Triggering the creation of biomass logistic centres by the agro-industry

SUCELLOG: IEE/13/638/SI2.675535

D4.3a
Summary of the current situation of Tschiggerl Agrar GmbH and feasibility study

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About SUCELLOG project

The SUCELLOG project - Triggering the creation of biomass logistic centres by the agro-industry - aims to widespread the participation of the agrarian sector in the sustainable supply of solid biofuels in Europe. SUCELLOG action focuses in an almost unexploited logistic concept: the implementation of agro-industry logistic centres in the agro-industry as a complement to their usual activity evidencing the large synergy existing between the agro-economy and the bio-economy. Further information about the project and the partners involved are available under www.sucellog.eu.

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About this document

This report corresponds to D4.3a of the SUCELLOG project - Summary of the current situation of Tschiggerl Agrar GmbH and feasibility study. It has been prepared by:

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1. Introduction

This report includes a description of the current situation of the agro-industrial company Tschiggerl Agrar GmbH and an assessment of the techno-economic feasibility to become a logistic centre in addition to its usual activities. As part of other tasks (Task 4.2, 4.3, 4.4, 4.5) in the project, data has been gathered by the partner Lk-Stmk through interviews with the company owner and other stakeholders. This data constitute the basis for this report. The aim of the feasibility study is to investigate whether the use of agricultural biomass residues in the region for bioenergy production in Tschiggerl Agrar GmbH - acting as a logistic centre - would be technically and economically feasible and most importantly sustainable.

2. Company description

Tschiggerl Agrar GmbH is one of the most important companies in cereal harvest, treatment and trading in Styria, Austria. Mr. Harald Tschiggerl, the owner and manager, established the company in 2012. The company is located in Styria in Austria, 8492 Halbenrain 229 (Figure 1).

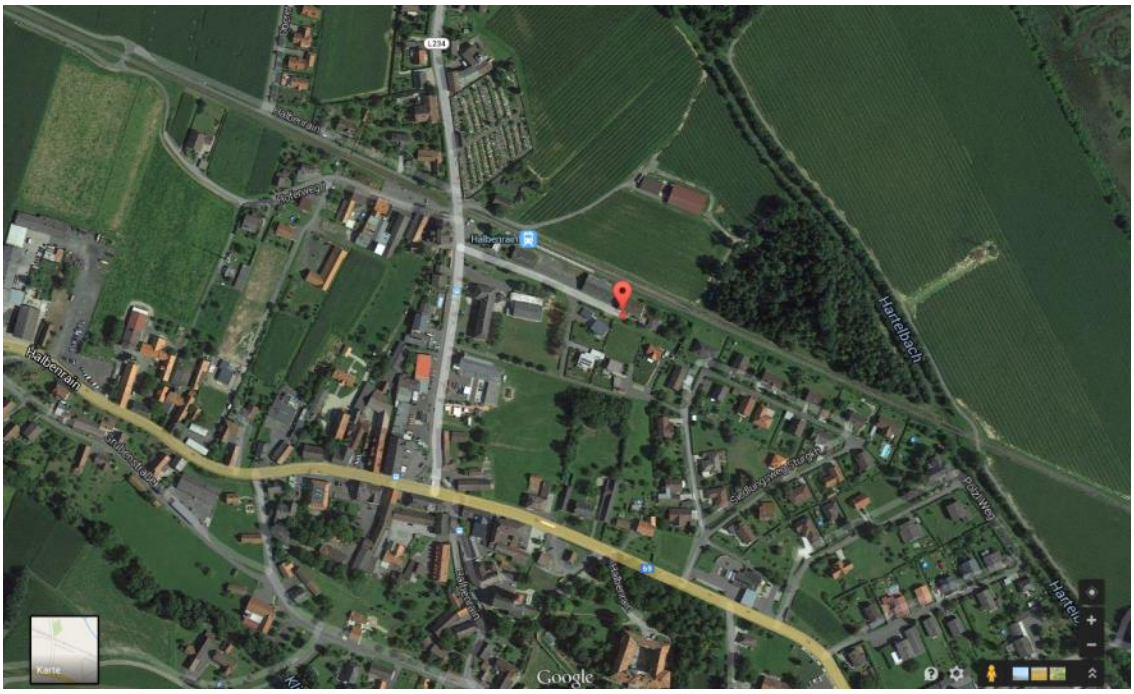

Figure 1: Location of Tschiggerl Agrar GmbH (Source: Google maps).

The current main activities of the company are the following:

a. Corn harvest, treatment and trading:
   - Corn drying to other farmers
   - Buying corn from other farmers and then selling it in the market
   - Harvesting the corn of other farmers acting as a logistic operator

   - ➢ Harvesting, drying and commercialising the corn of his own fields (150 ha/yr)

b. Logistic operator of straw:
   - ➢ Harvesting and baling straw and hay for the farmers (~ 600 ha/yr)

c. Pelletising for animal feeding and bedding:
   - ➢ Corn cob harvesting, drying and pelletising
   - ➢ Straw harvesting and pelletising

With respect to the last activity, Mr. Tschiggerl is a member of the association “Heu and Pellets”, which has their pelletising facilities in Tschiggerl Agrar GmbH site.

3. Development of a new business line as a agro-industry logistic centre

Mr. Tschiggerl is interested in starting a new business as biomass logistic centre producing and selling:

- 750 t/yr of cobs grits
- 1,500 t/yr of loose cobs (750 t/yr for own consumption of the agro-industry)
- 830 t/yr of pellets of cobs + hay
- 2,120 t/yr of pellets of cereal (wheat and barley) straw + hay

Corn cobs can produce different types of solid biomass products in different formats and sizes as it can be observed in Figure 2.

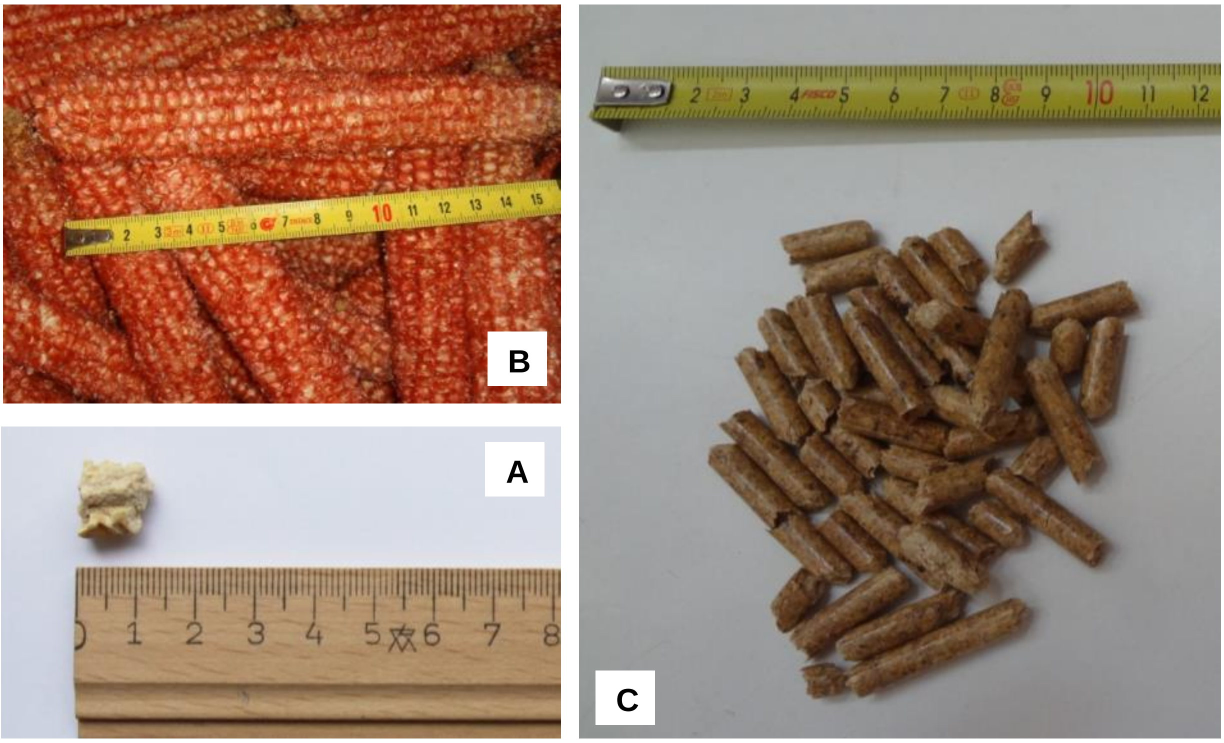

Figure 2: Different product formats and sizes (A: cobs grits; B: loose cobs; C: pellets).

For the new business line as logistic centre, Mr. Tschiggerl will use his current facilities during the idle periods, with no investment associated. Most concretely the following will be utilised:

- The drying facility that is currently used for the cobs used in animal bedding
- The pelletising facility from the association “Heu and Pellets”

4. Biomass resources availability

In task 4.2 of the SUCELLOG project, a biomass procurement and competitiveness assessment has been made for an area of 30 km around the company location. Figure 3 shows the map where the type of resources available can be observed.

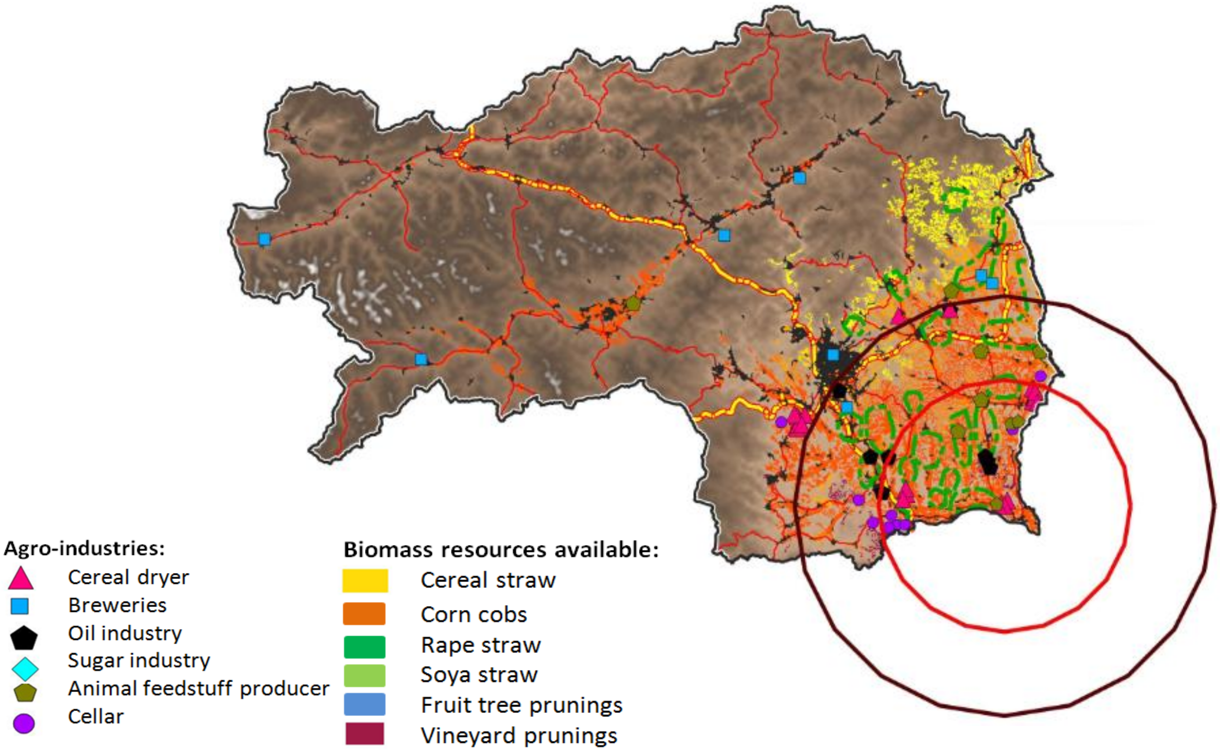

Figure 3: Type of resources available in a 30 km and 50 km radio.

The assessment showed that a considerable amount of agricultural residues are available for the production of solid biomass (no market competition) which can then be used for bioenergy production (Table 1). The moisture content (weight percentage in wet base), months of production and purchasing price without transport are also shown in this table.

Table 1: Data on the available agricultural residues in a 30 km distance.

Type of residue	Quantity available t/yr	Moisture content w-%, ar	Months of harvest	Purchasing price (€/t, VAT included)
Wheat straw	3,280	15	July-August	70 (baled)
Barley straw	1,910	15	July-August	90 (baled)
Hay	200	15	June-Sept	30 (baled)
Corn cobs	15,249	20-35	Sept-Oct	36-50 (loose)

Even though the high production of corn in the area, corn stalks cannot be considered as biomass resource for the logistic centre since in Austria it is highly recommended to leave it on the soil.

However, the corn cobs are rarely used, being normally left on the soil. It is important to mention that these residues are available on the long run since corn is the main crop of the area. Mr Tschiggerl is already using cobs for animal bedding, and has modified his own corn harvester to be able to separate the grain from the cob. The fact that Mr Tschiggerl provides services on 1,350 ha of land planted with corn and owning the corn cob harvester, makes the access to the corn cob (2,025 t) easier and advantageous for its utilization as a raw material for the logistic centre.

Hay and straw can be considered good residues for pellet production from the timing point of view as from June to September the company is in idle period and with no current market. Additionally, as said before Mr Tschiggerl work as a logistic operator of these 2 materials, owning a harvester, so he has easy access to them.

The hay available in the region is of poor quality and has no other uses. This lower quality is due to the fact that it was harvested too wet, or from bales, which were exposed to the rain and has mould problems.

5. Bioenergy market potential

In task 4.3 of the SUCELLOG project, an assessment of the bioenergy market has been conducted. In the area up 30 km away from the Tschiggerl farm, 60 % of the heating demand is covered by solid biomass (forest biomass: chips, firewood or pellets), 30 % by oil and 10 % by electricity. The aim is to substitute this 30 % oil with biomass but it is impossible with forest wood (they have to import a lot of wood chips from Romania, Hungary and Slovenia) so agrarian local biomass can be the key. The market is seasonal, 80% of the demand being from households and 20% from farms and industries.

The competing products will be therefore wood chips (current price of 72 €/t at 20 % moisture content, transport not included, VAT included) and wood pellets (current price of 240 €/t, transport not included, VAT included). Although the price for imported wood chips is a bit higher than the one from the national product, 80 €/t, for the feasibility study a price of 72 €/t will be considered.

The main consumers of the production of the new agro-industry logistic centre are expected to be farmers with own corn fields, who are currently using wood chips, for heating their houses and farms. Furthermore private households, who are currently using wood pellets or even fossil fuels, are expected to be new customers, as they get a cheaper and regional available fuel.

6. Technical assessment of the facility

The technical assessment will be conducted based on the logistical components which are present in the company, pointing out the needs for the new business line. These include: chipping, drying, pelletising, storage and heat production.

Figure 4 shows the flow diagram of the current agro-industry facility. The equipment that will be used for the new business line as biomass logistic centre are highlighted in this diagram and explained in detail in the further sub-sections. As it can be observed, production line 1 corresponding to the corn seeds drying will not be used for the biomass logistic centre due to the incompatibility of the equipment with the possible resources. On the contrary, the production lines related to the generation of animal fed and bedding products will be both used.

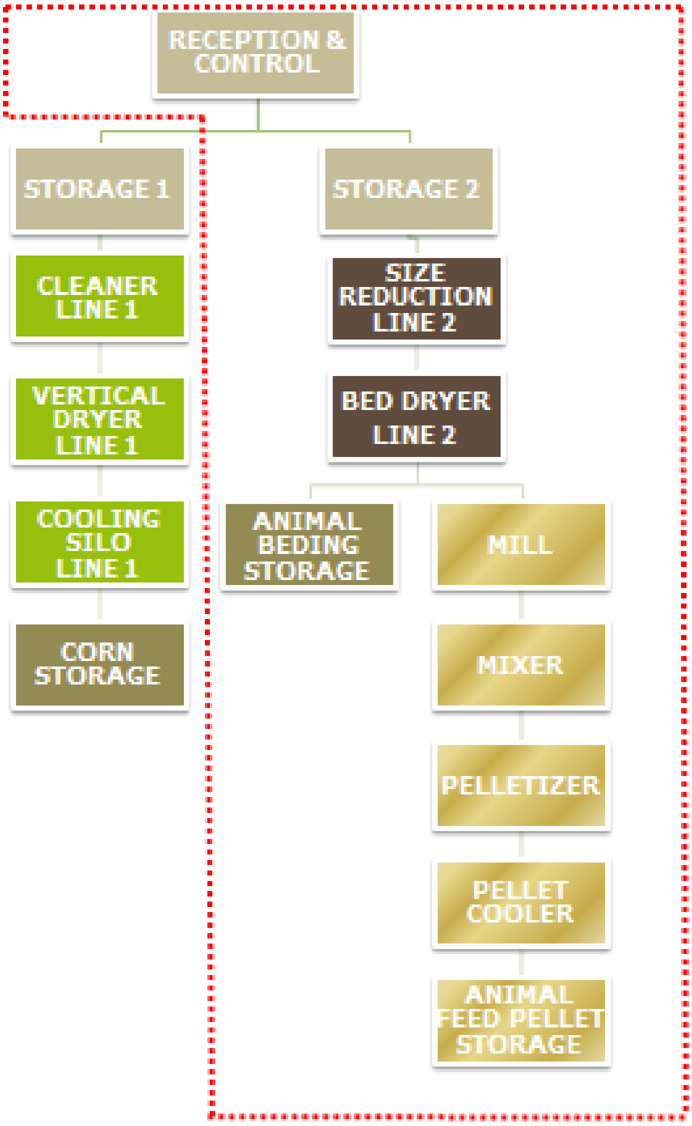

Figure 4: Flow diagram of the current agro-industry (equipment used for the biomass logistic centre surrounded in red).

7. Feasibility of the new business line as agro-industry logistic centre

The company is interested in starting a new business as a biomass logistic centre producing and selling the solid biomass products illustrated in Table 2.

Table 2: Solid biomass products to be studied

Type of solid biomass	Quantity available t/yr
Loose corn cobs	750
Corn cob grits	750
Mixed pellets of corn cobs and hay	830 (750 corn, 80 hay)
Mixed pellets of straw and hay	2,120 (2,000 straw, 120 hay)

As mentioned earlier Mr Tschiggerl harvests around 2,025 t of corn cobs per year for farmers. Of this amount, it can be considered that the cobs to produce 1,500 t of the products above can be purchased at a lower price directly from farmers (36 €/t) and the remaining amount required will be bought from the market (50 €/t). He will use 750 t/yr of the loose cobs for fulfilling his own heat demand. Therefore, for the feasibility study the remaining 750 t/yr will be considered. He can also easily buy 2,000 t of straw and 200 t of hay. This feasibility will study whether these are possible to be produced from a quality point of view.

In addition, in order to start this new business, it is important to check whether this process would be economically and technically feasible and sustainable. Different scenarios will be developed in order to choose the best case scenario.

7.1. Quality assessment of the new products

As a first approach for this study, it is necessary to clarify the quality parameters for solid biomass which the company aims to produce.

Nowadays, there is an international standard ISO 17225 which normalizes every category of solid biomass.

ISO 17225 – 1: General requirements
ISO 17225 – 2: Graded Wood Pellets
ISO 17225 – 3: Graded Wood Briquettes
ISO 17225 – 4: Graded Wood Chips
ISO 17225 – 5: Graded Firewood
ISO 17225 – 6: Graded non-woody Pellets
ISO 17225 – 7: Graded non-woody Briquettes

In addition, it is necessary to remember that boilers are made in order to use specific type of solid biofuels. For instance, a wood pellet boilers or wood pellet stoves can be constructed to burn only wood pellet graded ISO 17225 – 2 Class A1. If it is not the case and other type of fuel is used, the manufacturer may remove the warranty of his product.

In this study, we will focus on ISO 17225 – 6 for the quality of solid biomass to be studied but also on ISO 17225 – 4 and ISO 17225 – 2 in order to compare the quality with other current solid biomass in the market. Quality requirements are shown in Table 3.

Table 3: Quality parameters for these 3 types of biofuels.

ISO 17225	Wood Pellets ISO 17225-2 A1	Wood Pellets ISO 17225-2 A2	Wood Pellets ISO 17225-2 B	Wood Chips ISO 17225-4 A1	Wood Chips ISO 17225-4 A2	Wood Chips ISO 17225-4 B	AGROPELLETS ISO 17225-6 A	AGROPELLETS ISO 17225-6 B
Moisture (w-% ar)	≤ 10	≤ 10	≤ 10	≤ 10 ≤ 25	≤ 35	be mentionned	≤ 12	≤ 15
LHV (kWh/kg, ar)	≥ 4,6	≥ 4,6	≥ 4,6	be mentionned	be mentionned	be mentionned	≥ 4	≥ 4
Ash (w-% db)	≤ 0,7	≤ 1,2	≤ 2	≤ 1	≤ 1,5	≤ 3	≤ 6	≤ 10
N (w-% db)	≤ 0,3	≤ 0,5	≤ 1	-	-	1,00	≤ 1,5	≤ 2
S (w-% db)	≤ 0,03	≤ 0,05	≤ 0,05	-	-	0,10	≤ 0,2	≤ 0,3
Cl (w-% db)	≤ 0,02	≤ 0,02	≤ 0,03	-	-	0,05	≤ 0,1	≤ 0,3
As (mg/kg)	≤ 1	≤ 1	≤ 1	-	-	1,0	≤ 1	≤ 1
Cd (mg/kg)	≤ 0,5	≤ 0,5	≤ 0,5	-	-	2,0	≤ 0,5	≤ 0,5
Cr (mg/kg)	≤ 10	≤ 10	≤ 10	-	-	10,0	≤ 50	≤ 50
Cu (mg/kg)	≤ 10	≤ 10	≤ 10	-	-	10,0	≤ 20	≤ 20
Pb (mg/kg)	≤ 10	≤ 10	≤ 10	-	-	10,0	≤ 10	≤ 10
Hg (mg/kg)	≤ 0,1	≤ 0,1	≤ 0,1	-	-	0,1	≤ 0,1	≤ 0,1
Ni (mg/kg)	≤ 10	≤ 10	≤ 10	-	-	10,0	≤ 10	≤ 10
Zn (mg/kg)	≤ 100	≤ 100	≤ 100	-	-	100,0	≤ 100	≤ 100
shrinkage starting temp. (°C)	be mentionned	be mentionned	be mentionned	-	-	-	be mentionned	be mentionned
deformation temp. (°C)	be mentionned	be mentionned	be mentionned	-	-	-	be mentionned	be mentionned
hemisphere temp. (°C)	be mentionned	be mentionned	be mentionned	-	-	-	be mentionned	be mentionned
flow temp. (°C)	be mentionned	be mentionned	be mentionned	-	-	-	be mentionned	be mentionned

The comparison of the quality parameters of raw material with respect ISO 17225 – 6 standards is therefore essential. Indeed, possible limiting factors that prevent the use of the raw material to produce solid agro-fuels should be identified. However, it is necessary to precise that this comparison is just theoretical because the quality parameters of the raw material are from bibliography, since the exact raw material that Mr Tschiggerl aims to gather was not analysed at this stage of the project. In the following table, the difference in the quality values can be observed[1].

Table 4 shows the different quality parameters of cobs, straw, hay and standard guidelines for their comparison. The necessity with mixtures with wood to improve quality will be evaluated.

[1] Maisspindelverbrennung –Erfahrungen aus Testläufen. *Thomas Brunner*, Ingwald ObernbergerWerner Kanzian. brunner@bios-bioenergy.at*

Table 4: Quality of possible raw materials and guidelines from ISO 17 225 – 6 standard.

AUSTRIAN CASE - Tschiggerl Agrar	Corn Cobs			Straw		Hay	AGROPELLETS ISO 17225-6 A	AGROPELLETS ISO 17225-6 B
Data from bibliography	Bibliography	MixBiopells project		MixBiopells project		MixBiopells		
	Value	Mini.	Maxi.	Mini.	Maxi.	Value		
% weight								
Moisture (w-%, ar)	17,56	6,00	7,00	9,00	15,00	15,00	≤ 12	≤ 15
LHV (kWh/kg, db)	4,89	4,58	4,58	4,72	5,27	5,08	-	-
LHV (kWh/kg, ar) - 10 % moisture	4,33	4,05	4,05	4,18	4,68	4,50	≥ 4	≥ 4
Ash (w-% db)	2,77	1,00	2,00	4,40	7,00	5,50	≤ 6	≤ 10
N (w-% db)	0,39	0,40	0,90	0,30	0,80	1,60	≤ 1,5	≤ 2
S (w-% db)	0,03	0,03	0,03	0,06	0,12	0,04	≤ 0,2	≤ 0,3
Cl (w-% db)	0,14	0,02	0,02	0,03	0,05	0,09	≤ 0,1	≤ 0,3
As (mg/kg)	-	-	-	0,31	0,31	5,40	≤ 1	≤ 1
Cd (mg/kg)	-	-	-	0,17	0,17	0,90	≤ 0,5	≤ 0,5
Cr (mg/kg)	-	4,00	4,00	6,56	6,56	6,40	≤ 50	≤ 50
Cu (mg/kg)	-	4,00	4,00	2,10	2,10	6,20	≤ 20	≤ 20
Pb (mg/kg)	-	1,00	1,00	0,18	0,18	2,00	≤ 10	≤ 10
Hg (mg/kg)	-	-	-	0,02	0,02	0,20	≤ 0,1	≤ 0,1
Ni (mg/kg)	-	2,00	2,00	2,20	2,20	1,20	≤ 10	≤ 10
Zn (mg/kg)	-	11,00	11,00	1,40	1,40	6,00	≤ 100	≤ 100
Ash Softening Temperature (°C)	1030	1100	1100	800	900	820	be mentionned	be mentionned

According to this table, it can be said that:

- Agro-pellets graded ISO 17225 – 6 B can be produced with corn cobs or straw without mixing with wood. However, from RAGT's experience, it is necessary to precise that these quality values (especially low heating value) are quite risky.
- The best raw material is corn cobs with low Nitrogen, Sulphur and ash content. However, the Chlorine content is too high for quality ISO 17225 – 6 A. In order to avoid possible corrosion problems and to be included in category A, mixture with wood should be considered with a minimum amount of wood of 30 % of the total weight.
- Concerning straw, it could be possible to make graded agro-pellets ISO 17225 – 6 A, but the quality of combustion of straw is less effective compared to corn cobs with a lot of slagging ashes due to the low ash softening temperature. For this reason, a mixture with minimum 30 % wood is strictly required.
- Finally, the hay alone cannot be used for the production of agro-pellets graded ISO 17225 – 6. The only way to use this raw material will be to mix it with wood (15 % hay – 85 % wood).

All these quality issues will be considered in the economic assessment in order to suggest the possible scenarios to be studied.

7.2. Economic assessment

At a first stage, an assessment of the investment costs for the new business and the related costs will be made. In a second stage, the purchasing costs of the agricultural residues and the revenue from selling the produced solid biomass will be assessed in order to finally determine the profit.

It is important to mention that this feasibility takes into consideration only the activities of the new business line and all what is related to these activities. The current activities as agro-industry (stated in chapter 2) are not considered in the study except the savings in heat generation corresponding to the substitution of natural gas by loose corn cobs.

7.2.1. Investment costs

In the case of Tschiggerl Agrar GmbH, no investment will be done to become a logistic centre.

7.2.2. Purchasing costs

The agricultural residues needed for the new business will be purchased from farmers located in the vicinity of the company (maximum 30 km away).

Based on the quality assessment in section 7.1, the following production scenarios will be taken into consideration:

- Scenario MH: It represents the types of solid biomass that Mr Tschiggerl would like to produce. It is a highly risk scenario from the quality point of view and therefore not recommended by the SUCELLOG project. The types and quantities of solid biomass produced are shown in Table 5.

Table 5: Types and quantities of solid biomass produced according to Scenario MH.

Type of solid biomass	Quantity produced (t/yr)
Loose corn cobs	750
Corn cob grits	750
Mixed pellets of corn cobs (90 %) and hay (10 %)	830
Mixed pellets of straw (94 %) and hay (6 %)	2,120

- Scenario MWA: production of mixed wood and agro pellets of quality category A). The types and quantities of solid biomass produced are shown in Table 6.

Table 6: Types and quantities of solid biomass produced according to Scenario MWA.

Type of solid biomass	Quantity produced (t/yr)
Loose corn cobs	750
Corn cob grits	750
Mixed pellets of corn cobs (70 %) and wood (30 %)	830
Mixed pellets of straw (70 %) and wood (30 %)	2120

- Scenario noMP: no mixed pellets are produced. Chlorine content analysis is strictly required to prove that corn cob content is below the limits to be category A, otherwise it will be category B. The types and quantities of solid biomass produced are shown in Table 7.

Table 7: Types and quantities of solid biomass produced according to Scenario noMP

Type of solid biomass	Quantity produced (t/yr)
Loose corn cobs	750
Corn cob grits	750
Pellets of corn cobs (quality category A)	830
Pellets of straw (quality category B)	2120

- Scenario CC: only corn cobs in different types are produced. Chlorine content analysis is strictly required to prove that corn cob content is below the limits to be category A, otherwise it will be category B. In this case the selling price will be different. The types and quantities of corn cobs produced are shown in Table 8.

Table 8: Types and quantities of solid biomass produced according to Scenario CC.

Type of solid biomass	Quantity produced (t/yr)
Loose corn cobs	750
Corn cob grits	2200
Pellets of corn cobs (quality category A or B)	1500

In order to produce the desired respective amounts of solid biomass in each scenario, the quantities of raw material to be purchased should be higher as the moisture content of the raw material is higher than the produced product. Straw, hay, corn cobs and wood chips are purchased at a moisture content of 15 %, 15 %, 25 % and 20 % respectively. The pellets produced must have 10 % moisture content.

7.2.3. Pre-treatment costs

After purchasing the residues, they need to be pre-treated before being sold as solid biomass products:

- Straw and hay purchased at 15 % moisture content do not need to be dried, neither to be chipped before pelletising since they reach 12 % after natural drying.
- The corn cobs that are going to be sold loose (no grits) do not need to be dried, it is expected that natural drying will be enough to reach the 25 % moisture content of the final product.
- The corn cobs that are going to be sold like grits, need chipping and drying until they reach 20 % moisture content.

- The corn cobs that are going to be sold like mixed pellets, need chipping and drying until they reach 12 % moisture content. During the milling and pelletising process the moisture content of the material will decrease till the 10 % targeted for the final pellet.
- The wood chips to be bought to make the mixed pellets with cobs or with straw should also require a drying process to achieve 12 % moisture content before pelletising. No additional chipping is required before drying.

As mentioned before, Mr Tschiggerl is allowed to use the pelletising line for a price of 110 €/t of pellets produced. Since the costs of the process are strongly dependent on the capacity utilisation of the pelletiser, a new scenario was included. It is the same scenario as scenario MH, but with a doubled produced amount and a reduction of the pelletising costs to 100 €/t. This scenario will be referred to as MH2.

Table 9: Types and quantities of solid biomass produced according to Scenario MH2.

Type of solid biomass	Quantity produced (t/yr)
Loose corn cobs	1500
Corn cob grits	1500
Mixed pellets of corn cobs (90 %) and hay (10 %)	1660
Mixed pellets of straw (94 %) and hay (6 %)	4240

7.2.4. Personnel and other costs

A new person is planned to be hired for the regular agro-industry activities and for the new business line. The person will make 8 hours per shift, 5 days a week. The hourly cost is 29 €/h. The corresponding personnel cost associated to the new business line will be around 14,500 €/yr.

7.2.5. Production costs

Production cost, is the sum of:

- purchasing costs,
- pre-treatment costs,
- transport costs,
- personnel costs,

The production cost represents the minimum price at which the product should be sold in order to cover the expenses. It includes in this case the benefit coming from renting the warehouse for the pelletising machine which is equal to 1,500 €/month. Table 10 shows the production costs of the different solid biomass products in the different scenarios.

Table 10: Production costs of different solid biomass products in the different scenarios.

Type of Scenario	Quantity produced	Total costs			Fixed benefit (rent)	Production cost
		Personnel cost	Purchasing cost	Pretreatment costs		
	t	€/t	€/t	€/t	€/t	€/t
Scenario MH						
Corn cob grits	750	3.26	55.35	13.27	4.04	**67.83**
Loose corn cobs	750	3.26	51.89	0.00	4.04	**51.10**
Mixed cobs and hay pellets	830	3.26	58.31	121.89	4.04	**179.41**
Mixed straw and hay pellets	2,120	3.26	88.46	110.00	4.04	**197.68**
Scenario MH2						
Corn cob grits	1,500	3.26	59.10	12.35	2.02	**72.68**
Loose corn cobs	1,500	3.26	55.41	0.00	2.02	**56.64**
Mixed cobs and hay pellets	1,660	3.26	62.12	116.31	2.02	**179.67**
Mixed straw and hay pellets	4,240	3.26	88.46	100.00	2.02	**189.70**
Scenario MWA						
Corn cob grits	750	3.26	54.76	13.09	4.04	**67.07**
Loose corn cobs	750	3.26	51.34	0.00	4.04	**50.56**
Mixed straw & wood pellets	2,120	3.26	89.05	111.82	4.04	**200.09**
Mixed cobs & wood pellets	830	3.26	67.43	127.51	4.04	**194.15**
Scenario noMP						
Corn cob grits	750	3.26	55.60	13.16	4.04	**67.98**
Loose corn cobs	750	3.26	52.13	0.00	4.04	**51.34**
Straw pellets	2,120	3.26	92.50	110.00	4.04	**201.71**
Corn cobs pellets	830	3.26	62.55	122.83	4.04	**184.60**
Scenario CC						
Corn cob grits	2,200	3.26	59.10	12.19	4.04	**70.50**
Loose corn cobs	750	3.26	55.40	0.00	4.04	**54.62**
Corn cobs pellets	1,500	3.26	66.49	126.15	4.04	**191.85**

7.2.6. Products market price and profit

Since the products offered by the agro-industry logistic centre do not have a real market price yet, an estimation has been made taking into consideration the price of the products that can be competing in terms of quality (calorific value, bulk density and ash content).

As mentioned in section 5, the competing products are wood chips (72 €/t) and pellets (240 €/t). Corn cob grits can be compared with wood pellets, in terms of format, not requiring a specific screw feeding system for the boiler. Similarly, loose cobs could be used in chip boilers.

Taking into consideration the quality difference and their format similarities, the selling prices of the products generated by the agro-industry logistic centre have been estimated as follows:

- Loose corn cobs should be 20 % cheaper than wood chips (58 €/t).
- Corn cob grits should be 40 % cheaper than wood pellets (144 €/t).
- Pellets quality A should be 20 % cheaper than wood pellets (192 €/t).
- Pellets quality B price should be no higher than 110 €/t.

All prices include VAT (10 %) but not transport.

Because of the difference in the price of corn cobs pellets category A and B, 2 additional scenarios will be considered:

- Scenario A: the corn cob pellets produced are category A of higher quality.
- Scenario B: the corn cob pellets produced are category B of lower quality.

These 2 scenarios are considered only in the scenarios noPM and CC where corn cob pellets are produced.

Table 11 shows the difference between the production cost of each solid biomass proposed and its market price. It can be observed that in some cases, this difference is negative, meaning that the production of these fuels is not profitable and therefore these scenarios are not recommended by the SUCELLOG project. As a result, only the production of the following products is recommended:

- Corn cob grits.
- Loose corn cobs.
- Corn cobs pellets category A.

Table 11: The revenue from selling the different types of solid biomass in the different scenarios.

Type of Scenario	Quantity produced	Production cost	Selling price	Profit
	t	€/t	€/t	€/t
Scenario MH				
Corn cob grits	750	68	144	76
Loose corn cobs	750	51	58	6
Mixed cobs and hay pellets	830	179	110	-69
Mixed straw and hay pellets	2,120	198	110	-88
Scenario MH2				
Corn cob grits	1,500	73	144	71
Loose corn cobs	1,500	57	58	1
Mixed cobs and hay pellets	1,660	180	110	-70

Type of Scenario	Quantity produced	Production cost	Selling price	Profit
	t	€/t	€/t	€/t
Mixed straw and hay pellets	4,240	190	110	-80
Scenario MWA				
Corn cob grits	750	67	144	77
Loose corn cobs	750	51	58	7
Mixed straw & wood pellets	2,120	200	192	-8
Mixed cobs & wood pellets	830	194	192	-2
Scenario noMP-A				
Corn cob grits	750	68	144	76
Loose corn cobs	750	51	58	6
Straw pellets category B	2,120	202	110	-92
Corn cobs pellets category A	830	185	192	7
Scenario noMP-B				
Corn cob grits	750	68	144	76
Loose corn cobs	750	51	58	6
Straw pellets category B	2,120	202	110	-92
Corn cobs pellets category B	830	185	110	-75
Scenario CC-A				
Corn cob grits	2,200	71	144	73
Loose corn cobs	750	55	58	3
Corn cobs pellets category A	1,500	192	192	0.148
Scenario CC-B				
Corn cob grits	2,200	71	144	73
Loose corn cobs	750	55	58	3
Corn cobs pellets category B	1,500	192	110	-82

7.2.7. Total profit

As stated in the previous section, some scenarios are not feasible from the economic point of view. Total profit has been calculated (Table 12) only for the scenario CC-A recommended by the project, but even in this scenario, the production of corn cob pellets is not highly recommended if the market price is 192 €/t. In this scenario the savings from using corn cobs instead of natural gas for cereal dehydration is included.

Table 12: Total profit for scenario CC-A

Expenses (€)	**Investment costs**	**0**
	Purchasing costs	271,297
	Pretreatment costs	216,054
	Personnel and other costs	14,500
Income (€)	**Sales revenue**	648,000
	Savings from natural gas	201,750
Profit (€)		347,899

7.3. Risk assessment

The main risk for the new business line as biomass logistic centre would be the generation of products that do not satisfy consumers from the quality point of view.

Although a theoretical assessment of quality has been performed in section 7.1, a further analysis of quality differences with competing products is proposed in this section. All possible products have been evaluated, even if the economic assessment has proved that some of them are not feasible.

As it was mentioned in section 7.2.6, the price of the product depends on its quality. This means that not only the comparison in terms of €/t should be evaluated but in terms of price per kWh. Table 13 and Table 14 show their prices regarding their quality characteristics.

Table 13: Competing products main quality characteristics and prices.

	Quality characteristics			Prices	
	LHV (kWh/kg ar)	Bulk density (kg/m^3)	Ash content (w-% db)	€/t	€/kWh
Forest wood chips	3.9	250	≤ 3	72	0.018
Forest wood pellets	4.7	600	≤ 2	240	0.051

Table 14: Products quality characteristics and prices.

	Quality characteristics			Prices	
	LHV (kWh/kg ar)	Bulk density (kg/m^3)	Ash content (w-% db)	€/t	€/kWh
Loose corn cobs	3.50	178	2.77	58	0.017
Corn cobs grits	3.78	250	2.77	144	0.038
Mixed pellets of corn cobs (90 %) and hay (10 %) quality B	4.35	650	3.04	110	0.025
Mixed pellets of straw (94 %) and hay (6 %) quality B	4.44	650	5.54	110	0.025
Mixed pellets of corn cobs (70 %) and wood (30 %) quality A	4.43	650	2.15	192	0.043
Mixed pellets of straw (70 %) and wood (30 %) quality A	4.50	650	4.20	192	0.043
Pellets of corn cobs quality A	4.33	650	2.77	192	0.044
Pellets of corn cobs quality B	4.33	650	2.77	110	0.025
Pellets of straw quality B	4.43	650	5.70	110	0.025

From the comparison of prices, the conclusions about possible risks that the selling of these biomasses can face are the following:

- The different scenarios show us that loose corn cobs (with a kWh price of 0,017 €) could be a good competitor face to wood chips. However, it is important to remark that the boilers need specific ash removal system and specific heat exchanger to prevent some corrosion emissions (derived from high chlorine content) and slag formations. Finally, it is necessary that the conveyor system from fuel tank to the boiler is able to transport fuel with size more than 10 cm (typical length of corn cobs).

- Concerning corn cobs grits, they can be used with a classical screw conveyor which is present in a large range of boilers. Nevertheless, even if corn cobs grit have a very competitive kWh price compared to wood pellet, most of wood pellet boilers will not accept this biofuel because of the ash content (more maintenance required). The risk of losing the guarantee in force when using a non-woody pellet should also be taken into consideration.
- The agro-pellet products is suffering from an important pelletising cost (more than 100 €/t). That is the reason why it is difficult to have a competitive kWh price. However, it should be taken into consideration that the storage space needed with agro-pellets is several times lower compared to the other biofuels as it can be observed in Table 15.

Table 15: Products quantity required.

	Biofuel characteristics		Quantity needed for boiler 50 kW (90,000 kWh / yr)			
	LHV (kWh/kg ar)	Bulk density (kg/m^3)	t	m^3	load factor (%)	m^3 final needed
Wood chips	3.90	250	23	92	60	154
Loose corn cobs	3.50	178	26	144	60	241
Corn cobs grits	3.78	250	24	95	60	159
Mixed pellets of corn cobs (90 %) and hay (10 %) quality B	4.35	650	21	32	85	37
Mixed pellets of straw (94 %) and hay (6 %) quality B	4.44	650	20	31	85	37
Mixed pellets of corn cobs (70 %) and wood (30 %) quality A	4.43	650	20	31	85	37
Mixed pellets of straw (70 %) and wood (30 %) quality A	4.50	650	20	31	85	36
Pellets of corn cobs quality A	4.33	650	21	32	85	38
Pellets of corn cobs quality B	4.33	650	21	32	85	38
Pellets of straw quality B	4.43	650	20	31	85	37

7.4. Social assessment

The Social Impact Assessment includes the process of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative of planned interventions (policies, programmes, plans, projects) and any social change processes invoked by those interventions. Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment[2]. The social impacts are generally monitored through a set of indicators. In this study,

[2] http://www.iaia.org/publicdocuments/sections/sia/IAIA-SIA-International-Principles.pdf

the main social impacts and the indicators which will be assessed are mentioned in Table 16.

Table 16: Impacts and indicators assessed in the study

Social impacts	Indicators
a. Contribution to local economy	Employment
b. Working conditions	Employment benefits
c. Working rights	Health and safety at work, Gender, discrimination,
d. Land rights	Land rights and conflicts
e. Food security	Land converted from staple crops

a. Contribution to local economy: The implementation of a logistic centre using agricultural residues for the production of solid biomass has a positive effect on the economy from the social point of view as it will create a new employment opportunity or more working hours for part time workers. In addition, buying a currently not used residue from local farmers and therefore giving them an additional income is a positive social impact. Around 500 hours were estimated to be required for the new business line. 1 additional employee will be hired.

b. Working conditions: One of the main areas covered by EU labour law is working conditions. This includes provisions on working time, part-time, and fixed-term work, temporary workers, and the posting of workers. All of these areas are key to ensuring high levels of employment and social protection throughout the EU.

In Tschiggerl Agrar GmbH, the working conditions of the EU are applied. The part time workers have the same working conditions and employment benefits as the full time workers.

c. Working rights: In the EU, workers have certain minimum rights related to

- Health and safety at work: general rights and obligations, workplaces, work equipment, specific risks and vulnerable workers.
- Equal opportunities for women and men: equal treatment at work, pregnancy, maternity leave, parental leave.
- Protection against discrimination based on sex, race, religion, age, disability and sexual orientation.

In Tschiggerl Agrar GmbH, the working rights are all reserved. When dealing with both the raw material and the biomass produced, the workers should wear masks as the risk of inhaling dust particles, which can cause severe health issues, is high. Furthermore, from gender equity point of view, women also are employed for administrative work.

d. Land rights: The issue of land rights is very relevant in light of the increasing practice of land-scarce countries leasing land in developing countries. This leased land could be primarily used for producing strategic food resources. Nevertheless and irrespective of whether food or fuel resources are grown; the issue of land deals or 'land grabs' exemplifies the effects of increased demand for land, to which bioenergy development contributes. The practice of land deals raises serious concerns about the respect of customary land rights of small holders.

The concept of SUCELLOG project will not enhance the leasing of new lands for the production of bioenergy as it will use the residues of agricultural products making this impact irrelevant to the case.

e. Food security: Bioenergy production might compete with agriculture on land use leading to possible jeopardising of food security.

The concept of the SUCELLOG project will not affect food security as it is using the residues of agricultural residues creating no competition with food but on the contrary contributing to synergies with the agricultural sector. The only threat that might evolve is the competition on feed as straw for example can be used for animal feeding, but during the biomass procurement study only residues which have no competition with other uses were taken into consideration.

7.5. Environmental assessment

The Environmental Impact Assessment (EIA) is the process of identifying, predicting, evaluating and mitigating the bio-physical, social, and other relevant effects (positive or negative) of development proposals prior to major decisions being taken and commitments made. In the environmental assessment, the impacts, mainly biodiversity, soil, water and air are usually studied.

In this study since we are dealing with agricultural residues, biodiversity and water are not considered to be affected neither positively nor negatively. Therefore impacts on soil and air will be only discussed.

a. Soil: Addition of crop residues to soils is important because they are a major source of organic carbon (C) and nutrients. Organic C positively impacts soil fertility, soil structure, water infiltration, water holding capacity, and bulk density, and it sustains microbial activity. Removing all residues like straw from the field will have therefore a negative impact on soil. In order to have a sustainable process for the production of solid biomass with no negative impact on the soil, it should be taken into consideration during harvesting to keep a percentage of the residues on the field (between 20-30 %). It is important to highlight that, when stating the amount of raw material available in the biomass assessment study (section 4), all these aspects have been already taken into consideration.

Concerning corn cobs, they are considered to have a very limited nutritional value for the soil. Therefore removing all of it will not have negative impact on the soil.

b. Air: two aspects should be taken into account when it comes to air pollution. If the residues are burned in the field, they will emit a lot of pollutants (CO, CH_4, CO_2, SO_2, non-methane volatile organic carbon and ammonia). Therefore using the residues for the production of solid biomass is a good alternative with positive impact.

The report from the Commission to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling (COM(2010)11), recommends that Member States that either have, or who introduce, national sustainability schemes for solid and gaseous biomass used in electricity, heating and cooling, ensure that these in almost all respects are the same as those laid down in the Renewable Energy Directive. The directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 established the sustainability criteria for biofuels and bioliquids.

According to COM(2010)11, residues to produce solid biomass should fulfil the criteria of minimum greenhouse gas (GHG) saving values of 35 %, rising to 50 % on 1 January 2017 and to 60 % from 1 January 2018 for biomass produced in installations in which production started on or after 1 January 2017.

In order to check whether these values are fulfilled in the case of the production of loose cobs, cob grits and cob pellets, BIOGRACE tool (developed by the project BIOGRACE II funded by the Intelligent Energy for Europe programme) has been used. The excel sheet allows the calculation of GHG emissions savings entering the case characteristics and the distance from supplier and final consumer.

In the case of the possible logistic centre to be developed by Tschiggerl Agrar GmbH, the GHG reduction is considerably higher than 35 %. Only loose cobs and cob pellets have been analysed since the tool does not permit the calculation with grit format. However, the grit case can be considered in a middle position between the loose cob and the cob pellet. The whole logistics chain of the raw material has been considered in the analysis although the harvesting emissions have been allocated to the corn grain and not to the cob. The most adequate values from the ones reflected by the tool have been chosen in each case.

8. Summary and conclusions

Tschiggerl Agrar GmbH is an agro-industry whose current activities are: corn harvest, treatment and trading; logistic operator of straw; and pelletising for animal feeding and bedding. The Company is interested in making the agro-industry activity compatible with the production of solid biomass, initiating therefore a new business activity as biomass logistic centre.

An assessment of both the boundary conditions (biomass resources and market) and the Company conditions (equipment and management) has shown that:

- The agrarian residues available for the logistic centre will be: cereal straw, hay and corn cobs. The latter being the most interesting raw material due to the lack of competitive uses.
- The main consumers of the biomass products are expected to be farmers with own corn fields, who are currently using wood chips, for heating their

houses and farms. Households consuming woody pellets should also be considered. Wood chips and wood pellets are consequently the market competitors.

- ➢ The Company does not require any investment in equipment and will be able to work with the drying facility that is currently used for the cobs used in animal bedding and the pelletising facility from the association “Heu and Pellets” placed in the Company facilities.

The techno-economic feasibility study reported in this document have concluded that from all possible products to be generated by the logistic centre according to the raw material available, only corn cob-derived (loose, grits and pellets) are recommended by the SUCELLOG project. In other words, only the production costs of cob-derived products are lower than the market price (estimated according to quality characteristics and current price of competitors) generating a benefit for the Company. In particular, cob grits are by far the most profitable products.

However, it should be highlighted that the economic feasibility of the new business line is subject to quality characteristics (mainly to Chlorine percentage). This is especially important in the case of the cob pellets: if the pellet generated does not accomplish Chlorine levels stated by the quality standard ISO 17225-6 class A, there will no profit for the Company. Therefore, a previous quality analysis (mainly determination of moisture content, calorific value, ash content and Chlorine percentage) of a representative sample of the corn cob to be used as raw material for the logistic centre is strongly advisable before starting the new business activity. Intensive product quality evaluation will avoid unexpected dissatisfaction from consumers. Initial combustion tests with some target boilers can be a good option to test the viability of the product during conversion (evaluation of slagging formation for example).

The use of corn cobs for the production of solid biomass has no social and environmental negative impacts. On the contrary, they contribute to the improvement of society and the environment. This proves that the concept of the SUCELLOG project is sustainable from the 3 pillars point of view (economic, social and environmental).

After showing the results of the feasibility study to the manager of the Company, he decided to use only the corn cobs as raw material for the production of solid biomass using the agro-industry as a logistic centre. A tailor-made business model has been developed by the SUCELLOG project for this new activity (see the document D4.4 available on the website).