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

D 3.3

FINAL REPORT ON THE SUSTAINABILITY ASSESSMENT OF THE SELECTED ADVANCED BIOENERGY VALUE CHAINS IN ALL THE CASE STUDY SITES

FAO

Food and Agriculture Organization of the United Nations

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

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	NAME	ORGANIZATION
AUTHOR(S)	Maria Michela Morese	FAO
	Marco Colangeli	FAO
	Lorenzo Traverso	FAO
CONTRIBUTOR(S)		

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1. Introduction

The assessment of the sustainability of the bioenergy pathways studied in the three case study countries begun in June 2017. It is largely based on information obtained through the harmonized data collection campaign carried out in FORBIO. The campaign was led by FAO with the contribution of national teams: CREA, Biochemtex, FIB, WIP, SecBio and the BI. In some cases, specific information was not delivered through the harmonized data collection campaign and therefore secondary data collection has been performed, to the extent possible, by FAO.

The main critical aspect detected during the secondary data collection campaign is that information is available but often in aggregated form or in national language only. This has been the case of Italy where a relevant amount of information was found on public sources but in Italian only.

It was not possible to reach the same level of detail for the case studies of Germany or Ukraine due to the language barrier, but it should be noted for the future that adequate data collection is possible though time consuming and that national partners should support this with extended efforts.

That being said, the results obtained from the assessment of the sustainability of the bioenergy pathways studied in the context of FORBIO provide a number of interesting aspects that will require a close analysis under WP4 to understand the extent to which economic and non-economic barriers can be overcome.

In the following chapters the results of the assessment of the sustainability of the selected bioenergy pathways tested in the three case study locations are presented.

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2. The case Study in Italy:

2.1 Case study description, setting, system boundaries and main assumptions

The analysis of the sustainability of a potential bioenergy value chain targeted the area of the Sulcis in the south-western part of the island of Sardinia, Italy.

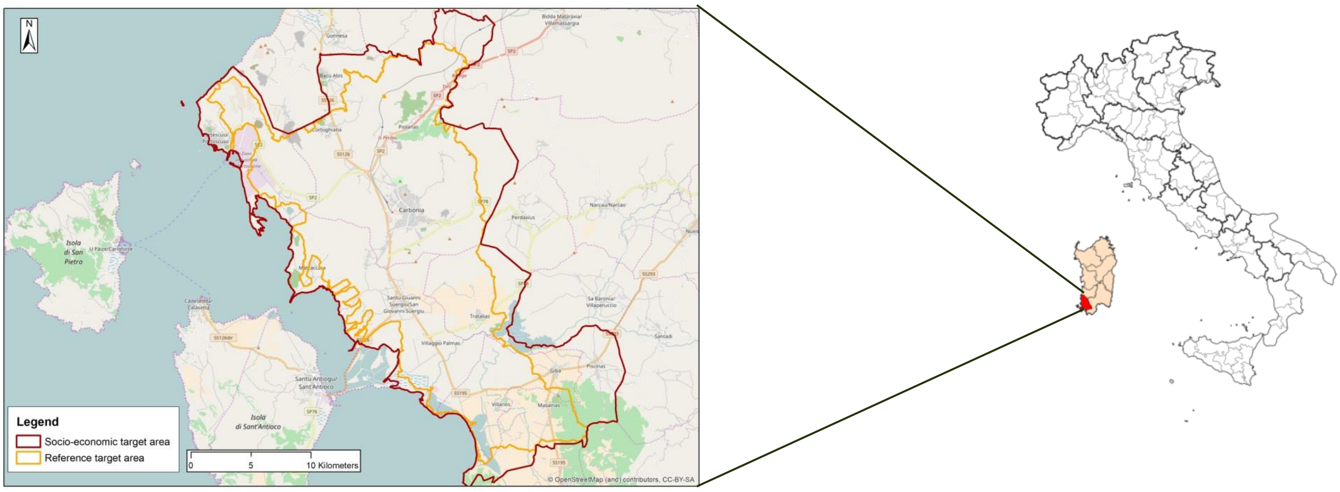

Figure. 1 The target area of Sulcis, Italy

Source: Gigillo83 - Own work., Public Domain, https://commons.wikimedia.org/w/index.php?curid=8090549

Starting from March 2014, the Municipality of Portoscuso enacted a decree which prohibits the sale of agricultural products produced within the Site of National Interest (SNI) (Figure 2a).

The reference target area used for the assessment of the sustainability of the selected bioenergy value chains has a surface of 35,745 ha and is the sum of the surfaces of the municipalities inscribed within the territory affected by soil contamination in this area. The area is a known Site of National Interest due to the presence of contaminants in the soils, particularly heavy metals.

The analyses carried out by the Regional Environmental Protection Agency on a number of heavy metals in the soils returned in several measurement stations the concentrations above the legal limits for the specific category of land. Figure 2b (below) reports the example of Pb (max concentration admitted by law is 100 ppm). The red dots in the map refer to measuring stations whose values were higher than

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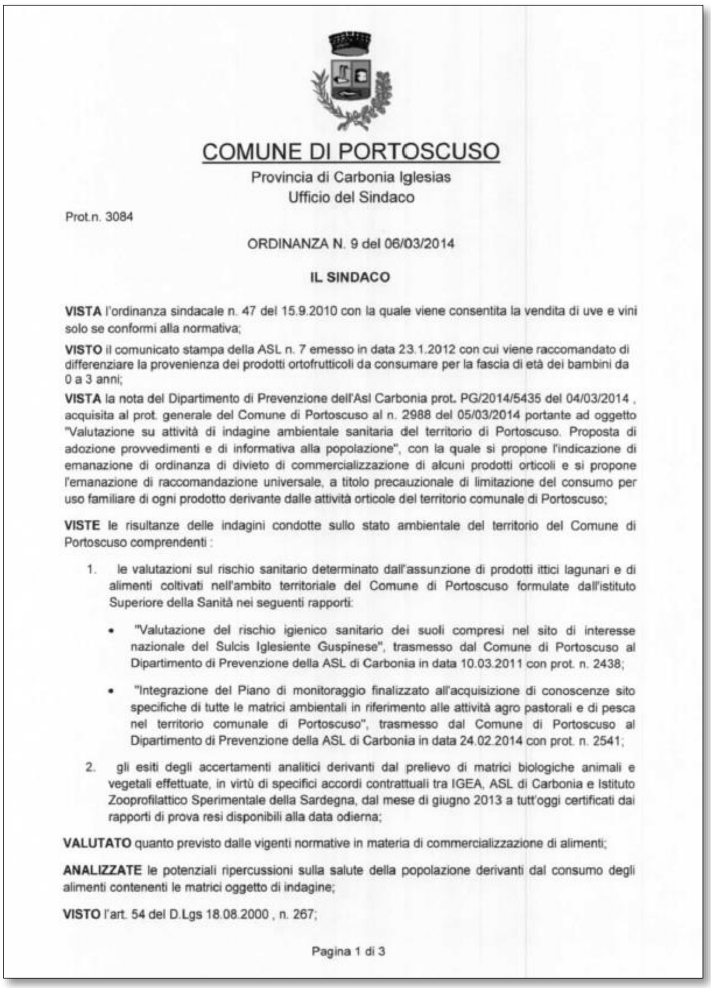
the limits admissible by law, and the number associated with each measuring point reports the average concentration measured in parts per million.



COMUNE DI PORTOSCUSO

Provincia di Carbonia Iglesias

Ufficio del Sindaco

Prot.n. 3084

ORDINANZA N. 9 del 06/03/2014

IL SINDACO

VISTA l'ordinanza sindacale n. 47 del 15.9.2010 con la quale viene consentita la vendita di uve e vini solo se conformi alla normativa;

VISTO il comunicato stampa della ASL n. 7 emesso in data 23.1.2012 con cui viene raccomandato di differenziare la provenienza dei prodotti ortofrutticoli da consumare per la fascia di età dei bambini da 0 a 3 anni;

VISTA la nota del Dipartimento di Prevenzione dell'Asl Carbonia prot. PG/2014/5435 del 04/03/2014 , acquisita al prot. generale del Comune di Portoscuso al n. 2988 del 05/03/2014 portante ad oggetto "Valutazione su attività di indagine ambientale sanitaria del territorio di Portoscuso. Proposta di adozione provvedimenti e di informativa alla popolazione", con la quale si propone l'indicazione di emanazione di ordinanza di divieto di commercializzazione di alcuni prodotti orticoli e si propone l'emanazione di raccomandazione universale, a titolo precauzionale di limitazione del consumo per uso familiare di ogni prodotto derivante dalle attività orticole del territorio comunale di Portoscuso;

VISTE le risultanze delle indagini condotte sullo stato ambientale del territorio del Comune di Portoscuso comprendenti :

1. le valutazioni sul rischio sanitario determinato dall'assunzione di prodotti ittici lagunari e di alimenti coltivati nell'ambito territoriale del Comune di Portoscuso formulate dall'istituto Superiore della Sanità nei seguenti rapporti:
   - "Valutazione del rischio igienico sanitario dei suoli compresi nel sito di interesse nazionale del Sulcis Iglesiente Guspinese", trasmesso dal Comune di Portoscuso al Dipartimento di Prevenzione della ASL di Carbonia in data 10.03.2011 con prot. n. 2438;
   - "Integrazione del Piano di monitoraggio finalizzato all'acquisizione di conoscenze sito specifiche di tutte le matrici ambientali in riferimento alle attività agro pastorali e di pesca nel territorio comunale di Portoscuso", trasmesso dal Comune di Portoscuso al Dipartimento di Prevenzione della ASL di Carbonia in data 24.02.2014 con prot. n. 2541;
2. gli esiti degli accertamenti analitici derivanti dal prelievo di matrici biologiche animali e vegetali effettuate, in virtù di specifici accordi contrattuali tra IGEA, ASL di Carbonia e Istituto Zooprofilattico Sperimentale della Sardegna, dal mese di giugno 2013 a tutt'oggi certificati dai rapporti di prova resi disponibili alla data odierna;

VALUTATO quanto previsto dalle vigenti normative in materia di commercializzazione di alimenti;

ANALIZZATE le potenziali ripercussioni sulla salute della popolazione derivanti dal consumo degli alimenti contenenti le matrici oggetto di indagine;

VISTO l'art. 54 del D.Lgs 18.08.2000 , n. 267;

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Figure. 2a Municipal decree to prohibit and advise against the sale and consumption of foodstuffs produced within the contaminated area of the SNI. Source: Gruppo Intervento Giuridico Web, 2018.

The scenarios considered in this analysis derive from the conclusions of Deliverable 2.1 and 2.2.

The bioenergy pathway selected is lignocellulosic ethanol with the presence of a Combined Heat and Power plant within the biorefinery.

Two sources of biomass were identified: giant reed (*Arundo donax*) irrigated; and giant reed under rainfed management system.

From the outcomes of D 2.1 and D 2.2 of FORBIO two aspects emerge that strongly place giant reed as a valid candidate as feedstock for lignocellulosic ethanol biorefinery in this case study area: 1) the high biomass to ethanol yield (i.e. 4.5 tons

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of biomass per ton of ethanol); 2) the high biomass yields obtainable in the case study area already during the early stages of the cycle (e.g. year II and year III).

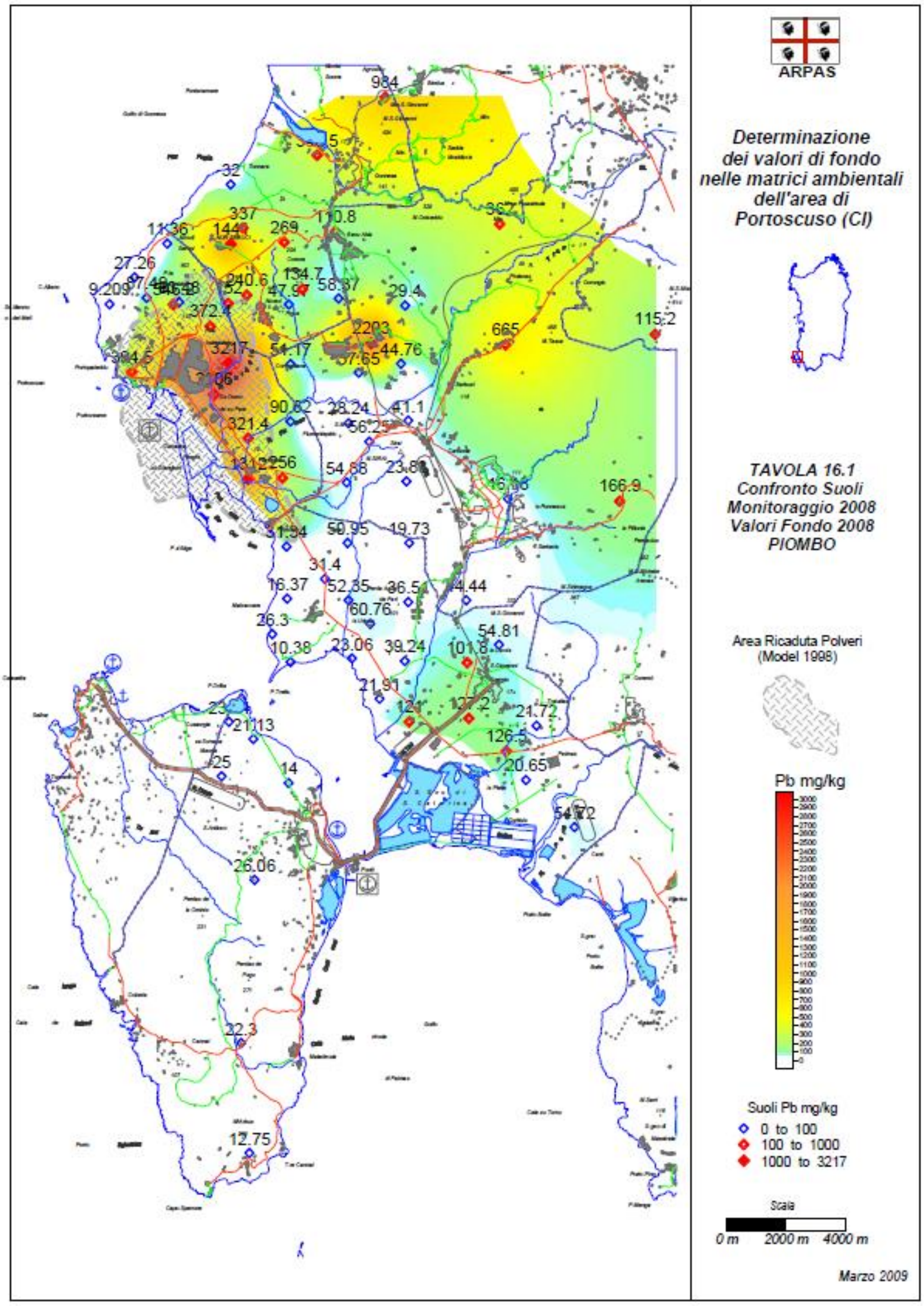

Figure. 2b The contamination levels of Pb in the target area of Sulcis, Italy

Source: Regional Environmental Protection Agency of Sardinia, 2009. Available at http://www.sardegnaambiente.it/documenti/21_236_20090710143354.pdf

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The target output of this hypothetical biorefinery is 40,000 tons of ethanol per year and the technology employed is the PROESA® (steam-explosion, Enzymatic liquefaction, SSF) belonging to Biochemtex, partner of the FORBIO project and technology provider. This value is equal to the regime capacity of the biorefinery in Crescentino operated by Beta Renewables.

From figure 3, it is clear how the highest concentrations of heavy metals are found in the immediate vicinity of the industrial pole of Portovesme and thus the scenario with bioenergy production considers that the biorefinery is built within the industrial pole of Portovesme, in the Municipality of Portoscuso (Figure 4). This would place the industrial building of the biorefinery in an area that is already classified as industrial land, it would provide a number of logistical advantages for the supply of raw materials as well as for the distribution of end products.

The suitable sites identified in D 2.1 are all inscribed within a 30 km radius from the industrial pole of Portovesme and are to be considered underutilized in light of the Municipal Decree of the Municipality of Portoscuso, and by the presence of contamination as confirmed by the Regional Environmental Protection Agency of Sardinia.

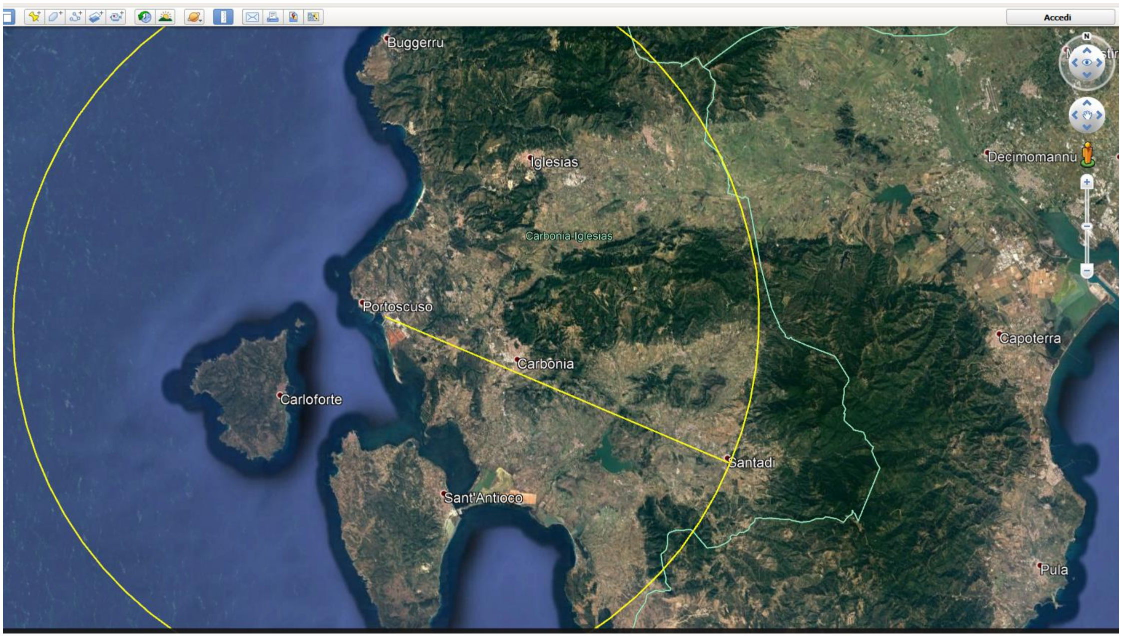

Figure. 4 The target area of Sulcis, Italy is entirely inscribed within a 30 km radius from the industrial pole of Portovesme.

Source: Google Earth, own elaboration.

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Within the target area (total surface 35,745 ha), a total of 18,706 ha of current agricultural land is to be considered underutilized (because contaminated or bordering contaminated sites). These lands have been identified as suitable for biomass production in the agronomic assessment carried out in Deliverable 2.1.

The assessment of the *Baseline situation* as shown in Figure 5 summarizes the land categories and cover types currently present in the ***target area***.

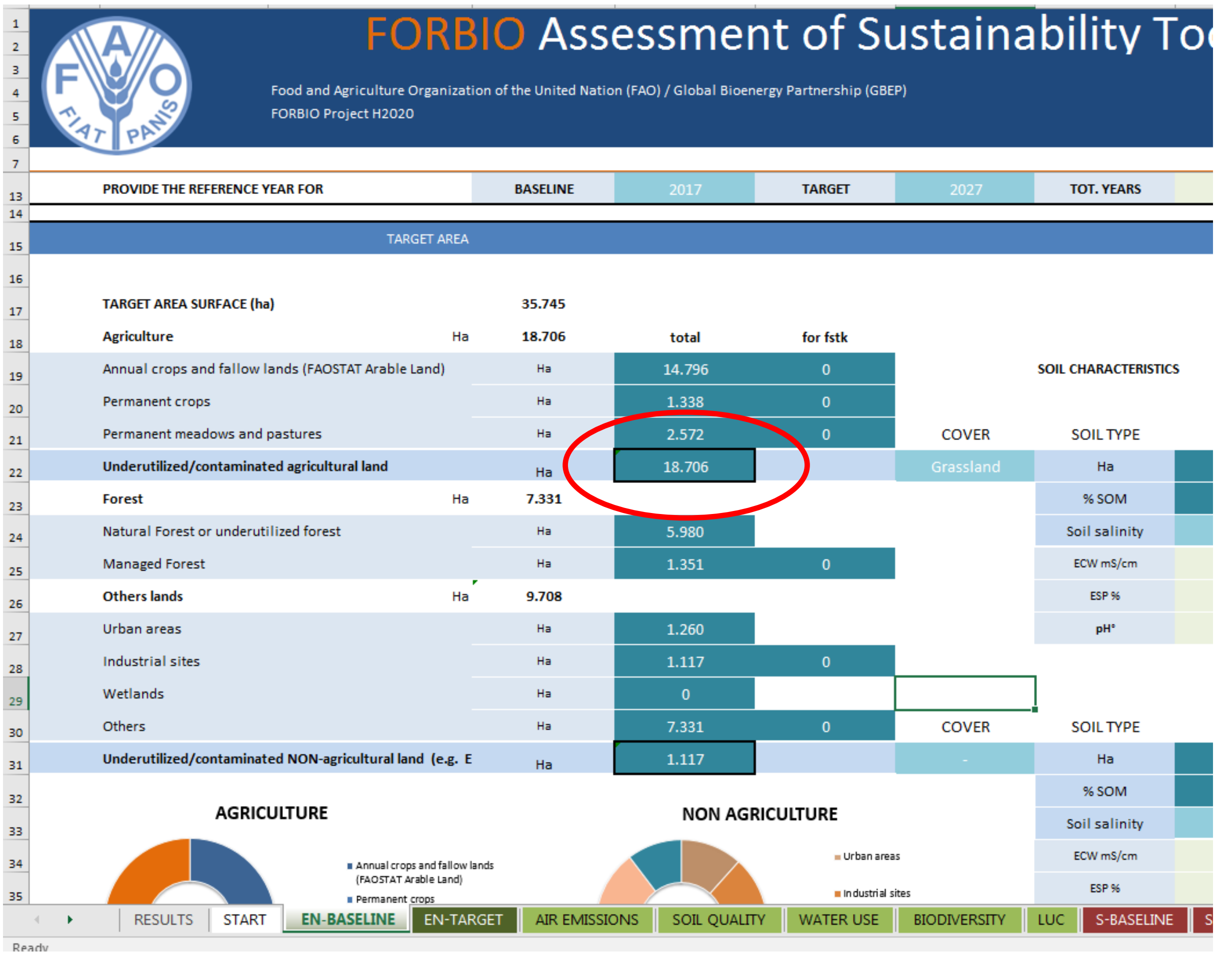

Figure. 5 The baseline situation of the case study area in the Sulcis, Italy, is characterized by the presence of 18,706 ha of contaminated agricultural land.

In Deliverable 2.1, the FORBIO project assessed the expected yields of giant reed under irrigated and rainfed conditions in the case study area. Irrigated giant reed can yield steadily some 25 tons of dry biomass per hectare per year (t ha-1 yr-1) in the Sulcis, whereas giant reed production under rainfed conditions reports yields of around 10 t ha-1 yr-1. All biomass yields in this document are expressed on a dry matter basis.

Given the biomass to ethanol yield of giant reed (4.5 tons of feedstock per ton of ethanol produced), and the size of the hypothetical biorefinery (i.e. 40,000 tons of

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ethanol/year), the biomass required to supply the biorefinery is 180,000 tons per year.

From Deliverable 2.1, it is clear how the superior characteristics of giant reed under irrigated management system, lead to highly desirable yields. However, as it is often the case, the theory alone cannot be used to base reliable analyses and through the series of information days, capacity building events, multistakeholder discussions and literature reviews, information on the actual feasibility of using the necessary surface for the production of biomass under irrigated conditions was not verified. In fact, in the ***target area***, the local irrigation infrastructure covers only approximatively 1,000 ha of the 7,200 ha required to supply the hypothetical biorefinery in Portovesme.

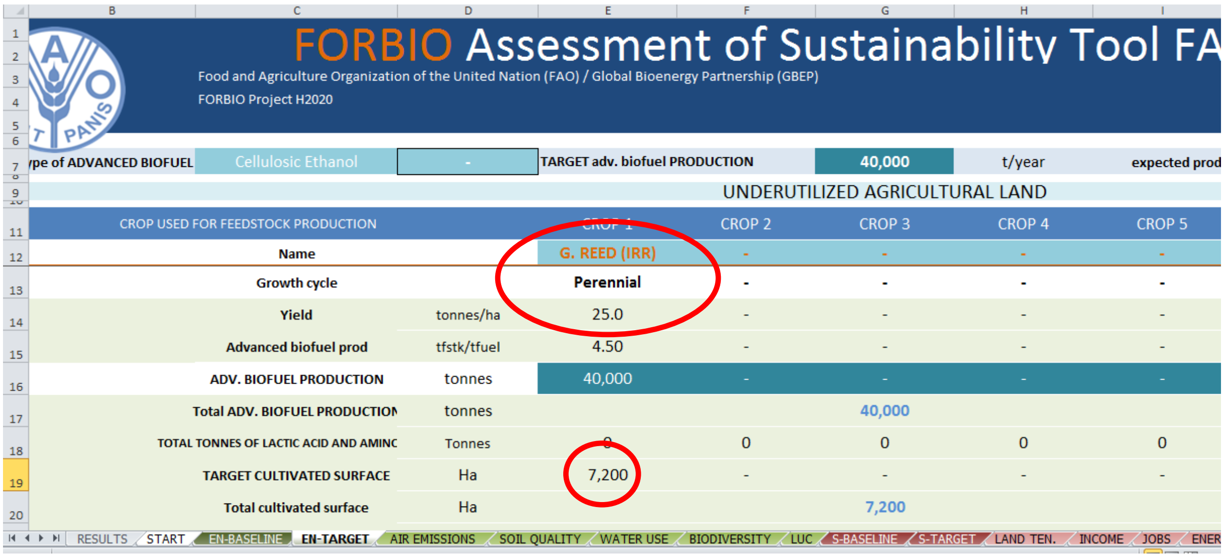

Figure. 6 The target scenarios tested situation of the case study area in the Sulcis, Italy, shows the land requirement when giant reed is cultivated with artificial irrigation (7,200 ha).

In addition to insufficient coverage of the irrigation infrastructure, the area has also inefficient irrigation infrastructures (i.e. losses amount to 65% in the study area, LaNuovaSardegna, 2018) and there are plans for the updating of the irrigation network. At some point then, it is possible that an appropriate and efficient irrigation infrastructure will be available in the ***target area*** and it is possible that the presence of a bioenergy value chain may contribute to the development of such improvement. However, for the purpose of this sustainability assessment, a second scenario based on the production of feedstock from giant reed under rainfed conditions was also analyzed and tested.

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FORBIO Assessment of Sustainability Tool FAST

Food and Agriculture Organization of the United Nation (FAO) / Global Bioenergy Partnership (GBEP)

FORBIO Project H2020

Type of ADVANCED BIOFUEL	Cellulosic Ethanol	-	TARGET adv. biofuel PRODUCTION	40.000	t/year	expected prod.	40.000	t/year

		UNDERUTILIZED AGRICULTURAL LAND					UNDERUTILIZED	
CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 1	CROP2
Name		G. REED	-	-	-	-	-	-
Growth cycle		Perennial	-	-	-	-	-	-
Yield	tonnes/ha	10,0	-	-	-	-	-	-
Advanced biofuel prod	tfstk/tfuel	4,50	-	-	-	-	-	-
ADV. BIOFUEL PRODUCTION	tonnes	40.000	-	-	-	-	-	-
Total ADV. BIOFUEL PRODUCTION	tonnes			40.000				
TOTAL TONNES OF LACTIC ACID AND AMINC	Tonnes	0	0	0	0	0	0	0
TARGET CULTIVATED SURFACE	Ha	18.000	-	-	-	-	-	-
Total cultivated surface	Ha			18.000				
REQUIRED FSTK QUANTITY	Tonnes	180.000	-	-	-	-	-	-
Total	Tonnes			180.000				
Distance from field to Fuel Plant	Km	40	-	-	-	-	-	-
TRANSPORT OF BIOMASS	Vehicle type	Tractor	-	-	-	-	-	-
Distance from Fuel Plant to distributors (km)	100							
TRANSPORT OF FUEL	Vehicle type	Truck	-	-	-	-	-	-
SOIL CHARACTERIZATION								
SANDY	Suitability	Suitable	-	-	-	-	-	-

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC

Figure. 7 The target scenarios situation tested shows the land requirement when giant reed is cultivated under rainfed conditions (18,000 ha).

In the rainfed scenario, given expected yields of 10 t ha-1 yr-1, giant reed would require some 18,000 ha for the production of the amount of biomass that the biorefinery requires.

This value is attainable, at least in theory, in light of a surface of underutilized/contaminated agricultural land in the ***target area*** of 18,706 ha.

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2.2 Sustainability Assessment results by Indicator

2.2.1 Air Quality

The assessment of the sustainability of bioenergy value chain cannot disregard the lifecycle assessment of greenhouse gas (GHG) emissions. In this project, the baseline situation is represented by the traditional fuel currently used by the fleet which would be partially substituted by the 2G ethanol produced in the ***target area***. It is common practice to assess the sustainability impact of bioenergy production and use on the basis of GHG emission intensity per unit of energy. The GHG emission intensity is therefore expressed in grams of carbon dioxide equivalent per megajoule of bioenergy produced (gCO_{2eq}/MJ).

In the baseline scenario the reference fuel used in petrol. The emission intensity of European petrol is 83.3 gCO_{2eq}/MJ (Biograce, 2014).

In the target scenario the emission intensity of lignocellulosic ethanol produced in the ***target area*** is therefore compared to the emission intensity of the reference fuel and the relative (in %) and absolute (in g, Kg, or t of CO_2) change is reported.

The main contributors and components of a GHG LCA of biofuel production and use are:

1) Feedstock production;
2) Feedstock transport;
3) Feedstock processing; and
4) Fuel transport/distribution.

The PROESA technology foresees the use of by- and co-products of the ethanol value chain and thus an allocation among the various products was performed. This is the case of the lignin produced in the processing of the biomass which is used to fuel a combined heat and power (CHP) boiler which fulfills the internal needs of the biorefinery and produces some 104 GWh of excess electricity, currently sold to the grid.

The most appropriate methodology for the correct allocation and attribution among co-products of the bioenergy value chain is a highly debated topic. In general, allocation based on economic value of the co-products returns the most reliable results. However, this is true when the comparison is to be made at present or over a short term period. Over a the long term (10+ years) in fact, the unpredictability of market conditions makes it difficult to rely on economic value esteemed at present to project into the next decade the share of impacts among the various co-products of the bioenergy value chain.

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In order to avoid these uncertainties, in this exercise the energy content method was chosen to attribute to each co-product its share of impacts.

Summarizing the extensive calculations performed on this aspect, the 40,000 tons of lignocellulosic ethanol produced yearly are equal to 1,072,400,000 MJ. The generation of 104 GWh of electricity in excess to what is used in the processing stages, equals to a further 374,400,000 MJ. This means that a correct allocation among co-products in energy terms is done as follows:

Ethanol: 74 percent

Surplus electricity: 26 percent

A further sophistication of GHG LCA and attribution is that not all stages of the supply chain generate emissions that require allocation. This is, for instance, the case of the processing of the biomass into fuel for which large quantities of enzymes and yeast are needed to treat the lignocellulosic biomass and produce fermentable sugars. The emissions linked to the production of enzymes and catalysts are not attributable to the surplus electricity but solely to the production of fermentable sugars and therefore ethanol.

The results of this assessment are presented below:

Baseline: petrol

Emission intensity of petrol: 83.3 gCO_{2eq}/MJ (Source: BioGrace, 2014).

Target 1): lignocellulosic ethanol from giant reed irrigated

Emission intensity of lignocellulosic ethanol (allocated results): 26.36 gCO_{2eq}/MJ

Emission reduction compared to baseline: 68.54%

Avoided emissions: 61,227 tons CO_2 per year

Target 2): lignocellulosic ethanol from giant reed rainfed

Emission intensity of lignocellulosic ethanol (allocated results): 30.19 gCO_{2eq}/MJ

Emission reduction compared to baseline: 63.97%

Avoided emissions: 57,147 tons CO_2 per year

Giant reed irrigated:

LCA GHG emission share - allocated results: 26.36 gCO_{2eq}/MJ

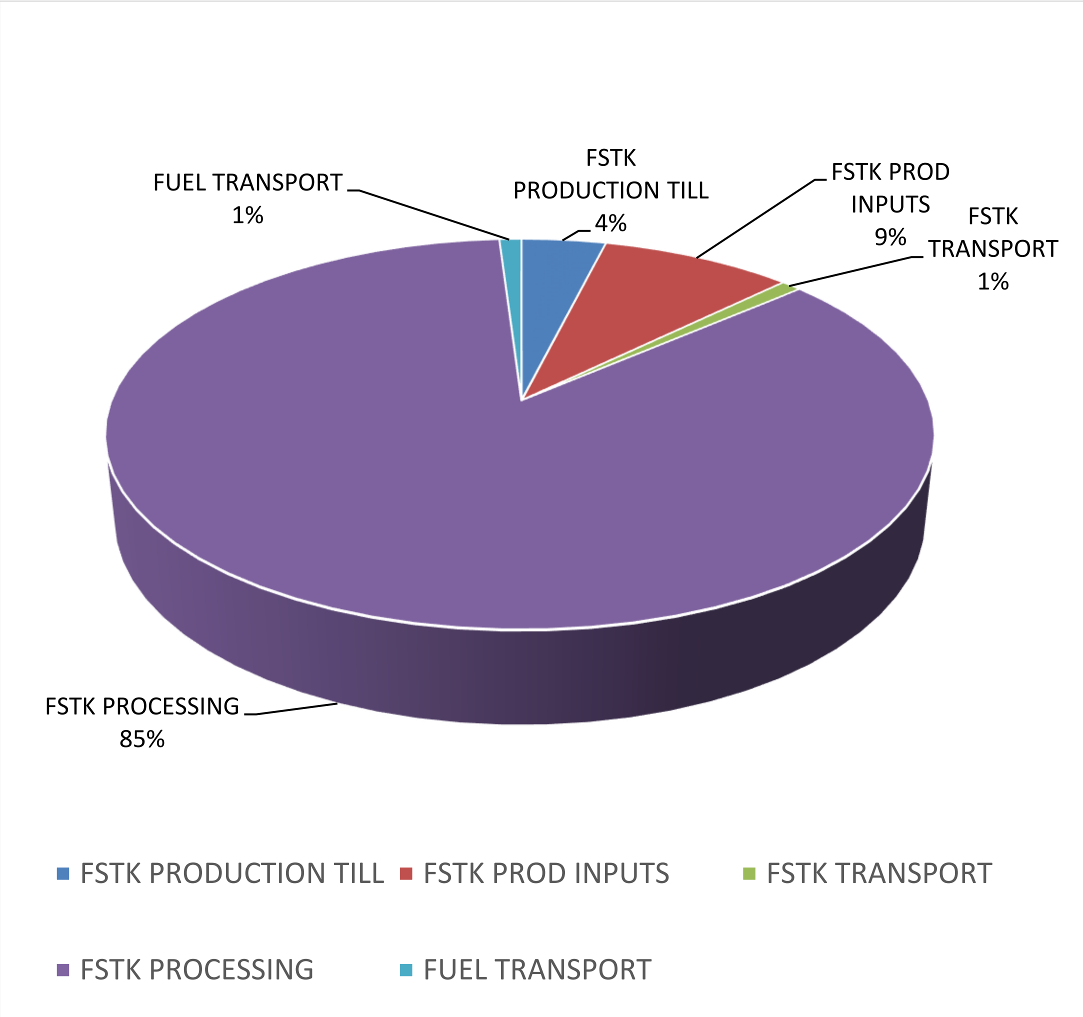

Figure. 8 Share of GHG emission attributable to the various components of the bioenergy value chain of lignocellulosic ethanol from irrigated giant reed.

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Giant reed rainfed:

LCA GHG emission share - allocated results: 30.19 gCO_{2eq}/MJ

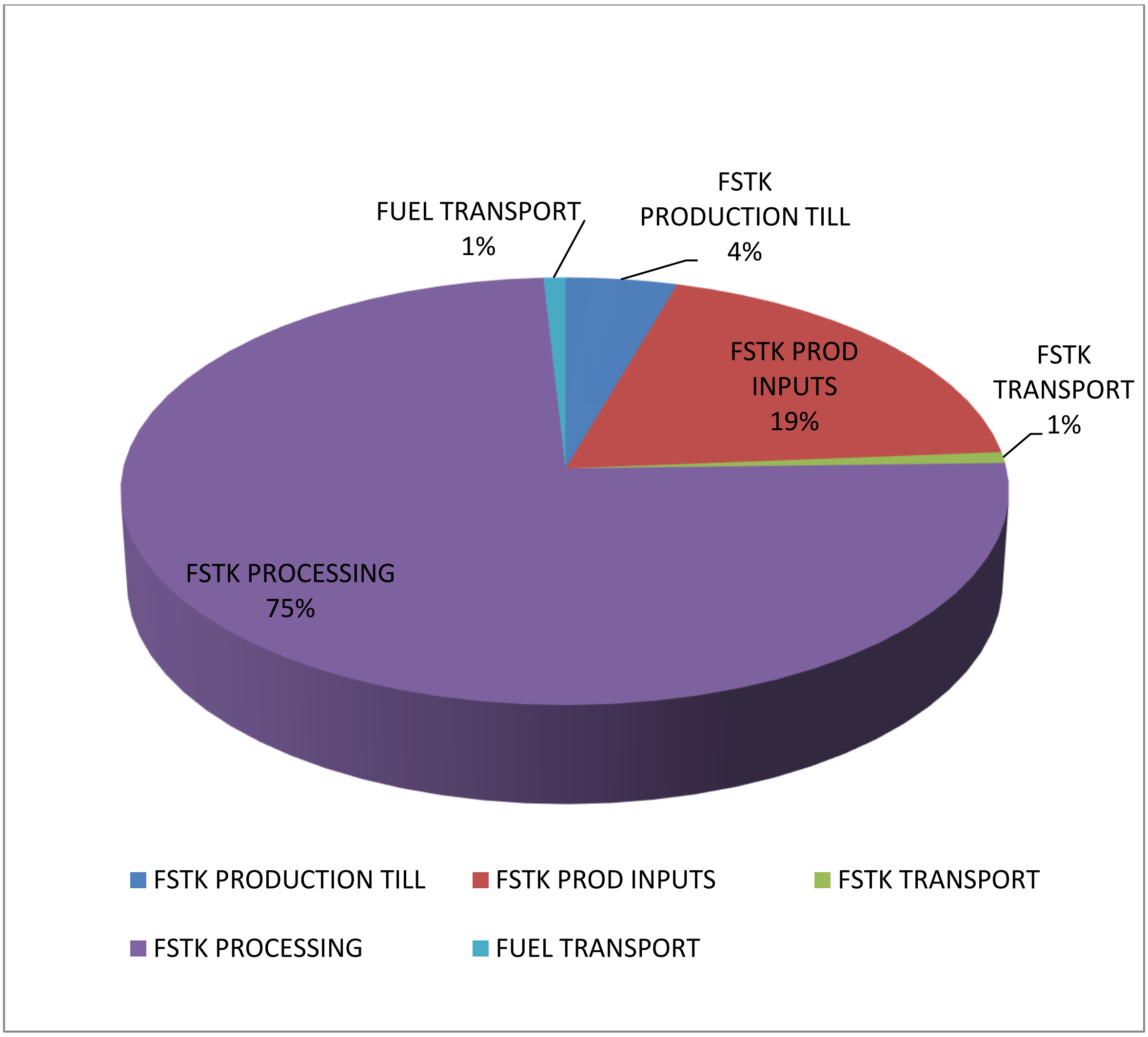

Figure. 9 Share of GHG emission attributable to the various components of the bioenergy value chain of lignocellulosic ethanol from rainfed giant reed.

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The main contributor to the GHG emission intensity of both giant reed scenarios is represented by the emission at the processing stage. The production of enzymes, yeast and other catalyzers of the reactions are energy-intense operations. In the scenario tested, as in the reference biorefinery of Crescetino, these inputs are produced outside the biorefinery by third party actors and therefore the emission intensity of production coupled with the large quantities needed by the biomass conversion technology lead to a relevant share of emissions attributable to this single stage of production. The values calculated in this exercise are in line with the values found on the specific literature on this same topic (Olofsson et al., 2017). These take place outside the system, and the catalysts are subsequently imported.

The most appreciable differences between the two scenarios tested reside in the share total emissions attributable to feedstock production via tillage and inputs, mainly N fertilizers. Fertilizer application to giant reed is limited compared to other bioenergy feedstocks, and given the limited amount a similar quantity of N fertilizer is assumed to be used for both irrigated as well as rainfed cultivation regimes since in literature the yields mentioned and used in this LCA are obtained with similar nutrient management schemes.

Figure. 10 Giant reed under irrigated management regime in one of the field trials in the Sulcis, Italy. Photo credit: Marco Colangeli, FAO.

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2.2.2 Soil Quality

Changes in soil quality of the underutilized lands in the case study have been assessed on the basis of projections and forecasts. The necessity to rely on long term measurement and surveys in the field to survey physico-chemical changes made the quantitative assessment of this indicator through the use of primary data impossible within the extent of this project. Therefore theoretical changes in soil quality parameters have been performed and the results should be interpreted in a qualitative manner, identifying possible trends and reaching indicative conclusions.

The baseline scenario the natural vegetation of the area is represented by Mediterranean grassland which is characterized by very low if not null accumulation and removal of Soil Organic Carbon (SOC). In fact, grassland systems in low productivity, marginal areas tend to be in equilibrium. This means that over the long term there is a particularly slow accumulation of organic matter which tends to be removed at virtually the same rate as the deposition. In agricultural lands in this part of Sardinia, the SOC loss rates are actually rather high. Arca (2016) assessed these changes to be between 7.36 and 9.67 tons per ha per year.

In the target scenario, the cultivation of those underutilized lands with giant reed will introduce carbon (C) inputs in the form of cultivation residues (from above ground biomass) and from below ground biomass (roots, rhizomes, etc.). Arca (2016), measured in three experiemental fields in the ***target area*** the changes in SOC due to the cultivation of giant reed. The assessment of the natural depletion of SOC in the soils on an annual basis in the baseline scenario was higher than 7.36 Mg ha-1 whereas when giant reed was cultivated with N fertilization (100 kg ha-1) the increased production of biomass leaves residues in the fields (both above and below ground) which contribute to constitute a C input of 6.91 tons ha-1 yr-1. The losses in this scenario would be 7.36 tons ha-1 yr-1 which reduce the C losses down to 0.45 Mg of C ha-1.

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2.2.3 Water use and efficiency

Sardinia is located in the heart of the Mediterranean Sea. Its climate is typically characterized by mild wet winters and warm dry summers often with an evident water deficit during the warmest months. However, the abundant precipitations of the fall and winter seasons discharge relevant amounts of water into the basins but the retention capacity of the soils is lower than the discharge and surface runoff occurs. Starting from the second half of the previous century, regional and national authorities have created reservoirs and water catchments in Sardinia to gather the precipitation concentrated during the wet season.

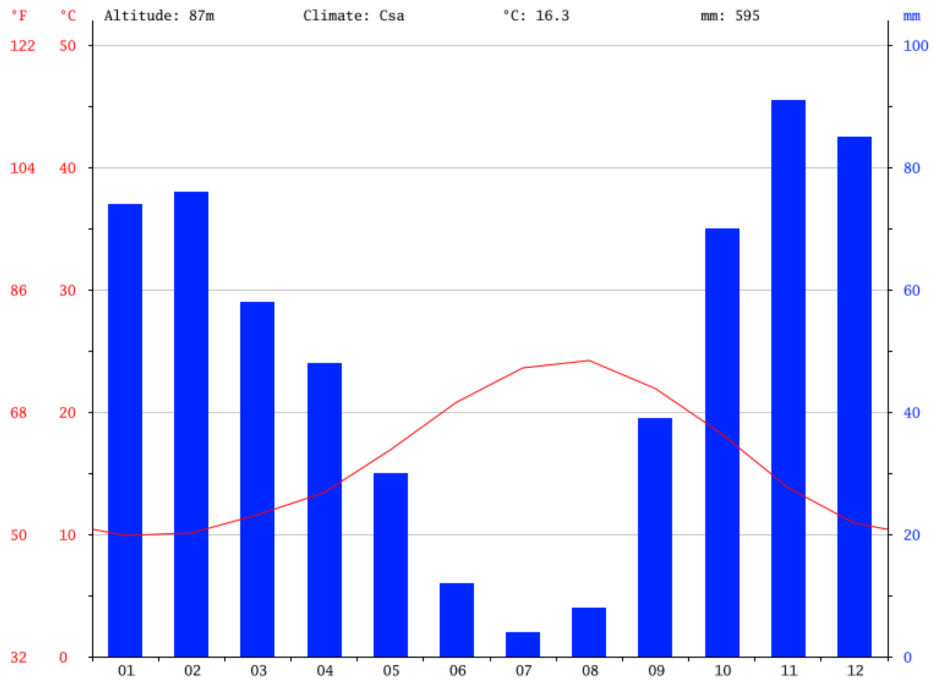

Figure. 11 Climate profile of Carbonia, Sulcis. Source: https://it.climate-data.org/location/14493/

These infrastructures however, are now partially obsolete and require retrofitting in most cases, especially due to the very high losses reported by local sources even though the infrastructure provides water at 5 bar pressure to any outlet and there is no need for further pumping for irrigation systems that work at normal operating pressure. However, the past two years have delivered more water to the reservoirs than the reservoirs can contain, and the administrative authorities have discharged into the bodies of water and ultimately to the sea the water that could not be contained in by the dams. In addition, the abandonment of agricultural activities in the ***target area*** contributes to limit the demand of water for irrigation and the *Consorzi di bonifica*, the local irrigation administrations, are eager to supply irrigation water that remains unsold. Therefore, irrigated vs rainfed agriculture in this particular area of Sardinia is in the case of biomass production more than ever at the center of the debate.

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Along these lines, the two scenarios have been both tested in order to contribute to the aforementioned debate with possibly further science based evidence. The results of the analyses are summarized in Figure 12a and b for the production of lignocellulosic ethanol from irrigate vs rainfed giant reed respectively.

				CROP 1	CROP2	CROP 3	CROP 4
13		Name		G. REED (IRR)	-	-	-
14		Growth cycle		Perennial	-	-	-
15							
16	WATER WITHDRAWN FROM WATERSHEDS WITHIN THE TARGET AREA						
17							
18	Wfstk.ren Renewable Water used for Bioenergy Feedstock Production						
19	Productivity	Crop yield	tonnes/ha	25.0	-	-	-
20	Area Planted	TARGET CULTIVATED SURFACE	Ha	7,200	-	-	-
21		CROP ET	mm/year	857	-	-	-
22		Effective Precipitation	mm/year	662	-	-	-
23		Crop production	tonnes	180,000	-	-	-
24		A. Irr. Req.	mm/year	195	-	-	-
25		Unitary Water req	m3/ha	8,570	-	-	-
26			Km3/year	0.10490400	-	-	-
27		Unitary W(IRR) req	m3/ha	6,000	-	-	-
28			Km3/year	0.04320000	-	-	-
29		Tot Unitary W(IRR) Req.	Km3/year			0.04320000	
30		Wfstk ren	Km3/year	0.10490400	-	-	-
31	TOT Wfstk ren	0.10490400	Km3/year				
32	% Blue water	41.18%					
33	Wpro.ren Renewable Water used for Bioenergy Processing				TARWR Total Actual Renewable Water Resources		

Figure. 12a Water use and efficiency profile for irrigated giant reed.

The production of biomass from irrigated giant reed requires additional 6,000 m^3 of blue water per hectare. This translates into a total water requirement of 0.1049 km^3/year to provide water for the entire value chain (7,200 ha for 40,000 tons of ethanol). The blue water percentage over total water use of the agricultural phase is 41.18%.

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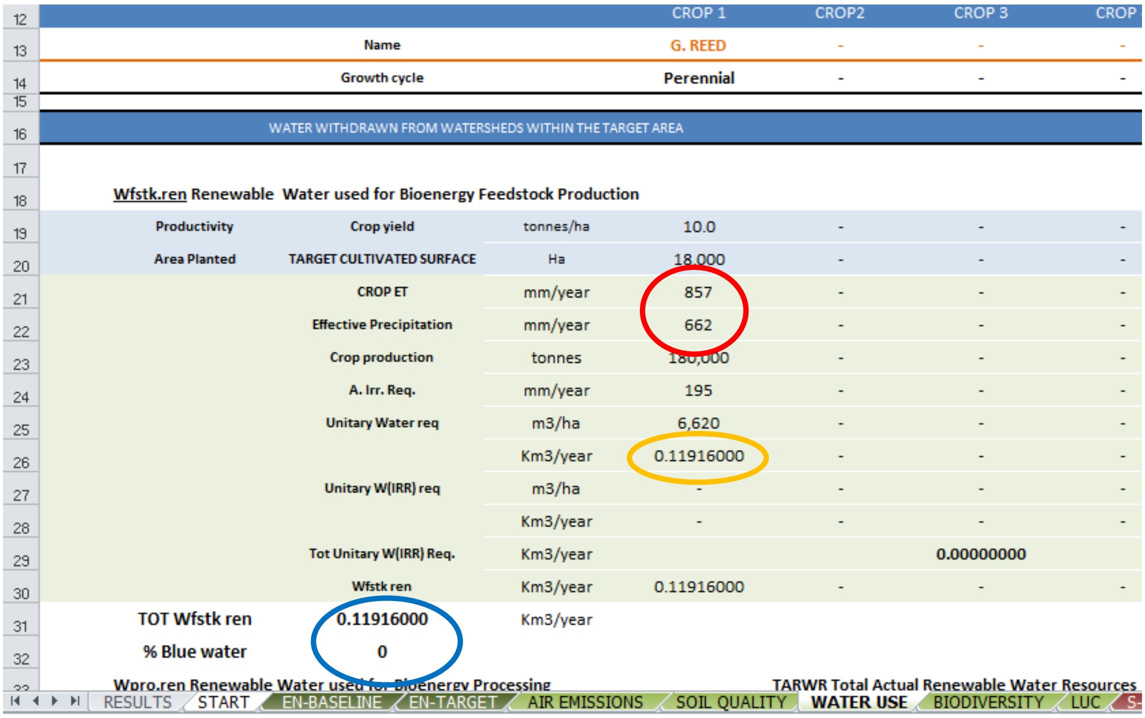

				CROP 1	CROP2	CROP 3	CROP
13		Name		G. REED	-	-	-
14		Growth cycle		Perennial	-	-	-
15							
16	WATER WITHDRAWN FROM WATERSHEDS WITHIN THE TARGET AREA						
17							
18	Wfstk.ren Renewable Water used for Bioenergy Feedstock Production						
19	Productivity	Crop yield	tonnes/ha	10.0	-	-	-
20	Area Planted	TARGET CULTIVATED SURFACE	Ha	18,000	-	-	-
21		CROP ET	mm/year	857	-	-	-
22		Effective Precipitation	mm/year	662	-	-	-
23		Crop production	tonnes	180,000	-	-	-
24		A. Irr. Req.	mm/year	195	-	-	-
25		Unitary Water req	m3/ha	6,620	-	-	-
26			Km3/year	0.11916000	-	-	-
27		Unitary W(IRR) req	m3/ha	-	-	-	-
28			Km3/year	-	-	-	-
29		Tot Unitary W(IRR) Req.	Km3/year			0.00000000	
30		Wfstk ren	Km3/year	0.11916000	-	-	-
31	TOT Wfstk ren	0.11916000	Km3/year				
32	% Blue water	0					
33	Wpro.ren Renewable Water used for Bioenergy Processing				TARWR Total Actual Renewable Water Resources		

Figure. 12b Water use and efficiency profile for rainfed giant reed.

The production of biomass from rainfed giant reed requires no additional irrigation water but returns lower yields (10 t ha-1 yr-1 vs 25 t ha-1 yr -1) than irrigated giant reed. This translates into a total water requirement of 0.1191 km^3/year to provide water for the entire value chain (18,000 ha for 40,000 tons of ethanol). The blue water percentage over total water use of the agricultural phase is 0% as the totality of the water used by the plants is green water.

Therefore, as expected, from a water use point of view, under rainfed conditions the use of blue water is zero compared to 0.0432 km^3/year in case the bioenergy feedstock is irrigated.

In terms of efficient use of water resources however there are some interesting differences. The impact of water use and efficiency of the water requirements of the processing stage (i.e. water makeup of 1.30 m^3 per ton of feedstock) is obviously the same in both scenarios and thus the differences are solely attributable to the cultivation phase of the supply chain.

Under irrigated regime, the amount of total water (blue, green and grey) used for the production of 1 megajoule of ethanol is 0.098 m^3.

Under rainfed conditions, the amount of total water (blue, green and grey) used for the production of 1 megajoule of ethanol is 0.111 m^3.

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

These differences are to be attributed to the enhanced efficiency of biomass production due to the conditions of water stress. In other words, by eliminating the water stress not only the giant reed produces 2.5 times more biomass per ha than in rainfed conditions, but this production is also about 10% more water efficient.

IRRIGATED GIANT REED

$W_{bioenergy\_ren}$ / TARWR x 100%	-		
$W_{bioenergy}$/TAWW x 100%	-		
TAWW	-	m3/year	
			l/MJ
$W_{bioenergy}$ / E_{total}	0.09803991	m3/MJ	98.03991048
Production	2622.60	$m^3/t_{feedstock}$	

SIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET

Figure. 13a Water use and efficiency results for irrigated giant reed.

RAINFED GIANT REED

$W_{bioenergy\_ren}$ / TARWR x 100%	-		
$W_{bioenergy}$/TAWW x 100%	-		
TAWW	-	m3/year	
			l/MJ
$W_{bioenergy}$ / E_{total}	0.111333458	m3/MJ	111.3334577
Production	2979.00	$m^3/t_{feedstock}$	

R EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | L

Figure. 13b Water use and efficiency results for rainfed giant reed.

The two scenarios tested in the target situation have returned different and interesting results for this crucial indicator. It should be noted that the outcomes of Deliverable D 2.1 and D 2.2 assumed that the biorefinery requirements in terms of feedstock can be entirely met with the production of giant reed under irrigation regime. As we have seen previously, to date the infrastructure is not present and thus giant reed could not be grown entirely under irrigated conditions.

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

2.2.4 Water Quality

The impacts of bioenergy production on water quality have been determined in the case study of Italy thanks to the excellent contribution of CREA and the support of the University of Texas and the United States Department of Agriculture (USDA). The experts of the Italian Council based in Cagliari, Sardinia, have performed a test using the Soil and Water Assessment Tool (SWAT) model, which was developed by the American University and USDA. This tool runs in a GIS environment and is capable of reconstructing the dynamics of transport of matter within a system. The system in this specific case was represented by the ***target area*** in the Sulcis. This is the first of-its-kind example of application of this tool to assess the impacts on water quality of giant reed for bioenergy purposes in the island of Sardinia. The outcomes of the exercise are particularly interesting from a scientific point of view for at least two reasons. Firstly because this assessment is to date the most reliable and accurate method to predict long term movement of matter (especially N fertilizer) into the bodies of water as a consequence of the transport, runoff, and leaching. Secondly, because this pioneering application of SWAT in this specific context will constitute a novelty in the specialized literature and it is expected to lead to further research in this field. The results of the assessment are based on the mapping of the area and on the spatial distribution of the variables analyzed in the Baseline vs Target Scenario.

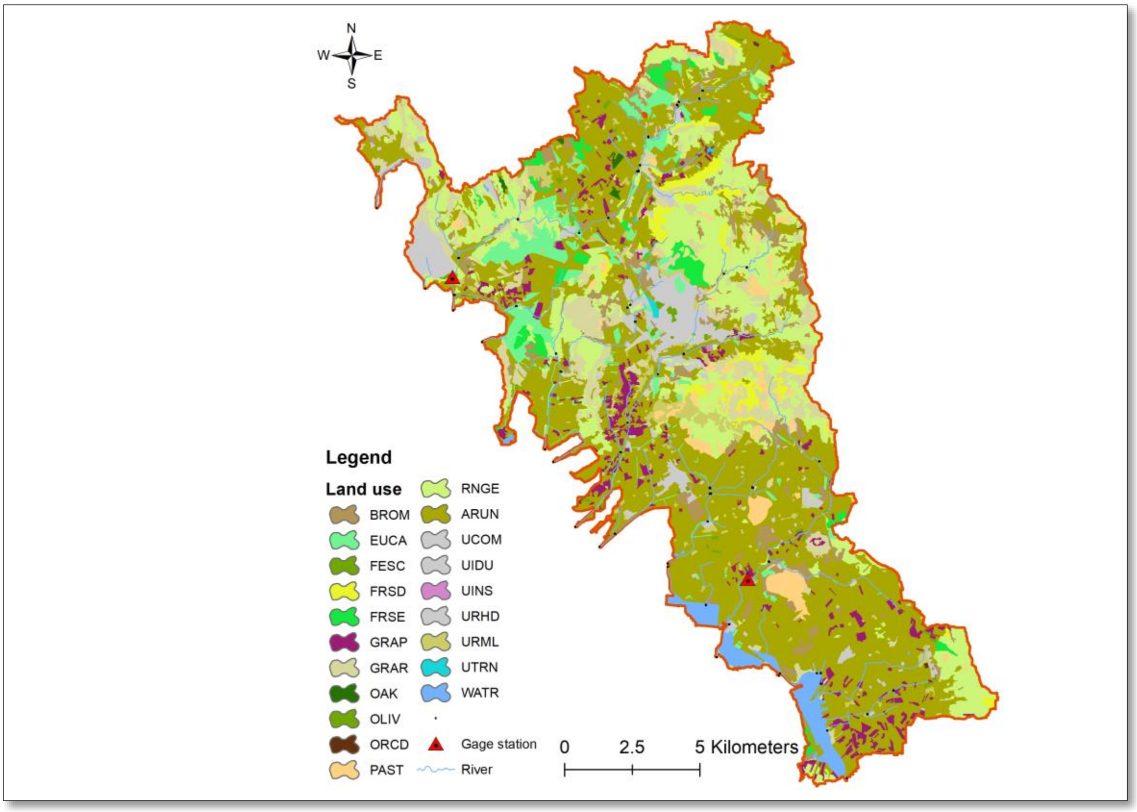

Figure. 14 Spatial distribution of rainfed giant reed (olive-green "ARUN" in the legend) on underutilized lands in the *target area*.

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

In Baseline, the most common crops grown in the ***target area*** are vegetables and cereals. The Target scenario looks at giant reed under rainfed conditions (figure 14). The results of the simulation between the two scenarios is presented in the table below:

Table 1. Loadings of sediments and pollutants in the bodies of water within the *target area*.

Scenario	Sediment loading	Total N losses	Surface runoff
Baseline scenario	2.4 Mg/ha	33.2 kg/ha	64.3 mm/yr
Target scenario	1.12 Mg/ha	16.4 kg/ha	68 mm/yr
Change	-64%	-51.61%	+5.7%

Author: Giuseppe Pulighe, CREA.

The SWAT model calculated, on the basis of the list of inputs and quantities used for the production of the various crops present in the area, the physico-chemical attributes of the ***target area*** and the management techniques applied, the changes in sediment loadings, total N losses and surface runoff attributable to the baseline and target scenario.

The scenario with giant reed, a perennial grass, is characterized by a reduced sediment loading transport of two thirds compared to the baseline scenario (wheat). Even though surface runoff is slightly higher with giant reed than with annual crops, the absence of tillage in the years following the first, reduce the sediment loadings into the bodies of water greatly. Total losses of N are about half the amount measured when a food crops is grown on the same areas because of the lower input demand of giant reed over the compared food crops and because, again, of the no tillage in subsequent years of production.

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2.2.5 Biodiversity

At EU level, there is a list of endangered species and critical habitats that should be monitored when these are naturally present in the area of a possible agricultural project. The list is reported in the figure below and represents the checklist of animal species of interest and their presence in the Italian territory.

COUNTRY	IT		
		SPECIES	**TYPICAL HABITAT**
	NO	Great bustard, Otis tarda	Dry grasslands and mosaic of crops and grasslands
	YES	Large blue butterfly, Maculinea arion	Dry grasslands
	YES	Corncrake, Crex crex	Meadows
	YES	Meadow viper, Vipera ursinii	Meadows
	YES	Yellow-bellied toad, Bombina variegata	Wetlands (and forests)
	YES	Bittern, Botaurus stellaris	Wetlands (reedbeds)
	NO	Hamster, Cricetus cricetus	Arable land
	YES	Skylark, Alauda arvensis	Arable land
	YES	Ortolan Bunting, Emberiza hortulana	Extensive arable land with single trees, orchards, forest mar
	YES	Scops owl, Otus scops	Extensive agri-pastoral systems especially with old trees or
	YES	Great capricorn beetle, Cerambyx cerdo	Forests and veteran trees
	YES	Capercaillie, Tetrao urogallus	Forests

Figure. 15 List of endangered species in Europe and their presence in the case study Country.

However, in the island of Sardinia some of the endangered species present in the Italian territory are not present (e.g. Bombina variegate, Vipera ursinii, Crex Crex, etc.). According to the data collection campaign carried out during the FORBIO project, the ***target area*** in Sardinia, Italy (35,745 ha), is interested by the presence of nationally determined critical habitats and high biodiversity areas for a total of 9,029 ha or about 25% of the ***target area***. The remaining 26,700 hectares within the ***target area*** then are not interested by the presence of critical habitats.

48	**Total target area**	**35,745** ha			
49	**Total high biodiversity areas surface**	Ha	9,029.0		BALANCE
50	Total areas where critically endangered species are found	Ha	**4,031.0**		**26,716**
51	Total important ecosystems	Ha	**4,998.0**		
52	Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species	Ha	**1,720.0**		
53	Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)	Ha	**2,311.0**		
54	Important natural landscape areas for natural ecological dynamics	Ha	**4,998.0**		
55	Areas that contain two or more contiguous ecosystems	Ha	**0.0**		
56	Areas containing rare or endangered ecosystems	Ha	**0.0**		
57	Not included		26,716		

Figure. 16 Breakdown of the areas of critically endangered species and important ecosystems are found within the *target area* in the Sulcis, Italy.

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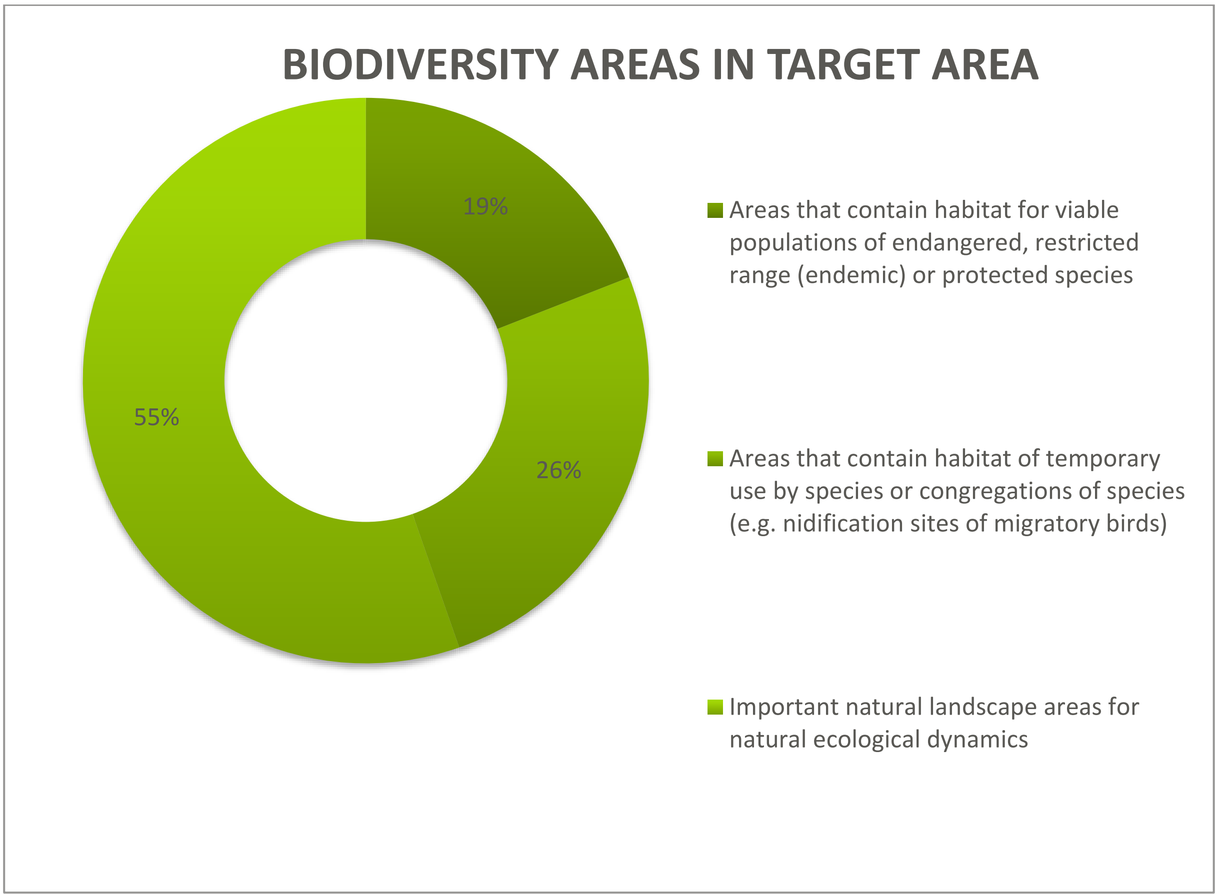

Figure. 17 Breakdown of high biodiversity value areas (critically endangered species + important ecosystems) and percentages within the *target area* in the Sulcis, Italy.

In Figure 5 the breakdown of the land cover types within the ***target area*** offers an overview of the various land cover types and an indication of their extension. Forest cover some 7,330 ha, agricultural land (contaminated and underutilized) some 18,700 ha, and other lands (including industrial sites and urban centers, but also natural meadows and shurblands) account for a further 9,700 ha. In particular, other natural land types such as meadows and shrublands (not agricultural, forest, or industrial/urban areas) represent about 7,331 ha.

Forests and other natural landscapes represent the majority of the Important natural landscape areas for natural ecological dynamics (4,998 ha) and areas that contain habitats for endangered populations, endemics and protected species.

The production of bioenergy in the target scenario would target solely undertulized agricultural land. These areas may contain habitats temporarily used by species or congregations (2,311 ha or 26% of total biodiversity value areas). During the

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

FORBIO project it was not possible to measure quantitatively species richness of the current underutilized and contaminated lands, and in literature only anecdotal information was retrieved. The analysis of species richness in the baseline scenario would require the collection of year-round primary data on the various components of the biota (e.g. plant diversity, animal diversity, soil diversity, including fungi and bacteria) therefore the assessment of this indicator has been more qualitative.

According to Sardinian Wetlands (2018), giant reed in the island represents an important habitat for migratory bird species that find protection through offered by the reeds during the winter period. The existence of a more complex canopy and layer structure in the reed bed when compared to agricultural lands is thought to provide a variety of habitats for different animal species. In addition, being *Arundo donax* a perennial grass, soil tillage does not take place after the first year. The lesser disturbance of the soil contributes to higher species diversity in this medium, as confirmed by several authors (Alexopoulou, 2018; Biemans et al., 2008).

One last aspect to keep into consideration is the invasive character of giant reed. The plant is known for its invasiveness even though in Sardinia the plant is established and could be considered a naturalized alien. This aspect should be regarded especially when it comes to the eradication of the crop, at the end of its life cycle. The need for powerful herbicides to inhibit the growth of giant reed thus may have a strong impact on the soil diversity as a consequence of the use of such pest control systems.

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FOR BIO

2.2.6 Land Cover and Land Use Changes

The production of biomass for energy purposes in the target scenario will lead to a change in land cover types when compared to the current conditions (baseline scenario). Understanding the entity of this change and the turnover between difference land cover classes is useful to land use planners to have an understanding of the development trends that will interest their territory.

The outcomes of the analyses of the dynamics of the two target scenario tested (T1 Irrigated Giant Reed; T2 Rainfed Giant Reed) are presented in Figure 18 and 19, below.

CHANGE IN LAND USE and LAND COVER TYPE — GIANT REED IRRIGATED — 7,200 ha

BASELINE			TARGET		
Total annual crops and fallow lands	Ha	14,796	Total Annual crops	Ha	7,596
Total annual crops and fallow lands for FSTK product	Ha	0	Total annual crops and fallow lands for	Ha	0
Total permanent crops	Ha	1,338	Total permanent crops	Ha	8,538
Total permanent meadows and pastures	Ha	2,572	Total permanent meadows and pasture	Ha	2,572
Total permanent crops for FSTK production	Ha	0	Total permanent crops for FSTK produc	Ha	7,200
Underutilized agricultural land	Ha	18,706	**Underutilized agricultural land**	Ha	11,506
Underutilized NON-agricultural land (e.g. EX-minin	Ha	1,117	**Underutilized NON-agricultural land (**	Ha	1,117

RATE OF CONVERSION

	% of conversion
Agriculture	
Annual crops and fallow lands (FAOSTAT Arable Land)	-48.7
Permanent crops	538.1
Underutilized agricultural land	-38.5
Others lands	
Underutilized NON-agricultural land (e.g. EX-mining sites)	0.0

RESULTS / START / EN-BASELINE / EN-TARGET / AIR EMISSIONS / SOIL QUALITY / WATER USE / BIODIVERSITY / LUC / S-BASELINE / S-TARGET / LAND TEN. / INCOME / JOBS / ENERGY

Figure. 18 Irrigated Giant Reed: Changes is land cover type and rates of conversion within the *target area* in the Sulcis, Italy.

At baseline, in the ***target area*** there are some 14,796 ha of underutilized (contaminated) agricultural land under annual crops or fallow management regime. As of today, no dedicated bioenergy feedstock is produced in the area. In the target scenario, the land required for the production of giant reed under irrigated conditions (7,200 ha) is obtained through the substitution of the current annual crops and fallow land. This will lead to a 48.7% decrement of said land cover category down to 7,596 ha. Concurrently, the total surface under perennial crops will grow from 1,338 ha to 8,538 and thus dedicated bioenergy feedstock production will increase to 7,200 ha (538% growth). This scenario would not interest permanent meadows and pastures since these are likely the last areas that could be equipped with irrigation infrastructures.

Finally, the expected rate of conversion of underutilized lands into dedicated bioenergy feedstock production land will be 38.5%.

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		GIANT REED RAINFED	18,000 ha		
CHANGE IN LAND USE and LAND COVER TYPE					
BASELINE			TARGET		
Total annual crops and fallow lands	Ha	14.796	Total Annual crops	Ha	0
Total annual crops and fallow lands for FSTK product	Ha	0	Total annual crops and fallow lands for	Ha	0
Total permanent crops	Ha	1.338	Total permanent crops	Ha	18.632
Total permanent meadows and pastures	Ha	2.572	Total permanent meadows and pasture	Ha	0
Total permanent crops for FSTK production	Ha	0	Total permanent crops for FSTK produc	Ha	18.000
Underutilized agricultural land	Ha	18.706	**Underutilized agricultural land**	Ha	632
Underutilized NON-agricultural land (e.g. EX-minin	Ha	1.117	**Underutilized NON-agricultural land (**	Ha	1.117

RATE OF CONVERSION	
Agriculture	% of conversion
Annual crops and fallow lands (FAOSTAT Arable Land)	-100,0
Permanent crops	1.292,5
Permanent meadows	-100,0
Underutilized agricultural land	-96,6
Others lands	
Underutilized NON-agricultural land (e.g. EX-mining sites)	0,0

Figure. 19 Rainfed Giant Reed: Changes is land cover type and rates of conversion within the *target area* in the Sulcis, Italy.

At baseline, in the ***target area*** there are some 14,796 ha of underutilized (contaminated) agricultural land under annual crops or fallow management regime. As of today, no dedicated bioenergy feedstock is produced in the area. In the target scenario, the land required for the production of giant reed under rainfed conditions (18,000 ha) is obtained through the substitution of the current annual crops and fallow land and the substitution of the current permanent pastures and meadows (2,572 ha) and the substitution of 706 ha of current permanent crops with the dedicated bioenergy crops. This will lead to a 96.6% decrement of the underutilized agricultural land, and only 3.4% of the contaminated land currently covered by perennial crops (olive groves, vineyards, etc.) will remain. Consequently, the total surface under perennial crops will grow from 1,338 ha to 18,632 ha of which 18,000 (96.6%) represented by giant reed under rainfed conditions, and the remaining 632 ha are represented by the aforementioned permanent crops.

Summarizing, the expected rate of conversion of underutilized lands into dedicated bioenergy feedstock production land will be 96.6% in this scenario.

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2.2.7 Land Tenure

The land tenure structure of the ***target area*** is rather straightforward: all agricultural underutilized land is privately owned. Information to define the rates of change between land cover categories is lifted from chapter 2.2.6 Land Cover and Land Use Changes and it was matched with records from the bureau of Geographical Statistics of Sardinia (Sardegna Geoportale, 2018).

Sardinia is the Italian region characterized by the largest average farm size in the country with 19.2 ha (Regione Sardegna, 2018). Traditionally agriculture in the region is characterized mainly by extensive agriculture types. The most common production typologies of farms registered in Sardinia is sheep farms equipped with small to medium size cheese factories, and grain production farms (Coldiretti Sardegna, 2018) both of which are extensive agriculture types which require large surfaces of land.

The results of this exercise reflect the rates of change explained in 2.2.6 and express the related incidence of change between tenure classes:

- Private land: smallholders, farmers and agricultural entrepreneurs up to 30 ha
- Companies: agricultural holdings and private company entities owning surfaces of more than 30 ha
- Public/Government: farms owned by public entities, both local or national
- Others: land owned by entities (often privates) that do not necessarily have the land registered for agricultural uses (e.g. banks, insurance companies, etc.)

In the ***target area*** the totality of the underutilized land for both scenarios tested is represented by current privately owned farms (less than 30 ha each).

The land registrar of Italy is well defined, modern and organized. The system is highly informatized and access to information is optimal. The service however, is not free of charge and a varying fee is to be paid for each operation, depending upon the operation. However, an interested user can access maps and obtain information on the ownership type of a specific parcel of land comfortably from home. The land registrar website (Catasto, 2018) offers click-ready services to anyone remotely. This system is extremely efficient (even though expensive) and would allow an interest user to get in touch with the owner of a specific parcel, shall the user be interested in purchasing or renting the land from that owner to develop a dedicated bioenery feedstock production. The history of the parcel is documented and the files obtained from the online land registrar constitute an evidence and body of proof, being also accepted in official land tenure acts. In the context of FORBIO then, it is expected that the land ownership of the underutilized lands (100% private land) will not change drastically, and remain primarily privately-owned land.

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Figures 20 reports a summary of the changes (or lack thereof) and the attribution to each ownership category of its contribution to the new land use pattern in the irrigated giant reed target scenario. The case of rainfed giant reed is similar in the lack of changes, but only absolute values change.

B / C	D	E	F	G	H	I	J	K	L	M	N
BASELINE		**total**	**BALANCE**	**Private land**	**%**	**Companies**	**%**	**Public or Governm**	**%**	**Others**	**%**
Annual crops and fallow lands (FAOSTAT Arable La	Ha	14,796	100.0%	0	100.0%	0	0.0%	0	0.0%	0	0.0%
Permanent crops	Ha	1,338	100.0%	0	100.0%	0	0.0%	0	0.0%	0	0.0%
Underutilized/contaminated agricultural land	Ha	18,706	100.0%	0	100.0%	0	0.0%	0	0.0%	0	0.0%
Underutilized/contaminated NON-agricultural la	Ha	1,117	100.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%
TARGET		**total**	**BALANCE**	**Private land**	**%**	**Companies**	**%**	**Public or Governm**	**%**	**Others**	**%**
Annual crops and fallow lands (FAOSTAT Arable La	Ha	7,596	100.0%	0	100.0%	0	0.0%	0	0.0%	0	0.0%
Permanent crops	Ha	8,538	100.0%	7,200	100.0%	0	0.0%	0	0.0%	0	0.0%
Underutilized agricultural land	Ha	11,506	100.0%	-7,200	100.0%	0	0.0%	0	0.0%	0	0.0%
Underutilized NON-agricultural land (e.g. EX-min	Ha	1,117	100.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%
CHANGE		**total**		**Private land**	**%**	**Companies**	**%**	**Public or Governm**	**%**	**Others**	**%**
Annual crops and fallow lands (FAOSTAT Arable La	Ha	-7,200		0	0.0%	0	0.0%	0	0.0%	0	0.0%
Permanent crops	Ha	7,200		7,200	0.0%	0	0.0%	0	0.0%	0	0.0%
Underutilized agricultural land	Ha	-7,200		7,200	0.0%	0	0.0%	0	0.0%	0	0.0%
Underutilized NON-agricultural land (e.g. EX-min	Ha	0		0	0.0%	0	0.0%	0	0.0%	0	0.0%

CHANGE IN PERCENTAGE

Annual	**Private land**	0.00%	Perennial	**Private land**	0.0%	Agricultural	**Private land**	0.0%	Non agricultural	**Private land**	0.0%
Agricultural	**Companies**	0.00%	Agricultural	**Companies**	0.0%	Underutilized	**Companies**	0.0%	Underutilized	**Companies**	0.0%
	Public or Government	0.00%		**Public or Governm**	0.0%		**Public or Governm**	0.0%		**Public or Governm**	0.0%
	Others	0.00%		**Others**	0.0%		**Others**	0.0%		**Others**	0.0%

RESULTS / START / EN-BASELINE / EN-TARGET / AIR EMISSIONS / SOIL QUALITY / WATER USE / BIODIVERSITY / LUC / S-BASELINE / S-TARGET / **LAND TEN.** / INCOME / JOBS / ENERGY

Figure. 20 Irrigated Giant Reed: Changes is land ownership type and rates of conversion within the land ownership category in the Sulcis case study, Italy.

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2.2.8 Jobs in the bioenergy sector

An indicator of particular relevance in the context of the case study of Italy is the indicator on changes on employment attributable to the bioenergy value chain. The Sulcis has one of lowest GDP per capita among the provinces of Italy and in recent years it classified on the last percentile of the provinces of Italy by overall quality of life (99th out of 110 provinces according to ItaliaOggi, 2017).

The total population in the ***target area*** is 127,062 inhabitants. The working population (men and women, age group 20-64) is 59,465 (ISTAT, 2018), thus the unemployment rate in this area of Italy is a whopping 53.1%. The share of unskilled vs skilled jobs in the area is 11.1% while 19% of the jobs are temporary as the remaining 81% are permanent jobs. At baseline, the number of employees in the bioenergy sector is zero.

Advanced bioenergy value chains have the potential to produce employment in the agriculture sector (feedstock production) as well as in the industrial sector (feedstock processing) and accessory sectors too (e.g. transport of biomass, induced jobs for the production of inputs, machineries, etc.). It is expected that the majority of the jobs in the agriculture and transport sectors will be temporary employment. In the processing stages and partially in the management of the farms (given the structure of farms in the ***target area*** which are mainly family-owned and managed) jobs are expected to be predominantly year-round permanent ones.

In the target scenario T1 (irrigated giant reed) the advanced bioenergy value chain would employ both temporary and permanent workers to plant, cultivate, harvest 7,200 ha and transport the feedstock to the hypothetical biorefinery located in Portovesme. The construction of the biorefinery would also generate jobs but these are considered indirect and not included in this forecast. Though the maintenance and operations of the biorefinery would generate some 121 highly skilled, permanent jobs which summed to the 701 jobs in the other sectors of the value chain would totalize 822 direct net jobs created by the value chain. Figure 21a and b recap the changes in employment due to the hypothetical advanced bioenergy value chain in the ***target area***. Once at regime, the lignocellulosic ethanol value chain would contribute to decreasing the unemployment rate of the area by 0.64%, employing 1.4 percent of the workforce. At the national level, these changes have minor relevance, though as the level of the ***target area*** the social impacts of this value chain may be considerable. In total 305 temporary and/or seasonal jobs and 517 permanent jobs would be created, 37 and 63% of total respectively. Lastly, it is interesting to note that 100% of the newly created jobs would be skilled jobs, as the nature of the value chain and its novelty in the area requires trained and skilled workers to carry out qualified tasks. The amount of jobs in the agriculture and transport sectors generated per ha would be 0.097 (only jobs in the processing stage are excluded from this calculation).

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FORBIO Assessment of Sustainability Tool FAST

Food and Agriculture Organization of the United Nation (FAO) / Global Bioenergy Partnership (GBEP)
FORBIO Project H2020

GY SECTOR

			UNDERUTILIZED AGRICULTURAL LAND					UNDERUTILIZED NON AGRICULTURAL LAND				
FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1	CROP2	CROP 3	CROP 4	CROP 5
Name		G. REED (IRR)	-	-	-	-	-	-	-	-	-
Growth cycle		Perennial	-	-	-	-	-	-	-	-	-
TARGET CULTIVATED SURFACE	Ha	7,200	-	-	-	-	-	-	-	-	-
	SPECIALIZED + SKILLED	9,870	0	0	0	0	0	0	0	0	0
	TEMPORARY	3,660	0	0	0	0	0	0	0	0	0
	PERMANENT	6,210	0	0	0	0	0	0	0	0	0

NUMBER of JOB POSITIONS			
	TOTAL	822	
	UNSKILLED	0	
	SPECIALIZED + SKILLED	822	
	TEMPORARY	305	37.08%
	PERMANENT	517	62.92%

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY

Figure. 21a Irrigated Giant Reed: changes in employment due to the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy).

NATIONAL	BASELINE	TARGET	BASELINE	TARGET	Δ NUMBER	Δ%
total population	60,589,445	60,589,445				
Total working population, men and women, age group 20-64	37,747,224	37,748,047	62.3	62.3	822	0.001
Low skilled persons, age group 20-64	19,251,084	19,251,084	51.0	51.0	0	-0.001
Skilled persons, age group 20-64	18,496,140	18,496,962	49.0	49.0	822	0.001
Total temporary employees	4,454,172	4,454,477	11.8	11.8	305	0.001
Total permanent employees	33,293,052	33,293,569	88.2	88.2	517	-0.001
Number of men and women, age group 20-64 in the **BIOENERGY SECTOR**	0	822	-	0.0	822	0.000

TARGET AREA	BASELINE	TARGET	BASELINE	TARGET	Δ NUMBER	Δ%
total population	127,062	127,062				
Total working population, men and women, age group 20-64	59,465	60,288	46.8	47.4	822	0.647
Low skilled persons, age group 20-64	6,589	6,589	11.1	10.9	0	-0.151
Skilled persons, age group 20-64	52,258	53,080	87.9	88.0	822	0.165
Total temporary employees	11,298	11,603	19.0	19.2	305	0.247
Total permanent employees	48,167	48,684	81.0	80.8	517	-0.247
Number of men and women, age group 20-64 in the **BIOENERGY SECTOR**	0	822	0.0	1.4	822	1.364

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY

Figure. 21b Irrigated Giant Reed: changes in employment due to the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy).

In the target scenario T2 (rainfed giant reed) the advanced bioenergy value chain would employ both temporary and permanent workers to plant, cultivate, harvest 18,000 ha and transport the feedstock to the hypothetical biorefinery located in Portovesme. As before the likely jobs attributable to the construction of the biorefinery are not included in this forecast. Maintenance and operations of the biorefinery would generate some the same 121 highly skilled, permanent jobs. Similarly to many other bioenergy value chains, the relative weight of the agricultural phase in the total balance of jobs is relevant. The amount of jobs created per unit of surface would be 0.067/ha, though this multiplied for a much higher number of hectares leads to a total of 1,229 new jobs for a total of 1,350 direct jobs created by the advanced biofuel value chain. Figure 22a and b recap the changes in

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employment due to the hypothetical advanced bioenergy value chain in the ***target area***. Once at regime, the lignocellulosic ethanol value chain would contribute to decreasing the unemployment rate of the area by 1.06%, employing 2.2 percent of the workforce. At ***target area*** level the social impacts of this value chain may be considerable. In total 613 temporary and/or seasonal jobs and 737 permanent jobs would be created, 45 and 55% of total respectively. Lastly, as in the case of T1, 100% of the newly created jobs would be skilled jobs, as the nature of the value chain and its novelty in the area requires trained and skilled workers to carry out qualified tasks.

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GY SECTOR

		UNDERUTILIZED AGRICULTURAL LAND					UNDERUTILIZED NON AGRICULTURAL LAND				
FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1	CROP2	CROP 3	CROP 4	CROP 5
Name		G. REED	-	-	-	-	-	-	-	-	-
Growth cycle		Perennial	-	-	-	-	-	-	-	-	-
TARGET CULTIVATED SURFACE	Ha	18,000	-	-	-	-	-	-	-	-	-

NUMBER of JOB POSITIONS	TOTAL	1,350	
	UNSKILLED	0	
	SPECIALIZED + SKILLED	1,350	
	TEMPORARY	613	45.38%
	PERMANENT	737	54.62%

NATIONAL	BASELINE	TARGET	BASELINE	TARGET	NATIONAL	
					Δ NUMBER	Δ %
total population	60,589,445	60,589,445				

EN-BASELINE / EN-TARGET / AIR EMISSIONS / SOIL QUALITY / WATER USE / BIODIVERSITY / LUC / S-BASELINE / S-TARGET / LAND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASEL

Figure. 22a Rainfed Giant Reed: changes in employment due to the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy).

NATIONAL	BASELINE	TARGET	BASELINE	TARGET	NATIONAL Δ NUMBER	Δ %
total population	60,589,445	60,589,445				
Total working population, men and women, age group 20-64	37,747,224	37,748,574	62.3	62.3	1350	0.002
Low skilled persons, age group 20-64	19,251,084	19,251,084	51.0	51.0	0	-0.002
Skilled persons, age group 20-64	18,496,140	18,497,490	49.0	49.0	1350	0.002
Total temporary employees	4,454,172	4,454,785	11.8	11.8	613	0.001
Total permanent employees	33,293,052	33,293,789	88.2	88.2	737	-0.001
Number of men and women, age group 20-64 in the **BIOENERGY SECTOR**	0	1,350	-	0.0	1350	0.000

TARGET AREA	BASELINE	TARGET	BASELINE	TARGET	TARGET AREA Δ NUMBER	Δ %
total population	127,062	127,062				
Total working population, men and women, age group 20-64	59,465	60,815	46.8	47.9	1350	1.062
Low skilled persons, age group 20-64	6,589	6,589	11.1	10.8	0	-0.246
Skilled persons, age group 20-64	52,258	53,608	87.9	88.1	1350	0.269
Total temporary employees	11,298	11,911	19.0	19.6	613	0.585
Total permanent employees	48,167	48,904	81.0	80.4	737	-0.585
Number of men and women, age group 20-64 in the **BIOENERGY SECTOR**	0	1,350	0.0	2.2	1350	2.219

EN-BASELINE / EN-TARGET / AIR EMISSIONS / SOIL QUALITY / WATER USE / BIODIVERSITY / LUC / S-BASELINE / S-TARGET / LAND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASEL

Figure. 22b Rainfed Giant Reed: changes in employment due to the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy).

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2.2.9 Changes in Income

Changes in income between the baseline and target scenarios are calculated as the difference in attainable revenues per ha between a common economic activity currently found within the ***target area*** and the activities linked to the production of bioenergy feedstock or the processing of the biomass into fuel. Transport of biomass and biofuel are not compared to similar economic activities since the transport sector has rather homogenous characteristics in the case study area and changes in income may not be noticeable.

The production of biomass is an agricultural activity that would give work to the majority of the employees in the advanced biofuel value chain. For reliability reasons, this activity was compared to the most common agricultural production currently practiced in the Region of Sardinia: the production of durum wheat.

Sardinia, like the rest of Italy, has a long history of production of this staple food crop. However, international market dynamics are starting to make the profitability of this crop more challenging in recent years. The most popular Italian agricultural magazine, the *Informatore Agrario* offers a number of services to Italian farmers including averaged cost-benefit analyses for various crops. This is the case of durum wheat production edited by Pazienza and Zanni (2009). The authors presented an average case study based on a yield of 3.5t/ha of grain and an average production cost of EUR 992/ha. Given the annual market price of durum wheat of EUR 234/t in 2018 (Obiettivo Cereali, 2018) the cost-benefit estimate proposed by the *Informatore Agrario* shows an evident deficit, or negative income of EUR 170/ha.

This calculation does not take into account the possible contribution of regional, national or EU-level incentives to agricultural activities in this specific area (e.g. CAP, etc.).

Given the current farm conditions and production costs, experts report that the minimum market price of durum wheat to achieve the breakeven of total costs should be EUR 280/t. In addition, a market price of EUR 300/t was calculated to be the minimum price that could generate a noticeable income for farmers.

As of 2018, durum wheat production in Sardinia benefits from a *de minimis* contribution from the Common Agricultural Policy of EUR 150/ha. In addition, the regional Law 1096/1971 established that for virtuous farmers who use certified seeds, an additional public contribution of EUR 50/ha is granted to the farmers (Agronotizie, 2017). The sum of public contributions to the production of durum wheat in Sardinia then, generates a revenue of EUR 30/ha, in light of a public incentive of EUR 200/ha.

The aforementioned contributions are provided to farms between 5 and 20 ha maximum. This is in line with the information concerning the average size of farms in Sardinia. The income generated by durum wheat from an average farm in the ***target area*** would be between 150 EUR/year (5 ha farm) to 600 EUR/year (for a 20 ha farm). Clearly, given the conditions of the market, farmers may need to find ways to

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cut down production costs by performing some in-farm work that would be otherwise accounted for as a cost.

The cost-benefit analyses for the T1 and T2 scenarios are based on information from Deliverable 2.2 (techno-economic feasibility). Assuming a premium paid to the farmer for the production of biomass of EUR 24/t, the cultivation of giant reed may generate a net income of 240 EUR/ha in rainfed conditions or EUR 600/ha in irrigated conditions. Assuming as in the case of durum wheat that the average farm size is between 5 and 20 ha, the net income of a farm producing biomass for a lignocellulosic ethanol value chain would be 1,200 – 3,000 EUR/year for farms up to 5 hectares of surface (T2 and T1 respectively), and 4,800 – 12,000 EUR/year for a 20 ha farm (T2 and T1 respectively).

Summary of cost-benefit analysis of baseline situation:

Durum Wheat: 3.5 t/ha
Production cost: 992 EUR/ha
Price: 234 EUR/t
Revenue: (234 EUR/t * 3.5 t/ha) – 992 EUR/ha = - 170 EUR/ha
Breakeven price for wheat in Italy is 280 EUR/t in 2018, minimum income achieved at EUR 300/t.
CAP: 150 + 50 EUR/ha
Total Income: -170 EUR/ha + 200 EUR/ha = 30 EUR/ha

Biomass – Arundo Rainfed: 10 t/ha
Production cost: 57 EUR/ha (source: FORBIO D 2.2)
Landowner fee: 24 EUR/t (source: FORBIO D 2.2)
Total Income: (24 EUR/t * 10 t/ha) = 240 EUR/ha

Biomass – Arundo IRRIGATED: 25 t/ha
Production cost: 61 EUR/t (source: FORBIO D 2.2)
Landowner fee: 24 EUR/t (source: FORBIO D 2.2)
Total Income: (24 EUR/t * 25 t/ha) = 600 EUR/ha

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The income generated by the other components of the value chain (transport and processing stages) is summarized in figure 23.

	Name		G. REED	-	-	-
	Growth cycle		Perennial	-	-	-
CROP SPECIFICATIONS	TARGET CULTIVATED SURFACE	Ha	18,000	-	-	-
WAGES PAID IN BIOENERGY FEEDSTOK PRODUCTION, TRANSPORT, AND PROCESSING						
TARGET BIOENERGY CROP						
AVERAGE WAGES PAID FOR EMPLOYMENT IN BIOENERGY FEEDSTOCK PRODUCTION						
		PM/ha/yr		-	-	-
	BETWEEN DIFFERENT OCCUPATIONS	Wage €/yr	16,320	-	-	-
		Wage €/PM	1,360	-	-	-
AVERAGE WAGES PAID FOR EMPLOYMENT IN BIOENERGY FEEDSTOCK TRANSPORT						
		PM/ha/yr	0	-	-	-
	BETWEEN DIFFERENT OCCUPATIONS	Wage €/yr	24,000	-	-	-
		Wage €/PM	2,000	-	-	-
AVERAGE WAGES PAID FOR EMPLOYMENT IN BIOENERGY FEEDSTOCK PROCESSING						
		PM/ha/yr	0	-	-	-
	BETWEEN DIFFERENT OCCUPATIONS	Wage €/yr	27,000	-	-	-
		Wage €/PM	2,250	-	-	-

EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JO

Figure. 23 Average yearly income by job category in the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy).

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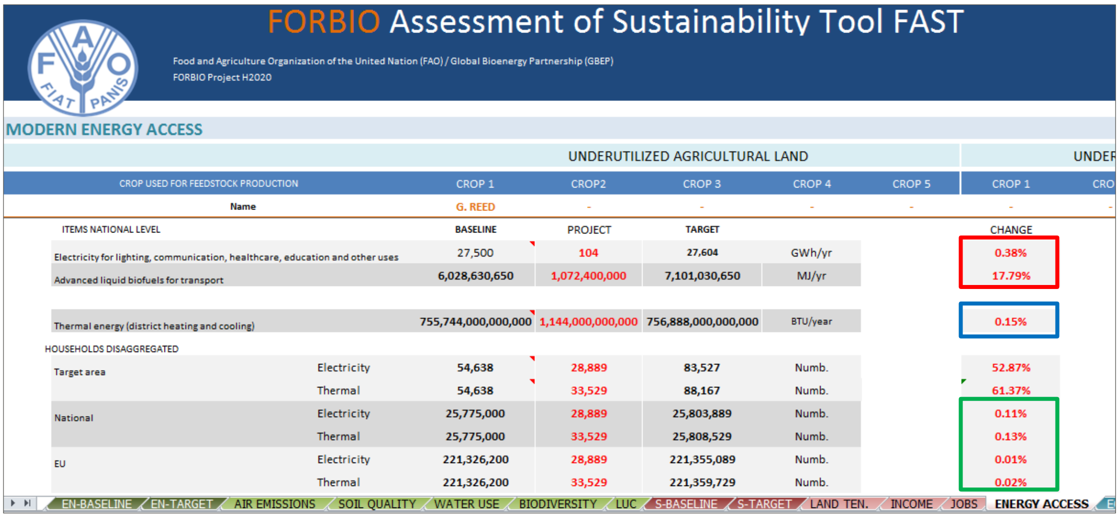
2.2.10 Energy Access

This indicator measures the contribution of advanced biofuels to the access of households to modern bioenergy services. In order to do so, it directly tackles the share of liquid biofuel into the mix on the one hand and, in the specific case of second generation ethanol, where lignin is a co-product use in the biorefinery's Combined Heat and Power (CHP) plant, the production of excess heat and electricity are also accounted for as. In the European Union several countries have are characterized by a 100% rate of access to modern energy services (e.g. % of the population who has access to electricity, etc.). However, the substitution among forms of energy or the substitution among sources of the same energy type (i.e. renewable vs fossil) is accounted for in this indicator as an index of development towards a more diversified access to modern energy services. Therefore, changes are expressed in relative or absolute terms depending upon the viability of either method: if, as in the case of Italy, all households have access to electricity, the surplus energy produced will not be absorbed by residential areas currently disconnected from the electricity grid since these do not exist, but said surplus will contribute to reducing the demand for the same form of energy to be produced from other sources, often times fossil ones.

A biorefinery which produces 40,000 tons per year of lignocellulosic ethanol has the potential to increase by 17.79% the access of Italian consumers to modern biofuels, a the national level, when compared with the baseline.

The contribution of the electricity generated by the CHP and injected into the national grid will contribute to increase by 0.38% the production of electricity of the country (red square in Figure 24).



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MODERN ENERGY ACCESS

		UNDERUTILIZED AGRICULTURAL LAND					UNDER
CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1
Name		G. REED	-	-	-	-	-
ITEMS NATIONAL LEVEL		BASELINE	PROJECT	TARGET			CHANGE
Electricity for lighting, communication, healthcare, education and other uses		27,500	104	27,604	GWh/yr		0.38%
Advanced liquid biofuels for transport		6,028,630,650	1,072,400,000	7,101,030,650	MJ/yr		17.79%
Thermal energy (district heating and cooling)		755,744,000,000,000	1,144,000,000,000	756,888,000,000,000	BTU/year		0.15%
HOUSEHOLDS DISAGGREGATED							
Target area	Electricity	54,638	28,889	83,527	Numb.		52.87%
	Thermal	54,638	33,529	88,167	Numb.		61.37%
National	Electricity	25,775,000	28,889	25,803,889	Numb.		0.11%
	Thermal	25,775,000	33,529	25,808,529	Numb.		0.13%
EU	Electricity	221,326,200	28,889	221,355,089	Numb.		0.01%
	Thermal	221,326,200	33,529	221,359,729	Numb.		0.02%

EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS

Figure. 24 Contribution to modern energy access of the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy).

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The CHP installed in a hypothetical biorefinery, may also produce excess low-temperature heat. The heat, if properly channeled through a district heating infrastructure may contribute to enhancing the access of local and national population to modern bioenergy forms for heating purposes. According to Bottio & De Lorenzi (2017), in Italy some 8,588 MWth constitute the installed district heating capacity of the country. This value is equal to some 755 x 10^{12} billion BTUs. The CHP of the hypothetical biorefinery in Portovesme could generate additional 1.4 x 10^{12} BTUs or 0.15% more (blue square in Figure 24).

At the household level, the aforementioned contributions would translate into additional 28,889 households connected to the electrical grid, and additional 33,529 household connected to a renewable district heating system.

At the ***target area*** level, this would imply that more than half (52.87%) of the households in the Sulcis region would be supplied by renewable electricity produced by the biorefinery and that 61.37% of all households in the ***target area*** could receive district heat from the biorefinery.

At the national level, this contribution would be respectively 0.11% and 0.13% for electricity and heat. Finally, at the EU level, the hypothetical biorefinery in Sardinia would increase the access to modern bioelectricity services by 0.01% and to modern renewable district heating by 0.02% (green square in Figure 24).

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2.2.11 Productivity

This indicator measures the productivity of the bioenergy value chain in terms of quantities and unitary costs. The excellent work done by CREA and Biochemtex with Deliverable 2.1 and 2.2 provided an important share of the information included in this indicator. Direct communication with Biochemtex provided the necessary elements to produce and estimate of production costs and its components.

Giant reed in irrigated management regime can produce steadily at least 25 tons of biomass per ha per year. Year 1 and 2 usually register low productivity values but starting from the third year of cultivation the peak productivity is reached and is kept steadily for the next 15 to 20 years. Experimental field trials performed in Italy have demonstrated that long term productivity of giant reed under high input regime (fertilizer and irrigation provided) can yield an average of 37.7 t ha-1 yr-1 (Angelini et al., 2009).

Giant reed in rainfed conditions has not been studied on large scale plots in Sardinia as conversely to the case of irrigated trials. However, several authors in Italy have researched the yields of this plant in rainfed conditions. Dragoni et al (2015), reported yields of rainfed plots to be comparable with irrigated ones, hovering around 35 t ha-1 yr-1. These values are much higher than values recorded by Biochemtex in D 2.1 for irrigated giant reed. Biochemtex and the University of Sassari, indicated a likely long term reliable average yield of giant reed under rainfed conditions in the ***target area*** to be likely 10 t ha-1 yr-1. This value seems conservative in light of the pertinent literature and it could be used as the basis for long term feasibility assessments.

The estimate of productivity cost was performed through a number of calculations and data obtained both from direct communication with Biochemtex and information found in the specialized literature.

The components that make up production cost are the Capital expenditure (CAPEX) and the Operational Expenditures (OPEX). The CAPEX was quickly estimated for the hypothetical biorefinery in Portovesme on the basis of the investment needed for the similar plant in Crescentino, Italy. A total initial investment of EUR 150 million was considered adequate to the construction and running of a 40,000 t lignocellulosic ethanol plant using the PROESA technology.

Operational Expenditures were calculated as follows:

Feedstock expenditure: EUR 12,780,000 per year

Enzymes, yeast, catalysts, other inputs: EUR 13,000,000 per year (E4tech, 2017)

Salaries: EUR 2,952,000 per year

Miscellaneous: EUR 1,200,000 per year

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In total the production cost of lignocellulosic ethanol was calculated to be EUR 936 per ton. This value calculated in the real case scenario of FORBIO was compared to values found in literature. According to E4TECH (2017), lignocellulosic ethanol production costs in Europe range between EUR 940 and 1,010 per ton.

2.2.12 Energy Balance

Unfortunately, reliable information on the energy balance of the processing stages of lignocellulosic ethanol production could not be shared by Biochemtex and therefore this indicator could not be measured for this case study.

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2.2.13 Gross Value Added

This indicator measures the contribution to the GDP of a given bioenergy value chain. In the case study of Sulcis, the products that contribute to GDP are the sales of bioethanol and the sales of excess electricity. The hypothetical sale of excess heat was not included in this calculation.

The current European price for ethanol is registering an all-time low at 424 EUR/m^3 (534 EUR/t). At current market prices, sales of ethanol would generate some 21,360,000 EUR/year. In addition, the surplus electricity produced by the CHP of the biorefinery could generate some 104 GWh per year of renewable electricity. The price per unit of electricity generated is as much of a key aspect in evaluating the economics of a second generation ethanol biorefinery as the price paid per ton of ethanol. In fact, at the current price of electricity for large scale biomass-fueled power plants of EUR 115/MWh as per DM 26 July 2016, (Gazetta Ufficiale, 2016) revenues for the generation of electricity would account to EUR 11,960,000 per year for the next 20 years. Total revenues for a 40,000 t/year biorefinery at current market conditions would then be EUR 33,320,000 per year.

However, the total production cost of lignocellulosic ethanol in Sardinia as we have seen in previous chapter would be 936 EUR/t or 37,440,000 EUR/year.

Thus, given the current market conditions, the Gross Value Added of a second generation biorefinery would be negative by some EUR 4,120,000 per year (Figure 25a).

Ethanol price volatility though is a key parameter. In this exercise we tested a further scenario which used the price of ethanol FOB at Rotterdam of June 2017, thus 1 year prior to this investigation. Then the ethanol price was 756 EUR/t and at this rate the GVA would be positive by EUR 4.7 million (Figure 25b).

TARGET AREA (Advanced biofuel value chain)								
Total gross revenues from sales (Adv. Biofuels + other services)								
Advanced biofuel sales	**€/year**	**21,360,000**	-	-	-	-	-	-
Other services (e.g. electricity)	**€/year**	**11,960,000**	-	-	-	-	-	-
by product from grass	**€/year**	-	-	-	-	-	-	-
TOTAL	**€/year**	33,320,000	-	-	-	-	-	-
						33,320,000		
Cost of production (including processing inputs and raw materials)								
TOTAL	**€/year**	**37,440,000**	-	-	-	-	-	-
Cost of services from outside suppliers (e.g. transport of final product)								
TOTAL	**€/year**	**0**	-	-	-	-	-	-
TOTAL	**€/year**	37,440,000	-	-	-	-	-	-
						37,440,000		

GVA	-4,120,000	€/year
CONTRIBUTION TO GDP	-0.000240	%

LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY | REFERENCE

Figure. 25a Cost-Revenues analysis and estimated GVA of the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy) using ethanol market price as of June 2018.

TARGET AREA (Advanced biofuel value chain)								
Total gross revenues from sales (Adv. Biofuels + other services)								
Advanced biofuel sales	**€/year**	**30,240,000**	-	-	-	-	-	-
Other services (e.g. electricity)	**€/year**	**11,960,000**	-	-	-	-	-	-
by product from grass	**€/year**	-	-	-	-	-	-	-
TOTAL	**€/year**	42,200,000	-	-	-	-	-	-
						42,200,000		
Cost of production (including processing inputs and raw materials)								
TOTAL	**€/year**	**37,440,000**	-	-	-	-	-	-
Cost of services from outside suppliers (e.g. transport of final product)								
TOTAL	**€/year**	**0**	-	-	-	-	-	-
TOTAL	**€/year**	37,440,000	-	-	-	-	-	-
						37,440,000		

GVA	4,760,000	€/year
CONTRIBUTION TO GDP	0.000277	%

LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY | REFERENCE

Figure. 25b Cost-Revenues analysis and estimated GVA of the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy) using ethanol market price as of June 2017.

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2.2.14 Infrastructure

The analysis of the infrastructure for the logistics of transport of biomass and biofuels, adds to the information discussed under the indicator on water use and efficiency to present a complete overview of the characteristics of the ***target area*** from this point of view. This indicator has a quantitative and a qualitative component. The quantitative component requires the user to assess the distances between the production areas and the hypothetical site of the biorefinery, as per the primary assumption behind the T1 and T2 scenarios. Subsequently, through the use of GIS tools, the actual distances between the production sites and the collection site are calculated. On the basis of the characteristics and the status of maintenance of the infrastructure the indicator measures the time spent to collect and deliver the biomass at the biorefinery's gate. The qualitative analysis of information in this indicator looks at the logistics side of operations within the value chain.

The assessment of this indicator was done by using georeferenced information obtained from the Regional Geographic Information System (*Sardegna Geoportale*). From the portal, layers and maps can be downloaded and used in a GIS working environment for the calculation of the presence of infrastructure for the transport of the biomass and its logistics.

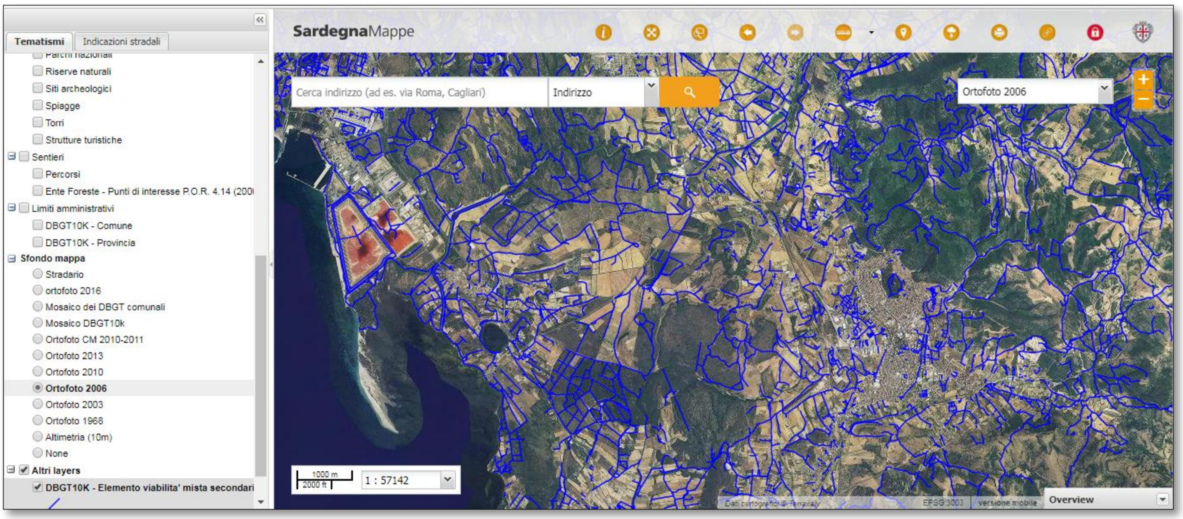

Figure. 26 The road infrastructure of pertinence in the case of the hypothetical advanced bioenergy value chain in the *target area* (Sulcis, Italy). Source: Sardegna Geoportale.

The calculation of the average yearly transport time of the biomass was calculated using the average loading capacity of the vehicles used (tractor, truck, rail, etc.) for each stage of the transport (field to road, road to biorefinery gate, etc.), the average speed admitted on the specific trait of road in km/h, and the averaged real distance between the various production sites and the collection site.

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

The results of this analysis confirm the adequate level of completeness and maintenance of the road system in the ***target area***. Within a radius of 30 km from the hypothetical site of the biorefinery (industrial pole of Portovesme), an average distance of 43.2 km is calculated between the fields and the biorefinery gate. Of these, 4.2 km on average are represented by rural roads, whereas the remaining 39 km are represented by medium speed primary roads (*Strada Provinciale*) as summarized in Figure 27.

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INFRASTRUCTURES AND LOGISTICS

		UNDERUTILIZED AGRICULTURAL LAND				
CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5
Name		G. REED	-	-	-	-
INFRASTRUCTURE						
Distance from field to Fuel Plant	Km	43.2	-	-	-	-
TRANSPORT OF BIOMASS	Vehicle type	Truck	-	-	-	-
PRIMARY ROAD	Speed Class	Medium Speed	-	-	-	-
	Km	39.0	-	-	-	-
SECONDARY ROAD	Speed Class	Rural Road	-	-	-	-
	Km	4.2	-	-	-	-
Fuel transport						

LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY | REFERENCE

Figure. 27 Summary of the road infrastructure and related logistics of the case study area in Sulcis, Italy.

The indicator calculated the amount of time necessary to move 180,000 tons of feedstock using the average vehicle (truck) and its average payload (40 tons) at the average speeds of the type of road they travel on (30 km/h on rural roads, 60 km/h on secondary, class 2 roads).

		FSTK tonnes	180,000.0	-	-	-	-
FEEDSTOCK TRANSPORT		Total km	43.2	-	-	-	-
		Vehicle type	Truck	-	-	-	-
		loading capacity	40	0	0	0	0
	PRIMARY						
	HIGH	km	0.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	80	0	0	0	0
	hours	hrs	0.0	0.0	0.0	0.0	0.0
	MEDIUM	km	175,500.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	60	0	0	0	0
	hours	hrs	2,925.0	0.0	0.0	0.0	0.0
	SECONDARY						
	LOW	km	0.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	50	0	0	0	0
	hours	hrs	0.0	0.0	0.0	0.0	0.0
	RURAL	km	18,900.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	30	0	0	0	0
	hours	hrs	630.0	0.0	0.0	0.0	0.0
		hrs	3,555.0	0.0	0.0	0.0	0.0

LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY

Figure. 28a Summary of the travel time on road infrastructure and related logistics of the case study area in Sulcis, Italy.

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

In Figure 28b the travel time needed to reach the fuel distributors from the biorefinery was estimated to be on average 100 km. The liquid fuel trucks have maximum payload of 29 tons and can travel at maximum speed of 80 km/h.

The total travel time to reach the distributors is calculated in 5,310 hours per year.

	hours	hrs	630.0	0.0	0.0	0.0	0.0	0.0	0.0
		hrs	3,555.0	0.0	0.0	0.0	0.0	0.0	0.0
	IF RAIL	Km	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		hrs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	IF SHIP	Km	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		hrs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FUEL TRANSPORT	Km plant to distributors	100							
	Vehicle type		Truck	-	-	-	-	-	-
	Fuel quantity	tonnes	40,000	-	-	-	-	-	-
	capacity	tonnes	29	0	0	0	0	0	0
	final distance	Km	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	final distance	trips not ceilded	1,403.5	0	0	0	0	0	0
		trips ceiulded	1404	0	0	0	0	0	0
TOTAL HOURS	5,310.00	Kmh	80	0	0	0	0	0	0
		hrs	17.5	0.0	0.0	0.0	0.0	0.0	0.0
		hrs	1,755.0	0.0	0.0	0.0	0.0	0.0	0.0

LAND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASELINE / EC-TARGET / PRODUCTIVITY / NET E BALANCE / G V A / **INFRASTRUCTURE** / CAPACITY / REFERENCE

Figure. 28b Summary of the travel time on road infrastructure and related logistics of the case study area in Sulcis, Italy.

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

2.2.15 Capacity of use of bioenergy

The contribution to reaching the capacity of using bioenergy of a country is measured in this indicator. Due to the increasing fuel efficiency of vehicles, consequence of emission reduction policy at the EU-level, petrol consumption is expected to decrease over time, and was assumed to stay constant at 2017 values at best.

The capacity of a fleet to use biofuels in the case of ethanol is given by the maximum amount of biofuel that can me blended with gasoline without requiring retrofitting of the fleet (blend wall). According to the European Petroleum Refiners Association (EPRA, 2018) this amount is 10% for petrol engines in Europe.

To date in Italy the current ethanol blend in petrol is 3.95%. Therefore, the capacity to use biofuel is far from being reached. The production of additional 40,000 tons of bioethanol from the hypothetical biorefinery studied in this feasibility assessment would contribute to closing such gap. This specific analysis does not make sense at the ***target area*** level, but only at the national and European level since the current use of ethanol in the target area (given the size of the local fleet and the average sale of petrol) was a mere 227 tons in 2017. In Italy as a whole, in 2017, 224,865 tons of ethanol were blended into the petrol sold at the fuel stations nationwide, and in Europe 4,225,095 tons of ethanol were mixed to the fossil fuel. It is obvious as the impact of the production of additional 40,000 tons should be evaluated against the national and EU conditions.

TYPE OF ADVANCED BIOFUEL	Cellulosic Ethanol		COUNTRY	IT
BASELINE	**Tfuel/year**	**TARGET AREA**	**NATIONAL**	**EU LEVEL**
Current biofuel use		227	224,865	4,225,095
Current TOTAL fuel use		5,738	5,696,000	84,949,000
TARGET	**Tfuel/year**	**TARGET AREA**	**NATIONAL**	**EU LEVEL**
Target biofuel use in the target area		227	224,865	4,225,095
TARGET biofuel use plus PROJECT PRODUCTION		40,227	264,865	4,265,095
Current TOTAL fuel use		5,738	5,696,000	84,949,000

	FINAL CAPACITY RATIO	TARGET ARE
	CAPACITY WITH BLENDING WALL	574
2017	Capacity ratio for BASELINE situation	0.40
	CAPACITY WITH BLENDING WALL	574
2027	Capacity ratio for BASELINE situation	0.40
	Change in %	0%
2027	Capacity ratio for TARGET situation	70.11
	Change in %	N/A
	PROJECT CONTRIBUTION TO CHANGE IN CAPACITY RAT	
	Change in %	N/A

Figure. 29 Summary of the bioethanol blend and quantities at baseline and target scenario for the case study Italy.

The case study serves as the basis to assess the contribution of the amount of ethanol that could be produced by the hypothetical biorefinery in the Sulcis to

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reaching the maximum capacity of using biofuels of Italy and in the EU. The results of this exercise are presented in Figure 30, below.

	FINAL CAPACITY RATIO		BLENDING WALL	10%
		TARGET AREA	NATIONAL	EU LEVEL
	CAPACITY WITH BLENDING WALL	574	569,600	8,494,900
2017	Capacity ratio for BASELINE situation	0.40	0.39	0.50
	CAPACITY WITH BLENDING WALL	574	569,600	8,494,900
2027	Capacity ratio for BASELINE situation	0.40	0.39	0.50
	Change in %	0%	0%	0%
2027	Capacity ratio for TARGET situation	70.11	0.47	0.50
	Change in %	N/A	18%	1%
	PROJECT CONTRIBUTION TO CHANGE IN CAPACITY RATIO			
	Change in %	N/A	17.788%	0.947%

TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPA

Figure. 30 Summary of the impacts on the capacity of using bioethanol of the national Italian fleet and the European passenger car fleet in 2027.

The maximum capacity to use bioethanol of the Italian fleet was calculated to be 569,600 tons/year (10% of total petrol volume). As of 2017 the country used only 224,865 tons, and the addition of further 40,000 tons would increase the total availability to 264,865 tons/year. This would contribute to closing the gap between the current levels of use of ethanol into the blend of petrol available at the pump stations in Italy and the maximum uptake (i.e. blending wall) by 17.78%.

The same metrics applied to at the EU level, would result in a contribution to closing the gap between current use and maximum actual capacity of use of ethanol by the fleet of 0.94%.

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3. The case Study in Ukraine:

3.1 Case study description, setting, system boundaries and main assumptions

The analysis of the sustainability of a potential bioenergy value chain targeted the Ivankiev Region of Ukraine, and specifically the non-exclusion zone just south of the Chernobyl disaster area.

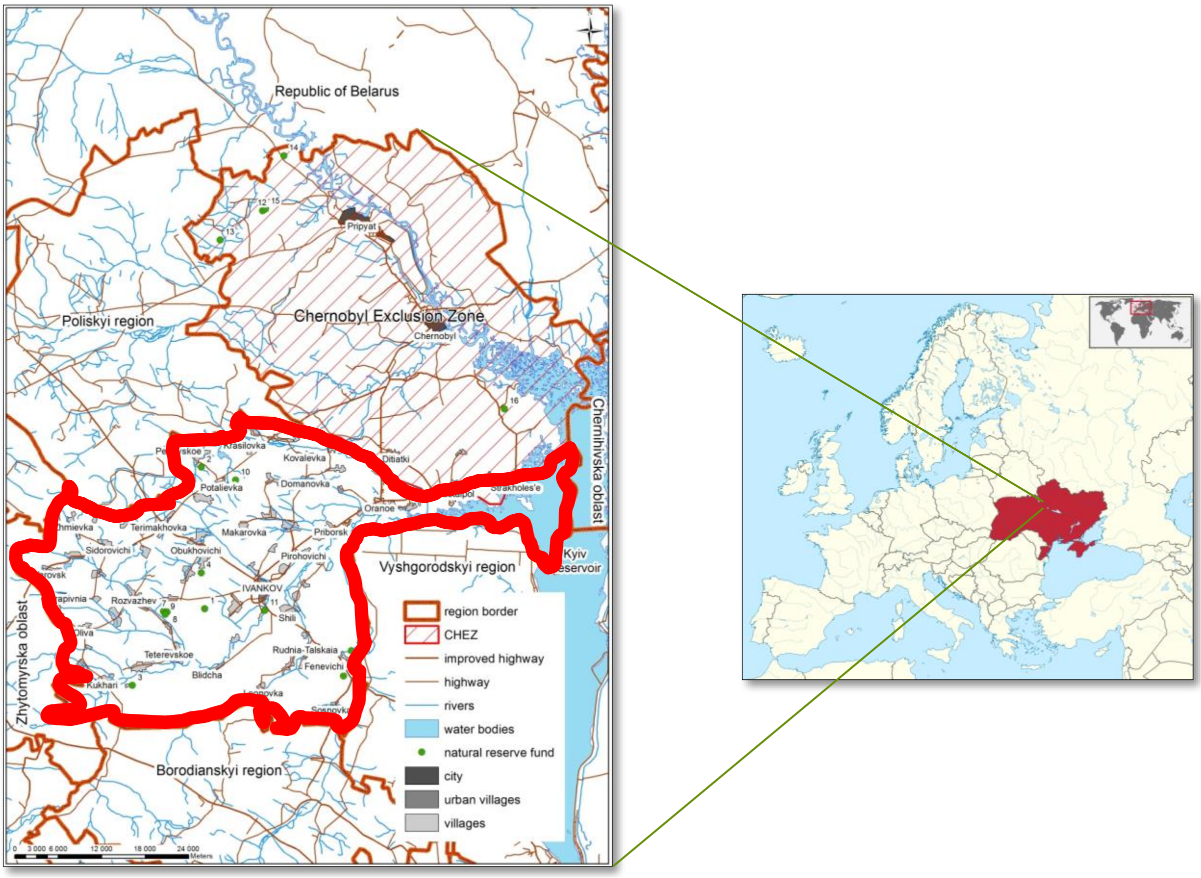

Figure. 31 The target area of Ivankiev, Ukraine.

The reference ***target area*** used for the assessment of the sustainability of the selected bioenergy value chains has a surface of 181,734 ha and is the area of the Non-exclusion Zone inscribed within the Ivankiev region. According to local authorities, the area is not subject to radioactive contamination. Two categories of land were considered as underutilized in the D 2.6 assessment:

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- abandoned agricultural land, i.e. land that is not needed any more for the production of food and feed crops or for other purposes;
- degraded or low productive land, i.e. land that is not suitable or no longer suitable for conventional commercial agriculture.

The amount of land falling under the two categories above in the Ivankiev region is considerable. In the Region, the main industrial area is found in Ivankiev Town and that is where the hypothetical advanced biofuels biorefinery is located in this exercise. Within a 50 km radius from Ivankiev town there are some 21,350 ha of underutilized lands, of which 16,200 ha are falling within the ***target area***.

The Target scenario tested in Ukraine then will explore the impacts of producing biomass for advanced biofuel purposes on 16,720 ha in the Ivankiev Region. This is due to the fact that information on a number of aspects has been collected only with regard to the Ivankiev Region and thus analysis and comparisons with areas outside the ***target area*** are not reliable.

The scenarios considered in this analysis derive from the conclusions of Deliverable 2.5 and 2.6.

The bioenergy pathway selected is lignocellulosic ethanol with the presence of a Combined Heat and Power plant within the biorefinery.

The source of biomass identified is willow (*Salix viminalis*) under rainfed management system.

From the outcomes of D 2.5 and D 2.6 of FORBIO it emerged that willow could be a valid candidate as feedstock for lignocellulosic ethanol biorefinery in this case study area because of the yields obtainable in the case study area on a short rotation coppice cycle (e.g. starting from year III).

The target output of this hypothetical biorefinery is 40,000 tons of ethanol per year and the technology employed is the PROESA® (steam-explosion, Enzymatic liquefaction, SSF) belonging to Biochemtex, partner of the FORBIO project and technology provider. This value is equal to the regime capacity of the biorefinery in Crescentino operated by Beta Renewables.

The assessment of the *Baseline situation* as shown in figure 32 summarizes the land categories and cover types currently present in the ***target area***. In Deliverable 2.5, the FORBIO project assessed the expected yields of willow under rainfed conditions in the case study area. This crop under rainfed conditions reports yields of around 10 t ha-1 yr-1. All biomass yields in this document are expressed on a dry matter basis.

Given the biomass to ethanol yield of giant reed (5 tons of feedstock per ton of ethanol produced), and the size of the hypothetical biorefinery (i.e. 40,000 tons of

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ethanol/year), the biomass required to supply the biorefinery is 200,000 tons per year.

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TARGET AREA SURFACE (ha)		**181.734**			
Agriculture	Ha	**80.954**	**total**	**for fstk**	
Annual crops and fallow lands (FAOSTAT Arable Land)	Ha		39.117	0	
Permanent crops	Ha		892	50	
Permanent meadows and pastures	Ha		24.225	0	COV
Underutilized agricultural land	Ha		16.720		Grass
Forest	Ha	**78.277**			
Natural Forest or underutilized forest	Ha		35.616		
Managed Forest	Ha		42.661	0	
Others lands	Ha	**22.503**			
Urban areas	Ha		3.377		
Industrial sites	Ha		175	0	
Wetlands	Ha		16.286		
Others	Ha		2.470	0	COV
Underutilized NON-agricultural land (e.g. EX-mining sites	Ha		195		-

AGRICULTURE NON AGRICULTURE

RESULTS / START / EN-BASELINE / EN-TARGET / AIR EMISSIONS / SOIL QUALITY / WATER USE / BIODIVERSITY / LUC / S-BASELINE / S-TARGET / LAND TEN.

Figure. 32 The baseline situation of the case study area in Ivankiev, Ukraine, is characterized by the presence of 16,720 ha of underutilized agricultural land.

In the tested scenario, given expected yields of 10 t ha-1 yr-1, willow would require some 20,000 ha for the production of the amount of biomass that the biorefinery requires.

This value is not attainable by relying solely on the use of underutilized lands from the Ivankiev region (16,720 ha) and likely there would be the need to produce the remaining feedstock from the nearby regions (total underutilized land 21,350 ha). Since the entire amount of feedstock necessary cannot be produced in the Ivankiev region, for this analysis it was assumed that the plant would work at 83.6% of its potential (33,440 tons of ethanol per year). This is done in order to have an assessment of the sustainability implications referred to the ***target area*** but it is likely that in the real case the remaining 16.4% of the feedstock is supplied from the nearby regions or is composed by other biomass types, such as wheat straw and other lignocellulosic material compatible with the PROESA technology.

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of ADVANCED BIOFUEL	Cellulosic Ethanol	IF BIOMETHANE -	TARGET adv. biofuel PRODUCTION		33.440	t/year	expected prod.	33.440

UNDERUTILIZED AGRICULTURAL LAND

CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 1
Name		WILLOW	-	-	-	-	-
Growth cycle		Perennial	-	-	-	-	-
Yield	tonnes/ha	10,0	-	-	-	-	-
Advanced biofuel prod	tfstk/tfuel	5,00	-	-	-	-	-
ADV. BIOFUEL PRODUCTION	tonnes	33.440	-	-	-	-	-
Total ADV. BIOFUEL PRODUCTION	tonnes			33.440			
TOTAL TONNES OF LACTIC ACID AND AMINO	Tonnes	0	0	0	0	0	0
TARGET CULTIVATED SURFACE	Ha	16.720	-	-	-	-	-
Total cultivated surface	Ha			16.720			
REQUIRED FSTK QUANTITY	Tonnes	167.200	-	-	-	-	-
Total	Tonnes			167.200			
Distance from field to Fuel Plant	Km	55	-	-	-	-	-
TRANSPORT OF BIOMASS	Vehicle type	Truck	-	-	-	-	-
Distance from Fuel Plant to distributors (km)	100						
TRANSPORT OF FUEL	Vehicle type	Truck	-	-	-	-	-
SOIL CHARACTERIZATION							
SANDY	Suitability	Unsuitable	-	-	-	-	-

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE

Figure. 33 The target scenarios situation tested shows the land requirement when willow is cultivated on the underutilized lands within the Ivankiev Region (16,720 ha).

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3.2 Sustainability Assessment results by Indicator

3.2.1 Air Quality

The assessment of the sustainability of bioenergy value chain cannot disregard the lifecycle assessment of greenhouse gas (GHG) emissions. In this project, the baseline situation is represented by the traditional fuel currently used by the fleet which would be partially substituted by the 2G ethanol produced in the ***target area***. It is common practice to assess the sustainability impact of bioenergy production and use on the basis of GHG emission intensity per unit of energy. The GHG emission intensity is therefore expressed in grams of carbon dioxide equivalent per megajoule of bioenergy produced (gCO_{2eq}/MJ).

In the baseline scenario the reference fuel used in petrol. The emission intensity of European petrol is 83.3 gCO_{2eq}/MJ (Biograce, 2014).

In the target scenario the emission intensity of lignocellulosic ethanol produced in the ***target area*** is therefore compared to the emission intensity of the reference fuel and the relative (in %) and absolute (in g, Kg, or t of CO_2) change is reported.

The main contributors and components of a GHG LCA of biofuel production and use are:

1) Feedstock production;
2) Feedstock transport;
3) Feedstock processing; and
4) Fuel transport/distribution.

The PROESA technology foresees the use of by- and co-products of the ethanol value chain and thus an allocation among the various products was performed. This is the case of the lignin produced in the processing of the biomass which is used to fuel a combined heat and power (CHP) boiler which fulfills the internal needs of the biorefinery and produces some 87 GWh of excess electricity and expected to be sold to the grid.

The most appropriate methodology for the correct allocation and attribution among co-products of the bioenergy value chain is a highly debated topic. In general, allocation based on economic value of the co-products returns the most reliable results. However, this is true when the comparison is to be made at present or over a short term period. Over the long term (10+ years) in fact, the unpredictability of market conditions makes it difficult to rely on economic value esteemed at present to project into the next decade the share of impacts among the various co-products of the bioenergy value chain.

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In order to avoid these uncertainties, in this exercise the energy content method was chosen to attribute to each co-product its share of impacts.

Summarizing the extensive calculations performed on this aspect, the 33,440 tons of lignocellulosic ethanol produced yearly are equal to 896,526,400 MJ. The generation of 87 GWh of electricity in excess to what is used in the processing stages, equals to a further 312,998,400 MJ. This means that a correct allocation among co-products in energy terms is done as follows:

Ethanol: 74 percent

Surplus electricity: 26 percent

A further sophistication of GHG LCA and attribution is that not all stages of the supply chain generate emissions that require allocation. This is, for instance, the case of the processing of the biomass into fuel for which large quantities of enzymes and yeast are needed to treat the lignocellulosic biomass and produce fermentable sugars. The emissions linked to the production of enzymes and catalysts are not attributable to the surplus electricity but solely to the production of fermentable sugars and therefore ethanol.

The results of this assessment are presented below:

Baseline: petrol

Emission intensity of petrol: 83.3 gCO_{2eq}/MJ (Source: BioGrace, 2014).

Target: lignocellulosic ethanol from willow

Emission intensity of lignocellulosic ethanol (allocated results): 36.10 gCO_{2eq}/MJ

Emission reduction compared to baseline: 56.67%

Avoided emissions: 42,319 tons CO_2 per year

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Willow:

LCA GHG emission share - allocated results: 36.10 gCO_{2eq}/MJ

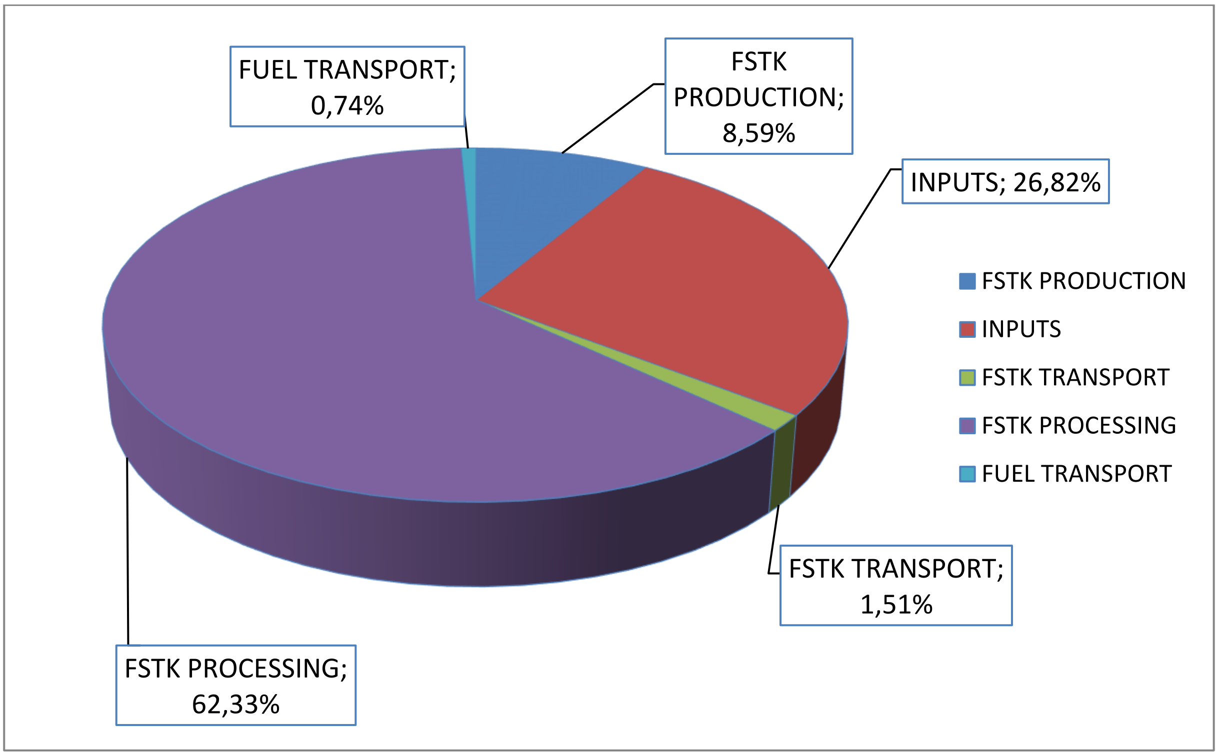

Figure. 34 Share of GHG emission attributable to the various components of the bioenergy value chain of lignocellulosic ethanol from willow in the case study site in Ukraine.

The main contributor to the GHG emission intensity is represented by the emission at the processing stage followed by emissions from the use of inputs, mainly fertilizers and pesticides. The production of enzymes, yeast and other catalyzers of the reactions are energy-intense operations. In the scenario tested, as in the reference biorefinery of Crescetino, these inputs are produced outside the biorefinery by third party actors and therefore the emission intensity of production coupled with the large quantities needed by the biomass conversion technology lead to a relevant share of emissions attributable to this single stage of production. The values calculated in this exercise are in line with the values found on the specific literature on this same topic (Olofsson et al., 2017). These take place outside the system, and the catalysts are subsequently imported.

Fertilizer and pesticide application to willow is the second emission source in order of magnitude. Feedstock production operations include soil preparation and harvesting, both mechanized operations which are the main contributors to emissions of this phase of the value chain.

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3.2.2 Soil Quality

Changes in soil quality of the underutilized lands in the case study have been assessed on the basis of projections and forecasts. The necessity to rely on long term measurement and surveys in the field to survey physico-chemical changes made the quantitative assessment of this indicator through the use of primary data impossible within the extent of this project. Therefore theoretical changes in soil quality parameters have been performed and the results should be interpreted in a qualitative manner, identifying possible trends and reaching indicative conclusions.

In the case of willow in Ukraine, the average impact that this form of vegetation has on the accumulation and removal of SOC over the long run was calculated. In baseline conditions, the area is covered by grasslands and these systems in low productivity, marginal areas tend to be in equilibrium in terms of SOC. This means that over the long term there is a particularly slow accumulation of organic matter which tends to be removed at virtually the same rate as the deposition.

The target scenario would foresee the cultivation of willow, a perennial deciduous tree crop which is harvested in winter, when the plants have shed their leaves. In this scenario no organic fertilization (e.g. manure) is performed and thus the SOC balance is only affected by the natural removal and the inputs from the debris represented by the above and below ground biomass. It was estimated that willow cultivation returns about 5,600 kg of biomass (mostly leaves and chips from the harvesting operation) per ha are left in the field at every harvest, which equals to some 1,867 kg per year. In total, the system has the potential to accumulate some 314 kg of SOM per ha each year.

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3.2.3 Water use and efficiency

In the Ivankiev Region, the climate is cold-temperate. Precipitations are abundant year round and even in the driest months relevant amounts of water are recorded. According to the Köppen and Geiger climatic classification, the climate in the case study region is characterized by warm-summer humid continental climate type. Average yearly temperature in Kiev is 7.7 °C average annual rainfall is 640 mm, whereas in the case study area the data entry sheet filled out in the context of FORBIO reports slightly higher annual precipitations (662 mm).

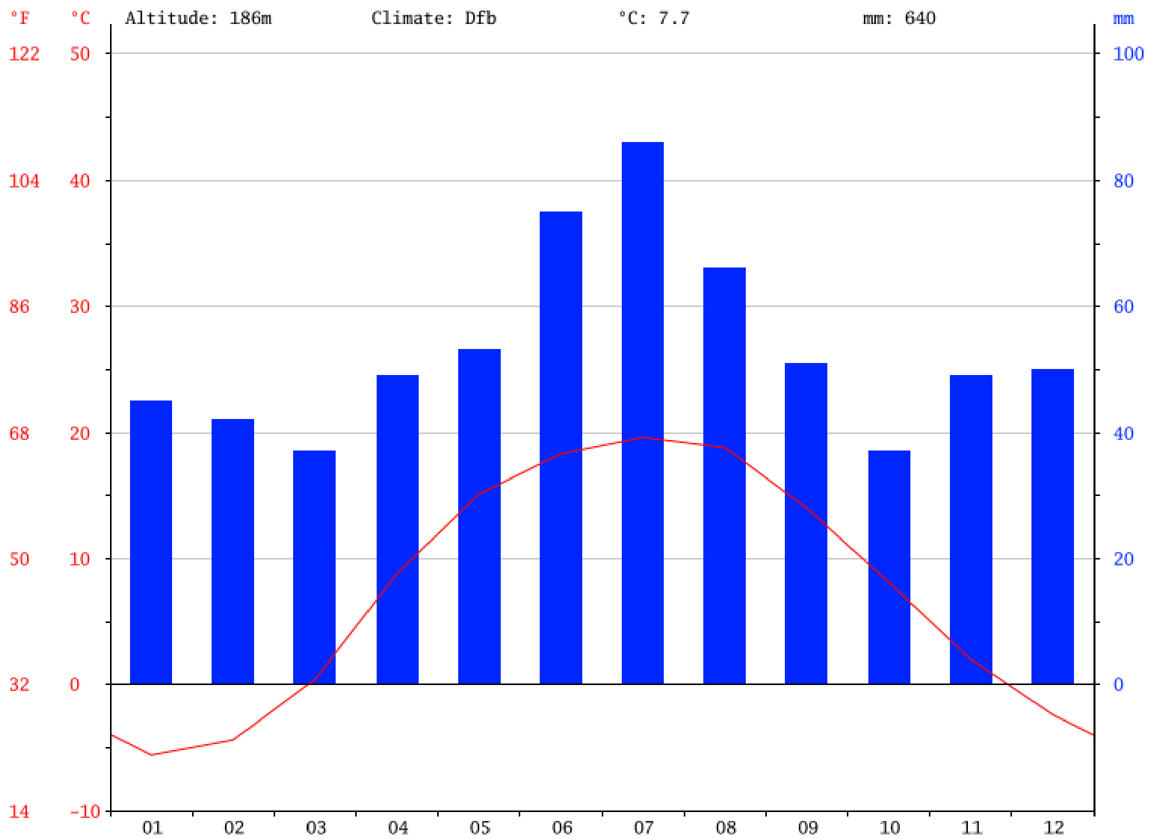

Figure. 35 Climate profile of Kiev, Ukraine. Source: https://it.climate-data.org/location/218/

The impact on water use and efficiency of willow in rainfed conditions was assessed on the basis of the amount of water required by the crop (600 mm according to D 2.5) and the distribution throughout the year of said precipitation. The contribution to water use made by the processing into fuel (water makeup in the biorefinery is 1.3 m^3 per ton of biomass) is accounted for as blue water and the indicator expresses the overall water requirement per unit of energy produced.

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WATER USE AND EFFICIENCY

UNDERUTILIZED AGRICULTURAL

			CROP 1	CROP2	CROP 3
	Name		WILLOW	-	-
	Growth cycle		Perennial	-	-

WATER WITHDRAWN FROM WATERSHEDS WITHIN THE TARGET AREA

Wfstk.ren Renewable Water used for Bioenergy Feedstock Production

			CROP 1	CROP2	CROP 3
Productivity	Crop yield	tonnes/ha	10,0	-	-
Area Planted	TARGET CULTIVATED SURFACE	Ha	16.720	-	-
	CROP ET	mm/year	620	-	-
	Effective Precipitation	mm/year	662	-	-
	Crop production	tonnes	167.200	-	-
	A. Irr. Req.	mm/year	-42	-	-
	Unitary Water req	m3/ha	6.200	-	-
		Km3/year	0,10366400	-	-
	Unitary W(IRR) req	m3/ha	-420	-	-
		Km3/year	-0,00702240	-	-
	Tot Unitary W(IRR) Req.	Km3/year			-0,00702240
	Wfstk ren	Km3/year	0,10366400	-	-
TOT Wfstk ren	0,10366400	Km3/year			

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TA

Figure. 36a Water use and efficiency profile for rainfed willow in Ukraine.

The production of biomass requires no additional irrigation water in the case study site and it returns yields of around 10 t ha-1 yr-1. Actually, the Ivankiev region offers more water than the clones of *Salix viminalis* used for biomass production in this area require. This translates into a total water requirement of 0.1036 km^3/year to provide water for the production of biomass (16,720 ha for 33,400 tons of ethanol). The blue water percentage over total water use of the agricultural phase is zero as the totality of the water used by the plants is green water. The impact of water use and efficiency of the water requirements of the processing stage is given but the process' requirements for water makeup which is 1.30 m^3 per ton of feedstock.

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

Summarizing, the water used by the value chain for the production of 1 ton of feedstock is 3,100 m^3 whereas the amount needed for a unit of energy from ethanol is 0.115 m^3/MJ.

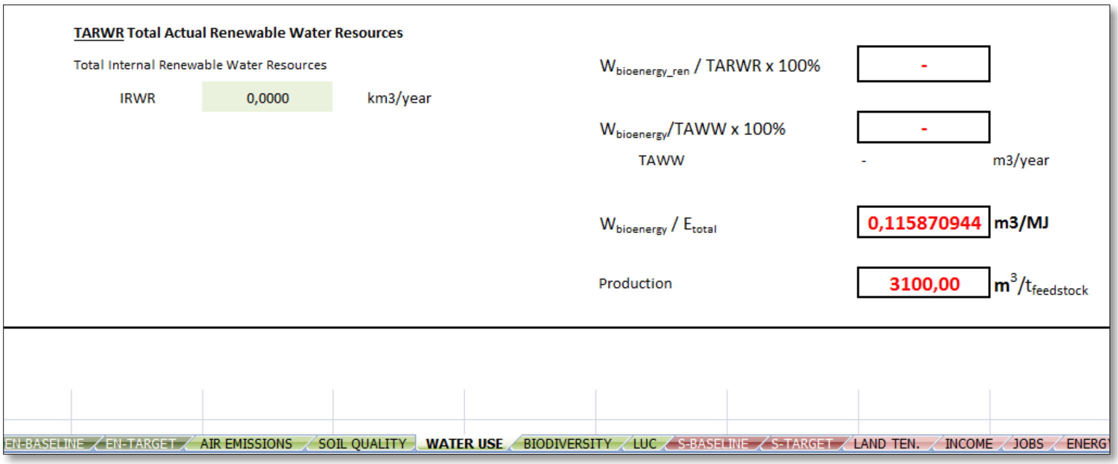


Figure. 36b Water use and efficiency results for rainfed willow in Ukraine.

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

3.2.4 Water Quality

This indicator could not be measured in Ukraine due to lack of data and shapefiles necessary to run the SWAT model. It is suggested that stronger efforts are made in future phases of the project to retrieve such information and perform the assessment of pollutant loadings into the bodies of water as a consequence of the production of advanced biofuels within the ***target area***.

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

3.2.5 Biodiversity

At EU level, there is a list of endangered species and critical habitats that should be monitored when these are naturally present in the area of a possible agricultural project. The list is reported in the figure below and represents the checklist of animal species of interest and their presence in Ukraine as well.

COUNTRY	UA (ENP)	SPECIES	TYPICAL HABITAT
	NO	Great bustard, Otis tarda	Dry grasslands and mosaic of crops and grasslands
	YES	Large blue butterfly, Maculinea arion	Dry grasslands
	YES	Corncrake, Crex crex	Meadows
	NO	Meadow viper, Vipera ursinii	Meadows
	NO	Yellow-bellied toad, Bombina variegata	Wetlands (and forests)
	YES	Bittern, Botaurus stellaris	Wetlands (reedbeds)
	YES	Hamster, Cricetus cricetus	Arable land
	YES	Skylark, Alauda arvensis	Arable land
	YES	Ortolan Bunting, Emberiza hortulana	Extensive arable land with single trees, orchards, forest mar
	YES	Scops owl, Otus scops	Extensive agri-pastoral systems especially with old trees or p
	YES	Great capricorn beetle, Cerambyx cerdo	Forests and veteran trees
	NO	Capercaillie, Tetrao urogallus	Forests

Figure. 37 List of endangered species in Europe and their presence in the case study Country (UA).

According to the data collection campaign carried out during the FORBIO project, the ***target area*** in Ivankiev Region, Ukraine (181,734 ha), is interested by the presence of nationally determined critical habitats and high biodiversity areas for a total of 48,915 ha or about 27% of the ***target area***. The remaining 132,819 hectares within the ***target area*** then are not interested by the presence of critical habitats.

CRITICAL AREAS AND CONSERVATION OF SELECTED SPECIES OF WILDLIFE			
Total target area **181.734** ha			
Total high biodiversity areas surface	Ha	48.915,5	BALANCE
Total areas where critically endangered species are found	Ha	48.874,5	**132.819**
Total important ecosystems		41,0	
Areas that contain habitat for viable populations of endangered, restricted range (endemic) or pı	Ha	48.870,0	
Areas that contain habitat of temporary use by species or congregations of species (e.g. nidificati	Ha	4,5	
Important natural landscape areas for natural ecological dynamics	Ha	41,0	
Areas that contain two or more contiguous ecosystems	Ha	0,0	
Areas containing rare or endangered ecosystems	Ha	0,0	
Not included		132.819	

Figure. 38 Breakdown of the areas of critically endangered species and important ecosystems are found within the *target area* in the Ivankiev Region, Ukraine.

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

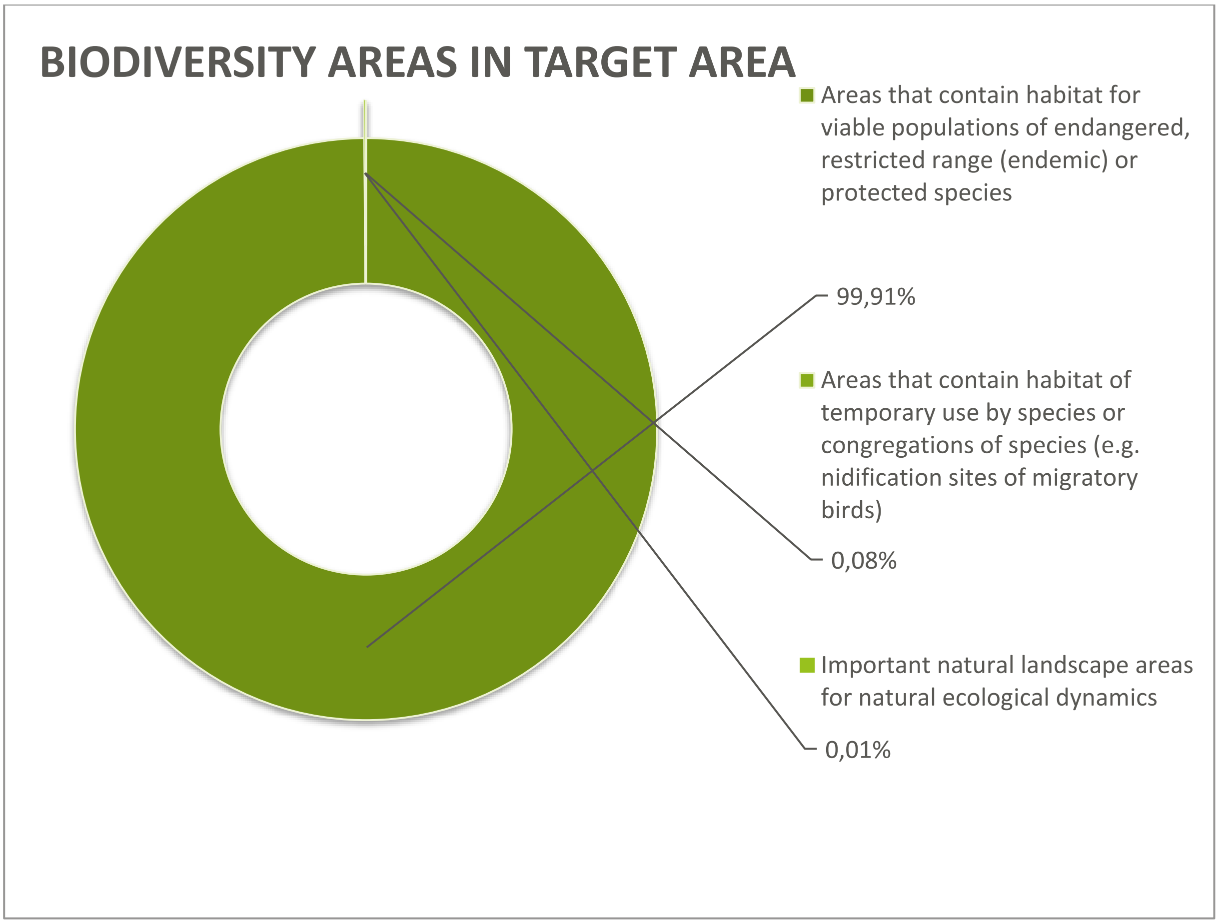


Figure. 39 Breakdown of high biodiversity value areas (critically endangered species + important ecosystems) and percentages within the *target area* in the Ivankiev Region, Ukraine.

In Figure 38 the breakdown of the land cover types within the ***target area*** offers an overview of the various land cover types and an indication of their extension. Forest cover some 78,277 ha, agricultural land some 80,954 ha (of which 16,720 are underutilized), and other lands (including industrial sites and urban centers, but also natural meadows and shurblands) account for a further 22,503 ha. In particular, other natural land types such as wetlands, meadows and shrublands (not agricultural, forest, or industrial/urban areas) represent about 18,756 ha.

Forests and other natural landscapes represent the majority of the Important natural landscape areas for natural ecological dynamics and areas that contain habitats for endangered populations, endemics and protected species.

The production of bioenergy in the target scenario would target solely undertulized agricultural land. These areas are likely to contain habitats for endangered species often found in meadows or arable lands (e.g. Hamster, Skylark, and the Ortolan bunting). During the FORBIO project it was not possible to measure quantitatively species richness of the current underutilized lands, and in literature only anecdotal information was retrieved for Ukraine. As in previous case study sites, the assessment of species richness in the baseline scenario would require the collection of year-round primary data on the various components of the biota (e.g. plant diversity, animal diversity, soil diversity, including fungi and bacteria) and the assessment of the target scenario would rely on literature because there exist broad differences in population dynamics depending upon the size of the ecosystem. As in the previous analyses then, the assessment of this indicator has been primarily qualitative.

According to Rowe et al. (2013), in willow short rotation coppice plantations in England higher biodiversity was detected than in nearby cropland and set-aside land. Many other authors agree with these findings to varying extents but the most complete study on biodiversity in willow SRC in Europe was carried out in 2007 by the Institute of Biological, Environmental and Rural Sciences, Aberystwyth University in the context of the EU-funded project *Willows for Wales* (Fry and Slater, 2007). This study considered both plant and animal diversity in willow SRC and among the animal species, great detail was provided not only at the level of soil dwellers or birds (as in the case of most biodiversity studies on perennial bioenergy crops) but also small and large mammals were included in the study.

The summary conclusions of the study confirmed that planting SRC could be a landscape element of significant benefit to biodiversity. Weed floral diversity and abundance would be increased and this would have significant knock on benefits for a wide range of bird species. Soil fauna has been found to be more diverse and abundant than on improved grassland and set-aside land nearby. Moreover, small and large mammals rely on SRC areas as feeding areas and the increased diversity at the landscape level enhances bird and mammals livelihoods. Based on the aforementioned findings, the presence of willow SRC seems to be superior to the current land use from the biodiversity point of view.

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

3.2.6 Land Cover and Land Use Changes

The production of biomass for energy purposes in the target scenario will lead to a change in land cover types when compared to the current conditions (baseline scenario). Understanding the entity of this change and the turnover between difference land cover classes is useful to land use planners to have an understanding of the development trends that will interest their territory.

The outcomes of the analyses of the dynamics of the target scenario tested is presented in Figure 40, below.

LAND USE AND LAND USE CHANGE RELATED TO BIOENERGY FEEDSTOCK PRODUCTION

	UNDERUTILIZED AGRICULTURAL LAND					
CROP USED FOR FEEDSTOCK PRODUCTION	CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1
Name	WILLOW	-	-	-	-	-

BASELINE			TARGET		
Total annual crops and fallow lands	Ha	39.117	Total Annual crops	Ha	39.117
Total annual crops and fallow lands for FSTK production	Ha	0	Total annual crops and fallow lands for FSTK	Ha	0
Total permanent crops	Ha	892	Total permanent crops	Ha	17.612
Total permanent crops for FSTK production	Ha	50	Total permanent crops for FSTK production	Ha	16.770
Underutilized agricultural land	Ha	16.720	**Underutilized agricultural land**	Ha	0
Underutilized NON-agricultural land (e.g. EX-mining sites)	Ha	195	**Underutilized NON-agricultural land (e.g. E**	Ha	195

RATE OF CONVERSION	
Agriculture	% of conversion
Annual crops and fallow lands (FAOSTAT Arable Land)	0,0
Permanent crops	1.874,4
Underutilized agricultural land	-100,0
Others lands	
Underutilized NON-agricultural land (e.g. EX-mining sites)	0,0

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGE

Figure. 40 Willow SRC: Changes is land cover type and rates of conversion within the *target area* in the Ivankiev Region, Ukraine.

At baseline, in the ***target area*** there are some 16,720 ha of underutilized agricultural land. As of today, the total permanent crop area within the ***target area*** is 892 ha of which 50 ha are represented by dedicated bioenergy feedstock already produced in the area. In the target scenario, the land required for the production of willow SRC (16,720 ha) is obtained through the substitution of the current underutilized land. This will lead to a 100% decrement of said land cover category down to 0 ha in target scenario. Concurrently, the total surface under perennial crops will grow from 892 ha to 17,612 and thus dedicated bioenergy feedstock production will increase to 16,720 ha (1,874% growth). This scenario would not interest areas used for annual crops production (such as wheat, sugar beet, sunflower, etc.).

Finally, the expected rate of conversion of underutilized lands into dedicated bioenergy feedstock production land will be 100%.

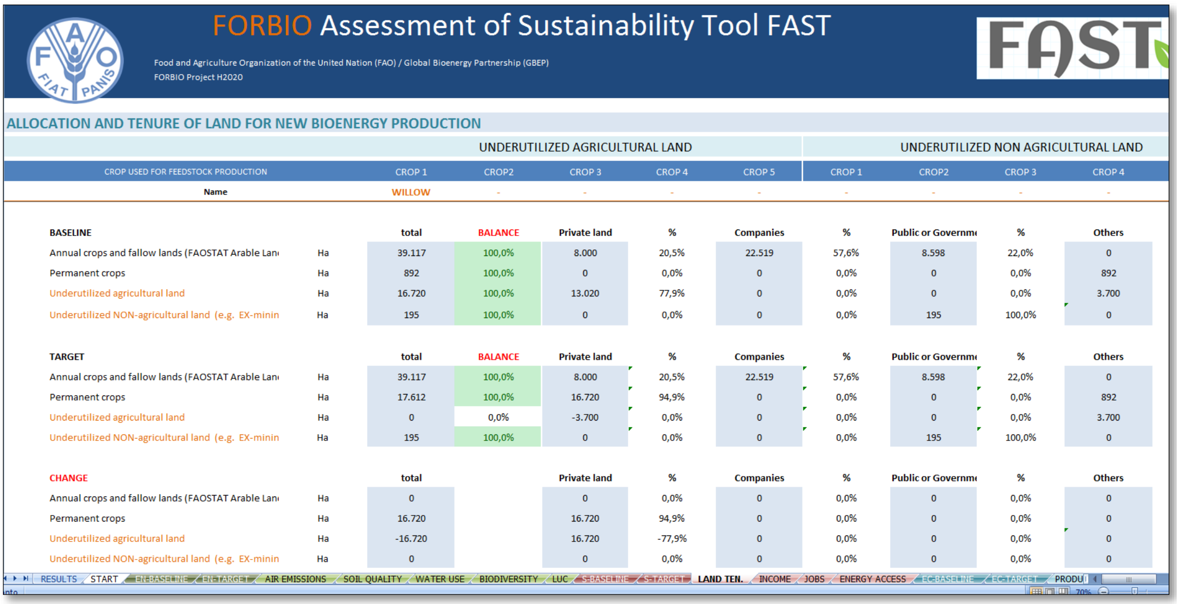
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691846.

3.2.7 Land Tenure

The land tenure structure of the ***target area*** is rather complex and still under development. This indicator is critical because understanding the ownership structure of the country is pivotal to propose any possible development scenario for the bioenergy sector (as well as for any other agricultural or land-planning related sector). The land-ownership structure in the ***target area*** was described in this exercise thanks to the outstanding contribution of the project partners SECBio and Blacksmith Institute who collaboratively retrieved the bulk of information necessary to describe and assess the baseline situation and use it as a stepping stone to project into the future the target situation under the coordination of FAO, who also built a solid literature database on the matter.

After the collapse of the former USSR, agriculture in Ukraine has been dominated by large extension of land owned by private entities, mainly agri-holdings. According to Lapa et al (2008), the 18 largest agricultural companies of Ukraine control a cumulative agricultural area of about 1,7 million hectares, which represents approximately 11% of all farmland mananaged by large and middle-size private farms of Ukraine. Starting from the 2000s however, the trend changed and lesser large agri-holdings acquired land in favor of small private actors. Farmers during the 1990s owned on average 20 ha farms, whereas in 2005 the average farm size grew to about 90 ha on average (European Commission, 2009).

Companies manage surfaces of more than 100 ha and employ more than 50 employees and large agri-holdings (referred to in the FORBIO indicator as "Others") manage more than 1,000 ha (Lapa et al, 2008).


FORBIO Assessment of Sustainability Tool FAST

Food and Agriculture Organization of the United Nation (FAO) / Global Bioenergy Partnership (GBEP)
FORBIO Project H2020

ALLOCATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION

		UNDERUTILIZED AGRICULTURAL LAND					UNDERUTILIZED NON AGRICULTURAL LAND			
CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1	CROP2	CROP 3	CROP 4
Name		WILLOW	-	-	-	-	-	-	-	-
BASELINE		total	BALANCE	Private land	%	Companies	%	Public or Governm	%	Others
Annual crops and fallow lands (FAOSTAT Arable Lan	Ha	39.117	100,0%	8.000	20,5%	22.519	57,6%	8.598	22,0%	0
Permanent crops	Ha	892	100,0%	0	0,0%	0	0,0%	0	0,0%	892
Underutilized agricultural land	Ha	16.720	100,0%	13.020	77,9%	0	0,0%	0	0,0%	3.700
Underutilized NON-agricultural land (e.g. EX-minin	Ha	195	100,0%	0	0,0%	0	0,0%	195	100,0%	0
TARGET		total	BALANCE	Private land	%	Companies	%	Public or Governm	%	Others
Annual crops and fallow lands (FAOSTAT Arable Lan	Ha	39.117	100,0%	8.000	20,5%	22.519	57,6%	8.598	22,0%	0
Permanent crops	Ha	17.612	100,0%	16.720	94,9%	0	0,0%	0	0,0%	892
Underutilized agricultural land	Ha	0	0,0%	-3.700	0,0%	0	0,0%	0	0,0%	3.700
Underutilized NON-agricultural land (e.g. EX-minin	Ha	195	100,0%	0	0,0%	0	0,0%	195	100,0%	0
CHANGE		total		Private land	%	Companies	%	Public or Governm	%	Others
Annual crops and fallow lands (FAOSTAT Arable Lan	Ha	0		0	0,0%	0	0,0%	0	0,0%	0
Permanent crops	Ha	16.720		16.720	94,9%	0	0,0%	0	0,0%	0
Underutilized agricultural land	Ha	-16.720		16.720	-77,9%	0	0,0%	0	0,0%	0
Underutilized NON-agricultural land (e.g. EX-minin	Ha	0		0	0,0%	0	0,0%	0	0,0%	0

Figure. 41 Willow SRC: Changes is land ownership type in the baseline vs target scenario in the Ivankiev Region, Ukraine.

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

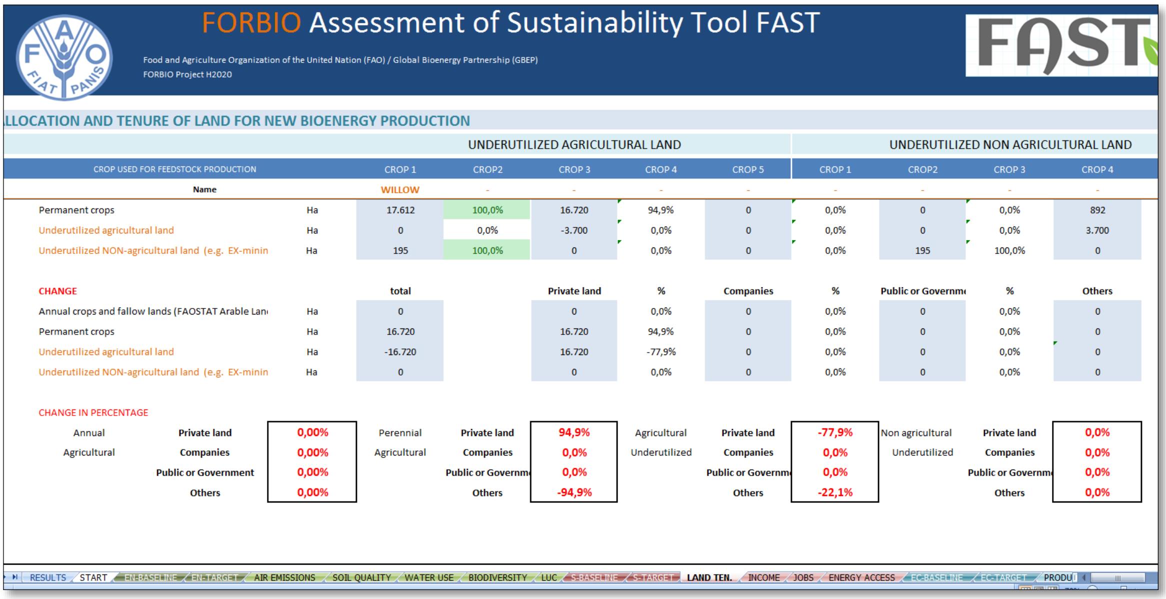


Figure. 42 Willow SRC: rates of conversion within the land ownership category in the baseline vs target scenario in the Ivankiev Region, Ukraine.

As shown in figure 41 and 42 the rates of change between land ownership type will follow the trend started over the recent decade. Underutlized agricultural land in the ***target area*** is currently owned partially (77.9% of total underutilized land) by private farmers (average farm size 90 ha) and partially (the remaining 22.1%) by a few large agri-holdings (3,700 ha in total). Following the development trend of recent years it is likely that smallholder farmers will turn into cultivation the underutilized land they already own, and that subsequently acquire further land from the agri-holdings that own the remaining 3,700 ha. This would take place within a consortium type of setting that offers smallholder farmers coordination and negotiation power.

The hypothetical advanced biofuel value chain in Ivankiev will therefore reclaim the currently underutilized agricultural land owned by the two aforementioned categories of land owners and likely smallholders will be in the position to acquire plots of underutilized agricultural land from agri-holdings, as it has been the trend over the past two decades. The shares of land owned by mid-size companies and government entities under the other land cover classes (i.e. annual crops and permanent crops) would remain unchanged, whereas the share of permanent crops would increase for private smallholders by 94.9%.

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

3.2.8 Jobs in the bioenergy sector

The total population in the ***target area*** is 30,021 inhabitants. The working population (men and women, age group 20-64) is 11,465, thus the unemployment rate in this area of Ukraine is 38.2%. The share of unskilled vs skilled jobs in the area is 66.8%. The vast majority of the jobs are permanent, but in agriculture sector, and specifically in the willow SRC companies 33.6% of jobs are temporary while the remaining two thirds are permanent. At baseline, the number of employees in the bioenergy sector is 44.

Advanced bioenergy value chains have the potential to produce employment in the agriculture sector (feedstock production) as well as in the industrial sector (feedstock processing) and accessory sectors too (e.g. transport of biomass, induced jobs for the production of inputs, machineries, etc.). In willow biomass production, with the exception of the first year and only for specific agricultural phases (i.e. planting) and for the transport of the biomass, the majority of the jobs are expected to be permanent. In the processing stages and partially in the management of the farms (given the structure of farms in the ***target area*** which are mainly family-owned and managed) jobs are expected to be predominantly year-round permanent ones.

In the target scenario the advanced bioenergy value chain would employ both temporary and permanent workers to plant, cultivate, harvest 16,720 ha and transport the feedstock to the hypothetical biorefinery located in Ivankiev Town. The construction of the biorefinery would also generate jobs but these are considered indirect and not included in this forecast, as in the previous case studies. Though, the operations and maintenance of the biorefinery would generate some 100 highly skilled permanent jobs.

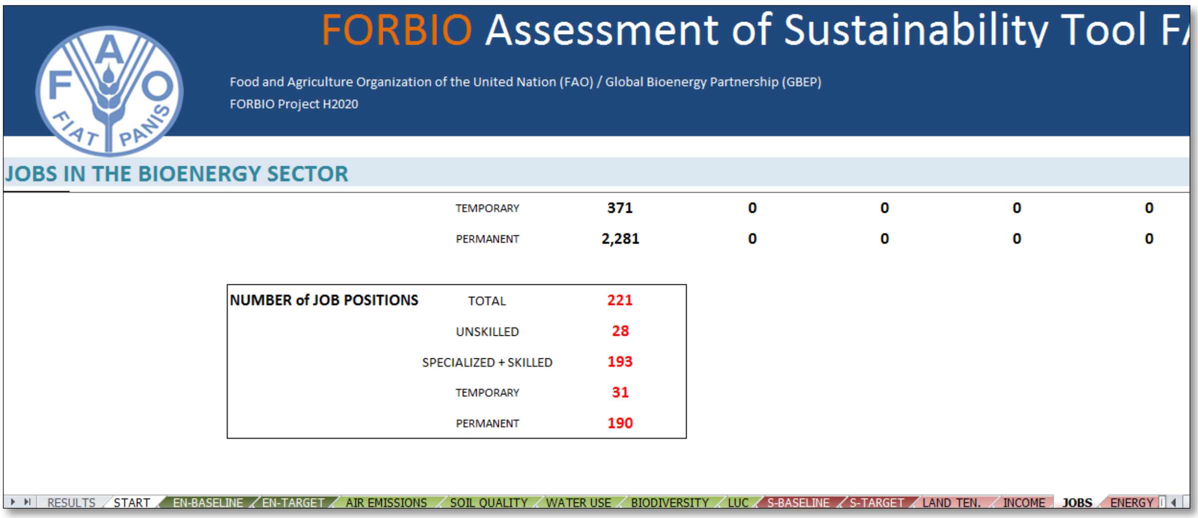


Figure. 43a Willow SRC: changes in employment due to the hypothetical advanced bioenergy value chain in the *target area* (Ivankiev Region, Ukraine).

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

The jobs in the processing stages summed to the 121 jobs in the other components of the value chain (feedstock production and biomass transport) would totalize 221 direct net jobs created by the value chain.

Figure 43a and b recap the changes in employment due to the hypothetical advanced bioenergy value chain in the ***target area***. Once at regime, the lignocellulosic ethanol value chain would contribute to decreasing the unemployment rate of the area by 0.73%, employing 2.3 percent of the workforce. At the national level, these changes have minor relevance, though as the level of the ***target area*** the social impacts of this value chain may be considerable. In total 31 temporary and/or seasonal jobs and 190 permanent jobs would be created, 14 and 86% of total respectively. Lastly, it is interesting to note that 88% of the newly created jobs would be skilled jobs, as the nature of the value chain requires trained and skilled workers to carry out qualified tasks.

NATIONAL	BASELINE	TARGET	BASELINE	TARGET	NATIONAL ΔNUMBER	NATIONAL Δ%
total population	**44,009,214**	**44,009,214**				
Total working population, men and women, age group 20-64	28,253,915	28,254,136	64.2	64.2	221	0.001
Low skilled persons, age group 20-64	10,821,250	10,821,277	38.3	38.3	28	0.000
Skilled persons, age group 20-64	17,432,666	17,432,859	61.7	61.7	193	0.000
Total temporary employees	3,390,470	3,390,501	12.0	12.0	31	0.000
Total permanent employees	24,863,446	24,863,636	88.0	88.0	190	0.000
Number of men and women, age group 20-64 in the **BIOENERG**	480,317	480,538	1.7	1.7	221	0.001

TARGET AREA	BASELINE	TARGET	BASELINE	TARGET	TARGET AREA ΔNUMBER	TARGET AREA Δ%
total population	**30,021**	**30,021**				
Total working population, men and women, age group 20-64	11,465	11,686	38.2	38.9	221	0.736
Low skilled persons, age group 20-64	7,653	7,681	66.8	65.7	28	-1.024
Skilled persons, age group 20-64	3,806	4,000	33.2	34.2	193	1.025
Total temporary employees	0	31	0.0	0.3	31	0.265
Total permanent employees	11,465	11,655	100.0	99.7	190	-0.265
Number of men and women, age group 20-64 in the **BIOENERG**	44	265	0.4	2.3	221	1.884

START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY

Figure. 43b Willow SRC: changes in employment due to the hypothetical advanced bioenergy value chain in the *target area* (Ivankiev Region, Ukraine).

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

3.2.9 Changes in Income

Changes in income between the baseline and target scenarios are calculated as the difference in attainable revenues per ha between a common economic activity currently found within the ***target area*** and the activities linked to the production of bioenergy feedstock or the processing of the biomass into fuel. Transport of biomass and biofuel are not compared to similar economic activities since the transport sector has rather homogenous characteristics in the case study area and changes in income may not be noticeable.

The production of biomass is an agricultural activity that would give work to a consistent share of the workforce employed in the advanced biofuel value chain. However, a consistent share will be employed in the biorefinery. For reliability reasons, the agricultural activities were compared to the production of wheat.

Ukraine has a long history of production of this grain which dates back at the times of the former USSR (FAO, 2012). According to a study carried out by the Thünen institute of Farm Economics (Möllmann, 2009), winter wheat production in a model farm in Ukraine leads to good margins because production costs (particularly fertilizers, pesticides, land and labour) are low and yields are particularly high (8 t/ha). The underutilized lands in the Ivankiev Region however, have a lower production potential and production costs would not make wheat production in this area competitive with the production in other parts of the country. Being the wheat market a fully international market, the competition would be unsustainable and therefore the need to find alternative products and markets for these areas is impellent. In the ***target area*** the production cost of wheat is EUR 600/ha. At current international market price, wheat is exchanged at EUR 184/t (USD 213/ton according to IndexMundi, 2018). The breakeven point to enable winter wheat production is a minimum yield of 3.26 t/ha. Unfortunately, in the underutilized lands in the Ivankiev region, this minimum yield is not achieved and as a consequence neither the production of wheat nor the production of other food crops is economically sustainable. Currently, land owners in the Ivankiev region then, have no income source from their underutilized lands and this indicator's value in the baseline scenario is 0.

According to the Deliverable 2.6 (techno-economic assessment), production cost of willow SRC in the case study location is EUR 28.7 per ton of biomass delivered at the biorefinery gate. Biomass transport costs represent a contribution of EUR 3.5/t. Considering an average yield of 10 t ha-1 yr-1, the landowner fee was calculated at EUR 1.3/t or EUR 13/ha. Assuming that all field operations are carried out by third party actors, the income for an average farm (90 ha) owner in the Ivankiev Region would be EUR 1,170/year.

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

TARGET BIOENERGY CROP

AVERAGE WAGES PAID FOR EMPLOYMENT IN BIOENERGY FEEDSTOCK PRODUCTION

	PM/ha/yr	0.0128	-	-	-
BETWEEN DIFFERENT OCCUPATIONS	Wage €/yr	3,551	-	-	-
	Wage €/PM	296	-	-	-
	Wage €/ha	4	-	-	-

AVERAGE WAGES PAID FOR EMPLOYMENT IN BIOENERGY FEEDSTOCK TRANSPORT

	PM/ha/yr	0.0022	-	-	-
BETWEEN DIFFERENT OCCUPATIONS	Wage €/yr	2,848	-	-	-
	Wage €/PM	237	-	-	-
	Wage €/ha	1.420	-	-	-

AVERAGE WAGES PAID FOR EMPLOYMENT IN BIOENERGY FEEDSTOCK PROCESSING

	PM/ha/yr	0.0145	-	-	-
BETWEEN DIFFERENT OCCUPATIONS	Wage €/yr	27,000	-	-	-
	Wage €/PM	2,250	-	-	-
	Wage €/ha	-	-	-	-

COMMON LOCAL CROP

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOM

Figure. 44 Average yearly income by job category in the hypothetical advanced bioenergy value chain in the *target area* (Ivankiev Region, Ukraine).

From Figure 44 it is clear how the wages in the processing of the feedstock into fuel, calculated on the basis of international values for highly specialized workers to be employed in the biorefinery, stand out for being 8 to 10 times higher than wages paid in other stages of production. As discussed, this is mainly due to the international rate used for these calculations but crucially these also reflect the increased expertise, training and knowledge that highly skilled workers in the advanced bioenergy sector possess.

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3.2.10 Energy Access

This indicator measures the contribution of advanced biofuels to the access of households to modern bioenergy services. In order to do so, it directly tackles the share of liquid biofuel into the mix on the one hand and, in the specific case of second generation ethanol, where lignin is a co-product use in the biorefinery's Combined Heat and Power (CHP) plant, the production of excess heat and electricity are also accounted for as. The World Bank (2016) reports 100% rate of access to modern energy services (e.g. % of the population who has access to electricity, etc.) in Ukraine. However, the substitution among forms of energy or the substitution among sources of the same energy type (i.e. renewable vs fossil) is accounted for in this indicator as an index of development towards a more diversified access to modern energy services. Therefore, changes are expressed in relative or absolute terms depending upon the viability of either method: if, as in the case of Ukraine, all households have access to electricity, the surplus energy produced will not be absorbed by residential areas currently disconnected from the electricity grid since these do not exist, but said surplus will contribute to reduce the demand for the same form of energy to be produced from other sources, often times fossil ones.

As of 2014 Ukraine consumed 82,000 tons of ethanol fuel (Janda & Stankus, 2017). A biorefinery which produces 33,400 tons per year of lignocellulosic ethanol has the potential to increase by 10.3% the overall access of Ukrainian consumers to modern biofuels, at the national level, when compared with the baseline.

The contribution of the electricity generated by the CHP and injected into the national grid will contribute to increase by 0.06% the production of electricity of the country (red square in Figure 45).

	Growth cycle		Perennial	-	-	-	-
CROP SPECIFICATIONS	TARGET CULTIVATED SURFACE	Ha	16,720	-	-	-	-
ENERGY ACCESS							
ITEMS NATIONAL LEVEL			BASELINE	PROJECT	TARGET		CHANGE
Electricity for lighting, communication, healthcare, education and other uses			144,890	87	144,977	GWh/yr	0.06%
Advanced liquid biofuels for transport			2,218,983,270	896,526,400	3,115,509,670	MJ/yr	40.40%
Thermal energy (district heating and cooling)			359,222,948,612,000	956,384,000,000	360,179,332,612,000	BTU/year	0.27%
HOUSEHOLDS DISAGGREGATED							
Target area	Electricity		11,631	24,151	35,782	Numb.	207.65%
	Thermal		11,631	28,030	39,661	Numb.	241.00%
National	Electricity		17,050,000	24,151	17,074,151	Numb.	0.14%
	Thermal		17,050,000	28,030	17,078,030	Numb.	0.16%
EU	Electricity		221,326,200	24,151	221,350,351	Numb.	0.01%
	Thermal		221,326,200	28,030	221,354,230	Numb.	0.01%

ND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASELINE / EC-TARGET / PRODUCTIVITY / NET E BALANCE / G V A / INFRASTRUCTURE / CAPACITY / REFERENCE

Figure. 45 Contribution to modern energy access of the hypothetical advanced bioenergy value chain in the *target area* (Ivankiev Region, Ukraine).

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

The CHP installed in a hypothetical biorefinery, may also produce excess low-temperature heat. The heat, if properly channelled through a district heating infrastructure may contribute to enhancing the access of local and national population to modern bioenergy forms for heating purposes. According to Business Sweden (2016), in Ukraine 58% of the population is connected to district heating (DH) systems (26 million people) which are predominantly in major cities and largely natural gas-fueled (99%) with biomass having very small share in one single DH. the installed district heating capacity of the country. Municipal and residential sector use some 359,222 x 10^9 BTUs. The CHP of the hypothetical biorefinery in Ivankiev Town could generate additional 956 x 10^9 BTUs or 0.27% more energy for residential heat (blue square in Figure 45).

At the household level, the aforementioned contributions would translate into additional 24,151 households connected to the electrical grid and additional 28,030 household connected to a renewable district heating system.

The amount of energy generated by the CHP plant of the biorefinery would be enough to supply more than two times the amount of energy necessary for to meet the electricity and DH needs of the ***target area***.

At the national level, this contribution would be respectively 0.14% and 0.16% for electricity and heat. Finally, at the EU level, the hypothetical biorefinery in Ivankiev Town would increase the access to modern bioelectricity services and modern renewable district heating by 0.01% (green square in Figure 45).

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

3.2.11 Productivity

This indicator measures the productivity of the bioenergy value chain in terms of quantities and unitary costs. The excellent work done by SECBio, the Blacksmith Institute and Biochemtex with Deliverable 2.5 and 2.6 provided an important share of the information included in this indicator. Unfortunately, the communication with Biochemtex provided only indicative values to produce and estimate production costs and its components, other than feedstock production cost.

Willow in the case study area produces steadily at least 10 tons of biomass per ha per year. The SRC cycle foresees a three year growing period between harvests and the stumps stay in the field under productive conditions for 20 – 25 years. The information above was recoded from experimental field trials and analyses of the performances of the 50 ha willow SRC plantation in the Ivankiev Region and are included in Deliverable 2.5.

The estimate of ethanol production cost was performed through a number of calculations and data obtained both from direct communication with Biochemtex and information found in the specialized literature. However, it should be noted that most derive from general costs based on existing experiences (thus in the EU, and not in UA).

The components that make up production cost are the Capital expenditure (CAPEX) and the Operational Expenditures (OPEX). The CAPEX was quickly estimated for the hypothetical biorefinery in Ivankiev Town on the basis of the investment needed for the similar plant in Crescentino, Italy operated by Biochemtex but reduced in order to meet the effective size of the plant in Ukraine. A total initial investment of EUR 125 million was considered adequate to the construction and running of a 33,400 t lignocellulosic ethanol plant using the PROESA technology in Ukraine.

Operational Expenditures were calculated as follows:

Feedstock expenditure: EUR 4,681,000 per year

Enzymes, yeast, catalysts, other inputs: EUR 10,790,000 per year (adapted from E4tech, 2017)

Salaries: EUR 2,592,000 per year

Miscellaneous: EUR 1,000,000 per year

In total the production cost of lignocellulosic ethanol was calculated to be EUR 720 per ton. This value calculated in the real case scenario of FORBIO was compared to values found in literature. According to E4TECH (2017) lignocellulosic ethanol production costs in Europe range between EUR 940 and 1,010 per ton. The feedstock price advantage in the Ukrainian case study is the principal responsible for the price difference with values found in the literature.

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

3.2.12 Energy Balance

Unfortunately, reliable information on the energy balance of the processing stages of lignocellulosic ethanol production could not be shared by Biochemtex and therefore this indicator could not be measured for this case study.

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3.2.13 Gross Value Added

This indicator measures the contribution to the GDP of a given bioenergy value chain. In the case study of the Ivankiev Region, the products that contribute to GDP are the sales of bioethanol and the sales of excess electricity. Given the popularity of DH systems in Ukraine, the hypothetical sale of excess heat was also included in this calculation as it seems very likely the existence the necessary infrastructure.

The current European price for ethanol is registering an all-time low at 424 EUR/m^3 (534 EUR/t). At current market prices, sales of ethanol would generate some 17,835,600 EUR/year. In addition, the surplus electricity produced by the CHP of the biorefinery could generate some 87 GWh per year of renewable electricity. The price per unit of electricity generated is a contributor to the overall balance of the advanced bioethanol value chain. The current price of electricity for large scale biomass-fueled power plants of EUR 123.9/MWh as per Article 20 of Law "On Heat Energy Supply", (2018), revenues for the generation of electricity would account to EUR 10,779,300 per year for the next 20 years. Total revenues for a 33,400 t/year biorefinery at current market conditions would then be EUR 33,520,152 per year. The generation of heat to serve 28,030 households in the country would deliver additional EUR 4,905,252/year. This is calculated agaist total production cost of lignocellulosic ethanol in Ukraine of 720 EUR/t or 24,048,000 EUR/year.

Thus, given the current market conditions, the Gross Value Added of a second generation biorefinery would be negative by some EUR 9,457,152 per year.

Ethanol price volatility though is a key parameter. As in the case of Italy, we tested a further scenario which used the price of ethanol FOB at Rotterdam of June 2017, thus 1 year prior to this investigation. Then the ethanol price was 756 EUR/t and at this rate the GVA would be positive by EUR 16,871,952 (Figure 47).

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

TARGET AREA (Advanced biofuel value chain)								
Total gross revenues from sales (Adv. Biofuels + other services)								
Advanced biofuel sales	**€/year**	**17,835,600**	-	-	-	-	-	-
Other services (e.g. elec	**€/year**	**10,779,300**	-	-	-	-	-	-
Heat	**€/year**	**4,905,252**	-	-	-	-	-	-
TOTAL	**€/year**	**33,520,152**	-	-	-	-	-	-
					33,520,152			
Cost of production (including processing inputs and raw materials)								
TOTAL	**€/year**	**24,063,000**	-	-	-	-	-	-
Cost of services from outside suppliers (e.g. transport of final product)								
TOTAL	**€/year**	**0**	-	-	-	-	-	-
TOTAL	**€/year**	**24,063,000**	-	-	-	-	-	-
					24,063,000			

GVA	9,457,152	€/year
CONTRIBUTION TO GDP	0.010	%

S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY | REFE

Figure. 46 Cost-Revenues analysis and estimated GVA of the hypothetical advanced bioenergy value chain in the *target area* (Ivankiev Region, Ukraine) using ethanol market price as of June 2018 at EUR 534/ton.

TARGET AREA (Advanced biofuel value chain)								
Total gross revenues from sales (Adv. Biofuels + other services)								
Advanced biofuel sales	**€/year**	**25,250,400**	-	-	-	-	-	-
Other services (e.g. elec	**€/year**	**10,779,300**	-	-	-	-	-	-
Heat	**€/year**	**4,905,252**	-	-	-	-	-	-
TOTAL	**€/year**	**40,934,952**	-	-	-	-	-	-
					40,934,952			
Cost of production (including processing inputs and raw materials)								
TOTAL	**€/year**	**24,063,000**	-	-	-	-	-	-
Cost of services from outside suppliers (e.g. transport of final product)								
TOTAL	**€/year**	**0**	-	-	-	-	-	-
TOTAL	**€/year**	**24,063,000**	-	-	-	-	-	-
					24,063,000			

GVA	16,871,952	€/year
CONTRIBUTION TO GDP	0.017	%

S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY | REFE

Figure. 47 Cost-Revenues analysis and estimated GVA of the hypothetical advanced bioenergy value chain in the *target area* (Ivankiev Region, Ukraine) using ethanol market price as of June 2017 at EUR 756/ton.

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3.2.14 Infrastructure

The analysis of the infrastructure for the logistics of transport of biomass and biofuels, adds to the information discussed under the other indicators to present a complete overview of the characteristics of the ***target area*** from this point of view. This indicator has a quantitative and a qualitative component. The quantitative component requires the user to assess the distances between the production areas and the hypothetical site of the biorefinery, as per the primary assumption behind the target scenario. Subsequently, through the use of GIS tools, the actual distances between the production sites and the collection site are calculated. On the basis of the characteristics and the status of maintenance of the infrastructure the indicator measures the time spent to collect and deliver the biomass at the biorefinery's gate. The qualitative analysis of information in this indicator looks at the logistics side of operations within the value chain.

The assessment of this indicator was done by using information obtained from Deliverable 2.6. From the deliverable, a quantitative assessment of the real distances between the hypothetical production areas and the hypothetical site of the biorefinery were calculated.

The calculation of the average yearly transport time of the biomass was performed using the average loading capacity of the vehicles used (tractor, truck, rail, etc.) for each stage of the transport (field to road, road to biorefinery gate, etc.), the average speed admitted on the specific trait of road in km/h, and the averaged real distance between the various production sites and the collection site.

The results of this analysis confirm the adequate level of completeness and maintenance of the road system in the ***target area***. Within a radius of 50 km from the hypothetical site of the biorefinery (industrial pole of Portovesme), an average distance of 57 km is calculated between the fields and the biorefinery gate. Of these, 2 km on average are represented by rural roads, whereas the remaining 55 km are represented by medium speed primary roads as summarized in Figure 48.

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FORBIO Assessment of Sustainability Toc

Food and Agriculture Organization of the United Nation (FAO) / Global Bioenergy Partnership (GBEP)
FORBIO Project H2020

ATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION

UNDERUTILIZED AGRICULTURAL LAND

CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4
Name		WILLOW	-	-	-
TRANSPORT OF BIOMASS	Vehicle type	Truck	-	-	-
PRIMARY ROAD	Speed Class	Medium Speed	-	-	-
	Km	50	-	-	-
SECONDARY ROAD	Speed Class	Rural Road	-	-	-
	Km	2	-	-	-
Fuel transport					
Km plant to distributors	100				
	Vehicle type	Truck	-	-	-
	Fuel quantity	33,440	-	-	-

LUC / S-BASELINE / S-TARGET / LAND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASELINE / EC-TARGET / PRODUCTIVITY / NET E BALANCE

Figure. 48 Summary of the road infrastructure and related logistics of the case study area in Ukraine.

The indicator calculated the amount of time necessary to move 167,200 tons of feedstock using the average vehicle (truck) and its average payload (40 tons) at the average speeds of the type of road they travel on (30 km/h on rural roads, 60 km/h on secondary, class 2 roads) as shown in figure 49a.

FEEDSTOCK TRANSPORT		FSTK tonnes	167,200.0	-	-	-	-
		Total km	57.0	-	-	-	-
		Vehicle type	Truck	-	-	-	-
		loading capacity	40	0	0	0	0
	PRIMARY						
	HIGH	km	0.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	100	0	0	0	0
	hours	hrs	0.0	0.0	0.0	0.0	0.0
	MEDIUM	km	209,000.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	70	0	0	0	0
	hours	hrs	2,985.7	0.0	0.0	0.0	0.0
	SECONDARY						
	LOW	km	0.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	50	0	0	0	0
	hours	hrs	0.0	0.0	0.0	0.0	0.0
	RURAL	km	8,360.0	0.0	0.0	0.0	0.0
	Vehicle speed	Kmh	30	0	0	0	0

LUC / S-BASELINE / S-TARGET / LAND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASELINE / EC-TARGET / PRODUCTIVITY / NET E BALANCE / G V A / INFRASTRUCTURE

Figure. 49a Summary of the travel time on road infrastructure and related logistics of the case study area in Ivankiev Region, Ukraine.

In Figure 49b the travel time needed to reach the fuel distributors from the biorefinery was estimated to be on average 100 km. The trucks for the transport of liquid fuels have maximum payload of 29 tons and can travel at maximum speed of 80 km/h.

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The total travel time to reach the distributors is calculated in 3,382 hours per year.

	IF RAIL	Km	0.0	0.0	0.0	0.0	0.0
		hrs	0.0	0.0	0.0	0.0	0.0
	IF SHIP	Km	0.0	0.0	0.0	0.0	0.0
		hrs	0.0	0.0	0.0	0.0	0.0
FUEL TRANSPORT	Km plant to distributors	100					
	Vehicle type		Truck	-	-	-	-
	Fuel quantity	tonnes	33,440	-	-	-	-
	capacity	tonnes	285	0	0	0	0
	final distance	Km	0.0	0.0	0.0	0.0	0.0
	final distance	trips not ceilded	117.3	0	0	0	0
		trips ceiulded	118	0	0	0	0
		Kmh	100	0	0	0	0
TOTAL HOURS	3,382.38	hrs	1.2	0.0	0.0	0.0	0.0
		hrs	118.0	0.0	0.0	0.0	0.0

LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE

Figure. 49b Summary of the travel time on road infrastructure and related logistics of the case study area in Ivankiev Region, Ukraine.

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3.2.15 Capacity of use of bioenergy

The contribution to reaching the capacity of using bioenergy of a country is measured in this indicator. Due to the increasing fuel efficiency of vehicles, consequence of emission reduction policy at the EU-level, petrol consumption is expected to decrease over time, and was assumed to stay constant at 2017 values at best.

The capacity of a fleet to use biofuels in the case of ethanol is given by the maximum amount of biofuel that can me blended with gasoline without requiring retrofitting of the fleet (blend wall). According to the European Petroleum Refiners Association (EPRA, 2018) this amount is 10% for petrol engines in Europe.

To date in Ukraine the current ethanol blend in petrol is 2.55%. Therefore, the capacity to use biofuel is far from being reached. The production of additional 33,400 tons of bioethanol from the hypothetical biorefinery studied in this feasibility assessment would contribute to closing such gap. This specific analysis does not make sense at the ***target area*** level, but only at the national and European level since the current use of ethanol in the target area (given the size of the local fleet and the average sale of petrol) was a mere 56 tons in 2014. In Ukraine as a whole, in 2014, 82,767 tons of ethanol were blended into the petrol sold at the fuel stations nationwide, and in Europe 4,225,095 tons of ethanol were mixed to the fossil fuel. It is obvious why the impact of the production of additional 33,400 tons should be evaluated against the national and EU levels.

TYPE OF ADVANCED BIOFUEL	Cellulosic Ethanol		COUNTRY	UA (ENP)

BASELINE	Tfuel/year	TARGET AREA	NATIONAL	EU LEVEL
Current biofuel use		**56**	**82,767**	**4,225,095**
Current TOTAL fuel use		**2,214**	**3,245,000**	**84,949,000**

TARGET	Tfuel/year	TARGET AREA	NATIONAL	EU LEVEL
Target biofuel use in the target area		56	82,767	3,912,125
TARGET biofuel use plus PROJECT PRODUCTION		**33,496**	**116,207**	**3,945,565**
Current TOTAL fuel use		**2,214**	**3,245,000**	**84,949,000**

	FINAL CAPACITY RATIO
	CAPACITY WITH BLENDING WALL
2017	Capacity ratio for BASELINE situation
	CAPACITY WITH BLENDING WALL
2027	Capacity ratio for BASELINE situation
	Change in %
2027	Capacity ratio for TARGET situation
	Change in %
	PROJECT CONTRIBUTION TO CHANGE IN CAPA
	Change in %

S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E BALANCE | G V A | INFRASTRUCTURE | CAPACITY | REFE

Figure. 50 Summary of the bioethanol blend and quantities at baseline and target scenario for the case study in Ukraine.

The case study serves as the basis to assess the contribution of the amount of ethanol that could be produced by the hypothetical biorefinery in Ivankiev Town to

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reaching the maximum capacity of using biofuels of Ukraine and in the EU. The results of this exercise are presented in Figure 51, below.

FINAL CAPACITY RATIO		BLENDING WALL	10%
	TARGET AREA	NATIONAL	EU LEVEL
CAPACITY WITH BLENDING WALL	221	324,500	8,494,900
Capacity ratio for BASELINE situation	0.26	0.26	0.50
CAPACITY WITH BLENDING WALL	221	324,500	8,494,900
Capacity ratio for BASELINE situation	0.37	0.26	0.46
Change in %	46%	0%	-7%
Capacity ratio for TARGET situation	151.32	0.36	0.46
Change in %	59228%	40%	-7%
PROJECT CONTRIBUTION TO CHANGE IN CAPACITY RATIO			
Change in %	-	40.403%	0.791%

Figure. 51 Summary of the impacts on the capacity of using bioethanol of the national Ukrainian and European passenger car fleet in 2027.

The maximum capacity to use bioethanol of the Ukrainian fleet was calculated to be 324,500 tons/year (10% of total petrol volume). As of 2014 (most recent year of statistics) the country used only 82,767 tons, and the addition of further 33,400 tons would increase the total availability to 116,207 tons/year. This would contribute to closing the gap between the current levels of use of ethanol into the blend of petrol available at the pump stations in Italy and the maximum uptake (i.e. blending wall) by 40.4% reaching a share of the maximum capacity equal to 35.8%.

The same metrics applied to at the EU level, would result in a contribution to closing the gap between current use and maximum actual capacity of use of ethanol by the fleet of 0.79%.

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4. The case Study in Germany:

4.1 Case study description, setting, system boundaries and main assumptions

The German case study is characterized by two study areas both located in Brandenburg, Northeastern part of Germany. In this area there are two sites and in each site two bioenergy value chains are investigated for a total of four target scenarios. The former sewage irrigation fields near the city of Berlin will be tested for the production of biomethane from spontaneous grass. As for the lignite reclamation sites in Lusatia, the crops selected for the case study are alfa-alfae (alfalfa) and sorghum. These are feed crops that even though used for the production of biomethane do not qualify as advanced biofuels.

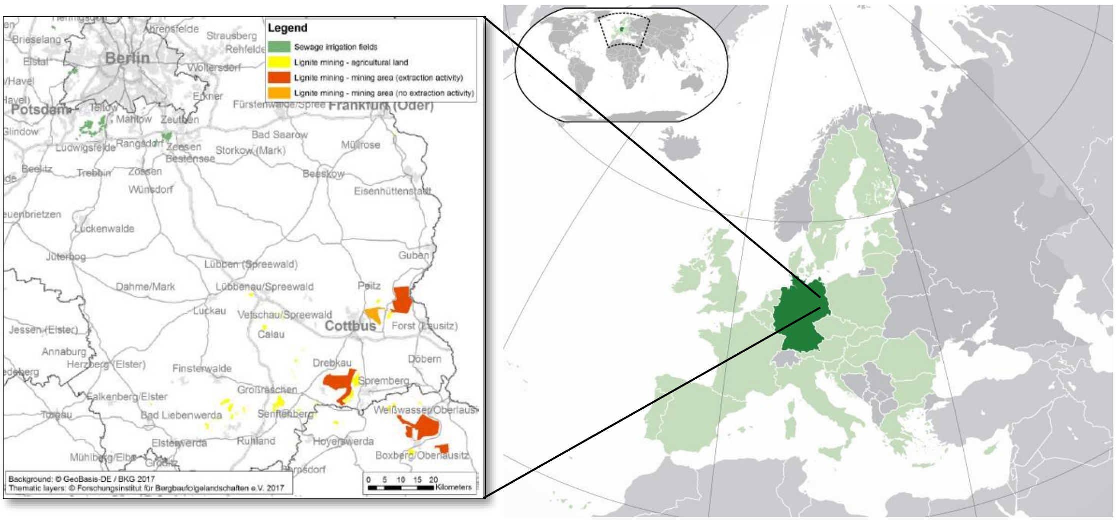

Figure. 52 The target area of Berlin and Brandenburg, Germany.

Source: Map of Europe with Germany from Wikipedia Creative Commons- https://en.wikipedia.org/wiki/Germany#/media/File:EU-Germany.svg

The scenarios considered in this analysis derive from the conclusions of Deliverable 2.3 and 2.4.

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4.2 Sustainability Assessment results by Indicator

4.2.1 Air Quality

In this project, the baseline situation is represented by the traditional energy carrier currently used in the country which would be partially substituted by the bioenergy produced in the ***target area***. In the case of the sewage irrigation fields the different feedstocks will produce biomass for biomethane production. In the case of the spontaneous grasses, a novel pathway is investigated as primary product, the production of high value compounds such as amino acids and lactic acid, whereas miscanthus is tested in a scenario of electricity generation via direct combustion. It is common practice to assess the sustainability impact of bioenergy production and use on the basis of GHG emission intensity per unit of energy. In the case of the lignite mining sites in Lusatia, alfalfa and sorghum have been studied also for the production of biomethane. The GHG emission intensity of all pathways is expressed in grams of carbon dioxide equivalent per megajoule of bioenergy produced (gCO_{2eq}/MJ).

In the baseline scenario the reference fuel used is natural gas for the biomethane production and the national energy mix for electricity generation. The emission intensity of natural gas is 56 gCO_{2eq}/MJ (Biograce, 2014). Emission intensity of German electricity mix is 534 gCO_{2eq}/kWh or 148.3 gCO_{2eq}/MJ (Moro and Lonza, 2017).

In the target scenario the emission intensity of energy produced in the ***target area*** is therefore compared to the emission intensity of the reference energy source and the relative (in %) and absolute (in g, Kg, or t of CO_2) change is reported.

The main contributors and components of a GHG LCA of bioenergy production and use are:

1) Feedstock production;
2) Feedstock transport;
3) Feedstock processing; and
4) Fuel transport/distribution (for biomethane, no transport or distribution emissions are calculated for electricity distribution).

The technology employed for the production of biomethane starts for the anaerobic digestion of biomass and the subsequent upgrading of the biogas to biomethane. The use of by- and co-products of the biomethane value chain and thus an allocation among the various products was performed. This is the case of the biochemical (amino acids and lactic acid) produced in the processing of the grass from the sewage irrigation fields. The remaining material (fiber) is then sent to a biogas plant to be converted into biomethane. This technology is not widespread however, and many uncertainties were found during the measurement of this indicator.

The most appropriate methodology for the correct allocation and attribution among co-products of the bioenergy value chain is a highly debated topic. In general, allocation based on economic value of the co-products returns the most reliable results. In the case of the biomethane from grasses the value of the co-products is immensely higher than the value of the energy co-product (9 times higher), so much so that the relevance of this analysis should be minimal. However, this technology and the market for the products are particularly immature. A comparison was done on an economic value basis. The low degree of reliability of the data retrieved (from deliverable 2.4) on this scenario make any meaningful analysis quite unlikely.

Biomethane production from spontaneous grasses in a biorefinery concept, thus where co-products have high added value (as in the case of amino acids), is particularly advantageous from a GHG LCA point of view. In fact, if we do not consider leakages, the production of this energy carrier would save 84.05% of the emissions produced by natural gas (8.93 gCO_{2eq}/MJ). The other relevant emission source is represented by transport of the fuel to the gas stations, assumed to be 100 km. However it should be noted that biogas systems rarely have zero leakage. Comparable biomethane plants have a leakage of at least 1.1% of total biomethane produced. Being CH_4 an extremely powerful GHG (25 times higher Global Warming Potential than carbon dioxide), the total emission increases from 8.93 gCO2eq/MJ to 46.47 gCO_{2eq}/MJ when leaking is factored into the analysis making the biofuel only 17% less carbon intense than natural gas.

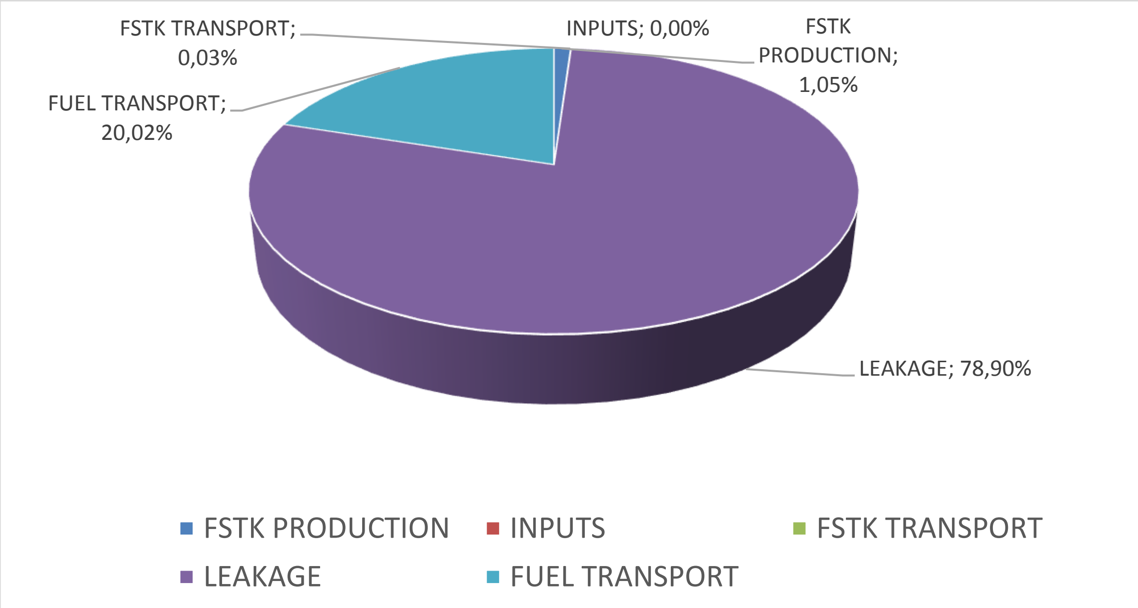

Figure. 53 Share of GHG emission attributable to the various components of the bioenergy value chain of biomethane from spontaneous grass.

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The use of alfa-alfa and sorghum was studies as if 100% of the underutilized land was devoted to the former (L1 scenario) or the latter (S1 scenario.

The 7,295 ha available in Lusatia if devoted to the production of biomethane from alfa-alfa could generate some 8,098,000 m^3 of methane gas (L1).

If the available underutilized land would be devoted to sorghum production this could generate 10,615,000 m^3 of methane gas (S1).

Any other combination (e.g. X thousand ha of sorghum and the remaining Y thousand of alfa-alfa) could be tested and the results estimated relatively easily. In reality, the most likely arrangement of cultures would foresee some 3,648 ha of alfa-alfa and 2,431 ha of sorghum for a total production of 7,586,385 m^3 from 6,079 ha. In this scenario, more realistically, some 1,216 ha would remain underutilized in the ***target area***. This is the L+S scenario.

Biomethane production in the L1 scenario does not have valuable co-product. Digestate is a compound that is found to be extremely useful in agriculture but to date it does not have a consolidated market.

The allocation of emissions in this case is solely to the production of biomethane. This energy carrier in the L1 scenario would save 75.00% of the emissions produced by natural gas (14.01 gCO_{2eq}/MJ) if we exclude the possibility that leaking of methane occurs. The other relevant emission source is represented by transport of the fuel to the gas stations, assumed to be 100 km. As mentioned previously biogas – and thus biomethane – systems rarely have zero leakage. Using the same characteristics of comparable biomethane plants (leakage of 1.1% of total biomethane produced according to Hjort-Gregersen, 2014) the real-world emission intensity of the system would be 47.40 gCO_{2eq}/MJ. One unit of energy (MJ) produced through biomethane is only 15% less carbon intense than natural gas.

As in the previous case, also in the case of sorghum used to produce methane, no valuable co-products require the allocation of emissions. As a consequence the production of biomethane from sorghum would have the following GHG emission profile:

- Without considering leaking: 11.13 gCO_{2eq}/MJ or 80.11% emission reduction when compared to natural gas;

- Including leaking of methane the actual usable energy would emit: 44.53 gCO_{2eq}/MJ which in emission reduction terms would equal a 20% reduction over natural gas.

In the L+S scenario, the carbon intensity of the system would be 12.55 gCO_{2eq}/MJ without considering the leaking of methane, and more realistically 45.95 gCO_{2eq}/MJ

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including the leaking. This would give an emission reduction of 18% if compared to the use of the same amount of energy in the form of natural gas.

L1:

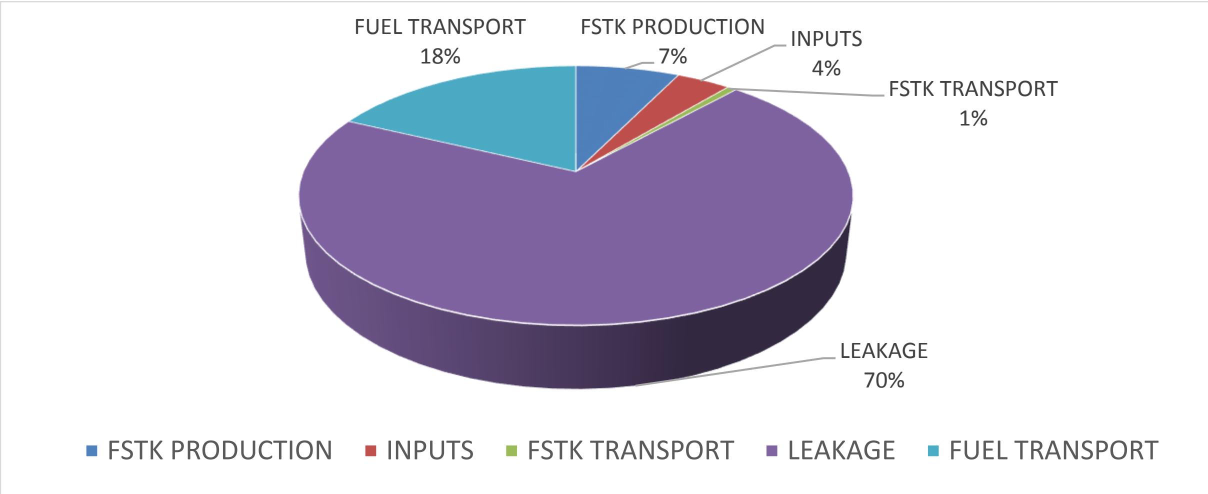

Figure. 54 Share of GHG emission attributable to the various components of the bioenergy value chain of biomethane from alfa-alfa (alfa-alfa).

S1:

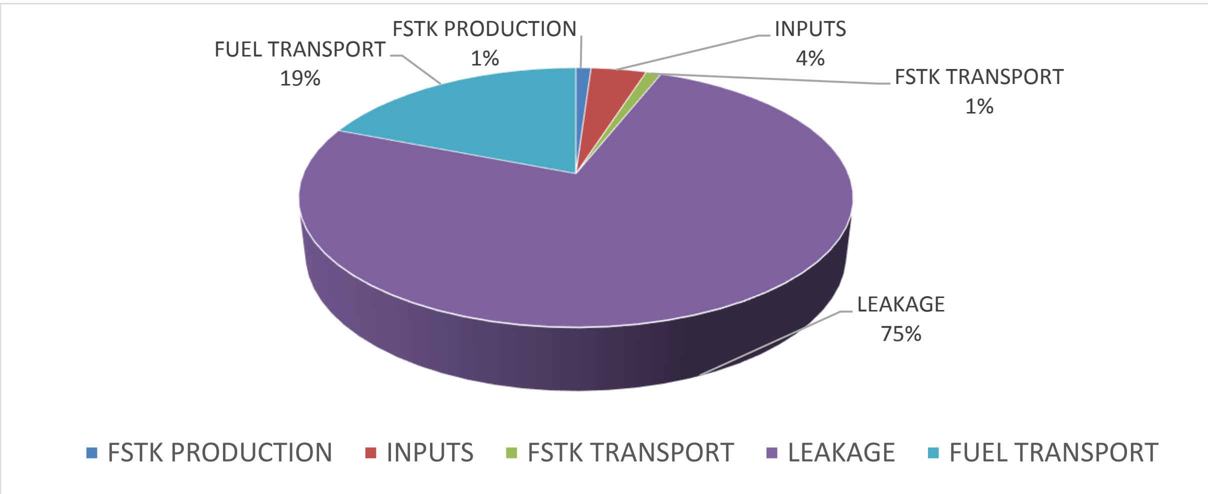

Figure. 55 Share of GHG emission attributable to the various components of the bioenergy value chain of biomethane from sorghum.

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L+S:

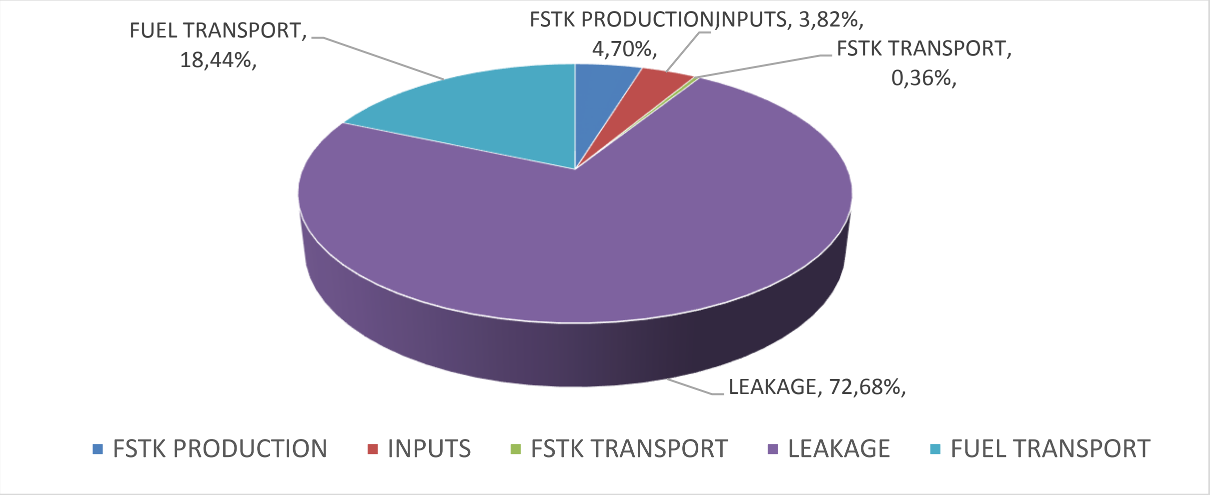

Figure. 56 Share of GHG emission attributable to the various components of the bioenergy value chain of biomethane from alfa-alfa and sorghum combined.

Figure 57. Sorghum fields in the lignite mining reclamation area in Germany. Photo credit: Marco Colangeli, FAO.

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4.2.2 Soil Quality

Changes in soil quality of the underutilized lands in the case study have been assessed on the basis of projections and forecasts. The necessity to rely on long term measurement and surveys in the field to survey physico-chemical changes made the quantitative assessment of this indicator through the use of primary data impossible within the extent of this project. Therefore theoretical changes in soil quality parameters have been performed and the results should be interpreted in a qualitative manner, identifying possible trends and reaching indicative conclusions.

In the case of spontaneous grasslands in Germany, the average impact that this form of vegetation has on the accumulation and removal of Soil Organic Carbon over the long run is null. In fact, grassland systems in low productivity, marginal areas tend to be in equilibrium. This means that over the long term there is a particularly slow accumulation of organic matter which tends to be removed at virtually the same rate as the deposition.

However, when the grass is harvested for the production of amino acids and bioenergy, the residues left in the fields return considerably less organic matter to the soil. An impoverishment of the SOC as a consequence of a diminished rate of return of organic matter to the soil is the most indicative effect. A further qualitative aspect is the increased soil bulk density as a consequence of the mechanized harvesting of the grass. In turn this will reflect on a number of aspects, for some positively and for others possibly negatively. For instance water infiltration capacity on these soils is high at 73 mm/hour and thus water retention is low. The compaction of the soils is likely to increase this value and thus decreasing the infiltration and loss of water in from the root sphere. This is expected to lead to improve, at least in the first few years, the productivity of the land. However, the likely long-term impacts on the system are hard to predict, thus this aspect should be monitored closely.

The scenario L1 would foresee the cultivation of alfa-alfa, a nitrogen fixing crop on former lignite mining areas. In this scenario additional 6,000 kg of manure are anyway added to the soil as fertilizer. The addition of manure increases the SOM content in the soil and counterbalances the losses due to the harvest of biomass as well as the mineralization rate. The return of SOM through the decomposition of the debris and harvest residues is also accounted for. In total, the system has the potential to accumulate some 23 kg of SOM per ha each year.

In scenario S1, the considerable demand for manure (17,000 kg/ha) translates into higher accumulation rates of SOM in the soils, equal to about 2,397 kg ha^{-1} yr^{-1}. The L+S scenario would have the L1 accumulation rate where alfa-alfa is cultivated and the S1 rate where sorghum is grown and expressing the average would not make much sense in this exercise.

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These positive net changes in SOM content are an important aspect to take into account for the rehabilitation and remediation of underutilized and contaminated soils like the ones found in Lusatia and the differences between them are to be considered when planning the best spatial arrangement of the dedicated energy crop distribution.

4.2.3 Water use and efficiency

In the ***target area*** the climate is warm-temperate. Precipitations are not scarce in Cottbus area (568 mm per year), average annual temperature is around 9.2 °C. In Berlin area, there is a very similar precipitation pattern, average temperatures are 9.1 °C and rainfall amounts to 570 mm. The two parts of the ***target area*** are at least from the climatic point of view uniform.

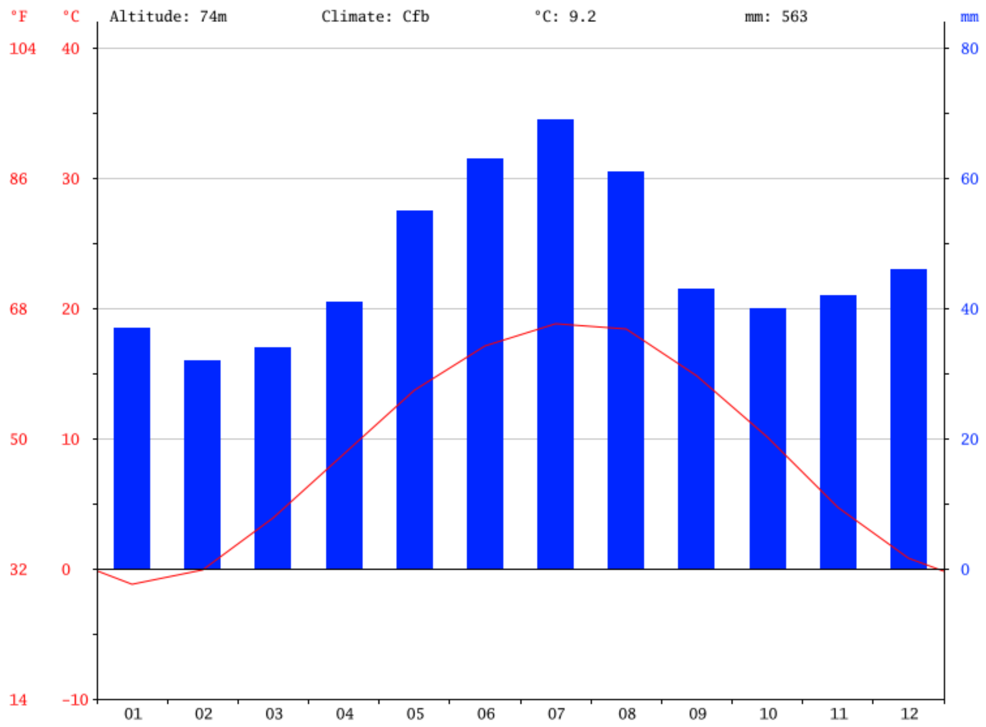

Figure. 58 Climate profile of Carbonia, Sulcis. Source: https://it.climate-data.org/location/6314/

The production of biomass in the ***target area*** would take place under rainfed conditions. This indicator estimates the amount of water required for the production of a unit of energy (MJ) and the share of the total actual renewable water resources used by the bioenergy production. Thanks to the outstanding contribution of FIB who provided information on the total annual water withdrawal of the area, and the total actual water resources available within the target area, this indicator could be fully measured. The production of biogas and thus biomethane requires the addition of water to a varying ration depending upon the composition of the feedstock. This is necessary to induce the maximum anaerobic digestion during the retention time. In the case of grass, silage and lignocellulosic or starchy material, this amount is at least 3 m^3 of water per ton of feedstock. In the L+S scenario this translates in 127,650 m^3 of blue water per year (Figure 59b). As far as green water is concerned,

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the evapotranspiration potential of both lucerne and sorghum is lower than the annual precipitation (Figure 59). However, against a Total Actual Renewable Water Resource of 0.2035 km^3/year in the ***target area*** in Lusatia the water used for feedstock production is 0.02383 km^3/year, or 11.7% of the available resource. The blue water used for the processing of the feedstock is 0.87% of total annual water withdrawal of the ***target area*** (Figure 60). Finally, the water efficiency of the production of biomethane in the L+S scenario is 0.062 m^3/MJ.

	Growth cycle		ALFA-ALFA	SORGHUM	-	-
WATER WITHDRAWN FROM WATERSHEDS WITHIN THE TARGET AREA						
Wfstk.ren Renewable Water used for Bioenergy Feedstock Production						
Productivity	Crop yield	tonnes/ha	5.0	10.0	-	-
Area Planted	TARGET CULTIVATED SURFACE	Ha	3,648	2,431	-	-
	CROP ET	mm/year	330	480	-	-
	Effective Precipitation	mm/year	568	568	-	-
	Crop production	tonnes	18,240	24,310	-	-
	A. Irr. Req.	mm/year	-238	-88	-	-
	Unitary Water req	m3/ha	3,300	4,800	-	-
		Km3/year	0.01203840	0.01166880	-	-
	Unitary W(IRR) req	m3/ha	-2,380	-880	-	-
		Km3/year	-0.00868224	-0.00213928	-	-
	Tot Unitary W(IRR) Req.	Km3/year			**-0.01082152**	
	Wfstk ren	Km3/year	0.01203840	0.01166880	-	-
TOT Wfstk ren	**0.02370720**	Km3/year				
Irrigation water						

Wpro.ren Renewable Water used for Bioenergy Processing		
Water consumption:	3.00	m3/tfeedstock
	0.00005472	km^3/year

TARWR Total Actual Renewable Water Resources		
Total Internal Renewable Water Resources		
IRWR	0.2035	km3/year

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | **WATER USE** | BIODIVERSITY | LUC | S-BASELINE

Figure. 59a Water use profile for the L+S scenario.

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Tot Unitary W(IRR) Req.	Km3/year			-0.01082152		
Wfstk ren	Km3/year	0.01203840	0.01166880	-	-	

TOT Wfstk ren	**0.02370720**	Km3/year

Irrigation water

Wpro.ren Renewable Water used for Bioenergy Processing

Water consumption:	3.00	m3/tfeedstock
	0.00012765	km^3/year
Advanced Biofuel	7,586,385	t/year
LHV	50.00	MJ/m^3
Total energy output	**379,319,250**	MJ/year

TARWR Total Actual Renewable Water Resources

Total Internal Renewable Water Resources

IRWR	0.2035	km3/year

Wbio.ren Total Renewable Water used for Bioenergy

$W_{feedstock\_ren} + W_{processing}$	**0.02383485**	km^3/year

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JO

Figure. 59b Water use profile for the L+S scenario, particular of processing stage water use.

-0.00213928	-	-	-	-	-	-	-
	-0.01082152					**0.00000000**	
0.01166880	-	-	-	-	-	-	-

TARWR Total Actual Renewable Water Resources

Total Internal Renewable Water Resources

IRWR	0.2035	km3/year

$W_{bioenergy\_ren}$ / TARWR x 100%	**11.7%**	
$W_{bioenergy}$/TAWW x 100%	**0.083%**	
$W_{bioenergy} / E_{total}$	**0.062835857**	**m3/MJ**
Production	**3.12**	**$m^3/t_{feedstock}$**

TART | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY

Figure. 60 Water efficiency profile for the L+S scenario.

The production of biomethane from spontaneous grass in the former sewage irrigation fields would have an impact on the TARWR of 5.57% of the available resource, which in turn would lead to an efficiency of 0.047 m^3/MJ of energy produced.

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4.2.4 Water Quality

This indicator could not be measured in Germany due to lack of data and shapefiles necessary to run the SWAT model. It is suggested that stronger efforts are made in future phases of the project to retrieve such information and perform the assessment of pollutant loadings into the bodies of water as a consequence of the production of advanced biofuels within the ***target area***.

In the case of the sewage irrigation fields, where spontaneous grass is hypothetically employed as bioenergy feedstock, the net change between the baseline and target scenario would be zero, since no additional pollutants (in the form of N and P fertilizers or pesticides) would be applied.

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4.2.5 Biodiversity

At EU level, there is a list of endangered species and critical habitats that should be monitored when these are naturally present in the area of a possible agricultural project. The list is reported in the figure below and represents the checklist of animal species of interest and their presence in Germany as well (Figure 61).

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COUNTRY	DE	SPECIES	TYPICAL HABITAT
	YES	Great bustard, Otis tarda	Dry grasslands and mosaic of crops and grasslands
	YES	Large blue butterfly, Maculinea arion	Dry grasslands
	YES	Corncrake, Crex crex	Meadows
	NO	Meadow viper, Vipera ursinii	Meadows
	YES	Yellow-bellied toad, Bombina variegata	Wetlands (and forests)
	YES	Bittern, Botaurus stellaris	Wetlands (reedbeds)
	YES	Hamster, Cricetus cricetus	Arable land
	YES	Skylark, Alauda arvensis	Arable land
	YES	Ortolan Bunting, Emberiza hortulana	Extensive arable land with single trees, orchards, forest margins amongst others
	NO	Scops owl, Otus scops	Extensive agri-pastoral systems especially with old trees or patches of bushes, open for
	YES	Great capricorn beetle, Cerambyx cerdo	Forests and veteran trees
	YES	Capercaillie, Tetrao urogallus	Forests

Figure. 61 List of endangered species in Europe and their presence in the case study Country (UA).

According to the data collection campaign carried out during the FORBIO project, the ***target area*** in Germany (135,771 ha), is interested by the presence of nationally determined critical habitats and high biodiversity areas for a total of 46,095 ha or about 34% of the ***target area***. The remaining 89,676 ha in the ***target area*** are not interested by the presence of habitats of high importance from a biodiversity point of view (Figure 62).

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CRITICAL AREAS AND CONSERVATION OF SELECTED SPECIES OF WILDLIFE		
Total target area 135,771 ha		
Total high biodiversity areas surface	Ha	46,095.0
Total areas where critically endangered species are found	Ha	0.0
Total important ecosystems		46,095.0
Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species	Ha	0.0
Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)	Ha	0.0
Important natural landscape areas for natural ecological dynamics	Ha	46,095.0
Areas that contain two or more contiguous ecosystems	Ha	0.0
Areas containing rare or endangered ecosystems	Ha	0.0
Not included		89,676

Figure. 62 Breakdown of the areas of critically endangered species and important ecosystems are found within the *target area* in Lusatia (lignite mining district), Germany.

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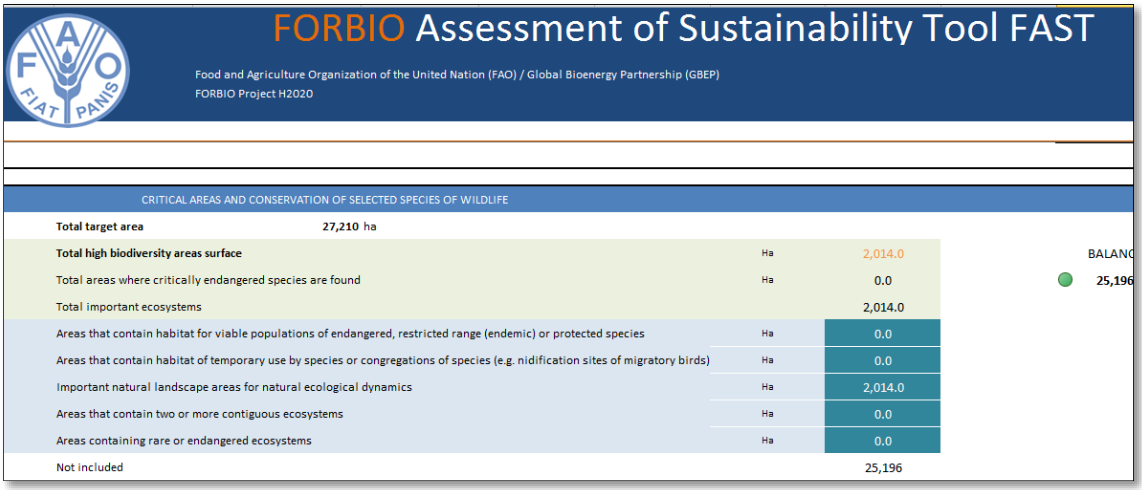

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CRITICAL AREAS AND CONSERVATION OF SELECTED SPECIES OF WILDLIFE

Total target area	**27,210** ha			
Total high biodiversity areas surface	Ha	2,014.0		BALANC
Total areas where critically endangered species are found	Ha	0.0		**25,196**
Total important ecosystems		2,014.0		
Areas that contain habitat for viable populations of endangered, restricted range (endemic) or protected species	Ha	0.0		
Areas that contain habitat of temporary use by species or congregations of species (e.g. nidification sites of migratory birds)	Ha	0.0		
Important natural landscape areas for natural ecological dynamics	Ha	2,014.0		
Areas that contain two or more contiguous ecosystems	Ha	0.0		
Areas containing rare or endangered ecosystems	Ha	0.0		
Not included		25,196		

Figure. 63 Breakdown of the areas of critically endangered species and important ecosystems are found within the *target area* in the Berlin former sewage irrigation fields, Germany.

The high biodiversity areas will not be interested by the cultivation of biomass for energy purposes in the lignite district nor in the former sewage irrigation fields, where only 969 ha are to be harvested and these are excluded from the 2,014 ha of important natural landscape areas for natural ecological dynamics found within the ***target area***.

In addition to the above, the cultivation of biomass in the lignite district area will apply a number of good environmental practices such as the adoption of light tillage operations, continuous soil cover and creation of buffer zones.

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4.2.6 Land Cover and Land Use Changes

The production of biomass for energy purposes in the target scenario will lead to a change in land use and land cover types when compared to the current conditions (baseline scenario). Understanding the entity of this change and the turnover between difference land cover classes is useful to land use planners to have an understanding of the development trends that will interest their territory.

The case of the spontaneous grass in the former sewage irrigation fields is an exception because the land cover type will remain unchanged whereas the land use would changes, since from underutilized, the land covered by spontaneous grass will be used as annual crops for bioenergy production.

The outcomes of the analysis of the dynamics of the target scenario for the sewage irrigation fields are presented in Figure 64, below.

Permanent crops	Ha	969	0	0	0	0	0

CHANGE IN LAND USE

BASELINE			TARGET		
Total annual crops and fallow lands	Ha	7,883	Total Annual crops	Ha	8,852
Total annual crops and fallow lands for FSTK production	Ha	0	Total annual crops and fallow lands for FST	Ha	969
Total permanent crops	Ha	0	Total permanent crops	Ha	0
Total permanent crops for FSTK production	Ha	0	Total permanent crops for FSTK production	Ha	0
Underutilized agricultural land	Ha	1,140	**Underutilized agricultural land**	Ha	171
Underutilized NON-agricultural land (e.g. EX-mining sites)	Ha	0	**Underutilized NON-agricultural land (e.g. E**	Ha	0

RATE OF CONVERSION

	% of conversion
Agriculture	
Annual crops and fallow lands (FAOSTAT Arable Land)	12.3
Permanent crops	0.0
Underutilized agricultural land	-85.0
Others lands	
Underutilized NON-agricultural land (e.g. EX-mining sites)	0.0

EN-BASELINE / EN-TARGET / AIR EMISSIONS / SOIL QUALITY / WATER USE / BIODIVERSITY / LUC / S-BASELINE / S-TARGET / LAND TEN. / INCOME / JOBS / ENERGY ACCESS / EC-BASEL

Figure. 64 Spontaneous grass: Changes is land cover type and rates of conversion within the *target area* in the Sewage irrigation fields in Germany.

At baseline, in the ***target area*** there are some 1,140 ha of underutilized agricultural land. As of today, within the ***target area*** there are 7,883 ha cultivated with annual crops, but none of this land is used for bioenergy feedstock production. In the target scenario, the usable underutilized land (969 ha out of 1,140 ha in total) is harvested which makes its classification switch from underutilized to annual crops, specifically the annual crops used for feedstock production sub-category. This will lead to an 85% decrement of said land use category down to 171 ha in target scenario. Concurrently, the total surface under annual crops will grow from 7,883 ha to 8,852 ha (12.3%) and thus dedicated bioenergy feedstock production will increase to 969 ha.

Concerning the lignite mining reclamation area in Lusatia, at baseline there are some 7,295 ha of underutilized agricultural land. Inside the ***target area*** there are 9,986

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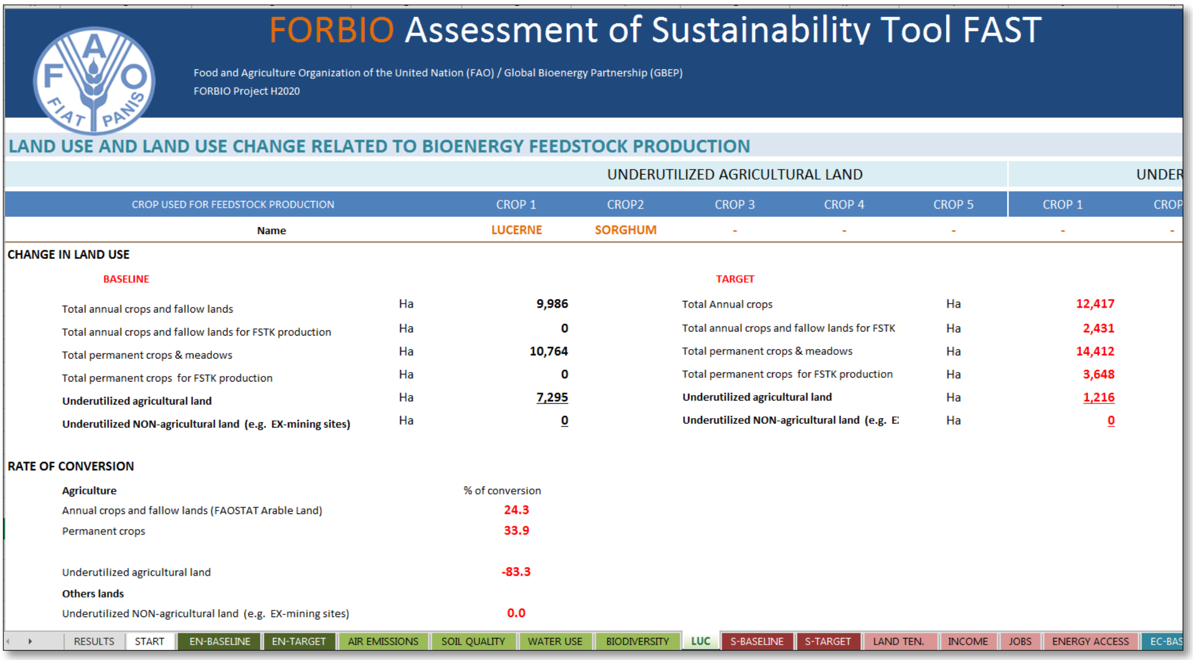
ha cultivated with annual crops, but none of this land is used for bioenergy feedstock production. Permanent crops and meadows cover 10,764 ha.

In the target scenario L + S, the usable underutilized land is 6,079 ha out of 7,295 ha in total. Out of the total usable 6,079 ha, some 3,648 ha are cultivated with Lucerne and the remaining 2,431 ha are planted with sorghum. The former (alfalfa) represents land now cultivated with perennial crops dedicated to bioenergy feedstock production, whereas the latter (sorghum) in the target scenario adds up to the agricultural land dedicated to annual crops for bioenergy production (Figure 65). This will lead to an 83.3% decrement of the total underutilized land down to 1,216 ha in the target scenario. Concurrently, the total surface under annual crops will grow from 9,986 ha to 12,417 ha (24.3%), whereas permanent crops and meadows will reach 14,412 ha with the addition of 3,648 ha cultivated with alfalfa, which is a permanent crop used for bioenergy feedstock production (increase 33.9% for permanent crops).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LAND USE AND LAND USE CHANGE RELATED TO BIOENERGY FEEDSTOCK PRODUCTION

	UNDERUTILIZED AGRICULTURAL LAND					UNDER	
CROP USED FOR FEEDSTOCK PRODUCTION	CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1	CROP
Name	LUCERNE	SORGHUM	-	-	-	-	-

CHANGE IN LAND USE

BASELINE			TARGET		
Total annual crops and fallow lands	Ha	9,986	Total Annual crops	Ha	12,417
Total annual crops and fallow lands for FSTK production	Ha	0	Total annual crops and fallow lands for FSTK	Ha	2,431
Total permanent crops & meadows	Ha	10,764	Total permanent crops & meadows	Ha	14,412
Total permanent crops for FSTK production	Ha	0	Total permanent crops for FSTK production	Ha	3,648
Underutilized agricultural land	Ha	7,295	**Underutilized agricultural land**	Ha	1,216
Underutilized NON-agricultural land (e.g. EX-mining sites)	Ha	0	**Underutilized NON-agricultural land (e.g. E**	Ha	0

RATE OF CONVERSION

	% of conversion
Agriculture	
Annual crops and fallow lands (FAOSTAT Arable Land)	24.3
Permanent crops	33.9
Underutilized agricultural land	-83.3
Others lands	
Underutilized NON-agricultural land (e.g. EX-mining sites)	0.0

RESULTS | START | EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BAS

Figure. 65 Lucerne + Sorghum Scenario: Changes is land cover type and rates of conversion within the *target area* in the lignite mining land reclamation area in Lusatia, Germany.

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4.2.7 Land Tenure

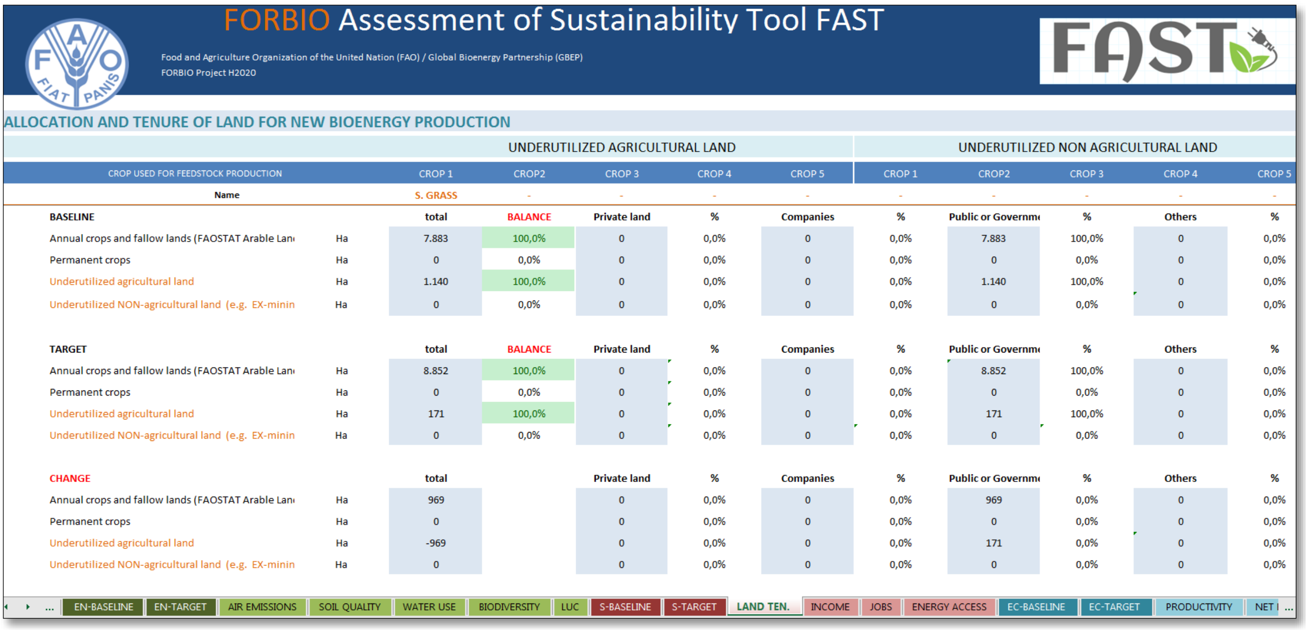
Deliverable 2.3, together with the information included in the data entry sheet for the sewage irrigation fields prepared by FIB provided the bulk of information for the assessment of this indicator. According to official registers, former irrigation fields are classified as contaminated sites. However, residential developments and infrastructures interest 16% of the ***target area***. Some 6,700 ha of former irrigation fields are already used for agricultural land, but with site-specific use restrictions. In total, within the ***target area*** there are 7,883 ha of land used for agricultural purposes. There exist high-level, national landscape planning programmes as well as local land-use plans for which a share of the former irrigation fields currently used for agriculture should be converted to other uses, including residential but also recreational. On the other hand, for some 4,000 ha of these former sewage irrigation fields the final use and productive destination is still unplanned. Since this land is not designated for a specific development objective, initially this was thought to be the possible are for the development of bioenergy feedstock production. However, considering increasing urbanisation, the presence of a recreational form of landscape in the area is gaining importance for regional planning. Though, a considerable share of the managed disused sewage farms are looking for an alternative agricultural use, for example the low-input, second generation biofuel production (Deliverable 2.3, 2017).

This is why the available potential area for the cultivation of energy crops on former sewage irrigation fields was calculated in 1,140 ha, of which 171 are represented by built-up dams and roads that would not constitute useful crop land unless heavy machineries are employed for their leveling, and the remaining 2,900 odd hectares are likely going to be destined to recreational or ecological functions.

It is clear then, how in the former sewage irrigation fields the planning and the introduced restrictions are going to strongly affect the development of a bioenergy sector in the ***target area***, already characterized by a relatively limited amount of land. Additionally, it is very likely that the concessions and leases offered by the public authorities will have a limited duration in time. This should be decided in agreement between the municipalities that have ownership of the sewage fields (Deliverable 2.3, 2017) and the interested farmers. Such duration would most likely coincide with the duration of the agreements that farmers may find on the bioenergy market, if bioenergy is the primary business option, or with the duration of agreements with the biorefinery in the case of a production of amino acids is the primary driver for this operation.

The utilization of the spontaneous grass may in some sense be negotiated with the municipalities as a form of management of areas that are set aside for ecological purposes, which would increase the total usable surface within the ***target are*** up to 3,917 ha.

Given the nature and classification of the pollution it is likely that the ownership of the unplanned 1,140 ha will remain with the local public authorities (municipalities) even during the transition period. This land though will be managed by private entities on the basis of the aforementioned agreements. From a quantitative point of view then, the land use change will interest only the actual arable land within the former irrigation fields (e.g. 969 ha) whereas 171 ha will be unused whereas no change in ownership is expected (Figure 66).



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ALLOCATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION

		UNDERUTILIZED AGRICULTURAL LAND					UNDERUTILIZED NON AGRICULTURAL LAND				
CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1	CROP2	CROP 3	CROP 4	CROP 5
Name		S. GRASS	-	-	-	-	-	-	-	-	-
BASELINE		**total**	**BALANCE**	**Private land**	**%**	**Companies**	**%**	**Public or Governm**	**%**	**Others**	**%**
Annual crops and fallow lands (FAOSTAT Arable Lan	Ha	7.883	100,0%	0	0,0%	0	0,0%	7.883	100,0%	0	0,0%
Permanent crops	Ha	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
Underutilized agricultural land	Ha	1.140	100,0%	0	0,0%	0	0,0%	1.140	100,0%	0	0,0%
Underutilized NON-agricultural land (e.g. EX-minin	Ha	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
TARGET		**total**	**BALANCE**	**Private land**	**%**	**Companies**	**%**	**Public or Governm**	**%**	**Others**	**%**
Annual crops and fallow lands (FAOSTAT Arable Lan	Ha	8.852	100,0%	0	0,0%	0	0,0%	8.852	100,0%	0	0,0%
Permanent crops	Ha	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
Underutilized agricultural land	Ha	171	100,0%	0	0,0%	0	0,0%	171	100,0%	0	0,0%
Underutilized NON-agricultural land (e.g. EX-minin	Ha	0	0,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
CHANGE		**total**		**Private land**	**%**	**Companies**	**%**	**Public or Governm**	**%**	**Others**	**%**
Annual crops and fallow lands (FAOSTAT Arable Lan	Ha	969		0	0,0%	0	0,0%	969	0,0%	0	0,0%
Permanent crops	Ha	0		0	0,0%	0	0,0%	0	0,0%	0	0,0%
Underutilized agricultural land	Ha	-969		0	0,0%	0	0,0%	171	0,0%	0	0,0%
Underutilized NON-agricultural land (e.g. EX-minin	Ha	0		0	0,0%	0	0,0%	0	0,0%	0	0,0%

EN-BASELINE | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET I

Figure. 66 Sewage irrigation fields: Changes is land ownership type in the baseline vs target scenario in the former sewage irrigation fields, Germany.

As for the lignite mining reclamation areas, these areas are owned by the mining company. The company is responsible for their rehabilitation and is supposed to return the land in a state that is re-vegetated and able to sustain the native potential vegetation type. This process can take several decades to some centuries, and thus any activity that can speed up this process by contributing to soil formation is attractive in this area. This is the reason why for instance alfalfa was selected as a feedstock in this land, because it can contribute to the fixation of nitrogen into the soils while producing valuable biomass. This ecological service can be mediated and ameliorated during the production cycle. In light of the above then, it is expected that the land under reclamation will not change ownership until the end of the process, when it could be sold to private farmers.

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

4.2.8 Jobs in the bioenergy sector

Even excluding the population of the city of Berlin, the total population in the former sewage irrigation fields ***target area*** is 2.9 million inhabitants. The production of biomass from the sewage irrigation fields would imply only harvesting, biomass transport, and biomass processing operations, since no cultivation operation is envisaged. Moreover, at the processing stage, the majority of the jobs would be created in the biorefinery which produces amino acids and other added value products from the grass juice, thus leaving little jobs to be allocated to bioenergy. Given the relatively small biomass quantity, the bioenergy component would only create a limited number of temporary jobs. A total of 15 seasonal jobs would be created for the harvesting and transport of the biomass for energy purposes but these would equal 1.3 full time permanent job position. According to PlanET Biogas (2018), a company that runs a biomethane plant in Brandenburg, a plant producing 700 m^3 of methane per hour (6.1 million m^3 per year) would employ 3 permanent regular workers plus 1 specialized technician to run the equipment year-round. The biomass available in the ***target area*** could produce up to 813,960 m^3 of biomethane per year, thus 13% of the output of such plant. In theory, it would be possible to assume that the utilization of the biomass from the sewage irrigation fields would generate 0.4 permanent jobs per year in the processing stages. In reality, it is unlikely that any job is created at the biomethane plant as a consequence of increased supply of feedstock but likely, the elasticity of the demand-supply relationship would absorb the additional feedstock and generate an increase amount of biomethane without reflecting on employment (but possibly only on income) generation. It is obvious as the contribution to employment rate changes in the ***target area*** would be virtually null.

In the lignite mining district of Lusatia, the biomethane value chain would in this case also have a component linked to feedstock production in the field and benefit from larger extensions of land. The average working hours per ha for the cultivation stages of Lucerne and sorghum is 2.07/ha. For a cumulative surface of 7,295 ha some 15,100 working hours would be necessary. These are equal to 107 Person Months, thus to a total of 9 full time jobs (or the equivalent additional part time or seasonal jobs). Including the number of jobs created at the biomethane plant (4 full time permanent jobs) and the increased demand for transport of biomass and fuel, the total employment generated by the whole value chain was estimated to be the equivalent of 23 new full time year-round jobs. Even in this case then, the creation of jobs would be minimal though some 22 times higher than in the sewage irrigation scenario.

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

4.2.9 Changes in Income

Changes in income between the baseline and target scenarios are calculated as the difference in attainable revenues per ha between a common economic activity currently found within the ***target area*** and the activities linked to the production of bioenergy feedstock or the processing of the biomass into fuel. Transport of biomass and biofuel are not compared to similar economic activities since the transport sector has rather homogenous characteristics in the case study area and changes in income may not be noticeable.

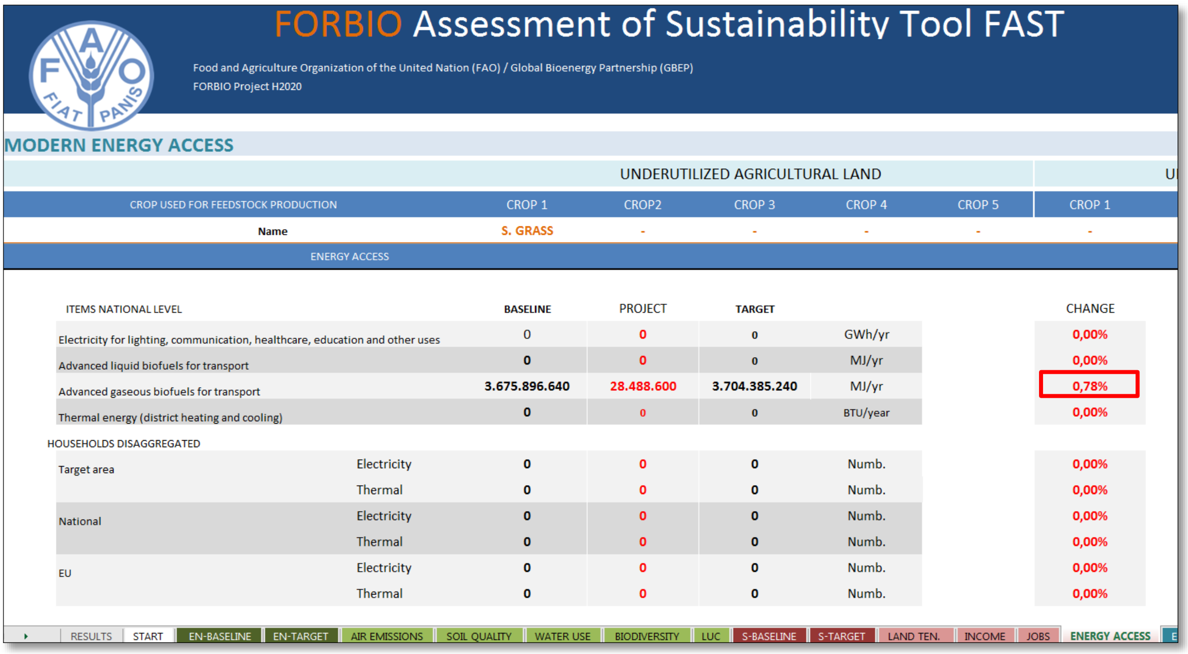
Since the production of the biomass proposed in the lignite mining reclamation site does not differ from the current alternative use of the land, differences in income for the production of a multipurpose feedstock cannot be found. In fact, the market would decide what route should the biomass follow and this would apply to all producers of alfalfa and sorghum in the area. If the silage of these two products will be more competitive in a given year, it is obvious that farmers will chose to sell their crops to the feed industry. Unless long term stable contracts are made with the biomethane plant this scenario cannot be tested in terms of changes in income.

The production of grass for the extraction of amino acids and other high added value products is not currently practiced and there is no commercial scale plant in the ***target area***. In addition, given the average price of the primary products and the initial investments for the biorefinery (Deliverable 2.4), it is likely that the residual value of the fiber cake would be minimal, capable of covering only transportation costs to the biomethane plant (as in the case of manure) thus not generating income for the harvester.

4.2.10 Energy Access

This indicator measures the contribution of advanced biofuels to the access of households to modern bioenergy services. In order to do so, it directly tackles the share of biomethane into the fuel mix of the transportation sector. In the European Union several countries have are characterized by a 100% rate of access to modern energy services (e.g. % of the population who has access to electricity, etc.). However, the substitution among forms of energy or the substitution among sources of the same energy type (i.e. renewable vs fossil) is accounted for in this indicator as an index of development towards a more diversified access to modern energy services. Therefore, changes are expressed in relative or absolute terms depending upon the viability of either method. In the case of Germany, all user have access to energy, but an increased production and thus accessibility of renewable energy will contribute to reducing the demand for the same amount of energy to be produced from other sources, often times fossil ones. Moreover, in the case of biomethane, the substituted energy carrier (LPG or methane) is usually imported rather than produced domestically.

In 2018, Germany consumed the equivalent of 105 million m^3 of methane for the transport sector. A biomethane plant which produces 813,000 m^3 per year of gas has the potential to increase by 0,78% the access of German consumers to modern biofuels, a the national level, when compared with the baseline (red square in Figure 67).



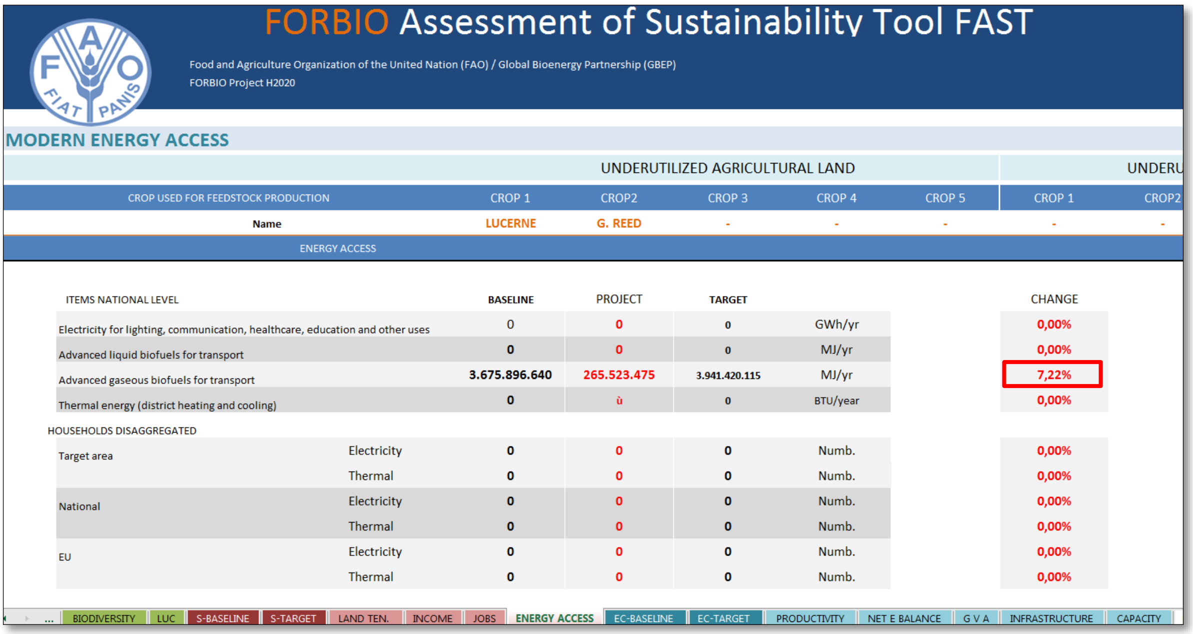
CROP USED FOR FEEDSTOCK PRODUCTION		CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1
Name		S. GRASS	-	-	-	-	-

ITEMS NATIONAL LEVEL		BASELINE	PROJECT	TARGET		CHANGE
Electricity for lighting, communication, healthcare, education and other uses		0	0	0	GWh/yr	0,00%
Advanced liquid biofuels for transport		0	0	0	MJ/yr	0,00%
Advanced gaseous biofuels for transport		3.675.896.640	28.488.600	3.704.385.240	MJ/yr	0,78%
Thermal energy (district heating and cooling)		0	0	0	BTU/year	0,00%
HOUSEHOLDS DISAGGREGATED						
Target area	Electricity	0	0	0	Numb.	0,00%
	Thermal	0	0	0	Numb.	0,00%
National	Electricity	0	0	0	Numb.	0,00%
	Thermal	0	0	0	Numb.	0,00%
EU	Electricity	0	0	0	Numb.	0,00%
	Thermal	0	0	0	Numb.	0,00%

Figure. 67 Contribution to modern energy access of the hypothetical advanced bioenergy value chain in the *target area* (Sewage irrigation fields, Germany).

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

The lignite district has the potential to provide feedstock for the production of some 7,586,385 m^3 of biomethane from the cumulative surfaces cultivated with Lucerne and sorghum. This value would generate enough energy to provide the German fleet of methane powered vehicles with 7.22% of the biomethane demand as of 2018 (Figure 68).



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MODERN ENERGY ACCESS

	UNDERUTILIZED AGRICULTURAL LAND					UNDERU	
CROP USED FOR FEEDSTOCK PRODUCTION	CROP 1	CROP2	CROP 3	CROP 4	CROP 5	CROP 1	CROP2
Name	LUCERNE	G. REED	-	-	-	-	-

ENERGY ACCESS

ITEMS NATIONAL LEVEL		BASELINE	PROJECT	TARGET		CHANGE
Electricity for lighting, communication, healthcare, education and other uses		0	0	0	GWh/yr	0,00%
Advanced liquid biofuels for transport		0	0	0	MJ/yr	0,00%
Advanced gaseous biofuels for transport		3.675.896.640	265.523.475	3.941.420.115	MJ/yr	7,22%
Thermal energy (district heating and cooling)		0	ù	0	BTU/year	0,00%
HOUSEHOLDS DISAGGREGATED						
Target area	Electricity	0	0	0	Numb.	0,00%
	Thermal	0	0	0	Numb.	0,00%
National	Electricity	0	0	0	Numb.	0,00%
	Thermal	0	0	0	Numb.	0,00%
EU	Electricity	0	0	0	Numb.	0,00%
	Thermal	0	0	0	Numb.	0,00%

Figure. 68 Contribution to modern energy access of the hypothetical advanced bioenergy value chain in the *target area* (lignite mining reclamation site, Germany).

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

4.2.11 Productivity

This indicator measures the productivity of the bioenergy value chain in terms of quantities and unitary costs. The work done by FIB and WIP with Deliverable 2.3 and 2.4 provided an important share of the information included in this indicator. The rest of the data required was retrieved in the literature.

The spontaneous grass growing in the former sewage irrigation fields in the outskirts of Berlin produces some 3 tons of biomass per ha per year. This crop does not receive any input or aid to sustain its growth and the long-term implications of harvesting of the biomass without the replenishing of nutrients in the soil may reflect on productivity. The production of the feedstock then it only accounts for those costs related to harvesting and transport to the biorefinery, since no other production operation takes place. The land, as seen in the related indicator, is publicly owned and the landowner fee is included in the following calculation. However, the correct attribution of the share of costs to the bioenergy component is key. In fact, the grass biorefinery will mainly purchase the feedstock for the extraction of the juice and therefore of the amino acids, whereas the fiber cake will be considered a residue. The cost of the biomass then would only be the delivery cost and assuming that the biomethane plant is located within a radius of 40 km from the biorefinery the cost of delivery is around EUR 10/ton.

Lucerne and sorghum growing in the ***target area*** return yields of 5 tons ha^{-1} yr^{-1} and 10 tons ha^{-1} yr^{-1}, respectively. According to Deliverable 2.4 lucerne has a production cost of EUR 50.87 per ton produced in the lignite reclamation sites, whereas sorghum can be produced at the cost of EUR 31.25 per ton. The calculation of total production costs have been performed in Deliverable 2.4 by WIP and in this assessment the total yearly cost estimate is based on such calculations.

The Lucerne+sorghum biomethane plant would have a yearly cost of about EUR 9.7 million. In Deliverable 2.4 no interest rates are calculated on the actual installation cost at year 0. OPEX costs have been summarily assessed as a share of 10 percent of the CAPEX but the cost of biomass is excluded from this estimate and dealt with separately. Yearly feedstock cost for the biomethane plant using Lucerne and sorghum would be EUR 3.72 million. Excluding interest rates, the yearly production cost for biomethane in the lignite mining district would be EUR 4.25 million, which translates into a cost per m^3 of EUR 0.56.

4.2.12 Energy Balance

This indicator calculates the difference in energy inputs necessary to produce the biomass, transport it to the biorefinery/bioenergy plant, process it into advanced biofuel and, lastly, distribute the fuel. From an energy balance point of view the analysis of the biomethane production obtained from the spontaneous grass growing on the former sewage irrigation fields returned valuable information which highlight the energy efficiency of the system. This is mainly due to the fact that cultivation does not require any form of additional energy other than for harvesting operations. Subsequently, only transport and processing into fuel are the stages that constitute the energy input section of the indicator. In fact, as shown in Figure 69, the energy inputs in the feedstock production phase is zero with the sole exception of the energy required to harvest the biomass.

FEEDSTOCK PRODUCTION									
	SEEDS	type	S. GRASS	-	-	-	-	-	-
		MJ	0	0	0	0	0	0	0
	ORGANIC FERTILIZATION	Type	-	-	-	-	-	-	-
		Kg/ha	0,0	-	-	-	-	-	-
		Kg TOT	0,0	0,0	0,0	0,0	0,0	0,0	0,0
		MJ	0	0	0	0	0	0	0
	CHEMICAL FERTILIZATION								
	N Ammonium	Kg/ha	0,0	-	-	-	-	-	-
		Kg TOT	0,0	0,0	0,0	0,0	0,0	0,0	0,0
		MJ	0	0	0	0	0	0	0
	N Nitrate	Kg/ha	0,0	-	-	-	-	-	-
		Kg TOT	0,0	0,0	0,0	0,0	0,0	0,0	0,0
		MJ	0	0	0	0	0	0	0
	P	Kg/ha	0,0	-	-	-	-	-	-
		Kg TOT	0,0	0,0	0,0	0,0	0,0	0,0	0,0
		MJ	0	0	0	0	0	0	0
	K	Kg/ha	0,0	-	-	-	-	-	-
		Kg TOT	0,0	0,0	0,0	0,0	0,0	0,0	0,0
		MJ	0	0	0	0	0	0	0
	PESTICIDES	Kg/ha	0,0	-	-	-	-	-	-
		Kg TOT	0,0	0,0	0,0	0,0	0,0	0,0	0,0
		MJ	0	0	0	0	0	0	0
	MECANICAL INPUTS (LINK TO AIR INDIC	MJ	2.045.213	0	0	0	0	0	0
	GRAN TOTAL	**MJ**	**2.045.213**	**0**	**0**	**0**	**0**	**0**	**0**
TRANSPORT OF FEEDSTOCK									
	TRACTOR	Hrs	87,210	0,000	0,000	0,000	0,000	0,000	0,000

... | EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET

Figure. 69 Energy inputs for feedstock production phase: spontaneous grass on former sewage irrigation fields in Germany.

The transport to the biomethane plant and its processing are other energy negative processes which accounted as inputs.

The energy outputs are the production of biomethane obviously, but also the production of amino acids and the other added value products. These energy inputs and outputs are subtracted (via allocation) to the portion of energy attributable to the bioenergy pathway only. Lastly, it is assumed that the fuel is transported via

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truck tank for a distance of 100 km or it is injected under pressure into the grid, with approximately the same energy requirement for the pressurization and injection into the grid (Figure 70).

MECANICAL INPUTS (LINK TO AIR INDIC	MJ	2.045.213	0	0	0	0	0
GRAN TOTAL	MJ	2.045.213	0	0	0	0	0
TRANSPORT OF FEEDSTOCK							
TRACTOR	Hrs	87,210	0,000	0,000	0,000	0,000	0,000
Diesel	MJ	65.974,617	0,000	0,000	0,000	0,000	0,000
TRUCK	MJ	0,000	0,000	0,000	0,000	0,000	0,000
RAIL	MJ	0,000	0,000	0,000	0,000	0,000	0,000
SHIP	MJ	0,000	0,000	0,000	0,000	0,000	0,000
GRAN TOTAL	MJ	65.975	0	0	0	0	0
FEEDSTOCK PROCESSING INTO FUEL							
TOTAL	MJ	0	0	0	0	0	0
BY PRODUCTS FROM GREENREFINERY	TONNES	872	0	0	0	0	0
	MJ	21.803	0	0	0	0	0
FUEL TRANSPORT							
TRUCK	MJ	3.897.104	0	0	0	0	0
RAIL	MJ	0	0	0	0	0	0
SHIP	MJ	0	0	0	0	0	0
TOTAL	MJ	3.897.104	0	0	0	0	0
TOTAL ENERGY INPUT	MJ	6.030.095	0	0	0	0	0
ENERGY OUTPUTS							
	BioMethane						

... EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASE

Figure. 70 Energy inputs for feedstock transport, processing and fuel transport phases: spontaneous grass on former sewage irrigation fields in Germany.

Energy outputs take into account all co-products of the value chain, including the digestate which, even though not necessarily used for energy purposes, has an energy content that is accounted for as a substitute of the energy necessary for the production of its alternative substitute (e.g. N fertilizers).

Lastly the net energy ratio (EO/EI or TFO/TFI)is presented in Figure 71. This is the ratio between the energy output attributed to the advanced biofuel and the input necessary for its production. In the case of spontaneous grass for biomethane the final EO/EI ratio is 6.34.

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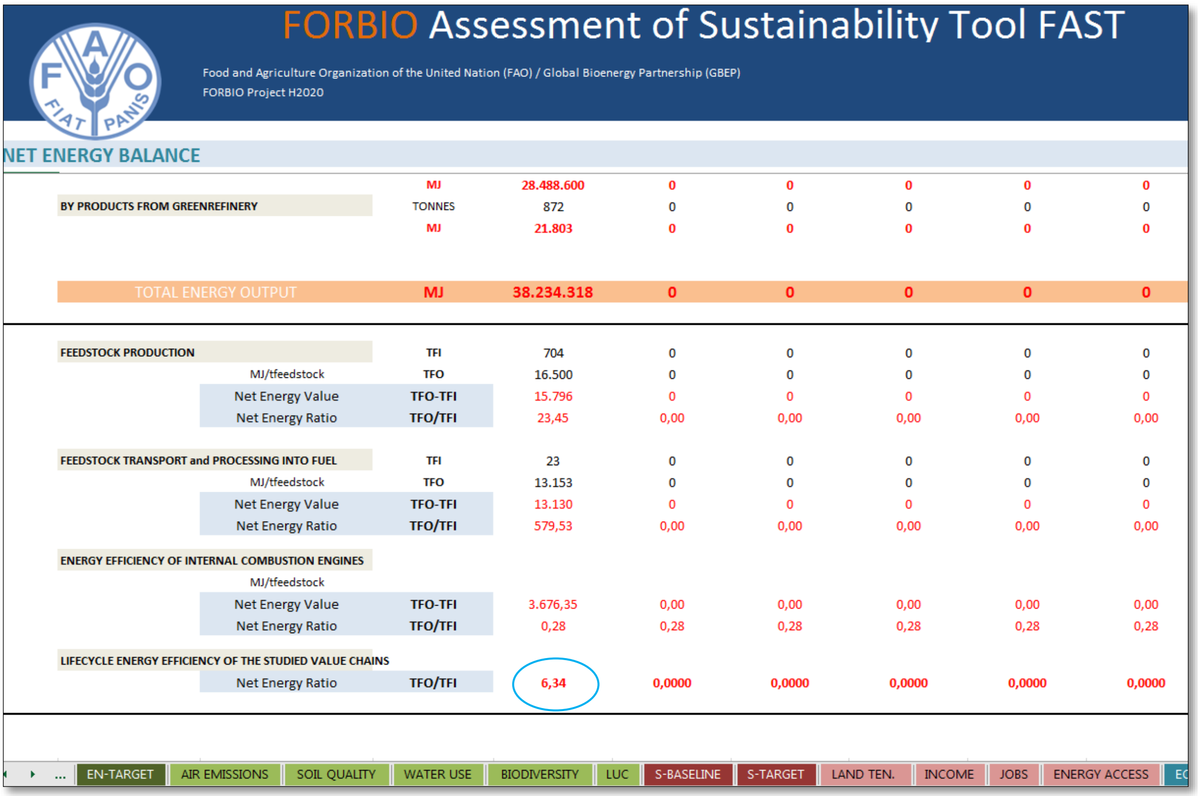

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NET ENERGY BALANCE

	MJ	28.488.600	0	0	0	0	0
BY PRODUCTS FROM GREENREFINERY	TONNES	872	0	0	0	0	0
	MJ	21.803	0	0	0	0	0
TOTAL ENERGY OUTPUT	MJ	38.234.318	0	0	0	0	0
FEEDSTOCK PRODUCTION	TFI	704	0	0	0	0	0
MJ/tfeedstock	TFO	16.500	0	0	0	0	0
Net Energy Value	TFO-TFI	15.796	0	0	0	0	0
Net Energy Ratio	TFO/TFI	23,45	0,00	0,00	0,00	0,00	0,00
FEEDSTOCK TRANSPORT and PROCESSING INTO FUEL	TFI	23	0	0	0	0	0
MJ/tfeedstock	TFO	13.153	0	0	0	0	0
Net Energy Value	TFO-TFI	13.130	0	0	0	0	0
Net Energy Ratio	TFO/TFI	579,53	0,00	0,00	0,00	0,00	0,00
ENERGY EFFICIENCY OF INTERNAL COMBUSTION ENGINES							
MJ/tfeedstock							
Net Energy Value	TFO-TFI	3.676,35	0,00	0,00	0,00	0,00	0,00
Net Energy Ratio	TFO/TFI	0,28	0,28	0,28	0,28	0,28	0,28
LIFECYCLE ENERGY EFFICIENCY OF THE STUDIED VALUE CHAINS							
Net Energy Ratio	TFO/TFI	6,34	0,0000	0,0000	0,0000	0,0000	0,0000

EN-TARGET | AIR EMISSIONS | SOIL QUALITY | WATER USE | BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC

Figure. 71 Energy Output-Energy Input ratio for the biomethane from spontaneous grass on former sewage irrigation fields in Germany.

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

The alfalfa + sorghum (L + S) scenario is characterized by the presence of energy inputs in the agricultural phases but these are somewhat counterbalanced by the increased productivity per ha. In addition, the use of manure for the production of the biomass is not accounted directly as an energy input. If the energy content of manure was accounted for as an energy input, the EO/EI ratio would be only marginally positive (TFO/TFI=0.43). Instead, considering that manure is produced regardless of its use as fertilizer and that therefore its energy content is not the directly attributable to its use as fertilizer, the net energy ration of the system would be 5.15 for Lucerne biomethane and 5.71 for sorghum (Figure 72), considering that the share produced is 53% from Lucerne and 47% from sorghum, the weighted average TFO/TFI would be 5.41.

FEEDSTOCK PRODUCTION		TFI	925	156	0	0	0
	MJ/tfeedstock	TFO	16.019	16.400	0	0	0
	Net Energy Value	TFO-TFI	15.094	16.244	0	0	0
	Net Energy Ratio	TFO/TFI	17,32	105,09	0,00	0,00	0,00
FEEDSTOCK TRANSPORT and PROCESSING INTO FUEL		TFI	39	16.935.719	0	0	0
	MJ/tfeedstock	TFO	10.434	0	0	0	0
	Net Energy Value	TFO-TFI	10.395	-16.935.719	0	0	0
	Net Energy Ratio	TFO/TFI	268,36	0,00	0,00	0,00	0,00
ENERGY EFFICIENCY OF INTERNAL COMBUSTION ENGINES							
	MJ/tfeedstock						
	Net Energy Value	TFO-TFI	2.910,63	-4.742.001,20	0,00	0,00	0,00
	Net Energy Ratio	TFO/TFI	0,28	0,28	0,28	0,28	0,28
LIFECYCLE ENERGY EFFICIENCY OF THE STUDIED VALUE CHAINS							
	Net Energy Ratio	TFO/TFI	5,1486	5,7117	0,0000	0,0000	0,0000

... BIODIVERSITY | LUC | S-BASELINE | S-TARGET | LAND TEN. | INCOME | JOBS | ENERGY ACCESS | EC-BASELINE | EC-TARGET | PRODUCTIVITY | NET E

Figure. 72 Energy Output-Energy Input ratio for the biomethane from alfalfa and sorghum (L+S) in the reclaimed lignite mining site in Lusatia, Germany.

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

4.2.13 Gross Value Added

This indicator measures the contribution to the GDP of a given bioenergy value chain. In the case study of Berlin and Brandenburg, the products that contribute to GDP are the sales of biomethane. The sale of amino acids etc. from spontaneous grasses is external to the bioenergy pathway studied and thus not included in these calculations.

According to Eurostat (2018), in the second half of 2017 the natural gas price in Germany was EUR 0.06 per kWh, or EUR 0.58/m^3. As seen in indicator 4.2.11 – Productivity – biomethane in the lignite district could be produced at a cost of EUR 0.56 per m^3. This would make the biomethane produced in the lignite mining reclamation area competitive with the price of fossil natural gas. However, as anticipated in the reference chapter, the calculations are incomplete because interest rates, as well as additional costs due to connection to the natural gas grid and the rental costs of accessing to the grid are not included. More importantly, the Eurostat price is the real price (including taxes) paid at the household level, rather than the cost of production. In Germany, there are feed-in tariffs that contribute to the economic balance of bioenergy production as set forth in the Renewable Energy Source Act, EEG 2012 (IEA, 2016).

This document clearly addresses the tariff system for biogas plants generating electricity but do not directly tackle biomethane as an advanced fuel for transport. However, applying the same restrictions formulated for biogas plants the first limitation is that the energy generated is obtained less than 60% from maize and grain. In the case study of Germany, sorghum would represent up to 47% of the total biomethane output and thus, this first condition is met. The tariff structure is composed by four capacity-oriented categories (from EUR Cent 6 to 14.3/kWh_e). Large plants receive the lower incentive of EUR 0.06/kWh_e. In the case study of Germany biomethane is not directly employed to power a generator, but the incentive per m^3 can be derived by the conversion factor between fuel and energy. At average efficiencies, 1 m^3 of methane will generate 1.84 kWh_e and thus should qualify to receive a remuneration of EUR 0.11 m^3.

According to the EEG 2012 (IEA, 2016) a bonus of EUR Cent 1 to 3/kWh is paid for processing and feed-in of bio-methane. For the sake of this hypothetical analysis the average value was chosen. This means adding a further EUR 0.02/kWh_e which would drive the calculation per m^3 of biomethane to a tariff of EUR 0.14 m^3.

From Deliverable 2.4, it emerges that biomethane injected into the grid generates an income for the producer of EUR 0.073 kWh (approximately EUR 0.38 m^3).

The initial basic tariff decreases by two percent per year, whereas the fuel-related tariff does not change but in this calculation such decrease is neglected.

Every year the sale of the 7,5+ million m^3 of biomethane would generate revenues for EUR 2.7 million (Deliverable 2.4).

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However, the total production cost of biomethane in the lignite mining district was estimated at 0.56 EUR/m^3 (against a price paid to the producers of EUR 0.38 m^3) or EUR 4.2 million per year (against a potential revenue of EUR 2.7 million per year). Even if in Deliverable 2.4 there is the mention to additional direct payments/bonus, it is confirmed that the operation would still be unprofitable and thus its Gross Value Added negative.

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

2.2.14 Infrastructure

The analysis of the infrastructure for the logistics of transport of biomass and biofuels, adds to the information discussed under the previous economic indicators to present a complete look of the characteristics of the ***target area*** from this point of view. This indicator has a quantitative and a qualitative component. The quantitative component requires the user to assess the distances between the production areas and the hypothetical site of the biomethane plant, as per the primary assumption behind the tested scenarios. Subsequently, through the use of GIS tools, the actual distances between the production sites and the collection site are calculated. On the basis of the characteristics and the status of maintenance of the infrastructure the indicator measures the time spent to collect and deliver the biomass at the biomethane plant's gate. The qualitative analysis of information in this indicator looks at the logistics side of operations within the value chain.

The assessment of this indicator is based on the information gathered in Deliverable 2.3 and 2.4.

The potential location for a grass biorefinery within the ***target area*** was studied by WIP taking into account the distribution of available underutilized lands in the former sewage irrigation fields around Berlin, and it was concluded that the southern part of Berlin would be considered as a suitable place for a biorefinery (Figure 14). However, this biorefinery not necessarily would use the fiber cake after pressing to obtain biomethane. In case a grass biorefinery is built next to an existing biogas plant (adequately equipped with methane upgrading systems) in the southern part of Berlin (Figure 73), the logistics of this value chain would have the following characteristics:

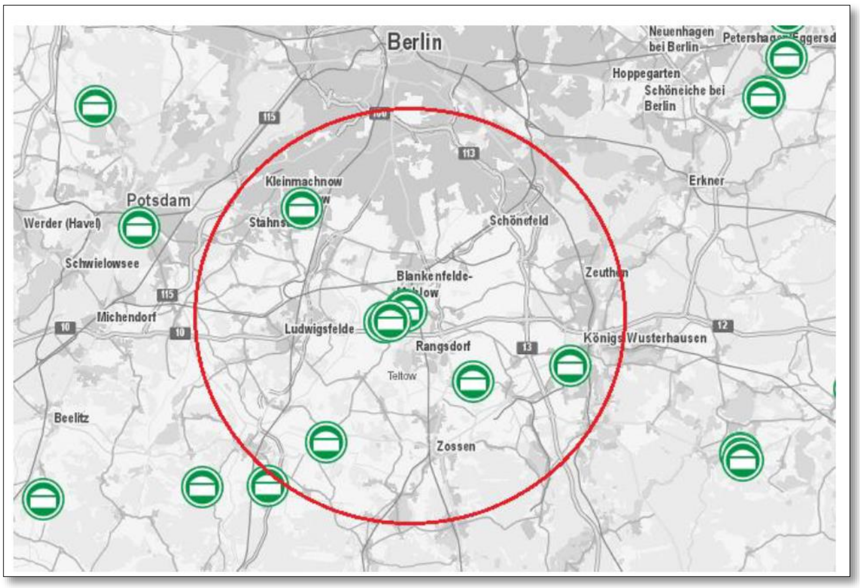

Figure. 73 Most likely location of the biorefinery adjacent to existing biogas plants (to be upgraded to biomethane) in South of Berlin. Source: Deliverable 2.4.

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The biomethane plants would be located in Blankenfelde-Mahlow. In this area there are three biogas plants located next to each other and their output is between 164-200 kW_{el} and there is one biogas plant is in Groß Machnow which has a power output of 1,123 MW_{el}. The biomethane plants are all within a 12 km radius from an hypothetical grass biorefinery which would gather the feedstock. As of 2018, the infrastructure for this type of scenario does not exist. There is no grass biorefinery of any size in the area and the biogas plants found in the suitable area are, at least for the time being, equipped with methane upgrading systems.

That being said, the road system in this part of the country was found to be excellent and to cover the 20 odd km between the sewage irrigation fields and the location of the biorefinery, only 27 minutes on average would be required. The additional transport of the pressed cake to the biomethane plants (13 km on average) would require additional 25 minutes each trip.

The lignite mining district reports a condition that is more spread out concerning the location of the possible fields (in yellow in Figure 74).

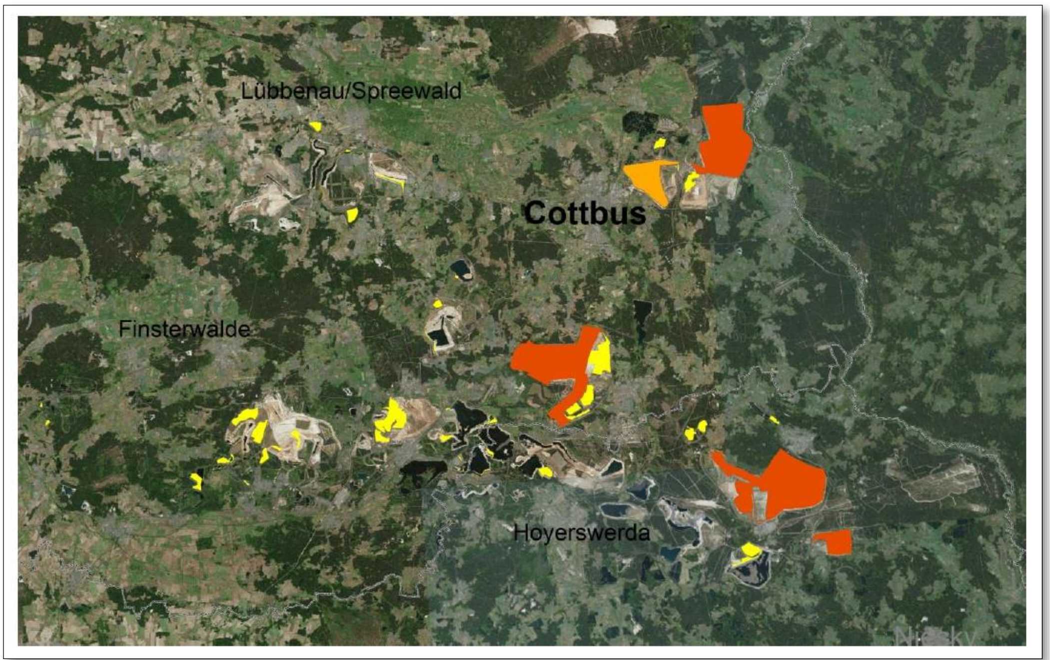

Figure. 74 Most likely location of the reclamation sites for lucerne and sorghum production in Lusatia (yellow areas). Source: Deliverable 2.4.

The potential location for the biomethane plant to receive the feedstock produced in the reclaimed fields would be located in Schwarze Pumpe (Figure 75), which is a large industrial area which offers interesting logistical and infrastructural advantages over other sites in the area. The connection with the natural gas grid would allow to inject the biomethane directly into the grid and the vast logistical network in the area would guarantee smooth operations of the biomethane plant.

However, from a more accurate analysis of the distances from the potential fields, even though on average these are 48 km from Schwarze Pumpe, the road

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infrastructure in the area would return greater real distances (which take into account the geography and the average speeds attainable). In fact, on average, a truck would need to cover 58.1 km to reach the biomethane plant and given the road infrastructure this would take approximately 1h25min minutes each way.

Figure. 75 Most likely location of the biomethane plant in Lusatia (red triangle). Source: Deliverable 2.4.

However, total travel time required to transport the feedstock to the processing plant would be 1,021 hours per year.

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4.2.15 Capacity of use of bioenergy

The contribution to reaching the capacity of using bioenergy of a country is measured in this indicator. Due to the increasing fuel efficiency of vehicles, consequence of emission reduction policy at the EU-level, petrol consumption is expected to decrease over time, and was assumed to stay constant at 2018 values at best.

The capacity of a fleet to use biofuels in the case of biomethane is given by the total amount of natural gas consumed by the fleet, which is directly linked to the number of circulating bi-fuel (petrol and natural gas) vehicles in the country. According to the European Compressed Natural Gas association (CNG Europe, 2018) this amount is 95,708 vehicles in Germany.

To date in Germany the CNG marching vehicles are estimated to use 105,025,618 m^3 of methane per year. The additional production of 7,586,385 m^3 of biomethane per year would displace about 7.22% of the fossil natural gas used by the fleet. Considering that according to the European Biogas Association, in Germany 3% of the biomethane produced is used as transport fuel. Total production in 2018 was 1,038,636,364 m^3 of which 31,159,091 were used by the transport sector m^3. The contribution of additional 7.5 million m^3 of biomethane produced could enhance the capacity of the fleet to use biomethane relatively to its current use by 24.34%.

The production of 7.5 million m^3 of biomethane in the target area would satisfy 99% of the current demand for this advanced biofuel for the transport sector.

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