of other factors) in the observed price increases and/or supply decreases.

The causal descriptive assessment described here aims to determine the share of the demand for modern bioenergy in a given country that is met through each of the six ways described below, as different combinations of them are associated with different levels of probability of a downward pressure on supply – and of an upward pressure on prices – of the relevant food basket(s) and/or of its components. This type of analysis may be carried out by a multidisciplinary team of experts convened by the relevant domestic authority based on data from national statistics or obtained through market surveys.

The causal descriptive assessment represented in the accompanying Diagram entitled “Causal descriptive assessment” and described below aims to provide an indication of the probability that the demand for modern bioenergy in a given country resulted in a downward pressure on supply – and to an upward pressure on prices – of the relevant food basket(s) and/or of its components. A number of relevant supply- and demand-side factors need to be considered when this assessment is conducted. These include: changing demands for food/feed; energy prices affecting bioenergy demand and prices of inputs/food; and weather conditions affecting supply (responses).

As explained in detail below, in order to assess whether or not this probability is low or high, the causal descriptive assessment aims to determine how the demand for modern bioenergy was met, including consideration of the sources of the bioenergy feedstock(s) (e.g. expansion of agricultural land vs. yield increases), as well as possible effects from the co-production of animal feed.

In the Diagram, the likelihood of a downward pressure on supply and an upward pressure on prices being low is indicated with a “check mark” symbol (□). Scenarios for which it is possible that bioenergy production and use will lead to a downward pressure on food supplies and upward pressure on food prices are indicated by a “magnifying glass” symbol (□□), which indicates the need for further analysis. The five different means discussed below for sourcing bioenergy feedstocks are each given a distinct colour in the Diagram. The colour scheme is intended only to improve the clarity of the presentation and to facilitate following the information flow within the Diagram. Methods of further analysis are described in Tier III and include the use of quantitative methods such as time series techniques, Computable general equilibrium (CGE) and/or Partial equilibrium (PE models described in Tier III The causal descriptive assessment

[56] If a country already analyses household level welfare implications of food price rises, e.g. through the net benefit ratio (see section 3 below), then these can be applied at this stage in light of the identified probable impact of bioenergy on food prices.

alone may be sufficient to provide countries with an indication of possible corrective actions that would likely mitigate the identified risks.

Not only can the causal descriptive assessment be used to identify risks to food security created by the production and use of bioenergy, but it can be used to identify ways to compensate for increased demand created by bioenergy production. The demand for modern bioenergy in a given country can be met through any combination of the following:

- **A. Imports**
- **B. Non-agricultural Waste**[57]
- **C. Residues from agriculture, fisheries and forestry**
- **D. Additional crop production**
- **E. Diversion of crops**

A Imports.

If the demand for modern bioenergy in a given country is met through imports, then this demand is not likely to directly affect the domestic supply and prices of the relevant food basket(s) and/or of its components in the country considered. In this case, the probability of a downward pressure on domestic supply – and of an upward pressure on prices – of the relevant food basket(s) and/or of its components would normally be low.

Meeting the domestic demand for modern bioenergy in a given country through imports may impact the international market and the markets in countries from which modern bioenergy and/or feedstocks are imported. In order to determine the extent of these impacts, importing countries could assess the effects that their imports have on the international price and supply of such commodities using the quantitative approaches described in Tier III. Given the links between international and national markets, this analysis of the international effects would also provide relevant information on the potential changes in the price and supply of food basket items at the domestic level.

Although it is beyond the scope of this indicator, countries engaged in the trade of bioenergy and bioenergy feedstocks may decide, on a purely voluntary basis, to collaborate on data sharing and analysis of the impact of trade in bioenergy and bioenergy feedstocks on their respective national food basket(s).

B Non-agricultural Waste.

Modern bioenergy may be produced from non-agricultural waste. For instance, biogas may be obtained from the organic component of municipal solid waste or from sewage sludge. If the demand for modern bioenergy in a given country is met through bioenergy obtained from waste, the probability of a downward pressure on supply – and an upward pressure on prices – of the relevant food basket(s) and/or of its components is likely to be low. This positive scenario is indicated with a check mark.

C Residues from agriculture, fisheries and forestry.

Modern bioenergy may be produced from agricultural, fisheries and forestry residues. Biogas, for instance, may be obtained from livestock manure, while second-generation liquid biofuels may be obtained from ligno-cellulosic residues from both agriculture and forestry.

The change in availability of feed resulting from the use of residues for modern bioenergy production and from the associated co-product generation (C1) should be assessed, and then taken into account in the context of E (Diversion of crops from the food/feed market).

Agricultural and forestry residues are used for other purposes as well, such as animal feed, soil management - both to prevent erosion as soil cover and as a source of soil organic carbon and other nutrients. If agricultural and forestry residues are used to produce modern bioenergy, it is important to assess how soil quality is affected, as measured by GBEP Indicator 2 ("Soil quality") If there is no significant decrease in soil quality, the probability of a downward pressure

[57] This includes the organic component of the by-products of all sectors excluding agriculture and forestry - e.g. residential, commercial, industrial, public and tertiary.

on supply – and of an upward pressure on prices – of the food basket(s) and/or of its relevant components is likely to be low (check mark) (C2). If such decrease occurs (C3), this probability could be high (magnifying glass.

In rural areas of developing countries, agricultural and forestry residues are an important source of fuel for cooking and heating (i.e. the traditional use of biomass energy). Modern bioenergy obtained from residues could replace – at least in part – the traditional uses of biomass (including residues), as captured by GBEP indicators 14 (*Bioenergy used to expand access to modern energy services*) and 20 (*Change in consumption of fossil fuels and traditional use of biomass*). This would lower the demand for residues for such traditional uses. GBEP Indicator 3 *(Harvest levels of wood resources)* could inform and be informed by this section as well, as it deals with the harvesting of wood resources, including forestry residues, for modern bioenergy production.

The use of agricultural and forestry residues for modern bioenergy production will generate a number of co-products. These co-products (which may be defined as "secondary" residues) may replace – at least in part – the use of ("primary") agricultural and forestry residues for feed, soil management and/or traditional use of biomass for energy. Bio-slurry, for instance, which is a co-product of biogas production from livestock manure, can be used as fertilizer and/or feed (Marchaim, 1992).

D Additional crop production.

The demand for modern bioenergy may be met through a supply response, in other words through additional production of a certain crop/feedstock induced by the additional demand for this crop.[58] The additional production of crop A may be obtained through an increase in the area under cultivation of this crop (D1) and/or through an increase in crop yields (D2).

A number of co-products will be generated when this additional quantity of crop A is used to produce modern bioenergy. As shown in figure, these co-products – minus those associated with the displaced production of food and feed from the same crop – is to be accounted for in the context of E (Diversion of crops from the food/feed market).

For this fourth option (i.e. "Additional production of crop A"), the assessment described in the sub-sections below is to be carried out for each crop used as modern bioenergy feedstock.

D1 Increased land area.

The increase in the area under cultivation of crop A (D1) may be achieved through agricultural expansion (D1a) and/or through the displacement (by crop A) of items included - or not included - in the food basket (D1b) and (D1c, respectively). If the increase in the area under cultivation of crop A is the result of agricultural expansion (D1a), it is important to consider which land-use changes took place, as measured by GBEP Indicator 8 (*Land use and land-use change related to bioenergy feedstock production*), as land-use changes may affect a number of ecosystems goods and services that are important for food security.

In order to determine whether this agricultural expansion is associated with a high or low probability of a downward pressure on supply and/or an upward pressure on prices of the food basket(s) and/or of its relevant components, the efficiency of crop A production (measured in terms of yields/inputs) on this new land should be assessed. The efficiency of water use – as measured by GBEP Indicator 5 (*Water use and efficiency*) – can be considered as well. If the efficiency is the same as – or higher than – the average in the country for crop A (D1a1),then the probability of a downward pressure on supply – and of an upward pressure on prices is likely to be low (check mark). If this efficiency is lower than average (D1a2), then this probability could be high (magnifying glass). As in this case the increase in the area under cultivation of crop A will result in a decrease in the average productivity of this crop and will lead to an increase in the demand for inputs and water (including internationally) and thus to a potential decrease in their availability and/or to an increase in their price, which may be transmitted at least in part to the price of the food basket(s) and/or of its components.

Increasing the area used to cultivate of crop A may displace the production of agricultural items that are not included in the food basket (D1b). Examples of these non-food basket items include

[58] As shown in figure, weather conditions may affect this supply response.

agricultural products used for fibre and other uses, such as cotton or tobacco. In this case, it is important to understand whether this displacement of non-food crops leads to the displacement of food basket items. If there is no displacement of food basket items (D1b1), then the probability of pressure on supply and/or prices of the food basket(s) and/or of its components is likely to be low (check mark). If there is displacement (D1b2) that results in a significant decrease in the domestic availability of the displaced food basket items, then the probability of pressure on supply and could be high at the domestic level and further study is warranted (magnifying glass). If this displacement of food basket items is compensated through trade and results in significant changes in imports/exports of the displaced food basket items (D1b3), then an analysis of the international effects can be undertaken through the quantitative approaches described in tier III (magnifying glass). It should be noted that here one assesses only the qualitative probability. While beyond the scope of this indicator, consideration of the extent to which the expansion of crop A displaces production items of relevance to nutrition that are not in the food basket can be undertaken with these data.

If the increase in the area under cultivation of crop A is the result of a displacement (by crop A) of food basket items (D1c) and this leads to a significant decrease in the domestic availability of the displaced food basket items (D1c1), then the probability of pressure on the supply and price of the food basket(s) and/or of its components could be high at the domestic level (magnifying glass). If the displacement (by crop A) of food basket items is compensated through trade and results in significant changes in imports/exports of the displaced food basket items (D1c2), then an analysis of the international effects can be undertaken through the quantitative approaches described in tier III (magnifying glass).

D2 Increased crop yields.

The additional production of crop A may also be achieved through increased yields of crop A (D2). Consistent with GBEP Indicator 8 (*Land use and land-use change related to bioenergy feedstock production*), users of the indicator are encouraged to determine the share of these yield increases that is “additional” (i.e. a result of the additional bioenergy use and domestic production being analysed). If these increased yields are the result of improved technology or an increase in the efficiency (i.e. yields/inputs) in the production of crop A (D2a) - including in terms of water use (see GBEP indicator 5) – for instance through the introduction of improved agricultural management practices, the probability of price and supply pressure is likely to be low (check mark).

If the increased yields of crop A are simply the result of an increase in the use of inputs and/or water (D2b) - without any efficiency improvements – and this leads to a significant decrease in the domestic availability of these inputs then the probability of price and supply pressure could be high at the domestic level (D2b1, magnifying glass) . If this increase in the use of inputs is compensated through trade and results in significant changes in imports/exports of inputs and/or water (D2b2), then an analysis of the international effects can be undertaken through the quantitative approaches described in section step 3 (magnifying glass).

E Diversion of crops from the food or feed

E1 No decrease in available food or feed

The demand for modern bioenergy may be met through the diversion of crops/feedstocks A, B, C, etc. from the feed market. In this case, the co-products generated by modern bioenergy production (minus those associated with the displaced production of feed from the same crops) are to be considered. The co-products generated by the use of the additional production of crop A (situation D) for modern bioenergy, as well as those resulting from the diversion of crop A from the food market (E2), can be added to these. In addition, the change in availability of feed (before trade) resulting from the use of residues for modern bioenergy production (C) can be taken into account.

If, overall, the diversion of crop A from the feed market is sufficiently compensated by the aforementioned co-products of modern bioenergy production and thus there is no significant net decrease – before trade – in availability of feed (E1), then the probability supply and price pressure is likely to be low (check mark).

If the diversion of crop A from the feed market is more than compensated by suitable co-products of modern bioenergy (resulting from C, D and E), then the “extra” co-products can be considered in the context of the “additional production of crop A” (situation D), as they may reduce the demand for crop A and thus the additional production required in order to meet the demand for modern bioenergy. In the case of E1 the effects resulting from the diversion of each crop (i.e. A, B, C, etc.) used for bioenergy is expected to be additive. As such, there is a need to sum different types of animal feed and to determine the share of the “extra” co-products mentioned above that are to be considered as adding to the ”Additional production of crop A” when individual crops are considered in situation D. This means that the extent to which one type of feed might substitute for another type of feed or for a food crop is to be determined, based on inputs from experts convened by the relevant domestic authority. If this compensation does not occur or is not sufficient there may be a significant net decrease – before trade – in the availability of crop A for feed (E2). In this case, it is important to determine whether or not this decrease is compensated through trade. If this compensation does not occur and there is a significant decrease in domestic availability of feed, then the probability of price and supply pressure is high (E2a) (magnifying glass). If this compensation occurs and results in significant changes in imports/exports of feed, then an analysis of the international effects can be undertaken through the quantitative approaches described in tier III (E2b) (magnifying glass).

E2 Diversion of crops from the food or feed

The demand for modern bioenergy may also be met through the diversion of crop A from the food market. A number of co-products will be generated when a certain quantity of crop A is diverted from the food market in order to produce modern bioenergy. These co-products - minus those associated with the displaced production of food from the same crop - are to be taken into account in the context of E2.

If the diversion of crop A from the food market is not compensated through trade and results in a significant decrease in the domestic availability of crop A for food or feed (E2a), then the probability price and supply pressure is likely to be high at the domestic level, especially if crop A is a staple crop(magnifying glass)

If the diversion of crop A from the food or feed markets is compensated through trade and results in significant changes in imports/exports of the displaced food basket items (E2b), then this probability could be high at the international level, especially if crop A is a staple crop (among the main trading partners)(magnifying glass).

As stated above, if the causal descriptive assessment indicates that bioenergy production and/or use could significantly contribute to a downward pressure on the supply – and/or an upward pressure on the prices – of the food basket(s) and/or of its components, then it would be necessary to use the quantitative approaches described in tier III in order to quantify these effects. However, the causal descriptive assessment may provide countries with an indication of possible corrective actions/measures to be taken in order to mitigate the identified risks; thereby, lessening the need to carry out more quantitative analyses.

Step 2, Tier III: “Quantitative approaches – time-series techniques and computational modelling (e.g. CGE and PE).

The indicator on supply and price of relevant food basket elements is intrinsically multivariate. The variables to be considered will vary country-by-country. Using the data collected on the factors affecting the price and supply of a national food basket, countries can perform economic analyses to estimate the relative effects of these many factors, including bioenergy production, on the price of a national food basket. The multivariate nature of the problem invites time-series techniques and computational approaches (PE and CGE).

Assessment of market integration and price transmission often use time series techniques. Market integration refers to the extent to which different markets are linked, and price transmission refers to the effect of prices in one market on prices in another market (Rapsomanikis et al, 2006). Countries with sufficient data on existing biofuels programs can use standard econometric techniques to provide a historical assessment of bioenergy on the price of a national food basket. Econometric models have the advantage of being relatively straightforward to develop. They require time-series data to provide historical assessments. Via regression analysis the modeller can identify the factors that contribute to changes in the price of a national food basket.

Two different aspects should be considered:

- Links between domestic production/use and international prices. Time series methodologies such as error correction models (Hallam and Zanolli, 1993, CCP/FAO, 2010) can be used as simpler approaches to this assessment. While relatively simple they are rather static. On the other hand PE models would provide more dynamic information but these models require more assumptions, which are based on experts' judgments. As a general rule of thumb, such techniques require a minimum of thirty data points collected at thirty consecutive time points. Monthly data on supply, prices, etc., would clearly be preferable, though quarterly or yearly data could be sufficient provided that they were available over a sufficiently long time period.
- Links between international and domestic prices use price transmission approaches, which measure transmission elasticity, defined as the percentage change in the price in one market given a one percent change in the price in another market (Minot, 2010). Although the markets could be for related commodities (e.g. maize and soybeans) or for products at different points in the supply chain (e.g. wheat and bread), here we focus on the case of markets for the same commodity in two locations, in this case between international markets and domestic markets. This latter could form part of analysis for this indicator, for instance in the case of a major biofuel importer that wished to assess the impact of this domestic biofuel use on international commodity prices and then assess how this impact fed back to the price and supply of their national food basket items. Another case could be for a small price-taker to work out to what extent their prices followed international ones rather than domestic factors.

The simplest way to assess price transmission is through simple correlation coefficients of contemporaneous prices (Rapsomanikis et al, 2006). A high correlation coefficient is evidence of co-movement[59] and is often interpreted as a sign of an efficient market. Another simple method is to use regression analysis on contemporaneous prices, with the regression coefficient being a measure of the co-movement of prices. Information on the different methods, their pros and cons and level of complexity can be found in Awudu (2006) and Rapsomanikis et al. (2006). Each of these methods is taken to present evidence about the components of transmission thus providing particular insights into its nature. Collectively, these techniques offer a framework for the assessment of price transmission and market integration.

Examples of assessment of price transmission of agricultural commodities can be found in Dawe (2008) and Minot (2010). Specific examples related to bioenergy can be found in Balcombe and Rapsominakis (2008) and Elam and Meyer (2010). Generally speaking, computable models (partial equilibrium/PE or general equilibrium/CGE) regarding the impacts of bioenergy and other relevant factors on agricultural markets "start with a baseline which describes the model's 'best estimate' description of the present or future state of the world's markets and agricultural policies" (Edwards et al, 2010). This baseline is then "shocked" with a change, such as an increase in the demand for modern bioenergy. The results then show changes in a number of important variables, including agricultural and food prices (Edwards et al., 2010).

Equilibrium models can be divided into general or partial equilibrium models. Computable General Equilibrium (CGE) models "calculate an equilibrium state for a system including all relevant economic markets" (Ecofys, 2010). These models, therefore, take into account all sectors of the economy.[60]

CGE models provide effective means of economic analysis (Wing, 2004), and as such, have often been used in bioenergy, not without controversy though. As with many computational modeling approaches, the approach and assumptions underlying the modeling effort must be clearly understood and stated. The results of the modeling must be understood in the context of the caveats associated with the assumptions underlying the model. This standard tool can be

[59] Co-movement and completeness of adjustment implies that changes in prices in one market are fully transmitted to the other market at all points in time.
[60] Due to this feature, CGE models tend to be more comprehensive than Partial Equilibrium (PE) models (which are described in the last paragraph of this section) and more suitable for calculating the indirect effects of a sector – such as modern bioenergy – on other sectors of the economy. However, as described in the section on anticipated limitations, CGE models tend to be particularly sensitive to the assumptions made and to the choice of input parameters as well.

used to analyse the impacts of economic changes, including the impacts of a nascent bioenergy sector. CGE models have been applied to areas as diverse as fiscal reform, development planning (Dixon and Rimmer, 2002), international trade (Taylor and Black, 1974, Hertel, 1997), environmental regulations and food policy. CGE models can be implemented using publicly available software such as the General Algebraic Modeling System (GAMS)[61] and the General Equilibrium Modeling PACKage (GEMPACK) on standard microcomputers (Lofgren, Harris and Robinson, 2002).

Countries with sufficient data on existing biofuels programs can use standard econometric techniques to provide a historical assessment of bioenergy on the price of a national food basket (Greene, 2008). Econometric models have the advantage of being straightforward to develop. They require time-series data to provide historical assessments. Via regression analysis the modeller can identify the factors that contribute to changes in the price of a national food basket.

Another option for exploring the impact of biofuels on the price of a national food basket is the use of advanced partial equilibrium forward-looking models. Partial Equilibrium (PE) models calculate an equilibrium state for one specific sector – i.e. the agricultural sector in this case – while all other sectors are exogenous, and as such time-dependent developments of key macroeconomic variables are determined independently of the model (Solberg et al., 2007).” They are based on linear relations between prices, demand and production described by linking elasticities. The elasticities are derived from statistical data of past market movements” (Edwards et al., 2010).

These models highlight challenges and opportunities that might materialize in some countries/commodity markets as they analyse key relationships and trends that could develop in agricultural markets. Forward-looking models are based on historical inputs, but require sets of assumptions and parameter estimation. As such, it is essential that they be utilized with appropriate caveats and clear expression of the underlying assumptions. Forward-looking projections are an established component of modern agricultural economics. They are resource intensive and require considerable support. USDA supports the Food and Agriculture Policy Research Institute (FAPRI), the EU supports the Common Agriculture Policy Regionalized Impact analysis (CAPRI), and the OECD and UN FAO support AGLINK – COmmodity SIMulation MOdels (AGLINK-COSIMO). Other institutions that model national, regional and world economic development include the World Bank, World Food Program and International Food Policy Research Institute. Partial equilibrium models facilitate policy and market analysis of agricultural markets by allowing the modeller to observe the impact of various changes in policies and/or market conditions, such as the development of a bioenergy sector.

As is discussed in more detail in the section on anticipated limitations, the results of both CGE and PE models are quite sensitive to the assumptions made, as well as to the choice of input parameters.

Net impacts of food price changes on national, regional and household welfare levels.

When there is a significant change in global, national and/or regional food prices, regardless of the possible influence of bioenergy and other relevant factors, then it is essential to assess the resulting welfare effects at national, regional and household levels. Users of the indicator are encouraged to assess welfare effects in parallel with the data collection and analysis of the rest of this indicator. Assessing welfare effects is critically important in the case of low-income food deficit countries (LIFDCs) and for poor households and vulnerable groups. An increase in the prices of the food basket(s) and/or of its components will have different impacts on different types of countries, regions and households.

Price volatility and price changes of foodstuffs will affect welfare at the household, regional and national levels. In order to further their understanding of national level effects users of the indicator can consider measuring the "terms-of-trade effect". As explained in Benson et al. (2008), the "terms-of-trade effect" is the effect of a change in the international price of a commodity (or group of commodities) on the value of a country's exports and imports as a percent of GDP. In countries that are net exporters the "terms-of-trade effect" will likely reveal how commodity producers (i.e. farmers) benefit at the national level. Likewise for countries that

[61] See electronic sources section.

are net importers of commodities, the "terms-of-trade effect" will provide national level information on the challenges posed by increased international commodity prices. In the context of this indicator, one way to measure the terms-of-trade effect would be to calculate the change in the value of net exports of the food basket(s) and/or of its components due to changes in international prices of such basket(s)/components as a proportion of the size of the economy as measured by GDP.[62]

In countries that are particularly large and/or heterogeneous, it would be useful to measure this indicator at regional and local levels as well. This would be especially important in food insecure and vulnerable areas. This could be done by applying the same methodology described above to the outflows and inflows of food basket components respectively from and to the specific area considered.

In order to further understand how changes in the prices of the food basket(s) and/or of its components affect food security, it is important to assess the net welfare impacts of these changes at the household level, and especially on poor households.[63] In order to assess the net welfare impacts on poor households arising from bioenergy production and/or use, only the share of the price change that is due to bioenergy use and domestic production – as determined by the CGE or PE modelling – should be considered.

Households may be both producers and consumers of food basket components such as staple crops. The impact of a change in the price of staple crops on household welfare can be decomposed into the impact on the household as a producer of these crops and the impact on the household as a consumer of them. In the short run, the net welfare impact will be the difference between the two – i.e. between the producer gains and the consumer losses.[64] More precisely, as described in FAO (2010a) - appendix 14.5, the short-run welfare impact on households (also referred to as “net benefit ratio”) is calculated as:

$$\frac{\Delta w^1}{x_0} \%P_{p,i} * PR_i - \% P_{c,i} * CR_i$$

where $\Delta w^1 / x_0$ is the first order approximation (i.e. assuming no supply and demand responses in the short-run) of the net welfare impact on producer and consumer households deriving from a price change in crop i, relative to initial total income x_0 (in the analysis income is proxied by expenditure);

$P_{p,i}$ is the producer price of crop i;

$\%P_{p,i}$ is the change in producer price for crop i;

PR_i is the producer ratio for crop i and is defined as the ratio between the value of production of it to total income (or total expenditure);[65]

$P_{c,i}$ is the consumer price of crop i;

$\%P_{c,i}$ is the change in consumer price for crop i;

CR_i is the consumer ratio for crop i and is defined as the ratio between total expenditure on crop i and total income (or total expenditure).[66]

[62] For instance, the terms of trade effect of a 40 percent increase in the price of agricultural commodity *a* in a country with exports and imports of this commodity worth US$ 0.1 billion and US$ 1 billion respectively, and with a GDP of US$ 9 billion, would be (0.1 x 0.40 – 1 x 0.40)/9 = -0.36/9 = -4 percent.

[63] Other measures could be used as well, such as the movement of households across the poverty line. This poverty line might be a food poverty line, based on the nationally lly determined food basket (Appleton, 1999 and 2009; Duc Tung, 2004; Hoang & Glewwe, 2009; Rio Group, 2006).

[64] For a detailed description of the methodology to calculate the net welfare impacts of price changes at the household level, please refer to Deaton (1989) and Dawe & Maltsoglou (2009). For an example of the application of this methodology, please see FAO (2010b).

[65] In other words, the proxy used for the production ratio (PR) is the share of the value of agricultural sales and own production in total household income.

[66] In other words, the proxy used for consumption (CR) is the share of the value of food purchases and own consumption in total household expenditures.

This type of analysis does not allow for household responses in production and consumption decisions.[67] In the very short run, however, the adjustments in crop production are limited, and on the consumption side the poorest households are likely to have only minimal substitution possibilities (FAO, 2008a).

By differentiating welfare impacts across quintiles, it is possible to target the poorest segments of the population and understand how they are affected by a change in the price of the food basket(s) and/or of its components. In addition, differentiating by location allows for comparisons between the net welfare impacts on households in urban vs. rural areas or in different regions.

Another important differentiation that may be introduced is by household-head gender. This would allow one to determine whether male- and female-headed households are affected differently – and how their welfare is impacted – by a change in the price of main staple crops.[68] Households may be further distinguished by land ownership, education level, age, and so on.

In addition to the household-level analysis described above, it would be useful to analyse the welfare impacts of a change in the price of the food basket(s) and/or of its components at the intra-household level as well. As argued by Benson et al. (2008), "the welfare impact of a food crisis [e.g. of a significant food price increase] may differ across members of the same household" (p. 6). This is mainly due to the fact that generally resources are not distributed equally to all household members, with women and girls often being disadvantaged, with varying degrees across countries, regions and household characteristics (Quisumbing, 2003, cited in Benson et al., 2008). This individual level analysis could be carried out if detailed individual-level data are collected through household surveys.[69]

Anticipated limitations:

With regard to the so-called "Preliminary indication" (i.e. step 2, tier I of the methodology – see section 2.2), it might be difficult to develop accurate estimates of crop production (as well as of stocks and trade) and of the share of main staple crops used for food, feed and fuel; and of prices of main staple crops in some areas, particularly those most dependent on local production.

With regard to step 2, tier II of the methodology, as described in section 2.3 the Causal descriptive assessment may be carried out by a multidisciplinary team of experts convened by the relevant domestic authority, based on data from national statistics or obtained through market surveys. In some cases, these will need to be combined with expert judgment and educated guesses, which will be sensitive to the assumptions that the experts convened by the domestic authority will need to make (in a transparent way).

Numerous factors influence agricultural commodity markets and prices. These factors have very complex effects resulting from their nonlinear interactions with each other, making the identification and measurement of any one factor a difficult challenge. Disentangling these multi-faceted and complex interactions makes it difficult to precisely quantify the effects of any one factor. Evaluation of impacts across different factors may depend on the sequencing of the factors in the evaluation and thus can lead to non-unique results and misleading implications. Neither the CGE nor the econometric approach is immune to this potential limitation.

As already mentioned in section 2.4, the results of both CGE and PE models are sensitive to the assumptions made and to the choice of input parameters, which should be fully disclosed when

[67] Both supply and response elasticities, however, could be factored into the analysis of the household welfare impacts of price changes over the medium run (see, for instance, Benson et al., 2008).

[68] It has been observed in different contexts that all other things being equal, female-headed households tend to spend a greater share of their income on food. In different rural contexts, female-headed households have also been found to have less access to land and to participate less in agricultural income generating activities. When this is the case, female-headed households are less likely than male-headed households to participate in the benefits of food price increases than male-headed households (FAO, 2008b).

[69] For more details about this and another approach that could be followed in order to carry out this type of analysis, please refer to Benson et al. (2008).

the results are presented. In particular, CGE models, which tend to be more comprehensive than PE models, can include more uncertainties in assumptions (Ecofys, 2010). Another important limitation of CGE models is “the need to limit sectoral and regional disaggregation and the level of institutional detail”. For instance, in CGE models the number of agricultural products rarely exceeds ten (Gerdien Prins et al., 2010).

Practicality

Data requirements:

- calorie contribution by crop
- production of main staple crops (both nationally and regionally/locally)
- changes in stocks of main staple crops
- exports and imports of main staple crops
- energy costs and their impact on agricultural production and distribution costs
- impacts of weather on crop production
- price inflation
- change in demand for foodstuffs
- shares of main staple crops used for food, feed, fibre and fuel;
- prices of main staple crops
- household income and expenditure by crop
- data required for the Causal descriptive assessment (see annexed table)

These data, collected at the national or regional level can be sourced from national or international statistical accounts. If necessary, these data can be gathered through interviews and surveys.

Data sources (international and national):

In the vast majority of countries, detailed data is available on domestic production, consumption and imports/exports of crops (especially staple crops). In most cases, data is available by region/area. In addition, USDA and FAO maintain global databases that provide data relating to food and agriculture, including production and trade of main staple crops, for some 200 countries. Further, USAID’s FEWS and FAO's GIEWS can provide detailed, up-to-date data on food prices for countries for which market data are not readily available. Data on household income and expenditure by crop is available for the large majority of countries. Part of the data required for the Causal Descriptive Assessment may be obtained from national statistics.

Known data gaps:

Through the above data, it should be possible to estimate the share of main staple crops used (both nationally and regionally/locally) for food, feed and fuel; and FAOSTAT provides up-to-date specific data for food and feed (combined). In order to disaggregate them and identify the share of main staple crops used for fuel production, it is necessary to consult with local stakeholders (including governments). Market and/or households surveys could be conducted to fill any gaps in the data, including those required for the Causal descriptive assessment.

Relevant international processes:

Data on the production, supply and prices of a national food basket is used in a number of international processes and is widely available.

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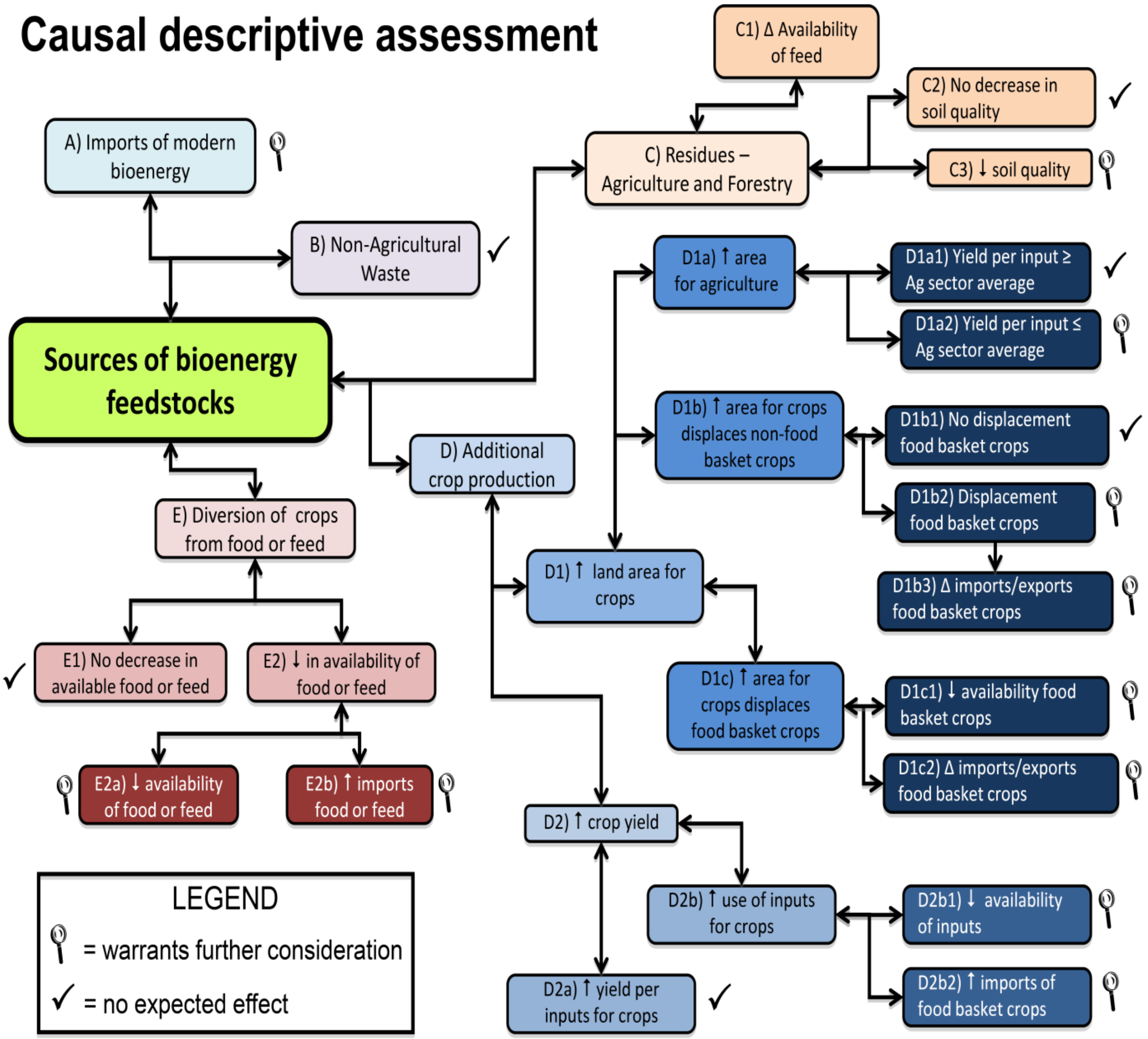
Causal descriptive assessment



Indicator 11 Change in income

Description:

Contribution of the following to change in income due to bioenergy production:

(11.1) wages paid for employment in the bioenergy sector in relation to comparable sectors

(11.2) net income from the sale, barter and/or own-consumption of bioenergy products, including feedstocks, by self-employed households/individuals

Measurement unit(s):

(11.1) local currency units per household/individual per year, and percentages (for share or change in total income and comparison)

(11.2) local currency units per household/individual per year, and percentage (for share or change in total income)

Relevance

Application of the indicator:

This indicator is applicable to bioenergy production and to all bioenergy feedstocks/pathways.

Relation to themes:

This indicator is primarily related to the theme of *Rural and social development*. It will also inform the themes of *Price and supply of a national food basket, Labour conditions*, and *Economic development*. It aims to measure the changes in both wage and non-wage income due to bioenergy production. More precisely, the first part of this indicator focuses on the wages paid for employment in the bioenergy sector in relation to comparable sectors. Employment and wages in the bioenergy sector can be important drivers of rural and social development, particularly in developing countries. In addition, wage levels provide an important indication of the labour conditions enjoyed by the people employed in this sector in relation to comparable sectors.

Furthermore, the second part of this indicator aims to measure the change in income deriving from the sale, barter and/or own-consumption of bioenergy products, including feedstocks, by self-employed households or individuals. In addition to wage income, self-employment is another important source of income that can be associated with bioenergy production and through which the latter can affect rural and social development by increasing the purchasing power, diversity of livelihood options and the overall welfare of self-employed households and individuals. Net job creation (see closely-related Indicator 12) and income generation in the bioenergy sector can lead to an increase in the standard of living in terms of household consumption levels and also in terms of social cohesion and stability. They can lead to a reduction in social trends such as high unemployment and rural depopulation (Madlener and Myles, 2001).

How the indicator will help assess the sustainability of bioenergy at the national level:

The potential contribution of bioenergy production to economic and social development through the income effects described above, particularly in rural areas, means that income generation is a key indicator of the sustainability of the sector. In a number of countries increasing wages, particularly in rural areas, is a major goal of their biofuel/bioenergy policies and programmes. Wage levels are important on their own, but they can also serve as a proxy for labour conditions, which is an additional factor of interest when assessing the social sustainability of the bioenergy sector. The measurements of changes in income derived from self-employed bioenergy production can inform national and sub-national assessments of the degree to which bioenergy production is contributing to the social sustainability of bioenergy production and use.

Furthermore, the change in income data generated by evaluating this indicator can inform analysis of the change in income distribution. A useful approach to characterizing income distribution is to use measures such as the Gini Index, which is the ratio of income for the highest and lowest quintiles or the percentage of the population under a poverty line. If the values of these three measures are reduced as a result of bioenergy production in an area, this will indicate that the bioenergy development in that area has promoted a well-balanced rural, social and economic development.

Comparison with other energy options:

Comparisons may be made with other agricultural activities and the fossil energy industry Comparison may be also made with other renewable energy sources.

With regard to income, comparisons may be made with that derived from self-employment along the supply chain of the aforementioned energy sources, including with regard to impacts on income distribution.

Scientific Basis

Methodological approach:

Definition of income

The ILO's Resolution concerning household income and expenditure statistics (ILO, 2003) defines income as follows: "Household income consists of all receipts whether monetary or in kind (goods and services) that are received by the household or by individual members of the household at annual or more frequent intervals, but excludes windfall gains and other such irregular and typically onetime receipts. Household income receipts are available for current consumption and do not reduce the net worth of the household through a reduction of its cash, the disposal of its other financial or non-financial assets or an increase in its liabilities."

In accordance with the FAO/World Bank Rural Income Generating Activities Study (Carletto et al, 2007), it is suggested that wage and non-wage income components be annualized, net of costs and expressed in local currency units. Purchases and sales of durable goods, investments and windfall gains should be excluded, since these are not transactions undertaken regularly by households and can result in the significant over- and under-stating of permanent income. (For the purposes of this indicator, private and public cash and in-kind transfers received by households or individuals are not included, since the indicator considers only income from bioenergy production.)

Definition of the scope of direct and indirect employment in the bioenergy sector

This indicator applies equally to the income from direct and indirect employment in the bioenergy sector. The following could be included in the measurement of direct employment created by the production and use of bioenergy:

- bioenergy feedstock production;
- biomass transportation;
- biomass conversion and processing;
- production of equipment for the deployment of bioenergy (including plants and equipment specifically designed for the use of bioenergy, such as flex-fuel technology or improved cookstoves) – for comparison with other sources of energy, these first four steps could together be considered the manufacturing phase, which includes manufacturing relating to both the production and use of bioenergy;
- bioenergy supply and distribution (including biofuel suppliers and utilities selling electricity, heating, cooling from bioenergy);
- installation of bioenergy plants and other equipment for the deployment of bioenergy;
- operation and maintenance of bioenergy plants and other equipment for the deployment of bioenergy;

- major research and development related to any of the above activities.

Indirect employment in the bioenergy sector is defined as jobs in other businesses or industries supplying goods and services to the bioenergy sector. For example, a bioenergy plant provides direct employment in the bioenergy sector by hiring employees that work in that plant and are paid directly for their labour in the plant. This plant is also expected to provide indirect employment to retailers, accountants and various trades who do not work at the plant but whose goods and services are necessary for the plant to produce bioenergy. The directly and indirectly employed workers (and their families) use their wages from direct and indirect employment in the bioenergy sector to buy goods and services for their own use, creating induced employment, which is not included in indirect employment, and induced income generation (see below for further discussion of induced income effects) (UNTERM[70]; B.C. Ministry of Forests, Mines and Lands, 2010; UNEP/ILO/IOE/ITUC 2008).

Measurement of 11.1

The average wage paid for employment in the bioenergy sector may be calculated by analyzing a sample of employment contracts at different stages of the bioenergy supply chain, or by consulting relevant industry and worker associations. Wages in bioenergy feedstock production could be compared with the average wage in the agricultural sector, for which data should be available in national statistics and/or in an agricultural census if available. Wages in the biomass processing industry could be compared with the average wage in the manufacturing sector (according to national statistics), while for biomass and biofuel transportation, the appropriate comparator would be the transportation sector as a whole, for which data on the average wage should be available in national statistics as well. Different energy sources could be compared through computing a weighted average wage along the value chain, on the basis of the participation of different types of job in the production of a unit of energy or power capacity.

Wage levels throughout the various stages of the bioenergy supply chain could also be compared with national legally established minimum wages (if existing) or with the minimum wage levels according to ILO standards - “National minimum wages are economy-wide wage floors that apply to all workers, with possible variations between regions or broad categories of workers, in particular young workers or other groups such as domestic workers (ILO, 2008). This might be particularly useful for countries where union workers represent a low percentage of workers, or where the freedom of association is often not guaranteed and wages are not subject to collective bargaining.

In order to measure the contribution of wage employment in bioenergy production to the change in a household or individual’s income, it would be necessary to deduct wages earned in prior employment substituted by employment in bioenergy production.

Measurement of 11.2

Data for the income from the sale of bioenergy products by self-employed households and individuals can be extrapolated from household surveys or sales contracts of such products. The sales contracts data can be derived from voluntary surveys of businesses in the bioenergy sector. The income from bioenergy (or feedstock) production should be measured net of all expenditures related to these activities, such as seed and fertilizer purchases and the hire of farm labour. However, more detailed analysis could also consider the income arising from the additional demand for these inputs for bioenergy.

Where a household or individual gains self-employment income from the activities of an enterprise, the total income from the enterprise should be weighted by the share of the enterprise owned by the household or individual.

For the valuation of barter and own-consumption of bioenergy feedstocks or other products, the quantities of products bartered and of own-produced bioenergy used may be obtained through specially designed household surveys. Methods for imputing the value of own-consumption and bartered goods are described in Carletto et al. (2007) and references therein.

In order to measure the change in income, it is necessary to have a data baseline of income level per household, including not only currency but also equivalents in goods (e.g. bags of rice)

[70] See electronic sources section.

before involvement in bioenergy production starts and to deduct income previously gained from activities substituted or displaced by bioenergy production from income gained from this bioenergy production.

Aggregation and distributional effects

Income derived from wage (11.1) and non-wage (11.2) employment in bioenergy production could be summed at the household or individual level (and aggregated as desired, e.g. by feedstock, scale of production or sub-national region) to give a more complete picture of the contribution of (different kinds of) bioenergy production to income generation. Likewise the total change in a household or individual's income due to both wage and non-wage employment in bioenergy production could be found and aggregated to the desired level.

The primary focus of this indicator is the change in income due to bioenergy production. This information could be particularly useful in countries for which one objective of bioenergy policy is economic development and poverty reduction. The data collected for this indicator can facilitate analysis examining the extent to which these objectives are being achieved and poverty is being reduced. Furthermore, these data can facilitate a broader examination of the contribution of bioenergy production and use to income distribution beyond the reduction in poverty.

Change in income distribution can be measured by using measures such as the percentage of the population under a poverty line, the ratio of income for the highest and lowest quintiles or the Gini index (see Bellu et al., 2006 and other FAO Easypol[71] modules on analysis and monitoring of socio-economic impacts of policies). Such measures could be applied to the data collected for 11.1 and 11.2 separately and/or combined. The Gini index, or coefficient, is a statistical evaluation of income distribution as represented by a Lorenz curve, which is a graphical representation of the distribution of wealth in a population. In the Lorenz curve the cumulative share of income earned is plotted against the cumulative share of the population from lowest to highest incomes. The "Line of Equality" is the 45 degree line that connects the (0%,0%) point to the (100%,100%) point. The Gini Index is the area between the "Line of Equality" and the Lorenz curve. The smaller the Gini index the more evenly distributed wealth is among the populations. For instance, the Gini index, income ratio or poverty rate could be calculated for the income distribution for one measurement period and then subsequently for the same income distribution plus the change in income due to wage and non-wage income from bioenergy production measured for this indicator. The difference between these two values would show the change in income distribution due to direct and indirect employment in bioenergy production. Alternatively, the changes in combined wage and non-wage income due to bioenergy production measured at the household/individual level could be allocated to income quintiles and the change in income for the richest quintile compared to the change in income for the poorest quintile.

To determine the full distributional effect, rather sophisticated economic models are needed, for which the data are often not available. For this reason, a narrower, more practical approach could be preferable. In cases where income data is measured at the household level for other purposes, it may be more practical to use this to estimate the change due to bioenergy, applying econometric techniques. The Gini coefficient, where already measured for income in general, and/or the Living Standard Measurement Surveys (Escobar, 2001) or similar household income surveys allow one to evaluate income distribution and compare two regions (with and without bioenergy production) or different households within the same area. If a statistical relation between a lower Gini Index and the presence bioenergy production in an area can be proven, it may indicate that the bioenergy development in that area has promoted a well-balanced rural and economic development. The boundary of the bioenergy production area would have to be defined country by country and at national level, according to some criteria as the number of workers employed in the bioenergy sector and the share of national GDP (see Indicator 19, *Gross value added*) attributable to bioenergy production in the area. Such analysis would, however include induced or spillover effects on income generation due to bioenergy production which are not within the scope of the income changes principally addressed by this indicator (as discussed below).

The change in income distribution due to bioenergy production can also be calculated through other statistical methods and tests on the basis of data availability.

[71] See electronic sources section.

This indicator focuses on measuring income from bioenergy production for those directly and indirectly involved in the production of bioenergy. However, as mentioned above, there will also be induced income effects that might reach widely into an economy. Indeed, the access to cost-effective energy services in rural areas has significant spillover effects that could create a new dynamic for job creation and development. Such increases in employment and revenues may lead, in turn, to higher consumption and demand for goods and services. Such demand may generate more employment (UN Foundation, 2008). At the community level, the production and use of bioenergy can impact on local production of food, transportation of biomass, construction of infrastructures (e.g. new roads, schools, waste management facilities, water and sewer, etc.), number and quality of jobs produced or lost (measured by Indicator 11), and generation of new income sources for local community. Also, farmers and entrepreneurs have a role to play in leading the creation of biofuels markets, particularly in rural areas. Small and medium enterprises can also participate across the supply chain, including feedstock development and production, processing, transportation and marketing. Furthermore, bioenergy production could result in lower household energy bills due to the displacement of costlier alternatives.

Anticipated limitations:

It may be difficult to measure wage levels if a considerable share of the jobs in the bioenergy sector is informal (i.e. without contracts).

Similar difficulties might be encountered in the measurement of the income of self-employed households and individuals, as there might not always be market transactions involved, especially if part or all of the bioenergy (and/or the associated products) produced is for own-consumption. However, standard methods for imputing prices in these situations are mentioned above.

The data for this indicator are likely mainly to come from household surveys. Since these surveys differ in method and data collected, the results of different surveys may not be strictly comparable. Efforts to standardize survey methods are improving the situation, but there remain differences for example in whether income or consumption expenditure is used as the living standard indicator and in the definition of income. Furthermore, differences in household size, the extent to which income is shared among household members, ages and consumption needs of household members may affect the comparability of survey results (UN DESA, 2007).

All these effects can be considered as changes in income due to bioenergy production, potentially contributing also to a major effect on distribution of income in the bioenergy production area. In order to calculate a disaggregated impact of these externalities on income, appropriately designed households surveys need to be carried out. Comparative analysis (using econometric techniques) of bioenergy production areas and non-bioenergy production areas would represent one methodological option (see above and Walter et al., 2008).

Practicality

Data requirements:

- wages in bioenergy production in relation to comparable sectors:
  - bioenergy feedstock production vs. agricultural production (local currency units/year);
  - biomass and biofuel transportation vs. the transportation sector (local currency units/year);
  - biomass conversion/processing to bioenergy vs. manufacturing sector (local currency units/year);
  - information regarding type of employment prior to bioenergy production is required in order to measure change in income due to wage employment in the bioenergy production;
- income from sale, barter or own-consumption of bioenergy products (including feedstocks) by self-employed households/individuals;

- types, quantities and prices (of the typical basket of) products substituted by self-employed production of bioenergy products, including feedstocks;
- cost of own-production of different bioenergy products;
- average household income level, including not only currency but also equivalents in goods (e.g. bag of rice) before bioenergy production starts;
- persons per household in bioenergy production.

Some countries may wish to use Gini Index values where available at regional/district/municipal level as reference data in order to make comparison among different regions/municipalities in terms of inequalities and measure the attribution of bioenergy development. For those countries where Gini index values are not available, it can be calculated for income with and without the change due to wage and/or non-wage income from bioenergy production according to the following standard formula:

$$G = Cov\{y, F(y)\}\frac{2}{\bar{y}},$$

where G is the Gini Index, Cov is the covariance between income levels y and the cumulative distribution of the same income F(y), and $\bar{y}$ is average income. For a step-by-step guide to calculating the Gini Index and related discussion, see Bellu et al, 2005. This calculation will require a database of income per household/individuals in regions with or without bioenergy production. Data are often provided in 5 quintiles of 20% from poorest to richest.

These data can be calculated using existing national/international statistical accounts and data such as employment contracts in the bioenergy sector, sales contracts of bioenergy products, or agricultural census. Alternatively, these could be collected through interviews and surveys at the regional, field, site or household level.

Data sources (international and national)[72]:

- employment contracts in the bioenergy sector
- sales contracts of bioenergy products
- national statistics and agricultural census
- ILO database on minimum wages
- national databases of minimum wages (for comparison), if available
- national databases on standard formula for Gini Index, if available
- data and information collected at national level through the Living Standard Measurements Surveys
- World Bank: World Development Indicators (WDI) publications and WDI online database

Known data gaps:

Data collection strategies implemented by trade unions, ministries of finance/economy (or equivalent), national statistics institutes, ministries of production/development/industry (or equivalent), universities, research centres, and certification reports may serve to fill existing data gaps.

Data gaps can be also filled by surveys at household level and/or by carrying out the Living Standards Measurements Surveys in the areas of interest.

Relevant international processes[74]:

- UN Millennium Development Goals (MDGs) indicator 1.6 (Proportion of employed people living below US$1 (PPP) per day);

[72] See electronic sources section.

- UN Millennium Development Goals (MDGs) indicators 1.1 (Proportion of population below US$1 (PPP) per day), 1.2 (Poverty gap ratio) and 1.3 (Share of poorest quintile in national consumption);
- CSD Indicators of Sustainable Development include three indicators on income and its distribution: proportion of population living below national poverty line, proportion of population below 1 $ a day, and ratio of share in national income of highest to lowest quintile;
- WWF-MPO is developing a poverty environment (P-E) information and indicator system (Percentage of Income generated by sale of biomass is one indicator).

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Indicator 12 Jobs in the bioenergy sector

Description:

Net job creation as a result of bioenergy production and use, total (12.1) and disaggregated (if possible) as follows:

- (12.2) skilled/unskilled
- (12.3) indefinite/temporary.

(12.4) Total number of jobs in the bioenergy sector; and percentage adhering to nationally recognized labour standards consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work, in relation to comparable sectors (12.5)

Measurement unit(s):

(12.1) number and number per MJ or MW

(12.2) number, number per MJ or MW, and percentage

(12.3) number, number per MJ or MW, and percentage

(12.4) number and as a percentage of (working-age) population

(12.5) percentages

Relevance

Application of the indicator:

This indicator applies to bioenergy production and use and to all bioenergy feedstocks/end uses/pathways.

Relation to themes:

This indicator is primarily related to the themes of *Rural and social development* and *Labour conditions.* The indicator measures the net job creation as a result of bioenergy production and use, disaggregated by quality and type of job, such as whether the resultant jobs are skilled or unskilled, temporary or indefinite.

According to the ILO "Declaration on Fundamental Principle and Rights at Work" (1998), the four principles enumerated in this Declaration have the status of human rights. These principles are:

a) freedom of association and the effective recognition of the right to collective bargaining;

b) the elimination of all forms of forced or compulsory labour;

c) the effective abolition of child labour; and

d) the elimination of discrimination in respect of employment and occupation.

The indicator provides information about the share of jobs in the bioenergy sector to which these ILO core principles are applied. It compares this proxy for labour conditions in the bioenergy sector with other relevant sectors, thus helping to assess the compliance with core labour rights essential to guarantee decent labour conditions in a labour-intensive sector such as the bioenergy sector. In addition, the data collected for this indicator put the jobs resulting from the production and use of bioenergy into a nationally relevant context.

Change in number, quality and type of job due to bioenergy production and use is fundamental to understand the social and economic sustainability of bioenergy development. The creation of different types and forms of employment is particularly linked to rural and social development by increasing and diversifying the sources of income for the local population. Moreover, improving the level of technology (and therefore skills) used in the whole supply chain of the bioenergy sector can stimulate the growth of better remunerated and more productive jobs. In combination with adequate policies, the creation of remunerative, productive jobs that adhere to the ILO fundamental principles and rights at work will help to reduce poverty, promote rural development and improve the overall socio-economic situation in a country (UN DESA, 2007; DFID, 2004).

This indicator is also related to the themes of *Human health and safety, Economic development*, and *Access to technology and technological capabilities*. It should be interpreted in conjunction with information provided by Indicators11 (*Change in income*), 16 (*Incidence of occupational injury, illness and fatalities*), and 21 (*Training and re-qualification of the workforce*) in order to more fully assess the quality of the jobs created.

How the indicator will help assess the sustainability of bioenergy at the national level:

Net job creation, with a high percentage of skilled, secure and decent jobs, can have a significant positive impact on sustainable development at the national and regional level. In order to inform national and sub-national decision-making, particular attention can be given to net job creation from bioenergy production and use in areas of high unemployment. In addition, a growing bioenergy sector can promote the transition over time towards a greater proportion of skilled jobs in areas with high pre-existing levels of unskilled jobs. The proportion of local workers employed and trends in the gender and age balance of the workforce might also be of interest when assessing the contribution of bioenergy to sustainable development.

If trends regarding respect of the ILO fundamental rights at work in the bioenergy sector show that the sector is improving over time and/or outperforming comparable sectors in the country, then this suggests a positive contribution to local or national sustainable development. Good labour conditions in the bioenergy sector are also likely to lead to a more productive and secure industry. A high level of employment or the creation of jobs that do not require training and/or education may not always be entirely positive, because such job creation could be a result of a lack of educational opportunities. As such, this indicator should be evaluated in close conjunction with the indicators mentioned above that provide further information on the quality of the jobs created.

Comparison with other energy options:

Net job creation due to bioenergy development can be compared to that in the fossil fuel industry (see Walter et al., 2008 and UNICA reports), as well as in other renewable energy sectors. Jobs in the bioenergy sector adhering to national labour standards consistent with internationally recognized fundamental principles and rights at work can also be compared with the fossil fuels industry and renewable energy sectors, given sufficient information (this may require gathering data along the supply chain for each sector).

Scientific Basis

Methodological approach:

There exists much variation in the literature, industry and government statistics regarding the definitions of jobs, direct jobs, indirect jobs, employment-to-population ratio, and metrics for expressing job creation in energy sectors. The commentary provided below is intended to highlight some of the most common and practical options for the various steps entailed in measuring this indicator, as well as the need to clearly state the methodology used, in order to avoid misleading, confusing and incomparable results.

Definition of a job

Many of the required definitions regarding measurement of employment in general are contained in the “Resolution concerning statistics of the economically active population, employment, unemployment and underemployment”, adopted by the Thirteenth International Conference of Labour Statisticians (ICLS[73]), Geneva, 1982. Employment statistics as defined by this ICLS resolution refer to persons above a specified age who performed any work at all (paid or self-employment) in the reference period, for pay or profit (or pay in kind), or were temporarily

[73] See electronic sources section.

absent from a job for reasons such as illness, maternity or parental leave, holiday, training or industrial dispute. The concept of economic activity, or employment, is defined in terms of production of goods and services as set forth by the United Nations System of National Accounts. Generally three categories of the total employed are distinguished (UN DESA, 2007):

- wage and salaried workers (also known as employees);
- self-employed workers that include self-employed workers with employees (employers), self-employed workers without employees (own-account workers) and members of producers' cooperatives; and
- contributing family workers (also known as unpaid family workers; note this is a sub-category of self-employed workers, separated on account of the fact that the socio-economic implications associated with this status can differ significantly from other self-employed workers)

How many hours constitute a job?

The ICLS 1982 resolution also states that unpaid family workers who work for at least one hour should be included in the count of employment, although many countries use a higher hour limit in their definition. On the other hand, sometimes the number of jobs is quoted in full-time equivalent (FTE) jobs. A full-time job has been defined as a job that occupies employees for thirty or more hours per week.

For the period of one year, one FTE job could represent one full-time employee or two or more part-time employees whose weekly hours add up to at least thirty hours (all employed for a full year), or two or more seasonal workers who work at least 30 hours per week over fractions of a year that add up to make one whole year (World Bank et al., 2008). It is important to state the number of hours used to define one job when stating the indicator result.

12.1: Definition of the scope of the bioenergy production and use value chain, including direct and indirect jobs

To measure this indicator, it will be necessary to define the scope of the bioenergy value chain (or the bioenergy sector) to be considered. In particular, attention should be paid to defining the type of jobs that could be considered to have been created as a result of the use of bioenergy. It is helpful to distinguish between direct and indirect jobs. The following value chain steps require employment that could be included in the measurement of direct jobs created by the production and use of bioenergy:

- bioenergy feedstock production;
- biomass transportation;
- biomass conversion and processing;
- production of equipment for the deployment of bioenergy (including plants and equipment specifically designed for the use of bioenergy, such as flex-fuel technology or improved cookstoves) – for comparison with other sources of energy, these first four steps could together be considered the manufacturing phase, which includes manufacturing relating to both the production and use of bioenergy;
- bioenergy supply and distribution (including biofuel suppliers and utilities selling electricity, heating and cooling from bioenergy);
- installation of bioenergy plants and other equipment for the deployment of bioenergy;
- operation and maintenance of bioenergy plants and other equipment for the deployment of bioenergy;
- major research and development related to any of the above activities.

Indirect jobs in the bioenergy sector are defined as jobs in other businesses or industries supplying goods and services to the bioenergy sector. For example, a bioenergy plant providing direct employment in the bioenergy sector also provides indirect employment to retailers, accountants and various trades for special jobs that the bioenergy employees are not trained to handle, to produce the direct outputs of the bioenergy plant. The directly and indirectly employed workers (and their families) use their wages from direct and indirect employment in the bioenergy sector to buy goods and services for their own use, creating induced employment, which is not included in indirect employment (see below for further discussion of induced employment) (UNTERM; B.C. Ministry of Forests, Mines and Lands, 2010; UNEP/ILO/IOE/ITUC 2008).

Those in indirect jobs may be contracted by those directly involved in the bioenergy sector. Note that if the number of FTE jobs created in a year is being measured, employees in suppliers or contractors do not have to be permanently engaged in work for the operation for the employment to be counted. For example: a construction contractor who provided 20 workers for a fixed three-month period would have had the equivalent of 5 full-time jobs created from the operation in that year (20 x 0.25 = 5); and a supplier who employs 100 staff and who sells ten percent of his output in a year to the operation would also have had the equivalent of 10 full-time jobs created by the operation's custom (World Bank et al., 2007).

For both direct and indirect jobs, it is necessary to decide and to state whether or not jobs created in foreign countries as a result of manufacturing in the domestic bioenergy sector are to be included. For example, many jobs in installation, operation and maintenance may be created in countries that import bioenergy products.

The methodological approach described in this section does not attempt to measure induced job creation (e.g. jobs created by spending of those employed in the bioenergy sector), or spillover effects. To estimate such broader effects on the economy, local economies around specific supply chains could be studied and typical ratios of induced to direct and indirect jobs created determined (World Bank et al., 2008). Alternatively, two areas, with and without bioenergy production could be compared using econometric analysis. This could be combined with a broader analysis of the effect of bioenergy production on income (Walter et al., 2008) – see Indicator 11 (*Change in income*).

12.1: Definition of jobs lost/displaced as a result of bioenergy production and use (to give net job creation figure)

Since the indicator measures net job creation, the measurement of the number of jobs created (every year, or other measurement period) in the above steps of the bioenergy value chain must be complemented by the measurement (or estimation) of the number of jobs displaced or lost as a result of bioenergy production and use. This will entail two elements: jobs lost within the bioenergy sector and jobs displaced in other sectors. The former could be addressed by simply measuring the change in the total number of jobs in the bioenergy sector each year, rather than the numbers created and lost separately. However, the number of jobs lost in the bioenergy sector is required for Indicator 21 (*Training and re-qualification of the workforce*), so it is suggested to measure both numbers separately. The latter is more complicated, but is made simpler by concentrating on agricultural workers who have lost their jobs due to a change in land use for bioenergy feedstock production. If bioenergy is identified as displacing another form of energy (e.g. the fossil fuel equivalent, as determined by Indicator 20, *Change in consumption of fossil fuels and traditional use of biomass*), countries might wish to conduct a simple comparison of jobs per unit of energy of power capacity for these two energy sources. Alternatively, a more advanced form of analysis could be conducted to understand the consequences for other sectors, including other energy sub-sectors (e.g. using computable general equilibrium modelling).

12.2-12.3: Disaggregation of job creation figures

Definition of skilled and unskilled jobs

A skilled job is one that requires some special skill, knowledge or ability. A skilled worker may have acquired his or her skills or knowledge through attending a college, university or technical school or on the job. (See Indicator 21, *Training and re-qualification of the workforce*.) An unskilled job is a job that is not a skilled job. Jobs can be classified as skilled, unskilled and unknown based on the ILO's International Standard Classification of Occupations (ISCO-88) and, sometimes also on country-specific documentation.

Definition of temporary and indefinite jobs

A temporary job is one that is seasonal, periodic, summary, or that cannot be done by the regular staff of the company. In the case of temporary employment, which can also be referred to as having a fixed-term contract, the employment relationship is intended to last for only a specific and definite length of time or until a specific project is completed. Once the term or project is finished, the fixed-term employment relationship ends. Such employees are often referred to as being in a “contract” position. Jobs in the agricultural sector can often be for limited durations of time and involve finite seasonal activities specific to the cultivation and harvest of agricultural products. These temporary jobs are frequently referred to as seasonal employment. A seasonal jobs fall under the category of a temporary job.

Indefinite employment refers to both the duration and nature of the employment. Employment of an indefinite duration is work involving continuous service that is intended to last for an indefinite period of time. Indefinite employment has no explicitly specified or foreseeable end to the employment relationship. This type of employment is accompanied by a number of rights and obligations, most notably the right to reasonable notice upon termination.

Fixed term employment is work defined by a validly constituted fixed-term contract. An employer is not required to provide the employee with reasonable notice prior to terminating the duration of employment, because the employment relationship naturally comes to an anticipated end at either a specified time or upon the completion of a specified project.

In accordance with national norms and conventions, countries may determine that different pairs of terms, such as “short-term” and “long-term”, “seasonal” and “non-seasonal”, or “regular” and “irregular”, may provide more relevant descriptive terms for employment in the bioenergy sector.

Further disaggregation

If possible, these measures should also be disaggregated by gender and age categories. The gender differentiation of net job creation refers to Millennium Development Goal Target 1.B “Achieve full and productive employment and decent work for all, including women and young people”. It will be measured by percentage of women and young people (between 15 und 24 years, as agreed during preparations for the International Youth Year (1985), and endorsed by the General Assembly – see A/36/215 and resolution 36/28, 1981) compared to the total number of employees in the bioenergy sector.

12.1-12.3: Expressing the job creation figures in a consistent and informative manner

Suitable metrics, including for comparison with alternative energy sources

The sections above provide guidance on how to measure the number of jobs created and displaced/lost and disaggregate these numbers by various aspects of interest. Simply stating a net number of jobs created by bioenergy production and use in a country, however, may not be very informative, especially when making a comparison with other energy sub-sectors. In order to facilitate such comparison (and also monitor performance over time), job creation in the energy sector is commonly expressed using the metric of jobs per MW of installed capacity. This capacity is usually calculated on a cumulative basis, but sometimes only capacity installed in the year of measurement is counted. The latter approach is more subject to variation due to changes in policy and economic conditions (Dalton & Lewis, 2011). While the concept of “installed capacity” (e.g. in MJ per year) could also be used for fuels, jobs per MJ of energy content of fuels produced and used would perhaps be a more suitable metric for fuel production and use.

For countries that export or import bioenergy goods or services, separate figures could be stated for net jobs created along the whole value chain (per MJ and/or MW) and for net jobs created by the production (per MJ of energy delivered) or use (per MJ of energy used or MW of power capacity installed) of bioenergy in the country, as appropriate. This would avoid misleadingly high figures for exporting countries, if jobs per MW of installed capacity or MJ of energy used are stated.

Level of aggregation

The number and quality of jobs can be aggregated up to the desired spatial scale (national or regional), for the feedstock production and processing phases separately and in the agricultural phase for each feedstock. The agricultural jobs will be expected to decrease if mechanization increases, and it would be informative to note such explanatory factors as contextual information for the indicator values.

Different forms of energy will bring different kinds of jobs in different numbers and proportions. For example, the bioenergy sector in some countries is likely to require a lot of labour in the feedstock production phase; many renewable energy technologies are relatively labour-intensive in their installation; wind energy generally requires less operation and maintenance than other forms of renewable energy. These different types of jobs may have different characteristics (e.g. operation and maintenance might represent longer-term jobs than installation). It might therefore be useful to classify the different types of employment as: manufacturing; installation; operation and maintenance; research and development; and (if significant) distribution.

12.4: Measuring the total workforce and expressing it as a percentage of the working-age population

The indicator includes measurement of the total workforce in the bioenergy sector (12.4), which can be obtained by industry surveys. It is suggested to express 12.4 as a simple total and as an employment-to-population ratio or percentage for the sector. The population base for this ratio should be that used by the country for its overall employment-to-population ratio. This varies across countries, but in most cases, the resident non-institutional population of working age living in private households is used, excluding members of the armed forces and individuals residing in mental, penal or other types of institutions. For most countries, the working-age population is defined as persons aged 15 years and older. (For further details, see UN DESA, 2007.)

12.5: Measuring the percentage of jobs adhering to nationally recognized labour standards consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work

The most practical approach is likely to be to identify existing national legislation that promotes respect for the four principles listed above, the application of that legislation and any voluntary schemes that provide evidence of compliance with this national legislation or the ILO principles directly. The percentage of jobs adhering to all four principles could then be found by aggregating up evidence from police or government agency spot checks at bioenergy feedstock production and processing sites and from relevant voluntary certification schemes. The evidence should come from a sufficiently representative sample, and could be aggregated nationally or sub-nationally (if large variation exists) for each feedstock, for all feedstock production, for all processing and for the whole value chain. Several collection methods are suggested by the SIMPOC Manual[74] (Statistical Information and Monitoring Programme on Child Labour by ILO). In the absence of crop-specific surveys, ILO reports could be used to identify issues observed in relation to the adherence to the fundamental principles in a country.

12.5: Comparison with other sectors in a country

The value for 12.5 is given by first calculating the percentage of the total bioenergy workforce for whom the principles of the ILO Declaration are respected, as described above. This value is then compared with other relevant sectors. Since it is difficult to derive a value for the whole value chain, specific steps of the bioenergy value chain can be compared with comparable steps of the value chain of other sectors. Comparison with alternative sources of energy, could be conducted on a per unit of energy or installed power capacity basis, as outlined above, ideally covering the whole value chain. For the bioenergy feedstock production phase, another possibility is to compare the bioenergy value with an average value for agriculture in the country. In practice, this might involve an assessment of the typical labour conditions in the production of a certain crop or in agriculture of a certain scale within a country.

Anticipated limitations:

Measurement of this indicator will depend largely on definitions used for measurement of jobs, which vary widely across countries and studies. Such factors include the minimum number of hours required to have been worked in a week year, or other measurement period, to qualify as a job; recognition of self-employment and other less obvious forms of work, such as unpaid family work, apprenticeships or non-market production; differences in minimum and maximum

[74] See electronic sources section.

working ages; definitions of direct and indirect jobs; and inclusion or exclusion of jobs created abroad.

As discussed above, job creation or high employment per se is not necessarily entirely positive. The properties of the jobs are also important. Furthermore, a large number of jobs created per unit of energy is not necessarily a positive characteristic of an energy source. This will depend on national and local circumstances. The productivity of these jobs should also be taken into account: Indicator 19 (*Gross value added*) is relevant in this regard.

As discussed above, given that different sources of energy require different levels of labour for different phases in their production and use (e.g. manufacturing, distribution, installation, operation and maintenance, R&D), comparison of net job creation figures must be done with care. It might be necessary to derive typical numbers of jobs in each of the above-mentioned phases per unit of energy or power capacity, giving an indication of the lifetime (time-limited, recurring, ongoing, etc.) and location (domestic or foreign) of the jobs.

Practicality

Data requirements:

- Number of jobs created annually (or over some other stated measurement period) along the bioenergy supply and use value chain. This information should be disaggregated by:
    - skilled/unskilled
    - temporary/indefinite

and possibly further disaggregated by gender and age categories.

- Total number of workers along the value chain of the bioenergy sector.
- Number of workers that comply with the four above-mentioned ILO principles in the bioenergy production and use value chain.

These data can be gathered through national/international statistical accounts, stakeholders/industry information or, alternatively, through interviews and surveys, at the field, site or household level.

With reference to the bioenergy sector, where data are not readily available, the government can design supplementary methods to collect information, such as household-based surveys or spot-check of producers/operators.

Equivalent data will be required for comparison with other sectors, such as agriculture and other energy sectors.

Data sources (international and national)[75]:

The ILO website hosts a variety of databases and reports on labour statistics, including the Key Indicators of the Labour Market (KILM) database.

The International Standard Classification of Occupations (ISCO-88) classifications (including distinction between skilled and unskilled jobs)

ILO reports related to the Declaration on Fundamental Principles and Rights at Work can be used to give an overview of the labour conditions component of the indicator. They contain:

- compilation of annual country reports
- compilation of country baselines
- status by country
- archive of baselines by country; and
- observations by international employers and workers organization

[75] See electronic sources section.

Several collection methods are suggested by the ILO SIMPOC (Statistical Information and Monitoring Programme on Child Labour) Manual. Regarding secondary sources, the SIMPOC Manual notes that a wide range of institutions, while not primarily concerned with labour, often produce useful information pertaining to it. Examples are annual school reports compiled by ministries of education, school surveys and inspection reports, statistical reports by national statistical offices, surveys and research conducted by international development organizations, and other studies and reports prepared for national ministries and the donor community.

Known data gaps:

Data gaps on job creation can be filled by review of national and regional statistics. If these do not exist, data can be collected at regional/local level (producers and industrial sector). The methodology referenced in Moraes et al, 2008 can be used for disaggregating by region as well. Further, complete references that can be used as an example are those related to the sugar cane production in Brazil (see references).

Data gaps on jobs in the bioenergy sector adhering to nationally recognized labour standards can be filled by:

- random spot checks among producers/operators
- data collected by private labour audits
- comparable data from national statistics of workers in agriculture

Relevant international processes[76]:

Relevant international processes include:

- UN Millennium Development Goals (MDGs) indicator 1.5 (Employment-to-population ratio) and 3.2 (Share of women in wage employment in the non-agricultural sector);
- Statistical Information and Monitoring Programme on Child Labour (SIMPOC) by International Labour Organization (ILO) and the "Living Standard Measurement Survey" (LSMS) by World Bank;
- United Nations Children's Fund (UNICEF), through the Multiple Indicator Cluster Surveys (MICS);
- ILO reports and statistics;
- UNEP/ILO/IOE/ITUC Green Jobs Initiative and ILO Green Jobs Programme.

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

Description:

Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services

Measurement unit(s):

Hours per week per household, percentage

Relevance

Application of the indicator:

This indicator applies to the use of modern bioenergy services that have replaced traditional bioenergy services involving the collection of biomass (the value will be zero in all other cases).

Relation to themes:

This indicator is primarily related to the theme of *Rural and social development*. In most developing countries, firewood collection is an extremely time- and energy-intensive activity, particularly in remote rural areas. Generally, women are mostly responsible for these activities. Evidence from sub-Saharan Africa, for instance, shows that women spend, on average, up to three or four hundred percent more time than men collecting firewood, and fetching water as well. There is evidence that wood collection exposes women and girls to potential health and safety hazards and that it limits the time available to them for education and income generating activities. (Gaye, 2007; Nankuhni & Findes, 2003, cited in Rossi & Lambrou, 2009). In some cases, firewood collection has also been associated with child labour. Nankhuni (2004) found that in Malawi being female was the most significant determinant of a child participating in firewood (as well as water) collection. According to the same study, girls were more likely than boys to be involved in these activities while simultaneously attending school (Nankhuni, 2004; World Bank, 2006, cited in Rossi & Lambrou, 2009).

The switch to modern bioenergy can be considered a clear indicator of improvement in sustainable development at the local level, particularly at the household level, in rural areas or in general those with a dependence on use of solid fuels for cooking and heating. It directly measures the opportunity cost of time spent by women and children in collecting fuel, as well as providing an indication of the reduction in the probability of injuries from carrying large amounts of wood, restrictions on economic and educational activity due to poor air quality or lighting, environmental degradation due to increased resource stress from fuelwood collection, and the vulnerability of women to violence when collecting fuel in areas of civil unrest and war (Schirnding 2002).

This indicator will also inform the themes of *Land-use change, including indirect effects; Access to energy; Human health and safety;* and *Economic development*.

How the indicator will help assess the sustainability of bioenergy at the national level:

As described in the previous section, in most developing countries firewood collection is an extremely time-consuming activity for large sectors of the population, especially among women and children. This activity also bears a number of environmental and health risks. By measuring the time saved by women and children collecting biomass as a result of switching from traditional to modern bioenergy services (and indirectly the environmental and health benefits associated with this), this indicator provides an important indication of the contribution of the latter to sustainable development.

Comparison with other energy options:

The indicator could also be measured in case of a switch from traditional biomass use to modern energy services based on fossil fuels or renewable energy sources other than modern bioenergy.

Scientific Basis

Methodological approach:

Modern energy services are defined in the glossary and the methodology sheet for Indicator 14 (*Bioenergy used to expand access to modern energy services*).

Different types of methodologies may be used to conduct time use surveys (with a focus on firewood collection in this case). A list of eight methods used in time use surveys, including advantages and disadvantages of each, can be found in World Bank (2005, p. 37-38). As described in this document, "direct observation" is one of the most common and preferred approaches. In this case, the researcher observes what individuals do at particular times and records their activities. One of the main advantages of this approach is that it does not require that the person observed is literate and has an exact and standardized sense of time. On the other hand, this approach is highly costly and thus allows only for small sample sizes. Another method included in the list is called "interviewer administered time diary". In this case, there is not a questionnaire with a specific list of activities and the respondent describes each activity in his/her own words from the beginning to the end of a day. This approach provides consistency in time activity data – by forcing full accounting of time – and may also provide data on simultaneous activities.

The indicator and the time use survey should focus on the households where there was a switch from traditional use of biomass to modern bioenergy services. Data could be aggregated from household to sub-national regional and national levels.

Additional information about the use of the time saved for different activities (e.g. education, economic/trading, leisure) would be beneficial.

Travelling distance and time spent collecting firewood will depend, among other things, on the availability and accessibility of wood resources. In areas affected by deforestation or where nearby forests are protected, local communities may need to take longer trips that might be required in order to collect firewood. In Uganda, for instance, the average distance to collect firewood (mainly by women and children) increased from 0.06 Km in 2000 to 0.9 Km as a result of deforestation (Uganda Ministry of Finance, Planning and Economic Development, 2003; cited in UN DESA, 2010).

For this reason, mapping and analysing the supply and demand of wood resources would provide a good indication of the travelling distance that people in a certain area need to cover in order to collect firewood. This can be done using FAO's Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology. This is a spatially explicit methodology that maps the supply and demand of biomass for energy uses and quantifies the supply of biomass from direct and indirect sources. Understanding spatial differences in biomass supply from direct and indirect sources and woodfuel use patterns allows highlighting areas showing surpluses or deficits.

Anticipated limitations:

The main limitations are data gaps: see next page.

Practicality

Data requirements:

- Hours per week saved collecting biomass at household level.

Interviews and surveys at the household level will be used as measuring methods if data are not readily available.

Data sources (international and national):

In recent years, some developing countries have implemented nation-wide time use surveys, some of which include firewood collection among the activities considered. Examples of countries that have carried out such surveys include India and Nepal 1999, South Africa 2000, and Mauritius 2003 (World Bank, 2005). In additional to national statistics (in the few countries where they are available), additional data sources include:

- FAO Fuelwood surveys
- UN Statistics and UNDP surveys
- NGO reports

Known data gaps:

Data is often lacking with regard to the energy source (e.g. bioenergy, fossil, solar) used in the modern energy service that has replaced a prior dependence on solid biomass for heating and cooking, and indeed the nature (e.g. bioenergy, fossil) of this solid biomass. Household surveys with questions more specifically targeted at this issue could be undertaken to fill such gaps in the available data.

Very few countries collect and have available statistics on the number of women and men collecting firewood and on the time spent by them on this task. Even when such data are available, information might be lacking on the purpose of firewood collection, e.g. for household needs, for sale or as an input for income generating activities such as a bakery or brick kiln. Therefore, it might be difficult to calculate the share of time saved thanks to the switch from traditional biomass use to specific modern bioenergy services.

Relevant international processes[77]:

- Global Alliance for Clean Cookstoves
- The World Bank's World Development Indicators
- UNDP's World Energy Assessment
- United Nations Millennium Development Goals

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Indicator 14 Bioenergy used to expand access to modern energy services

Description:

(14.1) Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of (14.1a) energy and (14.1b) numbers of households and businesses

(14.2) Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass

Measurement unit(s):

(14.1a) Modern energy services can take the form of liquid fuels, gaseous fuels, solid fuels, heating, cooling and electricity. A change in access to each of these forms of modern energy can be measured in MJ per year and this is preferable in order to allow comparison of different forms of energy service, but each may also be measured in appropriate units of volume or mass per year, which may sometimes be more convenient, leading to the following possible units for this indicator component:

- liquid fuels: litres/year or MJ/year and percentage[78]
- gaseous fuels: cubic metres/year or MJ/year and percentage
- solid fuels: tonnes/year or MJ/year and percentage
- heating and cooling: MJ/year and percentage
- electricity: MWh/year or MJ/year (for electricity used), MW/year (if only electricity generation capacity to which new access is deemed to have been gained can be measured), hours/year (for the time either for which electricity is used or for which there is access to a functioning electricity supply) and percentage

(14.1b) number and percentage

(14.2) number and percentage

Relevance

Application of the indicator:

The indicator applies to bioenergy use and to all feedstocks, end uses and pathways.

Relation to themes:

This indicator is primarily related to the theme of *Access to energy*. It measures the expansion of access to energy and particularly to modern energy services provided by modern bioenergy for both households and businesses.

The UN Secretary-General's Advisory Group on Energy and Climate Change defined universal energy access as: "access to clean, reliable and affordable energy services for cooking and heating, lighting, communication and productive uses" (AGECC, 2010). In practice, this requires providing affordable access to the following categories of modern energy services: electricity for lighting, communication and other household uses; modern fuels and technologies for cooking and heating; and mechanical power for productive use (e.g. irrigation, agricultural processing), which could be provided through electricity or modern fuels or directly from renewable sources such as hydropower (Bazilian and Nussbaumer, 2010). Modern bioenergy may play an important role in providing or improving access to modern energy services. By measuring the total amount and percentage of increased access to modern energy services gained through

[78] When converting between litres/year and MJ/year for liquid fuels the Lower Heating Value (LHV) for the given liquid fuel should be used. For example, the energy content (LHV) of anhydrous ethanol is 21.1 MJ/litre. Furthermore, the difference in energy content per litre should be taken into account when comparing different liquid fuels.

modern bioenergy and the total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass, this indicator provides an important indication of the contribution of modern bioenergy to energy access.

Access to energy is strongly correlated to a number of social and economic development indices, such as GDP per capita and the Human Development Index (Bazilian & Nussbaumer, 2010), while "modern energy services are an essential component of providing adequate food, shelter, water, sanitation, medical care, education and access to communication. Lack of access to modern energy services contributes to poverty and deprivation and limits economic and human development. Adequate, affordable and reliable energy services are necessary to guarantee sustainable economic and human development and also achievement of the Millennium Development Goals" (UNDESA, 2006). Expanding access to energy and to modern energy services through modern bioenergy (as opposed to traditional use of biomass for energy or fossil fuels) will lead to a number of environmental and socio-economic benefits, particularly through a reduced dependence on fuelwood and charcoal.

For these reasons, the indicator is also related to the themes of *Greenhouse gas emissions; Productive capacity of the land and ecosystems* (particularly Indicator 3, *Harvest levels of wood resources*); *Air quality; Land-use change, including indirect effects; Price and supply of a national food basket; Rural and social development* (it is closely related to Indicator 13, *Change in unpaid time spent by women and children collecting biomass*); *Human health and safety* (it is closely related to Indicator 15, *Change in mortality and burden of disease attributable to indoor smoke*); *Economic development* (including a close link with Indicator 20, *Change in consumption of fossil fuels and traditional use of biomass*); and *Energy security/Diversification of sources and supply*.

How the indicator will help assess the sustainability of bioenergy at the national level:

This indicator provides an assessment of the contribution of modern bioenergy to households' and businesses' access to energy and modern energy services. In view of the fundamental importance of energy access to sustainable development (as outlined above), the indicator helps assess the contribution of modern bioenergy to sustainable development in a country. Generally an increase in the access to modern energy services gained through modern bioenergy (14.1) will indicate positive impact on sustainable development. However, ideally, the quality (e.g. continuity/level of service) of the energy – and the associated services – provided by modern bioenergy should be considered as well. High costs and unreliable electricity service, for instance, may constitute a severe obstacle to business operation and growth (Bazilian and Nussbaumer, 2010). Likewise, generally an increase in the number of households and businesses using modern bioenergy (14.2) will represent a positive contribution to sustainable development and to the sustainability of a country's energy mix. However, as shown by Indicator 22 (*Energy diversity*), there comes a point where a country's dependence on bioenergy (or at least a limited range of sources of bioenergy) might not be optimal.

Comparison with other energy options:

A comparison can be made with all other energy options (both renewable and non-renewable) that provide modern energy services.

Scientific Basis

Methodological approach:

The GBEP working definition of modern energy services[79] is the availability for the end user (e.g. a household or a business for the purpose of this indicator) of:

- electricity for lighting, communication, healthcare, education and other uses;
- modern fuels or technologies for cooking, heating and cooling;
- mechanical power for productive use (e.g. irrigation, agricultural processing), provided

[79] Modern energy services are defined in the Glossary. The definition is re-stated here to provide clarity to the text.

through electricity or modern fuels, or directly through renewable sources such as hydropower; and

- transport, provided through electricity or modern fuels.

The GBEP definition of modern energy services is based on two criteria: energy efficiency and safety to human health. Where modern energy services rely on the combustion of fuels, the fuels (whether solid, liquid or gaseous) must be burned in efficient and safe combustion chambers, improved cookstoves,[80] or fuel cells. Efficiency is meant here as the energy output as a percentage of the heating value of the fuel. Safety refers to the absence of indoor air pollutants and low amount of air pollutants released in the open-air by the energy system.

Modern energy services might also be defined by what they are not. They do not include: use of kerosene or other fuels for lighting; combustion of fuels on open stoves or fires without chimneys or hoods (or any other energy systems that release flue gases indoors or release high concentrations of air pollutants); or human and draught animal power.

Modern bioenergy services are defined as modern energy services relying on biomass as their primary energy source.

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; 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.

14.1: Since this component of the indicator measures increased access to modern energy services, it is necessary to establish what access to modern energy services means, and which households and businesses do not have it or did not have it prior to the start of the measurement period. Increased access to modern energy services for the purposes of this indicator is not intended to include increased consumption of energy for additional leisure activities, for instance. (Neither is it intended to include new use of bioenergy by a household or business for modern energy services that were previously accessed through use of other energy sources, such as fossil fuels.) Thresholds for energy access have been proposed and international work on such definitions is ongoing (Practical Action, 2011; Bazilian and Nussbaumer, 2010; Bazilian et al., 2010; AGECC, 2010; UNDP and WHO, 2009; IEA, 2009; UNDESA, 2006; Modi et al., 2006). However, there is broad agreement that energy access requires a certain level of affordable access to the following three categories of modern energy services at the household and business level (which represent a subset of the above definition of modern energy services):

- electricity for lighting and communication;
- modern fuels and technologies for cooking and heating;
- mechanical power for productive use (e.g. irrigation, agricultural processing), provided through electricity or modern fuels, or directly through renewable sources such as hydropower.

[80] Improved cookstoves are defined in the Glossary. Improved cookstoves comprise closed stoves with chimneys, as well as open stoves or fires with chimneys or hoods, but exclude open stoves or fires with no chimney or hood. Improved cookstoves usually have energy efficiency higher than 20-30% and their flue gases are released distant from their users.

Cooling services for food refrigeration and maintaining room temperatures below a threshold of, for example, 30 ºC are also suggested by some authors as basic energy requirements (Practical Action, 2011). Members of households should also have access to such basic services as education and healthcare, which themselves require modern energy services. Furthermore, a certain level of access to transport may be essential for livelihoods and this could hence be included alongside mechanical power for productive use (AGECC, 2010; IEA, 2009). Such definitions and thresholds may, in practice, be constrained by data availability.[81]

The evaluation of 14.1 might therefore be made more efficient by an assessment for each of the three above categories of energy services of the areas in a country where households and businesses are deemed not to have adequate access to these services at the start of the measurement period. Where possible, the share of households and businesses without access to electricity should be calculated separately from the share without access to modern fuels or technologies for cooking and heating (or those that rely on open combustion of coal and traditional use of biomass as their primary energy option for cooking and heating), and the share without access to mechanical power for productive use. Likewise, expansion of access to electricity, modern fuels and technologies for cooking and heating, and mechanical power for productive use should be stated separately in addition to a total figure.

If new heat and/or power capacity has been installed in the country and delivered to households or businesses previously without access to modern energy services, one approach to determine the contribution from modern bioenergy would be to identify the quantity of additional heat and power produced and provided to the grid from bioenergy and non-bioenergy sources (separately) and compare this with the average consumption of a household and a business in the area. In the case of stand-alone, off-grid power plants, their power capacity should be readily available from project documents or from the management of the plant. With regard to improved cookstoves, energy for heating and cooking provided by biogas, and mechanical power provided by straight vegetable oil and other biofuels, the quantity of energy provided to households and businesses previously without access to modern energy services could be estimated based on the sales (or the distribution in case of development/aid programmes) of the equipment that is required in order to produce and use these types of energy. Market and/or household surveys could be carried out in order to validate and/or complement this data. Such surveys would be particularly helpful for users of this indicator that wish to evaluate the number of people benefitting from increased access to personal transport through modern bioenergy (as opposed to increased use of transport for non-productive uses or substitution of modern fossil fuels for transport with modern biofuels or bioelectricity). Data collected locally should be aggregated to form a national figure.

In order to express the contribution of bioenergy to increased access to modern energy services as a percentage of the total increase in this access, the above procedure should be extended to all energy sources used to increase access to modern energy services over the measurement period.

14.2: This component of the indicator, in contrast to 14.1, measures the extent of the use of all of the possible forms of modern bioenergy services categorized at the start of this section across the whole population, as well as the level of traditional use of biomass for energy. The quantity of energy from modern bioenergy sources provided to households and businesses through grids in the form of electricity, cooling or heating can be divided by the average consumption per household and business to obtain an estimated value for the number of households and businesses using modern bioenergy. In the case of stand-alone/off-grid power plants, the estimated number and type of households and businesses supplied should be readily available from project documents or from the management of the plant. With regard to improved cookstoves, energy for heating and cooking provided by biogas, and mechanical power provided by straight vegetable oil and other biofuels, the number of households and businesses using them could be determined through market and/or household surveys and

[81] Simple guidelines for the calculation of the share of people without modern energy services can be found in UNDESA (2006). In these guidelines the “Share of population without electricity or other modern energy services” is defined by the share of households without access to modern energy or electricity and by the share of households that are heavily dependent on ‘traditional’ non-commercial energy options.

aggregated to a national figure. The number of households and businesses using bioenergy for transport could be estimated from transport fuel and vehicle sales figures, complemented by surveys. Market and/or household surveys can be used to determine the energy provided by traditional use of biomass.

The values for both 14.1 and 14.2 could be calculated separately for urban and rural households where this is relevant.

Anticipated limitations:

Lack of existing baseline data and information at the local level could be a limitation, especially in developing countries. Besides the constraint of data availability, the concept of access to modern energy services is multi-dimensional and context-specific, and hence difficult to define.

Practicality

Data requirements:

14.1:

- amount of additional electricity generated and provided to the grid from bioenergy and non-bioenergy sources;
- amount of additional electricity generated by off-grid systems from bioenergy and non-bioenergy sources and used by households or businesses that previously did not have adequate access to electricity;
- amount of additional energy used for cooking, heating and cooling through modern fuels or technologies by households and businesses that previously did not have adequate access to such services from bioenergy and non-bioenergy sources;
- amount of additional mechanical power used (productively) by households and businesses that previously did not have adequate access to mechanical power for productive uses from bioenergy and non-bioenergy sources;
- number of households and businesses gaining increased access to modern energy services through bioenergy and non-bioenergy sources or, if not known, average consumption per household and business of electricity; energy for cooking, heating, cooling through modern fuels and technologies; and mechanical power.

14.2

- amount of energy from modern bioenergy sources used by households and businesses in the form of electricity, heating/cooling and mechanical power and for transport;
- average consumption per household and business of electricity; energy for cooking, heating and cooling through modern fuels and technologies; mechanical power; and energy for transport;
- amount of energy used through traditional use of biomass;
- number of households and businesses using energy through traditional use of biomass or, if not known, average consumption of energy through traditional use of biomass in areas where this use is identified, and number of households and businesses in such areas.

These data can be gathered through national/international statistical accounts, calculation/computation of (existing) data or through market and/or household surveys. The collection can be done at the national, regional, field (farming) or household level.

Data sources (international and national):

- a large amount of data and sources of data at the global, regional and national levels on energy access are contained in UNDP and WHO (2009).
- IEA data on energy in developed and developing countries.

- annual country energy mix and national census.

Known data gaps:

Data gaps include the lack of disaggregation by energy source in some energy use and production statistics, particularly in developing countries. It could be useful to design or amend households surveys to capture which energy sources are used for the main energy uses such as cooking, lighting, heating/cooling, or personal transport.

Relevant international processes[82]:

- CSD Indicators of Sustainable Development. In particular, the indicator on Share of households without electricity or other modern energy services
- Energy Indicators for Sustainable Development (EISD). In particular, indicator SOC1: Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy
- HEDON Household Energy Network
- Global Village Energy Partnership
- Goal of ensuring universal access to modern energy services by 2030 (proposed in the 2010 report of the UN Secretary-General's Advisory Group on Energy and Climate Change, "Energy for a Sustainable Future")
- UNDP multidimensional poverty index (standard of living dimension): household uses "dirty" cooking fuel (dung, firewood or charcoal)
- UN Development Programme – Energy for Sustainable Development

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[82] See electronic sources section.

Questionnaire Design in Living Standards Measurement Studies.

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

Description:

(15.1) Change in mortality and burden of disease attributable to indoor smoke from solid fuel use

(15.2) Changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves

Measurement unit(s):

Percentages

Relevance

Application of the indicator:

The indicator applies to bioenergy use and to all bioenergy feedstocks/end uses/pathways.

Relation to themes:

This indicator is primarily related to the theme of *Human health and safety*. It is also related to the themes of *Rural and social development* and *Access to energy*. Lack of access to clean, efficient, modern sources of energy in the home can impact health in many ways. The most important direct health effects result from the air pollution caused by burning solid fuels, often indoors on open fires and simple stoves (Bruce et al., 2000; WHO, 2006). The indoor use of open fires or inefficient stoves in households releases large amounts of smoke from incomplete combustion of solid fuels – primarily wood, but in many cases coal, animal dung, and/or crop wastes. This smoke contains a range of health-damaging pollutants including small particulate matter, and carbon monoxide which affect human health. Breathing this smoke affects the health of all members of the family, but especially that of women and their young children (UNDP and WHO 2009).

As cooking takes place every day of the year, most people using solid fuels are exposed to levels of small particles many times higher than accepted annual limits for outdoor air pollution. The more time people spend in these highly polluted environments, the more dramatic the consequences for health. Women and children, indoors and in the vicinity of the hearth for many hours a day, are most at risk from harmful indoor air pollution.

Switching to cleaner fuels and increasing fuel efficiency through better stoves can reduce health risks for all family members. Beyond curbing respiratory problems, a more secure household energy situation enables water to be boiled and thus helps reduce the incidence of water-borne diseases. It can also increase the number of hot meals consumed per day and thus improve food safety and nutrition. A closed, raised stove prevents infants and toddlers falling into the fire or knocking over pots of hot liquid and being burned or scalded.

Closing the household energy gap can therefore be a springboard for achieving the health-related Millennium Development Goals. Introducing household energy practices that, in addition to decreasing levels of indoor smoke, save fuel and reduce greenhouse gas emissions can make an important contribution to achieving Millennium Development Goal 7.

How the indicator will help assess the sustainability of bioenergy at the national level:

Burning solid fuels produces extremely high levels of indoor air pollution: typical 24-hour levels of PM_{10} in biomass-using homes in Africa, Asia or Latin America range from 300 to 3,000 micrograms per cubic meter (µg/m^3). Peaks during cooking may be as high as 10,000 µg/m^3. By comparison, the annual mean PM_{10} limit agreed by the European Union is 40 µg/m^3.

Inhaling indoor smoke doubles the risk of pneumonia and other acute infections of the lower respiratory tract among children under five years of age. Women exposed to indoor smoke are three times more likely to suffer from chronic obstructive pulmonary diseases (COPD), such as chronic bronchitis or emphysema, than women who cook with electricity, gas or other cleaner fuels (WHO, 2006).

A shift towards cleaner and more efficient modern fuels, such as biogas, liquefied petroleum gas (LPG), biopropane, and ethanol gel fuel could dramatically reduce health risk and prevent almost 2 million deaths a year globally (UNDP and WHO 2009). In the short term, the promotion of more fuel-efficient and cleaner technologies, such as improved cooking stoves, smoke hoods, and insulated retained heat cookers could substantially reduce indoor air pollution and would bring about many other socio-economic benefits.

This indicator will help assess the extent to which there is a transition towards clean, modern energy services for cooking and heating and the health implications of this transition (15.1) and in particular the role that modern bioenergy plays in this transition (15.2).

Comparison with other energy options:

Alternative comparisons can be made with other energy forms which deliver modern energy services.

Scientific Basis

Methodological approach:

Household surveys should be undertaken to gather data about use of modern energy services (including modern bioenergy separately) versus traditional solid fuels (e.g. charcoal, coal) and equipment used indoor (e.g. cookstoves), combined with data on mortality and burden of disease due to indoor air pollution from solid fuel use. Once a locally or nationally applicable burden of disease is known, information obtained for Indicator 14 (*Bioenergy use to expand access to modern energy services*) could be used to attribute a change in the burden of disease to a switch from the traditional use of solid fuels for cooking and heating to modern bioenergy services.

The disease burden of the study population can be measured using various metrics, such as prevalence of severe pneumonia in infants, disability-adjusted life years (DALYs) lost, or deaths. The general method comprises the following steps:

Step 1, Obtain key data: Obtain estimates of the local assessment's key data – exposure characteristics (e.g., percentage of the population exposed to solid fuels use (SFU), and disease burdens (infant hospitalizations, DALYs lost, or deaths from health outcomes associated with SFU), from either primary research or secondary sources.

Step 2, Calculate attributable fractions: Using exposure characteristics, relative risks, and the appropriate equation, calculate attributable fractions for each disease/age/sex grouping.

Step 3, Calculate the attributable burdens: Multiply attributable fractions from Step 2 by corresponding disease burdens, and calculate attributable burdens for each disease/age/sex grouping.

Step 4, Final results: Sum attributable disease burdens calculated in Step 3 to obtain the total burden of disease from SFU. The results can also be presented on a per capita basis, by disease, and by age/sex grouping.

Since exposure-response information for SFU relies primarily on a binary classification of SFU, a local assessment should at least tally the dominant fuel types or energy services used within surveyed households and classify them into modern energy services, modern bioenergy services or other fuels. (These binary classifications should also be validated by exposure-response data based on actual particulate matter and carbon monoxide measurements.) The essential questions to be included into a survey of household energy use include:

- What are the dominant energy services used for cooking?
- What are the dominant energy services used for heating?

- Which stove types are used (improved or traditional)?
- Where is the kitchen located (indoor or outdoor)?
- How many windows are in the kitchen?
- What are the staple foods that are cooked on a daily basis?

Possible energy services would include traditional use of solid biomass (e.g. dung, charcoal, wood, or crop residues), coal, modern fuels (e.g. biogas, ethanol gel, natural gas, liquefied petroleum gas) and electricity. Where possible, the source of the electricity should be stated (e.g. coal, biomass, hydropower).

A possible approach is suggested in WHO (2004).

Anticipated limitations:

Measurement of traditional use of solid fuels (or non-commercial energy) and access to modern energy services for cooking and heating generally involves identifying households with a dependence on solid fuels or for whom these fuels represent the primary energy option. The definitions applied vary and measurement is subject to interpretation. For example, "access to electricity" could reflect different concepts, like the physical access to electricity (connectivity to the grid) or the financial access to electricity (ability to pay the electricity bill).

Practicality

Data requirements:

- number of households that depend on traditional use of biomass or other solid fuels for heating and cooking;
- number of households that make use of modern energy services, including (separately) modern bioenergy services, (e.g. biofuels, improved cookstoves, electricity from biomass) to replace traditional use of biomass or other solid fuels for heating and cooking;
- statistics on acute lower respiratory infections (ALRI) and chronic obstructive pulmonary disease (COPD).

Data sources (international and national[83]):

- proportion of population using solid fuels (WHO, 2006);
- World Health Organization Survey data center. Population data: United Nations population division estimates of the de-facto population (2002 revision);
- WHO estimates of deaths and DALYs from ALRI, COPD and lung cancer World Health Organization, Death and DALY The most important source of data on commercial and non-commercial fuel and electricity consumption is household surveys. The results of these surveys can be obtained from reports published by government statistical agencies. About two-thirds of the developing countries have conducted sample household surveys that are representative nationally, and some of these provide high-quality data on living standards. International agencies such as the United Nations Children's Fund (UNICEF) also carry out their own surveys of households. Data on household fuel and electricity consumption by average population are available from the International Energy Agency (IEA) Energy Balances of OECD Countries and Energy Balances of Non-OECD Countries;
- Indoor smoke from solid fuels: assessing the environmental burden of disease at national and local levels (Desai et al., 2004);
- Indoor air pollution from household solid fuel use (Smith et al. in WHO, 2004, chapter 18).
- Comparative quantification of health risks: global and regional burden of disease

[83] See references and electronic sources section.

attributable to selected major risk factors (WHO, 2004);

- a large amount of data and sources of data at the global, regional and national levels on energy access and health impacts of household energy use are contained in the UNDP and WHO 2009 The World Energy Assessment: Energy and the Challenge of Sustainability, by UNDP, UN DESA and the World Energy Council contains relevant data and other information regarding energy use and associated indoor air pollution and health effects.

Known data gaps:

There is currently a gap regarding the types of modern energy services that are replacing the use of solid fuels for cooking and heating. More detailed household surveys could be employed to fill this gap.

Relevant international processes[84]:

- WHO’s Programme on Indoor Air Pollution. To combat this substantial and growing burden of disease, WHO has developed a comprehensive programme to support developing countries. WHO's Programme on Indoor Air Pollution focuses on:
    - research and evaluation
    - capacity building
    - evidence for policy-makers.
- UN Millennium Development Goals (MDGs) indicators 6.9 (Incidence, prevalence and death rates associated with tuberculosis) and 4.1 (Under-five mortality rate).
- The Global Alliance for Clean Cookstoves is “a new public-private partnership to save lives, empower women, improve livelihoods, and combat climate change by creating a thriving global market for clean and efficient household cooking solutions. The Alliance’s ‘100 by 20’ goal calls for 100 million homes to adopt clean and efficient stoves and fuels by 2020. The Alliance will work with public, private, and non-profit partners to help overcome the market barriers that currently impede the production, deployment, and use of clean cookstoves in the developing world”.
- The Global Energy Assessment (GEA) is a major initiative established by the International Institute for Applied Systems Analysis (IIASA) to help decision-makers address the challenges of providing energy services for sustainable development, whilst ameliorating existing and emerging threats associated with: security of supply; access to modern forms of energy for development and poverty alleviation; local, regional and global environmental impacts; and securing sufficient investment.
- World Bank Group initiative. Its aim is to provide up to 250 million people in sub-Saharan Africa with access to non-fossil fuel based, low cost, safe, and reliable lighting products with associated basic energy services by the year 2030.
- Hedon provides descriptions of cookstoves and methods to measure efficiency and emission of cook stoves.
- UN-DESA Indicators of Sustainable Development: Percentage of population using solid fuel for cooking and share of households without electricity or other modern energy services.

References:

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[84] See electronic sources section.

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- Global Burden of Disease (GBD), http://www.who.int/healthinfo/global_burden_disease/en/index.html [Accessed September 2011].
- Global indoor air pollution database. http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=dcp2&part=A6048 This Access database on indoor air pollution, commissioned by WHO and developed by researchers at the University of California at Berkeley, aims to provide the scientific community with an overview of measured household indoor air pollution levels in about 250 communities around the world. Researchers can review and analyse findings within and across studies, and can either query the database directly or export the files into a statistical programme for in-depth analysis. [Accessed September 2011].
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Indicator 16 Incidence of occupational injury, illness and fatalities

Description:

Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors

Measurement unit(s):

Number/ha (for comparison with other agricultural activities) or number/MJ or MW (for comparison with alternative energy sources)

Relevance

Application of the indicator:

The indicator applies to bioenergy production and to all bioenergy feedstocks/pathways.

Relation to themes

This indicator is primarily related to the themes of *Air quality* and *Human health and safety*. The four components of the indicator refer to different aspects of air quality.

The indicator is primarily related to the theme of *Human health and safety*. It is also related to the themes of *Rural and social development* and *Labour conditions*. It refers to safety and health at work and can help providing a framework for assessing the extent to which workers are protected from work-related hazards and risks, which relates to sustainability of production in general terms.

This indicator and other safety and health at work indicators are usually used by enterprises, governments and other stakeholders to formulate policies and programmes for the prevention of occupational injuries, diseases and deaths as well as to monitor the implementation of these programmes and to signal particular areas of increasing risk such as a particular occupation, industry or location.[85]

How the indicator will help assess the sustainability of bioenergy at the national level:

The indicator provides data on work-related injuries, illnesses and fatalities which is a direct measure of the safety of the population employed in the industry.

By comparing rates of work-related injuries, illnesses and fatalities in bioenergy production in relation to other comparable sectors, one can assess the sustainability of the bioenergy sector at the national level in terms of safety and labour conditions.

Comparison with other energy options:

Comparison can be made with occupational injury, illness and fatalities that can occur in the energy production from fossil fuel and other energy sources.

[85] Other safety and health at work indicators are: Indicators of capacity and capability: number of inspectors or health professionals dealing with occupational safety and health; and Indicators of activities: number of trainee days, number of inspections; see electronic sources section. Other important aspects related to safety and health at work that could be measured in addition to the issues captured by this indicator are the following: machinery safety and ergonomics, handling and transport of materials, sound management of chemicals, protection against biological risks, and welfare and accommodation facilities are important components of health and safety for workers.

Scientific Basis

Methodological approach:

Usually, data on occupational injuries are collected by sector. Therefore in order to identify the incidence of occupational injuries, illness and fatalities related to bioenergy feedstock production it will be necessary to design specific modules of questionnaires, to be attached to regular labour force surveys (household surveys for labour conditions).

In addition, these specific questionnaires can be used to collect data on occupational injuries, illness and fatalities occurring in the informal part of the agriculture sector and self-employed workers (usually not gathered in national statistics).

Since data of this nature has been collected for other industries for some time, it could be possible to establish a reference for comparison.

If possible, the health of workers coming into the bioenergy industry would need to be assessed to have a more direct baseline comparison. Conceivably, the baseline health of workers in bioenergy could be better or worse than the 'national average'. In this case, workers in poorer overall health may be more susceptible to a work-related injury or illness. References on this approach can be found in the work carried out by the United States Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH) and by the International Labour Organization (ILO).

Data on occupational injuries combined with data from national statistics institutes will highlight the interaction between the injury frequency index trend and the evolution of industrial production throughout the years.

Multiple regression with log transformed rates can be adopted to model the trends of occupational fatalities for each industrial group.

Possibly, the type of work-related injury, illness and fatalities should also be reported.

Anticipated limitations:

Usually data on occupational injuries are collected by sector (for bioenergy it is mainly the agricultural sector) and it is not easy to disaggregate them for energy crops and other crops.

For practical reasons, there is a discrepancy between the number of accidents that actually occur and those that are published and analysed in reports or periodicals. Therefore, the relatively rare major accidents have a much greater probability of being registered than do the much more frequent or routine accidents that are less publicized (IAEA et al., 2005). Furthermore, workers sometimes choose not to report injuries or illnesses as work-related because of fear of losing their job.

The design of specific household surveys aimed to help the measurement of disaggregation of the impact along the different agricultural activities can be a relatively expensive approach.

Moreover the sample size has to be large enough to detect the relatively rare occurrences of occupational injuries.

It is recognized that the current state of knowledge concerning delayed health effects from accidents associated with different energy systems is limited (IAEA et al., 2005).

Practicality

Data requirements:

- hectares used for bioenergy production and total biofuel production and installed bioenergy power capacity in the country or region;
- number of work-related injuries, illnesses and fatalities reported in bioenergy production;
- number of work-related injuries, illnesses and fatalities reported in other agricultural activities and sectors;
- number of days missed due to work-related injury or illness by bioenergy production and other agricultural activities and sectors;
- type of work-related injury, illness and fatalities reported by bioenergy production and other agricultural activities and sectors.

These data can be collected from national/international statistical accounts or calculation/computation of (existing) data, when available, at the national or regional level. Alternatively they can be collected by means of interviews and surveys.

They can also be collected through hospital records relating to their emergency departments.

Data sources (international and national):

- Data on occupational injuries from national organizations for labour injury insurance. Most countries compile statistics on occupational injuries. In general these come from the administrative reports of injuries submitted to agencies responsible for compensation, labour inspection or occupational safety and health.
- About 110 countries regularly send their data to the ILO for publication in its Yearbook of Labour Statistics. ILO has also conducted many other surveys of occupational health and safety in more specific industries and regions (The International Labour Organization LABORSTA database). Current international statistical guidelines on occupational injuries are found in the “Resolution concerning statistics of occupational injuries (resulting from occupational accidents) - [ILO], adopted by the Sixteenth International Conference of Labour Statisticians in 1998.
- Methodological descriptions of the national statistics of occupational injuries disseminated by the ILO are produced and updated on the basis of information supplied by the relevant national organizations in response to special questionnaires. Information is also drawn from other sources, including national and international publications and websites, and other official documents provided to the ILO. The main aim of producing these descriptions is to provide basic information on the sources and methods used in each country in compiling the statistics of occupational injuries disseminated by the ILO, so as to enhance the usefulness of these data for different purposes, and to indicate the differences between the national series as regards their coverage, definitions, methods of measurement, methods of data collection, reference periods, etc.
- The Major Accident Reporting System (eMARS) was set up by the European Commission (EC) and is operated by the Major Accident Hazards Bureau (MAHB) at the EC’s Joint Research Centre in Ispra, Italy. The Worldwide Offshore Accident Databank (WOAD) was established by the Norwegian organization Det Norske Veritas.
- In the United States, NIOSH and CDC have several Occupational Health surveillance programs such as Work-RISQS.

Known data gaps:

In some countries, data regarding the cause of the injury or illness is already being collected upon admission to a hospital, therefore it is realistic to assume those visits due to occupational illness or injury can be reasonably monitored. However, in many countries, there is a lack of information concerning injuries and their causes, which may mean that measuring fatalities only would provide a more reliable, though much less comprehensive, indicator.

Within data collection regarding the agricultural sector a deeper analysis by crop production could be evaluated.

A possible method to collect the data is through the Hospital records for Emergency Department visits due to work-related injury or illness. This method of data collection is currently used in the US for the Work-RISQS database noted above.

Relevant international processes:

- ILO has developed and maintains a system of international labour standards. Through this work, they acquire and maintain datasets of occupational health and safety for various industries.
- The Energy Indicators for Sustainable Development, developed by the IAEA, UN DESA, IEA, Eurostat and EEA, have an indicator Accident fatalities per energy produced by fuel chain (see IAEA et al., 2005).

References:

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ECONOMIC PILLAR	
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar: 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	
INDICATOR NAME	INDICATOR DESCRIPTION
17. Productivity	▪ Productivity of bioenergy feedstocks by feedstock or by farm/plantation ▪ Processing efficiencies by technology and feedstock ▪ Amount of bioenergy end product by mass, volume or energy content per hectare per year ▪ Production cost per unit of bioenergy
18. Net energy balance	Energy ratio of the bioenergy value chain with comparison with other energy sources, including energy ratios of feedstock production, processing of feedstock into bioenergy, bioenergy use; and/or lifecycle analysis
19. Gross value added	Gross value added per unit of bioenergy produced and as a percentage of gross domestic product
20. Change in the consumption of fossil fuels and traditional use of biomass	▪ Substitution of fossil fuels with domestic bioenergy measured by energy content and in annual savings of convertible currency from reduced purchases of fossil fuels ▪ Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content
21. Training and re-qualification of the workforce	Percentage of trained workers in the bioenergy sector out of total bioenergy workforce, and percentage of re-qualified workers out of the total number of jobs lost in the bioenergy sector
22. Energy diversity	Change in diversity of total primary energy supply due to bioenergy
23. Infrastructure and logistics for distribution of bioenergy	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each
24. Capacity and flexibility of use of bioenergy	▪ Ratio of capacity for using bioenergy compared with actual use for each significant utilization route ▪ Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity

Indicator 17 Productivity

Description:

(17.1) Productivity of bioenergy feedstocks by feedstock or by farm/plantation

(17.2) Processing efficiencies by technology and feedstock

(17.3) Amount of bioenergy end product by mass, volume or energy content per hectare per year

(17.4) Production cost per unit of bioenergy

Measurement unit(s):

(17.1) Tonnes ha per year

(17.2) MJ/tonne

(17.3) Tonnes/ha per year, m^3/ha per year or MJ/ha per year

(17.4) USD/MJ

Relevance

Application of the indicator:

The indicator applies to bioenergy production and to all bioenergy feedstocks/pathways.

Relation to themes:

This indicator is primarily related to the theme of *Resource availability and use efficiencies in bioenergy production, processing, and distribution.* Productivity is a measure of output from a production process, per unit of input and can be used to measure the efficiency with which inputs are transformed into end products. This indicator focuses on the productivity of the land used to produce bioenergy, as well as the overall economic efficiency of the production, which to an extent will capture the overall efficiency of use of all inputs. The indicator is formed by four values: productivity of bioenergy feedstocks, the efficiency of feedstock processing, the overall efficiency of production of the end products (e.g. biofuels) for bioenergy purposes, and the associated production costs per unit of bioenergy. The indicator can be used to measure productivity and resource use efficiency at the farm, landscape or national level taking into account other co-products. This indicator focuses on productivity of bioenergy, rather than distribution and end-use, but these can be included where appropriate.

A more efficient use of resources increases availability of resources, reduces negative environmental impacts, and promotes economic sustainability.

This indicator also measures local bioenergy production costs in relation to those of domestic and international fossil fuels, other renewable energy sources and international bioenergy, which can help to determine whether local bioenergy is economically viable and competitive at the national level.

Note that the efficiency with which inputs such as water, fertilizers and labour are used in bioenergy production is not directly addressed by this indicator, but indirectly addressed through the final productivity measurement and production costs. Indicator 5 measures water use efficiency, indicator 6 tangentially addresses fertilizer and pesticide use efficiency, and Indicator 12 may be used to assess labour efficiency in bioenergy production.

This indicator will also inform the themes of *Greenhouse gas emissions, Productive capacity of the land and ecosystems, Water availability, use efficiency and quality, Land-use change, including indirect effects, Price and supply of a national food basket, Economic development* and *Economic viability and competitiveness of bioenergy.*

How the indicator will help assess the sustainability of bioenergy at the national level:

Increasing productivity may translate to a more efficient use of inputs, increased availability of land and other resources, and reduced burden on the environment. Decreased need of land and inputs reduces costs of production and consequently increases profits. Both aspects are crucial for the national environmental and economic sustainability.

The economic viability and competitiveness of bioenergy production, as demonstrated through productivity and cost, contribute to its overall sustainability and give an indication of the competitiveness of local bioenergy and the efficiency with which a country uses its resources to provide for its needs. They can also inform decisions about the scaling up of bioenergy production in a country.

Long-term economic sustainability is a function of long-term, steady increases in productivity (Alston et al., 2010). Productivity growth in the bioenergy sector will be closely tied to increased productivity of feedstocks, which may reflect a general rise in agricultural productivity (Ball et al., 2001).

NOTE: Increased productivity can result from using more inputs rather than using existing inputs more efficiently. Resource use efficiencies are not implicit unless best practices are adopted and over time innovations in feedstock development and processing technologies are developed and implemented. Monitoring trends in other inputs as suggested in the methodology can give a better understanding of the efficiency of inputs in comparison to the efficiency of overall production.

Comparison with other energy options:

Productivity in terms of land use does not lend itself to comparison with other forms of energy. Rather it informs choices about the use of agricultural land. Likewise the efficiency of processing of feedstock to biofuels is not generally comparable to other energy options, since such comparisons should be made on a full lifecycle basis. Hence 17.1–17.3 will generally only be of value for monitoring performance in bioenergy production and making comparison with other forms of agriculture. However, in some cases, there may be value in comparing use of land area for other energy options if these could compete with bioenergy or agriculture for this land.

Economic efficiency does lend itself to comparison across all energy types. Local bioenergy production costs can be usefully compared with the equivalent domestic and international fossil fuel and alternative renewable energy production costs in terms of US dollars per unit of useful energy output.

Scientific Basis

Methodological approach:

The data for feedstock productivity (17.1 and 17.3) and production costs (17.4) could be collected at the national (or regional) level if assessment of agricultural performance exists, otherwise through sampling (or surveys) at the field level, and subsequent aggregation. Similarly, data for the processing phase (17.2) could be collected at the national (or regional) level if reports of efficiency of biofuel production plants exist, otherwise through sampling at the processing plant level. Choice of sample size should take into consideration the degree of variation of productivity and production costs across local or national production. Methods used to analyse the productivity of the agricultural sector could potentially be generalized to analyse bioenergy feedstock productivity. For example, though their methods of analysis differ in important ways, the major agricultural productivity studies by Kendrick and Grossman (1980), Jorgenson, Gollop, and Fraumeni (1987), and Jorgensen and Gollop (1992) are potentially useful to the broader bioenergy feedstock community.

The indicator as defined relates to the productivity of bioenergy feedstocks and the efficiency of their processing, distribution, and to bioenergy production costs. However, in recognition that much bioenergy feedstock production is associated with the production of non-bioenergy feedstocks on the same land or farm (e.g. through crop rotation, intercropping, integrated crop and livestock production, landscape management, etc.), the productivity of all agricultural production on land used for bioenergy feedstock production is to be taken into account to derive the productivity of the bioenergy feedstock. The same principle could also be applied to the processing phase (e.g. through consideration of co-products).

The system boundaries for the calculations of productivity and production costs need to be clearly defined and stated in order to facilitate meaningful monitoring of trends and comparison across energy sources. Particularly for 17.2 and 17.3, it will need to be made clear whether energy losses during transmission, distribution and transportation are included. The processing method whose efficiency is measured by 17.2 should start with unprocessed feedstock in the same state as the feedstock whose productivity is measured by 17.1, so that the two figures can be combined to give a value for productivity of end products.

Although this indicator only measures the overall productivity of the land and the associated cost, an assessment of trends in productivity should also be accompanied by an assessment of trends in levels of other inputs, such as fertilizer, water, technology and labour; these inputs directly contribute to the overall productivity of the land, and are all components of the production cost.

Monitoring trends in production costs, and separately the feedstock and processing components of these total production costs, would allow an assessment of technological advances and perhaps also help identify potential for further cost reductions. Monitoring trends in the value of co-products would also inform the extent to which bioenergy production is diversifying and hence spreading risks for producers and investors and the extent to which markets for non-bioenergy products are affecting the economic viability and efficiency of the bioenergy sector.

Measuring productivity and production costs at the farm or landscape level (for feedstock production) and across all co-products (for processing), will provide a more complete understanding of the role of resource use efficiency and good agricultural practices in bioenergy production. For example, where intercropping or crop rotation is used with the intention of increasing overall productivity of a farm or plantation, the overall productivity of the farm or plantation can be taken into account, not just the productivity of the bioenergy feedstock. Even if the intercropping causes a drop in productivity of the bioenergy crop, it might cause an overall increase in productivity on the farm or plantation.

Anticipated limitations:

In many developing countries, a lack of capacity to collect and analyse the data, and a lack of capacity building to strengthen these areas, may be a limiting factor in aggregating the productivity, production cost and processing efficiency information. This may apply more to public data.

Data from international private companies operating in developing countries may be better aggregated, but may not be readily shared and available.

Production costs across the supply chain are proprietary information and not likely to be available.

The productivity of private land is proprietary information and not likely to be available.

Further, local production costs may vary widely between regions of a country and therefore a large sample may be necessary to calculate an average cost.

Practicality

Data requirements:

17.1: Average production yields of bioenergy feedstocks in the country by feedstock. Alternatively, where it is not possible to disaggregate the data, the average production yield of a crop/feedstock (not specifically intended for bioenergy) can be considered (e.g. average national production yield for rapeseed). Where intercropping or crop rotation is used, the production of the bioenergy feedstock per unit of land has to be adjusted accordingly.

17.2: Processing efficiencies of bioenergy feedstocks into end products. Processing efficiencies of bioenergy feedstocks need to capture the transformation of feedstocks into liquid fuels and/or heat and/or electricity by technology and by feedstock.

17.3: Amounts of bioenergy produced and the land area used to produce this energy. Bioenergy and/or feedstocks measured in energy, mass or volume as is most appropriate to the type of bioenergy. Overall bioenergy end product production efficiency and/or data on efficiency of transmission, distribution and transportation, if it is desired to include these phases of the lifecycle rather than just feedstock production and processing.

17.4: Local and/or domestic bioenergy production costs per energy unit.

These data can be collected through national/international statistical accounts or calculation/computation of existing data, gathered at the national, regional, field (farming) or site (processing plant) level.

Data sources (international and national)[86]:

- production yields of agricultural crops are provided for main crops and countries by FAOSTAT;
- IEA World Energy Outlook;
- national or sub-national databases of ministries of agriculture, energy, industry, finance, etc. ;
- national statistics institutes;
- national and regional bioenergy industry associations/chambers;
- the Sun Grant Initiative works with the Biomass Program of the United States Department of Energy Efficiency and Renewable Energy to develop and implement a Regional Biomass Partnership to address barriers associated with the development of a sustainable and predictable supply of biomass feedstocks. .

Known data gaps:

Data collection from individual biofuel production plants (surveys) may be necessary in some cases.

Relevant international processes:

- Conversion Efficiencies: Energy Indicators for Sustainable Development: Guidelines and methodologies (IAEA. 2005).
- The U.S. Department of Agriculture (USDA) has been monitoring agriculture productivity as a function of land and inputs for decades. The various means data collection and modes of analysis are relevant to countries seeking put into place their own data collection and analysis programs. USDA estimates land used on the basis of county-level data obtained from the Census of Agriculture86, which is the primary source of data of U.S. agriculture. USDA recently started collecting data regarding on-farm energy production including anaerobic digesters.

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[86] See electronic sources section.

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- USDA On-Farm Energy Survey. http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/On-Farm_Energy_Production/index.asp [Accessed October 2011].

Indicator 18 Net energy balance

Description:

Energy ratio of the bioenergy value chain with comparison with other energy sources, including energy ratios of

(18.1) feedstock production,

(18.2) processing of feedstock into bioenergy,

(18.3) bioenergy use; and/or

(18.4) lifecycle analysis

Measurement unit(s):

(18.1) ratio

(18.2) ratio

(18.3) ratio

(18.4) ratio

Relevance

Application of the indicator:

The indicator applies to bioenergy production, conversion and use, and to all bioenergy feedstocks, end-uses, and pathways.

Relation to themes:

This indicator is primarily related to the theme of R*esource availability and use efficiencies in bioenergy production, conversion, distribution and end-use*. Production of bioenergy requires energy as an input at different steps of the value chain. Primary energy needs of bioenergy production may be met through consuming fossil and/or renewable energy.

The net energy ratio (i.e. ratio of energy output to total energy input) is a useful indicator of the relative energy efficiency of a given pathway of bioenergy production and use.

The more energy consumed during the bioenergy lifecycle, the less energy is available to meet other energy needs. Efficient use of energy is essential for improving energy security and for optimizing the use of available natural resources. Energy inputs to the bioenergy production process sometimes come from hydrocarbons; therefore, a high net energy ratio will indicate efficient use of these non-renewable resources.[87] Furthermore, since energy requirements (for both feedstock production and processing) can contribute significantly to bioenergy production costs, this indicator is linked to economic efficiency, as measured through production costs in Indicator 17 (*Productivity*). This indicator will also inform the themes of *Greenhouse gas emissions, Access to energy, Economic viability and competitiveness of bioenergy,* and *Energy security/Diversification of sources and supply.*

How the indicator will help assess the sustainability of bioenergy at the national level:

A net energy ratio greater than one for the combined production, processing and use of a given bioenergy feedstock indicates that its production is sustainable from an energy perspective. In other words it indicates that the quantity of energy that the biofuel can provide is higher than the amount of energy needed for its production. In many cases, the net energy balance will represent the extent to which the bioenergy displaces fossil fuels, which is another clear indication of its contribution to sustainable development (see Indicator 20, *Change in the consumption of fossil fuels and traditional use of biomass*).

[87] This aspect of net energy balance is addressed more fully in Indicator 20 (*Change in the consumption of fossil fuels and traditional use of biomass*).

The indicator provides a basis for identifying the most energy efficient ways to produce bioenergy among a given set of options and may be used to select appropriate feedstocks, technologies and practices. Looking at the three lifecycle phases of production, processing and use separately will inform potential improvements in the energy efficiency of both agricultural and industrial practices involved in the production and use of bioenergy.

Note: Implicit in the indicator is that different countries will be producing and consuming bioenergy in very different ways. In some countries transport and power will be the predominant uses of bioenergy. However, this is unlikely to be the case in many regions of the world where traditional biomass is used for household purposes such as cooking and lighting. In some developing countries the main use of bioenergy will take place at the household level, and this could be considered as the only relevant level for analysis.

Comparison with other energy options:

The net energy ratio and balance of diverse types of bioenergy can be compared to other relevant energy types depending on downstream use. Biofuels for transport should be compared with fossil fuels and/or electric vehicles. Bioenergy for electricity, such as that produced by anaerobic digesters, should be compared with electricity production from *inter alia* fossil fuels, solar cells and wind.

Average efficiencies of fossil fuel refineries could be compared with bioenergy processing plants. The average energy efficiency of internal combustion engines of the national car fleet and of national bioenergy plants for heat and power generation could be compared to fossil fuels alike.

Other energy comparisons are contingent on available datasets or methods of estimation. The overall lifecycle energy ratio could be assessed for the fossil fuel or alternative energy option, and embedded energy inputs (e.g. the energy required to extract, refine/process and transport or distribute fossil fuels)should be considered for a comprehensive comparison.

Scientific basis

Methodological approach:

The indicator can consist of a single value corresponding to the lifecycle energy ratio of the chain considered and/or a set of values for each step of the chain, including the efficiency of the feedstock production, processing and end-use of biofuels, etc.

The energy output is calculated by assessing the bioenergy use under consideration. The energy input is estimated by summing all energy required at each stage of bioenergy production and use using available data, and models if needed (see for example Liebbrandt et al., 2011). If bioenergy feedstock production is integrated with other non-energy productions (e.g. intercropping) this value should be adjusted accordingly. Feedstock energy content is currently characterized by the assumed conversion value for the material within each primary biofuel product pathway. Energy impacts of feedstock losses throughout supply and conversion are subsequently accounted for in this way. Current efforts to investigate and develop distributed processing concepts are also developing comprehensive mass and energy balance tracking in order to facilitate rigorous understanding of direct feedstock energy content throughout the bioenergy system.

The presence of water (H_2O) in biomass complicates the comparison of different sources of bioenergy and the comparison of biomass to non-water containing fuels. For the sake of consistency, the lower heating value (LHV) of inputs and outputs should be considered in order to compare different combustion processes. The lower heating value assumes that the end state of the water in the fuel is water vapour, as opposed to liquid water. The transition from vapour to liquid releases more heat, but this heat is rarely captured and put to good use. Energy content of fossil fuel inputs should be reported. The range of energy sources considered in the calculation of the energy input should also be stated.

The methodology for co-product allocation and input energy values (e.g. energy required for fertilizer or seed production) should be transparent and based on a well known methodology for LCA. To this end, the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy is recommended as a reference and common basis to explicitly identify the assumption made and the steps covered in the bioenergy production chain. The data could be collected at the national level if assessment on agricultural performance exist, or alternatively through sampling at the field level and subsequent aggregation. The United States Department of Energy has developed the Greenhouse gas, Regulated Emissions, and Energy use in Transportation (GREET) model to assess lifecycle greenhouse gas emissions associated with various transportation fuels (see Data Sources). The GREET model also reports on energy use, i.e. output, and so can provide useful insights into evaluating bioenergy use (18.3) and lifecycle analysis (18.4).

Similarly, the data for the processing of feedstock into bioenergy (18.2) phase could be collected at the national (or regional) level if reports on efficiency of biofuel production plants exist, otherwise at the processing plant level. The U.S. Department of Energy produces design reports to better understand the current state of conversion technologies and to identify where improvements need to take place in the future (see Data Sources). Likewise information about bioenergy use could consider a representative sample of the country's bioenergy power plants, while information about the car fleet can be collected by private or public surveys.

Although in this indicator we suggest use of the net energy ratio for measuring the energy efficiency of a bioenergy system, additional value may be gained from including the net energy value (sometimes also called energy balance, net energy or net energy gain). A useful reference on calculating and using the energy balance (net energy value = energy output – energy input) is provided in the Energy and Resource Group Biofuel Analysis Meta-Model (EBAMM) (Farrell et al., 2006).

Anticipated limitations:

Variations in the definition of system boundaries for the net energy ratio calculation and the use of alternative metrics such as net energy balance and net energy yield could hinder comparisons. The suggestion is to use peer-reviewed methodologies for calculations, including the method used for co-products allocation, clearly specifying which methodology has been used for the calculation of net energy ratios, adopting the approach of the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy as a basis for a means to transparently report the assumptions made and the steps covered in the bioenergy chain.

Furthermore, a difference between energy and GHG LCA is worth noting: different sources of energy (e.g. solid and liquid fuels) have different uses and different (often locally dependent) values to society. However, this indicator (if measured in its simplest form) measures only energy output/energy input without differentiating between the various forms of energy in this equation.

Practicality

Data requirements:

The three main blocks of the bioenergy value chain identified in the brief description, production, processing and use should be calculated on a common basis taking into consideration

(1) Ratio of energy inputs (primary energy) required for the production of harvested feedstock (e.g. fertilizers production and application, chemicals, labour and embedded energy in machinery) to energy content of one unit of feedstock (ready to be processed) and associated co-products.

(2) Ratio of energy content of biofuel and co-products produced to energy content of feedstock input.

(3) Average energy efficiency of internal combustion engines of the national car fleet and of national bioenergy plants (for heat and power generation) or other approximation as convenient (with rationale).

In more detail, the following data are required:

18.1:

- feedstock agricultural yields (tonne/ha);
- primary energy inputs per unit of feedstock produced (MJ/tonne);
- indirect energy (e.g. embedded in machinery) per unit of feedstock produced (MJ/tonne).

18.2:

- energy content of the feedstock produced/processed (if the previous measurements are not available) (MJ);
- energy efficiencies of conversion plants (sample).

18.3:

- energy content of the bioenergy source considered (MJ);
- segmentation of national car fleet and relative efficiencies;
- efficiencies of a representative sample of national bioenergy power plants, as reported by plant owners.

These data can be collected through national/international statistical accounts when available or alternatively through computation of (existing) data, physical, biological or chemical measurements or interviews and surveys at the national, regional, field (farming) or site (processing plant) level.

Data sources (international and national)[88]:

- The Energy Balance of Corn Ethanol (USDA, 2002);
- United States Department of Agriculture's Economics Research Service: Agricultural Productivity in the United States;
- United States Department of Energy Information Administration (EIA) publishes the thermal conversion factors that it uses to estimate gross heat content in British Thermal Units (Btus) of a given amount of energy measured in physical units. EIA's conversion factors for fuel ethanol and biodiesel can be found at EIA webpage;
- United States Department of Energy Biomass Program produces design cases that assess the energy content of biofuels produced. An example can be found in NREL (2007, p. 33);
- GREET Model Documentation;
- if possible, national and international reports about efficiency of car fleet, efficiencies of bioenergy plants, and national assessments on agricultural performance, can be used as ready-available data sources.

Known data gaps:

GREET or similar models could be used to estimate the energy of the final product on the basis of information about energy content of other inputs. Other alternatives include monitoring conversion facility performance data, monitoring feedstock production management data, and monitoring end use data such as vehicle mileage.

Relevant international processes:

Energy and Resource Group Biofuel Analysis Meta-Model (EBAMM) developed by the University of California, Berkeley

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Indicator 19 Gross value added

Description:

Gross value added per unit of bioenergy produced and as a percentage of gross domestic product

Measurement unit(s):

US$/MJ and percentage

Relevance

Application of the indicator:

The indicator applies to bioenergy production and use and to all bioenergy feedstocks/end uses/pathways.

Relation to themes:

This indicator is primarily related to the theme of *Economic development*, which is defined by the World Bank as qualitative change and restructuring in a country's economy in connection with technological and social progress. One of the most commonly used indicators of economic development is Gross Domestic Product (GDP) per capita, which measures the level of total economic output of a country relative to its population and to a degree, reflects the standard of living of the country's population.

Economic development is closely linked with economic growth, defined by the World Bank as quantitative change or expansion in a country's economy. Economic growth is often conventionally measured as the annual percentage increase in GDP[89]. Economic growth comes in two forms: an economy can either grow "extensively" by using more resources (such as physical[92], human[92], or natural capital[92]) or "intensively" by using the same amount of resources more efficiently (productively). When economic growth is achieved by using more labour, it does not result in per capita income growth. But when economic growth is achieved through more productive use of all resources, including labour, it results in higher per capita income and improvement in people's average standard of living[92]. Intensive economic growth requires economic development[92]. Intensive and extensive growth interacts in complex ways to produce changes in the economy.

Gross value added (GVA) is defined as the value of output less the value of intermediate consumption and is a measure of the contribution to GDP made by an individual producer, industry or sector. GVA provides a monetary value for the amount of goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production. This indicator will also inform the theme of *Economic viability and competitiveness of bioenergy*.

How the indicator will help assess the sustainability of bioenergy at the national level:

The indicator shows the size of the contribution of the bioenergy sector to the national economy. The indicator also shows the contribution to GDP per unit of bioenergy. This allows for more informative comparison with other forms of energy.

It may be difficult to define whether GVA and changes in GDP will necessarily lead to economic development, and moreover, to sustainable development; this may be in part addressed by calculating net change in value added (as described as an extension to the methodology) on a regional basis. In addition, the degree to which the contribution of bioenergy to GDP results in

[89] these terms are defined by the World Bank in their Beyond Economic Growth Student Book glossary – see electronic sources section.

extensive or intensive economic growth should be taken into account (GVA per member of the bioenergy workforce may be informative in this regard.) However, the user of these indicators can make their own assessment, given the stage of economic development of their country, as to the link between increasing GDP and economic development, taking into account other factors. The indicator should be complemented by a system of environmental-economic accounting (or green accounting), as described below.

Comparison with other energy options:

Comparison can be made with the GVA of any industry and energy source.

Scientific Basis

Methodological approach:

The following definition is adopted for the purpose of this indicator (see UN, 2009) :

- Gross value added = Total output value - Intermediate inputs

Bioenergy producers would be surveyed regarding their production accounts. The methodological approach would include defining the bioenergy value chain. If this includes the feedstock production phase, calculating the GVA of the bioenergy sector (i.e. its contribution to the economy) requires determining which agricultural feedstock production is destined for bioenergy production, or making simplifying assumptions to allow this disaggregation to be made (e.g. if 10% of one crop produced in the country is used for bioenergy, so 10% of the GVA by those producing this crop counts towards bioenergy).

Three main extensions to the methodology are possible, dependent on a country's chosen system of national accounts:

Net value added (NVA): Value added and GDP may also be measured net by deducting consumption of fixed capital, a figure representing the decline in value during the period of the fixed capital used in a production process.

Green accounting: The conversion of natural resources (natural capital) into financial gains is rewarded in GDP with no accounting for the depletion of these natural resources. For this reason, in green accounting, net domestic product (NDP, for a country) or net value added (NVA, for a sector or region) is used, where the depreciation of fixed capital – including natural capital such as fossil fuel reserves, land and forests – is subtracted from GDP or GVA. So while GVA for the bioenergy sector is proposed as a good measure of the short-term contribution to economic development of the bioenergy sector, NVA could be estimated and compared with the NVA of other energy sources. For the calculation of NVA under green accounting, disaggregation of changes in land quality (land degradation or improvement, deforestation, afforestation, reforestation, etc.) and therefore in value or stocks of natural capital caused by bioenergy production as opposed to other causes is required.

Net Change in Value-Added: This version of the indicator would be an aggregate measure of economic contributions from bioenergy production to a given region. The indicator would require estimation of total gross value-added (or any of the above extensions) for the region of interest. In addition, a valid baseline value for the scenario without the change in bioenergy production since the previous measurement (or reference period) would also be estimated. The net change in value-added measure is then the difference between the "with new bioenergy production" and the baseline ("without new bioenergy production") estimates. These estimates may be based on an aggregation of individual sector estimates, but could also be compiled on the basis of the type of aggregate data that is likely to be more readily available at the national/sub-national level. This measure nets out changes in other sectors of the economy that accompany bioenergy production in estimating the overall valued added contribution of the bioenergy sector to the regional economy. This regional measure may also be adjusted for balance of transfer and other changes in international flows and stock of assets. Possible approaches this measurement are described in Wicke et al. (2009) and Arndt et al. (2008).

Anticipated limitations:

Gross value added can be obtained quite simply once the appropriate accounting system is put in place.

Methodological limitations include the lack of accounting for changes in natural capital stocks if NVA under green accounting is not adopted (see above). This is particularly important if a longer-term view is desired, particularly with regard to a comparison between renewable and non-renewable forms of energy. Estimation of the depreciation of natural capital is a rather complicated exercise, though simple tools have been created by e.g. FAO and the World Bank (see references) and work is ongoing on a System of Environmental-Economic Accounting (SEEA), along with a specific SEEA for Energy, which together will represent an international statistical standard regarding so-called green accounting.

The calculation of the GVA of the bioenergy sector does not show the contribution to the national economy due to induced economic activity as a result, for example, of the spending of wages by those working in the bioenergy sector.

Limitations in data will arise when trying to measure inventory and own consumptions, but approaches for inputting these values using simplifying assumptions may be used to supplement available information.

Practicality

Data requirements:

- total output value = change in inventories + sales revenues + own final consumption
- intermediate inputs

Note that if measuring NVA, depreciation of fixed capital would be an additional data requirement.

These data, to be collected at the national level, can be gathered from national/international statistical accounts or through interviews and surveys.

Data sources (international and national):

- national accounts;
- national accounts from international sources including the World Bank, International Monetary Fund, and the United Nations.

Known data gaps:

Data gaps can be overcome using data collection strategies implemented by national statistic institutes, ministries of energy, finance (or equivalent), agriculture (or equivalent), regional governments, national bioenergy chambers, national central banks, etc. A value chain analysis system may need to be established prior to data collection in countries where this kind of accounting is not done.

Relevant international processes[90]:

The World Development Indicators (WDI) collected by the World Bank based on data from international sources includes information on income measures mainly at the national level.

The System of Environmental-Economic Accounting (SEEA) is a framework to compile statistics linking environmental statistics to economic statistics.

The Economics of Ecosystems and Biodiversity (TEEB) study is a major international initiative to draw attention to the global economic benefits of biodiversity and costs of biodiversity loss.

[90] See electronic sources section.

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- WDI. http://data.worldbank.org/data-catalog/world-development-indicators [Accessed September 2011].
- World Bank.Beyond Economic Growth Student Book glossary. http://www.worldbank.org/depweb/english/beyond/global/glossary.html [Accessed September 2011].

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

Description:

(20.1) Substitution of fossil fuels with domestic bioenergy measured by energy content (20.1a) and in annual savings of convertible currency from reduced purchases of fossil fuels (20.1b)

(20.2) Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content.

Measurement unit(s):

(20.1a) MJ per year and/or MW per year

(20.1b) USD per year

(20.2) MJ per year and/or MW per year

Relevance

Application of the indicator:

The indicator applies to bioenergy production and use and to all bioenergy feedstocks, end-uses and pathways.

Relation to themes:

This indicator is primarily related to the theme of *Economic development* and is also closely related to *Energy security/diversification of sources and supply* and *Rural and social development* (Sagar and Kartha, 2007). The use of locally produced biomass for bioenergy can displace the consumption of fossil fuels and/or traditional use of biomass for energy, which would have significant positive impacts on the economic development and energy security of a country or region.

Reducing the consumption of imported fossil fuels can bring about savings in convertible currency. For low-income, developing countries, these savings could lead to increases in reserves of convertible currencies. The level of convertible currency reserves is relevant to sustainable economic development of many countries, particularly low-income countries, since it provides the means to purchase imports and to protect the value of their currency. The financial stability of a country is used to determine its credit rating and greater reserves may facilitate borrowing, which may contribute to sustainable development. As such, using bioenergy to reduce the consumption of fossil fuels can create positive feedback that could have far-reaching impacts on a countries economic security and potential for development. Furthermore, public savings from avoided fossil imports could be diverted to promote development locally through investments in infrastructure, education, sanitation, and other essential services.

Depending on the country context producing bioenergy may be either more or less expensive than importing fossil fuel. These relative production costs, investment costs, and the cost of building the infrastructure necessary for a vibrant bioenergy sector should be considered when calculating the effects on savings in convertible currency. As such, this indicator should be evaluated in relation to Indicator 17 (*Productivity),*Indicator 23 (*Infrastructure and logistics for distribution)* and Indicator 24 (*Capacity and flexibility of use of bioenergy)*.

Replacing traditional use of biomass with modern bioenergy will bring a wide range of benefits for social and economic development, particularly in rural areas. It is therefore related to the themes of *Access to energy* and *Human health and safety* in addition to the themes mentioned above. The indicators relevant to these themes include Indicator 14 (*Bioenergy used to expand access to modern energy services)* and Indicator 15 (*Change in mortality and burden of disease attributable to indoor smoke)*.

This indicator is also closely related, particularly in terms of data requirements, to Indicator 18 (*Net energy balance*). Since this indicator measures the extent to which modern bioenergy substitutes fossil fuels and traditional use of biomass at the national level, it will also inform an assessment of the consequences of this change in the energy mix of a country in relation to all the themes and indicators for which a comparison between modern bioenergy and these displaced forms of energy is undertaken.

How the indicator will help assess the sustainability of bioenergy at the national level:

Reducing the consumption of fossil fuels and traditional use of biomass gives an important overview of the extent and pace of a transition to modern bioenergy and hence informs the overall assessment of the contribution of bioenergy to sustainable development at the national level (Gehlhar et al., 2010).

More specifically, annual savings in convertible currency due to the substitution of fossil fuels with bioenergy will give an indication of whether and to what extent the country is economically better or worse off due to this substitution. In order to make this assessment, savings in convertible currency should be interpreted in light of both the overall impacts on the monetary costs of their energy supply, taking into account the relative costs of producing or purchasing bioenergy and fossil fuels, and the special value of convertible currency (vis-à-vis the national currency) to the country and its economic development.

Comparison with other energy options:

Comparison can be made with other renewable energy sources for both 20.1 and 20.2 by applying the same approach as for modern bioenergy. The indicator already involves a comparison with fossil fuels and traditional use of biomass for energy. Comparison between different types of bioenergy is also possible.

Scientific basis

Methodological approach:

20.1

a) Quantity of fossil fuel energy substituted

A simple means to approximate the amount of energy from fossil fuels that has been substituted with domestic modern bioenergy, would be to use the following formula for each imported type of fossil energy (i):

$E_{fossilsub\ i} = E_{bioenergydom}$ X(1 – 1/NER_i),

where:

- $E_{fossilsub\ i}$ is the amount of fossil fuel energy, disaggregated by fossil fuel type, substituted by modern domestic bioenergy in the country;
- $E_{bioenergydom}$ is the amount of domestically produced modern bioenergy consumed in the country; and
- $NER_{dom\ i}$ is the (national average) net energy ratio for domestically produced modern bioenergy consumed in the country disaggregated by fossil fuel type and calculated according to the methodology sheet for Indicator 18, Net energy balance, and using only fossil fuel inputs for the energy input term (net energy ratio = energy output/energy input).

The aggregate of $E_{fossilsub\ i}$ measurements will equal the total fossil fuel substitution, though the individual values may be more informative. The substitution measurement may be disaggregated into the different types of fossil fuel e.g. oil and petroleum products, coal and natural gas, and electricity in the calculation. Note that this approach assumes that modern bioenergy is only displacing fossil fuels and not other forms of renewable energy.

New bioenergy production and use does not always displace current fossil fuel consumption, but sometimes assists in meeting new energy demand. The bioenergy is then displacing growth of fossil fuel consumption and associated costs. In order to determine the marginal form of energy whose consumption was displaced by bioenergy, a projected baseline of national energy consumption without this additional bioenergy would be required.

Furthermore, new bioenergy production can create additional energy demand. More sophisticated analysis would therefore involve estimating the extent to which domestic bioenergy production had resulted in an increase in total energy consumption through exerting downward pressure on energy prices (the so-called "rebound effect").

b) Annual savings in convertible currency

As stated above, countries can identify and estimate the types and quantities of imported fossil fuels displaced by the domestic production and use of bioenergy, assuming that imports rather than domestic production of fossil fuels are displaced. These quantities can then be multiplied by the average purchase cost (in US dollars) of the respective fuel or electricity over the year under consideration and summed to give annual savings in convertible currency due to the displacement of fossil fuel imports.

Where inputs are imported to produce domestic bioenergy, the value calculated as described above will not truly reflect the actual savings in convertible currency as a result of substituting domestic bioenergy for fossil fuels. This is because only the cost of the fossil fuel required to produce these inputs is included in this calculation. Therefore, if significant quantities of convertible currency are used to purchase inputs (e.g. fertilizer, feedstock or methanol), a comparison between the purchase prices of these inputs and their embedded fossil fuel should be made and the difference subtracted from the annual savings calculated as described above.

c) Aggregation

National-level aggregation could be done by fuel type or sector (heat, power, transport). Aggregation at the level of sub-national regions (e.g. using data from provinces or local/regional chambers of commerce) might be appropriate if bioenergy production practices or marginal energy sources displaced by bioenergy differ significantly on a regional basis.

d) Possible extensions to the scope of the indicator

The scope of the indicator focuses on the changes in the domestic use of fossil fuels and traditional use of biomass for energy as a result of domestically produced modern bioenergy. GBEP Partners agreed to develop these indicators as trade neutral; therefore, assessing the effect of exports of bioenergy, while important, is beyond the scope of this indicator. Nevertheless, exporting bioenergy could play an important role in promoting economic development, particularly in low-income countries, by generating revenue in convertible currency that can be invested in local sustainable development. In addition, exporting bioenergy, could, in some cases, make the domestic bioenergy sector economically viable. As such, the relevant data would be earnings from bioenergy exports.

20.2

Quantity of traditional use of biomass energy substituted

This calculation is focused on cooking and heating at the household level. In order to derive an accurate measure of this quantity, a thorough analysis of the substitution of traditionally used biomass by modern domestic bioenergy is necessary, ideally from household survey data.

Alternatively, an approximation may be derived using data from Indicator 14 (Bioenergy used to expand access to modern energy services), particularly measurement 14.1: quantity of modern bioenergy used to expand access to modern energy services. See methodology 14.1 to calculate this initial value. The quantity of substituted traditionally used biomass energy differs from 14.1 in the following ways:

- If modern bioenergy is used to expand access to modern energy services, it can be assumed at the household level, that this would displace traditional use of biomass energy, in addition to displacing fossil energy used in the household (20.1), thus it follows that the quantity of traditionally used biomass energy substituted is equal to the quantity of new modern bioenergy (14.1) less the quantity of fossil fuel energy displaced.
- There may also be situations in which modern bioenergy only partially substitutes use of traditional bioenergy, so the amount of traditional biomass for energy substituted is equal to the amount of modern bioenergy.
- Modern bioenergy may also completely substitute traditional biomass for energy and also provide additional energy, so the amount of traditional biomass for energy substituted is

equal to the amount of traditional biomass for energy used.

Anticipated limitations:

The measurement of the indicator can be limited by:

- lack of accounting for bioenergy products not traded in formal markets or for trade in off-grid rural areas; and
- different assumptions about the ratio of bioenergy consumption to fossil fuel displacement and to changes in imports.

Practicality

Data requirements:

- consumption of domestically produced bioenergy, by bioenergy end product (MJ or MWh)
- net energy ratio of domestically produced bioenergy, disaggregated by energy input source for each imported energy source used in the domestic production of bioenergy
- marginal energy source displaced due to bioenergy consumption, by bioenergy end product (%)
- energy import prices (US$ per MJ or MWh)
- cost of inputs imported to produce bioenergy (millions of US$ per year)
- foreign exchange reserves (millions of US$) (if it is desired to express the annual savings in convertible currency as a percentage of total reserves)
- historical consumption of traditionally used biomass energy at the household level (MJ or MWh)

These data can be gathered from national/international statistical accounts or calculation/computation of (existing) data at the national level.

Data sources (international and national):

Data could be available from national government's assessments and reports.

Known data gaps:

If data is not available, countries would need to track of convertible currency incomes/outflows for bioenergy and fossil fuel as part of their Gross National Income statistics.

Relevant international processes:

References:

- ERIA. 2007. *Investigation on Sustainable Biomass Utilization Vision in East Asia* .Research Project Report 2007 No. 6-3. available at http://www.eria.org/research/images/pdf/PDF%20No.6-3/No.6-3-4%20Chap%203%20Bioamss.pdf [Accessed November 2011].
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Indicator 21 Training and re-qualification of the workforce

Description:

(21.1) Share of trained workers in the bioenergy sector out of total bioenergy workforce, and

(21.2) share of re-qualified workers out of the total number of jobs lost in the bioenergy sector

Measurement unit(s):

Percentage (per year)

Relevance

Application of the indicator:

The indicator applies to bioenergy production and use and to all bioenergy feedstocks/end-uses/pathways.

Relation to themes:

The indicator is primarily related to the theme of *Access to technology and technological capabilities*. It provides information about the quantity as well as the level of training of the bioenergy sector workforce. A trained worker is defined as a worker who has been trained in a workshop or training courses. It gives information on the skills and training provided to the bioenergy workforce which directly reflects the "technological capabilities" component of the theme. It also reflects the ability of these workers to be re-employed by the bioenergy or other sectors. The indicator also measures the degree to which workers who have lost their jobs in the bioenergy sector as a result, for example, of mechanization of harvesting, are re-qualified and therefore have the opportunity to obtain new employment. The indicator is also strongly related to the theme of *Rural and social development* (and particularly connected with Indicator 12, *Jobs in the bioenergy sector*) and is indirectly related to other themes such as *Labour conditions, Human health and safety*, and *Economic development*.

How the indicator will help assess the sustainability of bioenergy at the national level:

The indicator helps to assess the share of the national bioenergy workforce that had access to education/training for activities in the bioenergy sector.

It will also help to assess the capacity for re-employment of the workforce and; therefore, how new and less labour-intensive technologies and techniques can be absorbed by the local labour market.

A trained and skilled workforce will facilitate the absorption of new technology and provide an enabling environment for its deployment in a country.

It is worth noting that this indicator addresses mainly those countries where the bioenergy industry has been modernized, including harvesting processes. In many developing countries, where bioenergy projects are still to be introduced or under development, job creation can be expected in the short term, not the immediate reduction of unqualified jobs. This means these countries will need support in qualifying workers to the needs of their developing bioenergy industry.

Comparison with other energy options:

Similar analysis could be done for the workforce in the fossil-fuel equivalent industry as well as for workforce in other renewable energy sectors.

Scientific basis

Methodological approach:

21.1: The workforce includes jobs as defined in Indicator 12 (*Jobs in the bioenergy sector*): wage and salaried workers; self-employed workers; and contributing family workers. A trained worker is defined as a worker who has received any training for activities in the bioenergy sector including in a workshop, training course, certification programme, or received a degree from a technical school or higher education institution. Training that addresses bioenergy should be considered. General training on renewable energy and agricultural techniques should be considered if they relate directly or indirectly to bioenergy development. If these data have not been collected at the governmental level, a survey could be undertaken involving companies that are working in the bioenergy production (including feedstock production, processing and use industries), considering a balanced assessment among these three steps of the value chain. Each company will report information about the number of trained workers in the previous 'n' years out of total workers.

21.2: The number of workers that have been re-qualified for other jobs after having lost their job in the bioenergy sector (including seasonal workers who lost their jobs due to mechanization or other changes in bioenergy production and processing). Re-qualification of these workers can have been done through national training programmes. This information can be collected in countries where such programmes exist. This value is an annualized percentage of the change of the number of workers (including seasonal) over the defined number of years used for measurement of the indicator.

Local and regional governments, as well as association of bioenergy producers could also be a source of data to build this indicator.

Anticipated limitations:

If data from government or companies are not readily available, the cost of conducting the surveys/interviews and the coverage of the entire workforce in the bioenergy sector needs to be taken into consideration.

Practicality

Data requirements:

21.1:

- number of employed workers in the bioenergy sector (per year);
- number of workers in the bioenergy sector that have been trained in workshops or training courses (per year);
- number of workers that took part in the survey.

21.2

- number of re-qualified workers from the bioenergy sector (per year);
- number of job lost in the bioenergy sector (per year).

These data can be gathered through national/international statistical accounts at the national level (if possible) or alternatively through interviews and surveys at the field (farming) or site (processing plant) level.

Data sources (international and national):

National statistical institutes and other government databases (e.g. United States Bureau of Labor Statistics, 2010)

Known data gaps:

Data gaps can be filled undertaking surveys in selected areas of the bioenergy production and use chain (equally spread according to a criterion to be agreed, e.g. territorial distribution).

Realistically some data could be collected at the ministerial level and could also indicate the number of events (on bioenergy technology) where the ministry participated to some extent (funding, co-funding, participating in or promoting the event).

Relevant international processes:

References:

- Clean Energy Council. 2009. Australian Renewable Energy Training and Workforce Strategy for 2020: Renewable Energy Training in Australia 2009. Available at http://www.cleanenergycouncil.org.au/cec/resourcecentre/reports.html [Accessed September 2011].
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Electronic sources:

- Bureau of Labor Statistics. 2010. 2008-18 National Employment Matrix, industry employment by occupation. U.S. Department of Labor 2010. Available at http://www.bls.gov/emp/ep_table_108.htm [Accessed September 2011].

Indicator 22 Energy diversity

Description:

Change in diversity of total primary energy supply due to bioenergy

Measurement unit(s):

Index (in the range 0-1)

MJ bioenergy per year in the Total Primary Energy Supply (TPES)

Relevance

Application of the indicator:

The indicator applies to bioenergy production and use, and to all bioenergy feedstocks, end uses, and pathways.

Relation to themes:

This indicator refers primarily to the theme of *Energy security/Diversification of sources and supply.*

The UN Development Programme World Energy Assessment defines energy security as "the availability of energy at all times in various forms, in sufficient quantities and at affordable prices without unacceptable or irreversible impact on the environment".

There are several inter-related aspects associated with energy security. These include:

- Availability – are the required energy sources physically available?
- Accessibility – can the energy supplies be delivered taking into account both physical and geopolitical aspects?
- Adequacy of capacity – is there sufficient capacity to produce deliver, distribute and use the energy?
- Affordability – can the energy be delivered at a price which is acceptable?
- Environmental sustainability – can unacceptable or irreversible impacts on the environment be avoided?

Given the number of factors considered under this heading, and their complex interrelationships it is not surprising that there is no single indicator for energy security. One approach is to look at how potential interruptions to energy supply can be minimized, using a risk management approach. An important part of that approach is to consider how a diverse set of energy sources can reduce the risks of supply interruption and this indicator focuses on this aspect of energy security. This indicator provides a metric for measuring changes in diversity of energy supply, and the more diverse the supply, the higher the level of energy security, all other things being equal.

Bioenergy can make a contribution to a country's energy security by improving the diversity of supply options and so insulating the country against supply interruptions and price hikes, either by producing and using bioenergy produced indigenously or through imports.

The rationale of this indicator is that the contribution of bioenergy to energy security cannot be assessed in isolation, since it depends on the other elements of the supply mix.

In addition a more diversified mix of bioenergy sources provides comfort that this component of the energy mix will itself be more secure. The higher the number of bioenergy sources, the more diversified and secure the mix of supply.

In addition to the closely related theme of *Energy security/Infrastructure and logistics for distribution and use*, this indicator will also inform the theme of *Economic development.*

How the indicator will help assess the sustainability of bioenergy at the national level:

The comparison of energy diversity with and without bioenergy provides a measure of the impact of bioenergy on diversity. Likewise, examination of the diversity of bioenergy sources will give an indication of how robust these supplies are.

The analysis shows the role of bioenergy in enhancing energy diversity. The impact on the index is greater in cases where other energy diversity is low. Where biomass has a share that is greater than other sources, an increase in bioenergy's share may actually decrease diversity, according to this measure. However, further consideration may show that having such a high bioenergy contribution may contribute to energy security in other ways and may contribute to other aspects of sustainability.

By knowing the sources and volumes of the major components of bioenergy supply, the degree of diversity of the bioenergy component can be assessed. Again, all other things being equal, the more diverse the sources of bioenergy in the total primary energy supply mix, the more sustainable the mix.

However, the multidimensional nature of energy security means there can be no 'one-size-fits-all' solution, and an assessment of the impact of changes in diversity of total primary energy supply (TPES, see glossary for definition) due to bioenergy on the contribution of bioenergy to energy security and more broadly sustainable development will need to take into consideration other factors particular to the national context. For example, measures designed to diversify a country's energy supply may differ from measures aimed at improving energy affordability. Furthermore, different types and sources of energy may have different levels of security of supply and therefore an analysis of the numerical diversification of energy supply will need to be accompanied by a more qualitative analysis of the reliability of each of the sources of supply. Indicators 23 and 24 will help inform this analysis by identifying critical distribution systems and a country's dependence on them.

Comparison with other energy options:

The same procedure could be used to understand the contribution of other energy options to energy diversity.

Scientific Basis

Methodological approach:

By considering the national energy supply mix with and without bioenergy a picture of energy diversity, and the role of bioenergy in securing it can be established.

This indicator is based on the data for total primary energy supply (TPES), e.g.

- % of oil in TPES
- % of coal in TPES
- % of gas in TPES
- % nuclear in TPES
- % of other renewables in TPES
- % of bioenergy in TPES

The degree of resolution is a matter for judgement. This judgement should be guided by the principle that the risks to the security of supply of each energy-supply category defined by a country or region should be as independent of each other as possible. This will mean that achieving a diverse portfolio of these categories of energy supply will truly mean that the risks to security of supply have been hedged. Where there are significant levels of particular distinct renewable energy sources (e.g. hydro or geothermal) or of other resources which are distinctly differentiated in any way they can be used as separate categories if the level of supply is above a threshold (suggested at 5%).

The contribution from bioenergy can also be broken down into different categories which are sufficiently distinctive – for example addressing different market segments such as power generation, transport or traditional biomass, or coming from distinct regions.

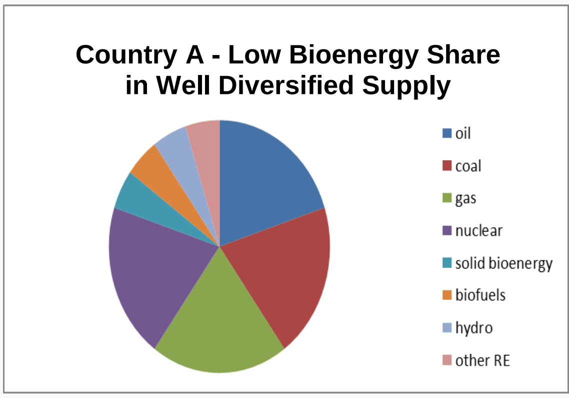
Displaying the information graphically provides a clear representation of the overall diversity of the energy system and the role of bioenergy in achieving that, as the graphs below show for examples for four countries:

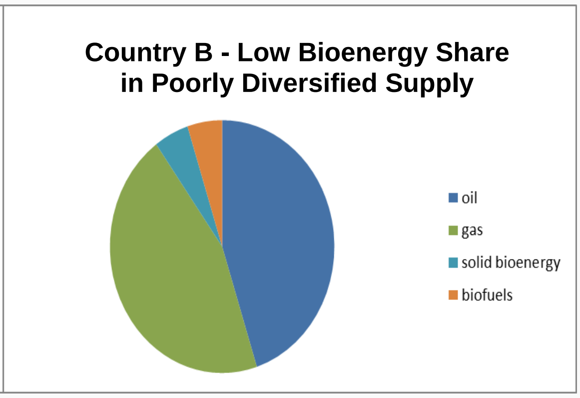
A: Low bioenergy share in well diversified supply

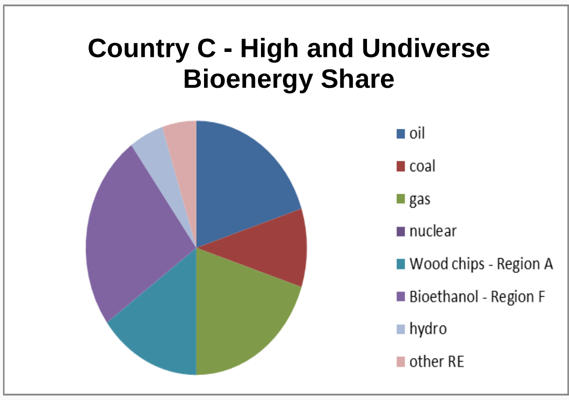
B: Low bioenergy share in poorly diversified supply

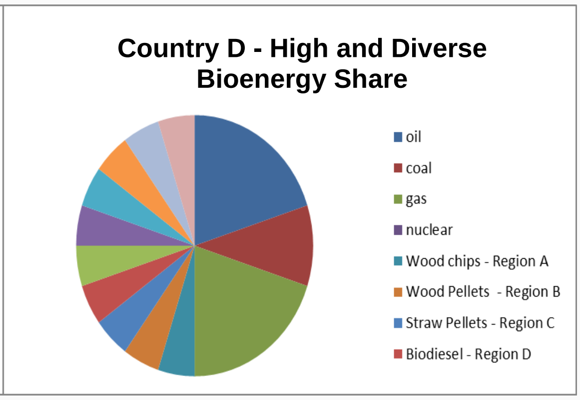
C: High and undiverse bioenergy share

D: High and diverse bioenergy share









One way of quantifying diversity in supply is to use the Herfindahl index, which is simply the sum of the squares of the shares (i.e. fractions) of TPES provided by each energy supply category. This is an index used to measure diversity in a number of fields, and is widely used within the IEA to evaluate energy diversity (see for example IEA, 2005). Other indices could also be used. (See Kruyt, van Vuuren, de Vries and Groenberg, 2009). The impact of bioenergy on diversity can be assessed using the Herfindahl index by calculating it with the bioenergy components included and comparing this to the index calculated without the bioenergy components, allocating the fractions supplied by bioenergy to the most likely alternative use.

The Table below shows the calculation for the four examples displayed graphically above.

	Country C - High and Diverse Bioenergy Supply (% TPES)		Country D - High but Undiverse Bioenergy (% TPES)	
		No Bio		No Bio
Oil	20%	40%	20%	40%
Coal	10%	25%	10%	25%
Gas	20%	25%	20%	25%
Nuclear	0		0	
Wood chips – Region A	5%		15%	
Wood pellets – Region B	5%			
Straw pellets – Region C	5%			
Biodiesel – Region D	5%			
Biodiesel – Region E	5%			
Bioethanol – Region F	5%		25%	
Bioethanol – Region G	5%			
Bioethanol – Region H	5%			
Hydro	5%	5%	5%	5%
Other RE	5%	5%	5%	5%
Herfindahl Index	0.115	0.29	0.18	0.29

	Country A - Low Bioenergy in Well Diversified Supply (% TPES)		Country B - Low Bioenergy in Undiversified Supply (% TPES)	
		No Bio		No Bio
Oil	20%	25%	45%	50%
Coal	20%	25%		
Gas	20%	20%	45%	50%
Nuclear	20%	20%		
Solid Bioenergy	5%		5%	
Biofuels	5%		5%	
Hydro	5%	5%		
Other RE	5%	5%		
Herfindahl Index	0.17	0.21	0.41	0.50

Anticipated limitations:

The indicator focuses on the diversity aspect of energy security. In general improving diversity should also help minimize risks of price rises and so help ensure affordability too.

The categorization of energy supply options influences the outcome of the Herfindahl Index, introducing some form of subjectivity. To counteract this weakness, detailed analysis may be undertaken to determine whether diversity will really help to provide resilience to physical supply disruptions. An important element of this analysis would be an appraisal of the degree to which physical supply disruptions for one category of energy are translated into price shocks, which can spill over from one market to another. Such analysis would help to determine whether an indicator measuring diversity of supply will act as a good proxy for an indicator of security of supply, especially when considered in conjunction with an assessment of capacity through Indicators 23 (*Infrastructure and logistics for distribution of bioenergy*) and 24 (*Capacity and flexibility of use of bioenergy*).

Practicality

Data requirements:

- total primary energy supply from each source, including total domestic bioenergy production;
- number of significant sources of bioenergy supply and associated amounts of energy (MJ). The categories can relate to the products being produced such as biofuels (e.g. biodiesel, bioethanol, other liquid biofuels), and bioenergy sources aimed at the heat and/or power generation sectors (e.g. wood chips, pellets, agricultural residues). The sources of supply should take into account the regions where the fuels are produced. Total domestic supply can be generated by aggregating the significant sources of supply;
- although it is outside the scope of this indicator, evaluating the total amount of domestic bioenergy consumption would facilitate analysis of the contribution of bioenergy to a country's energy diversity.

These data can be gathered through national/international statistical accounts or calculation/computation of (existing) data aggregated at the national level.

Data sources (international and national):

- National and international (such as IEA) energy statistics.

Known data gaps:

One potential data gap relates to flexible supply routes. Volumes and types of energy inputs from different regions via road transport or naval shipments (especially for bioenergy) can be unavailable in some countries.

Relevant international processes:

- The IEA is assessing countries' energy diversity, highlighting price risks stemming from supply (or sellers) market concentration. The assessment of supply concentration is done by means of a Herfindhal–Hirschman Index. A measure of political stability is also included, giving extra weight to politically instable countries based on two of the six 'worldwide governance indicators' of the World Bank. The supply concentration measure for each fuel market is weighted according to the fuel share in primary energy supply to assess a country's vulnerability to these concentration risks. The balance between the parameters for supply concentration and political stability is arbitrary.
- CSD Decision 9/1[91] (10.a) invites governments, as appropriate, to consider "the increased use of renewable energy sources" as a means of contributing to the achievement of sustainable development. This implies a role for energy diversity in sustainable development.
- JPOI, (chapter III) calls upon Governments, as well as relevant regional and international organizations and other relevant stakeholders, to […]Diversify energy supply by developing advanced, cleaner, more efficient, affordable and cost-effective energy technologies, including renewable energy technologies (UN, 2002).

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Indicator 23   Infrastructure and logistics for distribution of bioenergy

Description:

(23.1) Number and (23.2) capacity of routes for critical distribution systems, along with (23.3) an assessment of the proportion of the bioenergy associated with each

Measurement unit(s):

(23.1) number

(23.2) MJ, m^3, or tonnes per year; or MW for heat and power capacity

(23.3) percentages

Relevance

Application of the indicator:

The indicator applies to bioenergy production and use and to all bioenergy feedstocks, end-uses and pathways.

Relation to themes:

This indicator is primarily related to the theme of *Energy security/Infrastructure and logistics for distribution and use.*

Diversifying energy sources and transit routes for energy supplies is fundamental for energy security. Introducing reliable but flexible supply sources depends on a comprehensive and efficient energy infrastructure. Therefore, data about infrastructure and logistics for bioenergy supply and distribution are useful in assessing the risks to energy security associated with bioenergy supply routes, taking into account the geographic pattern of supply and demand. These data can provide important information about sustainable development bottlenecks and obstacles that must be overcome in order to ensure sustainable growth of the bioenergy sector.

How the indicator will help assess the sustainability of bioenergy at the national level:

Safe, reliable, cost-effective, appropriate and available infrastructure will help ensure adequate and secure energy supplies that will facilitate sustainable development.

This indicator considers the capacity of bioenergy distribution systems. These data will facilitate managing the risks associated with delivering and distributing bioenergy in a country, which could result from an inflexible infrastructure. An example of an inflexible, development limiting infrastructure would be a single route for the import and/or distribution of bioenergy via port facilities, pipelines, rail, or inland waterways.

As explained below, this indicator is intended for use in an assessment of the role of bioenergy in contributing to the energy security of a country. A country can begin to estimate its energy security, and the role played by bioenergy, by evaluating GBEP Indicators 22 (*Energy diversity*), 23 (*Infrastructure and logistics for distribution of bioenergy*) and 24 (*Capacity and flexibility of use of bioenergy*). Additional considerations, such as the stability of supply routes, including the transportation equipment, would improve the quality of the information provided by this indicator. If bioenergy capacity were to be evenly distributed across a high number of supply routes, taking advantage of unused capacity already present in these routes, then this would be beneficial to energy security and sustainable development. Either the expansion of infrastructure and logistics for bioenergy or the better utilization of existing infrastructure and logistics would be a positive contribution towards the overall sustainability of a country's bioenergy sector.

Bioenergy production and use has the potential to promote the development of a network of modern infrastructure and also foster energy security associated with bioenergy supply routes. These positive impacts on sustainable development can be measured by identifying new infrastructure facilities attributable to bioenergy production, distribution and use.

Bioenergy production and use can influence economic development in many ways and at many economic levels, and new infrastructure is just one of those ways. Bioenergy produced and used locally, particularly through own-consumption, may not depend upon infrastructure and distribution systems (except perhaps for distribution systems for inputs). In fact, local production and use of bioenergy can foster efficient energy production and use and region-specific economic development. As such, the meaning of a low aggregate value for 23.3 is best considered in the context of other indicators, such as those related to social and economic development, including Indicator 14 (*Bioenergy used to expand access to modern energy services*) and Indicator 22 (*Energy diversity*).

Comparison with other energy options:

The methodologies applied to bioenergy are the same methodologies applied to traditional sources of energy, and as such comparisons with fossil fuels and sources of renewable energy will be straightforward.

Scientific Basis

Methodological approach:

A review of the adequacy and diversity of key infrastructural components will allow an assessment of the limitations of current energy supply infrastructure and indicate how bioenergy could contribute to make a given country's energy supply more secure.

This indicator requires measurement of the number of critical supply routes or distribution systems for bioenergy. Critical routes are those which are subject to significant risk of disruption and which could not easily or quickly be replaced, such as pipelines, port facilities, etc., taking into account the relative volume capacity of each mode.

In general distribution systems (for example reliance on road transport) are likely to be less sensitive and as substitutes may be available.

It is also 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 (to diagnose particularly sensitive systems).

Measures of energy supply routes are amongst the most commonly used indicators for energy security (IEA, 2011). 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. 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.

To calculate the indicator:

1) Identify critical distribution systems for bioenergy feedstocks, fuels and electricity production and distribution systems.

2) Determine the capacity values for each of the distribution systems identified in Step 1.

3) If the amount of energy per system can be determined, then the overall capacity of each system can be expressed as a percentage of total national bioenergy consumption – these percentages could also be summed to produce an aggregate value.

In the case of 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, through 23.3, of the proportion of a country's bioenergy that relies upon each distribution system. 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.

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), whilst for an electricity transmission or distribution system, the share of generation capacity delivered through a system (in MW) could be used. 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).

In addition to quantifying the way in which bioenergy supply is spread across distribution systems identified as critical, some qualitative assessment of the reliability of these different systems would also likely be useful. In addition to the ports and pipelines that are suggested above as likely critical components of the distribution infrastructure, an national of risks to and identification of weak points in national distribution systems is recommended. This analysis should take into account the various transport modes used and their characteristics.

The assessment of the diversity and stability of distribution systems should be placed in the context of information provided by Indicator 22 on the diversity of sources of bioenergy supply and by Indicator 24 on the flexibility of infrastructure to switch between bioenergy and other energy sources.

Anticipated limitations:

The measures included in this indicator try to capture the level of development of infrastructure for distribution of bioenergy in some kind of objective quantitative metric, which could usefully inform policy-making. However, the analysis required to assess the contribution of a country or region's infrastructure and logistics for bioenergy distribution to the sustainability of the bioenergy is perhaps rather heuristic. The quantitative indicator is therefore more valuable in the context of more information and expert analysis (experts would be convened by the relevant domestic authority).

Practicality

Data requirements:

Assessment and evaluation of key elements of the supply infrastructure in terms of number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each. The modes of transport used in each country and the overall distribution system needs to be recognized and assessed. Critical elements need to be identified on a case by case basis but may include:

- number and capacity of port facilities capable of importing solid biomass compared to actual level of utilization;
- capacity for handling and storage compared with actual level of bioenergy utilization;
- number of port facilities capable of importing liquid biofuels, compared with actual level of biofuel utilization;
- capacity for handling and storage of biofuels compared with actual level of biofuel utilization;
- capacity and reliability of blending facilities and terminals;
- number and capacity of pipelines for bioenergy import.

These data can be collected through interviews and surveys at the national level.

Although it is outside the scope of this indicator, an assessment of the extent to which the domestic bioenergy production infrastructure is concentrated or, conversely, distributed could also be taken into account, especially having in mind its important contribution to promoting access to bioenergy. Countries may, therefore, wish to add relevant information on their national production/generation (number of plants, production capacity and distance to the market, etc.).

Data sources (international and national):

Information about supply routes are usually collected at the governmental level.

Known data gaps:

One potential data gap relates to flexible bioenergy supply routes (such as road transport or naval shipments) as capacity could be difficult to estimate.

Relevant international processes[92]:

- UN Department of Economic and Social Affairs: Division for Sustainable Development: Energy;
- Commission on Sustainable Development 15 (CSD-15) Energy for Sustainable Development;
- US Department of Agriculture Regional Roadmap for Meeting the Biofuels Goals of the Renewable Fuels Standard by 2022. The USDA has analysed infrastructure requirements for the U.S. bioenergy sector and presented some of these analyses in this report. The overall approach is informative to other policy-makers as they seek to develop their own programmes and analyses;
- JPOI. The 20th paragraph of the JPOI calls "upon Governments as well as relevant regional and international organizations and other relevant stakeholders to […] (v) Strengthen and facilitate, as appropriate, regional cooperation arrangements for promoting cross-border energy trade, including the interconnection of electricity grids and oil and natural gas pipelines" (UN, 2002);
- CDS 9/1: "Governments, taking into account their national circumstances, are encouraged to:
  - (C.1) establish or strengthen national and regional arrangements for promoting energy accessibility within the country;
  - (C.3) develop and implement appropriate national, regional and international policies and measures to create an enabling environment for the development, utilization and distribution of renewable energy sources".

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[92] See references and electronic sources section.

Indicator 24 Capacity and flexibility of use of bioenergy

Description:

(24.1) Ratio of capacity for using bioenergy compared with actual use for each significant utilization route

(24.2) Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity

Measurement unit(s):

Ratios

Relevance

Application of the indicator:

The indicator applies to bioenergy use.

Relation to themes:

This indicator refers primarily to the theme relating to *Energy security/Infrastructure and logistics for distribution and use.*

Unused or flexible capacity in using bioenergy contributes to overall energy security and can be considered as an aim for infrastructure development for bioenergy use. A flexible bioenergy system helps to reduce the risks and further bring down operating costs.

This indicator also informs the themes of *Economic development*, *Energy security/Diversification of sources and supply,* and *Price and supply of a national food basket* (since if a country is relying on the same raw materials for bioenergy and food production, a country's ability or inability to flexibly adjust bioenergy use, e.g. in response to a poor harvest, so as to reduce demand for the raw material for bioenergy production will affect the price and supply of food). It provides useful information on the flexibility of the demand side to rapidly increase or diminish fuel or feedstock consumption and therefore its ability to respond to unexpected shortages of bioenergy and/or bioenergy feedstock due to adverse conditions or political implications. On the other hand, a high degree of flexibility in the use of bioenergy can translate into a rapid increase of bioenergy consumption under favourable economic conditions.

How the indicator will help assess the sustainability of bioenergy at the national level:

Countries that have a limited or inflexible bioenergy capacity risk supply interruptions.

Assessing the ratio of capacity for using bioenergy compared with actual use for each significant utilization route (24.1) will allow quantitative assessment of the capacity to use the various sources of bioenergy relevant within a particular country. The ratio indicates the level of capacity for using the bioenergy compared to the actual utilization for each critical sector.

Assessing the ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity (24.2) will provide information on the flexibility of utilization systems to switch between bioenergy and other fuels sources. Examples include the presence of flex-fuel vehicles in the vehicle fleet or the capacity for flexible power generation that can use either bioenergy or other fuels. For instance, the recent emergence and rapid dominance of flex-fuel vehicle engines in Brazil has created an incentive for car owners to choose the cheapest fuel at the pump, and in recent years this has mainly been ethanol.

Understanding the capacity constraints and margin and the flexibility on fuel use allows an appreciation of the risks associated with using bioenergy.

Comparison with other energy options:

A similar approach could be used to assess the capacity and flexibility of use of other energy options including fossil fuels.

Scientific Basis

Methodological approach:

The suggested approach is to carry out an analysis for each of the ways of using bioenergy within a country which are judged to be significant. First the actual current level of use is assessed (for example the volume of bioethanol, currently being used in the transport sector, or the amount of solid biomass being co-fired). This can then be compared with the potential to use the fuels within the country (for example the capacity of the vehicle fleet to use bioethanol, or of the power generation capacity to use biomass by co-firing). As a final step the proportion of the capacity which is flexible can be assessed (for example the proportion of flex-fuel vehicles in the fleet and their fuel using capacity, or the proportion of power generation systems which can operate in a fuel flexible mode.

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 = 300/100 = 3; Capacity ratio for country B = 120/100 = 1.2

Flexibility ratio for country A = 250/300 = 83%; Flexibility ratio for country B = 40/120 = 33%;

Country A has sufficient excess capacity to absorb the bioenergy being used so the bioenergy utilization is unlikely to be hampered. Most of that capacity is flexible so interruptions in supply would not compromise energy security. Country B has less excess capacity and a low proportion of flexible capacity, so is expected to be more sensitive to interruptions in either user capacity of bioenergy supply.

With reference to liquid biofuels which have the potential to displace fossil fuels currently used for transport, the assessment could encompass both the technology from the demand side (appliances, flex-fuel engines, etc.) and the production of biofuels such as Biomass To Liquid-based biofuels which can be directly fed into the existing infrastructure.

Ethanol-gasoline blends above a certain percentage can pose problems for gasoline engines and similarly for other biofuel blends, but pure or “hydrous” ethanol can be used in specially designed engines. The engine/equipment manufacturer warranty/guidelines or any applicable legislation will be considered to determine the bioenergy use capacity.

For increasing levels of biofuels use, the requirements differ. At low levels the vehicle fleet is able to absorb the biofuels without problems but at some point the capacity to absorb higher levels becomes restricted (sometimes referred to as the ‘blending wall’) and using higher levels of biofuels requires some changes to the fleet, such as the widespread adoption of flex-fuel vehicles. In the longer term, the development of fuels which can mix in any proportion with gasoline or diesel should overcome such problems.

The analysis outlined above should be done on the basis of key ways in which bioenergy may be used in a country, covering the various solid, liquid or gaseous fuels felt to be significant. However, the scope of this indicator is not limited to bioenergy use in the transport sector and similar considerations could be applied to bioenergy co-combustion and co-firing (with coal or gas) in industry and power plants, for example by assessing the co-firing capacity across a range of suitable fossil fuel plants. In relevant cases, users of the indicator could consider the aggregate flexibility of domestic bioenergy processing plants to switch between or simultaneously use various feedstocks.

Anticipated limitations:

It could be difficult to identify all relevant bioenergy utilization routes as well as to put a value on bioenergy utilization capacity of traditional systems such as biomass co-firing plants.

Practicality

Data requirements:

- capacity for main bioenergy utilization routes (e.g. power generation capacity, bioenergy-compatible vehicles);
- proportion of capacity which is fuel or feedstock flexible.

These data can be collected through interviews and surveys at the national level.

Data sources (international and national)[93]:

Many associations of car manufacturers, research institutes, initiatives and foundations regularly collect information about flex-fuel vehicles and their market share. Examples include

- BioAlcohol Fuel Foundation
- BEST project in Europe
- Associação Nacional dos Fabricantes de Veículos Automotores (Anfavea) in Brazil
- United States Department of Energy National Renewable Energy Laboratory (US DOE NREL)

Known data gaps:

Data gaps exist for capacity and flexible capacity in using bioenergy other than in the transport sector, such as industry co-combustion and co-firing equipment and other appliances.

Relevant international processes[93]:

- International Energy Agency
- UN Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM)
    - CDM energy efficiency improvement projects: the methodology considers “improvement” the installation of a technology that can be installed in new facilities creating a flexible use of energy.
    - CDM for Emissions reduction through partial substitution of fossil fuels with alternative fuels or less carbon intensive fuels in cement or quicklime manufacture (when the substitution is made through co-firing).

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[93] See electronic sources section.

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Glossary

Agriculture

Unless otherwise stated in this report, the term agriculture is used in accordance with the FAOSTAT definition: namely, agriculture corresponds to the divisions 1-5 of the International Standard Industrial Classification (ISIC, revision 3) and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. (Note that this corresponds to divisions 1-3 of ISIC revision 4, released in August 2008.)

Bioenergy

Energy produced from biomass

Biofuel

Fuel derived from biomass. The term covers a wide range of fuels, including:

- liquid biofuels: fuels and bioadditives such as bioethanol, biodiesel, biobutanol, biomethanol, bioETBE (ethyl tert-butyl ether), bioMTBE (methyl tert-butyl ether), biogasoline, and combustible oils produced by plants;
- gaseous biofuels: such as biogas, mainly methane and carbon dioxide produced by the process of anaerobic digestion of biomass;
- solid biofuels: such as wood pellets, wood chips and charcoal, including char-briquettes.

Biomass

Material of biological origin excluding material embedded in geological formation and/or transformed to fossil

Co-product

Any of two or more products coming from the same unit process or product system

Conversion

Transformation of one form of energy into another

Note that while the terms conversion and processing of biomass into biofuels or electricity are often used interchangeably, for clarity, in this report, the term processing is used to describe the transformation (including preparation) of feedstock into the bioenergy end product. The term conversion is reserved to describe conversion of one form of energy into another: note that this conversion can occur during the processing of the feedstock into the bioenergy end product or during the use of this end product, whereas processing is defined as part of the bioenergy production phase.

Distribution

Transport of the end product from the last stage of its production to consumers

Fuel

Energy carrier intended for energy conversion

Feedstock

Raw material that constitutes the principal input for bioenergy production

Improved cookstove

Improved cookstoves comprise closed stoves with chimneys, as well as open stoves or fires with chimneys or hoods, but exclude open stoves or fires with no chimney or hood. Improved cookstoves usually have an energy efficiency value greater than 20-30% and their flue gases are released distant from their users.

This is usually achieved by combining all or some of the following elements:

- Sliding firebox door
- Inlet
- Grate
- Baffles
- Dampers
- Chimney dampers to control air supply
- Cowl – a metal cap attached to the chimney
- Using cleaner fuel (usually gaseous or liquid fuel)

Intermediate product

Output from a unit process that is input to other unit processes that require further transformation within the system

Lifecycle (see Figure 1)

Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal

Lifecycle analysis

Analysis of consecutive and interlinked stages of a product system, from raw material production and/or extraction to final disposal

Lifecycle assessment

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

Modern energy services

Availability for the end user of:

- electricity for lighting, communication, healthcare, education and other uses;
- modern fuels or technologies for cooking, heating and cooling;
- mechanical power for productive use (e.g. irrigation, agricultural processing), provided through electricity or modern fuels, or directly through renewable sources such as hydropower; and
- transport, provided through electricity or modern fuels.

The GBEP definition of modern energy services is based on two criteria: energy efficiency and safety to human health. Where modern energy services rely on the combustion of fuels, the fuels (whether solid, liquid or gaseous) must be burned in efficient and safe combustion chambers, improved cookstoves,[94] or fuel cells. Efficiency is meant here as the energy output as a percentage of the heating value of the fuel. Safety refers to the absence of indoor air pollutants and low amount of air pollutants released in the open air by the energy system.

Modern energy services might also be defined by what they are not. They do not include: use of kerosene or other fuels for lighting; combustion of fuels on open stoves or fires without chimneys or hoods (or any other energy systems that release flue gases indoors or release high concentrations of air pollutants); or human and draught animal power.

Modern bioenergy services are defined as modern energy services relying on biomass as their primary energy source.

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; 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.

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.

Multi-stakeholder process

A process which aims to bring together in a participative dialogue equitable representation of all appropriate and relevant stakeholders, including government representatives, civil society, private sector entities, international organizations, and major groups' representatives (as defined in Agenda 21). The process has to allow participants to bring into the dialogue their own perspectives, taking locally relevant aspects as well as their own value systems into account. Multi-stakeholder processes are based on democratic principles of transparency, equity and participation. The exact nature of any such process will depend on the issues, its objectives, participants, scope and timelines, as defined in the UNED Forum framework for Multi-Stakeholder Processes.

[94] Improved cookstoves are defined above.

Processing

The transformation (including preparation, or pre-treatment) of feedstock into the bioenergy end product: fuel or electricity.

Residue

Substance or material that is not deliberately produced in a production process and that is neither a co-product nor a waste; includes agricultural, aquaculture, fisheries and forestry residues and processing residues

NOTE 1: Agricultural, aquaculture, fisheries and forestry residues are directly produced by agriculture, fisheries, aquaculture and forestry; they do not include residues from related industries or processing.

NOTE 2: A processing residue is a substance which is not the end product that a production process directly seeks to produce. It is not a primary aim of the production process and the process has not been deliberately modified in a way compromising quantity or quality of any co-product to produce it.

Transport

General term covering all phases where feedstock, intermediate products and end product (fuels or electricity) are carried from one place to another, including fuel distribution and electricity transmission and distribution

Transmission

Transport of electricity from generating plants to substations near consumers. Note in this report the term “distribution” is used, with respect to electricity, to include both what is generally referred to as the transmission of electricity and what is generally referred to as its distribution from substations to end users.

Total Primary Energy Supply

Total primary energy supply (TPES) is made up of production + imports – exports – international marine bunkers – international aviation bunkers ± stock changes. For the world total, international marine bunkers and international aviation bunkers are not subtracted from TPES.

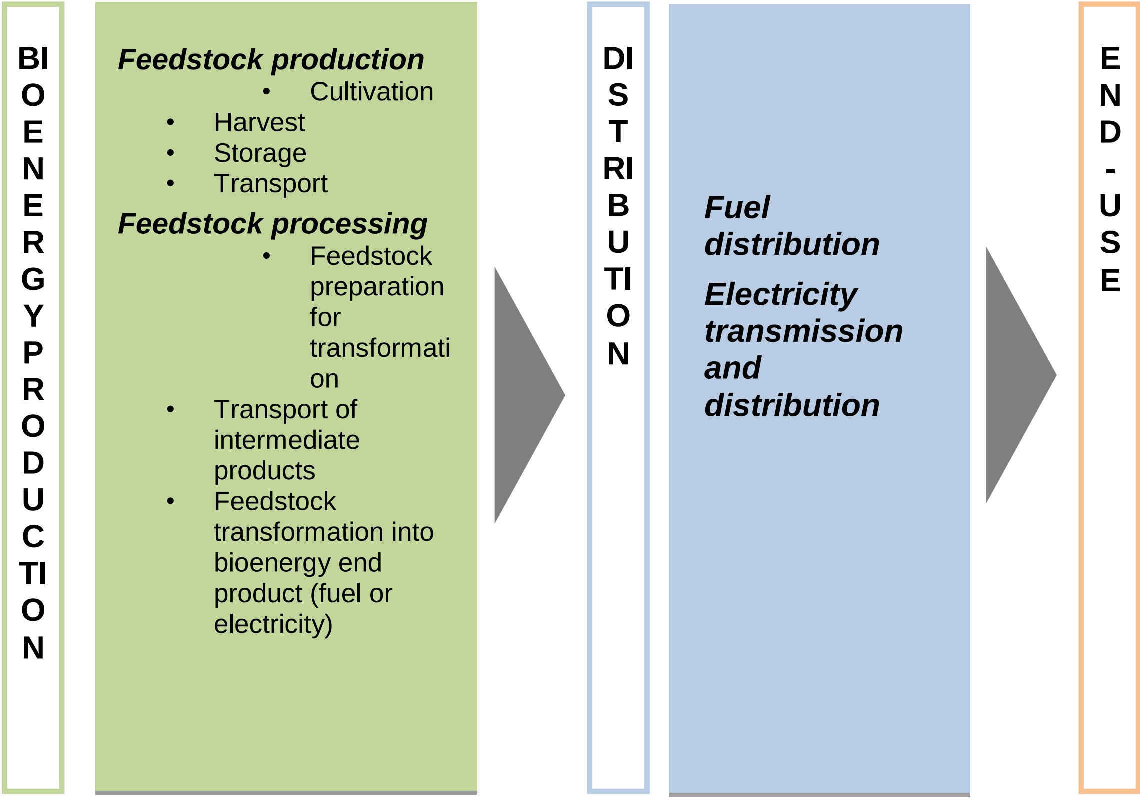
Useful energy

The portion of final energy which is actually available after final conversion to the consumer for the respective use. In final conversion, electricity becomes for instance light, mechanical energy or heat.

Waste

Any substances or objects, which have no economic value in the holder’s accessible market, that are discarded, intended to be discarded or required to be discarded.

Figure 1: Bioenergy Lifecycle



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