FOSTERING SUSTAINABLE FEEDSTOCK PRODUCTION FOR ADVANCED BIOFUELS ON UNDERUTILISED LAND IN EUROPE

D 3.2

REPORT ON THE DESIGN OF THE SUSTAINABILITY INDICATOR SET

FAO

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FIGURE 1 View of the Schwarze Pumpe Lignite power plant near the land restoration site of Welzow-sud in Brandeburg, Germany

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1. Introduction

Assessing the sustainability of the advanced bioenergy value chains is a complex exercise. The work carried out by FAO, and presented here, not only focused on drafting a list of sustainable indicators, but formulated several methodologies and tools around a core concept based on environmental, social and economic aspects, able to interact and measure information in a comprehensive and integrated manner.

Nowadays, the goal of assessing the sustainable biomass potential as well as the sustainability of the bioenergy value chains in Europe is underlined by the growing attention posed by governments on renewable energy aspects. As biofuels gain market share and international trading of biomass, raw materials and biofuels expand, the need to ensure the environmental, social and economic sustainability along the value chains becomes more pressing. Therefore, in setting the basis for building up and strengthening local bioenergy value chains, FORBIO considers crucial the effort of meeting the highest sustainability standards, in line with global and European sustainability policies and standards.

As for biomass in general, the use of biomass produced on underutilized or contaminated lands for biofuel production is gaining increasing interest in Europe. One of the reasons why this is happening, is the expected sustainability potential of biomass produced on these specific type of lands, compared to biomass grown on agricultural land. In the context of FORBIO, biomass production does not imply the use of land suitable for food production. On the other hand, unlike for biomass grown on common agricultural land, there is no commonly accepted set of sustainability criteria or methodologies designed to test sustainability aspects of these specific projects. Moreover, when advanced bioenergy is obtained recovering underutilized and marginal lands the existing general methodologies for assessing sustainability performances of these systems may fail to capture relevant features that are characteristic of these lands.

In the context of the FORBIO Project, a set of indicators to assess sustainability of bioenergy feedstock productions was developed by FAO, drawing on and putting together existing sustainability standards and methodologies for bioenergy production from different pathways including lignocellulosic ethanol. Furthermore, these indicators not only apply to feedstock production (agricultural activities), but also measure the impact of bioenergy production of the entire value chain.

In addition, due to the several challenges posed by bioenergy production under the three pillars of sustainability, the use of efficient tools and methodologies can provide a better understanding of these issues by conceptualizing and explaining the relationships and dependencies among environmental, social and economic aspects. The aforementioned purpose-built set of sustainability indicators developed under FORBIO, may represent an important resource for other EC and bioenergy

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sustainability assessment projects that share characteristics with the sites studied in FORBIO. This report in fact, represents a manual for the assessment of the main sustainability aspects that are relevant for the market uptake of proposed and/or planned advanced bioenergy value chains in Europe and neighbouring countries.

FIGURE 3 Lignite opencast mine of Welzow-Süd in Brandenburg, Germany

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2. Internationally recognized sustainability indicators for bioenergy and the FORBIO Project

Sustainability indicators represent the backbone of monitoring progresses towards the achievement of policy goals, be it the EU-set of policy objectives, the Sustainable Development Goals or any other local, national, regional, and/or global compendium of policy targets. Most internationally-recognized sustainability indicators are intended to assess performances of an existing bioenergy value chain at different scales. When sustainability indicators results are checked against a threshold (e.g. as set by a given standard) these can compose the skeleton of a certification scheme. Clearly, the scope of the work carried out in FORBIO is not to present yet another set of indicators to check against a standard, threshold or limit, as to inform on certification of sustainability of bioenergy. Similarly, this work does not intend to propose an alternative set of indicators for monitoring sustainable development of the bioenergy sector, since excellent work on this field has been done by a number of far better equipped initiatives from which FORBIO takes stock for the majority of the available knowledge which it applies to the specific context of this project.

"The set of FORBIO indicators provides predictive information on the trajectory that a given intervention in the context of bioenergy is taking with respect to a reference policy target."

In this report, instead, FORBIO presents a purpose-built set of sustainability indicators for bioenergy to be used as a planning tool. The assessment of the set of indicators developed under FORBIO provides ex-ante, predictive information on the effects that a proposed bioenergy project will have on specific sustainability parameters with respect to a reference policy target. In other words, this analysis firstly projects into the future the impacts on a number of environmental, social and techno-economic indicators of the current situation (e.g. the quality of soils on contaminated underutilized lands X years from now) and subsequently, it estimates the deviation from the aforementioned path attributable to the proposed advanced bioenergy value chain on the same lands over the same future timeframe.

While sustainability indicators used as monitoring tool (thus performing ex-post assessments) return an understanding of the direction that the existing bioenergy sector has taken to date, the need to foresee what will be the impact of a planned bioenergy activity on a number of relevant sustainability aspects is of utmost importance to ensure that investments are bankable. This represents a key contribution to the market uptake of advanced biofuels from underutilized lands in Europe. The challenges to achieving a reliable set of indicators accompanied by specific methodologies are numerous, but the endeavour benefitted from the vast knowledge acquired to date on the matter by FORBIO partners. This is why the work of the FAO starts from the most broadly recognized tool for the *monitoring* of bioenergy sustainability at the *national* level (The Global Bioenergy Partnership Sustainability Indicators for Bioenergy) and adapts it, with selected additions on specific indicators, to a *predictive* and *sub-national* context. The methodologies for each indicators are developed specifically for FORBIO and are based on the concept of scenario comparison between a baseline (current situation, without the existence of a bioenergy value chain) and a target scenario, which assumes that actions set forth in a planned project lead to the creation of a certain advanced biofuel value chain. The possibility of tweaking the target scenarios by changing as many variables as it is of interest gives the opportunity to *plan* investments on advanced bioenergy on the basis of the sustainability impacts of the various indicators and the evaluation of these in the context of a reference systems (e.g. set of policy targets) of choice. In the case of the set presented in this report, where possible, EU-targets have been selected as the reference system for the comparisons among scenarios and the evaluation of the sustainability of each indicator but the methodologies proposed apply to any other set of thresholds with no foreseeable limitations.

2.1. The Global Bioenergy Partnership sustainability indicators for bioenergy

In 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." Ever since the partnership has grown at today it accounts more than 75 members among countries and international organizations. The purpose of the Global Bioenergy Partnership is to provide a mechanism for Partners to organize, coordinate and implement targeted international research, development, demonstration and commercial activities related to production, delivery, conversion and use of biomass for energy, with a focus on developing countries. 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. The indicators, published by FAO in 2011[1], address all types of biofuels (e.g. liquid, solid, gaseous) for electricity, heat and transport. FAO has provided substantial technical inputs to this work, and is also among the founding members of the Partnership and hosts the Secretariat in Rome. The indicators are intended to inform policy-makers about the

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1. Available at: http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

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environmental, social and economic aspects of the bioenergy sector in their country and guide them towards policies that foster sustainable development. Measured over time, the indicators will show progress towards or away from a nationally defined sustainable development path. 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 (fifty) and international organizations (twenty-six). The GBEP indicators are mainly designed for ex-post assessment of a country's bioenergy sector, thus aggregating performances of individual operators into an average national value. The indicators are value-neutral, do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding.

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 analysing 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 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. Finally, the GBEP Indicators are recognized as the most complete checklist of aspects of relevance when assessing bioenergy sustainability and the experience gained by FAO with their first iteration led the way to pursuing the goal of creating an unprecedented tool for sustainable bioenergy planning based on this solid architecture.

<table>
<tr><th colspan="3">PILLARS
GBEP’s work on sustainability indicators was developed under the following three pillars,
noting interlinkages between them:</th></tr>
<tr><th>Environmental</th><th>Social</th><th>Economic</th></tr>
<tr><td colspan="3">THEMES
GBEP considers the following themes relevant, and these guided the development of indicators under these pillars:</td></tr>
<tr><td>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.</td><td>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.</td><td>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.</td></tr>
<tr><td colspan="3">INDICATORS</td></tr>
<tr><td>1. Lifecycle GHG emissions</td><td>9. Allocation and tenure of land for new bioenergy production</td><td>17. Productivity</td></tr>
<tr><td>2. Soil quality</td><td>10. Price and supply of a national food basket</td><td>18. Net energy balance</td></tr>
<tr><td>3. Harvest levels of wood resources</td><td>11. Change in income</td><td>19. Gross value added</td></tr>
<tr><td>4. Emissions of non-GHG air pollutants, including air toxics</td><td>12. Jobs in the bioenergy sector</td><td>20. Change in consumption of fossil fuels and traditional use of biomass</td></tr>
<tr><td>5. Water use and efficiency</td><td>13. Change in unpaid time spent by women and children collecting biomass</td><td>21. Training and re-qualification of the workforce</td></tr>
<tr><td>6. Water quality</td><td>14. Bioenergy used to expand access to modern energy services</td><td>22. Energy diversity</td></tr>
<tr><td>7. Biological diversity in the landscape</td><td>15. Change in mortality and burden of disease attributable to indoor smoke</td><td>23. Infrastructure and logistics for distribution of bioenergy</td></tr>
<tr><td>8. Land use and land-use change related to bioenergy feedstock production</td><td>16. Incidence of occupational injury, illness and fatalities</td><td>24. Capacity and flexibility of use of bioenergy</td></tr>
</table>

TABLE. 1 The original set of 24 Sustainability Indicators developed by GBEP (FAO, 2011).

2.2. A tailored set of sustainability indicators: The work of FAO in FORBIO

As we have seen, sustainability indicators may perform different functions. They can lead to a better understanding of the issues related to existing bioenergy production, as well as lead decisions and effective actions by generating, simplifying, and when necessary, harmonizing information made available to policy makers and industrial actors engaged in the planning of bioenergy developments and investments. They can help incorporating knowledge into the decision-making process, and contribute to measuring progress toward sustainable development goals.

The need for developing new methodologies and tools for assessing the impact of bioenergy at local (regional or sub-regional) and site-specific (municipality) level, encourages FAO to develop a user-friendly and tailored set of sustainability indicators to be used in the context of the FORBIO Project for measuring the impacts of the advanced bioenergy value chains studied. It was imperative that, in order to ensure comprehensiveness and reliability of the operations, the starting point for the production of the FORBIO set of indicators was the most broadly accepted tool for bioenergy sustainability analyses: the GBEP sustainability indicators for bioenergy. Specifically, the set of indicators developed in the context of FORBIO is thought to support the ex-ante expedite but reliable assessment of advanced biofuels value chain' sustainability at the local level. In addition, the study setting requires the production of an assessment of the local impacts on the various facets that compose sustainability (local level analysis). It was clear from the inception of FORBIO then, that a solid starting point was represented by the GBEP Indicators that though needed a specific adaptation to produce valuable results.

Sustainability consideration can facilitate the evaluation of the sustainability of advanced biofuels value chains in Europe or the calculation of sustainable biomass potential. The FORBIO set of sustainability indicators has been thought to assess adv. biofuels biomass potential and value chain sustainability in EU respectively, taking advantage of a series of methodologies that have been developed starting from the GBEP knowledge on the matter. In addition, all relevant policies issues and the practical aspects that are related to the project and to the measurement of these indicators have been considered. Indeed, the indicators are set to match the needs of the new selected advanced biofuel value chains with the relevant EU sustainability perceptions and goals and taking in consideration the three aspect of sustainability.

Specifically, the FORBIO indicators have been developed as tools for the sustainability assessment of the project value chains at local level, in line with the need of increasing the use of biomass as feedstock for bioenergy production in the member countries (diversify Europe's energy supply), assessing sustainability in creating growth and jobs, and lowering greenhouse gas emissions. In accordance with EU2020 goals, FORBIO does not consider the use of biomass from land converted from forest, high carbon stock areas, or highly biodiversity areas, but focusses on the use of marginal and underutilized lands in Europe. The results of the assessment of sustainability through the use of the FORBIO indicators for instance, will inform on whether the advanced biofuels that could be produced on the case study sites emit at least 35percent less greenhouse gases over their lifecycle (cultivation, processing, transport, etc.) when compared to fossil fuels.

As already discussed in the *inventory of existing environmental, social and economic data source in Italy, Germany and Ukraine* (official derivable D3.1 of this project), the indicators selected in FORBIO refer to man-made operations and their interactions with the natural environment, components of the economy, as well as impacts on local stakeholders and thus they require the inscription within a known reference system in order to be evaluated correctly. The impacts of these operations must be calculated with regard to a specific area which is defined in FORBIO as the ***target area***. The definition and characterization of the extent containing the value chains studied is of paramount importance. In fact, the assessment of most sustainability aspects should not be done only in absolute terms, but on the contrary it provides useful information only when it is contextualized within the extent of its relative reference system. The size and borders of the reference system in this latter case may change dramatically the evaluation of benefits and/or impacts of the bioenergy value chain. Therefore, FORBIO introduces the concept of ***target area*** into its analyses of sustainability. The ***target area*** is the smallest surface of land as defined by subnational boundaries of A) physical, B) political; and/or C) cultural origin that is interested by the bioenergy production and use operation and which contains all the direct interactions procured by the bioenergy value chain. This definition is broad in scope because the variability of local conditions imposes to do so.

This work distinguishes between different types of indicators that play different roles in sustainability assessment. Considering the possibility of working on contaminated or polluted lands, the environmental indicators are numerous and developed to assess the contribution of bioenergy to the restoration of environmental quality (e.g. soil, water, air quality) of the underutilized contaminated sites. In addition, social and economic indicators are constructed in a manner such that they are able to describe the contribution of bioenergy to creating sustainable development in the areas affected by high level of marginality. As for the environmental indicators, the social and the economic sustainability indicators are thought to assess the impact of the bioenergy productions on marginal contexts in EU and neighbouring countries, using specific approaches and methodologies and understanding the possible contribution to local sustainable development.

FIGURE 3 Black locust field trials for identification of most productive and stress tolerant clones in the context of FastWOOD project in Welzow-Süd, Brandenburg, Germany

FIGURE 4 A tractor for the mechanical planting of a willow SRC field in the Ukrainian case study site

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3. Overview of the FORBIO revised sustainability indicators

3.1. General description

The 17 indicators selected in the context of FORBIO and their methodology sheets are intended to provide both private and public sector with a tool through which they can assess the environmental, social and economic sustainability of advanced biofuel production and use on underutilized lands in EU countries. The indicators are meant to guide analyses at local level for assessing sustainable production and use of bioenergy as a means towards meeting national and European goals of sustainable development (e.g. Europe2020 strategy).

The indicators are divided into the three pillars of sustainability (environmental, social and economic) and each indicator was developed with three parts: indicator's name, a short description, and methodology sheet that provides in-depth guidance needed to carry out the indicator's measurement. The methodology sheets describe how the indicators relate to relevant themes of sustainability and how the value chains studied contribute towards achieving policy goals sustainability at local, national or EU level (where available). The methodology sheets outline the approach for collecting and analysing the data needed to evaluate the indicator and for making relevant comparisons to other energy options or agricultural systems. The methodology sheets also provide information on data limitations and highlight potential bottlenecks to data acquisition.

In this new set of FORBIO indicators, the approach to sustainability is structured as the analysis of the difference in impacts caused by two (or more) reference scenario projections: baseline vs target projections. A baseline scenario is projected into the future to present the foreseeable development of each selected sustainability indicator given the current circumstances and conditions, thus without the existence of the advanced biofuel value chain tested. For instance, the baseline scenario of the soil quality indicator is described as the trajectory that the specific soil quality parameter (e.g. SOM content) will have if no action is taken. The timeframe is explicitly decided at the beginning of each analysis and it must be consistent for both scenario projections. One example of baseline scenario projection could be the estimated content of SOM in the underutilized soils 20 years into the future. At present, this value could a hypothetic 3 percent. The estimated apposition of organic material (litter from the current land cover type) will be contrasted by the natural rate of mineralization of the organic matter in the soils. The value of SOM that theoretically, given the set of conditions described, will be achieved in 20 years is considered the value achievable without the interference of the feedstock production for bioenergy purposes (i.e. baseline scenario). We can, for the sake of this example, assume that in 20 years, the content of SOM in the soil will pass from 3 to 3.2

percent if no action is taken. The target scenario will be calculated as the projection over the same time frame (20 years in this example) of the same parameter (variation of the SOM content) but with the consideration of the interference that the production of feedstock for advanced biofuel production (e.g. giant reed, miscanthus, switchgrass, willow, etc.) may have on the process of organic matter apposition and mineralization. This includes a number of factors, such as the use of organic fertilizers like manure and/or compost, soil tillage, as well as the presence of irrigation and other factors that can concur to either alter the accumulation of organic matter in the soils with respect to the baseline scenario. Again, for the sake of this example, let us assume that SOM content will pass from 3 to 3.4 percent over 20 years if on the land considered the project cultivates giant reed with the presence of organic fertilization and leaving the post-harvest residues in the fields. The difference between the two values is attributable to bioenergy feedstock production and thus, its sustainability can be evaluated as a consequence. In this example, the difference between target and baseline projections would be 3.4 – 3.2 percent, thus + 0.2 percent increase in SOM.

As we have seen in the previous example, the indicator has taken into account the effective impact of the project value chains, that is meticulously measured considering the differences from the evolution of the initial situation (BASELINE scenario or no-bioenergy scenario) and the situation at the end of project (TARGET scenario, or bioenergy scenario). A baseline situation is the initial condition before the implementation of the proposed value chain and related activities, while the target is the specific, planned level of bioenergy production to be achieved within the total planned project duration. A baseline measurement is important for the project outputs and goals determination and a rigorous impact evaluation cannot be conducted without a clear definition of baseline conditions. Information concerning the TARGET scenarios will be used for the sustainability indicators measurement in the environmental, social and economic sustainability assessment of the proposed project value chains. This information is directly related to feedstock production, transport, processing into fuels etc., covering the whole value chain. The final assessment of environmental, social and economic sustainability will be obtained through the comparison between the natural evolution of the BASELINE scenario throughout the whole project duration and that one concerning the development of the bioenergy value chains (TARGET scenario).

$$I_V = TS_V - BS_V$$

Where

IV: Indicator's Value

TS_V: Target Scenario Value

BS_V: Baseline Scenario Value

Seven indicators grouped under the *environmental pillar of sustainability* were selected in the case of advanced bioenergy value chains on underutilized lands. Analyses related to greenhouse gas and non-greenhouse gas are debated in two different indicators in order to better deal with both the climate change and the air pollution topics. The **Greenhouse Gas-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 at local, national and EU 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. This aspect is particularly relevant in the case of advanced biofuels. Life Cycle Assessment (LCA) is an important tool for estimating GHG emissions and comparing the GHG emissions from different energy sources. Along the same lines, the final assessment of environmental sustainability should provide a comprehensive analysis of relevant sources of **non-GHG air pollutant emissions** in relation to advanced biofuels 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.

As in the case of GHG and non-GHG air pollutants, water use and water quality are also crucial aspects of a sustainability assessment. The production and processing of bioenergy feedstock can require substantial amounts of water. In regions featuring competing demands on surface or groundwater, the change in withdrawals for feedstock production or processing into energy carrier can alter the use of available water resources (FAO, 2014). In addition, depending upon the intrinsic characteristics of the landscape, the cultivation of bioenergy feedstock over areas originally presenting a different land cover type and/or category may affect the water balance of the region possibly even beyond the borders of the ***target area.*** For instance, the hydrological cycle of a specific area may by disrupt by the conversion of portions of its surface to the production of bioenergy feedstock, even without factoring irrigation but only naturally occurring precipitations. Often times, highly productive bioenergy feedstock are fast growing plants that have characteristics such as a well-developed root system and strong photosynthetic capabilities and as a consequence, such theoretical feedstock usually is characterized by comparatively high evapotranspiration rates. If a substantial share of precipitations is intercepted by the growing bioenergy feedstock and emitted into the atmosphere via evapotranspiration, the components of the landscape downstream of the bioenergy feedstock production site (e.g. a river, agricultural fields, a forest, etc.) may receive less water and be affected negatively by the presence of bioenergy feedstock. This is the case of Eucalyptus lots in South Africa which were originally planted with the scope to provide the local population with a source of affordable wood-fuel, and are now being eradicated because they were recognized to cause serious water unbalances to the hosting landscape. It is clear that such aspects are strictly linked to the specific features of a particular landscape and therefore this indicator suggests to **measure water requirements and impacts on annual water resources** including the effective water use of bioenergy feedstock, thus by accounting for its effective evapotranspiration potential. Evaluating the water use and efficiency indicator will provide basic information on the role that bioenergy production and use plays in water management at the watershed level and beyond.

As for the water use and efficiency, to **preserve the quality of local and regional water sources** is a crucial aspect in the development of a bioenergy value chain, especially in situations of underutilization of the land due to pre-existing contamination of the soils and waters. The water quality indicator developed by FAO in the context of the FORBIO project, aims at measuring and monitoring the impacts 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. This phenomenon is known as eutrophication[2]. 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. Calculating the movement of nutrients in the soil, from the soil to the bodies of water, and in the network of surface waters is a highly complex task. The experience with this type of analysis in bioenergy sustainability assessments gained by FAO throughout the years, has led to the choice of testing a specific GIS-based model to simulate these complex dynamics. In fact, especially for the future looking nature of the analyses carried out in FORBIO, computer-models are indispensable for producing credible scenarios and perform sustainability analyses.

Another aspect covered by the FORBIO set of sustainability indicators is primarily related to the theme of Biological diversity. Bioenergy production can pose several

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[2] "Eutrophication" is the enrichment of surface waters with plant nutrients. While eutrophication occurs naturally, it is normally associated with anthropogenic sources of nutrients. Source: http://www.fao.org/docrep/w2598e/w2598e06.htm

risks for biological diversity. Conversion of land within **areas recognized 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 feedstock to become invasive and displace or adversely affect native species (FAO 2011). Conversely, the use of lands currently under-exploited, where the soil formation processes are slow, where productivity of the land is limited, and where in general the production of biomass for advanced biofuels could drag these areas out of marginality, has also the potential to enrich the ecological diversity of ecosystems found in the areas studied (e.g. from bare land, through amelioration actions, to the formation of soils and various layers of vegetation) and in turn increase biological diversity. Also, the phytoremediation potential of many species studied in FORBIO holds the potential to enable the recolonization of the contaminated lands by a number of both plant as well as animal species.

Last but not least, in exploring the connection between land cover and indicators of environmental quality, the first and most obvious point is that land cover data is, in itself, an indicator of environmental condition (Jones 2016). Evaluating the land cover and land use change indicator will provide basic information on the role that advanced biofuels production and use play in **land use and land-use change**. The interpretation of this indicator is significantly improved if it is considered simultaneously with land quality and suitability, for example some bioenergy feedstock 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. (FAO 2011)

The *social pillar of sustainability* consists of four different sustainability indicators: land tenure, change in income, jobs in the bioenergy sector, and access to modern bioenergy services.

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.) (FAO, 2014). 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. This aspect is particularly relevant for the Ukrainian case study.

The first objective of this indicator is to map the land tenure system within the ***target area*** and specifically describe the tenure features of the land that is expected/planned/designated to be devoted to bioenergy production (for feedstock production as well as storage and processing facilities). 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

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(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 second objective of this indicator is to describe the relationships between access rights to land in two scenarios: the baseline (i.e. current situation) and the bioenergy production scenario (i.e. future scenario where the intended/planned bioenergy production takes place). In other words, if a planned bioenergy production operation interferes with current land use rights (e.g. grazing allowance, informal agreements, etc.) the social impacts and implications of these interferences should be assessed. Anyway, it is important to underline that the FORBIO project exclusively refers to bioenergy value chains on underutilized and/or contaminated land, where land use rights can be temporarily suspended or permanently suspended.

Income generation is a key indicator of the sustainability of the sector because the **potential contribution of bioenergy production to economic and social development**, particularly in rural and marginal[3] areas, can be a strong driver for the creation of effective value chains. Wages in the bioenergy sector have to be competitive with wages in comparable sectors. This aspect is closely linked to the theme of profitability but it does not coincide with it. Especially on underutilized and/or contaminated lands, externalities (e.g. ecosystems services, contamination remediation, etc.) should be considered in order to evaluate the actual value of the planned operation, which may be relevant even though the operation is not necessarily profitable. In other words, if given the local market conditions a planned bioenergy production may not be deemed profitable, due to externalities this may still be considered viable and feasible. On the other hand, the income of those who operate in the bioenergy value chain must be competitive or else, their contribution would be unsustainable over time. As this seems quite straight forward in the case of skilled labour, especially in the latest stages of the value chain (e.g. biomass processing, fuel transport, etc.), wages in the agricultural stages and feedstock production must ensure a competitive form of income to workers in comparison to those employed in similar agricultural activities. Particularly in the case of underutilized lands, unless other factors limit their usability (e.g. contaminated soils, etc.) often it is due to lack of profitability with traditional agriculture that these lands are abandoned. Bioenergy could represent an alternative when a certain set of condition is met, including a favourable market landscape for energy products as compared to agricultural products. One relevant component of the overall economic balance of modern bioenergy value chains is the cost (and availability) of biomass.

The themes of Rural and social development and labour conditions are also debated. A specific indicator developed for measuring the impacts on job creation referred to local, national and EU level goals and targets has been developed. The indicator measures the **net job creation as a result of advanced biofuels production**

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[3] In this sense, the term *marginal* refers to the presence of underutilized lands, including contaminated sites.

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and use, disaggregated by quality and type of jobs, such as whether the resultant jobs are skilled or unskilled, temporary or indefinite. Change in number, quality and type of jobs due to bioenergy production and use is fundamental to understand the social and economic sustainability of a planned advanced biofuel value chain development. The creation of different types and forms of employment through bioenergy is strictly linked to rural and social development as it can increase and diversify income sources for the local population (see indicator: income). 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 (FAO 2011).

Europe’s 2020 Strategy summarizes the EU agenda for economic growth and job creation for the current decade. It emphasises smart, sustainable and inclusive growth as a way to overcome the structural weakness in Europe’s economy, to improve its competitiveness and productivity and to underpin a sustainable social market economy. Employment is a key policy component of the Europe 2020 strategy. Paid employment is crucial for ensuring sufficient living standards and it contributes to economic performance, quality of life and social inclusion, making it one of the cornerstones of socioeconomic development and well-being.

In this context, the EU employment guidelines, proposed by the Commission and approved by the Council, present common priorities and targets for the national employment policies. They have been integrated in the package with the Broad Economic Policy Guidelines since 2005. The newly proposed set of integrated guidelines reflects the new approach to economic policy-making built on investment, structural reform and fiscal responsibility.

They do so by targeting four key domains:

- Boosting demand for labour, and in particular guidance on job creation, labour taxation and wage-setting;
- Enhanced labour and skills supply, by addressing structural weaknesses in education and training systems, and by tackling youth and long-term unemployment;
- Better functioning of the labour markets, with a specific focus on reducing labour market segmentation and improving active labour market measures and labour market mobility; and
- Fairness, combating poverty and promoting equal opportunities.

Along these lines then, this indicator measures the net possible creation of job attributable to the advanced biofuel value chains in the case study locations disaggregated by job type and category and it evaluates the contribution of bioenergy to meeting the intended goals of the related EU policy.

Europe’s energy policy is a key contribution to achieving the objectives of the new strategy for smart, sustainable and inclusive growth in support of a strong,

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diversified and competitive industrial base. (COM2010) The new European energy strategy focuses on five priorities: Achieving an energy-efficient Europe; Building a truly pan-European integrated energy market; Empowering consumers and achieving the highest level of safety and security; Extending Europe’s leadership in energy technology and innovation; Strengthening the external dimension of the EU energy market.

The **modern energy access** indicator developed by FAO for the FORBIO context aims at providing an assessment of the contribution of advanced biofuels productions to households’ and businesses’ access to and modern energy services at national and local level. Furthermore, in EU countries where underdeveloped areas or regions (specific target areas) present a low rate of access to modern bioenergy, the indicator also helps assessing the contribution of advanced biofuel in terms of increase in number of households’ and businesses’ able to reach a sufficient level of energy access, in line with the European development strategies.

Six indicators have been developed under the *economic pillar* of sustainability. Increased **productivity and competitiveness** of agriculture calls, first of all, for improved resource efficiency in order to produce with less water, energy, fertilisers (especially phosphorus and nitrogen), and pesticides. 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, particularly in the case of advanced biofuels on underutilized lands. Achieving high productivity encompasses also the increased use of renewable energy sources and the reduction of waste, in line with the orientations given by the 'Roadmap to a Resource efficient Europe'[4]. Sustainability requires pollution reduction, to protect water quality and soil functionality, the preservation of biodiversity and ecosystem services, as well as a reduction in greenhouse gas emissions (COM 2012). Solutions need to go beyond the individual farm and also integrate the broader geographical context, including forestry and nature reserves. Appropriate technology as well as new management tools can maximize productivity potential. Sustainable intensification of yields is considered the most important agricultural practice to achieve high efficiencies in bioenergy systems (and more in general agricultural systems). However, in the specific case of underutilized lands, the drawbacks of targeting maximum productivity per unit of surface may undermine sustainability. This could be, for instance, the case of producing the same crop with vs. without irrigation, when only evapotranspiration is the yield limiting factor. Productivity is a pivotal aspect of sustainable advanced biofuels value chains and on underutilized lands, it is fundamental to take into account a number of variables that in traditional bioenergy value chains may be overlooked. Education and training are essential for developing the skills needed to enhance yields sustainably. Strengthening the farmers' position in the supply chain requires innovative approaches that enhance transparency, information, and management capacity and deliver new quality products. Lastly, such innovative approaches are often the result of intuitions and ideas of intelligent

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[4] COM(2011) 571final

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farmers that apply their knowledge and inventions to their fields, often taking risks of failure. This is why any policy and agreement for the constitution of advanced bioenergy value chains should not neglect the importance of creating the stimulus for farmers to experiment and achieve higher productivity as long as this is done sustainably.

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. 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 advanced 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. The FORBIO Net energy balance indicator is primarily related to the theme of Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use.

Broad-based economic growth is essential for long-term sustainable and socially-inclusive development. Economic growth creates the income opportunities needed to raise living standards and lift people out of poverty. The European Union’s actions aimed at encouraging economic growth in partner countries focus on support for: private sector development, aid for trade, regional economic integration, public finance and macroeconomic assessment. EU actions that encourage economic growth through trade and private sector development and support for regional economic integration effectively complement actions by the EU’s Member States and development partners. These actions target the creation of better regulatory environments in partner countries, business development and access to finance, with a particular focus on job-creating micro, small and medium-sized businesses (COM 2017). In FORBIO, a specific 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. **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 (FAO 2011).

Smart growth means strengthening knowledge and innovation as drivers of future growth. This requires improving the quality of education, strengthening research performance, promoting innovation and knowledge transfer throughout the Union, making full use of information and communication technologies and ensuring that innovative ideas can be turned into new products and services that create growth, quality jobs and help address European and global societal challenges. But, to succeed, this must be combined with entrepreneurship, finance, and a focus on user needs and market opportunities (COM 2010). The indicator training of the FORBIO set of sustainability indicators 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 on Jobs in the bioenergy sector) and is indirectly related to other themes such as Labour conditions, Human health and safety, and economic development (FAO 2011).

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 (FAO 2011). In this regard, a specific indicator in the FORBIO set of sustainability indicators has been developed with the aim of identifying critical distribution systems for bioenergy feedstocks, fuels and electricity production and distribution systems and determining the capacity values for each of the identified distribution systems. This indicator will necessarily imply the use of GIS mapping and simulation methodologies because statistics alone can hardly define the most effective and realistically achievable logistics for the transport and distribution of bioenergy raw materials, inputs and final products.

Finally, the FORBIO set of sustainability indicators covers the critical aspect of **capacity and flexibility of use of bioenergy**. 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. Understanding the capacity constraints and margin and the flexibility on fuel use allows an appreciation of the risks associated with using bioenergy (FAO 2011). The following paragraphs of this report provide information on how the indicators were developed, trying to contribute to EU development strategies, e.g. Europa2020, and a description of the sustainability indicators divided by the three pillars of sustainable – economic, environmental, and social – in the context of advanced biofuels production.

3.2. Indicators as tools for assessing the sustainability of bioenergy projects in Europe

FORBIO will contribute to developing better policy and market support at the national and sub-national level by identifying the barriers to the deployment of modern bioenergy and presenting strategies and best practices for overcoming such barriers.

The added value of the FORBIO project, which directly affects the increase in the share of bioenergy consumption, is represented by the activities dedicated to the establishment of partnerships among all economic and non-economic actors in all case study sites (Germany, Italy and Ukraine) in order to set the basis for agreements that will enable investments for the large-scale production of sustainable bioenergy. FORBIO will produce a roadmap for the development of advanced biofuels value chains with specific steps to allow the highest sustainability standards are met. This will contribute to achieving more sustainable agriculture and forestry. Clearly, the highest sustainability standards encompass the carbon footprint of the fuels that could potentially be generated from the value chains tested in FORBIO, thus contributing to GHG emission reduction in the EU.

FORBIO will provide technical documentation and guidelines (including all aspects on sustainability) so that developed value chains can be exploited, thus supporting further adoption of bioenergy technologies in EU Member States. The guides and documentations of value chains and techno-economic potential assessments will be scaled up for sharing and distributing at EU level, therefore the discovered and applied technologies can penetrate the market at national and international level.

FORBIO will foster bioenergy production in target areas of Europe where the land is underutilized and/or contaminated (marginal lands), and therefore food crops are not grown, minimizing direct and indirect competition with other uses. The project will facilitate the set-up of bioenergy value chains in the target areas and farmers will be encouraged to produce biomass for energy sustainably by the creation of the necessary enabling environment and business connections. This could set the basis for increased employment opportunities in these areas. In addition, when the land is sustainably managed, which is the primary goal of the roadmap that will be developed in the context of FORBIO, the conservation and restoration of ecosystems is a key action. Underutilized lands usually are abandoned. In the case of lignite mining sites for instance, this abandonment affects negatively the ecological successions which is expected to require up to 1,000 years before reaching its final stage. With rehabilitation techniques, this gap can be shortened by a factor of 10, while increasing the biodiversity value of those ecosystems.

Identification and monitoring of areas converted to bioenergy production and of potentially invasive species used as bioenergy feedstock are the first steps being pursued by FORBIO toward preventing loss of biodiversity. A set of sustainability indicators has been developed with the aim of assessing the sustainability of the project value chains focusing on landscape and biodiversity preservation. Implementation of nationally recognized conservation methods in and around biofuel production areas can help reduce negative and promote positive impacts on biodiversity of the cultivation of biofuel feedstock. For instance, preliminary findings indicate that in one of the case study areas, the perspective use of the land and the cover with giant reed, may contribute to the creation of habitats and ecological corridors for a number of birds species.

FORBIO CONTRIBUTION TO EU DEVELOPMENT STRATEGIES

RED: Directive 2009/28/EC on the promotion of the use of energy from renewable sources (known as the Renewable Energy Directive, RED)

- In 2020 20 percent of the EU energy consumption is produced from renewable energy sources.
- Promotion of security of energy supply.
- Promotion of technical development and innovation.
- Promotion of employment and regional development, especially in rural and isolated areas.

Europe 2020 strategy

- Climate change and energy (- greenhouse gas emissions 20 percent lower than 1990 levels; - 20 percent of energy coming from renewables; - 20 percent increase in energy efficiency).
- Research and development (- 3 percent of the EU's GDP to be invested in R&D).
- Employment (- 75 percent of people aged 20–64 to be in work).
- Poverty and social exclusion (- at least 20 million fewer people in – or at risk of – poverty/social exclusion).

Biodiversity Strategy 2016- Natura2000

- Protect species and habitats – Target 1;
- Maintain and restore ecosystems – Target 2
- Achieve more sustainable agriculture and forestry - Target 3
- Combat invasive alien species – Target 5;
- Help stop the loss of global biodiversity – Target 6
- Natura2000 birds and habitats directives

TABLE. 2 FORBIO contribution to EU strategies, policies, and programmes

3.3. Structure of the sustainability indicators

The methodology sheets for the FORBIO sustainability indicators, which include supporting information relating to the relevance, practicality and scientific basis of the indicators, are presented in chapter 4 of this report.

The following content is included for each indicator:

THE STRUCTURE OF SUSTAINABILITY INDICATORS

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, , depending on data availability, other units may be used (in case conversion is impossible).
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 local, regional and when possible national and EU level indicator.
DATA REQUIEREMENTS	These are the basic data that are required to build the indicator, in accordance with the methodological approach described above.
SUGGESTED STEPWISE APPROACH	In this section the all the steps that compose the indicator are explained.
METHODOLOGY	This step technically describes the methodological approach and the assessment of the sustainability of the value chains.
REFERENCE	References are listed for each sustainability indicator.

TABLE. 3 FORBIO sustainability Indicators contents

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Figure. 1 Willow plantation in Kukhari Village, Kiev, Ukraine

Figure. 2 Aerial view of the aluminium red-sludge lake in Portoscuso, Italy. The metallurgic industry has emitted heavy metals into the atmosphere and caused the leaching of these harmful compounds into the water table

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4. The FORBIO sustainability indicators for bioenergy

In the context of the FORBIO Project a set of sustainability indicators for bioenergy has been developed. These indicators are:

FORBIO BIOENERGY SUSTAINABILITY INDICATORS		
ENVIRONMENTAL	**SOCIAL**	**ECONOMIC**
Life-cycle GHG	Land Tenure	Productivity
Soil Quality	Change in Income	Net Energy Balance
Non GHGs	Jobs in Bioenergy Sectors	Gross Value Added
Water Use and Efficiency	Modern Energy Access	Training
Water Quality		Infrastructures and logistics for bioenergy distribution
Biodiversity		Capacity and flexibility of use of bioenergy
Land Use Change		

TABLE. 4 The FORBIO set of sustainability indicators

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4.1. Environmental pillar

ENVIRONMENTAL PILLAR

THEMES

FORBIO considers the following themes relevant, and these guided the development of indicators under this pillar: Greenhouse gas emissions, Productive capacity of land and soil contamination and pollution, Air quality, Water quality and availability, Biological diversity, Land use and land use change

INDICATOR NAME	INDICATOR DESCRIPTION
Lifecycle GHG emissions	Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology to be presented and defined in each of the FORBIO case study sites (at the local level), and based on the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'.
Soil Quality	Percentage and surface 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.
Non GHGs	Emissions of non-GHG air pollutants, including air toxic, form bioenergy feedstock production, processing, transport of feedstock, intermediate products and end products, and use; in comparison with other energy sources.
Water Use and Efficiency	Water withdrawn from watersheds within the target area for the production and processing of bioenergy feedstock; 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; water withdrawn from watersheds within the ***target area*** for the production and processing of bioenergy feedstock per unit of bioenergy output, disaggregated into renewable and non-renewable sources.
Water Quality	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; 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.
Biodiversity	Surface and percentage of high biodiversity value areas or critical ecosystems converted to bioenergy production; Area and percentage of the land used for bioenergy production where invasive species, by risk category, are cultivated; Area and percentage of the land used for bioenergy production where conservation methods are used.
Land Use Change	Within the ***target area***, the surface and percentage of land for bioenergy feedstock production as compared to: total land surface of the target area disaggregated by land use; total underutilized land including contaminated land, fallow land, abandoned land, degraded land, etc.

TABLE. 5 The FORBIO environmental sustainability indicators

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LIFECYCLE GHG EMISSIONS

DESCRIPTION:	Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology to be presented and defined in each of the FORBIO case study sites (at the local level), and based on the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'.
MEASUREMENT UNIT(S):	Grams of CO_2 equivalent per megajuole of biofuel (gCO_{2eq}/MJ) and percentage difference between comparable alternative fuel
METHODOLOGICAL APPROACH:	The Lifecycle greenhouse gas emissions (GHG LCA) of bioenergy presented is based upon the GBEP Common Methodological Framework as it allows the identification of the contribution of the various components of the value chain to total emissions. The framework consists of 10 "steps" of analysis. In steps 1 and 2 the user identifies the GHGs included in the LCA and the source of the biomass feedstock. Steps 3-9 walk the user through a full LCA appropriate for bioenergy production and use, including emissions due to land-use change, biomass production, manufacture, transport and use of fertilizers, co-products and by-products, transport of biomass, processing into fuel, transport of fuel, and fuel use (where applicable and appropriate). Step 10 is the comparison with the replaced/alternative 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.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** – Emission intensity of reference fuels for comparison (e.g. petrol, natural gas, etc.) **B - TARGET SCENARIO** – GHGs covered – Source of biomass (feedstock) – Information about land use change (direct) – 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

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

PLEASE NOTE THAT ALL VALUES REPORTED IN THE VARIOUS STEPS BELOW ARE MERELY INTENDED AS EXAMPLES AND DO NOT NECESSARILY REPRESENT REAL CASE STUDY VALUES

STEP 1: COMPARISON WITH REPLACED FUEL

A. Biofuel is used to replace transport fossil fuel

i. Relevant characteristics of crude:
ii. Type of crude: Conventional crude.
iii. Origin of fuel (region, refinery, etc.), if specified: All Colombian crude.
iv. Other important fuel characteristics, if specified.

v. Applicability conditions of the replaced fuel characteristics:

B. The reference fuel is considered as average of the specify region: Europe.

i. Emissions prior to extraction/production are accounted for: No.
ii. Emissions from extraction/production are accounted for: Yes.
iii. Crude is transported to the refinery: Yes.
iv. Refinery emissions are accounted for: Yes.
v. Fuel is transport or distributed prior to use: Yes.
vi. Fuel use emissions are accounted for: Yes.

B - TARGET SCENARIO

STEP 2: GHG COVERED & GW POTENTIAL

- CO_2, CH_4, N_2O
- GWP CO_2: 1 gCO_{2eq}/gCO_2
- GWP CH_4: 25 gCO_{2eq}/gCH_4
- GWP N_2O: 310 gCO_{2eq}/gN_2O

STEP 3: SOURCE OF BIOMASS

- Identification: e.g. Lignocellulosic biomass from dedicated energy crops
- These include: e.g. Giant reed (*Arundo donax*), Miscanthus, Lucerne, grass, willows and poplars. Main information sources are retrieved and analysed under WP2 by each of the case study-dedicated teams.

STEP 4: LAND USE CHANGE

The complete life cycle of dedicated energy crops such as giant reed, willows, poplars and miscanthus is approximately 25 - 30 years. In the case study areas, modern bioenergy production may already be taking place (e.g. Ukraine) and land use change associated with feedstock production (if any) must be accounted for starting from the beginning of the first planting cycle which produced biomass used for energy. Time series of land cover maps (possibly georeferenced) should be used to reconstruct the LUC dynamics of the case study sites. In strict terms, LUC refers to a change in use, thus if agriculture was already established, in theory no change is reported when switching between crops (be it any form of transition from food crops to energy crop). In practical terms however, and for the sake of an accurate accounting of GHG emissions (and sinks), an understanding of the land cover type and associated above and below ground biomass (and thus C stock) should be made. C stock estimated for various land cover types are also available in literature, from IPCC to many peer reviewed papers.

STEP 5: BIOMASS FEEDSTOCK PRODUCTION

In order to calculate emissions from e.g. irrigation, basic information such as type of energy carrier and technology used (e.g. electricity at the national mix; diesel; solar power; etc.) as well as the amount of water pumped at the watershed level should be retrieved and available. The same goes for the other sources of GHG emissions reported below:

- Sources of direct GHG emissions and removals to be accounted for (when applicable):
- – Emissions from operating farm/agricultural machinery (for land clearing and first implant, plus seasonal tillage and harvest etc);
- – Emissions from energy used for irrigation;
- – Emissions from energy usage in transport of raw materials;
- – CO_2 emissions from lime/dolomite applications;
- – N_2O emissions resulting from the applications of nitrogen fertilizers: Direct, volatilization and runoff/leaching;
- – N_2O emissions resulting from the applications of manure to soil: Direct, volatilization and

runoff/leaching.

- N_2O emissions resulting from the applications of other fertilizer (e.g. compost) to soil: Direct, volatilization and runoff/leaching;
- CH_4 emissions resulting from application of manure or other organic fertilizers;
- Emissions coming from the production of fertilizers, pesticides and agrochemicals;
- Other: Carbon capture and long term storage from biomass growth (e.g. root and carbon fixation in the soil).

- For all sources, find below assumptions and emissions reference values used:

Assumptions:

- Emissions from operating farm/agricultural machinery: Emissions from tillage (harrowing, ploughing, digging, stirring and overturning, furrowing, etc.), agricultural activities such as distribution of fertilizers and/or pesticides, and harvest need to be accounted for. The fuel used is assumed to be diesel, specify if different. Data from the work under WP2 should include an estimate of the workload applied per ha (e.g. in hours/ha/year, or in kg of fuel/ha/yr)
- Emissions from energy used in irrigation: It is assumed the use of electrical pumps, unless specified. The water source should be specified: is it surface, ground water or both?
- Emissions from transport of input:
    - + Fertilizer: Terrestrial transport.
    - + Synthetic Fertilizer: Terrestrial transport.
    - + Organic fertilizer: Terrestrial transport.
    - + Pesticides: Terrestrial and maritime transport.

Transport distances are estimated on the basis of market analyses for the commodities employed.

- CO_2 emissions from lime/dolomite applications: IPCC default factor emission. Deliverables under WP2 to inform on whether lime/dolomite is applied and at what rate;
- N_2O emissions resulting from the applications of nitrogen fertilizers: Direct, volatilization and runoff/leaching. Urea, diammonium phosphate and ammonium sulphate are considered synthetic fertilizers. The rates of application of these compounds should be provided by the deliverables under WP2;
- N_2O/CH_4 emissions resulting from the applications of manure to soil: Direct, volatilization and runoff/leaching. The rates of application of these compounds should be provided by the deliverables under WP2;
- N_2O/CH_4 emissions resulting from the application of other fertilizer (e.g. compost) to soil: Direct, volatilization and runoff/leaching. The rates of application of these compounds should be provided by the deliverables under WP2;
- Other: Carbon capture from biomass growth.

STEP 6: TRANSPORT OF BIOMASS

Biomass is transported from farm/plantation/forest to processing plant: Yes.

If yes:

- Transport from production site to use/processing is dedicated to this purpose: Yes.

If yes:

- Transport distance of biomass: e.g. 40.00 km
- Type of transport used: truck/tractors
- Energy efficiency for transport of biomass via truck/tractors: e.g. 0.94 MJ/t*km (BioGrace, 2012).

STEP 7: PROCESSING INTO FUEL

- GHG emissions associated with material inputs used in the conversion process (e.g. chemicals, water) are accounted for: (Y or N):

Specify method used to account for emissions: All transport emissions were accounted for using the energy efficiency adequate in each case.

- GHG emissions associated with the energy used in the conversion process are accounted for: (Y or N):

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Specify the method used to account for grid-related emissions (e.g. average/marginal, national/regional, actual/future, emission factors): e.g. Average grid emission intensity by country; source BioGrace.net

- GHG emissions from wastes and leakages (including waste disposal) are accounted for: Yes
- Other GHG emissions from the process are accounted for: Yes.
- GHG emissions associated with the plant construction are accounted for: No.
- List (and example values) of data on processing inputs needed for this step:
- – Inputs transport distances: e.g. 7,601 km
- – Transport distances via sea: e.g. 33,000 km
- – Reagents and enzymes total quantity (lime, sulfuric acid, sulphur, sodium hydroxide, carbon, biocides, surfactants, among others): e.g. 59.6 t/40,000 t_{EtOH}
- – Energy efficiency for truck: e.g. 0.94 MJ/km*t
- – Energy efficiency for ship: e.g. 0.12 MJ/t*km
- – Electricity to grid: e.g. 128.5 kWh/t ethanol
- – Electricity factor emission: e.g. 0.2916 $kgCO_{2eq}$/kWh
- – Emissions factor for cogeneration system: e.g. 0.71 $kgCO_2$/kg lignin; e.g. 0.0000052 kg N_2O/kg lignin

STEP 8: BY-PRODUCTS AND CO-PRODUCTS

By-products and co-products are produced:

- By/Co-products from biomass are accounted for: Yes.
- By/Co-products from non-biomass feedstocks are accounted for: No.
- Explain definition of by/co-products:
- – By-products: Waste from biomass transformation processes, which is obtained through the supply chain.
- – Co-product: Additional commodity obtained as a result of the value chain.

- Select method used to analyze the by-products or co-products, and the by-products or co-products for each:

Co-products include:

- – Electricity by cogeneration: sold to the grid.
- – Compost: Fertilizer. It is included as organic fertilizer. Inputs for this unit are the treatment sludge from the waste waters, leaves and sugarcane sweep, ashes from the cogeneration process and a stillage fraction.
- – Lignin: e.g. sold to pellet industry

By-products are:

- – Vinasse (35 percent wt): It is considered an accounted for as organic fertilizer. A part of the stillage is directly applied over the fields.
- – Boiler ash: Employed in the fields as compost.
- – Wastewaters: For anaerobic treatment. Waste waters are anaerobic treated in a UASB digester. A methane capture systems is present, biogas is flared. Calculation of the methane produced is carried out using the emission factors given by the IPCC (Eggleston et al., 2006).
- – Wastewater sludge: Employed in the fields as compost
- – Condensates: Employed in the fields as compost
- – Others?

- An allocation method is used (Y or N): Yes.
- – Allocation by mass: No.
- – Allocation by energy content: Yes.
- – Allocation by economic value: Yes.
- – Other allocation method: No.

- A substitution method is used (Y or N): No
- Another method or combination of methods is used:
- For relevant sections, clarify assumptions:

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- Giant reed reference amount: 1 t.
- Electricity via cogeneration: 2.5 kWh
- Biocompost 0.03 t
- Bioetanol production: 0.25 t
- Wastewater to treat: 1.42 m^3
- Biogas generation from wastewater treatment: 0.21 t CH_4/ t treated DQO (Eggleston et al., 2006).
- Emitted nitrogen from biocompost production: 1.225 percent of total nitrogen (Eggleston et al., 2006).
- Methane generation from biocompost production: 10 g CH_4/kg dry material (Eggleston et al., 2006).
- LHV for bioethanol: 26.80 MJ/kg
- Energy contents of biocompost: 5 MJ/kg.

STEP 9: TRANSPORT OF FUEL

Fuel is transported from processing plant to use site: Yes.

- There is a multi-stage transport chain (e.g. truck to ship to truck or train or animal-traction vehicles to truck or train). No.
- Transport from the processing plant to the use site is dedicated to this purpose: Yes.

a. All transport emissions are accounted for: Yes.

- Return run of transport equipment is accounted for: No.
- For relevant sections, clarify assumptions:
- Distance: 100 km
- Energy efficiency: 1.01 MJ/km*t(BioGrace, 2012).
- Emission factor: 74.1 $gCO2_{eq}$/MJ (Eggleston et al., 2006).

STEP 10: FUEL USE

For transport fuels:

- Distance (km and miles) per energy unit are addressed: No.
- Tailpipe gas is addressed: No.
- Describe assumptions:
- General blend: E10
- Emission factor: 36 mg N2O/km (Eggleston et al., 2006).
- Emission factor for E8 blend: 62.45 (Rincón, 2012).
- Emissions factor for Colombian usage: 0.1758 kg CO2/km, 0.00075538 kg CO/km, 0.00035636 kg NOx/km, 0.000023067 kg N2O/km (Consorcio CUE, 2012).
- Fuel consumption: 0.085 L/km.
- E8 density: 0.8799 (Rincón, 2012).

METHODOLOGY

BASELINE: Petrol **83.8 $gCO2_{eq}$/MJ**

TARGET: e.g. 2G ethanol **32.4 $gCO2_{eq}$/MJ**

FINAL CHANGE IN GHG EMISSION INTENSITY:

TARGET – BASELINE

61.44 percent GHG emission reduction

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
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SOIL QUALITY

DESCRIPTION:	Percentage and surface of land for which soil quality, in particular in terms of soil organic carbon, bulk density (soil compaction) and soil erosion and salinization, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested.
MEASUREMENT UNIT(S):	Percentage and ha
METHODOLOGICAL APPROACH:	Soils are an essential determinant of the productive capacity of the land. Soil is a finite resource, meaning its loss and degradation is not recoverable within a human lifespan. As a core component of land resources, agricultural development and ecological sustainability, it is the basis for food, feed, fuel and fibre production and for many critical ecosystem services. Sustainable management of the world's agricultural soils and sustainable production have therefore become imperative for reversing the trend of soil degradation (FAO 2015b). 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 the following key factors that contribute to soil quality loss: – **Soil erosion**, leading to loss of soil, especially topsoil and thus to lower productive capacity of the land; – soil degradation and **loss of soil organic matter**, leading to decreased carbon content and soil fertility; – **soil compaction**, reducing water flow and storage, and limiting root growth; – accumulation in soils of **mineral salts (salinization) from irrigation** water and/or inadequate drainage, with possible adverse effects on plant growth; Loss of plant nutrients, (e.g. through intensive harvest) is also a crucial factor that can be considered in this assessment. Due to the interlinkages between these key factors affecting soil quality, assessing trends in soil organic carbon can provide much of the information needed. 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. Salinization is closely associated with the process of desertification. Salinity may have direct negative effects on crop yields by reducing the ability of plant roots to take up water. The reduced availability of water to the plant is due to soluble ions and molecules causing an osmotic pressure effect. Threshold relationships between the soil electrical conductivity (EC) and crop yield have been empirically determined for several crops and can be used to evaluate the influence of saline irrigation water on agricultural production (FAO 2007). Soil compaction occurs when soil particles are pressed together, reducing pore space between them. Heavily compacted soils contain few large pores and have a reduced rate of both water infiltration and drainage from the compacted layer. Soil compaction changes pore space size, distribution, and soil strength. One way to quantify the change is by measuring the bulk density. As the pore space is decreased within a soil, the bulk density is increased. Soils with a higher percentage of clay and silt, which naturally have more pore space, have a lower bulk density than sandier soils (J. DeJong-Hughes, et al. 2001). Most soil erosion research focuses on soil loss caused by water, wind or tillage

but soil loss due to crop harvesting (SLCH) may vary from few to tens of tonnes of soil per hectare per harvest. On cropland, SLCH may thus be as important as other soil erosion processes and should therefore not be disregarded (COM 2017).

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

Basic analysis of soil conditions of each bioenergy production site:

Within the borders of the ***target area***, total land on which bioenergy feedstock is or is expected/planned to be cultivated or harvested (in hectares or square kilometres). In order to obtain such information the following analyses should be carried out:

- physical, chemical and biological indicators;
- soil organic carbon content for each bioenergy production site (mg of organic carbon per g of soil sample)
- soil contamination or pollution due to the presence of xenobiotic chemicals or other alterations in the natural soil environment.
- Soil compaction, in terms of bulk density
- site characterization (soil classification, risk factors for nutrient loss, erosion, soil salinization based on site scale assessment and/or mapped information)

For forecasting future soil quality performances, additional information should be collected and proxies identified in order to assess with reasonable accuracy the potential effects of the proposed/planned actions on soils. Information on the application of Best Management Practices for enhancing soil quality should be provided.

Characteristics of the soils that take centuries to develop may change in the course of a few years, however, in most cases soil quality parameter should be monitored over the long period in order to obtain valuable information and derive trustworthy trends. This is why a monitoring section is added to this indicator for the purpose of periodically assessing variations in key soil quality parameters and derive recommendations for future management of the areas studied.

B - TARGET SCENARIO

Collect data related to all operation of the project implementation

- Bioenergy crops; soil and crop management practices related to selected crops (amount of feedstock production, amount of residues that are left in the field, type of fertilization)
- Soil compaction: identify all the agronomic practices that can cause soil compaction and measure mechanization impact on bulk density of the soil by production site.
- in case of increased soil salinization risk: identify all the agronomic practices that can cause soil salinization phenomena and collect data measurement of electric conductivity of the soil by production site;

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: TOTAL SURFACE OF UNDERUTILIZED LAND THAT CAN BE USED FOR BIOENERGY FEEDSTOCK PRODUCTION WITHIN THE *TARGET AREA* (IN HECTARES).

- Hectares of underutilized (agricultural and non-agricultural) land available in the project target area

- Soil cover type on underutilized lands

STEP 2: SITE CHARACTERIZATION

It is important to gain as much information as possible about the study area and its soils.

- Site and soil characterization

In general, there should be availability of reports and literature material that presents the main characteristics of the site within the target area. Relevant information in the literature should fulfil the list presented below, as well as where there is no available literature material, a description of the site must be carried out using the steps presented below:

Location of the *target area* and bioenergy production fields	Record longitude and latitude (if GPS unit is available), a description of the location (feet from landmarks), and a drawing of the field showing sampling areas
Climatic information	This item includes precipitation and high and low average temperatures for each month (data from a county or watershed level will often be sufficient)
Soil series	The soil series name can be found in the country soil survey or in the soil classification of each site[5].
Slope and geographical features of the field	Record percent slope at the sampling sites within the field, and describe any hills, knolls, ridges, potholes, depressions, etc.
Land degradation	Land degradation refers to the temporary or permanent reduction in the productive capacity of land as a result of human and natural action. – Type of degradation: water erosion, wind erosion, chemical deterioration, physical deterioration, and subdivisions of these. – Degree of degradation: light, moderate, strong, extreme. – Relative extent of degradation, as percentage of the mapping unit affected. – Causative factors of degradation: deforestation, overgrazing, agricultural activities (improper agricultural management), overexploitation of vegetation (cutting for fuel wood, etc.), industrial activities (pollution).
Erosion	Signs of erosion include gullies, rills, development of pedestals, exposed areas of subsoil, damage to plants caused by windblown materials, etc. in the majority of cases soil erosion (soil detachment, movement and deposition) is a measurable parameter[6] caused by water, wind and tillage. If possible, a quantitative assessment of material (i.e. topsoil) transport rates in t/ha/year for the reference study period should be provided.
Information on groundwater salinization risk	This item includes all the relevant information and descriptions of groundwater input system and salinization risks at local level for each of the bioenergy production sites.
Management history	This item includes a description of past and present land and crop management; kind, amount, and method of fertilization; prior tillage; and land levelling

STEP 3: PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS

Soil quality integrates the physical, chemical, and biological components of soil and their interactions. Therefore, to capture the holistic nature of soil quality, all parameters below should be measured and where feasible, monitored (USDA 2001b). As above, often the information required to assess physical, chemical and biological soil quality parameters is available from the specialized literature. When this is the case, the tables below should be filled with the adequate values (duly converted in case measurement units differ) taken from the literature. When there is no report on the specific *target area* which incorporates soil quality analyses, as in the case of Step 2 the description of soil's features must be carried out including the parameters listed below:

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[5] The Universal WRB Classification is a soil classification system for naming soils and creating soil map legends. The classification of soils is based on soil properties defined in terms of diagnostic horizons, diagnostic properties and diagnostic materials, which to the greatest extent possible should be measurable and observable in the field (USDA 2001a).

[6] The Universal Soil Loss Equation (USLE) is the most common soil loss mesurement equation that equates soil loss per unit area with the erosive power of rain, the amount arid velocity of runoff water, the erodibility of the soil, and mitigating factors due to vegetation cover, cultivation methods and soil conservation.

- Soil parameters

Parameter categories	**Symbol/abbreviation**	**Unit**
Physical		
Aggregate stability	*AS*	% of soil > 0.25mm
Available water capacity	*AWC*	% Volumetric water
Infiltration	*F*	mm/hrs
Soil crust		Kg/cm^3 or Mpa
Soil structure and macropores		
Total Porosity	PO	% volumetric
Chemical		
Reactive Carbon		mg/kg
Soil Nitrate	NO^-_3	mg NO3-N/m^{-2}
Soil pH	pH	°pH
Phosphorus	$H_2PO^-_4/HPO^{--}_4$	mg/kg
Potassium	K_2O	mg/kg
Biological		
Particulate Organic Matter	POM	g Kg^{-1}
Potentially Mineralizable Nitrogen	PMN	
Soil Enzymes		U g of dry soil
Soil Respiration		mg CO2-C/m^{-2}/day^{-1}

STEP 4: SOIL ORGANIC CARBON CONTENT FOR EACH BIOENERGY PRODUCTION SITE (MG OF ORGANIC CARBON PER G OF SOIL SAMPLE)

- Percentage of soil organic matter

Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM). SOM contains approximately 58% C; therefore, a factor of 1.72 can be used to convert OC to SOM. There is more inorganic C than TOC in calcareous soils. TOC is expressed as percent C per 100 g of soil (FAO 2015a).

Soil organic matter and total organic carbon in soil

PARAMETER CATEGORIES	UNIT
SOM	g/Kg or %
TOC	g/Kg or %

Soil Organic Carbon is an important parameter for soil quality assessments and a quantitative analysis of this feature should be provided.

STEP 5: BULK DENSITY AND SALINIZATION RISK INFORMATION

- Collect baseline information on soil compaction:
    a. Identify all the agronomic practices that can cause soil compaction
    b. Measure mechanization impact on bulk density of the soil by production site
    c. Measure bulk density level
- Collect baseline information on salinization risk due to irrigation activities:
    a. Identify the irrigation type
    b. Measure the impact of irrigation activities on soil salinization
    c. Measure soil salinization using Soil Electrical Conductivity (EC)

INDICATOR	PARAMETER CATEGORIES		UNIT
SOIL COMPACTION	**Bulk density**	*BD*	g/cm^3
SOIL SALINISATION	**Soil Electrical Conductivity**	EC	mS/cm

STEP 6: SOIL CONTAMINATION OR POLLUTION DUE TO THE PRESENCE OF XENOBIOTIC CHEMICALS (E.G. POLLUTANTS) OR OTHER ALTERATIONS IN THE NATURAL SOIL ENVIRONMENT

Soil contamination constitutes a critical issue to be addressed for the evaluation of soil quality indicator. Usually, contaminated sites are designate such on the basis of official, publicly available reports, often produced by local public authorities. These reports should constitute the basis for the analysis of this step of the Indicator, and in case these are not available primary data collection should be carried out.

- Most common pollutants in soil

PARAMETER CATEGORIES	SYMBOL/ABBREVIATION	UNIT
HEAVY METALS		
Lead	Pb	ppm or mg/kg
Chromium	Cr	ppm or mg/kg
Arsenic	As	ppm or mg/kg
Zinc	Zn	ppm or mg/kg
Cadmium	Cd	ppm or mg/kg
Copper	Cu	ppm or mg/kg
Mercury	Hg	ppm or mg/kg
PETROLEUM HYDROCARBONS		
Mono aromatics (e.g. benzene, toluene, ethyl-benzene, and xylenes etc.)	AHs	mg/kg
Polycyclic aromatic	PAHs	mg/kg
POLYCHLORINATED BIPHENYLS	PCBs	
Chlorinated aromatic compounds		mg/kg
DETERGENTS		
SOLVENTS		mg/kg
PESTICIDES		mg/kg
DDT		ppm or mg/kg
Hydrophobic, persistent, and bioaccumulable pesticides (organochlorine DDT, endosulfan, endrin, heptachlor, lindane and their TPs)		ppm or mg/kg
Polar pesticides (represented mainly by herbicides but they include also carbamates, fungicides and some organophosphorus insecticide TPs)		ppm or mg/kg
Fertilizers		
Nitrate	NO_3^-	ppm or mg/kg
Phosphate (e.g. Sodium triphosphate)	PO^{3-}_4	ppm or mg/kg
Phosphorous	P	ppm or mg/kg
Potassium	K	ppm or mg/kg
RADIONUCLIDES		mg/kg

B - TARGET SCENARIO

In the TARGET SCENARIO (with project situation), the balance of the soil organic matter will allow to measure the increase or decrease in soil fertility, monitoring a parameter that defines the status of the soils and therefore, their production potential. This balance takes account of the mineralization phase, the organic matter deposition in both scenarios as well as fertilization and sustainable use of residues in the field in the target scenario.

STEP 7: SELECTED BIOENERGY CROPS FOR FEEDSTOCK PRODUCTION.

Information related to the energy crops that are cultivated in the target area is crucial in the assessment of the soil fertility, specifically in the balance of the soil organic matter.

- Type of energy crop

- Hectares of land used for growing the selected energy crops divided by crop

STEP 8: CHEMICAL AND ORGANIC FERTILIZATION

- Amount of N, P, K per hectare
- Amount of organic fertilizers (manure, sewage and sludge)

STEP 9: PROTOCOL OF BEST MANAGEMENT PRACTICES FOR ENHANCING SOIL QUALITY

This step constitutes the instrument to assess the potential impact on future development of soil quality parameters in the ***target area***. It is important that the actions listed below are carefully considered and their implementation and implications in the bioenergy production sites within the ***target area*** are adequately evaluated.

- Best management practices

ACTION CATEGORIES	APPLICABILE	WILL BE APPLIED	DETAILS	DESCRIPTION
SOIL				
CROPPING RESIDUES IN FIELD	YES/NO	YES/NO	Amount (t/ha/yr)	Crop residues left intact help both natural precipitation and irrigation water infiltrate the soil, limits evaporation, conserving water for plant growth. Soil compaction is limited and plants are able to grow their roots deeper into the soil.
ORGANIC FERTILIZERS/COMPOST	YES/NO	YES/NO	Amount (t/ha/yr)	Maintaining or restoring soil organic content, by manure application, compost, use of grazing
GREEN MANURE	YES/NO	YES/NO	Amount (t/ha/yr)	In situ green manuring by growing pulse crops and crop rotation
PROVIDE GOOD FERTILIZATION	YES/NO	YES/NO		Application of fertilizers at appropriate moments and in adequate doses (i.e., when the plant needs the fertilizer), to avoid run-off

METHODOLOGY

BASELINE:

1. Natural SOM balance

[RESIDUES of natural cover (kg/ha*DM*k1) – ANNUAL MINERALIZATION (SOM*k2/100)]

FINAL AMOUNT OF SOM DUE TO NATURAL INCREASE

E.g.

SHRUBLAND: (18,000 kg/ha*0.40*0.20) – (50,750 kg/ha*2/100) =
1,440 – 1,015 = **+ 425** Kg/ha/year

2. Bulk density

level of bulk density at the baseline situation:

E.g.

BASELINE measured bulk density: **1.33** g/m^3

3. Salinization risk

level of Soil Electrical Conductivity:

E.g.

BASELINE measured EC: **3.33** mS/cm

TARGET:

1. target SOM balance

[Crop residues (kg/ha*DM*k1) + fertilization (kg/ha*DM*k1) – ANNUAL MINERALIZATION (SOM*k2/100)]

FINAL AMOUNT OF SOM DUE TO BIOENERGY FEEDSTOCK PRODUCTION

E.g.

(7,000 kg/ha*0.40*0.20) + (10,000 kg/ha MANURE*0.35*0.20) – (50,750 kg/ha*2/100) =
560 + 700 – 1,015 = **+ 245** Kg/ha/year

2. Bulk density

level of bulk density at the baseline situation:

E.g.

TARGET measured bulk density: **1.80** g/m^3

3. Salinization risk

level of Soil Electrical Conductivity:

E.g.

TARGET measured EC: **2.00** mS/cm

FINAL ASSESSMENT:

TARGET – BASELINE

1. Final change in SOM:
   245-425 = **- 180** Kg/ha/year

2. Final change in bulk density:
   180 – 133 = **+ 47** g/m^3

3. Final change in soil EC:
   2.0 – 3.3 = **+ 0.7** mS/cm

Where:

* K1= isohumic coefficient of the material applied (kg SOM / kg material)
* K2= mineralization coefficient of the soil (1/yr)
*DM= dry matter content

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691846.

EMISSION OF NON-GHG AIR POLLUTANTS, INCLUDING AIR TOXIC

DESCRIPTION:

Emissions of non-GHG air pollutants, including air toxics, from bioenergy production and in comparison with other energy sources disaggregated by supply chain stage: bioenergy feedstock production, processing, transport of feedstock, intermediate products and end products, and use.

MEASUREMENT UNIT(S):

Emissions of PM_1, $PM_{2.5}$, 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.

- Kg/ha, mg/MJ, and as a percentage
- mg/m3 or ppm
- mg/MJ
- mg/MJ

METHODOLOGICAL APPROACH:

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.

Description of common pollutants:

Pollutants	
Particulate matter (PM)	On terms of potential to harm human health, PM is one of the most important pollutants as it penetrates into sensitive regions of the respiratory system. PM is emitted from many sources, and is a complex heterogeneous mixture comprising both primary and secondary PM; primary PM is the fraction of PM that is emitted directly into the atmosphere, whereas secondary PM forms in the atmosphere following the oxidation and transformation of precursor gases (mainly SOX, NOX, NH3 and some volatile organic compounds (VOCs))
Nitrogen oxides (NOX)	NO_X are emitted during fuel combustion, as practiced by industrial facilities and the road transport sector. As with SO_X, NO_X contribute to acid deposition but also to eutrophication of soil and water. Of the chemical species that NO_X comprises, it is nitrogen dioxide (NO_2) that is associated with adverse effects on health: high concentrations cause inflammation of the airways and reduced lung function. NO_X also contribute to the formation of secondary inorganic particulate matter and tropospheric (ground-level) ozone with associated climate effects
Sulphur oxides (SOX)	SO_X are emitted when fuels containing sulphur are burned. They contribute to acid deposition, the impacts of which can be significant: adverse effects on aquatic ecosystems in rivers and lakes, and damage to forests. Further, the formation of sulphate particles results in reflection of solar radiation, which leads to net cooling of the atmosphere (UNECE 2013).

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. Particularly, in cases of contaminated lands, non-GHG air pollutants can derive from agricultural practices related to both soil and water management[7] and contain harmful substances other than common pollutants. As for the agricultural practices, pollutants produced by land clearing and crop residue burning operations. Field burning can affect air quality and turn out more dangerous with crops grown on contaminated soils.

Use of agricultural equipment in bioenergy feedstock production is another source of air pollutants. Possible pollutants dispersion from contaminated soils may also take place as a result of tillage. Irrigation with contaminated groundwater can also cause pollutants dispersion.

The methods for evaluating the emissions of non-GHG air pollutants due to bioenergy feedstock processing will need further specification as a function of location, feedstock processed and processing technology used[8].

Bioenergy production and processing can be a source of air pollutant emissions. Monitoring emissions from bioenergy production and processing can support the demonstration and uptake of best available technologies.

This indicator measures all emissions of air pollutants produced at each level of the processing chain.

Transporting biomass fuel to a power plant is an important aspect of any biomass energy project. Due to the low density of bioenergy feedstock, emissions from transportation can have the potential to impact air quality significantly. It will be a good proposition to develop biomass production sites at the location where energy plants are present, without bearing the additional air pollutants emissions of transportation. 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.

The use of bioenergy can be an important emission source in the life-cycle balance of non-GHG pollutants. In most countries, energy use and transport cause the major portion of national pollution inventories. Transport is responsible for more than half of all NO_x emissions, and contributes significantly (around 15 percent or more) to the total emissions of the other pollutants. Road transport, in particular, makes a significant contribution to emissions of all the main air pollutants (with the exception of SO_x). While emissions from road transport are mostly exhaust emissions arising from fuel combustion, non-exhaust releases contribute to both NMVOCs (from fuel evaporation) and primary PM (from tyre- and brake-wear, and road abrasion)[9].Tailpipe pollution from transport is the dominant factor affecting air quality in most cities of the world. In the urban areas, the use of second generation and modern biofuels can reduce non-GHG air pollution relative to fossil fuels with the decrease in particulate matter being quite significant. In the impact assessment the difference between the reference case and the biofuel scenario can be expressed as a change.

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5. Due to the diffusion of non-common pollutants from contaminated lands, this indicator is strongly related to indicator 2 (soil quality) and 6 (water use and efficiency).

6. The evaluation method will lead to different methodological approaches: a) Emission of pollutants per unit of useful energy in absolute terms; and b) change in ambient concentrations of pollutants per unit of useful energy.

7. European Environment Agency 2015. Indicator assessment_ emissions of air pollutants from transport

- Emissions of common air pollutants;
- Production of air toxics and other non-common pollutants.

DATA REQUIREMENTS:

Along the lines with the Indicator of GHG emission, data required for this assessment include information about:

A - BASELINE SCENARIO

- comparisons with fossil fuel-related emissions for the whole bioenergy value chain

B - TARGET SCENARIO

Collect data related to all steps of project value chains:

- ha of land on which land clearing and crop burning occur (from national spatial and land use inventories, remote sensing if possible);
- emissions from field burning of agricultural waste and residues;
- emission from crop production and soil tillage;
- emission from biomass processing into fuel;
- emission from transport of biomass (both due to vehicle types and distances);
- tailpipe emission factors from vehicles and off-gas emission from energy plants.

SUGGESTED STEPWISE APPROACH:

A – BASELINE SCENARIO

STEP 1: COMPARISONS WITH FOSSIL FUEL-RELATED EMISSIONS FOR THE WHOLE BIOENERGY VALUE CHAIN

i. Non-GHG emissions from bioenergy feedstock production in comparison with emissions from crude oil extraction

Please add any important fuel characteristics, if specified:

- Relevant characteristics of crude;
- Type of crude;
- Origin of fuel (region, refinery, etc), if specified;
- Other important fuel characteristics, if specified.

	Tot. emissions from feedstock production Mg/MJ	Tot. emissions from crude extraction Mg/MJ	COMPARISON %
CO			
NOx			
SO_2			
PM_{10}			
$PM_{2.5}$			
PM_1			

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691846.

ii. Non-GHG emission from the conversion plants and plants for energy supply for conversion processes in comparison with emissions from fossil fuel (e.g. petrol) production and refinement

	Tot. emissions from feedstock processing **Mg/MJ**	**Tot. emissions from crude refinement** **Mg/MJ**	**COMPARISON** **%**
CO			
NOx			
SO_2			
PM_{10}			
$PM_{2.5}$			
PM_1			

iii. Non-GHG emission factors from the transport of feedstocks, intermediate products and end products in comparison with emissions from fossil fuel transportation (production site to distributors)

No	**Category**	**Vehicle type**	**Km**	**Mg*km^{-1}**				
				CO	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
1	From production site to storage site (biomass)							
2	Storage to biorefinery/processing facility							
3	Transport of inputs (e.g. chemicals) and materials to processing facility/biorefinery							
4	Biorefinery to distributors							
	Total							
		Tot. Km		**CO**	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
	Emissions from bioenergy (step 5)							
	Emissions from fossil							

iv. Non-GHG emissions from use of biofuels in comparison with emissions from fossil fuel (e.g. petrol)

E blends category	**Vehicle type**	**Emission %**					
		CO	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**PM_1**
Gasoline		*0*	*0*	*0*	*0*	*0*	*0*
E1							
E5							
E10		*-17*	*-15*	*-34*		*-16 (PM_x)*	
E20							
E30							

EXAMPLE: emissions of non-GHG pollutants from E10 blends are generally lower than emissions from the use of pure petrol (tank-to-wheel). In particular, compared to petrol, in similar projects E10 was found to emit 17 percent less CO, 15 percent less NO_x, 16 percent less PM_x, and 34 percent less SO_x than pure petrol (FAO 2014b).

A - TARGET SCENARIO

STEP 2: HECTARES OF LAND ON WHICH LAND CLEARING AND CROP BURNING OCCUR TO ALLOW ADV. BIOFUEL FEEDSTOCK PRODUCTION (FROM NATIONAL SPATIAL AND LAND USE INVENTORIES, REMOTE SENSING IF POSSIBLE)

Site	Land cover type/crop	Contamination agents (if present)	Total Hectares
1			
2			
3			
…			

STEP 3: EMISSIONS FROM FIELD BURNING OF AGRICULTURAL WASTE AND RESIDUES

Waste/residue burned	Mg/ha						
	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	PM_1	…*
1							
2							
3							
…							

*If activities are developed on contaminated land it is important to account for emissions of harmful substances in addition to common pollutants

STEP 4: EMISSIONS FROM CROP PRODUCTION AND SOIL TILLAGE

Crop production and agricultural soils	Kg/ha						
	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	PM_1	…*
Clearing/weeding							
Soil tillage				0.167	0.092	0.042	
Harvesting				1.322	0.580	0.328	
Fertilization							
Use of pesticide							
Irrigation							
…							

EXAMPLE: Emission data of PM_{10}; $PM_{2.5}$; PM_1 for soil tillage and harvesting operations have been collected from: ENEA 2013

*If activities are developed on contaminated land it is important to account for emissions of harmful substances in addition to common pollutants

The percentage of water in the soil can influence soil aggregates and then emissions from tillage. In principle for the Mediterranean and Atlantic climate of Europe two different soil moisture conditions have to be distinguished at the time when tillage operations are carried out: in winter time soils are filled with water and so they are in the state of field capacity; in late summer, when the crops have exhausted the soil water in the root zone. In this case the soils can be desiccated up to a depth of some decimetres and all of the affected soil contributes to the dust emission during tillage.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691846.

STEP 5: EMISSIONS FROM BIOMASS PROCESSING INTO FUEL

Crop processed	Kg/ha						
	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	PM_1	…*
Sugarcane	0.2	21	0.1		10 (PM_X)		
…							
…							

EXAMPLE: the processing stage of a sugarcane ethanol supply chain in Colombia is responsible for the emission of NO_x and particulate matter from cogeneration at a rate of 21 mg/MJ and 10 mg/MJ respectively (FAO 2014b)

*If activities are developed on contaminated land it is important to account for emissions of harmful substances in addition to common pollutants

STEP 6: EMISSIONS FROM TRANSPORT OF BIOMASS (VEHICLE TYPES) AND DISTANCES

No	Category	Vehicle type	Km	Mg/MJ Biofuel				
				CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$
1	From field to storage site (biomass)							
2	Storage to refinery (biomass)							
3	Refinery to blending refinery (biofuel)							
4	B. refinery to distributors (blended biofuel)							
	Total							

STEP 7: TAILPIPE EMISSION FACTORS FROM VEHICLES AND OFF-GAS EMISSION FROM ENERGY PLANTS

i. Specific tailpipe gas emission from vehicles fuelled with biofuel

E blends category	mg/MJ					
	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	PM_1
E1						
E5						
E10						
E20						
E30						

ii. Specific off-gas emission from energy plants fuelled with biofuel

Fuel type	mg/MJ					
	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	PM_1
Lignin						

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691846.

METHODOLOGY

BASELINE:

- TOTAL Kg per MJ of fuel of: CO, NOx; SO_2; PM_{10}; $PM_{2.5}$; PM_1

TARGET:

- TOTAL Kg per MJ of fuel of: CO, NOx; SO_2; PM_{10}; $PM_{2.5}$; PM_1

FINAL CHANGE IN non-GHG emissions:

- TARGET – BASELINE

REFERENCES

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WATER USE AND EFFICIENCY

DESCRIPTION:

Evaluating this indicator will provide basic information on the role that bioenergy production and use plays in water management at the watershed level and beyond.

Water withdrawn from watersheds within the ***target area*** for the production and processing of bioenergy feedstock; 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; water withdrawn from watersheds within the target area for the production and processing of bioenergy feedstock per unit of bioenergy output, disaggregated into renewable and non-renewable sources

MEASUREMENT UNIT(S):

- percentages
- m^3/MJ of m^3/kWh; m^3/ha and m^3/tonne for feedstock production

METHODOLOGICAL APPROACH:

The intent of this 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) in the ***target area*** and as the percentage of total annual water withdrawals (TAWW) in the ***target area***. If water can be disaggregated into renewable and non-renewable sources, 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.

When a disaggregation is not possible, one should explicitly mention it and use only calculable renewable water resources as reference values for this analysis.

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

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

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

in which, for all bioenergy production in watersheds within the ***target area***,

$W_{bioenergy\_ren} = W_{feedstock\_ren} + W_{processing\_ren}$, 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 in the ***target area***, which is calculated from:

- sources of water within the ***target area*** (watersheds);
- water flowing into the ***target area*** (watersheds); and
- water flowing out of the ***target area*** (watersheds)

FAO, thought its AQUASTAT portal, offers TARWR at the country level, whereas for the scope of this analysis sub-national and watershed-level analyses are required. There exist different ways to calculate the TARWR of the ***target area***. In FORBIO, the most accurate calculation of TARWR was obtained in two ways, depending upon the case study considered. Local statistics and information from the local climate and weather statistical centers have been used to derive mean annual rainfall within and total surface of the ***target area*** (sum of the watersheds). Surface waters are also usually known from local statistics whereas groundwater estimates are more difficult. In fact, this is the most anticipated limitation of this approach that can hardly be overcome with the use of statistics alone. Another option to calculate the TARWR of the ***target area*** is to use the SWAT model (See indicator on water quality for further details). In this case, provided that the maps and raw data fed into the GIS-based model are adequate, SWAT is capable of deriving estimates of baseflow and groundwater recharge from streamflow records. The importance of this modeling aid in assessing the sustainability of parameters such as water use and efficiency in modern bioenergy systems is therefore apparent.

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

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. Providing this information in mapped form may also be helpful.

	m3/person/year
Water stress	1,700
Water scarcity	1,000
Absolute scarcity	500

UN Definitions of Water Stress Levels (UN, 1997)

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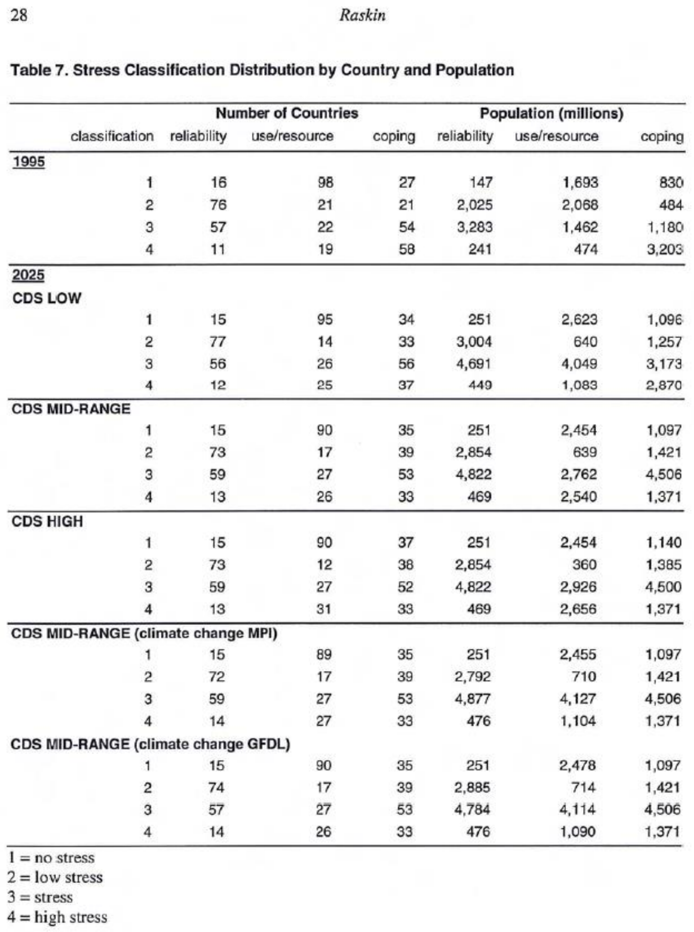

28 *Raskin*

Table 7. Stress Classification Distribution by Country and Population

		Number of Countries			Population (millions)		
	classification	reliability	use/resource	coping	reliability	use/resource	coping
1995							
	1	16	98	27	147	1,693	830
	2	76	21	21	2,025	2,068	484
	3	57	22	54	3,283	1,462	1,180
	4	11	19	58	241	474	3,203
2025							
CDS LOW							
	1	15	95	34	251	2,623	1,096
	2	77	14	33	3,004	640	1,257
	3	56	26	56	4,691	4,049	3,173
	4	12	25	37	449	1,083	2,870
CDS MID-RANGE							
	1	15	90	35	251	2,454	1,097
	2	73	17	39	2,854	639	1,421
	3	59	27	53	4,822	2,762	4,506
	4	13	26	33	469	2,540	1,371
CDS HIGH							
	1	15	90	37	251	2,454	1,140
	2	73	12	38	2,854	360	1,385
	3	59	27	52	4,822	2,926	4,500
	4	13	31	33	469	2,656	1,371
CDS MID-RANGE (climate change MPI)							
	1	15	89	35	251	2,455	1,097
	2	72	17	39	2,792	710	1,421
	3	59	27	53	4,877	4,127	4,506
	4	14	27	33	476	1,104	1,371
CDS MID-RANGE (climate change GFDL)							
	1	15	90	35	251	2,478	1,097
	2	74	17	39	2,885	714	1,421
	3	57	27	53	4,784	4,114	4,506
	4	14	26	33	476	1,090	1,371

1 = no stress
2 = low stress
3 = stress
4 = high stress

Disaggregated Water Stress Classification according to Raskin et al., 1997

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

Calculating 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:

- water use for feedstock production in the watershed(s) per tonne of feedstock produced in the watershed(s);
- water use for feedstock processing in the watershed(s) per unit of bioenergy produced; and
- 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.

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

- Size of the ***target area*** (ha or km^2)
- Precipitation within the target area (mm/year or km^3/year)
- Surface runoff (km^3/year)
- Groundwater recharge (km^3/year)
- Overlap (Q_{out}-Q_{in}) (km^3/year)

B - TARGET SCENARIO

Crop information:

- Productivity (t/ha)
- Evapotranspiration (mm/year)
- Effective Precipitation (mm/year)
- Actual irrigation requirements (mm/year)
- Area planted (ha)

Processing technology:

- Technology water consumption ($m^3/t_{feedstock}$ or km^3/year)[10]
- Type of water (blue or grey)

Energy Output:

- Bioenergy production (t/year)
- LHV (GJ/t)

SUGGESTED STEPWISE APPROACH:

A – BASELINE SCENARIO

STEP 1: TARWR AND TAWW

- Calculate or estimate TARWR in the ***target area*** by using local statistics or a modeling aid (e.g. SWAT).
- Calculate or estimate TAWW in the ***target area*** by using local statistics, interviews or a mix of the two.

A - TARGET SCENARIO

STEP 2 WATER FOR FSTK PRODUCTION:

Calculate water requirements of the crop on the basis of evapotranspiration (C_{ET}) data and surface planted. This will represent the total water for feedstock production (TW_{FP}). Information on precipitation (P) quantity will be fundamental to ascern whether irrigation is necessary. In case (C_{ET}) is > than (P), then a water deficit is verified. This will require irrigation in order to meet the productivity target. The total irrigation water required will be assessed as the difference between the total water for feedstock production and the possible water deficit.

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8. This approach is to be used in the case of a black-box type of data collection on the processing technology requirements. In case disaggregated data is available this could be preferred.

STEP 3 WATER FOR FSTK PROCESSING:

Calculate water requirements for processing in terms of amount used per unit of feedstock (usually m^3/dry ton). This will be possible via computational analysis of water uses in existing model plants or by obtaining aggregated values from the technology provider.

METHODOLOGY

BASELINE:

TARWR in the ***target area*** calculated through SWAT: 0.0914 km^3/year TAWW in the ***target area*** calculated starting from statistics and interviews: 150,000,000 m^3/year

TARGET:

Crop Yield: 10 t/Ha
Target cultivated surface: 1,150 Ha
Crop Evapotranspiration: 600 mm/Year
Effective Precipitation: 450 mm/Year
Crop Production: 11,500 t
Actual Irrigation Requirements: 150 mm/Year
Unitary Water Requirements: 6,000 m^3/Ha
Actual Feedstock Water Req: 6,000 m^3/Ha * 1,150 Ha = 0.0069 km^3/Year
Unitary Irrigation Water Req (aka water deficit): 1,500 m^3/Ha
Total Irrigation water Req: **0.001725 km^3/Year**
Total Water for Feedstock production (W_{fstk}): **0.0069 km^3/Year**
Total water for feedstock processing: 0.0002875 km^3/Year

FINAL ASSESSMENT OF WATER USE AND EFFICIENCY:

$W_{bioenergy\_ren}$ = **0.0069 km^3/Year** + **0.0002875 km^3/Year** = 0.0071875 km^3/Year

- $W_{bioenergy\_ren}$ / TARWR x 100% = 7.86 percent
- $W_{bioenergy}$/ TAWW x 100% = 1.15 percent

Efficiency:

- $W_{bioenergy}$ / E_{total} = 0.1161 m^3/MJ
- Feedstock production = W_{fstk} / Crop Production = 600 m^3/t

REFERENCES

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WATER QUALITY	
DESCRIPTION:	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; 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):	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 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
METHODOLOGICAL APPROACH:	In order to simulate the complexity of nutrient movement inside the target area the use of modeling software is felt to be the best option. GIS-based add-ons, like the Soil and Water Assessment Tool11 (SWAT), are a fundamental aid to the assessment of this indicator. The data and capacity requirements of SWAT are not negligible and in the case of FORBIO it was possible to perform its analysis only in one of the three case studies: Sulcis, Sardinia, Italy. SWAT is comprised of several different components including climatic inputs, crop growth and yield, hydrological cycling, representation of management practices, nutrient cycling and transport, erosion processes and resulting sediment transport, fate and transport of pesticides and pathogens, and the impacts of impoundments (e.g., ponds, reservoirs, wetlands) on water and pollutant routing. The model is usually executed on a daily time step although options are also provided for sub-daily time step applications. The analyses are carried out at watershed level and sub-units (hydrologic response units - HRU) that are spatial sub-basins that are characterized by attributes such as soil information, landscape patterns, land use and management practices aggregated across multiple fields that are not spatially identifiable within the sub-basin. SWAT runs in ArcGIS software or in QGIS software (free of charge). Data sources: • Climatic data: daily values of Temperature (°C), Precipitation (mm), Wind (m/s), relative humidity (fraction), Solar radiation (MJ/m2). If climatic data is not available with local station, it can be downloaded from the following web-site: https://globalweather.tamu.edu/. The database covers a 36-year period of 01/01/1979 to 31/07/2014. In

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9. http://swat.tamu.edu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691846.

the Sulcis target area this type of data with 4 stations was used. CSV or SWAT format.
- Digital Elevation Model (DEM): High resolution DEMs today are easily obtainable from governmental agencies or from the web. The best resolution depends upon the scale of the analyses. In the Sulcis area, a 10 meters resolution DEM was retrieved from the Sardinia Region web-portal. A freely available DEM is the ASTER GDEM v2, (30 meters resolution) available at: https://asterweb.jpl.nasa.gov/gdem.asp. Raster file format.
- Land use data: land use and land cover data are easily available from governmental agencies or research centers. In the Sulcis area, we used a land use map at 1:10.000 scale from the Sardinia region web-portal. The map should be detailed enough to include all forms of agricultural and environmental management (e.g. irrigated and dry crops, tree crops, forest management, etc.). Shapefile format.
- Soil data: Soil data represent the most critical component for the implementation of the model in SWAT. In the Sulcis area, we used a pedological map at 1:10,000 scale and some soil profiles from Sardinia region to complement the database. In SWAT soil is represented as layers, at least 1 layer of data is required. Soil component parameters are: soil type, soil depth, bulk density, clay, silt and sand content, rock (%). Some parameters can be recovered with *pedotransfer functions* like the SPAW model. Shapefile format.

After the setup of a SWAT project is performed, the first step is the Watershed Delineation and sub-basin delineation using the DEM. Subsequently, there is a land use and soil delineation, performed by the software by once the shapefiles have been added to the project. This creates hydrologic response units (HRUs), that are a new shapefile with defined polygons. Next, weather data are entered into the project, simply by identifying the file collected. A number of input setting parameters can be edited in the project (e.g. soil, channels, river, water use, etc.). Since these settings can be specific to the study area they can greatly improve the reliability of the final results (e.g. for nutrient losses, plant grow parameters, etc.).

Finally, the simulation can be initiated with a Simulation Setup, defining daily, monthly, or yearly setting and simulation length (start and end date). SWAT runs the model and writes the result defining the output such as: Soil Chem Output (N cycle, P cycle, plant grow, sediments, nutrient losses, etc.), Pesticide output (runoff of pesticides, if implemented), Soil Storage, etc.

It is important that at the end of the simulation the results are validated (using "Auto-calibration and Uncertainty Analysis" function), for example using ideological data, if available, or sediment losses from river data analyses.

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

- Climatic data: daily values of Temperature (°C), Precipitation (mm), Wind (m/s), relative humidity (fraction), Solar radiation (MJ/m2). CSV or SWAT format.
- Digital Elevation Model (DEM): High resolution DEMs today are easily obtainable from governmental agencies or from the web. Raster format.
- Land use data: land use and land cover data are easily available from governmental agencies or research centers. Shapefile format.
- Soil data: soil type, soil depth, bulk density, clay, silt and sand content, rock (%). Shapefile format.

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B - TARGET SCENARIO

- Crop production data: crop type, species, productivity, inputs and requirement, including N and P, water and evapotranspiration

SUGGESTED STEPWISE APPROACH:

A – BASELINE SCENARIO

STEP 1: RETIEVE ALL BASELINE DATA

Daily temperatures (°C), precipitations (mm), wind speed (m/s), relative humidity, solar radiation (MJ/m2), Digital Elevation Model (DEM), Land use and land cover data, soil type, soil depth, bulk density, clay, silt and sand content.

STEP 2: SET UP THE MODEL

This task begins with the Watershed Delineation and sub-basin delineation using the DEM. Subsequently, there is a land use and soil delineation, performed by the software once the shapefiles have been added to the project. This creates hydrologic response units (HRUs), that are a new shapefile with defined polygons. Next, climatic data are entered into the project, simply by identifying the file collected.

STEP 3: BASELINE RUN

SWAT runs the model and writes the result defining the output such as: Soil Chem Output (N cycle, P cycle, plant grow, sediments, nutrient losses, etc.), Pesticide output (runoff of pesticides, if implemented), Soil Storage, etc. This is done in a scenario that does not include the existence of dedicated energy crops on the underutilized lands inscribed within the ***target area***. This simulation projects into the future the movement of N and P and other chemicals in the underutilized soils in order to forecast what will be the undisturbed evolution of pollutant movement into the landscape.

B - TARGET SCENARIO

STEP 4: LOAD UP BIOENERGY CROP CHARACTERISTICS

Data on the cultivation of the specific bioenergy crop are also loaded up into the software and the model starts the simulation.

STEP 5: TARGET SCENARIO RUN

SWAT runs the model and writes the result defining the output such as: Soil Chem Output (N cycle, P cycle, plant grow, sediments, nutrient losses, etc.), Pesticide output (runoff of pesticides, if implemented), Soil Storage, etc. This time, the model considers the amount of inputs required by the dedicated bioenergy crop selected and writes results accordingly.

FINAL ASSESSMENT:

TARGET – BASELINE

The annual nitrogen (N) and phosphorus (P) loadings from fertilizer and pesticide active ingredient loadings attributable to bioenergy feedstock production (per watershed area) are calculated as the difference between the TARGET RUN and the BASELINE RUN in order to attribute to the bioenergy value chain its impacts and isolate them for the rest of the movement of chemicals.

REFERENCES

- Soil and Water Assessment Tool, SWAT. Available at http://swat.tamu.edu/
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BIODIVERSITY IN THE LANDSCAPE

DESCRIPTION:	Surface and percentage of high biodiversity value areas or critical ecosystems converted to bioenergy production; Area and percentage of the land used for bioenergy production where invasive species, by risk category, are cultivated; Area and percentage of the land used for bioenergy production where conservation methods are used.
MEASUREMENT UNIT(S):	ha; km^2; percentage; percentage of land used for 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 biodiversity value areas and specific methods for areas where conservation methods are used) or as a combined total across such categories.
METHODOLOGICAL APPROACH:	Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production: Land use change, including deforestation, is a major cause of the loss of biological diversity and is in most cases related to agricultural expansion. Underutilized lands, even not necessarily formally recognized as high conservation value areas by local regulations, can host a relevant biological diversity due to the lower anthropic pressure they withstand. Converting these areas to the production of bioenergy may impact species diversity. Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated: This component of the indicator will provide an indication of the scale of the risk presented by using invasive alien species as bioenergy feedstock. Since invasive alien species can cause trans-boundary environmental harm, this indicator could also help assess the risk of such harm as a result of trade in bioenergy feedstock. Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used: Specific cultivation, management and harvest practices can reduce negative and promote positive impacts on biodiversity within and around feedstock production sites and can thus be considered an important contribution to sustainable bioenergy production. Conservation methods currently exist, or are under development for many different crops, landscapes and national contexts. Indicative lists of such measures (also from surveys of agricultural practices) that may be used to help conserve biodiversity within and around biofuel production areas can be found at national level for the data collection. Furthermore, 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: – Use of traditional rotations – Light tillage operations – Guarantee soil cover all year round – No scrub removal – Low chemical inputs – Use 1 ha every 100 ha for planting legumes/cereals for wildlife – Avoid open field burning of residues

- Avoid irrigation
- Avoid overgrazing
- Report and protect nests
- Ensure that species are not collected

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

A list and accurate maps (at the highest resolution available) of areas of high biodiversity importance, updated as new areas are identified:

- Protected Areas (parks, reserves, sanctuaries, etc);
- Areas where critically endangered species are found;
- Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species;
- Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)
- Important natural landscape areas for natural ecological dynamics;
- Areas that contain two or more contiguous ecosystems;
- Areas containing rare or endangered ecosystems.

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.

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

- List of species used as bioenergy feedstock in the country in question and size of area on which they are cultivated;
- Information on which of these species are recognized as invasive[12];
- 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.

B - TARGET SCENARIO

Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used:

- 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

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[12] See page 3 of http://ec.europa.eu/environment/nature/invasivealien/docs/ias_discussion_paper.pdf

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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.

SUGGESTED STEPWISE APPROACH:

A – BASELINE SCENARIO

STEP 1: CRITICAL AREAS WITHIN THE TARGET AREA

- A list and accurate maps (at the highest resolution available) of areas of high biodiversity importance inscribed within the ***target area***

a - TARGET SCENARIO

STEP 2: NUMBER AND SIZE OF BIOENERGY PRODUCTION AREAS THAT ARE FOUND UNDER HIGH BIODIVERSITY AREAS

- A list and accurate maps (at the highest resolution available) of areas where bioenergy will be produced and/or total amount of hectares of high biodiversity areas that will be used for bioenergy production in the ***target area***

STEP 3: RISK OF BIODIVESITY LOSS DUE TO LAND USE CHANGE AND AGRICULTURAL ACTIVITY

- Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used

METHODOLOGY

BASELINE:

e.g.

Critical areas within the *target area*

Total target area **5,000** ha

Total high biodiversity areas surface	Ha	**1,000**
Total areas where critically endangered species are found	Ha	**400**
Total important ecosystems		**600**
Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species	Ha	200
Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)	Ha	200
Important natural landscape areas for natural ecological dynamics	Ha	200
Areas that contain two or more contiguous ecosystems	Ha	200
Areas containing rare or endangered ecosystems	Ha	200
Not included		4,000

TARGET:

e.g.

Critical areas within the *target area* devoted to bioenergy production

Total target area	**5,000** ha	
Total high biodiversity areas surface	Ha	**750**
Total areas where critically endangered species are found	Ha	**300**
Total important ecosystems		**450**
Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species	Ha	150
Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)	Ha	150
Important natural landscape areas for natural ecological dynamics	Ha	150
Areas that contain two or more contiguous ecosystems	Ha	100
Areas containing rare or endangered ecosystems	Ha	150
Not included		4,250

e.g.

Areas where nationally recognized conservation methods are used

Crop1:

- **Use of traditional rotations NO**
- **Light tillage operations NO**
- **Guarantee soil cover (spaces) all year YES**
- **No scrub removal NO**
- **Low chemical inputs YES**
- **Use 1ha every 100ha for planting legumes/cereals for wildlife NO**
- **Don’t burn residues YES**
- **No regular irrigation YES**
- **No overgrazing NO**
- **Report and protect nests NO**
- **Ensure the species are not collected NO**

FINAL ASSESSMENT:

TARGET – BASELINE

The final assessment look at the overlap between the high conservation value areas in BASELINE that are interested by the planned bioenergy production as per the TARGET scenario. This overlap, can be expressed in percentage term or absolute terms

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Total target area	**185.829**	ha	
Total high biodiversity areas surface		%	**75**
Total areas where critically endangered species are found		%	**75**
Total important ecosystems		%	**75**
Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species		%	75
Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)		%	75
Important natural landscape areas for natural ecological dynamics		%	75
Areas that contain two or more contiguous ecosystems		%	75
Areas containing rare or endangered ecosystems		%	75

e.g.

Areas where nationally recognized conservation methods are used

Crop 1*:

Use of traditional rotations	Ha	0,00%
Light tillage operations	Ha	0,00%
Guarantee soil cover (spaces) all year	Ha	100,00%
Scrub removal	Ha	0,00%
Low chemical inputs	Ha	100,00%
Use 1ha every 100ha for planting legumes/cereals for wildlife	Ha	0,00%
Don't burn residues	Ha	100,00%
No irrigation	Ha	100,00%
Overgrazing	Ha	0,00%
Report and protect nests	Ha	0,00%
Ensure the species are not collected	Ha	0,00%

* the assessment is stricltly related to the selected crops. In this example the indicator considers crop 1 as the only crop used for production of bioenergy in the target area. When more than one crop is produced, the final percentage is obtained by taking an evarage of the hectares on wich conservation methods are used.

e.g. Use of traditional rotation 50%
Crop1: 100 Ha YES
Crop2: 200 Ha NO
Crop3: 100 Ha Yes

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. 2014
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia. 2014

LAND USE AND LAND USE CHANGE RELATED TO BIOENERGY FEEDSTOCK PRODUCTION

DESCRIPTION:	Within the ***target area***, the surface and percentage of land for bioenergy feedstock production as compared to: total land surface of the ***target area*** disaggregated by land use; total underutilized land including contaminated land, fallow land, abandoned land, degraded land, etc. Net annual rates[13] of conversion between land-use types caused directly by bioenergy feedstock production on underutilized lands in the ***target area***, 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; underutilized land including contaminated land, fallow land, abandoned land, degraded land, etc.
MEASUREMENT UNIT(S):	Hectares and percentage, and Hectares per year
METHODOLOGICAL APPROACH:	The indicator is based on point estimates derived from data collected in periodic agricultural censuses and surveys as well as terrestrial observation. In order to measure this indicator, the total surface of the ***target area*** is required. Subsequently, a disaggregation of the various land use classes and categories within the ***target area*** is necessary to identify the relative shares and absolute surfaces occupied by agricultural land, managed forests, and other land categories. 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. By matching the expected/wanted bioenergy production by its expected productivity (derived from D 2.x for each of the case study sites) with the available underutilized land, the possible rates of conversion can be calculated. Ideally, in the context of the project there should be the opportunity to map the selected parcels of land that will change land use from underutilized to bioenergy crop production on the basis of discrete variables, such as the geographical attributes including location with regard to existing infrastructures, soil properties, etc. This would allow for the maximum efficiency in the compilation of final results for a number of indicators, including productivity, soil quality, water quality, water use, infrastructure and logistics, GHG and non-GHG emissions, land tenure and more.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** - Total ***target area'*** surface (ha) - Total land surface (ha) and percentage of agricultural land and managed forest surface inscribed within the target area; - Total area of land for bioenergy feedstock production and residues and wastes used as bioenergy feedstock and disaggregated by land use; - Area and percentage of underutilized and marginal or contaminated

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[13] Net annual rates of conversion include: possible, achievable, proposed, and/or potential area to be converted to bioenergy feedstock production. Values can be deduced or extrapolated from project documents (in the case in which a bioenergy value chain is proposed in the target area) or on the basis of other minimum objectives and requirements (e.g. the required amount of feedstock for the constitution of a bioenergy value chain in the target area), or from the literature on similar and comparable cases.

land disaggregated by land use;

B - TARGET SCENARIO

- Average productivity per ha of the selected bioenergy crops
- Expected bioenergy output in t/year or MJ/year and conversion pathway efficiencies

Alternatively, in case the production target is not set and it depends upon possible supply:

- Area of underutilized, marginal or contaminated land needed for bioenergy feedstock production;

Time necessary to reach 100% of target cultivated surface[14]

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: AREA AND PERCENTAGE OF LAND DISAGGREGATED BY LAND USE

Land data by categories	Year	Hectares	Percentage	Description/notes
Land use				
Total surface area	2016		100%	
Agriculture				
Forest				
Other land				
Agriculture				
Total agricultural area			100%	
Arable land				
Permanent crops				
Permanent meadows and pastures				
Forest				
Total forest area			100%	
Natural Forest				
Managed Forest				

STEP 2: AREA AND PERCENTAGE OF LAND USED FOR BIOENERGY FEEDSTOCK PRODUCTION DISAGGREGATED BY LAND USE

Land use data by categories	YR.	TOT. Ha	Used for bioenergy feedstock production		Used for residues and wastes used as bioenergy feedstock	
			Ha	%	Ha	%
Total surface area	2016					
Agricultural area						
Arable land						
Permanent crops						
Permanent meadows and pastures						
Total Forest						
Natural Forest						
Managed Forest						

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10. [14] It is important to estimate the time necessary to reach the full surface planted with the studied (TARGET) bioenergy crop. For instance, an investment may require one year to reach the full planted area as well as any other amount of time depending upon number of variables including investment funds, machineries (technical equipment), etc..

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STEP 3: AREA AND PERCENTAGE OF UNDERUTILIZED AND CONTAMINATED LAND DISAGGREGATED BY LAND USE

Land data by categories	Year	Hectares	Percentage	Description/notes
Land Use				
Total surface area			100%	
Underutilized and marginal land				
Polluted or contaminated land				
Agriculture				
Total agricultural area			100%	
Underutilized and marginal agricultural land				
Polluted or contaminated agricultural land				
Arable land				
Total Arable land			100%	
Polluted or contaminated arable land				
Forest				
Total forest area (Natural + Managed Forest)			100%	
Polluted or contaminated forest				

B - TARGET SCENARIO

STEP 4: TOTAL SURFACE OF UNDERUTILIZED AND CONTAMINATED LAND USED FOR BIOENERGY FEEDSTOCK PRODUCTION

	Year	Tot Ha	Crop 1	Crop 2	Crop 3	…n
Underutilized and marginal land						
Polluted or contaminated underutilized land						

METHODOLOGY

BASELINE:

e.g.

Data on disaggregation of land in the target area

Land data by categories	Ha
Total annual crop and fallow lands	39,117
Total annual crop and fallow land for FSTK production	0
Total permanent crops	900
Total permanent crops for FSTK production	50
Underutilized agricultural lands	16,720
Underutilized non-agricultural lands	0

TARGET:

e.g.

Hectares of underutilized lands used for bioenergy feedstock production:

Crop 1: **Willow** (Permanent Crop); Tot. hectares **1,150**

Land data by categories	Ha
Total annual crop and fallow lands	39,117
Total annual crop and fallow land for FSTK production	0
Total permanent crops	2,050
Total permanent crops for FSTK production	1,200
Underutilized agricultural lands	15,570
Underutilized non-agricultural lands	0

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FINAL ASSESSMENT:

TARGET – BASELINE

e.g.

Calculation of the conversion rates

Project duration: **10 years**

Time necessary to reach 100% of TARGET CULTIVATED SURFACE: **3 years**

Land data by categories	% of conversion	Annual % of conversion	Annual acreage of conversion (ha)
Total annual crop and fallow lands	0	0	0
Total permanent crops	127.8	42.6	383.33
Underutilized agricultural lands	- 6.9	- 2.3	- 383.33
Underutilized non-agricultural lands	0	0	0

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- E. Terrence Slonecker, U.S. Environmental Protection Agency; land cover and indicators of environmental quality breakout session report
- ILO. Local value chain development. 2017

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4.5. Social pillar

SOCIAL PILLAR

THEMES

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

Allocation and tenure of land for new bioenergy production, Change in income, Jobs in the bioenergy sector, Bioenergy used to expand access to modern energy services

INDICATOR NAME	INDICATOR DESCRIPTION
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 local system and/or socially accepted practices provide due process and the establishment procedures are followed for determining legal title
Change in income	Contribution of the following to the 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 feedstock, by self-employed households/individual
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 the EU employment guidelines consistent with the domains enumerated in the European Employment Strategy, in relation to comparable sectors
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 Total number and percentage of individuals, households and businesses benefitting from modern bioenergy services

TABLE. 6 The FORBIO social sustainability indicators

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ALLOCATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION

DESCRIPTION:	Surface and percentage of land for bioenergy production within the ***target area*** where a legal instrument or local authority establishes title and procedures for change of title; and Change in current (baseline) arrangements for access to land and its resources (e.g. grazing, agricultural activities, forestry, etc.) due to bioenergy production within the ***target area***.
MEASUREMENT UNIT(S):	ha and percentage of ***target area***, and change in percentage (before vs after) and surface expressed in ha (before vs after).
METHODOLOGICAL APPROACH:	This indicator aims to measure the percentage of land 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 in land tenure can help assess how new bioenergy activities influence the social sustainability and livelihoods of various populations in developing countries. FORBIO has developed a set of data entry tables to guide the user with the necessary information for the assessment of this indicator. The tables mirror the data entry of the indicator on Land Use and Land Use Change, but introduce a further column to the far-right end of the table that the user is asked to fill out with detailed information on the ownership type, management arrangements, and/or existing legal and customary constraints interesting each sub-category of land. In this section, the user should also indicate and report the surfaces (in ha) under each land use category interested by any form of legal constraint/binding obligation (e.g. forbid agricultural activities due to site contamination, etc.) as well as legally defined and/or customary rights for access to land and natural resources (e.g. concession of 30 ha of public land to 1 farmer for grazing; concession of 456 ha to 3 private enterprises for forestry production; etc.) and the stakeholders (individuals or enterprises) interested by said rights. It would be ideal if the information provided in the tables below is accompanied by maps that certify the de facto status of ownership, use rights, etc. of the land (e.g. from the Catasto, local, regional and or provincial authorities, municipalities, etc.).
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** – Area and percentage of land in the target area disaggregated by land classes and divided by: private land, companies, public or government, others. **B - TARGET SCENARIO** – Hectares land for bioenergy feedstock production disaggregated by: private land, companies, public or government, others.

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SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: AREA AND PERCENTAGE OF LAND IN THE TARGET AREA DISAGGREGATED BY: PRIVATE LAND, COMPANIES, PUBLIC OR GOVERNMENT, OTHERS

LAND DATA BY CATEGORIES	YEAR	HECTARES	PERCENTAGE	OWNERSHIP
Land use				
Total surface of ***target area***			100%	**e.g. private land, companies, public or government, others**
Agriculture				.
Forest				
Other land				
Agriculture				
Total agricultural area			100%	
Arable land				
Permanent crops				
Permanent meadows and pastures				
Forest				
Total forest area			100%	
Natural Forest				
Managed Forest				

B - TARGET SCENARIO

STEP 2: AREA AND PERCENTAGE OF LAND FOR BIOENERGY FEEDSTOCK PRODUCTION DISAGGREGATED BY: PRIVATE LAND, COMPANIES, PUBLIC OR GOVERNMENT, OTHERS

LAND DATA BY CATEGORIES	YEAR	HECTARES	PERCENTAGE	OWNERSHIP
Land use				
Total surface of ***target area***			100%	**e.g. private land, companies, public or government, others**
Agriculture				.
Forest				
Other land				
Agriculture				
Total agricultural area			100%	
Arable land				
Permanent crops				
Permanent meadows and pastures				
Forest				
Total forest area			100%	
Natural Forest				
Managed Forest				

METHODOLOGY

BASELINE:

Number of hectares of target area disaggregated by ownership type:

A) Private land
B) Companies
C) Public or government
D) Others

Then, disaggregated by:

A) Annual crops and fallow lands (FAOSTAT Arable land)
B) Permanent crops
C) Underutilized agricultural and non-agricultural land

LAND DISAGGREGATION BY OWNERSHIP AND CLASSES

TARGET:

Type of ownership of underutilized lands (agricultural and non-agricultural) used for bioenergy fstk production

A) Private land
B) Companies
C) Public or government
D) Others

OWNERSHIP OF UNDERUTILIZED LANDS USE FOR FSTK PRODUCTION

FINAL ASSESSMENT:

TARGET – BASELINE

e.g. EU country

Ownership type	**Crop**	**Targeted hectares**
(A) Private land	Willow (permanent crop)	2.000

PRIVATE LAND	**BASELINE**	**calculation**	**TARGET**	
Classes:	**Ha**		**Ha**	**∆%**
Annual crops	10.000		10.000	0%
Permanent crops	10.000	+ 2.000 of permanent crop	13.000	**+30%**
Underutilized	15.000	- 2.000 used for permanent crop	12.000	**-13.3%**
Total land	**35.000**		**35.000**	**0%**

FINAL DECREASE OF UNDERUTILIZED LAND OWNERSHIP TYPOLOGIES AND INCRISE IN PERCENTAGE OF ANNUAL CROPS AND PERMANENT CROPS DISAGGREGATED BY OWNERSHIP TYPE.

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. 2014
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia. 2014

CHANGE IN INCOME

DESCRIPTION:

A. Wages paid for employment in the bioenergy sector in relation to comparable sectors;

B. Net income from the sale, barter and/or own-consumption of bioenergy products, including feedstock, by self-employed households/individuals

C. Estimated sector-driven income for the community within the ***target area***

MEASUREMENT UNIT(S):

EUR per household/individual per year, and percentages (for share or change in total income and comparison)

EUR per household/individual per year, and percentage (for share or change in total income)

METHODOLOGICAL APPROACH:

This indicator applies equally to the income from **direct** and **indirect** employment in the advanced 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) – 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;

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 thus in this analysis.

The average wage paid for employment in the bioenergy sector may be calculated by analysing 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 should 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

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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.

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. In order to measure the change in income, it is necessary to have a data baseline of income level per household 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. The research of contracts paid to employers in the advanced bioenergy sector, when available, is clearly an asset to obtain data on the income of hired labour and its comparison with other sectors.

Income of feedstock producers can be the result of several factors, and can be calculated in various ways. Usually, market prices already include a share attributed to net profit. Using the difference between market prices of the feedstock and feedstock production costs (these latter taken from the techno-economic assessments under WP2) may be an option provided that the specific feedstock is an international commodity. In the case of lignocellulosic biomass, pellets and woodchips fall under this category. When a reference feedstock price is available on the local and or international market (as in the case of hardwood chips) this should be used as the maximum price that a producer/farmer can obtain at farm gate. The existence of a possible margin is given by the difference between reference price and the calculated production cost.

Raw biomass such as perennial grasses is not present on international exchange markets lists and therefore the calculation of their market price is expected to be cumbersome unless a bottom up approach is applied. The bottom-up approach would entail accounting for all gross production costs plus the recognition of a net profit for the farmers. Forestry and agricultural activities are characterized by net profit margins between 8 and 10 percent. Net income for biomass producers engaged in advanced biofuel value chains should not fall below the 10 percent net profit margin.

One last possibility to establish a reference feedstock price for commodities not currently listed on the international market is the calculation of value on the basis of energy content (MJ/ton or MJ/m^3) and cellulose content (t/t) in comparison with reference prices of lignocellulosic or similar commodities.

Detailed data requirements will include information about:

DATA REQUIREMENTS:

A - BASELINE SCENARIO

- Wages paid in sectors comparable to bioenergy production for:
  a. Production of commodities at the local or national level

b. Transport of commodities at the local or national level
c. Processing of commodities at the local or national level (including all stages, from unskilled to skilled workers)

B - TARGET SCENARIO

– Wages paid (and revenues from sales of) the following for use in advanced bioenergy value chains:
a. Feedstock production
b. Biomass transport
c. Biomass processing

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: WAGES PAID IN SECTORS COMPARABLE TO BIOENERGY PRODUCTION

Classes of occupation:	PM[15]/ha/yr	Wage €/yr	Wage €/PM	Wage €/ha
Production of common local or national crop				
Unskilled labour				
Regular labour				
Specialized/skilled labours				
Junior agronomist				
Senior agronomist				
Transport of common local or national crop				
Unskilled labour				
Regular labour				
Specialized/skilled labours				
Junior manager				
Mid-level manager				
Senior agronomist				
Processing of common local or national crop				
Unskilled labour				
Regular labour				
Specialized/skilled labours				
Junior manager				
Mid-level manager				
Senior manager				

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11. Person Month: A “person month” is the metric for expressing the effort (amount of time) that personnel devote to a specific task. This calculated as the number of productive working hours divided by the number of months in a year. By convention in hourly terms this is 143.3 hours/month. If a specific task (e.g. harvesting of biomass) requires e.g. 8 hours/day for 30 days of work, the total of PM required is: 8h * 30 days = 240h; 240h/143.3h = 1.67 PM.

B - TARGET SCENARIO

STEP 2: WAGES PAID FOR EMPLOYMENT IN BIOENERGY VALUE CHAINS

Classes of occupation:	PM/ha/yr	Wage €/yr	Wage €/PM	Wage €/ha
Feedstock production				
Unskilled labour				
Regular labour				
Specialized/skilled labours				
Junior agronomist				
Senior agronomist				
Biomass transport				
Unskilled labour				
Regular labour				
Specialized/skilled labours				
Junior manager				
mid-level manager				
Senior agronomist				
Biomass processing				
Unskilled labour				
Regular labour				
Specialized/skilled labours				
Junior manager				
mid-level manager				
Senior manager				

METHODOLOGY

BASELINE:

Average wages paid in sectors comparable to bioenergy production:

Average wages of the classes of occupation paid for production, transport and processing of common local or national crop disaggregated by: PM/ha/yr; Wage €/yr; Wage €/PM; Wage €/ha

e.g.

Production of common local or national crop:

PM/ha/yr = 3

Wage €/yr = 15.698

Wage €/PM = 1.308

Wage €/ha = 234

AVERAGE WAGES PAID

TARGET:

wages paid for employment in bioenergy value chains:

Average wages of the classes of occupation paid for production, transport and processing of

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bioenergy feedstock disaggregated by: PM/ha/yr; Wage €/yr; Wage €/PM; Wage €/ha

e.g.

PM/ha/yr = 3
Wage €/yr = 20.000
Wage €/PM = 2.500
Wage €/ha = 300

AVERAGE WAGES PAID

FINAL ASSESSMENT:

TARGET – BASELINE

Comparison (increase or decrease) between wages paid in bioenergy feedstock and wages for a common local crop

e.g.

PM/ha/yr = 3 – 3 = **0 PM/Ha/yr**
Wage €/yr = 20.000 - 15.698 = **4.302 €/yr**
Wage €/PM = 2.500 - 1.308 = **1.192 €/PM**
Wage €/ha = 300 – 234 = **66 €/Ha**

FINAL CHANGE IN WAGES PAID IN THE TARGET AREA DUE TO BIOENERGYPRODUCTION

METHODOLOGY FOR CALCULATING INCOME OF DIRECT PRODUCERS

In the context of FORBIO it is envisaged that farmers may also sign direct contracts with biomass buyers and their income will be calculated as follows:

BASELINE:

Average price of comparable biomass on international and national markets:

Woodchips: EUR 30/ton

TARGET:

Average price of advanced biofuel feedstock produced under FORBIO conditions:

Willow woodchips Ukraine case study**: EUR 27/ton**

FINAL ASSESSMENT:

TARGET – BASELINE

Income = (Woodchips price - Willow woodchips Ukraine case study prod cost) * productivity/ha = EUR 30/ton – EUR 27/ton = EUR 3/ton * 10 ton/ha = EUR 30/ha

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. 2014
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia. 2014

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JOBS IN THE BIOENRGY SECTOR

DESCRIPTION:	Net job creation as result of bioenergy production and use, total and disaggregates (if possible) as follows: - Skilled/Unskilled - Indefinite/temporary Total number of jobs in the bioenergy sector; and percentage adhering to the EU employment guidelines consistent with the domains enumerated in the European Employment Strategy, in relation to comparable sectors
MEASUREMENT UNIT(S):	number, number per MJ or MW, and percentage and as a percentage of (working-age) population
METHODOLOGICAL APPROACH:	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, local 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. (FAO 2011) If, with respect to the EU employment guidelines in the bioenergy sector, employment trends show that the sector is improving over time and/or outperforming comparable sectors in the country, this suggests a positive contribution to local or national sustainable development. Fair 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. In order to measure this sub-indicator 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. In the specific case of the advanced bioenergy value chains targeted by FORBIO, the relevant component of skilled jobs is expected as a result of the cutting-edge technology employed, especially in the processing stage. However, feedstock production for advanced biofuels also requires a high degree of specialization of the operators and thus, it is also expected that skilled labour will be necessary in the agricultural phases of the value chain. The indicator covers all steps of the bioenergy value chain. 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. Those in indirect jobs may be contracted by those directly involved in the bioenergy sector. (FAO 2011) 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. In the context of FORBIO, the underlining assumption for which no bioenergy activity exists within the ***target area*** may not always be verified in the real-world scenarios. 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. As for the latter, difficulties reside with ascertaining the existence of jobs (often informal) being displaced by the bioenergy activities in ***target area*** as a result of bioenergy activities.

Disaggregation of job creation figures:

Job definitions	
Skilled	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.
Unskilled	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), the European Employment Strategy of the European Commission and, sometimes also on country-specific documentation.
Temporary	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 job falls under the category of temporary jobs.
Indefinite	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.

The indicator includes measurement of the total workforce in the bioenergy sector, which can be obtained by industry surveys: the experience gained by the main advanced bioenergy technology providers (most of which are not at commercial scale) is the most valuable option for acquiring data on the number of jobs that can be created by a value chain like the ones analysed in FORBIO. It is suggested to express this data as simple total and as an

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employment-to-population[16] ratio or percentage for the sector. For most countries, the working-age population is defined as persons aged 20 years and older. (FAO 2011)

The value for this sub-indicator is given by first calculating the percentage of the total bioenergy workforce for whom the domains of the EU employment guidelines 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.

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

At both national and ***target area*** level:

- Population size
- Employment rate of the total population, men and women, age group 20-64
- Employment rate of low skilled persons, age group 20-64
- Employment rate of NON-low skilled persons, age group 20-64
- Permanent employees as percentage of the total number of employees
- Total number and percentage of temporary employees
- Total number and percentage of permanent employees
- Employment rate of men and women, age group 20-64 in the BIOENERGY SECTOR (if data are available, employment rate can be disaggregated by: unskilled/skilled and temporary/permanent)

B - TARGET SCENARIO

For all stages of the bioenergy value chain studied:

- Number and percentage of skilled/unskilled temporary employees
- Number and percentage of skilled/unskilled permanent employees
- Number and percentage of temporary employees
- Number and percentage of permanent employees

Simple mathematical calculations then will allow to derive total number and percentage of workforce employed in the advanced bioenergy value chain studied.

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12. Being the reference population the population in the selected ***target area***.

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: NATIONAL AND LOCAL (*TARGET AREA*) EMPLOYMENT RATES DISAGGREGATED BY DIFFERENT CLASSES

Classes:	Number or %
Employment rate of the total population, men and women, age group 20-64	
Population size	
Employment rate of low skilled persons, age group 20-64	
Employment rate of NON-low skilled persons, age group 20-64	
Permanent employees as percentage of the total number of employees	
Total temporary employees	
Total permanent employees	
Employment rate of men and women, age group 20-64 in the BIOENERGY SECTOR - Employment rate and number of unskilled persons employed in bioenergy, age group 20-64 - Employment rate and number of skilled persons employed in bioenergy, age group 20-64 - Total number and percentage of temporary employees in bioenergy - Total number and percentage of permanent employees in bioenergy	

B - TARGET SCENARIO

STEP 2: TOTAL NUMBER OF JOBS THAT REFER TO BIOENERGY VALUE CHAINS SELECTED

The indicator measures the impact of jobs created by bioenergy value chains (workforce at the target situation), derived as the difference between the target and the baseline scenario.

The work force (total number of jobs created) is measured along the entire bioenergy value chain of the project considering the following classes:

CLASSES:	NUMBER*
Tot. unskilled	
- Unskilled temporary	
- Unskilled permanent	
Tot. skilled	
- Skilled temporary	
- Skilled permanent	

* Persons/year

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The following list refers to the steps that compose the bioenergy value chain studied, from feedstock production to fuel transport, and that are considered in the in the indicator measurement. Jobs created in each of the following categories should be researched in order to give an understanding of the allocation of new jobs to each stage of the value chain:

VALUE CHAIN DISAGGREGATION
FEEDSTOCK PRODUCTION
Seeds and genetic material production
Land clearing
Weeding
Soil tillage - All Preparatory
Soil tillage complementary
Non-tillage operations
Harvesting
Fertilization, Pest management and irrigation
BIOMASS TRANSPORT
BIOMASS PROCESSING
MAINTENANCE AND RESEARCH ACTIVITIES
FUEL TRANSPORT

METHODOLOGY

BASELINE:

Number of jobs and employment rates:

e.g.

P_S. Population size= 1,000,000

E_R. Employment rate and number of the total population, men and women, age group 20-64: 85 percent; 850,000 people

E_{RB}. Employment rate and number of workers (W_B), men and women, aged 20 – 64 employed in the BIOENERGY SECTOR = 2 percent; W_B = 20,000 people

S_B. skilled in Bioenergy= 4,000

U_B. unskilled in Bioenergy= 16,000

Weighted percentage of skilled employees of total bioenergy employees

$S_{B\%} = S_B / E_{RB} * 100 =$

$S_{B\%} = 4{,}000/20{,}000*100 =$ **20 percent**

Weighted percentage of unskilled employees of total bioenergy employees

$U_{B\%} = U_B / E_{RB} * 100 =$

$U_{B\%} = 16{,}000/20{,}000*100 =$ **80 percent**

NATIONAL AND LOCAL (TARGET AREA) EMPLOYMENT RATES DISAGGREGATED BY DIFFERENT CLASSES

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TARGET:

Number of jobs created by bioenergy value chains:

e.g.

W_{AB}. Total number of men and women, age group 20-64 employed in the **advanced bioenergy** value chains studied = 2,000

S_{AB}. number of skilled jobs in the **advanced bioenergy** value chain: 600

U_{AB}. number of unskilled jobs in the **advanced bioenergy** value chain: 1,400

NUMBER OF JOBS CREATED AT LOCAL (TARGET AREA) LEVEL

FINAL ASSESSMENT:

TARGET – BASELINE

e.g.

- Jobs created by the **advanced bioenergy** value chain (J_{cAB}) as a weighted percentage of total population

$J_{cAB}= W_{AB}/P_s*100 =$

$J_{cAB}= 2{,}000/1{,}000{,}000*100 =$ +0.2 percent

- Contribution of advanced biofuel value chains (C_{AB}) to employment in the bioenergy sector

$C_{AB}= W_{AB}/W_B*100 =$

$C_{AB} = 2{,}000/20{,}000*100 =$ +10 percent

FINAL EMPLOYMENT RATE CHANGE IN THE BIOENERGY SECTOR

- Weighted contribution of advanced biofuel value chains (**$C_{AB}S_B$**) to skilled employees of total bioenergy employees

$C_{AB}S_B= (S_{AB}+S_B/W_{AB}+W_B*100) – S_{B\%} =$

$C_{AB}S_B= (600+4{,}000/2{,}000+20{,}000*100) – 20$ percent = +0.90 percent

FINAL CHANGE in SKILLED EMPLOYMENT RATES IN THE BIOENERGY SECTOR

- Weighted contribution of advanced biofuel value chains **($C_{AB}U_B$)** to unskilled employees of total bioenergy employees

$C_{AB}U_B= (U_{AB}+U_B/W_{AB}+W_B*100) – S_{B\%} =$

$C_{AB}U_B= (1{,}400+16{,}000/2{,}000+20{,}000*100) – 80$ percent = -0.91 percent

FINAL CHANGE in UNSKILLED EMPLOYMENT RATES IN THE BIOENERGY SECTOR

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. 2014
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia. 2014
- Council Decision (EU) 2015/1848 of 5 October 2015 on guidelines for the employment policies of the Member States for 2015

BIOENERGY USED TO EXPAND ACCESS TO MODERN ENERGY SERVICES

DESCRIPTION:	Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type) measured in terms of energy Total number and percentage of individuals, households and businesses benefitting from modern bioenergy services
MEASUREMENT UNIT(S):	Liquid fuels: tonnes/year, MJ/year and percentage; Gaseous fuels: cubic metres/year, MJ/year and percentage; Electricity: MWh/year, MJ/year and percentage; Heating and cooling: BTU/year, MJ/year and percentage; Number and percentages.
METHODOLOGICAL APPROACH:	Energy services from advanced biofuels can be intended as modern energy services originated from biomass and converted through advanced processing technologies. The impact of modern bioenergy services can be assessed at different levels: - local level: at this level, the contribution of the advanced biofuel production is assessed considering the direct impact, on the area, that new bioenergy can provide in terms of supply of district heating and/or district cooling; - country level: the improvement in modern energy access at national level is provided by the bioenergy plants' electricity surplus obtained from co- and by-products. - EU level: at this level, the advanced biofuels productions will directly increment the share of EU modern bioenergy access. Finally, it should be considered that inverting this classification, the contribution of higher levels (EU→Country→Local) of modern bioenergy services also impacts the lowest levels. For example, the electricity obtained from co- and by-products can be counted as increase of the local access as well, further considering the incidence cut-down of the energy dispersion when electricity is channelled into the grid. Similarly, the final biofuels increment considered at EU level could be counted directly as the impact of the liquid fuels on the national mix. This sub-indicator assesses the contribution of advanced biofuels to: Local level: the supply of energy as district heating and district cooling. A heat network enables valuable energy, which is all too often wasted in power generation or industrial processes, to be captured and supplied to householders and businesses. This can remove the need for additional energy to be generated or find new energy sources in areas where access is still low. Networks also have the ability to balance the supply and generation of heat or cool, across location and over time. Over the course of the day, heat demand shifts between residential consumers to commercial, industrial and public buildings and back again. A heat network can match and manage these flows, whilst maximising the utilisation of the plant providing the heat. Demand can also be managed across seasons, with networks supporting the operation of distributed absorption cooling plants in the summer providing cooling on a significant scale. The amount of modern bioenergy access of the district heating and cooling systems are calculated in BTU/year, MJ/year and

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	percentage. The electricity surplus obtained from the advanced biofuels production and directly addressed to the local network is considered as increment in the local modern bioenergy access and then counted in the final share or increase at local level. Furthermore, the production of advanced biofuels in the form of gaseous fuels can also be supplied to householders and businesses at local level and calculated in cubic metres/year or MJ/year and percentage. National level: In modern facilities, e.g. cellulosic ethanol production, co- and by- products can supply the plant's energy demands. Often, a surplus is generated which is commonly exporting to the national grid. This sustainable energy supply is calculated in MWh/year or MJ/year and percentage. At this level, the production of advanced biofuels for transport can be relevant compared to the national share. The national transport sector is supplied from the production of advanced biofuels and this increment can be calculated in tonnes/year or MJ/year and percentage. Starting from 2015, in a number of EU countries, the use of upgraded bio-methane for transport or for heating purposes has been increasingly looked at as a promising alternative use of biogas. Bio-methane can theoretically be supplied to national network through grids. In the indicator, its contribution to increasing access to modern energy services is calculated in cubic metres/year, MJ/year and percentage. EU level: the total production of advanced biofuels (considered as modern bioenergy access) is calculated in MJ/year and the increase compared to EU access of modern bioenergy is calculated in percentage. These values will also be accounted as a contribution to increased access to modern and advanced bioenergy forms targets set by the European Commission.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** Current amount of modern energy access disaggregated by: - electricity for lighting, communication, healthcare, education and other uses; - modern fuels for cooking, heating, and cooling including district heating systems; - advanced liquid biofuel for transport; - advanced gaseous biofuels; and - number (and percentage) of households and businesses benefitting from energy generated through or as a result of advanced biofuels production value chains (considered as modern bioenergy access) at regional, national and local level **B - TARGET SCENARIO** Additional amount of modern energy access disaggregated by: - electricity generated and provided to the grid from advanced biofuels production; - advanced liquid biofuel for transport; - advanced gaseous biofuels fuels; - thermal energy generated from advanced biofuels production (district heating and cooling);

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	- number (and percentage) of households and businesses benefitting from energy generated through or as a result of advanced biofuels production value chains

SUGGESTED STEPWISE APPROACH:

This indicator is primarily related to the theme of Access to energy. It measures the expansion of access to modern energy services provided by advanced biofuels for both households and businesses.

A - BASELINE SCENARIO

STEP 1: CURRENT AMOUNT OF MODERN ENERGY ACCESS

Modern energy sources:	Year	Value	Unit
Electricity for lighting, communication, healthcare, education and other uses			
Modern fuels for cooking heating and cooling			
Advanced liquid biofuels for transport			
Advanced gaseous biofuels for transport			

STEP 2: NUBER OF HOUSEHOLDS AND BUSINESSES BENEFITTING OF ADVANCED BIOFUELS PRODUCTION

- number (and percentage) of households and businesses benefitting from energy generated through or as a result of advanced biofuels value chains (considered as modern bioenergy access) at regional, national and local level

B - TARGET SCENARIO

STEP 3: ADDITIONAL AMOUNT OF MODERN ENERGY ACCESS

Modern energy sources:	Year	Value	Unit
Electricity generated and provided to the grid from advanced biofuels production			
Modern fuels for cooking heating and cooling			
Advanced liquid biofuel for transport			
Advanced gaseous biofuels for transport			
Thermal energy generated from advanced biofuels production (district heating and cooling)			

STEP 4: NUBER OF HOUSEHOLDS AND BUSINESSES BENEFITTING FROM ADVANCED BIOFUELS PRODUCTION

- number (and percentage) of households and businesses benefitting from energy generated through or as a result of advanced biofuels value chains (considered as modern bioenergy access) at regional, national and local level

METHODOLOGY

BASELINE:

A) **Current amount of modern energy access:**

e.g.

Electricity for lighting, communication, healthcare, education and other uses: **8.000 GWh/year**

Modern fuels for cooking, heating and cooling: **351,000 GJ/year**

Reference fuel used for transport – Petrol – : ***Target area*** **686,000 GJ/year; country level 700,000,000 GJ/year; Europe[17] 3,500 PJ ($3.5*10^{15}$ J)**

Advanced liquid biofuel for transport: **0 MJ/year**

Advanced gaseous biofuels for transport: **0 MJ/year**

Thermal energy (district heating and cooling): **0 BTU/year**

AMOUNT OF ENERGY DISAGGREGATED BY SOURCE

B) **Number of households and businesses benefitting from advanced biofuels production**

e.g.

Total number of household within ***target area***: **35,000**

Total number of businesses within ***target area***: **1,500**

Total number of household within ***country***: **23,848,000**

Total number of businesses within ***Europe***: **206,500,000**

Number of households benefitting from ADV BIO prod within ***target area***: **0**

Number of business benefitting from ADV BIO prod within ***target area***: **0**

MODERN ENERGY USERS DISAGGREGATED BY TYPOLOGY

TARGET:

A) **Future additional amount of modern bioenergy resources:**

e.g.

Electricity for lighting, communication, healthcare, education and other uses: **104 GWh/year**

Modern fuels for cooking heating and cooling: **0 MJ/year**

Advanced liquid biofuel for transport: **1,072,000 GJ/year**

Advanced gaseous biofuels for transport: **0 MJ/year**

Thermal energy (district heating and cooling): **12,000,000 BTU/year**

AMOUNT OF ENERGY DISAGGREGATED BY SOURCE

B) **Number of households and businesses benefitting from advanced biofuels production**

e.g.

Number of households benefitting from ADV BIO prod within ***target area***: **500**

Number of business benefitting from ADV BIO prod within ***target area***: **250**

MODERN ENERGY USERS DISAGGREGATED BY TYPOLOGY

FINAL ASSESSMENT:

TARGET – BASELINE

A) **Access to modern bioenergy:**

e.g.

Electricity for lighting, communication, healthcare, education and other uses: **+1.3 Percent**

Modern fuels for cooking heating and cooling: **0 percent**

Access to Advanced liquid biofuel for transport: **+0.15 percent (country level); +0.03 percent (European level)**

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13. Example data from https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/road_vehicle_fuel_consumption_en.pdf

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Advanced gaseous biofuels for transport: **0 percent**
Thermal energy (district heating and cooling): **+100 percent**
AMOUNT OF ENERGY DISAGGREGATED BY SOURCE

B) **Number and percentage of households and businesses benefitting of advanced biofuels production in the *target area*** [18]

e.g.

Total number and percentage of households (***target area***): **500; +7 Percent (electricity in *target area*)**

Total number and percentage of businesses (***target area***): **250; + 16.66 Percent (electricity in *target area*)**

Percentage of households (country): **+ 0.002 percent**

Percentage of households (Europe): **+ 0.000024 percent**

MODERN ENERGY USERS DISAGGREGATED BY TYPOLOGY

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. 2014
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia. 2014

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14. NOTE THAT advanced liquid fuels have national or European markets and thus their increased presence is considered only at the higher levels of aggregation

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4.10. Economic pillar

ECONOMIC PILLAR

THEMES

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

Productivity, Net energy balance, Gross value added, Training and re-qualification of the workforce, Infrastructure and logistics for distribution of bioenergy

INDICATOR NAME	INDICATOR DESCRIPTION
Productivity	The indicator covers advanced biofuel feedstock production and all processing stages of the value chain: productivity of bioenergy feedstock by feedstock or farm typology; processing efficiencies by technology and feedstock; production cost per unit of feedstock
Net energy balance	The indicator applies to bioenergy production, conversion and use, and to all bioenergy feedstocks, end-uses, and pathways: feedstock production; processing of feedstock into advanced biofuel; adv. biofuel use; and lifecycle analysis
Gross value added	Gross Value Added for unit of bioenergy produced and as a percentage of gross domestic product
Training and re-qualification of the workforce	Percentage of trained workers in the bioenergy sector out of total bioenergy workforce
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
Capacity and flexibility of use of bioenergy	Ratio of capacity for using advanced biofuels compared with actual use for each significant utilization route

TABLE. 7 The FORBIO economic sustainability indicators

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PRODUCTIVITY

DESCRIPTION:

This indicator covers advanced biofuel feedstock production and all processing stages of the value chain: productivity of bioenergy feedstock by feedstock or farm typology; processing efficiencies by technology and feedstock; production cost per unit of feedstock

MEASUREMENT UNIT(S):

Tonnes per ha per year; tonnes fuel/tonne feedstock; tonnes of fuel per ha MJ fuel/tonne feedstock and MJ fuel per ha; EUR/tonne feedstock

METHODOLOGICAL APPROACH:

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 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 or in a specific ***target area*** (FAO 2011). However, in the specific case of underutilized lands, the case for intensification may come at the expenses of other indicators of sustainability (e.g. water use and availability, soil quality, etc.) and it is therefore fundamental that all these are treated holistically and assessments are linked into a common harmonized system.

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

At both national and ***target area*** level:

- Average production yields of bioenergy feedstock in the ***target area*** by feedstock*;

*In case there is no record of actual performances of the selected feedstock in the ***target area***, a literature review based on the characterization of the specific site (in order to identify comparable study settings) is necessary

B - TARGET SCENARIO

- Processing efficiencies of bioenergy feedstock into end products

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: AVERAGE PRODUCTIVITY YIELDS OF BIOENERGY FEEDSTOCK IN THE *TARGET AREA* BY FEEDSTOCK

Projections based on estimations from the literature rather than on primary data collected in field trials however have a lower degree of accuracy and may be valid only at the prefeasibility assessment stage. Productivity is often the crucial aspect that determines a number of subsequential assumptions until the sizing of advanced bioenergy plants and hence it is an indicator of paramount importance. Data accuracy and credibility should be verified, to the extent possible. This information is derived from the Deliverables under WP2.

B - TARGET scenario

STEP 2: PROCESSING EFFICIENCIES OF BIOENERGY FEEDSTOCK INTO END PRODUCTS

Processing efficiencies of bioenergy feedstock need to capture the transformation of feedstock into advanced biofuels by technology and by feedstock; in general, this type of information is confidential as strictly related to private sector's competitiveness; even more so, when dealing with advanced – cutting edge – technologies like lignocellulosic ethanol, biomass to liquid, etc. this information may be protected by confidentiality agreements for which verification of data can be difficult. This limitation is to be taken into account. This information is derived from literature research as well as from direct communication with the technology provider in the case of lignocellulosic ethanol production.

STEP 3: LOCAL FEEDSTOCK PRODUCTION COSTS PER UNIT OF FEEDSTOCK

Production costs may vary greatly as a result of several aspects that at the local level may lead to the choice of one type of biomass (and consequently a specific processing technology) over another. Production costs should then be compared to national market prices for comparable feedstock in order to provide an understanding of the productivity of the intended advanced value chain. These aspects in turn, link directly to social indicators such as income and employment in the bioenergy sector. This information is derived from the techno-economic assessments produced under WP2.

METHODOLOGY

BASELINE:

Average production quantity per unit of surface by feedstock:

e.g.
a) **Giant reed (IRR)** in case study area – Sulcis – : **25 t/ha**
b) Giant reed (Rainfed) in Italy: 12 t/ha
c) Switchgrass in case study area – Sulcis – : 8 t/ha
d) Willow in case study area – Ukraine – : 10 t/ha
e) Grass in case study area – Germany – : 4 t/ha
f) Mischantus in case study area – Germany – : 15 t/ha

TARGET:

Processing efficiencies:

e.g.

a + b) Lignocellulosic ethanol from giant reed (both IRR and Rainfed): 0.25 $t_{fuel}/t_{feedstock}$ (source Biochemtex); 6.75 GJ/$t_{feedstock}$c) Lignocellulosic ethanol from switchgrass: 0.20 $t_{fuel}/t_{feedstock}$ (source Biochemtex); 5.38 GJ/$t_{feedstock}$

d) Lignocellulosic ethanol from willow: 0.20 $t_{fuel}/t_{feedstock}$ (source Biochemtex); 5.38 GJ/$t_{feedstock}$

e) Biomethane from grass: 5 $m^3/t_{feedstock}$; 175 MJ/ $t_{feedstock}$

f) Bioethanol from mischantus: 0.20 $t_{fuel}/t_{feedstock}$ (source Biochemtex); 5.38 GJ/$t_{feedstock}$

Production cost per unit of feedstock: e.g. **Giant reed** (IRR) **in case study area** (Italy): **EUR 71/t** Giant reed (Rainfed) in case study area (Italy): EUR 60/t
Switchgrass in the case study area: N/A
Switchgrass in Italy: EUR 51/t (literature)
Willow in Ukraine: EUR 27/t
Grass in Germany: EUR 14/t
Mischantus in Germany: EUR 50/t

FINAL ASSESSMENT:

In the case of this indicator the final assessment is made by highlighting the most productive and efficient feedstock alternative available among those tested in each case study location.

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. 2014
- FAO (GBEP). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia. 2014
- Council Decision (EU) 2015/1848 of 5 October 2015 on guidelines for the employment policies of the Member States for 2015

NET ENERGY BALANCE

DESCRIPTION:	The indicator applies to bioenergy production, conversion and use, and to all bioenergy feedstock, end-uses, and pathways: Feedstock production; Processing of feedstock into advanced biofuel; Adv. biofuel use; Lifecycle analysis
MEASUREMENT UNIT(S):	Ratio
METHODOLOGICAL APPROACH:	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 input to the bioenergy production process sometimes come from hydrocarbons; therefore, a high net energy ratio will indicate efficient use of these non-renewable resources (FAO 2011).
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** Starting from the assumption that in the baseline scenario there is no advanced bioenergy production, the analysis is only devoted to assessing energetic characteristics of the target scenario. **B - TARGET SCENARIO** As in the case of the lifecycle assessments under the Environmental set of indicators, the energy balance is calculated as the difference between the outputs of the value chain and all its inputs, in energy terms rather than in terms of GHG and/or non-GHG pollutants. In order to do so therefore, the same data list used for the aforementioned indicators should be used, this time with the attribution of the respective LHV for each component rather than their emission factor. Following is an outline of the major groups of data required: - 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 a. Feedstock agricultural yields (tonne/ha); b. Primary energy inputs per unit of feedstock produced (MJ/tonne); c. Indirect energy (e.g. embedded in machinery) per unit of feedstock produced (MJ/tonne). - Ratio of energy content of biofuel and co-products produced to energy content of feedstock input d. Energy content of the feedstock produced/processed (if the previous measurements are not available) (MJ); e. Energy efficiencies of conversion plants (sample);

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- 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)

f. Energy content of the bioenergy source considered (MJ);

g. Segmentation of national car fleet and relative efficiencies;

h. Efficiencies of a representative sample of national bioenergy power plants, as reported by plant owners.

SUGGESTED STEPWISE APPROACH:

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 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 feedstock, 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 (FAO 2011).

TARGET SCENARIO

STEP 1: RATIO OF ENERGY INPUTS REQUIRED FOR THE PRODUCTION OF HARVESTED FEEDSTOCK TO ENERGY CONTENT OF ONE UNIT OF FEEDSTOCK AND ASSOCIATED CO-PRODUCTS

- Type of advanced biofuel: e.g. lignocellulosic ethanol from giant reed.

  Energy inputs and outputs for the feedstock production step are shown as follows:

- Energy from operating farm/machinery. Energy used for all tillage operation, including land preparation, management, and mechanical harvest. The fuel used is: e.g. fossil diesel.
- Energy used for irrigation: e.g. electric pump, water is withdrawn from the local irrigation network, reservoir water.
- Energy used for transport of raw materials: fertilizers and pesticides.
- Energy associated with inputs production and application: N-fertilizer, P-Fertilizer, K-fertilizer, pesticides.
- Energy embodied in seeds and labour.
- Biomass energy output: in MJ/t of feedstock

STEP 2: RATIO OF ENERGY CONTENT OF BIOFUEL AND CO-PRODUCTS PRODUCED TO ENERGY CONTENT OF FEEDSTOCK INPUT

- Feedstock Transport distance: in km
- Energy efficiency for feedstock transport using diesel truck: in MJ/t·km
- Processing inputs transport distances via truck (cumulated): in km
- Transports distances via ship (cumulated): in km
- Reagents total quantity (lime, sulfuric acid, sulphur, sodium hydroxide, carbon, biocides, surfactants, among others): in t
- Energy efficiency for truck: in MJ/km·t
- Energy efficiency for ship: in MJ/t·km
- Co-products: Electricity to the grid in kWh/t ethanol or kWh/t feedstock
- Energy balance from cogeneration system
- Processing efficiency measured in Productivity Indicator
- Advanced biofuel LHV: in GJ/t
- Co-products LHV: in MJ/kg

- Bioethanol yield: from Indicator "Productivity"
- Co-products yields

STEP 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 the case of liquid biofuels for transport, the energy content of the most common biofuel blend employed and the average efficiency of the fleet should be considered for this analysis.

STEP 4: LIFECYCLE ENERGY EFFICIENCY OF THE STUDIED VALUE CHAINS

- In the case of liquid biofuels for transport, the energy efficiency of the whole value chain is obtained as the ratio between the final usable energy (in MJ per t of feedstock) divided by the energy content of 1 ton of feedstock

METHODOLOGY

TARGET:

STEP 1:

Bioenergy pathway A): e.g. lignocellulosic ethanol
(T_{FI}) Total feedstock production energy input: e.g. 286.15 $MJ/t_{feedstock}$
(T_{FO}) Total feedstock energy content (output): e.g. 2,950 $MJ/t_{feedstock}$ (also, energy content of 1 ton of feedstock)
(NEV) Net Energy Value = T_{FO} - T_{FI} = 2,950 $MJ/t_{feedstock}$ - 286.15 $MJ/t_{feedstock}$ = 2,663.85 $MJ/t_{feedstock}$
(NER) Net Energy Ratio = T_{FO} / T_{FI} = 2,950 $MJ/t_{feedstock}$ / 286.15 $MJ/t_{feedstock}$ = 10.30

Bioenergy pathway B): e.g. HVO
(T_{FI}) Total feedstock production energy input: e.g. 520.84 $MJ/t_{feedstock}$
(T_{FO}) Total feedstock energy content (output): e.g. 3,980 $MJ/t_{feedstock}$
(NEV) Net Energy Value = T_{FO} - T_{FI} = 3,980 $MJ/t_{feedstock}$ - 520.84 $MJ/t_{feedstock}$ = 3,459.16 $MJ/t_{feedstock}$
(NER) Net Energy Ratio = T_{FO} / T_{FI} = 3,980 $MJ/t_{feedstock}$ / 520.84 $MJ/t_{feedstock}$ = 7.64

STEP 2:

Bioenergy pathway A): e.g. lignocellulosic ethanol
As most of the energy used for the processing of feedstock into ethanol is obtained from the lignin, the efficiency of this stage of the ethanol supply chain is largely dependent on the efficiency of the co-generation unit. Given the set of conditions encountered in the hyphotetical example A) the NER calculated is:

NER = 0.87
NEV = 2,316 $MJ/t_{feedstock}$

Bioenergy pathway B): e.g. HVO
Unlike lignocellulosic ethanol, the processing of oilseed into HVO relies on substantial amounts of energy from outside the system, which in turn leads to a NER for this stage of the value chain calculated as:

NER = 0.70
NEV = 2,421 $MJ/t_{feedstock}$

STEP 3:

Bioenergy pathway A): e.g. lignocellulosic ethanol E5
NER = 0.25

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NEV = 579 MJ/$t_{\text{feedstock}}$

Bioenergy pathway B): e.g. HVO B5
NER = 0.36
NEV = 871 MJ/$t_{\text{feedstock}}$

STEP 4:
Bioenergy pathway A):
NER = 579 MJ/$t_{\text{feedstock}}$ / 2,950 MJ/$t_{\text{feedstock}}$ = 0.19

Bioenergy pathway B):
NER = 871 MJ/$t_{\text{feedstock}}$ / 3,980 MJ/$t_{\text{feedstock}}$ = 0.22

FINAL ASSESSMENT:

Based on the comparison of final results of various tested bioenergy options, the final assessment will provide information on the most energy-efficient pathway possible. This result is intended to guide policymakers and investors on their decision making process.

e.g. for STEP 1 and 2, the bioenergy pathway A) is the most energy efficient whereas concerning STEP 3 (fuel use) the energy efficiency of diesel engines (pathway B) is superior.
Per ton of feedstock, the bioenergy pathway B) yields a higher amount of useful energy, and it is thus more efficient than pathway A).

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011

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GROSS ADDED VALUE

DESCRIPTION:

Gross value added per unit of bioenergy produced and as a percentage of gross domestic product

MEASUREMENT UNIT(S):

EUR/MJ and percentage

METHODOLOGICAL APPROACH:

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. (FAO 2011)

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.

- 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).

This methodology 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 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.

In the case of FORBIO, the GVA becomes:

GVA = Sales + Income from other services - cost of raw materials - cost of production - cost of services availed from outside supplier

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

- Current GDP in the ***target area***

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B - TARGET SCENARIO

- total gross revenues from sale of advanced biofuels (e.g. ethanol)
- total gross revenues from sale of other services (e.g. electricity)
- cost of raw materials (e.g. feedstock)
- cost of production (e.g. plant, labour, licensing, etc.)
- cost of services from outside suppliers (e.g. transport of final product)

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: ESTABLISHMENT OF REFERENCE VALUES "WITHOUT BIOENERGY"

- Current GDP

B - TARGET SCENARIO

STEP 2: TOTAL OUTPUT VALUE "WITH BIOENERGY"

- Sales of Advanced Biofuel + Sales of Additional Services

STEP 3: INTERMEDIATE INPUTS "WITH BIOENERGY"

- Cost of Raw Materials + Cost of Production + Cost of External Services

METHODOLOGY

BASELINE:

STEP 1:
e.g. Target area A)
GDP = EUR 1,178,000,000

TARGET:

STEP 2:
e.g. Target area A)
SALES of advanced biofuel: 40,000 t/year * EUR 800/t = EUR 32,000,000/year
SALES of additional services (electricity): 104 GWh/year * EUR 0.14/kWh = EUR 14,560,000/year
Total: EUR 46,560,000/year

Step 3:
Cost of Raw Materials: 200,000 t/year * EUR 70/t = EUR 14,000,000/year
Cost of Production: EUR 3,520,000/year
Cost of External Services: EUR 875,000/year
Total: EUR 18,395,000/year

FINAL ASSESSMENT:

GVA = STEP 2 - STEP 3 = EUR 46,560,000/year – EUR 18,395,000/year = EUR 28,165,000/year

Contribution to GDP = + 2.39 %

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011

TRAINING

DESCRIPTION:	Share of trained workers in the bioenergy sector out of total bioenergy workforce
MEASUREMENT UNIT(S):	Number and Percentage
METHODOLOGICAL APPROACH:	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. The indicator is also strongly related to the theme of Rural and social development (and particularly connected with Indicator: Jobs in the bioenergy sector) and is indirectly related to other themes such as Labour conditions, Human health and safety, and Economic development. The measurement of this indicator in fact, completes the assessment of the conditions of workers in the bioenergy sector.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **B - TARGET SCENARIO** Skill requirements in the bioenergy force disaggregated by: - Agricultural phase (feedstock production) - Processing phase (feedstock processing into fuel)

SUGGESTED STEPWISE APPROACH:

B - TARGET SCENARIO

STEP 1: ASSESSMENT OF THE NUMBER AND SHARE OF AGRICULTURAL WORKERS FOR WHICH TRAINING IS REQUIRED

- In the case of advanced biofuel value chains, often the feedstock is a novel crop. Not all energy crops are common among farmers in various parts of Europe and an industry based on the use of a specific crop might need to provide farmers with the necessary training to grow efficiently the energy crop of interest. In the case of perennial crops such as giant reed or mischantus, require specific knowledge and skills in order to carry out all agricultural activities efficiently. Land preparation, correct planting spacing, selection of seedlings (e.g. in vitro vs rhizomes), are all key actions that a farmer needs to learn prior to embark in the cultivation of a crop that has relatively high initial investment costs and that is bound to stay in his fields for 20-25 years. The harvesting technique and equipment necessary for specific energy crops is also part of this stage and it also require adequate training. A calculation of the average number of trained workers should be done on a *per ha* basis and then inferred to the total coverage of the proposed bioenergy value chain studied.

STEP 2: ASSESSMENT OF THE NUMBER AND SHARE OF WORKERS IN THE PROCESSING PHASE (FEEDSTOCK PROCESSING INTO FUEL) FOR WHICH TRAINING IS REQUIRED

- Advanced biofuel value chains often rely on cutting-edge processing technology. Liquid fuels in this category are known to require a highly selected and well-trained workforce, at any of the several levels of responsibility that compose the staff of the plant. Labour force is trained to the specific operations that take place inside biorefineries, as well as all other technicians must have a unique a valuable base knowledge on which basis to build further experience directly through training and workshops.

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METHODOLOGY

TARGET:

STEP 1:

e.g.

16,720 ha of formerly underutilized land dedicated to biomass production in the ***target area A***. Feedstock: dedicated energy crops.

From indicator "Jobs in the bioenergy sector", an indication of the number of workers is provided.

e.g. 150 farmers involved. The needs for trainings of those farmers will be linked to the characteristics of the specific energy crop. These crops require the use of particular machineries that are capable of performing mechanical weeding for the first year after planting. One machinery can cover up to 10 ha per day and the weeding time window is 20 days. Therefore, it is expected that 84 farmers will need the necessary training to operate the machineries necessary to perform the specific mechanical weeding of 16,720 ha within the available time window.

STEP 2:

e.g.

a 33,000 t/y lignocellulosic ethanol plant is built within ***target area A***. The plant will offer some 2,000 new jobs, of which 95 percent have to be skilled jobs. Of these, only 5 percent are already at the level of skills necessary to start operations and the internal protocol of the plant requires all workers to undergo a periodic training course (every 12 months) to keep up with regulatory and scientific development.

FINAL ASSESSMENT:

- In the example presented above, for the agricultural phase:
  84 farmers require specific training on the use of machineries
  This is 56 percent of total workforce.

- For the processing phase:
  1,800 workers require to various extents some form of training, that is 90 percent of total workforce in the processing phase.

REFERENCES

– FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011

INFRASTRUCTURE AND LOGISTIC FOR DISTRIBUTION OF BIOENERGY

DESCRIPTION:	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each
MEASUREMENT UNIT(S):	Number; MJ, m^3, or tonnes per year; or MW for heat and power capacity percentages
METHODOLOGICAL APPROACH:	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 (FAO 2011). The concept of ***target area*** is strongly related to this indicator. To complete the classification of the ***target area*** and to improve the quality of the sustainability assessments, FORBIO considers crucial the need for identifying the capacity of bioenergy distribution systems. These data will facilitate managing the risks associated with delivering and distributing bioenergy in a country in an inefficient manner, as a result of an inadequate level of infrastructure network. 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. In FORBIO, these positive impacts on sustainable development can be measured by identifying new infrastructure facilities attributable to advanced biofuels production, distribution and use, which can be also employed for other scopes (e.g. roads, railroads, etc.). – Map all distribution and logistics features of the ***target area***; – Identify critical distribution systems for bioenergy feedstocks, fuels and electricity production and distribution systems; – Determine the capacity values for each of the identified distribution systems; – 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.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** – Annotated[19] GIS maps of the road, railroad and port systems within the target area; – number of port facilities capable of exporting advanced biofuels, – capacity for handling/storage of advanced biofuels – capacity and reliability of blending facilities and terminals; **B - TARGET SCENARIO**

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15. Including attributes such as e.g. size, conservation status, capacity and other characteristics of the infrastructures

- number of port facilities capable of exporting advanced biofuels, compared with level of advanced biofuel production after the project implementation;
- capacity for handling/storage of advanced biofuels compared with actual level of advanced biofuel production after the project implementation;
- capacity and reliability of blending facilities and terminals;

SUGGESTED STEPWISE APPROACH:

The indicator is made of a quantitative component and a qualitative component. The quantitative component, is ideally intended to provide the user with an indication of the i. distance from the production sites of the relevant facilities; and ii. with the capacity (expressed in terms of amount of biofuel feedstock/final product per year) that can be handled by those infrastructures. The qualitative component, will consist in the assessment of the most effective logistics on the basis of the quantitative analysis. The importance of this indicator for the sound planning of the bioenergy value chain proposed is therefore obvious. In fact, in the instance in which there are multiple options for the choice of production sites, or for the construction of storage facilities, etc. the indicator can guide planners to make the most efficient selection of feedstock production areas, storage facilities, processing facilities as well as exporting hubs.

A - BASELINE SCENARIO

STEP 1: MAPPING THE CURRENT INFRASTRUCTURE NETWORK IN THE TARGET AREA

Through the use of **annotated maps of the road, railroad and port systems within the target area**, in a GIS environment the user should superimpose the perimeter of the underutilized lands that could be possibly used for the production of the feedstock**;**

The two reference points in this initial analysis must be 1) the most likely location of the processing plant; and 2) the most likely availability of underutilized lands.

Subsequently, by projecting these infrastructures over the Digital Elevation Model of the area, the real distances and geography of the ***target area*** can be calculated in order to provide a primary fundamental assessment: the radius of the operations.

B - TARGET SCENARIO

STEP 2: QUANTITATIVE ASSESSMENT:

The superimposition of the areas where the proposed advanced biofuel value chain will have its milestones (feedstock production fields; feedstock storage facilities; biorefinery/processing plant; final use/distribution point/export gate) will allow for the automatic calculation of the distances and the volumes that can be moved along the existing network. It is likely that a number of options are available. These may differ for several aspects related to the number of attributes present in the annotated maps (e.g. distance, time spent traveling, maximum payload, etc.).

STEP 3: QUALITATIVE ASSESSEMNT

On the basis of the quantitative assessment, a qualitative definition of the most efficient logistics can be performed on the basis of a number of parameters. Feedstock transport distances should be minimized. More properly, feedstock transport time requirements should be minimized. Therefore, the quantitative assessment of relative distance (calculated in km) between two points should be considered in function of the other attributes of the infrastructure, including the geography and the size of the roads. In fact, if the shortest route (in relative km terms) is particularly cumbersome due to poor quality of the road, small displacement and consequent limited payload per trip, or other reasons, the most effective option will have to be found by evaluating – through expert opinions – the qualitative assessment of the quality of infrastructures present in the ***target area***.

METHODOLOGY

BASELINE:

MAPPING OF CURRENT INFRASTRUCTURES:

e.g.

In a radius of 50 km there is the existence of both reference points. These are georeferenced at XX° YY’ ZZ”; xx° yy’ zz”

TARGET:

QUANTITATIVE ASSESSMENT:

e.g.

Within the radius of operation identified in baseline, the GIS-tool employed has traced a total of 3 routes which cover the feedstock production areas (e.g. 10,000 ha of underutilized land within the ***target area***), the main roads to connect the fields with storage and processing facilities. The routes are ranked on the basis of the

QUALITATIVE ASSESSMENT:

e.g. Option 1) The shortest route identified within the 50 km radius is composed of:

a) 23 km of secondary, low speed (10 – 20 km/h), rural roads (including border roads, and linkage roads between farms);
b) 7 km of primary, paved 2-lane road, medium speed (50 – 70 km/h)
c) 3 km of primary, paved 4-lane road, high speed (max 100 km/h)

Option 2) The second shortest route identified within the 50 km radius is composed of:

a) 18 km of secondary, low speed (10 – 20 km/h), rural roads (including border roads, and linkage roads between farms);
b) 30 km of primary, paved 2-lane road, high-speed (max 80 km/h)

Option 3) The third route identified within the 50 km radius is composed of:

a) 27 km of secondary, low speed (10 – 20 km/h), windy rural roads (including border roads, and linkage roads between farms);
b) 14 km of primary, paved 2-lane road, high-speed (50 - 70 km/h)

Journey:
Option 1) = (23 km / 15 km/h) + (7 km / 60 km/h) + (3 km / 100 km/h) = 1.66 h
Option 2) = (18 km / 15 km/h) + (30 km / 80 km/h) = 1.57 h
Option 3) = (27 km / 15 km/h) + (14 km / 60 km/h) = 2.03 h

FINAL ASSESSMENT:

e.g.

In this case, the final assessment consists in the ranking of the routes for the logistics of bioenergy value chains studied as prefigured in the qualitative assessment component of the target scenario. An expert review and further multistakeholder consultations are then needed to confirm the selection of the most sustainable route.

In the example above, the qualitative assessment shows how **Option 2)** is the preferred route because, even though its overall length is 48 km (vs 33 km of Option 1), the expected travel time (1.57 h) is lower than that of Option 1 (1.66 h) and Option 3 (2.03 h).

* This indicator encompasses methodologies strongly related to qualitative and quantitative roads maps assessment in a given ***target area***, it does not take into account external and unstable factors (e.g. risk of traffic congestion due to the presence of schools, work sites, and shopping centres) that are not directly related to the typology of the road but can lead to a modification of the benchmarks of choices. However, if disaggregated statistics concerning yearly average speeds recorded on those specific routes are available, these should be substituted to the speed limit reported in the methodology and used instead as reference to calculate journey duration.

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011

- OJ L 80, 23.3.2002, Directive 2002/15/EC of the European Parliament

CAPACITY OF USE OF BIOENERGY

DESCRIPTION:

Ratio of capacity for using advanced biofuels compared with actual use for each significant utilization route;

MEASUREMENT UNIT(S):

Ratio and change in percentage

METHODOLOGICAL APPROACH:

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.

Assessing the ratio of capacity for using advanced biofuels compared with actual use for each significant utilization route will allow quantitative assessment of the capacity to use the various sources of advanced biofuels relevant within a selected ***target area***, but, in the case of advanced biofuel production, more likely at regional or country level. The ratio indicates the level of capacity for using the bioenergy compared to the actual utilization for each critical sector.

DATA REQUIREMENTS:

Detailed data requirements will include information about:

A - BASELINE SCENARIO

- Current capacity and current use of advanced biofuels
- Current biofuel blend
- Size of the fleet

B - TARGET SCENARIO

- Estimated additional availability, capacity, and use of advanced biofuels

SUGGESTED STEPWISE APPROACH:

A - BASELINE SCENARIO

STEP 1: ESTABLISHMENT OF REFERENCE SYSTEM'S VALUES

- To assess the current capacity and the current use of biofuels, at local, national, and European level and where possible disaggregated in traditional vs advanced biofuels

B - TARGET SCENARIO

STEP 2: CAPACITY AND FLEXIBILITY OF USING ADVANCED BIOFUELS

- Capacity for using advanced biofuels compared with actual conditions of the fleet (blending wall)

METHODOLOGY

Capacity ratio = Bioenergy use / Bioenergy capacity

BASELINE:

Consider the transportation sector at country level:

	Unit	BASELINE
Current biofuel use	MTOE/yr	100
Current biofuel capacity	MTOE/yr	250

Capacity ratio in BASELINE = 100/250 = **0.4**

TARGET:

e.g.

Consider the transportation sector at country level:

	Unit	TARGET
Target biofuel use	MTOE/yr	140
Target biofuel capacity	MTOE/yr	250

Capacity ratio for TARGET = 140/250 = **0.56**

FINAL ASSESSMENT:

In TARGET, the use of advanced bioenergy grows from 40 percent of the capacity to 56 percent of the capacity to use biofuels in the fleet.

REFERENCES

- FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011

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5. Conclusions

The set of indicators developed in the context of FORBIO represents the very first example of a compendium of aspects of relevance to the assessment of bioenergy sustainability that includes specific and detailed methodologies for the step-by-step assessment of each indicator. The individual methodology sheets can be used singularly or collectively to describe the most appropriated number of indicators and consequent sustainability aspects of relevance for a given bioenergy project. Users are offered with a complete manual that explains the main features of the indicator, its importance and potential relevance to the theme, in addition to a detailed section on data requirements. Subsequently, through a stepwise approach examples of how the indicator should be used are presented.

In the context of FORBIO, the description of the indicators will represent the reference instrument to perform a number of analyses and produce several difference scenarios, and it will deliver several results:

1) The assessment of BASELINE situation in the ***target areas*** studies for most indicators will provide a detailed overview of the sustainability conditions found in the sites studied (see D3.1 for a summary of data unavailable and consequent indicator measurement inefficiencies);

2) The assessment of a representative number of TARGET scenarios that cover the most promising advanced biofuel pathways will be produced;

3) The comparison of the various TARGET scenarios produced with the use of the indicators and the BASELINE conditions will allow to compare sustainability performances indicator-by-indicator and for any level of analysis (i.e. within the ***target area***, at national, or at European level)

The results of the indicator's measurements will be presented in D3.3. The analyses that can be performed on the basis of the results obtained will be used to present to local stakeholders the main sustainability features of the proposed bioenergy value chains. The discussions with the stakeholders that stem from the measurement of the indicators will provide the opportunity to produce a detailed roadmap for the market uptake of the advanced bioenergy value chains studied in Italy, Germany and Ukraine.

It is expected that such a comprehensive approach allows the broadest number of stakeholders to take on Deliverable D 3.2 even for future use outside of the extent of the FORBIO project. This is why the indicators have been collected as a report that can be made available to the general public as a resource for the assessment of sustainability aspects of bioenergy value chains like the ones studied in FORBIO.