BIKE

BIOFUELS PRODUCTION
AT LOW - ILUC RISK
FOR EUROPEAN SUSTAINABLE
BIOECONOMY

D 6.1

Reports for the good practice cases

Dissemination level:

PU

Date 14.2.23

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952872

Document control sheet

Project	BIKE – Biofuels production at low – Iluc risK for European sustainable bioeconomy
Call identifier	H2020-LC-SC3-2020–RES-IA-CSA
Grant Agreement N°	952872
Coordinator	Renewable Energy Consortium for Research and Demonstration (RE-CORD)
Work package N°	6
Work package title	Good practice case studies and lessons learnt for market uptake
Work package leader	CRES
Document title	Reports for the Good Practice cases
Lead Beneficiary	CRES
Dissemination level	PU
Authors	Efthymia ALEXOPOULOU
Contributors	ENI, UPM, RECORD, Imperial
Reviewer(s)	Andrea Salimbeni
Issue date	14/2/23

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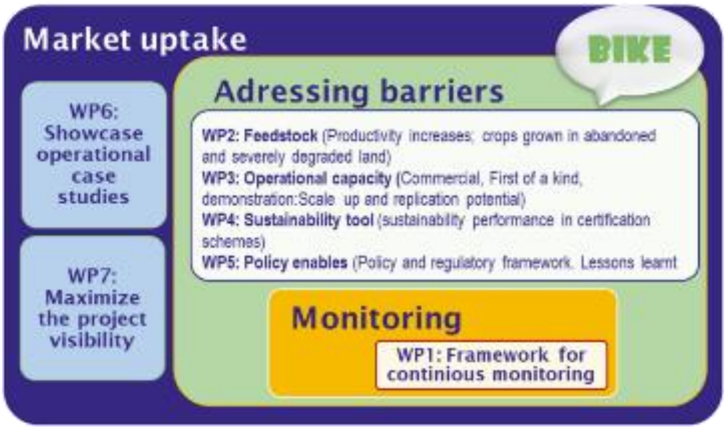
1 Executive summary



BIKE aims to propose scientifically robust solutions that will facilitate the wider uptake of low ILUC risk biofuels, bioliquids and biomass fuels by the transport sector in EU and lead to increased shares in the final energy consumption by 2030. It develops a certification module for low ILUC risk biofuels, bioliquids and biomass fuels and a decision support tool to guide policy and industry decision makers on the potential of low ILUC risk options in their country and on how to assess them. These can form the basis for more informed policy, market support and financial frameworks at national, regional and local level. The methodology applies a systemic approach through the seven Work Packages (see above graph).

2 Introduction

The main aim of **WP6** is to analyse and showcase the good practices of the case industry-led studies in BIKE, promoting their replicability at EU level, and to provide an overview of the lessons learnt for further market uptake of low ILUC risk biofuels.

D6.1 aims to present the good practices for selected BIKE case studies for further market uptake of low ILUC risk biofuels, bioliquids and biomass fuels. In BIKE two value chain types are including; matching definition for additionality, as it is provided so far by the Commission Delegated Regulation (EU) 2019/807 of 13 March 2019 supplementing Directive (EU) 2018/2001, i) **cultivation in unused**, **abandoned or severely degraded land** and ii) **productivity increases from improved agricultural practices**.

The work in WP6 has been organised in four tasks. In the first task concrete profiles for the selected low ILUC case studies have been compiled (D6.1), in the second a SWOT analysis for the case studies of D6.1 is being carried out using the refined criteria of WP4 as well as the main findings of the WPs 1-3 (**D6.2** by CRES; M34). In the third task they key lessons learnt from the case studies will be identified and then will be further analysed in order to be applicable to other cases throughout Europe (**D6.3** by CRES; M36). Last but not least in the fourth task open labs (open days) are being organised for the selected case studies (**D6.3** by ETA; M34).

Two open labs had been organised in M25 (both for value chain type 1; Figure 1); the **1st in Sardinia/Italy** for **castor bean** and the **2nd in Viotia/Greece for perennial lignocellulosic crops**. Two more have been planned for the second value chain type; the **1st in Thessaloniki, Greece for Brassica carinata** and the **2nd for Biogas Done Right model in Calabria, Italy**.

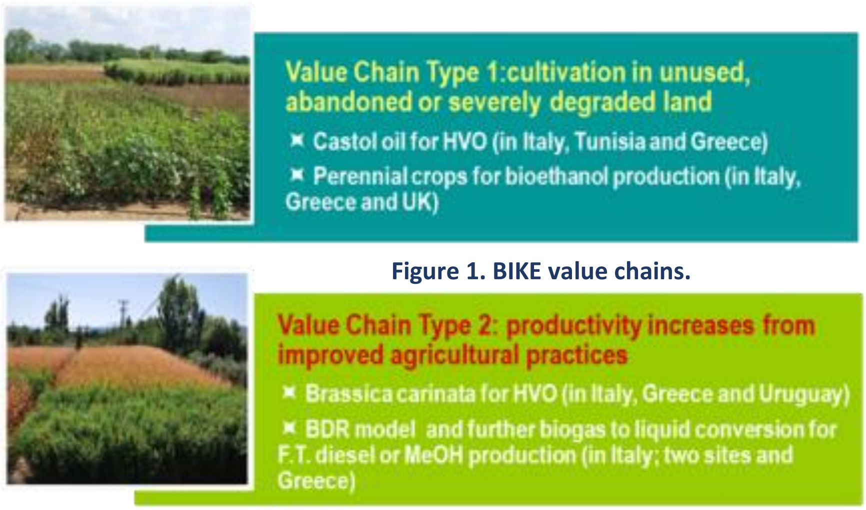


Figure 1. BIKE value chains.

2.1 Value chains produced from cultivation of feedstock on unused, abandoned or severely degraded land

These value chains analyse biomass feedstock options that can be cultivated on unused, abandoned or severely degraded land. They use as baseline the work in **Magic project** (www.magic-h2020.eu) which has characterised and analysed projections for current and future marginal lands in Europe facing natural constraints and provided a spatially explicit classification that serves as a basis for developing sustainable best-practice options for industrial crops in Europe[1] (WP2). Thereafter, the work further focus the data and assumptions used by examining additional lignocellulosic ethanol production from perennial/biannual crops (CRES, REC) feedstocks from the oil, starch and lignocellulosic categories as well

[1] https://iiasa-spatial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

as any crop management practices (cover crops, catch crops, rotation, agroforestry, etc.) that may benefit yields and soil improvements (e.g. biochar, etc.). The analysis in BIKE provides update, tailored information for feedstock production potentials (in tonnes and GJ) in Europe with disaggregation at NUTS2 level both for land types, suitable crops and cropping practices (WP2). Potential yield increases will also be provided based on analysis with the WOFOST and GWSI models[2]. In addition to the top down analysis BIKE is also evaluate the following Good Practice cases (WP6) for feedstock produced on unused, abandoned or severely degraded land (Figure 2):

I. **Castor oil cultivation in arid/degraded/abandoned land**, with biochar production for soil improvement, for HVO production (ENI, REC)

II. **Lignocellulosic Ethanol production from perennial/biannual crops** (CRES, REC)

2.2 Value chains produced crops which have increased yields from improved agricultural practices

These value chains analyse crop options that can have increased yields through improved agricultural practices. Yield increases that BIKE will examine will be the outcome of **improved crop management** (sowing, soil preparation, fertilisation, etc.); soil carbon increase with biochar, **crop rotation**; catch crops, improvements in harvest; **precision farming techniques**, etc. Except the top down analysis BIKE is also analyse the following Good Practice cases (WP6) for feedstock produced crops which have increased yields from improved agricultural practices (Figure 2):

I. **Brassica Carinata cultivation as cover crop** for low ILUC biofuel production (UPM)

II. **Biogas Done Right model for Biomethane production** in decentralized farms, virtually and regulatory integrated with centralized Biomethane-to-liquid conversion plants as F.T. diesel, kerosene, jet or MeOH production (CIB – REC)

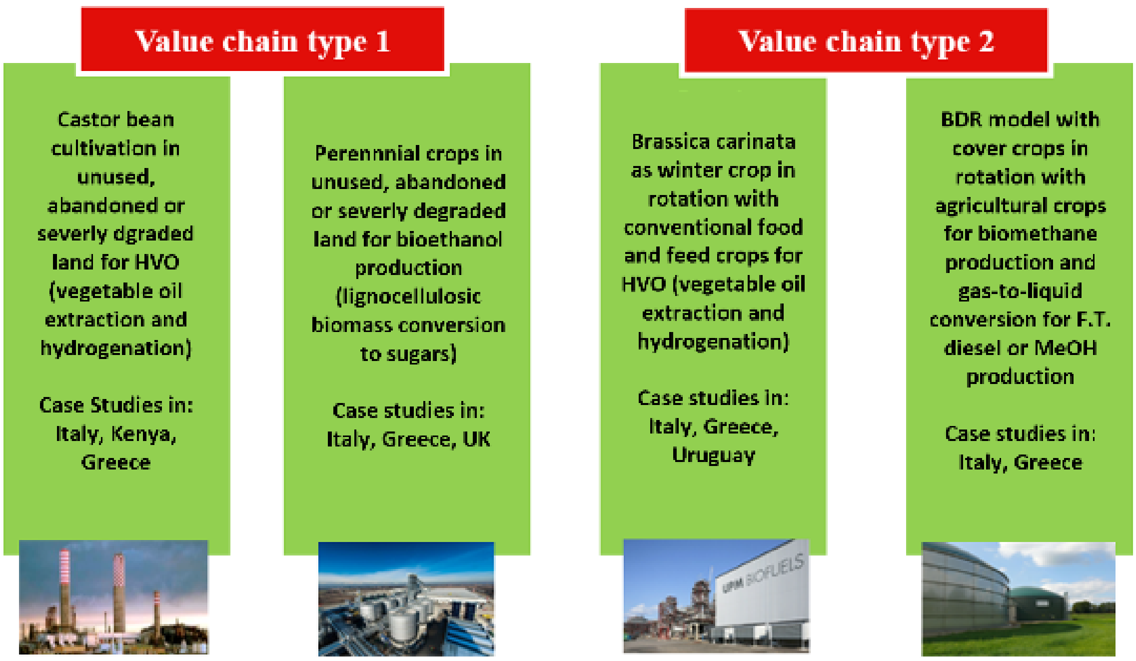


Figure 2. BIKE value chains

[2] http://www.yieldgap.org/web/guest/europe

D6.1 is related to the work that had been carried out in Task 6.1 and presents concrete profiles for the selected low ILUC case studies. As reported in Figure 2, only two case studies were identified about Biogas Done Right model. A third case study, cultivating cover crops for Low-ILUC risk biogas production, had to be identified in UK. However, this was not possible so far.

3 Case Study 1: Castor oil for HVO

3.1 CS 1 in Kenya by ENI

Kenya is one of the most advanced countries in Africa in terms of commitment to climate change. The Country signed the Paris Agreement and intends to reduce 32% of its emissions by 2030. Eni is supporting the Kenyan Government in the decarbonization process by developing sustainable energy crop value chains on degraded lands (low ILUC feedstock), such as castor bean. This initiative contributes to create opportunities for farmers to diversify their livelihood options. In fact, almost 70% of Kenya's (54 million) inhabitants are dedicated to agriculture.

Eni, in agreement with the country's Ministry of Agriculture, identified the target areas and launched the cultivation of drought resistant crops (such as castor) in areas less suitable for food production, thus offering farmers an additional source of income. Scientific support to the project has been provided by the Kenyan Agricultural and Livestock Research Organization (KALRO) and the University of Bologna, which have been jointly engaged since 2021 in the characterization of local crop varieties, including castor bean. Recommendations on cultivation techniques were issued and disseminated through BIKE project and circulated in 1st open lab in Sardinia.

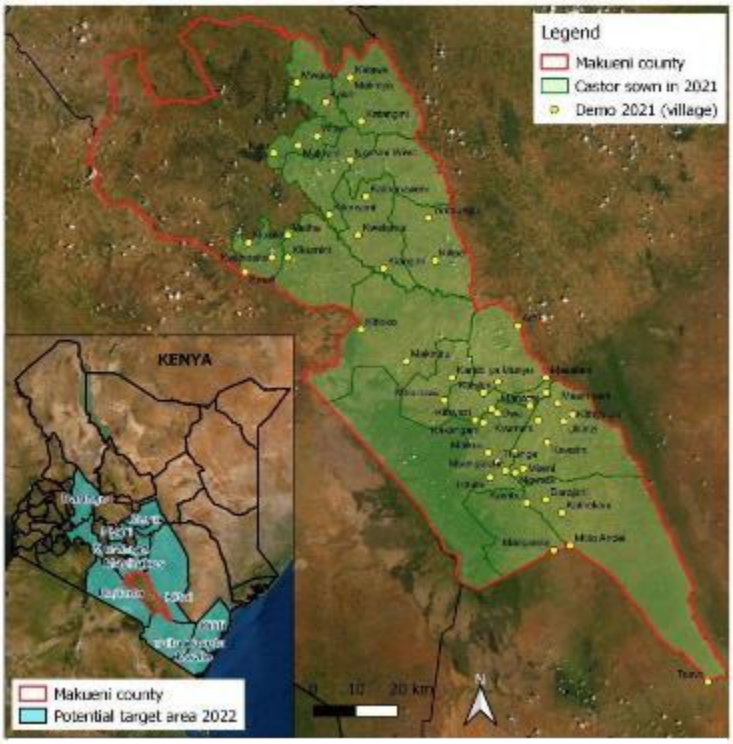


Figure 3. Project area for 2021 and 2022

The project is implemented in Makueni County (L 10 35΄ ÷ 10 32΄ S and L 37o 10΄ ÷ 38o 30΄ E), which covers a total area of 8176 km², with an arable land area of 3800 km^2 (46% of the total area). The area for castor cultivation aims tp cover a total of 15.000-20,000 ha, involving more than 15,000 rural households.

The BIKE demo fields were established in 2021 and covered an area of 200 ha, distributed in 44 villages (Demo 2021, Figure 3), in 17 wards of 4 sub-counties (Mboni, Kibwezi east, Kibwezi west, and Makueni) in the Makueni County. The cultivation was scaled up in 2022 for additional 2,000 ha in Makueni County and in other surrounding Counties (see potential target area 2022 in the map).

The identified area is classified as arid and semi-arid (agroecological zones 4 and 5), with an annual rainfall ranging between 500 and 800 mm. Kenya is one of the most hard-hit by climate change impacts by drought. In fact, since 1994, agricultural yields have been declining steadily. Increasing temperatures and scarce precipitation have affected crop productivity (especially during planting months between march and may). Given these elements of vulnerability, the Government, according to the national Strategic Plan of Ministry of Agriculture 2018-2022, included Makueni County as one of the priority areas of intervention.

Depending on the farmer's capabilities and access to mechanization, soil preparation for castor bean include mechanized ploughing or ripping in a single pass, animal-drawn ploughing, or manual hoeing. Site-specific recommendations suggested to adopt one ploughing for land preparation and the use of ridging in particularly dry areas to increase water harvesting.

In Kenya castor bean can be sown at the beginning of the rainy seasons: in October-November (short rain season) and March-April (long rain season), manually, with a density between 1600 to 4000 plants/ha. Farmers intercrop castor with beans, green grams, and others food crops. In 2021, in the project area, the crop was planted in mid-November with a spacing of 2.5 X 2.5 m in intercropping (1600 pp/ha) up to 1.5 x 1.5 m in monocropping systems (about 4400 pp/ha), with a recommended seed rate of 5-15 kg/ha.

KALRO conducted a research in 2015 to characterize local castor bean germplasm, selecting about ten varieties showing a good agronomic potential. Of these, 3 cultivars (KBC6, KC6, and NU70) were kept in multiplication to allow the start of the sowing campaigns. With the support of the Italian Agency for Development Cooperation (AICS), KALRO started a program to include the studied varieties in the national register. Further trials are underway, with the scientific coordination of the University of Bologna, evaluating the adaptability in rotation with cover crops (*Camelina sativa*, *Crambe abyssinia*, and *Brassica carinata*). Other castor seed lines that will be considered are KC1, KC2, KC3, KC4, and KC15 (table 1).

Table 1. Addional castor lines that will be considered in Kenya fields.

Varieties	Growing period (days)	Seed yields (kg/ha)	Oil content (%)
KC1	149	2205	46
KC2	142	2130	47
KC3	191	2855	47
KC4	191	3495	49
KC15	195	>3000	45

According to the results of the agronomic evaluation performed by KALRO and the University of Bologna, the weeding is recommended within the first month of the growing season, during the emergency phase. By following these recommendations, farmers mostly performed the weeding manually. At least one fertilization was recommended during the land preparation with organic farmyard manure (1 ton/ha). An additional fertilization of DAP (120 kg/ha) is recommended at weeding time. The sufficient rainfall for castor ranges between 500 and 600 mm/year. As in the case study area the annual rainfall is between 500 and 800 mm/year, no additional irrigation was needed. Constant monitoring during the crop growth is performed in field and no diseases/insects problems have been reported so far by farmers. The first harvest period wa carried out in June 2022. It should be pointed out that the harvesting was done manually at several dates according to the maturity time of the racemes.

The seed yields varied from 1500 to 2500 kg/ha with oil contet 45 to 50%. The oil profile was 85% ricinoleic, 5,4% linoleic, 3,2% oleic, and other fatty acids. Characterization of cake as it was: 50% C, 7% H, 5% N, 32% O, 7% ash.

The ENI project envisages: i) the production of low ILUC vegetable oils in Kenya destined to Eni biorefineries located in Italy (Gela and Marghera) in the short term, with further valorization locally thank sto the conversion of the Mombasa refinery into a biorefinery supplied through the collection of used cooking oil (UCO); ii) the development of agri value chains, including castor. Castor oil has been validated for Eni HVO proprietary technology.

The Agri Hub acts as an aggregation and processing center to produce oil and residual cake. The center also offers services to farmers, such as mechanization, distribution of agricultural inputs (seeds and fertilizers) and training. The business model adopted by the initiatives relies on local farmers for oil seed production and ensures the market access, whether they are smallholders, cooperatives, or large companies, through the formalization of a contract for seed supply (contract farming). The processing for the oil extraction will be performed through the creation of collection and processing centers (so called Agri Hubs).

Upon verification of HSE requirements, castor cake canbe used as soil enricher (NPK 5-1-1). The cake is approximately 50% in mass of the oilseeds, with a residual oil content of 5-7%. Currently Eni is studying the possibility to convert the residual biomass into biochar via slow pyrolysis, to be reintroduced in the soils as carbon farming measure. This additional practice may be accounted in the overall LCA of the biofuel produced or accounted separately with creation of a carbon project under a voluntaryscheme.

The model has a great impact on the Sustainable Development Goals (SDG) and it is based on the “Just Transition” principles, focusing onfive pillars: food security and health, jobs and rural income, economic development, access to land, territorial regeneration. Overall, the initiative in Africa aims at providing job opportunities and creating income for a large number of families in several countries.

The proposed approach has multiple values; the creation of a different energy mix in Africa and reduction of fossil fuel consumption, creation of socio-economic development and rural income from agro-industrial activities, diversification of agriculturalactivity and poverty reduction, in consistency with the values expressed by the SDGs. Starting from 2022, the project will enter into a production phase, with the implementation of all measures to ensure the compliance to ISCC-EU certification model.

The case study refers mainly to European legislation on biofuels. In particular to the REDII renewable energy policy. The Project focuseson the production of “low ILUC-risk biofuels” as defined in the Recast Renewable Energy Directive. They are fuels produced in a way that mitigate Indirect Land Use Change (ILUC) emissions, either becausethey are the result of productivity increase (agricultural rotations and intercropping) or because they come from crops grown on severelydegraded land.

The case study (Figure 4) will eventually contribute to generate knowledge for the development of carbon negative initiatives in Europe, such as Carbon Farming. The program is in line with the national Kenyan policies and, in particular, with the National Bioenergy Strategy 20-27 in which the castor is indicated as feedstock with high potential for cultivation inthe country.

MAKUENI AGRI HUB (Base foundation, Jan 2022) — **MAKUENI AGRI HUB** (HSE Induction, Feb 2022) — **MAKUENEI COUNTY** (Demo fields, Jan 2022) — **KADJAGO COUNTY** (Stekeholder engagement, Feb 2022)

Figure 4. Photos from the castor bean case study in Kenya

3.2 CS2 in Greece

The scope of SC1 case study was to investigate the opportunity to utilize castor crop in marginal areas as an energy crop for biofuels production that could help to reduction of fossil energy dependence, improvement of rural economies and the reduction of environmental impacts. It should be noted that in

Europe there is an urgent need to replace a several million t volume of low ILUC lipidic feedstock (mostly palm) from 2023 to 2030.

The last three years (2020, 2021 & 2022) demo fields had been carried out in central (Velestino) and north-east Greece (Xanthi). Each field had a size of 1 ha all of them established in abandoned agricultural areas. These case studies started in MAGIC project and conituned in BIKE. Castor bean has been selected by MAGIC non-food oilseed to be grown on marginal lands facing natural constraints and/or contaminated ones. It produces seeds with 45 to 50% oil that can be used for biofuels production. Castor bean as low ILUC feedstock has attact a growing interest from several Greek companies producing biodisel.

In this case study will be presented the one that was carried out in Thessaly (Velestino) in 2021. This 1 ha field was sown in a no-till farm using a no-tillage sowing maching. In Figure 5 presented the no tillage sowing as well as the rows of small plants and the dried weeds of the no-till field.

Soil samples were taken to characterize the field. The soil type was clay (47.1 clay, 32.7 silt and 20.1 sand), with 1.48% OM and pH 7.9. The field was abandoned the last years.

Hybrid Kaima C1012 was established at 24/4/2021 by direct drilling at rows 0.75m apart using 62,300 seeds per ha. Glyphosate was applied ten days prior sowing at a rate of 5 l per ha to control natural vegetation. Weed control was accomplished with one mechanical operation with a row crop cultivator in June. 13 kg N ha^{-1} and 46 kg P ha^{-1} were applied as basal fertilization prior sowing. Another 58.5 kg N ha^{-1} were added gradually with fertigation during the growing period. Sprinkler irrigation was applied for the first two irrigation events and afterwards, a drip irrigation system with pipes every second row, was established.

Figure 5. View of the Greek castor bean case study in 2021 at several stages of growth.

After 24/8/21, the field was divided 4 smaller areas (Figure 6) in which three termination applications were applied (Figure 7) that were: a) GLY = Glyphosate spraying at a dose of 6 l ha^{-1} at 27/8/21, about twenty days prior harvesting, b) DEF = Spotlight© BASF (carfentrazone-ethyl) spraying at a dose of 6 l ha^{-}

[1] also at 27/8/21, c) DIQ = Diquat spraying at a dose of 5 l ha^{-1} at 4/9/21, about ten days prior harvesting and d) control treatment where no spraying applied; ripening followed the physiological process. This was done to compare which practice performs best in the mechanical harvest.

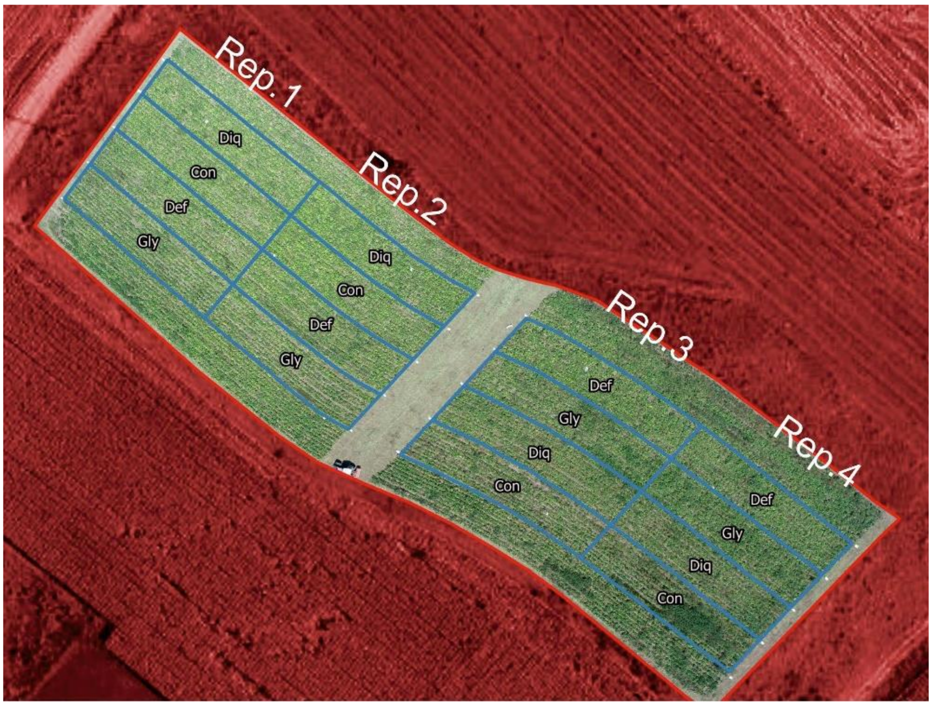


Figure 6. View of the Greek castor bean case study in 2021; three termination applications were applied and compared with control (no chemical application to terminate plant growth and plan the final mechanical harvest).

Figure 7. View of the Greek castor bean case study in 2021 at the spraying of the termination applications.

The combine harvester used was a New Holland mod. CX 780 equipped with a New Holland cereal header Type 17V 5.10 m wide (Figure 8). Initially, it was planned to do the harvesting by a combine used for sunflower but none was available at the harvesting time (both crops have similar harvesting dates). Moreover, due to the fact that castor bean is non-food seed, extra cleaning was necessary to the used harvesting machinery before visiting the next field especially when this a food or feed crop. According to the preliminary tests, the best setting for the cleaning shoe of the combine harvester was: 400 rpm for the threshing drum, 10 mm of clearance for the concave, while fan speed and sieves were set as reported above. This setting was kept constant throughout the harvesting in all treatments.

The mean seed yields were 1165 kg/ha (1064 kg/ha for CON, 1246 kg/ha for DEF, 1166 kg/ha for CON and 1182 kg/ha for GLY) with moisture content varied from 6 to 8%. With the used machinery large seeds losses have been measured. It should be pointed out that in Xanthi field that a sunflower header was used the seed yields were higher and the losses much lower. The dry residual biomass was varied from 400 to 1100 kg/ha. It was lower in the plots that defoliators were applied.

Figure 8. View of the Greek castor bean case study in 2021 at the harvesting.

It should be pointed out that in Greece biodiesel is mainly produced by rapeseed and sunflower and the biodiesel companies are currently looking for low ILUC feedstock from crops like castor bean growing on abandoned, unused and/or contaminated areas. Before the Ukraine-Russian war several studies had been carried out to get low ILUC feedstock by growing on abandoned lignite mining areas. In the area of the field trial there is a biodiesel plant using sunflower for biodiesel production.

3.3 CS1 in Italy

The Italian castor bean case study is located in Sardinia; Marrubiu (Figure 9). Sardinia is a representative area for the typical land degradation concerns affecting the Mediterranean Basin Region. Morphology, anthropogenic factors, as well as specific climatic events, such as recurrent drought and floods, increase the fragility and the sensitivity of the landscape to degradation. In Sardinia, Eni identified the target areas to develop a field case study to optimize agronomic practices aiming at optimizing the cultivation of drought-resistant crops in areas not suitable for food production (low ILUC feedstock), such as castor bean. This initiative contributed to create knowhow to support the development of the vertical integration model for agro-feedstock production of Eni in partner countries, therefore creating new opportunities for farmers to diversify their livelihood options.

A joint venture between Eni and Bonifiche Ferraresi (one of the largest farm in Italy, partly located in Sardinia as well) provided support to thedevelo pment of the Project in the agronomic characterization of castor bean. In fact, the case study was located within Bonifiche Ferraresi farm land.

The case study was established in Marrubiu (OR), in Sardinia, in 2021 on theEast Coast in Bonifiche Ferraresi farm– Site coordinates: 39°47’29.97”N8°35’40.47”E elev 0 m alt 422 m (Figure 1). The demo field selected for castorbean cultivation (1 ha) was considered as marginal, and it was uncultivated. The maximum temperature in selected area (May- September 2021) was 38 °C, with no precipitation recorded over the same reference period.

The case study is located in Italy, in Sardinia. Land degradation in Italy is mostly detected in the southern-central regions, mostly associated to climate characteristics, vegetation land cover and human activity pressure.

Figure 9. View of castor bean case study in Sardinia in 2021.

For the soil preparation a reduced tillage was applied (minimum tillage and rotary harrow). Two sowing techniques were applied: a) transplanting and b0 direct sowing at the depth of 3 cm, comparing different plant density. Both sowing practices were applied on 26th of Many 2021 and the emergence in the plots of the direct sowing was recorded 12 days later. In the plots that the transplanting was tested the plant population was 2000 plants/ha (0.2 pl/m2; 2.5x2 m). In terms of direct sowing four plant densities had been compared: 2000 pl/ha (0.2 pl/m2), 3333 pl/ha (0.3 pl/m2), 6666 pl/ha (0.7 pl/m2) and 16666 pl/ha (1.7 pl/ha).

In all trials one local improved genotype (semi-woody large shrub provided by University of Catania) was used. A weeding was performed chemically as pre-emergency with herbicide (active principle: pendimethalin and clomazone) and manually in postemergency.

A basic fertilization was provided, distributing a dose of 120 kg/ha of diammonium phosphate (18:46). Irrigation was needed to ensure the good status of the crop, through sprinkler irrigation. The total water amount was about 300 mm (from sowing to harvesting). The irrigation system design allowed to distribute low and regular volumes of water, guarantying the coverage of the plot, ensuring a high uniformity during the distribution. During flowering the presence of stink bugs (Halyomorpha halys) was detected. As a chemical control, a selective insecticide was applied.

The harvest was performed on 01 September 2021. The transplanted castor plants (2.5 m x 2 m) produced the greatest number of seeds. In general, the crop performances were limited, due to no optimal seasonal trend and high temperatures, especially during theflowering (up to 35-38°C, registered during the cultivation period). This caused the abortion of most of the flowers and consequently of the seeds number. The productivity of castor bean under the tested parameters is presented in Table 2. It is obvious that when the plant density was increasing the producting was also increasing.

Table 2. Castor bean yields (kg/ha)

	2.5x2.0 (transplanting)	2.5x2.0 (sowing)	2.5x1.5 (sowing)	1.5x1.0 (sowing)	1.0x1.06 (sowing)
Kg seeds/ha	106	66	69	146	268

The knowledge of 2021 castor bean field trial help ENI to design additional demos in spring 2022 (Figure 10). Thus, two castor bean varieties (Mia & Tamar) have been tested with direct sowing and AGF 6 after transplanting. In 2022 the distance between the rows and within the rows had been descreased (was tested 75 x 30 & 75 x 40) and thus the plant denisty was quite high. The sowing and/or transplating was done on 20th of May 2022.

Figure 10. View of AGF 6 (irrigated) on 23rd of June 2022.

The pilot study contributes to create know-how on castor bean cultivation on degraded land and to support Eni vertical integration model for agro-feedstock production.

The model implemented by Eni has a great impact on the Sustainable Development Goals (SDGs), promoting sustainable practices for agro-feedstock production, and land use. Moreover, it contributes to territorial regeneration of marginal areas.

The case study refers mainly to European legislation on biofuels. In particular to the REDII renewable energy policy. The Project focuses on the production of "Low ILUC-risk biofuels" as defined in the Recast Renewable Energy Directive.

They are fuels produced in a way that mitigate Indirect Land Use Change (ILUC) emissions, either because they are the result of productivity increase (agricultural rotations and intercropping) or because they come from crops grown on severely degraded land. The case study will eventually contribute to generate knowledge for the development of carbon negative initiatives in Europe, such as Carbon Farming.

4 CS2: Perennial lignocellulosic crops for advanced biofuels

4.1 CS2 in United Kingdom

The 1st CS2 study was located in Taunton in the United Kingdom. It was own in Miscanthus Nursery Limited, Lower Marsh Farm. Miscanthus Nursery Limited as a separate legal entity is the First Gathering Point for the Lower Marsh Farm. The Miscanthus Nursery Limited currently cooperates with 33 farms. Approximately 25 of them supply material to this First Gathering Point which is mainly coordinating these deliveries directly from the farms (without further storage) to the final buyer.

The Lower Marsh Farm covers a total area of 120 ha of farmland of which 95 ha are cultivated with miscanthus (Figure 11) and 25 ha is grassland. 10 ha of the grassland is leased to a company which installed and runs a solar panel park. No annual crops are cultivated at the farm anymore since 2013 and Miscanthus Giganteus is the exclusively cultivated crop at the Lower Marsh Farm and thus the soil quality

had been improved. Two types of fields involved: i) beaches (planted in 2006) and tanfield (planted in 2008, 2020, 2022).

Figure 11. Miscanthus Case study in UK.

Miscanthus Giganteus is a non-invasive, perennial second-generation bio-energy crop that grows up to 3 meters tall. It is established from a rhizome and harvested annually in spring to produce sustainable biodegradable biomass for renewable fuels, animal bedding and composites. The harvesting is mainly done with common corn harvesting machinery. The harvested material is pressed and supplied in big bales to the clients. The relevant interfaces at the farm comprise the harvest on the individual farm, the transport, and the distribution to the final buyer. The office of the Miscanthus Nursery Ltd. is responsible for marketing and sales coordination as well as the management of the harvested material. They have about 25 suppliers and the material is directly transported to the buyers, so the company does not need a storage for the harvested material.

Miscanthus Giganteus is the only officially registered variety of Miscanthus in the UK, this is the reason why comparisons between different varieties were not feasible, also comparisons between former annual crops and subsequent perennial crops (miscanthus production) were not possible because of missing data.

Two fields' "Beaches" (4.7 ha) and "Tainfield" (4.82 ha) were chosen to evaluate if any potential additionalities do occur. The plot "Beaches" was planted in 2006 and the plot "Tainfield" in 2008, 2020 and 2022. The only possibilities the farm management suggested were a comparison of yields or potentially a comparison of soil carbon content. In each site the harvesting takes place every spring using direct transport of the material to buyer after the harvest. The harvested material used for renewable fuels and composites.

These activities had been supported by the following policies: RTFO (UK), Renewable Energy Directive, RePowerEUes.

4.2 CS2 Greece

A field trial (case study) of switchgrass (a perennial grass with lifetime 10-20 years depending the site of cultivation) with size 0.5 ha was established in 1998 in central Greece (Aliartos). The site was a marginal abandoned agricultural area that had been left fallow for more than 2 decades (Figure 12).

The soil was prepared for sowing (harrowing, and ploughing). A fine seedbed was necessary due to small size of switchgrass seed. A chemical weed control was done before sowing. The distances between the rows were 15 cm. A basic fertilization (11-15-15) was applied before sowing and it was repeated every 5 years before regrowth. On annual basis a top nitrogen fertilization of 60 kg N/ha every spring (30-40 days from regrowth). No insects/diseases detected. A piping system was used for irrigation (in order detailed data to be collected).

Figure 12. Switchgrass case study in Greece.

Each year the regrowth started in mid-March and by end of July the flowering is initiated. The crop, depending on the site of cultivation and the specific climatic conditions of each year, can be harvested by early December to late February. The harvesting material contains 30-40% leaves and the moisture content could be varied from 15-30%.

The highest yields were recorded from the 2nd till the 4th growing period. A total number of 10 switchgrass varieties (lowland and upland ones) had been compared as presented in Figure 11. As a mean of 22 years dry yields of 11 t/ha can be obtained (Figure 13). The lowland varieties (like Alamo and Kanlow) were more productive compared to upload ones (like CIR).

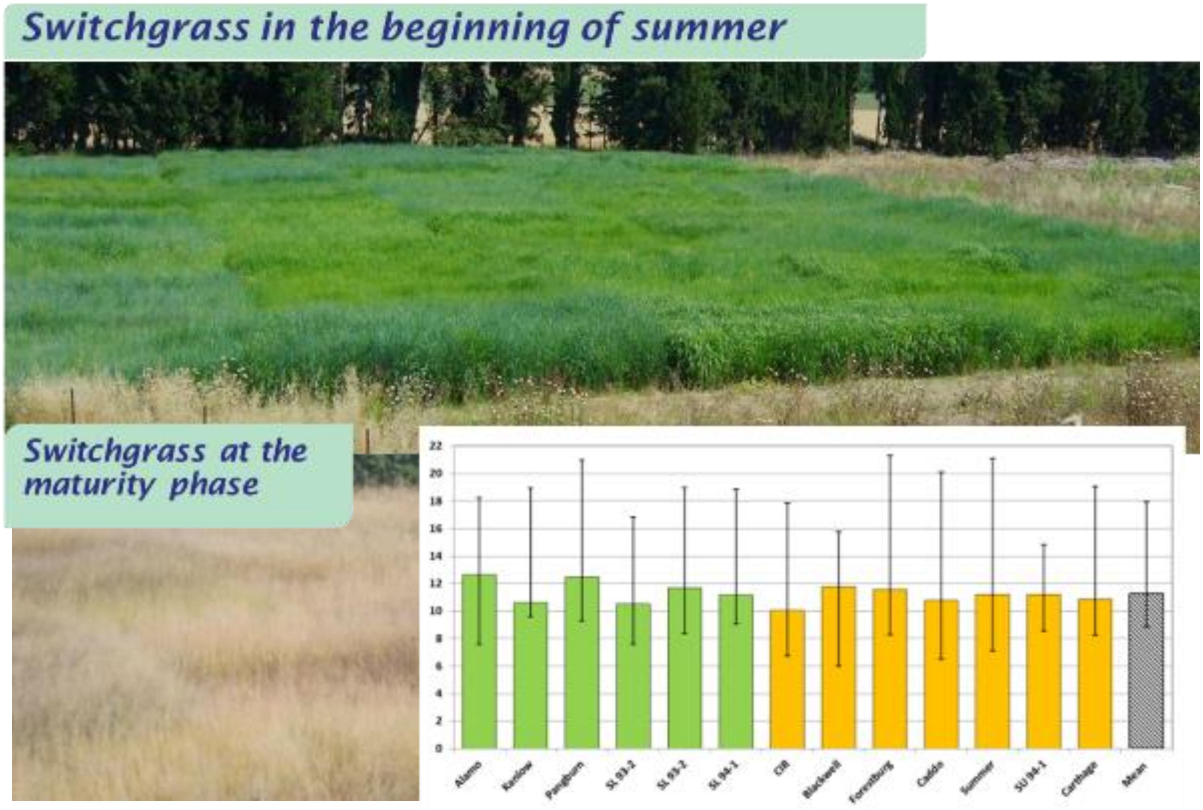


Figure 13. Switchgrass case study in Greece; view at rapid growing period, at the final harvest and mean dry matter yields (mean of 22 years).

4.3 CS2 Italy

A 3 ha miscanthus field was established in Italy (Lombardy). It was used the hybrid Miscanthus X Giganteus for the field establishment. The case study was established by Planeta Renewables s.r.l. The site coordinates were: 45°18'49.1"N 8°43'38.8"E; 45°18'03.5"N 8°46'35.1"E.

In terms of soil preparation ploughing and harrowing was done. Before planting a chemical weed, control was applied to remove weeds and invasive plants. Only after planting, based on the weed's situation, it could be necessary a mechanical control or chemical (ex. Stomp Aqua).

In terms of fertilization, it was applied manure or digestate. Irrigation was needed only after the planting based on soil type and weather. It was used to irrigate by sliding irrigation four time once every 10/15 days from planting and once a week during July. Once miscanthus was established no more necessary to irrigate (except for extreme hot weather situations).

Two harvest options were available: a) by using a traditional maize harvester and a dumper to produce miscanthus chips and/or b) to produce miscanthus bales (round bales or high-density bales) with a baler used for straw.

Miscanthus productivity varied from 20 to 25 t/ha with 22% moisture content. It was harvested the total biomass produced and thus no residual biomass was available. Miscanthus biomass could be stored as chips or high-density bales. Handling could be conducted using telescopic forklifts normally used into straw handling or silage management. The case study hasn't been yet certified as low ILUC feedstock. The land used for miscanthus production was not previously used for food production as is not considered suitable by the farmer due to soil characteristics. Thus, it is not compete with food production to promote lignocellulosic crop to farmers as we proposed to plant it into marginal land on their total available field. Normally, each medium farm in Italy has 10-20% of lands not used for food production (ex. Unused, SRC or just grasslands).

The policies that affected this case study are: European and Italian CAP for feedstock production, RED II for land use, local POR-FESR for conversion and REDII, Decreto FER2 for end use.

5 Case Study 3: Brassica carinata for HVO

5.1 CS3 in Uruguay

ENI since 2015 is growing Brassica carinata covering a total area that exceeding 50 000 ha. The productivity of cultivation area is increased by introducing brassicas to the local crop rotation as a productive winter crop. The exact crop rotation varies between fields.

Typically, the main summer crop cultivated before and after is soy and the winter period is not taken to optimal productive useThe pilot audit was conducted at the Nalmer S.A. farm in Uruguay (Figure 15). The farmer is a feedstock supplier for UPM being one of the project partners of BIKE. Case study performed in Uruguay. No tillage was used. Sowing in May (mid-autumn) with a density of 80 pl/m2 using direct seeding machines (without disturbance to the soil). Genotype used in Uruguay case study: Avanza641.

Chemical control of weeds in preemergence of the crop, as well in post emergence. The basic fertilization includes phosphorous and potassium in average rates of 40-50 kg P2O5 and K2O. The crop is fertilized with 90 Units of Nitrogen in average, splitting the dosage in two moments, 50% 30 days after emergence (dae) and 50% 70 dae. No irrigation was needed. Harvest date in average is late November. In 9/10 fields direct harvest is used with or without desiccant; in 1/10 swathing is used. The machinery is the same the farmers have for other crops (wheat, barley, soy). Adding carinata as new crop to the rotation mitigates disease and insect risks.

Carinata is grown as winter crop after soybean (Uruguay)

Figure 14. View of UPM case study in Uruguay

Typically carinata seed (grain) yield in Uruguay is approximately 1500 kg/ha, while even 2700 kg/ha has been achieved on commercial fields. Yields on test fields are typically significantly higher than on commercial fields. Yield of residual biomass left to the field is approximately 6000 to 10000 kg/ha. Yields from harvested grain are approximately 42% oil for biofuel production and 58% meal for animal feed. High erusic acid content in oil. Non-edible technical oil, suitable also for chemical industry uses. Fatty acid chain lengths optimized especially for aviation fuel purposes. Meal has high protein content, well suitable for animal feed use.

Life cycle to HVO consists of the following steps: harvesting, cleaning and drying, crushing, pre-treatment, hydrotreatment, fractionation. Currently, the oil has been commercially processed to conventional biodiesel with the following pathway: harvesting, cleaning and drying, crushing, neutralization and pre-treatment of oil, esterification.

The seed mean of Brassica carinata can be used as animal feed. Residual biomass of crop is left to the fields (only grain is harvested) in order to promote soil health and biodiversity.Residual biomass from grain crushing (husks) used for bioenergy.

The process was certified. Carinata production is certified under RSB EU RED and the rest of the supply chain is also certified under EU Commission approved voluntary schemes (final fuel is EU RED compliant). The policies that supported these cases studies were: Renewable Energy Directive, Fuel Quality Directive, local agricultural policies, EU import policies.

5.2 CS3 Italy

The case study had been developed by Azienda Agricola[1] C.A.P.O.G. in Italy (Sicily) (Figure14). It was part of the project entitled “ENERGIE RINNOVABILI DA COLTURE AGRICOLE”, with acronym ERICA, concerning a cooperation initiative for the innovation and technological development of the agro-energetic sector in Sicily. The activity on testing of *Brassica carinata* of the project had the objective of introducing two genotypes of *Brassica carinata* in the cultivation systems of Sicilian farms and disseminating the related knowledge about the cultivation techniques to be adopted, so that to provide farmers with indications on new species that can be introduced in rotation, and cover cropping, in particular with cereal crops, and create new opportunities to favor the modernization of the regional agricultural production system through the diversification of productions, and the use of biomass for energy purposes (residues crops, oilseeds, extraction cake, pellets, etc.). This action was also supported by analytical activities for the chemical and energy characterization of the grain produced, as well as by the economic evaluation of the costs to be incurred for cultivation. Field trials were conducted at the partner farms of the project indicated below:

- Soc. Coop. CAPOG, Marineo (PA);
- Vincenzo Catalan Company, Ciminna (PA);
- De Gregorio Gregorio Company, Monreale (PA);
- Genco Gian Vincenzo Company, Mussomeli (CL);
- Riggio Francesco Company, Ciminna (PA);
- Rizzo Benedetto Antonio Company, Assoro (EN);
- Virzì Fabrizio Company, Caltanissetta (CL).

Figure 15. Sites of the demo fields of Brassica carinata in Sicily.

The fields were operated for two consecutive years, in the agricultural years 2011-12 and 2012-13 extended individually by 2.5 hectares, for a total area invested equal to 17.5 hectares for each single year.

Figure 16. View of Brassica carinata demo case studies in Italy.

Two Brassica carinata trials with size 7 ha each was set up for two subsequent years (2020 and 2021). The field was established for two subsequent years. Two varieties had been compared; Defen and CT 180. A soil plowing up to 30 cm took place before sowing as well as two harrowing operations. Chemical week control was used. Two fertilization applications was applied; before and after the sowing. Irrigation was applied. The harvest was carried out between mid-June and early-July with a combine harvester. In the conversional plant the follwoing steps took place: a) mechanical extraction (screw press), b) oil decanting to eliminate impurities and c) transesterification with methyl alcohol and caustic soda. The squeezing capacity was 40 kg/h and the estimation capacity was 50 l/h.

Table 3. Oil and protein content (on fresh and dry basis).

	CT 180	Defen
Moisture content (%)	6.8	6.7
Oil content (%) on wet basis	39.6	41
Oil content (%) on dry basis	42.4	43.9
Protein (%) on wet basis	25.8	27.5
Protein (%) on dry basis	25.9	27.6
Seed yields (q/ha)	6.4	8.7

In the two-year period, the average unit yield recorded for the two varieties of Brassica carinata was equal to 7.6 q/ha, with average values of 8.7 q/ha for the Defen variety and 6.5q/ha for the CT 180 variety (Table 3).

In the first year, 7 of the 14 plots cultivated with the two varieties were fertilised with manure in the lowering phase, to evaluate the effect of the aforementioned cultivation practice on the incidence of the "foot ache" pathogens on the cereal crop in succession, while in the second year two of the 14 fields did not go into production due to problems that have compromised the seeding.

5.3 CS3 in Greece

In Greece several Brassica carinata fields had been established in central and northern Greece in the view of EU project entitled “FAIR CT 96 1946 – “Brassica carinata: The outset of a new crop for biomass and industrial non-food applications”. More specifically in northern Greece (Komotini) large field trials (>1 ha) had been carried out for a period of three sunseqent years (Figure 13). The cultivation practices of Brassica carinata are quite similar with those of rapeseed. Due to the fact that carinata is sensitive to frost the winter sowing was avoid and the establishment took place at the end of winter. It was decided to grow carinata instead of rapeseed due to its high tolerance to heat and drought and saline conditions.

Figure 17. View of the field trials in Komotini; north Greece.

The sowing was done mechnically and 8 kg of seeds per ha was used. The distance between the rows were 30 cm and the soil depth was not exceed 2 cm. The seeds used was provided by KOIPESOL SEMILLAS S.A. The plantations had a mean height of 120 cm. The mechanical harvest took place from the end of June to the first days of July and the mean seed yields was 1.5 t/ha. The oil content of the seeds was 40-42%. Each year the remaining straw was collected into bales and storage trials had been contacted. During all trials, the disease problems that recorded were almost the same with the ones recorded in the nearby area in rapeseed seeds and thus similar pesticides when needed.

In the area of the trials the oilseeds (rapessed and sunflower) like carinata are being grown for biodiesel production and thus the farming community is quite interesting in growing carinata for biodiesel since it is a non-food crop.

Currently, in the view of a new project entitled CARINA, new large field trials (>5 ha) are going to be established in Greece using seeds that will be provided by NUSEED. In this project, camelina will be grown as cover crop throughout Europe as well as in northern Africa.

6 Case Study 4: Biogas Done Right model for liquid biofuels

6.1 CS4 in Italy

The farm Uliva Societa Agricola S.S. (Uliva) is a feedstock producer for a biogas plant belonging to the same legal entity and located at the same site. The legal entity is cooperating with other farmers under the “framework” of the Biogas Gone Right model. The idea of this network is to produce biogas in a way minimizing the input resources for substrate production and mainly focuses on waste and residue feedstocks as well as secondary crops that are used to produce biogas, without impacting the yield of the primary crop. Because the farm and the biogas plant belong to the same legal entity and are located at the same site, the scope of the certification process is farm, First Gathering Point, and processing unit.

The farm has a total area of 250 ha (Figure 17), whereas 96.47 ha are used to cultivate the low ILUC-risk crops. Before the start of the biogas plant, the 96.47 ha were abandoned land, thus the whole biomass harvested from this land area can be claimed as low ILUC risk. In fact, of the total 96.47 ha, 59.9 ha is sowed area, 3.43 ha are cultivated with olives and 33.13 ha are cultivated with Alpha Alpha, being the relevant low ILUC-risk crops. Further crops cultivated at the farm are corn, sorghum, and wheat.

Their main barn has 900 cows, and they collect sheep and cow milk from 90 smaller stables. Every year the farm transforms 3 million litres of sheep milk and 3 million litres of cow milk. Lastly, they also have the biggest plant-based sewage-treatment facility in south of Italy.

The soil type is a clay, low organic content soil which suffered from progressive desertification. A reduced tillage (tillage using Vervaet Hydro-trike to distribute with precision bio-digestate) was applied for both corn and grain. Corn was planted at 75,000 plant per hectare in April and is the primary crop and grain was planted at 200kg/ha in October as a secondary crop. The hybrids used were for corn P2088 (Pioneer), DKC6752 (Dekalb) and Ludwig (Allseeds) for grain. Chemical weed control was applied (Lumax – Syngenta on Corn; Biatlon on grain). In terms of fertilization 200m^3/ha of bio-digestate (composite of energy crops like corn, byproducts like olive paste and agricultural wastes like manure). Corn had to be irrigated during summer. No insects of diseases detected. The harvesting was done with New Holland Harvester in September for corn and in March for grain.

The area of the case study it had been abandoned due to low productivity of mixed hay cultivation. Over the last 9 years it has had progressively higher organic matter in the soil and as a result, higher productivity. The acheived yields were 50 ton/hectare for corn and , 30 ton/hectare for grain.

The land was abandoned in 2000 due to low production caused by low content of organic matter in soil, semi-desert, and arid conditions. Additionally, the soil has high clay contents which involve a high expenditure of energy for cultivation.

The farm was taken over by the “Fattoria della Piana” in 2008 and the distribution of digestate began at that time to increase the organic matter and structure for soil improvement. Purchase documents of the property are not available now, but the unused plots were seen during the on- site audit.

Data about additional biomass is available starting from 2018. The data show that yield is increasing year by year due to the use of the biogas digestate as fertilizer.

Figure 18. View of the case study in Italy by CIB

This case study was also audited by ISCC in Work package 1.

6.2 CS4 in Greece

An rotation system have been applied in central Greece (Viotia) which was Durum wheat – Sunn hemp – Corn (Figure 18). A traditional soil preparation was done. No weed control was applied. The trial-case study started in December 2020 durum wheat that harvesting in June 2021. Immediately after, sunn hemp was sown that harvesting in October 2021 and in April 2022 corn will be established that will be harvested in September 2022. The varieties/hybrids used for durum wheat and corn where then ones grown in the area of the case study. For sunn hemp the seeds were imported by Italy. Basic and top fertilization was applied for wheat and corn. No insects/diseases detected.

A drip irrigation system was established in June 2021 for sunn hemp and it was also used for corn. The harvesting for wheat had been harvested with the existing machinery and the same will be done for corn. Mean seed yields of wheat varied from 5.8 to 6.5 t/ha. The dry yields of sunn hemp varied from 16 to 18 t/ha.

Figure 19. View of the demo case in Greece (wheat-sunn hemp-corn)

7 Conclusions

D6.1 presented the case studies that have been included in BIKE grouped in four groups. One case study per group had been selected for audit and the audit results presented in WP1 (D1.3). The audit case studies were: a) castor bean in Kenya, b) miscanthus in UK, c) Brassica carinata in Uruguay and d) BDR model in Italy. Two non-food oilseeds have been included in the case studies namely castor bean and Brassica carinata; the first should be grown in Med region, while the second could be grown as winter and sping crop in Med region and as spring crop in central and north of Europe. *Brassica carinata* could use the existing machinery used for rapeseed cultivation, while the cultivation of castor bean neeeds further improvemet in terms of mechanical harvesting. During the 1st Open Lab of BIKE in Sardinia the mechanical harvetsing of castor bean was tested using an improved header developed by an Italian company. Although, the mechanical harvesting of castor bean has been improved the last years, furter improvement is needed in order the fully meachnization of the crop to be acheived. At the same time a number of short castor bean hybrids are being tested in Europe having improved yields (2-3 t/ha seed yields acheived in Greece). Lately, breeding activities are being carried out for *Brassica carinata* and improved varieties/henotypes are going to be tested in whole Europe in the view of CARINA project (HORIZON EUROPE). Miscanthus is a perennial grass will lifetime > 15 years with several demo fields throughout Europe (the area of cultivation is higher than 25.000 ha) and is fully mechanised. Breeding activities are being carried out to produce gentotypes established by seeds. So far, miscanthus is being established either by rhizomes and/or planlets. Improved rotation schemes are being developed in Europe, where food and non-food crops are grown in rotation and cover crops are included. These cropping systems have been designed to avoid: a) the replacement of food and feed crops, b) to boost biodiversity, c) to increase the biomass production per land unit, d) to follow the low carbon farming, e) to avoid monoculture, soil erosion. Some of the identified case studies consists in demonstration initiatives which are currently anymore in place (es: Brassica Carinata in Italy). For this reason, they could not be visited during BIKE open labs. All the case studies still in place will be further analysed in D6.2.