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

D2.2

FEASIBILITY STUDY ITALY

TECHNO-ECONOMIC FEASIBILITY

CTXI

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Fostering Sustainable Feedstock Production for Advanced Biofuels on underutilised land in Europe

Introduction

This techno-economic feasibility study intends to analyze the different options available for the development of a sustainable feedstock production in Sulcis region in Sardinia, based on *Arundo donax* L. to produce advanced biofuels as, for example, lignocellulosic ethanol.

It is based on the previous Agronomic Feasibility Study performed by CREA and Biochemtex in collaboration with FAO, published in June 2016, to determine the most promising biomass type for the region and the available underutilised land in a 70 km maximum radius from an hypothetical plant located in the brownfield site of Portovesme.

The result of such feasibility study concluded that *Arundo donax* L. seems a good candidate for large scale deployment, and that approximately 50.000 hectares of underutilised land could be found in a 70 km maximum radius from Portovesme, including 1000 ha of polluted land, already equipped with irrigation systems [1].

The two principal questions that the present techno-economic study will try to address are:

1) *how?*

- to sustainably supply biomass to the plant gate in terms of production, handling and logistics;

2) *at what cost?*

- local farmers and logistical companies should be adequately remunerated while at the same time constitute acceptable operating costs of a lignocellulosic bioethanol plant.

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For the purpose of this study, the supply chain process has been ideally divided in two major steps, which are in practice interrelated:

- Biomass production, from planting until harvesting

- Handling, conditioning and transporting biomass from the field to the biomass processing plant gate

A hypothetical scenario in which the biomass is transformed in lignocellulosic ethanol has been devised. Each step includes more unit processes that require input flows and produce output flows.

Biomass production

Agricultural operations

The first step in cultivation of bioenergy feedstocks consists of soil preparation, aiming at restoring the physical structure of the soil to guarantee the health of the crop.

For clay soil, especially in case of perennial crops, breaking the tillage pan in order to allow the capillary water movements could be necessary. The equipment vertically ridges the soil at 60-80 cm in depth.

Ploughing is the main operation, aiming at creating a suitable environment for crop growth and at increasing the water storage capacity of the soil. The common depth for ploughing is around 30 cm. After ploughing soil needs to be refined with an appropriate harrow. Finally, soil is levelled and ready for transplanting.

Weeding is required only in the first year (in order to allow a fast growth of the crop and the development of a good canopy).

If crop height allows the tractor to enter the fields, mechanical weeding can be done as well by means of an inter row hoe or a rotary cultivator.

The **transplanting** system depends on the propagation material used. For rhizomes transplanting equipment can be derived from machines used in potatoes cultivation. For micropropagated plants, transplanting is performed using horticulture practices comparable to what is normally done locally with artichokesCuttings can be easily laid down in alleys.

Fertilization is done with rotary fertilizer distributor. A ternary NPK fertilizer 8-20-24 can be applied in the first year at a maximum dose of 300 kg/ha, depending on the soil conditions.

There are different methods of **irrigation**: in the field trials performed by Biochemtex, drip irrigation has been used with success.

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The choice between the different solutions of **harvesting** also depends on the strategy of supply and logistics.

Herbaceous crops can be harvested with forage harvesters or with cutter- balers.

Martelli et al. [2] evaluated an innovative collection system for *Arundo donax* L. based on single-pass harvesting in which the biomass was cut-shredded-baled to reduce handling and storage costs in comparison with a single-pass for chipping the biomass and loading on a tractor trailer, similarly to what is done for silage corn. In addition, these researchers evaluated the costs of harvesting, handling, storage and delivery to the conversion plant [2].

The solution normally applied by Biochemtex in its experimental fields in Italy and in Sardinia consists of a single-pass for chipping the biomass and loading on a tractor trailer, similarly to what is done for silage corn.

Forage harvesters may be currently found in the region, as leguminous forages like alfa-alfa are normally harvested with these devices: before baling, mowing-conditioning, raking and windrowing are needed.

The harvesting system of chipping/loading with a forage harvester may be effectively used on fields for "on demand" continuous supply to the bioethanol plant. In addition, in spring and summer months, the cutting, windrowing and baling system can complement the supply chain provision of biomass.

There are two methods for **baling**: large square bales (tipical size is 50-100 cm x 80-120 cm, with an adjustable length of 70-240 cm or more) and round bales (generally 90-180 cm in diameter and 100-120 cm wide).

The first solution is recommended for working capacity and logistic (handling and storage), but the risk of rainfall water penetration and self-combustion is quite high if the moisture content at baling is not below 20-25%.

Round bales are less affected by water rainfall if good weather conditions exist on site and can be left in the field for further drying. Round bales are not exempt from fire risk if the baled material is too wet.

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Handling, transport, logistics

The supply chain strategy is a compromise between the demand of biomass of the bioethanol plant during the year, the agricultural practices, the yield and the biomass harvesting period, the storage methods and facilities, as well as the transport logistics.

An industrial plant has a fixed storage capacity that usually cannot allow to store the entire seasonal production, due to the high biomass volumes required for the production of lignocellulosic bioethanol. Thus, next to the direct delivering after harvesting, middle storages or field storage should be envisaged.

The supply strategy and logistic involves the following steps:

- Transport from the field to a bioethanol plant

  or field storage

  or to a middle storage yard

- Middle storage or field storage or storage at the plant

- Transportation from middle storage to a bioethanol plant

Table 1 gives some examples of the biomass density [3].

The material chipped during the harvesting (forage harvester) is loaded into agricultural trailers (dumpers, more versatile; load volume ranges between 10 and 50 m^3) or road tractors (load volume from 30 to 58 m^3; size depends on the available space for manueuvre in the field) that follow the machine in the field.

To avoid the diseconomy of scale the distance should not exceed 5 km for agricultural trailers (average speed on road 30 km/h) and 10-15 km for road tractors (average speed on road 50 km/h). Such vehicles can deliver the biomass to the bioethanol plant or to a middle storage yard.

SPECIE	DENSITY (T/M^3)	REFERENCE MOISTURE CONTENT (%)
Cardoon	0.15	15
Sorghum	0.60	85
Giant reed	0.16	45
Poplar	0.35	51

Table 1 Density of milled biomass of some dedicated crops.

Herbaceous biomass bales can be stored in open-air piles or in shed. The latter solution implies higher investment costs when existing sheds are already used for

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other purposes. However, it ensures better material drying and the protection of harvest from rainfalls and snow.

Open-air piles of bales are generally covered with plastic material. Using this method particular care has to be taken about the on-field drying before baling, expecially for material with a moisture content at harvesting higher than 30%.

However, the cost of investment has to be seriously considered. Due to the fact that the soil is not perfectly plain, putting bales on a plain surface (concrete or stabilizated soil) is suggested. This also aims at protecting biomass from soil moisture. In order to avoid infiltrations of water and/or breaking of the covering, the best solution is to build a pile. The amount of biomass stored in each pile has generally to be approved by the local fire department authority. Pile height depends on the available equipment. A height of around 6 m is generally adopted. Bales handling is done with tractor forks [4]. Table 1 gives some examples of bales storage.

Figure 1 Biomass bales storage in open air

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	PLASTIC COVERED PILE NUMBER OF BALES	SHELD NUMBER OF BALES
ROUND BALES		
Round bales on the width	6	14
Round bales on the length	15	14
Round bales on the height	5	6
Total of round bales	300	1.176
LARGE SQUARE BALES		
Straw large square bales on the width	5	8
Straw large square bales on the length	28	16
Straw large square bales on the height	8	9
Total of large square bales	924	1.152

Table 2 Examples of bales storage on a surface of 400 m^2 [3].

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If the distance is greater than 10-15 km from the middle storage yard to the bioethanol plant, transportation can be done by vehicle with a higher load capacity, such as road tractor (plus trailer) or semitrailers. The transportation volumes range between 80 and 115 m^3 , while the recommended length for load is from 7 to 14 m. This helps optimizing longer delivery distances and decreases the cost of transport.

For the evaluation of the logistical supply chain costs of this report, the area was restrained to a realistic 40 km radius from the plant.

From farm to fuel

Lignocellulosic Bioethanol production

For the purpose of this techno-economic feasibility study, a scenario including a bioethanol plant in Portovesme has been hypothezised, with the following assumptions:

- Technology: Lignocellulosic bioethanol technology for fuel production
- Plant Capacity: 40.000 tons/year
- Mean biomass productivity: 25 dry tons/hectare
- Area needed for biomass production: 8.000 hectares
- Collection radius from the plant: 40 km. Since 70 km radius allows for a theoretical very large area available (50.000 ha), it seems realistic that in practice the collection radius could be reduced.
- Harvesting method: single-pass with loading on a tractor trailer

A flow diagram of a lignocellulosic ethanol enzymatic process is provided below for reference:

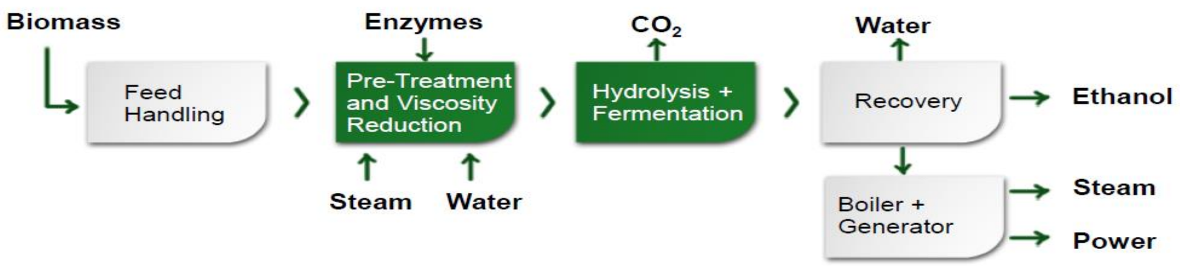

Figure 2 - Process flow diagram for lignocellulosic ethanol production

Based on its previous experience with similar supply chains, Biochemtex has developed a cost model per dry ton of biomass.

The model follows the 2nd to 10th year production of *Arundo donax* L., including amortization of installation (year 1) and eradication (year 10) costs.

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The model has been adapted for the Sulcis region, considering the actual costs derived from the agronomic field trials experience.

Results are summarized in

Table 3

This model shows a theoretical cost **71 €/dry ton** of biomass for biomass delivered to the plant gate and collected in a radius of 40 km.

Table 3 - Biomass Cost Delivered at Plant Gate.

ITEM	€/TON
LANDOWNER FEE	24
IRRIGATION FEE	8.4
FERTILIZATION COSTS	4
ANNUAL OPERATIONS	3.2
HARVESTING (SINGLE PASS WITH 2 TRACTORS)	13.3
PRO-ANNO INSTALLATION + ERADICATION COSTS	0.6
PRO-ANNO DRIP IRRIGATION INVESTMENTS	5.3
CAPITAL REMUNERATION (2.5%)	0.1
SUPPLY CHAIN MANAGEMENT	2
TECHNICAL FIELD COST	61
TRANSPORT (40 KM)	10
FINAL COST AT PLANT GATE	**71**

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Discussion

Table

Table 3 provides an overview for determining the costs of delivering biomass to the plant gate.

First of all, it should be noted that it does not allow for dynamic modelling: however it still can be taken as a useful tool for some considerations.

In addition, although the agronomic feasibility study goes into an acceptable degree of detail, the technical feasibility study is based on hypothesis of investment decisions on the production plant that are quite realistic, but cannot presently provide the necessary details.

For example, since Portovesme area presents brown fields, the re-use of existing areas for biomass storage could demonstrate to be useful and economically attractive. In this sense, the hypothesis of having a large, low capex, in-house capacity for multiple months of biomass storage could be a key for different priorities in the supply chain management and design (e.g. the mix between baled and chipped material, the need for intermediate or in-field storages).

Concerning **propagation** material, the economics of rhizomes and micropropagation are far less attractive than cuttings: if the results of the agronomic field trials are confirmed, and there are no significant differences in yield, then the cutting method could be applied successfully on the majority of the fields. However, the incidence of the propagation method applied on the productive life of the cultivation should be assessed.

A specific note should be made on the drip **irrigation** system, that involves higher investment costs (9% of the technical cost) if compared to other solutions, but seems capable of bringing higher savings in terms of cost and water in the case of a perennial plant.

The major impact of **transport** costs should be noted: in assumption of a 40 km radius from the plant, it represents almost 15% of the final cost.

However, the table accounts for a hypothetical situation in which all the fields are at 40 km from the plant, or in which it was not possible to contractualize all fields at, for example, 20 or 30 km from the plant.

In practice, there is a distribution effect towards which the model is not sensitive, in which the fields would realistically be more or less evenly distributed at various distances within the 40 km radius.

In fact, contractualization with landowners of nearer fields (ex. 20 km) could also result in a proportionally higher landowner fee: in any case the net remuneration for landowners (600 €/ha based on a realistic 25 tons/ha yearly production, representing

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33% of the final cost) seems higher than typical earnings deriving from competing production choices, and could probably be still acceptable for local farmers at lower levels.

The total final cost at plant gate here hypothesized could provide an acceptable business case for the plant owner, even if detailed sensitivity analysis would have to be performed taking into account external parameters and factors (e.g. legislation, tecnological optimizations, transport from Sardinia, biofuels market, fossil fuel price, other externalities etc.).

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