Promoting sustainable use of underutilized lands for bioenergy production through a web-based Platform for Europe

# D1.4

# Result oriented report

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## Table of Contents

# 1 Introduction

Bioenergy represents the highest share of renewable energies consumed in the European Union[1] and is still expected to grow. It plays an important role in reaching the European climate targets and supporting the UN Sustainable Development Goals (SDGs) in the context of climate change and energy security and implementing the Paris Agreement on climate change. In the special report of the IPCC on the impacts of global warming of 1.5°C, it was mentioned that bioenergy use is substantial due to its multiple roles in decarbonising energy, but only if it is well managed with no significant impact on agricultural and food systems, biodiversity, and other ecosystem functions and services[2]. The main concerns are food security, land use, and land use change risks on carbon emission increase or biodiversity reduction from bioenergy expansion, and challenges in achieving economic competitiveness and providing high quality and affordable energy services. Therefore, sustainability of bioenergy, which takes into consideration these issues, is a key element in order to comply with the aforementioned goals and to be socially accepted.

Measuring sustainability in its economic, environmental, and social aspects is a complex exercise, which needs a lot of data and know-how for its implementation. The Global Bioenergy Partnership (GBEP) has developed 24 indicators of sustainability regarding the production and use of modern bioenergy. However, these 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.

Several measures can support sustainable bioenergy expansion, one of which is the use of Marginal, Underutilised, and Contaminated lands (MUC) for biomass production. These are lands that are generally no longer suitable for food/feed production or for recreational and conservation purposes. However, in some cases, they retain the potential to produce a biomass feedstock suitable for bioenergy production. Furthermore, the use of these lands for biomass production could have positive environmental and socio-economic benefits such as restoring soil productivity, increasing biodiversity, promoting rural economic development, and increasing household income.

In an attempt to expand the production of sustainable biomass and bioenergy, the BIOPLAT-EU project developed a web-based platform in which a webGIS tool is embedded. This tool visualises MUC lands in an interactive map and assesses a set of environmental, social, and economic sustainability indicators of selected bioenergy value chains in an automated and easy way that can be performed online by any stakeholder without the need for extensive research, expertise, and funding. The objective of the project is therefore to promote the market uptake of sustainable bioenergy in Europe using MUC lands for biomass production through the web-based platform that gives first insights on the viability and sustainability performances of the selected value chain and serves as a support tool for decision-making.

1 EC. Brief on Biomass for Energy in the European Union. Available online: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC109354/biomass_4_energy_brief_online_1.pdf
2 IPCC. Global Warming of 1.5 °C. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

# 2 Main activities and results

In order to achieve the goal of the project and to help removing market uptake barriers of bioenergy production projects including mainly technical, financial, and legal barriers, a series of activities was implemented.

## 2.1 Development of the BIOPLAT-EU web-based platform

The BIOPLAT-EU platform acts as a hub for information and supports stakeholders in the evaluation and sustainability assessment of bioenergy value chains. It is mainly composed of two parts (Figure 1), the first one including information about the project and integrating a helpdesk function, which allows stakeholders to address questions to the consortium experts (Figure 2). The second part is composed of the webGIS tool, which combines a database on MUC lands (maps) in the EU and selected neighbouring countries with the Sustainability Tool for Europe and Neighbouring countries (STEN) (Figure 4). The maps are developed based on various existing data sets as well as remote sensing-based mapping approaches employing satellite image time series from the Copernicus Sentinel-2 and Landsat 8 missions. The STEN tool assesses the social, environmental, and techno-economic sustainability aspects of defined bioenergy value chains on MUC lands.

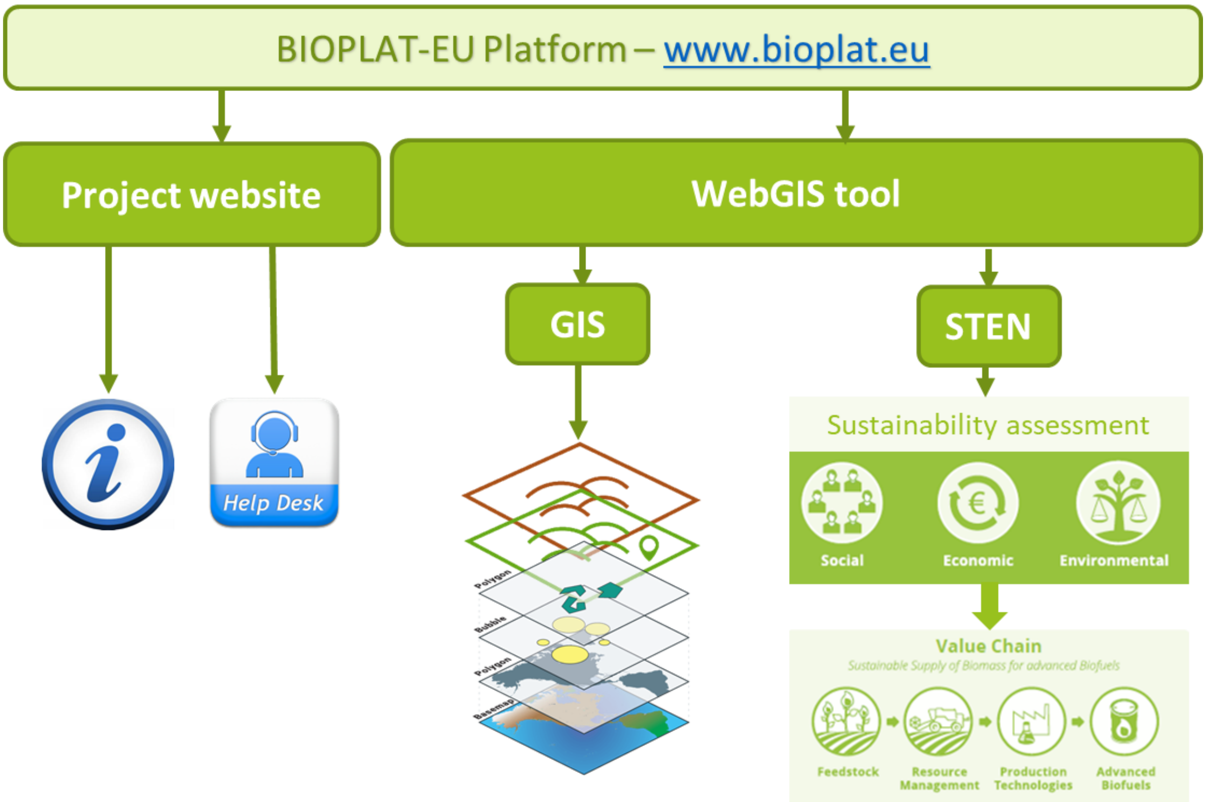


*Figure 1: Graphical design of the BIOPLAT-EU platform*

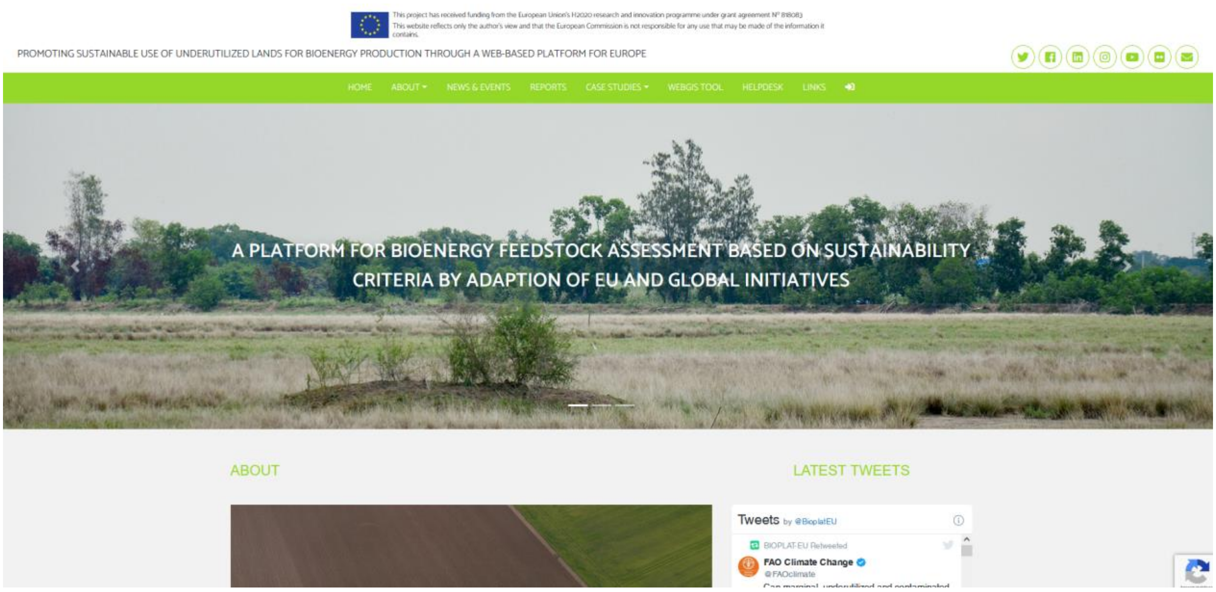


*Figure 2: The BIOPLAT-EU platform accessed at https://bioplat.eu/*

### 2.1.1 Mapping of MUC lands

The overall objective of this activity was the compilation of a geospatial database of MUC lands in Europe offering potential for bioenergy feedstock production, which is needed for the webGIS tool and its functionalities. Two types of maps were produced: first, a European-wide map of MUC lands (TIER-1 map) and secondly, regional maps for twelve case study areas (TIER-2 maps) in Germany, Hungary, Italy, Romania, Spain and Ukraine.

The first step was a comprehensive review of data provided by the COPERNICUS programme of the European Space Agency as well as other existing freely available geospatial data and an analysis of their usability within the project. The results of this review are available in D2.1.

For the identification of **underutilized land**, which are often marginal lands, the envisaged wall-to-wall, continental-wide coverage detection can only be achieved at reasonable effort by remote sensing approaches. Previous studies using Earth Observation data have shown, that underutilized land has a different spectral reflectance behaviour over time compared to utilized land due to missing human interventions[3,4,5]. Typical human interventions are mowing and ploughing, which result in clear changes in the spectral reflectance of the respective patch of land. It was shown that underutilized land usually shows different magnitudes and standard deviations of changes over time than utilized land due to missing above-mentioned interventions.

For the remote sensing-based differentiation between utilized and underutilized land, training data for both classes are needed. This training data was compiled in two ways: first, existing

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3 Alcantara, C.; Kuemmerle, T.; Baumann, M.; Bragina, E.V.; Griffiths, P.; Hostert, P.; Knorn, J.; Müller, D.; Prishchepov, A.V.; Schierhorn, F.; et al. Mapping the Extent of Abandoned Farmland in Central and Eastern Europe Using MODIS Time Series Satellite Data. Environ. Res. Lett. 2013, 8, 035035, doi:10.1088/1748-9326/8/3/035035.

4 Estel, S.; Kuemmerle, T.; Alcántara, C.; Levers, C.; Prishchepov, A.; Hostert, P. Mapping Farmland Abandonment and Recultivation across Europe Using MODIS NDVI Time Series. Remote Sens. Environ. 2015, 163, 312–325, doi:10.1016/j.rse.2015.03.028.

5 Estel, S.; Kuemmerle, T.; Levers, C.; Baumann, M.; Hostert, P. Mapping Cropland-Use Intensity across Europe Using MODIS NDVI Time Series. Environ. Res. Lett. 2016, 11, 024015, doi:10.1088/1748-9326/11/2/024015.

data on known underutilized lands were acquired through an outreach to governments as well as, public and private stakeholders. For this task, an online platform was developed, where existing data could be uploaded or digitized manually. Secondly, certain LUCAS point data that can serve as indicator for underutilized land (class U410 "Abandoned Areas" and class U420 "Semi-Natural and Natural Areas not in Use") were extracted for visual interpretation. The points were visually checked and converted into polygon information, if the areas proved to be underutilized for the past five years according to very high-resolution time series data available in Google Earth. Training data for the utilized land category was derived from existing Copernicus products.

For the generation of the European-wide TIER-1 map, Landsat 8 (L8) for from 2014 – 2019, with a spatial resolution of 30x30 m, was used to fulfil the five-year requirement and complemented by 10 m resolution Sentinel-2 (S2) data from 2018 and 2019. The analysis was carried out in a stratified manner by biogeographical region and country using Google Earth Engine (GEE), an online cloud-based processing engine for geospatial analyses, available free of charge for research projects. The separate assessment for each biogeographical region (BGR) is needed, as underutilized lands show significantly different properties depending on their climatic, elevation and soil properties. Based on the L8 time series imagery, a set of temporal statistical features was calculated, which was further used in an image classification approach using the random forest (RF) algorithm to map underutilized land. Detailed information on the European-wide approach to map underutilized lands can be found in D2.3 and Hirschmugl et al[6].

In contrast, S2 data was employed solely to generate detailed TIER-2 regional maps for the twelve case study regions. An advanced time series analysis approach was applied, using harmonic regression to reconstruct the continuous spectral curve. The parameters describing the calculated model were then used to train a random forest classifier to generate the underutilized land maps.

For the assessment of the **contaminated lands**, the JRC map of heavy metal concentration in soils was used[7,8]. It has a spatial resolution of 1x1 km and covers 27 EU member states (not including Croatia). Maps of nine different heavy metals are provided: Arsenic, Cadmium, Chromium, Cobalt, Copper, Mercury, Nickel, Lead, Manganese and Antimony. For each of the heavy metals, thresholds had to be defined to separate contaminated from non-contaminated soils. The threshold values represent the amount of heavy metals in soils, above which the use of the soil for food and fodder are not allowed/advisable. If available, national thresholds were used, otherwise thresholds reported by Tóth et al.[9] were applied.

To prevent land use change and, therefore, the food versus fuel debate as well as jeopardizing nature's biodiversity, existing data sets are used to remove certain areas from the whole assessment. These data sets include the COPERNICUS HRL Forest, imperviousness and water &

6 Hirschmugl, M.; Sobe, C.; Khawaja, C.; Janssen, R.; Traverso, L. Pan-European Mapping of Underutilized Land for Bioenergy Production. Land 2021, 10, 102, doi:10.3390/land10020102

7 Panagos, P.; Van Liedekerke, M.; Jones, A.; Montanarella, L. European Soil Data Centre: Response to European Policy Support and Public Data Requirements. Land Use Policy 2012, 29, 329–338, doi:10.1016/j.landusepol.2011.07.003.

8 European Soil Data Centre (ESDAC) Esdac.Jrc.Ec.Europa.Eu, European Commission, Joint Research Centre (JRC).

9 Tóth, G.; Hermann, T.; Da Silva, M.R.; Montanarella, L. Heavy Metals in Agricultural Soils of the European Union with Implications for Food Safety. Environ. Int. 2016, 88, 299–309, doi:10.1016/j.envint.2015.12.017.

wetness as well as certain CORINE Land Cover classes, Openstreetmap data, Natura2000 areas and Shuttle Radar Topography Mission digital elevation models (SRTM). Since the above-mentioned data sets do not cover the state of Ukraine, we used a separate land use classification and protected area data set provided by Myroniuk et al.[10] and the official Ukrainian cadastre[11]. In the last step, the data was prepared for the final integration in the webGIS tool by removing of polygons smaller than a certain minimum mapping unit (10 ha for TIER-1 and 0.5 ha for TIER-2), smoothing and simplification of the polygon borders for performance reasons of the tool and the calculation of additional attributes.

The final mapping result is shown in Figure 3. The map shows that there are large areas of contamination, specifically in Spain, Ireland, Denmark, Italy and Greece. This results from the mapping procedure in relation to the coarse input data and varying national thresholds. Thus, these results should be treated with caution. However, this was the only feasible approach to integrate contaminated lands in a European-wide map, because national maps are rare and/or often subject to confidentiality. Regarding underutilized land, about 5.3 Mio ha of were mapped with the TIER-1 approach across Europe, with the highest potential found in the Mediterranean and Continental BGR.

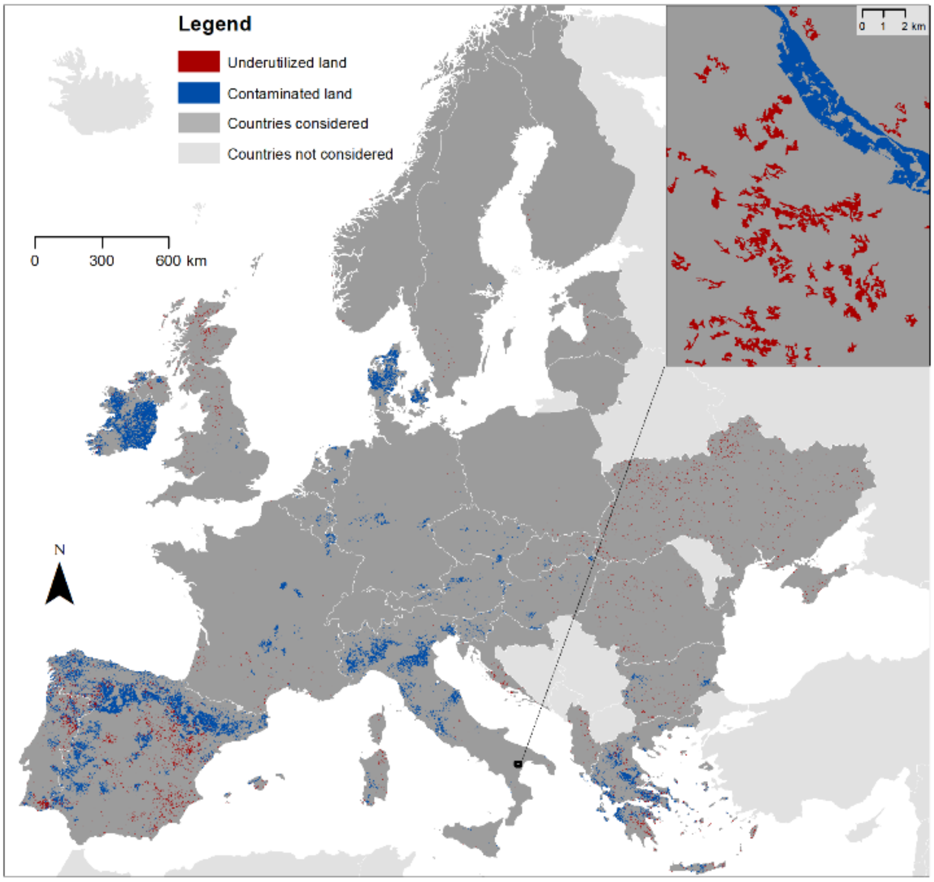


*Figure 3: Final combined TIER-1 and TIER-2 (example: rectangle top right) map of underutilized and contaminated lands*

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10 Myroniuk, V.; Kutia, M.; J. Sarkissian, A.; Bilous, A.; Liu, S. Regional-Scale Forest Mapping over Fragmented Landscapes Using Global Forest Products and Landsat Time Series Classification. Remote Sens. 2020, 12, 187, doi:10.3390/rs12010187.
11 https://map.land.gov.ua/

### 2.1.2 STEN Tool development

The first activities for the development of the STEN tool were aimed to investigate all EU and non-EU projects, which have produced valuable tools or methodologies addressing specific aspects of sustainability of the bioenergy sector. The project partners tried to provide the most efficient use of the available resources and research on the matter, to avoid the replication and repetition of existing research outputs and to compare several methodologies and results to reduce the range of calibration for the development of the software.

The following methodologies and tools employed in bioenergy sustainability analyses have been selected for review and harmonisation: Global Bioenergy Partnership (GBEP) Sustainability Indicators for Bioenergy, Global Agro-Ecological Zoning (FAO), IPCC guidelines, the EU-funded projects FORBIO, BioGrace Project, SEEMLA and MAGIC, JRC database on bioenergy processing plant and JRC Forest Information System for Europe (FISE). The detailed report on the harmonisation of methodologies and tools employed is available in D3.1.

Based on the GBEP indicators and their adaptation in the FORBIO project, further adaptation and harmonisation was required for the development of the STEN tool.

The sustainability indicators developed in the BIOPLAT-EU were based on the GBEP indicators that were adapted in the FORBIO project and further harmonised for BIOPLAT-EU. In the end, nine sustainability indicators were developed for the assessment (Table 1). These were divided into "standard" and "advanced" indicators. The tool measures the standard indicators automatically, only by providing the basic information to characterise the value chain and to specify where the analysis would take place (bioenergy site). In contrast, the users are required to fill out most of the information for the advanced indicators to assess the change between the baseline and the target (with project) scenario.

*Table 1: Sustainability Tool for Europe and Neighbouring countries (STEN) sustainability indicators.*

| | Standard Indicators | Advanced Indicators |
|---|---|---|
| Environmental | Air Emission | |
| | Water Use | |
| | Land Use Change | |
| Social | Jobs in Bioenergy sector | |
| Economic | Net Energy Balance | Income |
| | Gross Value Added | Land Tenure |
| | Infrastructure | Energy Access |
| | Capacity for the use of bioenergy | |

The second step was to link all the developed maps to the specific parameters in a software environment that allowed the communication between the interface, and the development of a sound database for the sustainability calculations. The first consists of a series of GIS layers and maps that are linked with and controlled by the tool. This information is mainly identified as data for the characterization of the baseline conditions (without project scenario) and consist of a series of well-defined social, economic and environmental data. The second main source of data, internal to the STEN structure, is represented by the STEN database. This database is characterized by different attributes and features that provide a combination of variables that allow the system to run the sustainability analysis based on the user's inputs. The details on the database of attributes for sustainability assessment is available in D3.2.

### 2.1.3 WebGIS tool

The webGIS tool was formed by integrating and combining the GIS maps and the STEN tool (Figure 4). Its development was carried out in three phases.

In the first phase, the conceptual design was defined. This included the identification of user requirements, user profiles, and the use cases. The main variables and the algorithms to compute the set of sustainability indicators were identified. The webGIS system interaction with users were defined using the wireframe technique to visualize how the user would interact with the maps and the STEN.

During the second phase, the prototype was developed. Its construction was carried out through agile management processes based on incremental life cycles to achieve a progressive growth of functionality. The prototype is based on the user requirements analysis, the construction of a mockup to ease interaction with users, the collection of information and elaboration of basic layers for the data model, and the development of the STEN tool for the calculation of the sustainability indicators. The webGIS tool prototype is a distributed information system with at least one server and one client, where the backend is a GIS server, and the front end is a webGIS client that runs in a Web browser. The architecture of the system is based on a client-server. The frontend includes the interface of the map, the form tool for STEN, and a representation of outputs. The map viewer allows displaying the information of interest and using that information to perform simulations of the MUC lands registered in the system. The map viewer core functionalities for layer management, layer editing, visualisation, and data management strategies were developed. The backend consists of a set of web services, libraries, and calculation engines that implement the logic of the system, as well as the data storage layer.

In the third phase, the webGIS prototype integrated all the GIS layers and the data required for its full operation and was tested and fine-tuned before making it available for public use. To familiarise users with the use of the webGIS tool including the STEN tool and its methodologies an instruction manual was also developed.

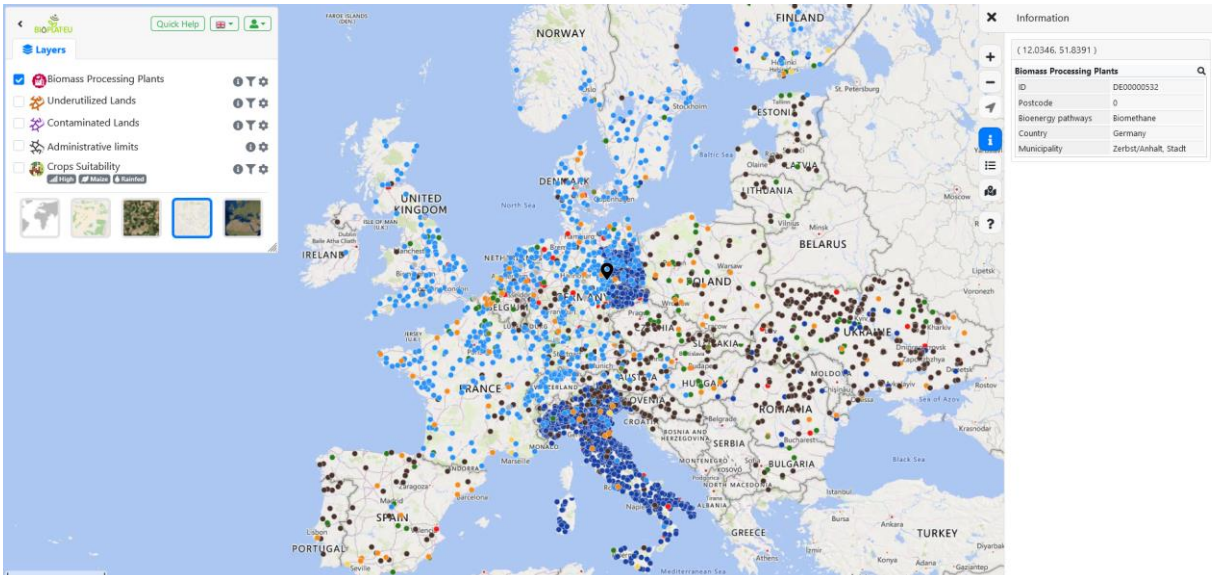


*Figure 4: BIOPLAT-EU webGIS tool accessed at [https://webgis.bioplat.eu/#/map](https://webgis.bioplat.eu/#/map)*

The webGIS tool allows any stakeholder to search for MUC lands in Europe. It will give the user some specifications about these lands such as agronomic and climatic ones and, consequently, what type of biomass can be planted on them. Then a sustainability assessment can be performed on the chosen value chain. This is believed to help in the decision making on whether to proceed or not for the implementation.

## 2.2 Tool testing on case studies and fine-tuning

After building the webGIS tool, an important and crucial step was to test it through a series of case studies. This operation is key to identify possible bugs, flaws and inefficiencies of the system and solve them, thus it is important to dedicate collaborative efforts to ensure that additional perspectives and viewpoints are considered when testing the tool. In order to make sure that the testing is effective, a set of representative case studies is a necessary attribute. Clearly, the role of the selection of representative case studies is pivotal to the successful testing of various potential scenarios of use for the webGIS platform.

As a first step, we analysed the defining characteristics of the selection of case studies, the selection process itself, and presented each of the selected cases in the test countries, namely Germany, Hungary, Italy, Romania, Spain and Ukraine.

In the selection process, national project partners first assessed the TIER-2 maps to identify the MUC lands and the most promising bioenergy pathways. Then, they had the prominent role of scouts and proponents based on their knowledge of local conditions for the sites to take into consideration for the final selection. Additionally, they did some site visits to confirm the MUC lands depicted. In order to diversify and include as mush as possible value chains, a list of crops and bioenergy pathways was taken int consideration for the selection process. Details about the selection process is available in [D4.1.](D4.1.)

In the end, 12 bioenergy value chains were selected in 12 regions, two per country (Table 2).

*Table 2: Bioenergy value chains in the 12 case study countries.*

| Country | Site Location | MUC type | Total hectares | Bioenergy crop | Bioenergy pathway | Plant capacity |
|---|---|---|---|---|---|---|
| **Germany 1** | Spree-Neiße | Underutilized (lignite mining reclamation sites) | 2,100 | Sorghum | Biomethane | 3,200,000 $m^3$/year |
| **Germany 2** | Dahme-Spreewald | Underutilized and contaminated (Former sewage irrigation fields) | 521 | Poplar (SRC) Miscanthus | CHP (solid biomass) | 650 kWe (5.2 GWh/year) |
| **Hungary 1** | Bács-Kiskun and Csongrád county | Marginal - underutilized | 10,000 | Maize | 1G ethanol | 5-10,000,000 liters/year |
| **Hungary 2** | Balaton Uplands region: Veszprém County and Fejér County | Marginal - Underutilized | 10,000 | Poplar, Willow, Black locust | CHP (gasification/pyrolysis) | 4.5 MWe (36 GWh/yr) |
| **Italy 1** | Sulcis | Contaminated - underutilized | 6,000 | Arundo donax | Biogas | 17.1 MWe (136 GWh/year) |
| **Italy 2** | Matera, Basilicata region | Contaminated | 14,000 | Oil seed; Sorghum | Biodiesel | 5,000,000 liters/year |
| **Romania 1** | Bacău County, Strugari and Blăgești | Underutilized | 95 | Miscanthus | CHP (solid biomass) | 45 KWe (360 MWh/year) |
| **Romania 2** | Oltenia mining area, Gorj County, Pesteana querry | Underutilized | 176 | Lucerne; Sorghum | CHP(Biogas) | 200 KWe (1.6 GWh/year) |
| **Spain 1** | Albacete | Contaminated - underutilized | 15,000 | Sunflower; Camelina | HVO | 5,000,000 liters/year |
| **Spain 2** | Cuenca | Contaminated – Underutilized | 15,000 | Camelina | Biodiesel | 5,000,000 liters/year |
| **Ukraine 1** | Khmelnytskyi and Ternopil | Underutilized | 30,000 | Miscanthus; switchgrass | CHP (solid biomass) | 40MWe (320 GWh/year) |
| **Ukraine 2** | Kyiv and Chernihiv regions | Underutilized | 30,000 | Willow | 2G ethanol | 30,000,000 liters/year |

* Bioenergy plants are assumed to operate for 8,000 hours/year. Therefore, for instance, a 1 MWe plant will generate 8,000 MWh or 8GWh in any operating year

After the selection of the case studies has been completed and in order to validate the tool and improve it further for more efficient and reliable results of its final release, project partners tested the beta version on the selected most promising value chains with a full sustainability analysis of all environmental, social and techno-economic indicators included in the webGIS tool. This represented the first official experiment of extensive multilocation access to the BIOPLAT-EU platform and specifically operations within the webGIS tool, performed by members outside the developers of the tool itself. The testing is meant to benchmark the functionalities of the model, highlight bugs and errors, as well as to assess critically the accuracy of the results. The testing of an incomplete and partial tool would have added limited value to the fine tuning of the WebGIS for the development of a system that works and performs up to expectations.

There were five main areas of interest in the testing phase, each linked to specific software development objectives. These include:

1. user friendliness, simulation limitations and procedure, clarity of the results, graphical aids, and then tests of platform load in order to assess the stability of the IT-platform
2. soundness of the algebra and reference values employed (through the advanced user feature)
3. the accuracy of default information (standard users)

4. evaluate the learning curve of a first cohort of users (case study Partners) and track how they obtain familiarity with the tool
5. define the characteristics of the simulations that will give input to the economic and financial assessments and bankability potential of each case study

Details about the testing through the case studies is available in D4.2.

The feedback from partners was taken into consideration and the tool was fine-tuned a first time accordingly before it's public release. At a second stage, the webGIS tool has been extensively tested by the members of the project Advisory Board and the stakeholders who participated in the webniars and different events.

The fine-tuning of the webGIS tool has allowed to fix issues of the tool that emerged thanks tothe reviews and the exchanges with local and international stakeholders, to the extent possible. In terms of bugs and glitches, all discovered errors of the system have been fixed. The calibration of the tool was carried out based on the feedback received and was necessary particularly for the yields and suitability of specific crops in low-suitability areas. The problem has been solved successfully and in the mean time the approach chosen expanded the potential usability of the tool, for advanced users. Data availability still constraints the standard user on fixing the issue of inaccuracy of yields and suitability of certain crops. Most reviewers however, found the tool very well integrated and little work on actual fine-tuning was required, whereas work on refinement and enhancement of the tool was predominant.

All users that have been exposed to the tool reported its high potential for decision making at many levels, and its swift and simple usability. Important missing features were added thanks to clever decisions and relentless work, although not without drawbacks. In the end however, the tool is more comprehensive and capable as a consequence of the fine-tuning phase. Details about the testing results and fine-tuning are available in D4.3.

## 2.3 Stakeholder mobilisation

The main aim of this activity was to mobilise stakeholders, inform them about the opportunities to produce biomass on MUC lands for bioenergy purposes and gather all actors to discuss the actual needs for the development of sustainable bioenergy projects on these lands and encourage and support them to implement such projects. In this context, a series of events were organised in the case study regions.

Working groups were held, in which stakeholders were invited to discuss the bioenergy options available in their regions, the main challenges and opportunities of these value chains with the aim of planning the development of a competitive bioenergy value chain on MUC lands in their region. Furthermore, the project results were demonstrated, the webGIS tool was tested and the stakeholders in return gave their feedback for the fine-tuning of the tool. Two working group meeting per region were held with follow-up actions in some cases. The reporting on these working groups is available in D5.2.

Two workshops in each of the case study regions were organised with the aim of promoting the efficacy and profitability of using MUC land for sustainable bioenergy production especially to public and private landowners. The promotion of the tool was also an important part of the workshops where a live demonstration on its functioning was given, and feedback was received. The reporting on the workshops is available in D5.3.

Some legal barriers may confront stakeholders for the implementation of bioenergy projects on MUC lands. Therefore, a main task in the project was dedicated to the communication with the legal authorities responsible for the decision-making of such issues in the case study regions through dedicated presentations and communication with the hope of positively influencing their decisions on specific issues that is hindering the deployment of bioenergy. The reporting on the presentations is available in D5.4.

## 2.4 Financial structuring support, feasibility studies and business models

Under this activity, the aim was to provide support to increase the financial marketability of (pilot) projects that will use the STEN tool for the development of bioenergy projects on MUC lands. The tasks performed under this activity can be best described through the diagram in Figure 5.

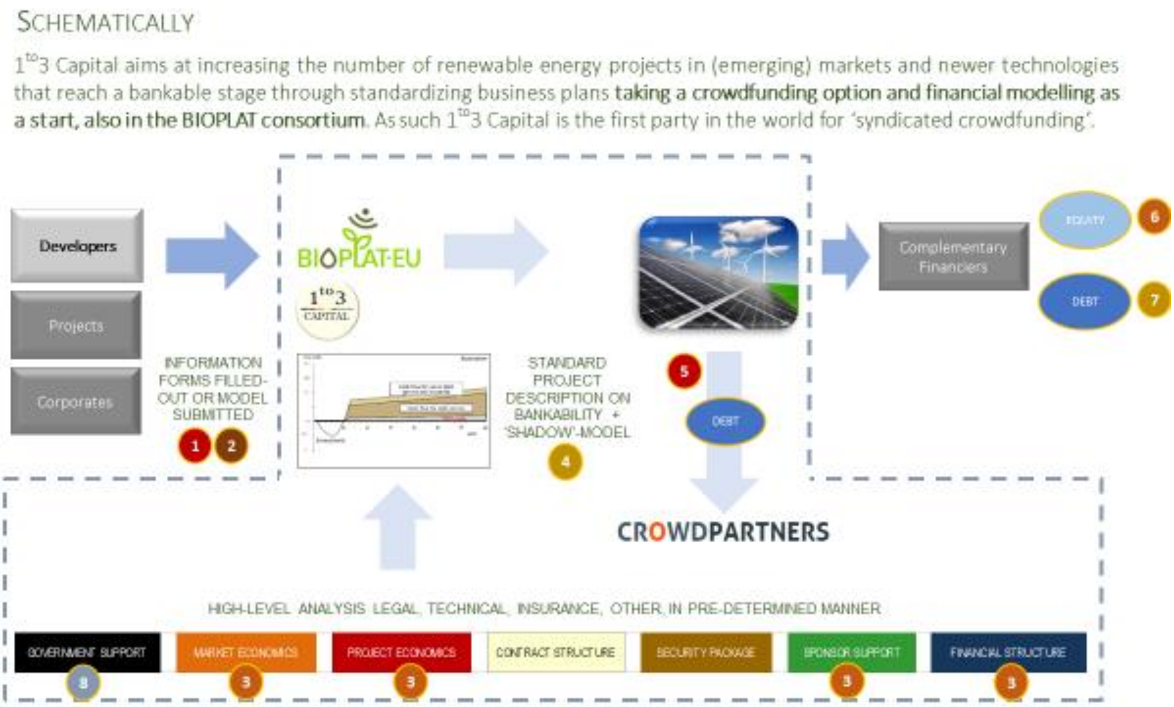


*Figure 5: Schematic description of the tasks*

In brief, the end-product aimed at are propositions for finance, both from an equity and debt perspective (bullet 6 and 7 in the diagram). To derive at these propositions, the following activities have been undertaken:

- Knowledge exchange has been accomplished on 'writing business plans' by making available a guide for business plan drafting. A template-guide was used that had been on the website of the UNDP for similar purposes and fully adjusted to the BIOPLAT-EU project.

- Project Identification Forms ("PIFs") and a generic financial model for project development and intake were integrated in the Guide for Business Plans. The financial model is accompanied by a very detailed user guide including description of the model from different perspectives (equity, debt, regulator).
- The BIOPLAT-EU project had some 12 case studies prepared by partners from 6 countries. The country partners used the PIFs for the description of the pilot projects. The pilot projects had different stages of development although all of them were not yet at a stage where credit proposals could be drafted. Hence, the work done was on (pre-) feasibility from a financial-economic perspective (indicated by bullet point 3 in the diagram). The output figures and pathways listed in **Table 2** were chosen for the analysis.
- The case studies explored have been reviewed for financial economic feasibility. The results are described in D6.3 and D6.4. A dedicated version of the financial model was produced for these pilot projects specifically. This model actually caters for all relevant technologies and up to 50 projects next to each other in one model. All projects were prepared using default values for taxation, depreciation, etc. per country. The remainder of the information for the pilot projects was derived from the filled-out PIF and the table above from the STEN database. The feasibility analyses were performed in a standard manner and the reporting is standardised as well (bullet point 4).
- The feasibility analysis and finance structuring require terms and conditions from both the debt and the equity side to make realistic calculations. In case any of the pilot projects would have been ready for financing the crowdfunding mechanism would have allowed for funding. Also, the financial model is prepared at such a quality level that also external debt and equity can be raised on it without an external model audit requirement.
- Lastly, quite some bioenergy projects seem eligible for funding from grant-programs (bullet point 8) like for example the Innovation Fund, in specific production of 2G ethanol from lignocellulosic biomass.

The feasibility results of the case studies are depicted in the diagram below.

| Categories of Feasibility: | Category 1: too optimistic | Category 2: feasible | Category 3: non-feasible, but | Category 4: non-feasible |
|---|---|---|---|---|
| 1st Route of Business Model: | MUC_land + Bio-energy Investment Plant | MUC_land + Bio-energy Investment Plant | MUC_land + Bio-energy Investment Plant + Grant Route | MUC_land Feedstock Production only |
| Preparation Format: | Format Crowdfunding / Commercial Banks | Format of Development Bank (EIB) / Crowdfunding | Format Grant Provider (like Innovation Fund) | No Format or Format of Regional (farmers') Bank |
| Case Studies: | Italy 2 | Germany 1, Germany 2, Romania 1, Romania 2 | Hungary 1, Hungary 2, Hungary 3, Italy 1, Ukraine 1, Ukraine 2 | Spain 1, Spain 2 |

*Figure 6: Results of feasibility and business models of the case studies*

Categories 1 and 2 represent feasible propositions for the *combination* of feedstock from MUC lands and further processing in envisioned investments in Combined Heat and Power plants (CHP) or production facilities for biomethane, biodiesel, HVO and ethanol. Hence, the business model for the Categories 1 and 2 might be an integrating approach of feedstock production from MUC lands and production facilities.  Three of the feasible case studies are 'hypothetical' in nature (Germany 1, Romania 1 and 2) as per the PIFs and the other two case studies are not based on detailed information. From all five feasible cases, only one case (Germany 1) has some contractual set-up at this stage as per PIF with supply and offtake contracts. Hence, the overall conclusion on business models for the feasible projects is positive but with the remark that much needs to be sorted out. The format for preparation in due course will likely be a combination of crowdfunding and development finance (EIB). The templates for such applications have been made available and are an integrated whole with the Project Identification Forms and the Financial Model, including a manual for the model-functioning (D6.1).

Categories 3 and 4 represent non-feasible propositions, at least at this early stage and based on the information available, for the *combination* of feedstock from MUC lands and further *exclusive* processing in production facilities. The feedstock produced from the MUC lands might be mixed with other (less expensive at the gate) feedstocks to become economic and / or might be deemed eligible for grant applications in a combined feedstock + investment case. Grant programs at European level like the Innovation Fund have been considered by the Consortium but at this stage applications are not being prepared. The case studies in Spain are not feasible at the moment even if grants would be considered and therefore it is assumed that these projects will be feedstock-production only and might appeal to an off-taker willing to pay a premium. Possible local banks might be approached for support who will bring their own templates.

At this stage the analysis has been performed for all projects taking a project finance route into mind because investors are not yet known (and therefore, corporate finance options cannot be assessed).

60% of the feasible projects comprise CHP. Almost 40% of the non-feasible projects are also CHPs, hence, it appears that even similar business models are very sensitive to the local context.

An area of attention for future projects is the pre-treatment technology and related expenses.

## 2.5 Pan-European assessment on MUC lands suitable for oil crop production

The aim of this task was to test the BIOPLAT-EU webGIS tool to find suitable MUC lands for sustainable oil crop production for bioenergy use at pan-European level. The testing in this task concentrated on three aspects related to the webGIS and STEN tool's capability: assisting in evaluating the potential for growing energy oil crops in Europe, identifying value chains, and STEN reports' potential for evaluating value chains towards the RED II (Renewable Energy

Directive (Recast) (EU)2018/2001) sustainability criteria. Key sustainability requirements include traceability, land use change (LUC) and greenhouse gas (GHG) emission reduction.

The results showed that the tool is technically applicable and easy to use for the mapping of the potential value chains. Potential MUC areas for oil crop production can be found with the webGIS tool for market actors to further evaluate in detail and to start to develop more detailed bioenergy value chains. When combining the tool's information on MUC lands and the crops suitability, there is a lot of potential throughout Europe, main potential existing in the Eastern and Southern parts of Europe. The evaluation found the rapeseed and sunflower oil to have the most potential in the pan-European assessment. Value chains could be identified to some extent, but as landowners or farmers could not be identified with the tool, further value chain development will require more detailed investigation of the area in question. STEN report gives the user preliminary information on GHG emissions and GHG emission reduction of the potential value chain. The webGIS tool's satellite imagery offers a high-quality view to the current status of the land use of a certain MUC area, whereas LUC is left outside the scope of this tool.

Overall, the webGIS tool proved to be an excellent assistant and the first stepping stone in evaluating the potential for value chain development for oil crop based biofuels. The tool offers an unprecedented outlook on the MUC land potential for bioenergy crop production in Europe.

The detailed assessment is available in the report D6.5.