BIKE

BIOFUELS PRODUCTION
AT LOW - ILUC RISK
FOR EUROPEAN SUSTAINABLE
BIOECONOMY

D 4.1

Report on the Design of the Sustainability Indicators Set

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List of Acronyms

2G: Second Generation

ENI: Ente Nazionale Idrocarburi, Italy

EU: European Union

FAO: Food and Agriculture Organization of the UN

FSTK: Feedstock

GBEP: Global Bioenergy Partnership

HVO: Hydrotreated Vegetable Oil

iLUC: Indirect Land Use Change

PM: Person Month

REDII: New European Renewable Energy Directive

SDGs: United Nations (UN) Sustainable Development Goals

UN: United Nations

WP: Work Package

EXECUTIVE SUMMARY

Sustainable bioenergy produced from biomass feedstocks is one of the multiple pathways for climate change mitigation and sustainable development. But to reach these goals, the components of a given supply chain should be evaluated holistically to understand the respective share of impacts in terms of sustainability. For these reasons it is important that comprehensive planning of feedstock production, processing, and sustainability assessments in all steps of the chain, begin before or proceed hand in hand with any project implementation.

Sustainability indicators represent the backbone of monitoring progresses towards the achievement of policy goals, be it the European Union (EU) Green Deal[1], the Sustainable Development Goals[2] (SDGs) 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 work together and ensure the creation of a sound certification scheme.

The work presented in this Deliverable builds upon information collected under other Work Packages (especially WP2) and on the related results to assess the environmental, social, and economic performances of the bioenergy pathways studied. In collaboration with WP2 project partners, data availability and quality were assessed, as these represent the foundation for the definition of a set of *measurable* sustainability indicators that return meaningful information to policymakers and other stakeholders. Several sets of indicators, at different levels, have been proposed and adopted in other projects, however those deemed difficult to measure with minimum accuracy due to low data availability and/or quality, were not considered in the context of BIKE. BIKE set off from the onset with the clear goal to keep concrete expectations on the results of the sustainability assessment based on the data available, thus with a ground-up approach that led to building indicators and their methodologies on the basis of data and information rather than on other, more or less arbitrarily set, measurement goals. Low iLUC risk

[1] Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the Regions. The European green deal. https://ec. europa.eu/info/sites/info/files/european-green-deal- communication_en.pdf
[2] https://sdgs.un.org/goals

biofuel pathways identified in WP2 will be analysed from the point of view of their environmental, social, and economic impacts based on the indicators produced and this exercise will be presented in D4.2.

This report presents the results of Task 4.1 (Development of a tailored set of sustainability indicators for bioenergy based on the specific conditions of each of the case study sites) and Task 4.2 (Compilation of existing environmental, social, and economic data necessary for the measurement of the tailored set of sustainability indicators for bioenergy). The main outcomes presented are: i) an Excel-based Data Entry Sheets and, ii) the BIKE tailored Set of Sustainability Indicators. Standardized Data Entry Sheets are a swift solution to collect data for a number of indicators in a harmonized manner and in one single event. Their preparation required exchanges and discussions with other BIKE project partners who offered useful insights and suggestions to maximise their user friendliness while conserving depth and completeness. Starting from the agreed data entry sheets and available methodologies, FAO developed a set of sustainability indicators for the low ILUC value chains selected. This set, in turn, will constitute a valuable aid to evaluate the sustainability in the context of the certification model. These outcomes are described in detail in the following chapters.

INTRODUCTION

As stated by the new Renewable Energy Directive II (REDII), within the 14% target of renewables in the transport sector, a dedicated target was established for advanced biofuels (Part A of Annex IX). In addition, the Directive established that the contribution of advanced biofuels as a share of final consumption of energy in the transport sector shall be at least 0,2 % in 2022, at least 1 % in 2025 and at least 3,5 % in 2030. A new category is also introduced, the low iLUC risk biofuels, bioliquids and biomass fuels that "are produced under circumstances that avoid iLUC effects, by virtue of having been cultivated on unused, abandoned or severely degraded land or emanating from crops which benefited from improved agricultural practices.".

In this context, the BIKE project is assessing the low-iLUC risk biofuels sector at EU level, to provide a reliable sustainability assessment of biofuel value chains and, consequently, produce a certification model for the advanced, low-iLUC biofuels, in order support the policy and market actors in the identification of a sustainable development pathway. To this end, BIKE approaches the low-iLUC biofuels market sector by identifying two main Low-iLUC biofuels production value chains, namely i) cultivation of feedstock on unused, abandoned or severely degraded land and, ii) crops which have increased yields from improved agricultural practices. Existing case studies are being assessed by the project. A broad range of renewable energy technologies to produce sustainable and advance biofuels, such as anaerobic digestion, hydrotreatment of lipids, thermochemical processing, are being considering for the four different case study sites and in general as potential options to be assessed at EU level. The Circular approach, particularly at the value chain level, is taken as reference in all scenario development, so to create the most of new business opportunities not only for the biofuel producers but also for the local communities, thus ensuring sustainability and creating consensus at different levels.

To ensure this approach, the work lead by FAO under WP4 is developing activities to assess the environmental, social, and economic sustainability performances of the low iLUC risk biofuels, bioliquids and biomass fuels at local, national and, to the extent possible, at EU level. This work is thought to produce guidance on how to maximise the benefits of these productions and pave the way to future use of UN SDGs indicators, as mentioned in the EU Green Deal.

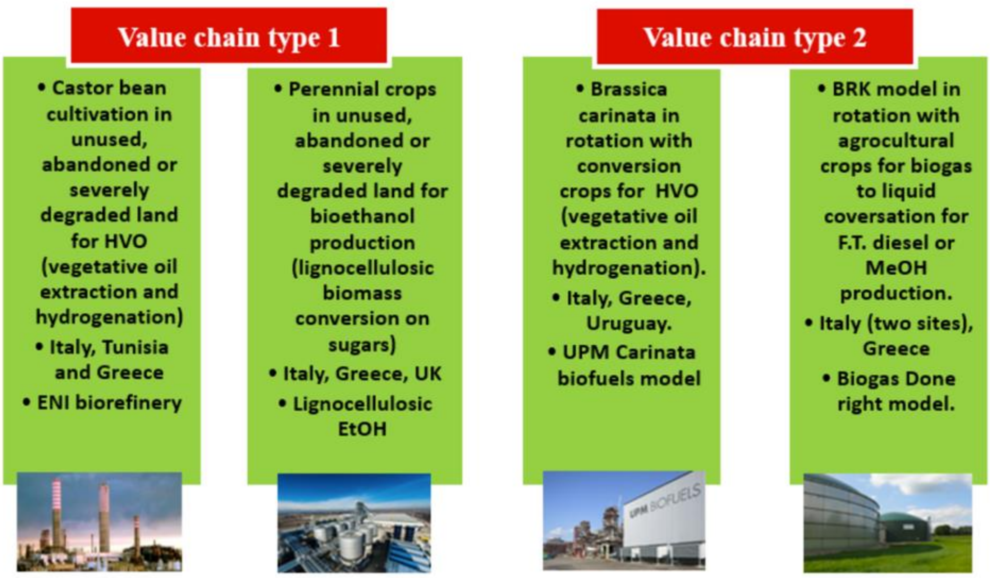
The need for developing new methodologies and tools for assessing the impact of bioenergy at different geographical levels, encouraged FAO to develop a user-friendly and tailored set of sustainability indicators to be used in the context of BIKE Project for measuring the impacts of the advanced bioenergy value chains studied. As shown in Figure 1, this kind of approach, where a tailored set of methodologies and sustainability indicators is being developed, was already applied by FAO in other H2020 projects (FORBIO[3], BIOPLAT-EU[4]), and resulted in a valid tool to comprehensively assess the sustainability of the studied value chains. Clearly the BIKE project has some highly peculiar characteristics which required a restructuring of existing work on the matter to adapt available methodologies and indicators' targets to low-iLUC value chains. The starting point to produce this set of indicators was the most broadly accepted tool for bioenergy sustainability analyses: the GBEP sustainability indicators for bioenergy[5]. Specifically, the set is thought to support the expedite but reliable assessment of advanced biofuels value chain' sustainability at the local, national and EU level. More detailed information concerning the adaptation of the GBEP sustainability indicators to develop the BIKE methodologies is presented in the following chapters.

[3] https://forbio-project.eu/assets/content/publication/D3.3_FINAL_02.07.2018.pdf
[4] https://bioplat.eu/assets/content/Deliverables/D3.1%20-%20Harmonization%20of%20Methodologies.pdf
[5] Available at:
http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioene rgy_FINAL.pdf

1. SECTION 1: DATA COLLECTION AND TAILORED DATA ENTRY EXCEL SPREADSHEETS

The importance of creating an inventory of data for the effective assessment of sustainability is primarily related to the need for defining a comprehensive framework of the four case study value chains considered in BIKE (Figure 1). Through an understanding of the available information from each of the sites, it was possible to establish whether the data collected is sufficient for the degree of accuracy aimed at when assessing the viability of sustainable feedstock production as a pre-feasibility study requires. An efficient and effective data collection and a reliable sharing system, resulting in an exhaustive data inventory, will help those using such data (e.g. universities, governments, local authorities, investors, etc.) to carry out comparable analyses and evaluate several sustainability aspects of these value chains, thus offering a strong and reliable decision making tool to some user categories, as well as a consolidated reference tool for monitoring certification validity of a given farm or value chain. These actors will be mapped and involved throughout the development of the advanced bioenergy value chains focusing on long term monitoring. Participation in the data collection and indicators' design processes also ensured that these outcomes are both practical and understandable, in turn increasing the quality of the results generated.

Figure 1. Case study value chains and sites of the BIKE Project.



1.1 The study setting

As shown in Figure 1, two value chain types: i) cultivation on unused, abandoned or severely degraded land and ii) productivity increases from improved agricultural practices, are considered by the BIKE project.

1.1.1 Bioenergy produced from cultivation of feedstock on unused, abandoned or severely degraded land

These value chains consider potential biomass feedstock that can be cultivated on unused, abandoned or severely degraded land. Particularly, i) additional lignocellulosic ethanol production from perennial/biannual crops feedstocks and ii) HVO production from vegetable oil are considered. The analysis in BIKE considers feedstock production potentials (in tonnes and GJ) in Europe with disaggregation at NUTS3 level both for land types, suitable crops and cropping practices. Potential yield increases are evaluated by following good practice cases.

- Castor oil cultivation in arid/degraded/abandoned land, for HVO production with biochar production for soil improvement;
- Lignocellulosic Ethanol production from perennial/biannual crops

Table 1. Land typologies considered by the BIKE project

Unused land	areas which, for a consecutive period of at least 5 years before the start of cultivation of the feedstock used for the production of biofuels, bioliquids and biomass fuels, were neither used for the cultivation of food and feed crops, other energy crops nor any substantial amount of fodder for grazing animals
abandoned land	unused land, which was used in the past for the cultivation of food and feed crops but where the cultivation of food and feed crops was stopped due to biophysical or socioeconomic constraints;
Severely degraded land	land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded.

1.1.2 Bioenergy produced from crops which have increased yields from improved agricultural practices

These value chains analyse crop options that can have increased yields through improved agricultural practices. "Yield increases that BIKE will examine will be the outcome of improved crop management (sowing, soil preparation, fertilisation, etc.); soil carbon increase with biochar, crop rotation; catch crops, agroforestry, improvements in harvest; precision farming techniques, etc. BIKE will also analyse the following Good Practice cases for feedstock produced crops which have increased yields from improved agricultural practices.

- Brassica carinata cultivation as cover crop for low ILUC biofuel production
- Biogas Done Right model for Biomethane production in decentralized farms, virtually and regulatory integrated with centralized Biomethane-to-liquid conversion plants as F.T. diesel, kerosene, jet or MeOH production

1.2 Reference system and boundaries

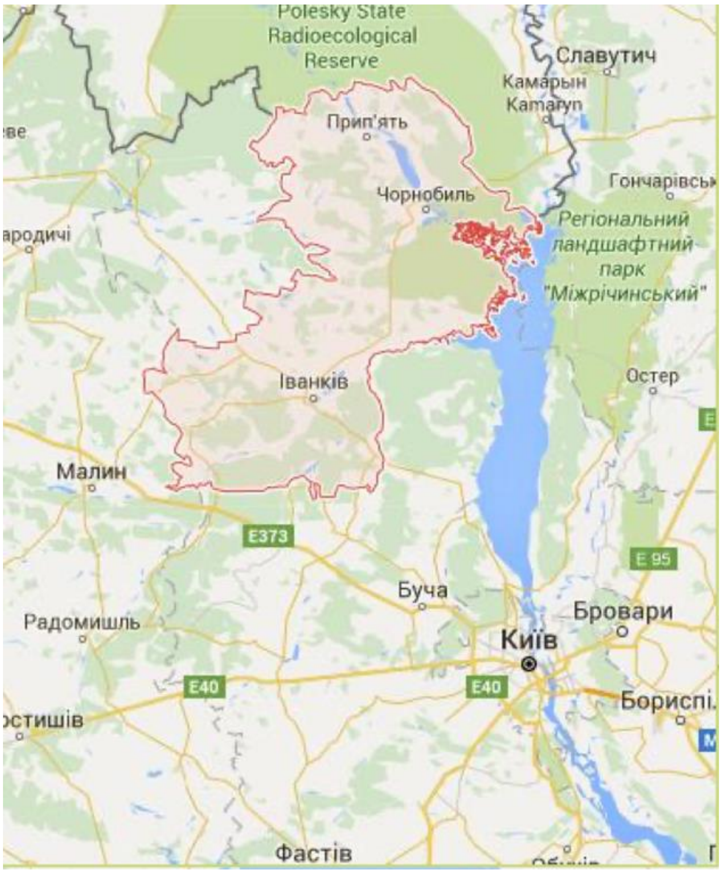
Any assessment, to be meaningful, must be inscribed within a well-defined reference system. A reference system defines a specific map projection, or an area, within which certain transformations take place. The definition and characterization of the extent containing the value chains studied is of paramount 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. In the context of the BIKE project, the approach selected by FAO is based on concepts previously developed for the FORBIO and BIOPLAT-EU projects (RES-28). This approach 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 operations, 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. In the case of a hypothetical production of bioenergy feedstock, the **target area** will be

a) the area of the watershed(s) in which the operation takes place; and/or
b) the area of the municipalities touched upon/interested by the bioenergy production operation; and/or
c) the area as defined by cultural heritage (e.g. regions or zones) that is touched upon/interested by the bioenergy production operation.

The **target area** should be defined and explicitly discussed with local stakeholders to find consensus on its size and coverage, location, and boundaries. However, clearly the concept cannot be reduced to the area of intervention, which is the surface of underutilized land directly interested by the change in use due to bioenergy production (both agricultural and industrial phases), nor extended to the whole region or country when considering single commercial-scale bioenergy value chains.

Figure 2. Example of Target area using administrative division, Ukraine



Source: FORBIO project deliverable

Environmental features require the identification of a specific **target area** likely described by geographically defined borders. In the case of water use and availability, or water pollution for instance, the smallest surface to be considered for the assessment of the impacts of the bioenergy value chain should coincide with the watershed or the watersheds (depending on the geography of the site) interested by the production of bioenergy. When describing social features of a given bioenergy production operation, the definition of the target area is also fundamental to allocate impacts correctly into their context. The sum of the surfaces of the municipalities involved in the bioenergy value chain proposed might, in this case, be most appropriate reference unit. Examples may go on as the possible variables are numerous. Therefore, a clear definition of the borders and locations of the target area is an exercise that must be carried out by local experts, who have a comparable advantage in assessing its extent, by considering all features and implications that the proposed bioenergy production operation might have. Based on FAO's experience with the aforementioned H2020 project, the most suitable compromise to selecting the appropriate **target area** is the administrative boundaries of the municipalities interested by any stationary and unmoveable asset that composes the value chain (e.g. the feedstock production fields; any intermediate storing facility; biomass processing and fuel refining infrastructures, etc.). The practice, therefore, has provided lessons learned on the choice of the reference system based on a mix of available data and representativeness of the approach. Municipality level, or NUTS3 level analyses are most often possible by using centralized data from EUROSTAT or other public data repositories, and therefore are considered the first choice for a reliable and comparable analysis.

1.3 Data entry tool

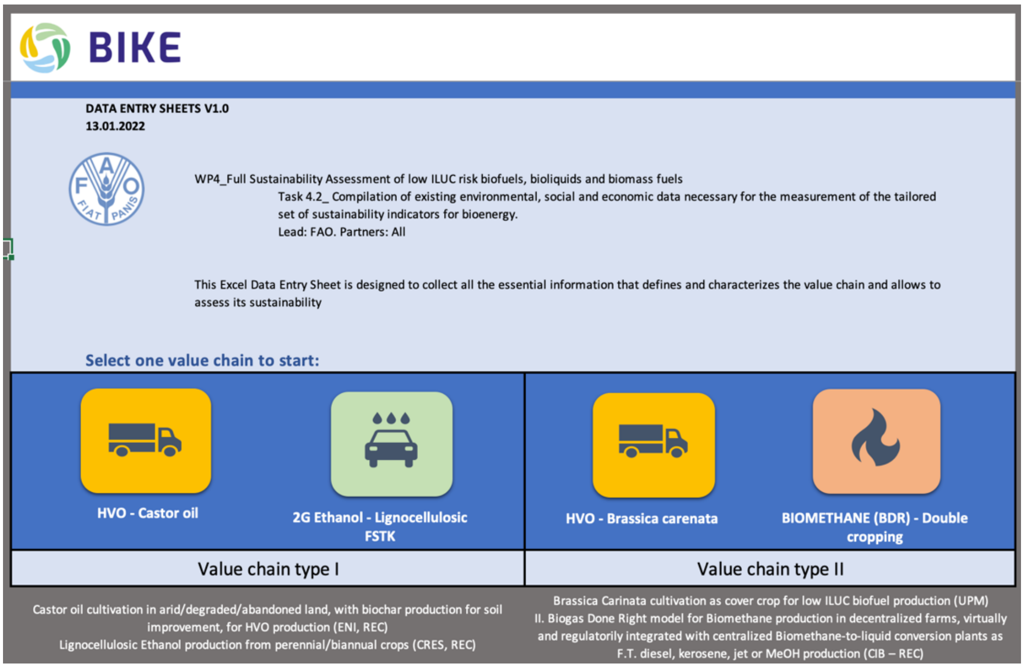
The quality of a sustainability analysis relies on the ability to collect and analyse quantitative and qualitative data. To achieve this, in the context of the BIKE project, it has been essential to define useful research practices and data collection methodologies as well as to understand limitations in data availability.

Accurate data collection begins with planning an efficient method to retrieve the necessary information. A preliminary study should define research questions and determine what measurements are needed to answer them. After several internal consultations, the WP leader (FAO) decided to develop a series of data entry sheets linked with the set of sustainability indicators being developed. The spreadsheets have been developed using Microsoft® Office Excel 2016. The Excel spreadsheets prepared are a user-friendly tool, that BIKE partners and local stakeholders could easily fill out providing the necessary information to measure sustainability indicators. The same data collected through the aforementioned data entry sheets will, at a later stage, serve to assess the impacts of each advanced biofuel value chain studied in their respective target area.

The excel spreadsheet files of the BIKE Data Entry Tool (DET) are used to collect information to assess the environmental, social, and economic sustainability of bioenergy from dedicated crop production. The DET is a single excel sheet, created contemplating the four different BIKE bioenergy pathways, and contains the list of environmental, social, and techno- economic data referred to the assessment of sustainability performances of those specific value chains. As discussed in the previous paragraphs, two value chain typologies for and four different bioenergy pathways are assessed by the BIKE project and therefore considered by the DET. Pathways selection is quickly visualized in the start tab of the spreadsheet via four macro buttons, representing the related bioenergy pathway of interest. For each pathway, the Excel Data Entry provides a series of spread sheets which should be filled out consequentially. Each sheet represents a specific step of the value chain. For each bioenergy pathways the following spreadsheets are provided:

i) Baseline site characterization;
ii) Feedstock production;
iii) Fuel production (or feedstock processing);
iv) Feedstock and fuel transport;
v) Economic and Financial data.

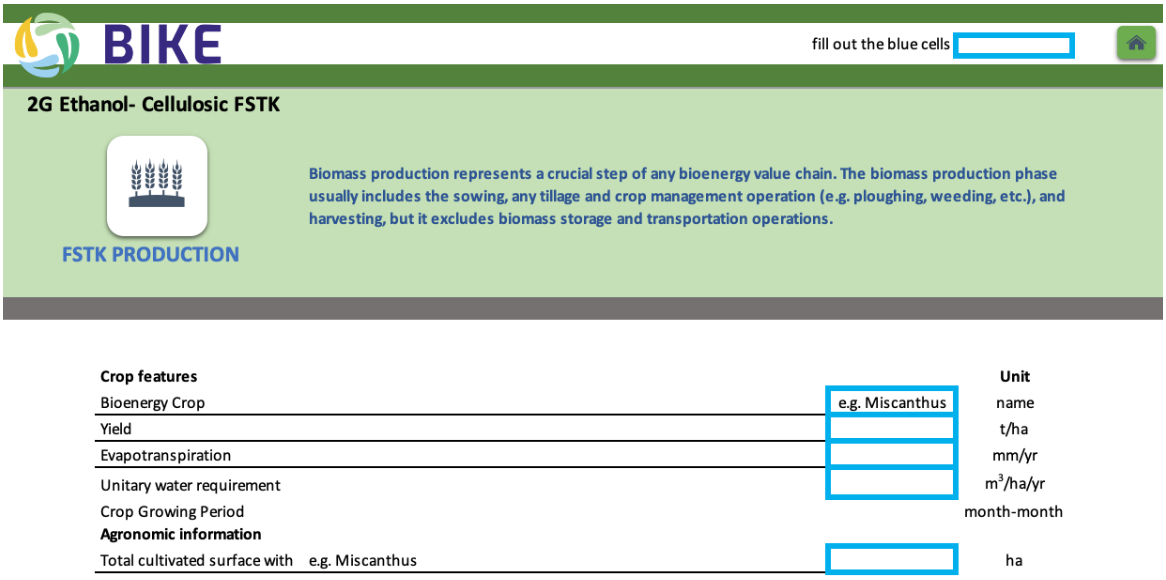
Figure 3. "Start" sheet of the BIKE Data Entry Tool



The first spreadsheet that is provided when a specific pathway selected is the *Baseline site characterization* sheet. This step contains the information required to characterize the studied area (target area) at the baseline situation. The data can be provided only if the system boundaries are previously defined (e.g. municipality level). The information requested mainly involve land characterization, population and employment statistics in the target area and at national level. Data concerning the bioenergy and energy sector are also requested. Figure 6 shows the *Baseline site characterization* sheet for one of the BIKE bioenergy pathways.

The second step (sheet) of the data collection for each pathway is the *feedstock production* spreadsheet. In this step information on crop management characteristics and agronomic operations is requested. Feedstock production is a crucial step in low-iLUC value chains and one where a large share of overall impacts (on several indicators) take place. To understand the feedstock production stage, information on tillage levels, irrigation and chemical input use, is crucial. Moreover, employment, income, and other social impacts also can be measured for a large extent starting from feedstock production stages of the bioenergy value chain.

Figure 4. Example of a section of the feedstock production spreadsheet of the BIKE Data Entry Tool



The third step covers the fuel production phase. The sustainability of a biorefinery depends on the comprehensive utilization of the biomass feedstock and the production inputs. This would only be possible with an optimal mix of processes. Biorefinery processes can be thermochemical, biochemical, chemical, or a combination of them and a multitude of physical processes are involved too (e.g. in the raw material pretreatment or the separation of intermediates and products). Environmental, social and economic aspects are all included under the fuel production step (or feedstock processing) and should be meticulously investigated with particular attention to technology adopted.

The last data collection step concerns operations related to feedstock and fuel transport (also intermediate productions e.g. vegetable oil for HVO production). This information is essential to assess the distances from the feedstock production sites, the processing sites and finally the distribution of bioenergy products. Based on the distances, the characteristics of the infrastructures and the vehicles used to transport the biomass and the fuels, several environmental, social and economic indicators can be measured to assess the sustainability of collecting and delivering biomass and bioenergy products along the value chain.

1.4 Additional literature review

In parallel with the data collected through the DET, a number of secondary data is collected from the literature. This information is useful to integrate the analysis and is also essential to measure the indicators when partners are not able to collect their own data.

2. SECTION 2: DESIGN OF THE TAILORED SET OF SUSTAINABILITY INDICATORS FOR BIOENERGY

The study of the sustainability of advanced bioenergy pathways requires a clear methodology to provide a solid basis for future comparisons and monitoring. To do so, an in-depth analysis of a broad range of existing tools and instruments for the assessment of the sustainability of the bioenergy value chains studied was performed. The result of this analysis led the Consortium to formulate a database of reference tools that should be used, to various extents, and adapted as necessary, to evaluate sustainability performances of the bioenergy value chains identified.

2.1 Internationally recognized sustainability indicators for bioenergy

2.1.1 The GBEP Sustainability indicators

The main and most comprehensive existing tool for the assessment of bioenergy sustainability is the Global Bioenergy Partnership (GBEP) Sustainability Indicators for Bioenergy Report (FAO, 2011). The report was developed by GBEP members from 2008 to 2011. The report presents 24 voluntary sustainability indicators for bioenergy intended to guide any analysis undertaken of bioenergy at the national level with a view to informing decision making and facilitating the sustainable development of bioenergy. In addition, supporting information relating to the relevance, practicality and scientific basis of each indicator, including suggested approaches for their measurement, is presented in a series of methodology sheets accompanying each indicator. The GBEP Indicators were produced by a broad range of national governments and international institutions and they put great emphasis on providing measurements useful for informing national-level policy analysis and development on the basis of performances of the existing bioenergy sector. The GBEP Indicators address all forms of bioenergy but do not feature directions, thresholds or limits and do not constitute a standard. Measured over time, the indicators are intended to show progress towards or away from a sustainable development path as determined nationally. The indicators have been tested in a number of countries at both regional and national level, to evaluate their feasibility and enhance their practicality as a tool for policymaking.

Figure 5. The original set of 24 Sustainability Indicators developed by GBEP (FAO, 2011)

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

2.1.2 The FORBIO and BIOPLAT-EU sustainability indicators

A first adaptation of the GBEP indicators was done in the context of the Horizon 2020 funded project "FOSTERING SUSTAINABLE FEEDSTOCK PRODUCTION FOR ADVANCED BIOFUELS ON UNDERUTILIZED LAND IN EUROPE - FORBIO" (grant agreement No691846). Although the GBEP indicators are meant to describe the sustainability of already existing bioenergy value chains (ex-post) at the national level, for the FORBIO project, the specifications of the analyses to be carried out required the production of scenarios of sustainability of bioenergy value chains that to date have not been developed (ex- ante). 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). In the context of FORBIO, the concept of **target area** has been tested with success. Result meaningfulness has been evaluated at different scales, from target area, to national and even at EU-level. Data collected for the measurement of the sustainability indicators applied in FORBIO was carried out within the consortium via a data entry sheet that proved too cumbersome and complex. Lessons learned from the FORBIO project informed the authors on how to streamline and guide users to collect data and in the context of BIKE culminated in the creation of the DET. From an internal data collection sheet, the DET has evolved into a publicly available aid to collect information in a guided, stepwise manner.

Indicators' methodologies presented in BIKE have also evolved from the first sub-national iteration created in the context of FORBIO and other H2020 projects, but have been adapted to the four low-iLUC value chains detailed in the current project.

2.2 Developing the BIKE sustainability indicators

2.2.1 The indicator selection

The intricate linkages between the multitude of indicators for sustainability may lead to thinking that the quality and representativeness of an assessment exercise is a function of the vastity of the indicators' spectrum. However, data availability and management and above all indicator's practicality are invested with equal, if not higher, responsibility when monitoring relevant key sustainability features of low-iLUC bioenergy production. Indicator's abundance alone would be a misleading measure for assessment's accuracy and thoroughness. With these concepts in mind, pragmatism, practicality and data management were applied over the pool of available trusted sustainability indicators described above to derive the set and related methodologies that allow for a meaningful and resource-efficient assessment of sustainability performances of low-iLUC biofuel value chains.

The indicators from the Global Bioenergy Partnership and the H2020 project FORBIO have been screened to free the final set of indicators from themes that are not applicable to low ILUC pathways in Europe and the other case study sites. For instance, several social GBEP indicators are linked to food security impacts, or health impacts caused by cooking fuels. Since BIKE is not concerned with land competition for food vs fuel production, the former is deemed less-than-relevant, while being BIKE's biofuels value chain predominantly for liquid and gaseous fuels and/or advanced intermediate carriers, the latter does not apply specifically to the context of the case study sites either. In addition to the standard methodologies and indicators selected based on the lessons learned from the application of the GBEP Indicators and the FORBIO project, and linked with the need for the Lifecycle Costing assessment – a concept only briefly touched upon in the original set of GSIs – the selection of indicators for BIKE was inspired predominantly by the economic and financial work carried out in the context of the FORBIO project (on 2G ethanol only, in that occasion) and was decided to dedicate an indicator to the crucial theme of *Investments* to assess the financial sustainability of the low ILUC value chains studied. Expert within the BIKE consortium have been consulted in order to define a tailored methodology which accounts for the needs expressed by relevant stakeholders in each case study and the following methodologies represent the result of these interactions. It is however foreseen that the methodologies prepared will require the contribution of additional data scoping and collection, as well as proxies to make up for possible data gaps that could be discovered once the indicator's measurement commences (Task 4.2 and Task 4.3).

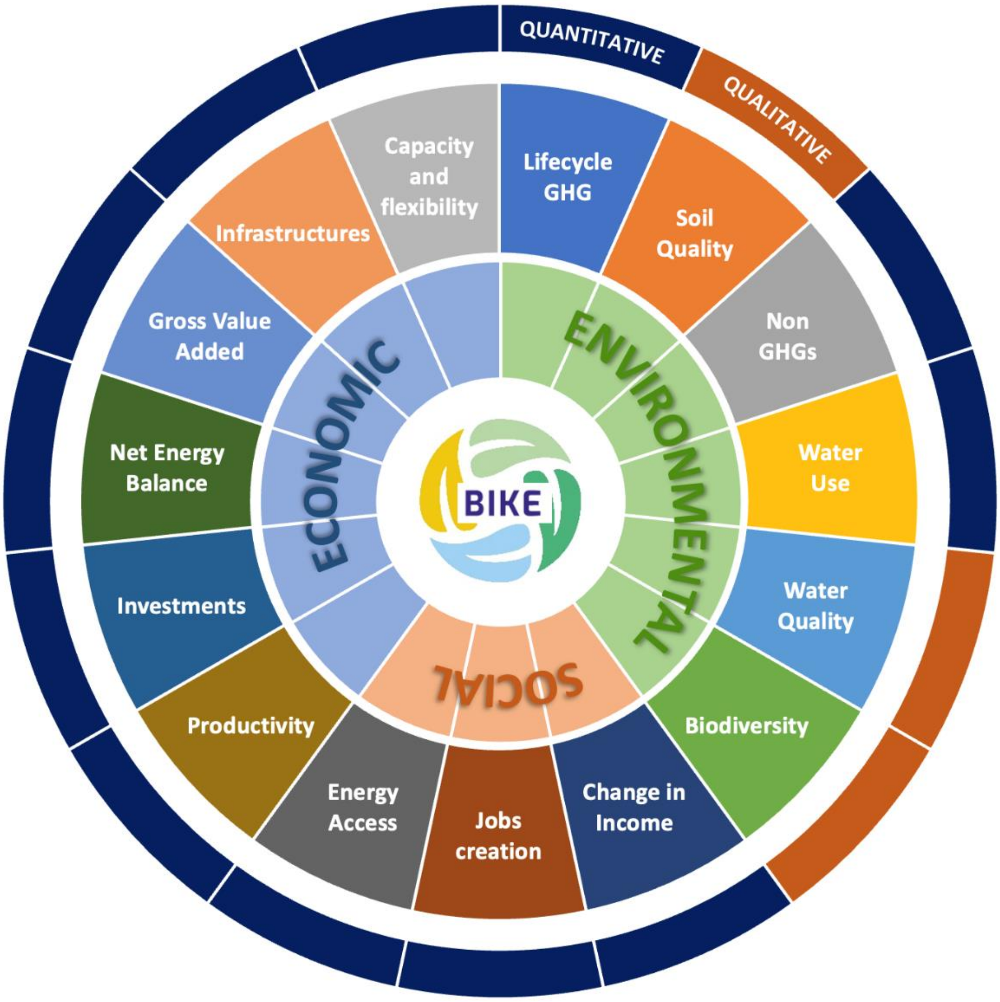
Following the above pre-selection of themes, a distinction between quantitative and qualitative indicators has been established within the set of indicators deemed applicable and relevant. Selected indicators may require complex and extensive datasets. Firstly then, a data scoping exercise required interaction with WP2 partners to pre-assess what data can indeed be expected as a result of the analyses carried out in BIKE, their depth and representativeness. Subsequently, an evaluation of the potential depth of the assessment and its possible accuracy was estimated.

In the case of analyses linked to soil quality, water quality and biodiversity specifically, such information is not readily available with the necessary depth unless primary data collection is carried out and sustained through monitoring over significant timeseries, to return trustworthy quantitative results. To solve this issue and still maintain an acceptable representativeness of the assessment and above all an indication of the direction towards which the management of low ILUC bioenergy value chains is going, qualitative methodologies have been developed ad-hoc for BIKE's qualitative indicators.

2.2.2 The methodologies

Below an overview of the indicators selected for BIKE is presented and individual indicators boxes are listed. The methodology sheets include a description of the indicator, its measurement units, data requirements and a brief explanation of how the data collected follows the rationale for the assessment of each indicator's value.

3. BIKE SUSTAINABILITY INDICATORS



ENVIRONMENTAL	SOCIAL	ECONOMIC & FINANCIAL
Lifecycle GHG	Change in Income	Productivity
Soil Quality	Jobs in Bioenergy Sectors	Investments
Non GHGs	Energy Access	Net Energy Balance
Water Use and Efficiency		Gross Value Added
Water Quality		Infrastructures and logistics for bioenergy distribution
Biodiversity		Capacity and flexibility of use of bioenergy

ENVIRONMENTAL PILLAR

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 BIKE 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	Dynamic soil properties which can be strongly influenced by management and are assessed and monitored in the top 20-30 cm of the soil. Qualitative assessment of potential treats to soil quality including erosion, decline in organic matter, contamination, sealing, compaction and salinization.
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	Water pollution problems related to agriculture are: (i) excess nutrients accumulating in surface and coastal waters that cause eutrophication, hypoxia and algal blooms; (ii) accumulation of nitrates in groundwater; and (iii) pesticides accumulated in groundwater and surface water bodies.
Biodiversity	Area and percentage of the land used for bioenergy production where conservation methods are used

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 BIKE 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 megajoule 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

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

Soil quality	
DESCRIPTION:	Soil quality needs to be defined with respect to the desired function. Soil functions may vary from biological, ecosystem or productive functions, and what define a soil having high ecosystemic quality might not equal to high productivity functions for the same soil. To avoid confusion then, the concept of soil quality set forth in this report is linked to soil use rather than soil functions, and in BIKE soil is primarily used to produce bioenergy crops. This definition is crucial otherwise assessing quality performances of this medium could be misleading. Other indicators in this report (e.g. water use and availability, biodiversity conservation, etc.) address potentially related but different functions (e.g. ecosystem functions, etc.). This indicator thus aims at measuring dynamic soil properties which can be strongly influenced by management practices. This will lead to the qualitative assessment of potential treats to soil quality including erosion, decline in organic matter, contamination, sealing, compaction, and salinization which may affect bioenergy crop productivity.
MEASUREMENT UNIT(S):	**Relative impact of treats to productivity potential of soils.**
METHODOLOGICAL APPROACH:	Firstly, it might be useful to define a baseline value for the state of soil quality. This could require the collection of quantitative data, at least once, whereas management practices' influence on soil properties and thus behaviour, is based on literature and forecast models. The effects of said practices are assessed and monitored in the top 30 cm of the soil to establish a qualitative assessment of impacts of bioenergy feedstock production on soil quality. Where possible, quantitative assessments of the following minimum soil characteristics should be performed: Soil Organic Carbon content (SOC); pH; N-P-K availability; bulk density; electrical conductivity. When quantitative data cannot be collected, the indicator is purely qualitative and based on the presence and frequency of specific management practices. However, quantitative indicators of soil quality are site specific, require long timeseries for monitoring, and accurate evaluation and skills. A qualitative assessment could provide the necessary set of conditions conducive to maintained or improved soil quality characteristics. The qualitative assessment of the number and specificity of the practices employed in the management of soils is used to provide an indication of potential benefits or challenges to soil quality in a given case study. The occurrence and frequency of traditional vs improved soil management practices is evaluated with a scorecard method. Different practices have different scores, as operations like mechanized plowing and tilling are found to higher detrimental effects than other practices (e.g. monocropping) on soil quality. The mix of various practices will lead to a qualitative indication of risk level for soil quality maintenance.
DATA REQUIREMENTS:	**Presence and frequency of the best management practices:** 1) organic matter addition (e.g. manure addition, biochar, etc.); value: 1 2) no-tillage, minimum tillage, reduced tillage; value: 3 3) crop rotation (incl. or excl. fallow, intercropping, etc.); value: 1 4) continuous cover crop; value: 1 5) organic agriculture (incl. IPM, INM, biological pest control, etc.); value: 2 6) windbreaks, shelterbelts, etc.; value: 1 7) biofertilizer and living organisms management; value: 1 **Occurrence and frequency of traditional soil management practices:** 1) mechanized land preparation; value -1 2) deep and surface tillage (incl. moldboard plow, ripper, etc.); value: -3

3) use and rates of synthesis fertilizers; value: -1
4) irrigation rates and irrigation systems (e.g. flooding, sprinklers, etc.); value: -1
5) monocropping (annual crops only); value: -1

REFERENCES

- **Bai *et al,* 2018. Effects of agricultural management practices on soil quality: A review of long-term experiments for Europe and China**
- **Bünemann *et al, 2016*. Concepts and indicators of soil quality – a review. iSQAPER-project.eu Ref. Ares(2016)6570044 - 23/11/**
- **Adeyolanu and Ogunkunle, 2016. Comparison of qualitative and quantitative approaches to soil quality assessment for agricultural purposes in South-western Nigeria.**
- **FAO. 2021. Keep soil alive, protect soil biodiversity. Global symposium on soil biodiversity, 19–22 April 2021 – Outcome document. Rome, Italy**
- **FAO and ITPS. 2021. Recarbonizing Global Soils - A technical manual of recommended sustainable soil management. Volume 3: Cropland, Grassland, Integrated systems, and farming approaches - Practices Overview. Rome.**

Emission of non-GHG air pollutants	
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_x, PM_{10}, NO_X, SO_x 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. 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. This indicator measures all emissions of air pollutants produced at each level of the processing chain via a Lifecycle Assessment, along the lines with the GHG methodology and following the identical stepwise approach to reconstruct emission sources along the value chain. The use of agricultural equipment in bioenergy feedstock production, the emissions of non-GHG air pollutants due to bioenergy feedstock processing, the transportation of bioenergy, and the energy use are measured. Particularly, 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.
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.

REFERENCES

- Dutch Pollutant Release and Transfer Register 2014. Methods for calculating the emissions of transport in the Netherlands.
- EP 2014. Directorate-general for Internal Policies. Measures at farm level to reduce greenhouse gas emissions from EU agriculture.
- EP 2015. Directorate-general for Internal Policies. The impact of biofuels on transport and the environment, and their connection with agricultural development in Europe.
- FAO 2011. The Global Bioenergy Partnership (GBEP) Sustainability Indicators for Bioenergy. First edition.
- FAO 2014a. Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia.

- FAO 2014b. Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia.

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 and 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 to produce 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: % of TARWR = ($W_{bioenergy\_ren}$/TARWR) x 100% % of TAWW = ($W_{bioenergy}$/TAWW) x 100%, TAWW is the total annual water withdrawals, which is calculated from all human water uses including industrial, agricultural, and domestic. TARWR and TAWW are not always available at target area or watershed level. Therefore, some guidance on how to derive a value at **target area** level should be provided There are several ways, the most accurate but also resource-intensive to be mentioned is modeling with GIS and hydraulic dynamic models; also, simpler – yet less-accurate ways – include inferring at target area level statistics at regional or province level; i.e. if statistics on TARWR are available at the closest subnational level (e.g. at Regional or Province level), a likely estimation of the amount of water withdrawn at target area level will be obtained by dividing the value at Regional or (better if) Province level by the population of the Province and then infer it with a simple ratio equation to target area level. E.G. TARWR of Province A = 1,000,000 m^3/year Population Province A = 300,000 people Population target area = 10,000 people TARWR of target area = 33,333 m^3/year
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); Type of water (blue or grey). Energy Output: Bioenergy production (t/year); LHV (GJ/t).

REFERENCES

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

Water quality	
DESCRIPTION:	Water pollution problems related to agriculture are: (i) excess nutrients accumulating in surface and coastal waters that cause eutrophication, hypoxia and algal blooms; (ii) accumulation of nitrates in groundwater; and (iii) pesticides accumulated in groundwater and surface water bodies. The qualitative assessment of the practices employed in the production of bioenergy is used to provide an indication of potential benefits or challenges to quality of the waters in the target area. The occurrence and frequency of traditional vs improved management practices with a direct impact on water quality is evaluated with a scorecard method. Different practices have different scores, as operations like nutrient application, pesticides use, lack of wastewater treatment plants at the biorefinery site, are found to have higher detrimental effects than other practices (e.g. organic fertilizer use) on water quality. The mix of various practices will lead to a qualitative indication of risk level for soil quality maintenance.
MEASUREMENT UNIT(S):	Rate of adoption
METHODOLOGICAL APPROACH:	Firstly, it might be useful to define a baseline value for the state of water quality. This could require the collection of quantitative data, at least once, to verify the presence of undesirable substances in the quantities which are harmful to people and vegetation. Where possible, quantitative assessments of the following water characteristics should be performed: *Toxic metals (e.g. Copper, Lead, Cadmium etc.); Organic, inorganic, nutrients, chemicals (e.g. Nitrate, sulfur, pesticides, etc.).* When quantitative data cannot be collected, the indicator is purely qualitative and based on the presence and frequency of specific agricultural and industrial management practices which preserve the quality of surface water as well as groundwater. However, quantitative indicators of water quality are site specific and require financial resources for monitoring. A qualitative assessment could provide the necessary set of conditions conducive to maintained or improved water quality characteristics. The qualitative assessment of the number and specificity of the practices employed in the agricultural activities (e.g. irrigation, fertilization, etc.) is used to provide an indication of potential benefits or challenges to surface water and groundwater quality in a given case study. The occurrence and frequency of traditional vs improved agricultural management practices is evaluated with a scorecard method. Different practices have different scores, as practices like high input management or sprinkler irrigation are found to higher detrimental effects than other practices (e.g. drip irrigation or integrated pest management) on water quality. The mix of various practices will lead to a qualitative indication of risk level for water quality maintenance in a given case study area.
DATA REQUIREMENTS:	**Presence and frequency of the best management practices:** **Conservation Tillage** - leaving crop residue (plant materials from past harvests) on the soil surface reduces runoff and soil erosion, conserves soil moisture, helps keep nutrients and pesticides on the field, and improves soil, water, and air quality; Value: 1 **Crop Nutrient Management** - fully managing and accounting for all nutrient inputs helps ensure nutrients are available to meet crop needs while reducing nutrient movements off fields. It also helps prevent excessive buildup in soils and helps protect air quality; Value: 3

	Integrated Pest Management - varied methods for keeping insects, weeds, disease, and other pests below economically harmful levels while protecting soil, water, and air quality; Value: 3 **Conservation Buffers** - from simple grassed waterways to riparian areas, buffers provide an additional barrier of protection by capturing potential pollutants that might otherwise move into surface waters. Irrigation Water Management - reducing nonpoint source pollution of ground and surface waters caused by irrigation systems; **Erosion and Sediment Control** - conserving soil and reducing the mass of sediment reaching a water body, protecting both agricultural land and water quality and habitat. Value: 1 **Wastewater treatment of bioenergy processing** – Wastewater from bioenergy processing (e.g. ethanol or biogas production) can present toxic compounds which require specific treatment measures. No pre-treatment, biological = + 2; Pre-treatment + UV + microfiltration = +3

REFERENCES

- FAO, SOLAW Background Thematic Report-TR08_Agriculture and water quality interactions: a global overview

Biodiversity	
DESCRIPTION:	Area and percentage of the land used for bioenergy production where conservation methods are used
MEASUREMENT UNIT(S):	ha; km2; percentage; percentage of land used for Absolute areas in hectares or km2 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 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 are provided below, additional ones may be available at the national level and could be included if accurately referenced. 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 (agricultural best management practices) are identified. The qualitative assessment of the number and specificity of the conservation practices employed in the agricultural activities (e.g. rotations, light tillage, etc.) is used to provide an indication of potential benefits or challenges to biodiversity preservation in a given case study. The occurrence and frequency of biodiversity conservation management practices is evaluated with a scorecard method. This is explained, as practices like high mechanisation or-and chemical management are found to higher detrimental effects than other practices (e.g. low tillage or low input management) on biodiversity preservation. The mix of various practices will lead to a qualitative indication of risk level for biodiversity maintenance in a given case study area.
DATA REQUIREMENTS:	**Presence and frequency of the best management practices:** – Use of traditional rotations (score: 3) – Light tillage operations (score: 3) – Guarantee soil cover all year round (score: 3) – No scrub removal (score: 2) – Low chemical inputs (score: 3) – Use 1 ha every 100 ha for planting legumes/cereals for wildlife (score: 2) – Avoid open field burning of residues (score: 1) – Avoid irrigation (score: 1) – Avoid overgrazing (score: 2)

	– Report and protect nest (score: 1) – Ensure that species are not collected (score: 1)

REFERENCES

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SOCIAL PILLAR

Indicator name	Indicator description
Income generation	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/individuals
Job creation	Net job creation as result of bioenergy production and use, total
Energy Access	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

Income generation	
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)
METHODOLOGICAL APPROACH:	This indicator applies equally to the income from direct and indirect employment in the bioenergy sector. 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.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **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 d. Biofuel transport

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

Job creation	
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 of jobs, number of jobs per MJ or MW of bioenergy produced, and percentage and as a percentage of (working-age) population
METHODOLOGICAL APPROACH:	The indicator includes measurement of the total workforce in the bioenergy sector, which can be obtained by industry surveys: the experience gained by bioenergy technology 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 BIKE. It is suggested to express this data as simple total and as an employment-to-population[6] ratio or percentage for the sector.
DATA REQUIREMENTS:	**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 **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.

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

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

Energy Access	
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 bioenergy production is assessed considering the direct impact, on the target 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 represented by biofuel production that enters the national fuel market, and/or by bioenergy plants' electricity surplus obtained from co- and by-products. - EU level: at this level, the advanced biofuels productions will wholly be accounted against an increment to the share of EU modern bioenergy access.
DATA REQUIREMENTS:	**A - BASELINE SCENARIO** **Current amount of modern energy access disaggregated by:** - Amounts of: electricity for all uses; Energy and fuels for all residential uses, including district heating systems; liquid biofuels for transport; gaseous biofuels; and - Number (and percentage) of households and businesses benefitting from energy generated through or as a result of bioenergy value chains (considered as modern bioenergy access) at regional, national and local level **B - TARGET SCENARIO** **Additional amount of modern energy access disaggregated by:** - Amounts of: electricity generated and provided to the grid from bioenergy production; liquid biofuel for transport; gaseous biofuels fuels; Thermal energy generated from biofuels production (district heating and cooling); and - Number (and percentage) of households and businesses benefitting from energy generated through or as a result of bioenergy value chains

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

ECONOMIC & FINANCIAL PILLAR

Indicator name	Indicator description
Productivity	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
Investments	Financial Net Present Value of selected investments in bioenergy
Net Energy Balance	The net energy ratio (i.e. ratio of energy output to total energy input) as useful indicator of the relative energy efficiency of a given pathway of bioenergy production and use.
Gross Value Added	Gross value added per unit of bioenergy produced and as a percentage of gross domestic product
Infrastructures and logistics for bioenergy distribution	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 biofuels compared with actual use for each significant utilization route

Productivity	
DESCRIPTION:	This indicator covers bioenergy 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:	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).
DATA REQUIREMENTS:	**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** **Local feedstock production costs per unit of feedstock** Production costs may vary greatly because 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 feedstocks 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. **Processing efficiencies of bioenergy feedstock into end products** Processing efficiencies of bioenergy feedstocks need to capture the transformation of feedstocks into advanced biofuels by technology and by feedstock; in general, this type of information can be confidential as strictly related to private sector's competitiveness. This limitation is to be taken into account, and in case this information should be derived from literature research as well as from direct communication with the technology provider in the case of lignocellulosic ethanol production, HVO or BDR.

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

Investments	
DESCRIPTION:	The indicator covers investments in fuel production at all level of the value chain. A financial analysis, where a standard cost benefit analysis (CBA) approach is applied to demonstrate net profits. This analysis is to compute the investment's financial performance indicators and is carried out in order to: – Assess the consolidated investment's profitability, With Project (WP) vs Without Project (WoP) scenarios; – Assess the profitability for the investor(s); – Outline the cash flows which support the calculation of the socio-economic costs and benefits.
MEASUREMENT UNIT(S):	Costs and benefits in € of producing feedstock and fuel and their related transport along the value chain
METHODOLOGICAL APPROACH:	A financial analysis is calculated, where a standard cost benefit analysis (CBA) approach is applied to demonstrate net profits. Determination of investment revenues and expenditures enables the assessment of the project profitability, which is measured by financial net present value (FNPV) and financial internal rate of return (FIRR) on investment. At the baseline level, a without project scenario (reference scenario) is calculated to be compared with the with project scenario (WP) to calculate the final incremental scenario. $$\boldsymbol{FNPV} = \sum_{t=0}^{n} \boldsymbol{a_t S_t} = \frac{\boldsymbol{S_0}}{(\boldsymbol{1}+\boldsymbol{i})^{\boldsymbol{0}}} + \frac{\boldsymbol{S_1}}{(\boldsymbol{1}+\boldsymbol{i})^{\boldsymbol{1}}} + \cdots + \frac{\boldsymbol{S_n}}{(\boldsymbol{1}+\boldsymbol{i})^{\boldsymbol{n}}}$$ While the FIRR is given by the following equation: $$\boldsymbol{0} = \sum \frac{\boldsymbol{S_t}}{(\boldsymbol{1}+\boldsymbol{FIRR})^{\boldsymbol{t}}}$$ Where: **S:** *annual financial net benefit* **t:** *time* **a$_t$:** *financial discount factor* **i:** *financial discount rate*
DATA REQUIREMENTS:	**A - BASELINE SCENARIO** Net annual benefits at all levels of the value chain **B - TARGET SCENARIO** Costs and revenues analysis at: – Agriculture production level (farm gate) – Fuel production level (plant gate) – Transportation (both feedstock and fuel)
REFERENCE	

- Commission. ***Guide to Cost-Benefit Analysis of Investment Projects: Economic Appraisal Tool for Cohesion Policy 2014–2020***; **Publications Office of the European Union: Luxembourg, 2014; ISBN 9789279347962.**
- **Boardman, A.E.; Greenberg, D.H.; Vining, A.R.; Welmer, D.L.** ***Cost-Benefit Analysis. Concepts and Practice***; **Cambridge University Press: Cambridge, UK, 2014; ISBN 13: 978-1-292-02191-1.**

<table>
<tr><th colspan="2">Net Energy Balance</th></tr>
<tr><td>DESCRIPTION:</td><td>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). 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</td></tr>
<tr><td>MEASUREMENT UNIT(S):</td><td>Ratio</td></tr>
<tr><td>METHODOLOGICAL APPROACH:</td><td>The indicator can consist of a single value corresponding to the lifecycle energy ratio of the chain considered and/or a set of values for each step of the chain, including the efficiency of the feedstock production, processing and end-use of biofuels, etc.
The energy output is calculated by assessing the bioenergy use under consideration. The energy input is estimated by summing all energy required at each stage of bioenergy production and use using available data, and models if needed. If bioenergy feedstock production is integrated with other non-energy productions (e.g. intercropping) this value should be adjusted accordingly. Feedstock energy content is currently characterized by the assumed conversion value for the material within each primary biofuel
product pathway. Energy impacts of feedstock losses throughout supply and conversion are subsequently accounted for in this way.</td></tr>
<tr><td>DATA REQUIREMENTS:</td><td><u>BASELINE AND TARGET SCENARIO</u>
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 materials and inputs) 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);
f. Energy content of the bioenergy source considered (MJ);</td></tr>
<tr><th colspan="2">REFERENCES</th></tr>
<tr><td colspan="2">– FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011</td></tr>
</table>

Gross Value Added	
DESCRIPTION:	The Gross Value Added (GVA) per unit of bioenergy produced and as a percentage of gross domestic product. 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. This indicator will also inform the theme of economic viability and competitiveness of bioenergy.
MEASUREMENT UNIT(S):	EUR/MJ and percentage
METHODOLOGICAL APPROACH:	GVA is calculated as the difference between the value of goods and services that have been produced, subtracted of the cost of all inputs and raw materials that are directly attributable to that production. Gross value added = Total output value - Intermediate inputs GVA = (Sales + Income from other services) - cost of raw materials - cost of production - cost of services availed from outside suppliers
DATA REQUIREMENTS:	**A - BASELINE SCENARIO** - Current GDP in the ***target area*** **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)
REFERENCES	
– FAO (GBEP). The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First edition. 2011	

Infrastructures and logistics for Bioenergy Distribution	
DESCRIPTION:	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each. 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 BIKE, these positive impacts on sustainable development can be measured by identifying new infrastructure facilities attributable to low-ILUC bioenergy production, distribution and use, which can be also employed for other scopes (e.g. roads, railroads, etc.).
MEASUREMENT UNIT(S):	Number; MJ, m^3, or tonnes per year; or MW for heat and power capacity percentages
METHODOLOGICAL APPROACH:	– Map distribution and logistics features of the ***target area using Google OSM;*** – Identify critical distribution systems for bioenergy feedstocks, fuels and electricity production and distribution systems; – Determine the capacity and transport duration values for each of the identified distribution systems ***using Google OSM***; 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:	**A - BASELINE SCENARIO** – Annotated[7] GIS maps of the road, railroad and port systems within the target area from ***Google OSM***; – number of port facilities capable of exporting low-ILUC bioenergy feedstock, intermediate or final products, – capacity for handling/storage of low-ILUC bioenergy feedstock, intermediate or final products, – capacity and reliability of blending facilities and terminals; **B - TARGET SCENARIO** – number of port facilities capable of exporting low-ILUC bioenergy feedstock, intermediate or final products,, compared with level of bioenergy products produced after the project implementation; – capacity for handling/storage of low-ILUC bioenergy feedstock, intermediate or final products compared with actual level of bioenergy products produced after the project implementation; – capacity and reliability of blending facilities and terminals;
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

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

Capacity and Flexibility of Use of Bioenergy	
DESCRIPTION:	Ratio of capacity for using advanced biofuels compared with actual use for each significant utilization route; 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.
MEASUREMENT UNIT(S):	Ratio and change in percentage
METHODOLOGICAL APPROACH:	The approach to measure this indicator will require the calculation of the current capacity and the current use of bioenergy in a given reference area and the assessment of what share of this capacity will be fulfilled by the additional bioenergy produced by the project. In the case of liquid biofuels for transport, the current capacity is represented by the blending wall for using biofuels in the fuel mix, for drop in-fuels, this capacity is the total amount of fuel used in the reference area (e.g. national diesel fuel consumption in a reference year). In case the bioenergy product studied is electricity, as in the case of drop-in fuels, the capacity of the reference area to substitute the traditional product with the renewable alternative is 100%.
DATA REQUIREMENTS:	**Detailed data requirements will include information about:** **A - BASELINE SCENARIO** - Current capacity and current use of biofuels - Current biofuel blend - Size of the fleet (for biofuels for transport) **B - TARGET SCENARIO** Calculated additional availability, capacity, and use of biofuels

REFERENCES

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

4. CONCLUSIONS

The set of indicators developed in the context of BIKE includes methodologies for the 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.

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

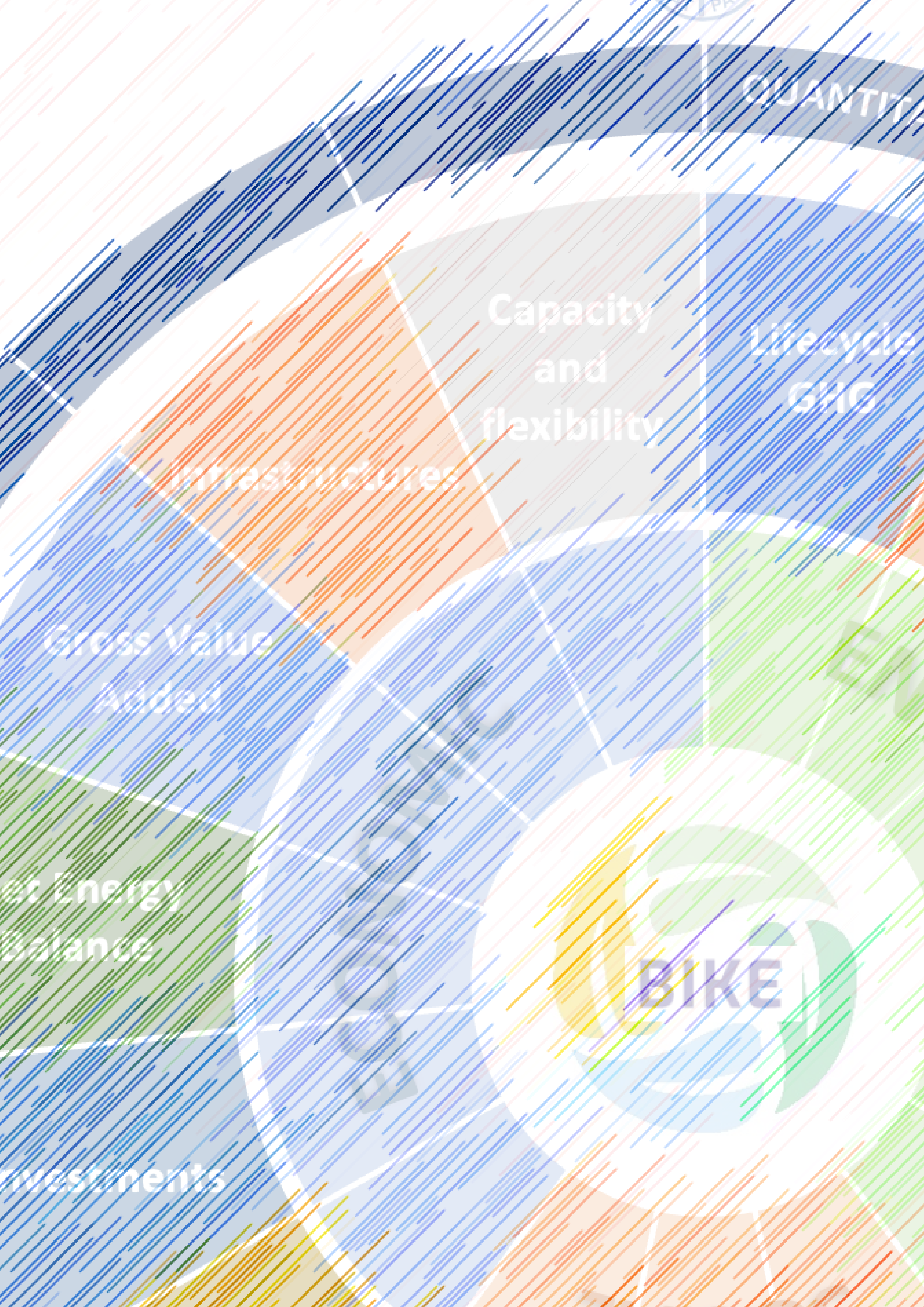
1) The assessment of BASELINE situation in the ***target areas*** studies for most indicators will provide a detailed overview of the sustainability conditions found in the sites studied;

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 D4.2. 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.

It is expected that such a comprehensive approach allows the broadest number of stakeholders to take on Deliverable D 4.1 and 4.2 even for future use outside of the extent of the BIKE 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 BIKE.



Capacity and flexibility
Lifecycle GHG
Infrastructures
Gross Value Added
BIKE