AgriWasteValue

To transform agricultural by-products
and residues into bioactive compounds

HOW TO CREATE A LOCAL HUB FOR TRANSFORMING PRUNING RESIDUES INTO ENERGY AND FERTILISER

With the financial support
of the European Regional
Development Fund and Wallonia

UNION EUROPÉENNE
Wallonie

EN SAVOIR PLUS

Interreg
North-West Europe
AgriWasteValue

HOW TO CREATE A LOCAL HUB FOR TRANSFORMING PRUNING RESIDUES INTO ENERGY AND FERTILISER

by Flora Mer, Biobased Products Project Manager, Valbiom

Introduction

This case study describes the complete cycle beginning with the collection of pruning residues in orchards to energy production and finishing with fertiliser application on the fields (Figure 1). Particular attention is given to the Belgian landscape.

The case study will present the following stages:

- Identification of a location for a local hub for extraction and energy production
- Collection of pruning residues from the orchards and storage of them
- Extraction of pruning residues
- Production of energy from extraction residues and valorizing digestate that will be returning to the orchards

Interreg North-West Europe AgriWasteValue

With the financial support of the European Regional Development Fund and Wallonia

Selection of a suitable area for a hub with a high quantity of pruning residues available

One objective of the AgriWasteValue project was to extract molecules from orchard pruning residues. In order to make it as viable as possible, the installation of the hub for molecule extraction and energy production from the extraction waste needed to be in a specific area where there is a high volume of pruning residues available in order to optimise the design of the equipment. This meant an area with a sufficiently high number of orchards which would have the added advantage of keeping transportation costs from the orchards to the extraction unit to a minimum.

The first stage of the AgriWasteValue project was to create a map showing the surface area of the orchards together with an estimation of pruning residues quantities for the region of the project. The map is available on the project website: www.agriwastevalue.eu.

After an initial investigation of the Belgian landscape, the highest concentration of orchards was found to be located in the East of the country, around Sint-Truiden.

Figure 1 and table 1 represent the district and the quantity of pruning residues (trimming waste) in each district where the orchards were located.

Based on this map, the best region to consider for the collection of pruning residues was in Sint-Truiden. In fact, the district of Sint-Truiden boasted 2487 ha of fruit trees and approximately 7000 tonnes of dry matter of pruning residues per year.

DISTRICT	FRUIT TREES AREA (HA)	TRIMMING WASTE (tDM/ha/yr)
Sint-Truiden	2487	7086
Borgloon	1172	3303
Nieuwerkerken	793	2273
Geetbets	720	2036
Herk-de-stad	623	1800
Kortenaken	586	1654
Gingelom	586	1636
Bekkevoort	492	1414
Alken	392	1140
Zoutleeuw	395	1123
Wellen	355	1009
Halen	312	896
Tongeren	317	893
Glabbeek	308	866
Kortessem	300	850
Heers	276	783
Tienen	264	761
Hoeselt	218	613
Riemst	213	596
Hasselt	203	587
Tielt-Winge	200	571
Linter	179	503

Table 1: Areas of orchards and tonnes of trimming waste (pruning residues) associated with the East of Belgium.

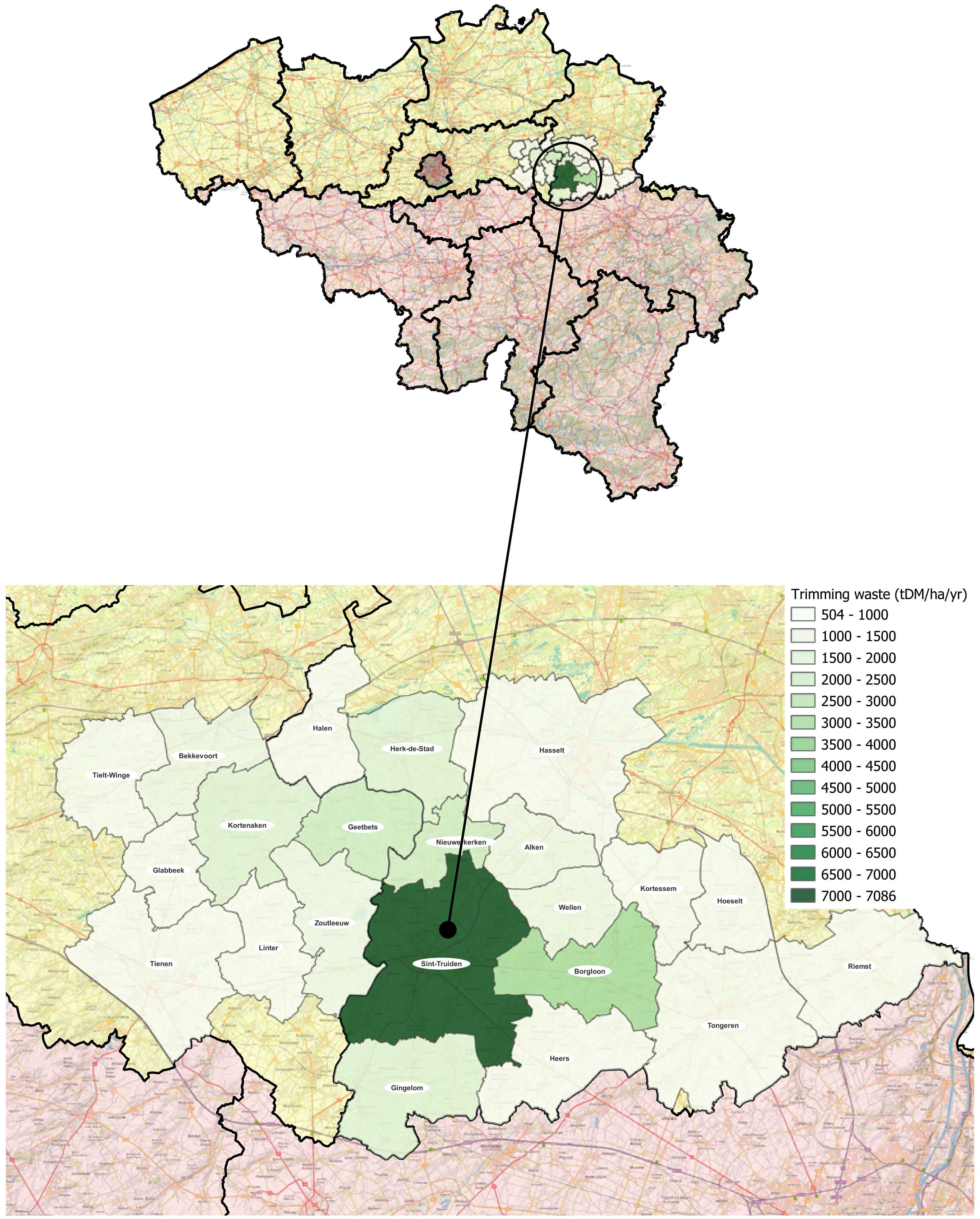

Figure 1: Belgian area with highest concentration of orchards and its pruning residues (= trimming waste).

Interreg North-West Europe AgriWasteValue

With the financial support of the European Regional Development Fund and Wallonia

Collection and storage of the pruning residues

The quantity of pruning residues that could be collected within a reasonable distance of Sint-Truiden was estimated to be between 1000 and 5000 tonnes of dry matter per year.

For this reason, the case-study for energy production will present 2 hypothetical quantities of residues of 1000 and 5000 tonnes of dry matter per year.

These residues were collected from November to March.

One difficulty concerned the most efficient way of collecting the residues. It would require a specific machine which was not included in the AgriWasteValue project but would need to be considered in any future project.

Regarding this limitation, it would be preferable to store the residues and have the extraction facility and energy production unit very close to the orchard, ideally in the same area or at a reasonable distance from it.

The storage area for the pruning residues would, in an ideal world, be situated at the same location as the extraction unit.

It is important to have appropriate storage conditions as it is vital to be able to dry the residues and then to keep them dry so that they remain in good condition.

During the AgriWasteValue project the composition of the pruning residues was analysed in the storage area and the results of the dry matter are represented in the table below.

BIOMASS COMPONENT	PERCENTAGE OF THE BIOMASS BASED ON DRY MATTER
Extractives	16.2 %
Cellulose	32.4 %
Hemicellulose	18.8 %
Lignin	37.4 %

Table 2: Composition of the collected and dried pruning residues

Extraction unit for pruning residues

An analysis of the composition of pruning residues together with an extraction test were carried out during the AgriWasteValue project. The pruning residues were found to have interesting levels of polyphenols that could be put to good use in a number of different sectors including the cosmetic, nutraceutical and phytosanitary sectors.

Several specific case studies about the cosmetic and nutraceutical sectors were also published within the AgriWasteValue project.

For the extraction plant, the following parameters were considered:

- An extraction plant with a capacity of 1000 or 5000 tonnes/year (t/y) (dry basis)
- The extraction unit would need to run for the entire pruning period. As this took place from November to March this meant that the total number of operating days was 150. Indeed, to preserve the pruning extracts and keep them stable, it is vital not to store the material for any longer than is strictly necessary.
- 25 years lifespan

CUTTING/ HARVESTING → 1000 OR 5000 T PER YEAR → EXTRACTION PROCESS → 800 OR 4000 T REMAIN FOR BIOGAS

Figure 2: Diagram illustrating the process from harvesting to the production of extraction residues for biogas

Once matter has been extracted, 80% of the input matter will, in fact, be waste. This waste is considered to be a by-product of extraction. These “extraction residues” will be used to produce biogas. The amount considered here is 800 or 4000 tonnes/year depending on the volume of pruning residues collected. The composition of the matter is presented in table 3.

BIOMASS COMPONENT IN	PERCENTAGE OF THE BIOMASS BASED ON DRY MATTER
Extractives	6 %
Cellulose	35.9 %
Hemicellulose	24.6 %
Lignin	34.5 %

Table 3: Composition of the residues after the extraction process (PFI)

With the financial support of the European Regional Development Fund and Wallonia

Production of energy with residues of extraction and avoiding digestate waste

Two scenarios are presented below. For each one, two options regarding the quantity of pruning residues collected were considered: 1000 t/y and 5000 t/y.

Scenario 1: Building an extraction unit and a biogas plant with a combined heat and power (CHP) unit next to the orchard

This scenario envisages the construction of a new biogas plant next to the extraction unit in order to provide the biogas produced to the extraction unit and other installations with the need of electricity and heat. The equipment is installed next to the orchards to limit the logistic aspect. To generate heat and electricity with the biogas produced, CHP needed to be installed.

DESIGN OF THE BIOGAS AND CHP PLANTS

In this scenario extracted residues were said to be 800 and 4000 t. These would be fed into the digester and produce biogas.

During the AgriWasteValue project, gas produced by the extraction residues was evaluated on a laboratory scale by doing a static biogas test. The value was 391 Nm^3 biogas/t, meaning that 1 ton of matter produced 391 Nm^3 of biogas. It was assumed that the biogas was composed of 55% of biomethane. This meant **that the biochemical methane potential (BMP) of the extraction residues was 215 m³/t**.

Due to the composition of the residues (table 3) and if no other types of residues were added, a dry anaerobic digestion system appeared to be the most suitable.

Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. Biogas consists mainly of methane (CH_4) and carbon dioxide (CO_2).

The dry anaerobic digestion systems for organic matter used a minimum of 20-40% dry matter.

The dry digestion is also known as discontinuous digestion because biogas production is sequenced with loading and unloading phases.

Before it can enter the digester, the dry matter needs to be properly inoculated with some of the digestate. It should be noted, however, that it would be necessary to buy digestate or adequate juice to inoculate the residues when the digester is used for the very first time. Further analysis would probably need to be performed for the moistening process.

Once both gas production per tonne and the quantity needed to feed the biodigester had been defined, it was possible to calculate the production of biogas and, subsequently, the amount of electricity and heat produced by the CHP unit.

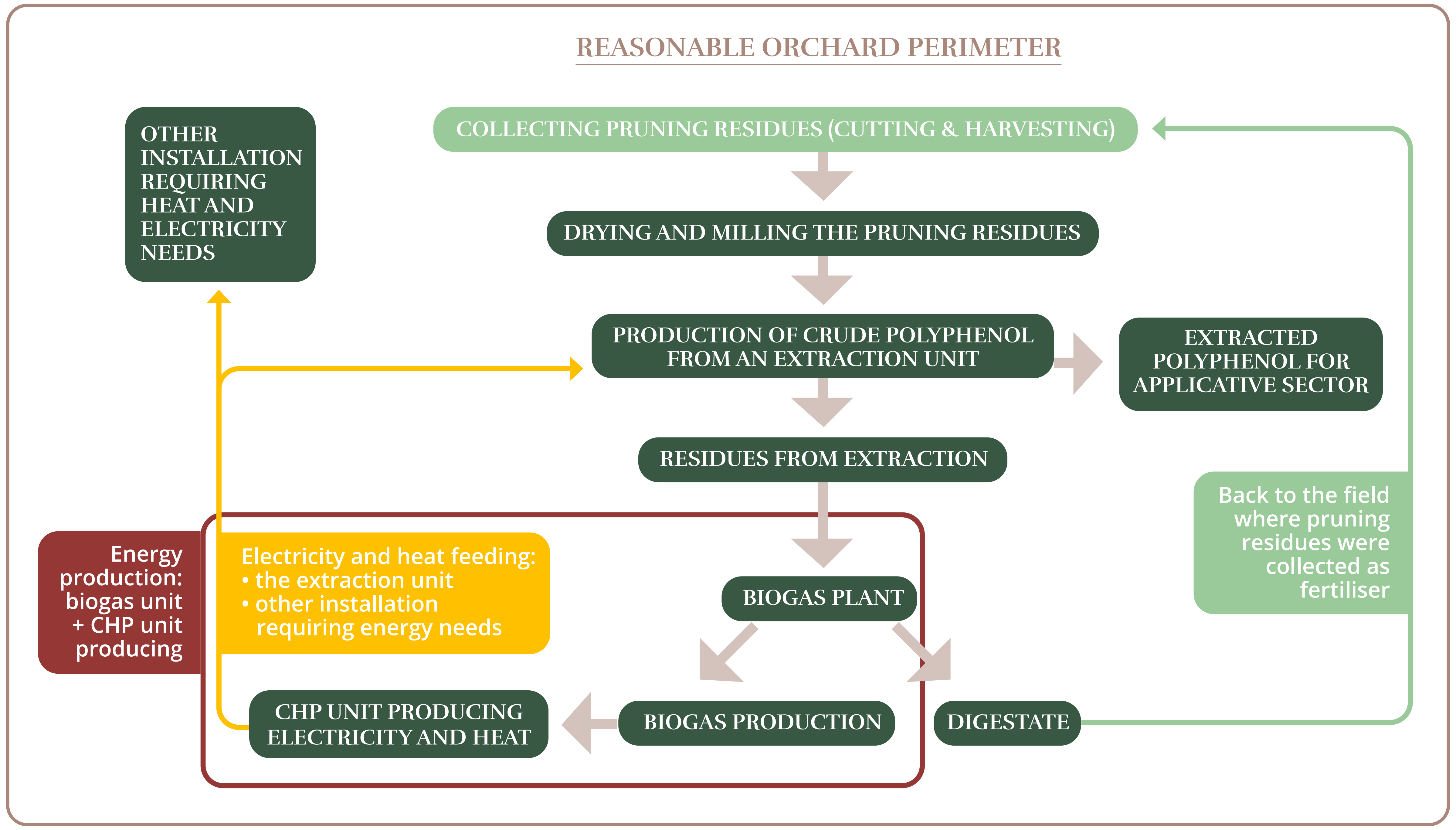

Figure 3: Diagram representing scenario 1

Figure 4: An example of a dry anaerobic digestion system for the production of biogas (Joly biogas plant in France)

With the financial support of the European Regional Development Fund and Wallonia

The fact that the extraction unit would be operating for only 6 months of the year, which corresponded to the period for harvesting the pruning residues, was also taken into consideration.

Moreover, it would be in winter when there is a higher need for heat which would be produced by the CHP plant. It would be a shame to waste the heat so a use for it needed to be found.

PARAMETER	1000 T BIOGAS PLANT	5000 T BIOGAS PLANT
Gas production [Nm³/t]	391	391
Biomass after extraction [t]	800	4000
Methane [%]	55	55
Biochemical Methane Potential [Nm³/t]	215	215
Calorific factor [kWh/Nm³ Methane]	9,96	9,96
Electrical efficiency [%]	40	40
Heating efficiency (CHP) [%]	40	40
Average operating hours per year [h]	5000	5000

Table 4: Parameter considered to design the biogas plant and CHP plant with 2 options: 1000 t/y and 5000 t/y of pruning residues (PFI)

PARAMETER	1000 T BIOGAS PLANT	5000 T BIOGAS PLANT
Total gas production [m³]	312.800	1.564.000
Methane production [m³]	172.040	860.200
Total energetic power [kWh]	1.713.518	8.567.590
Electrical energy [kWh]	685.407	3.427.035
Heating energy [kWh]	685.407	3.427.035
Electrical energy [kW]	137	685
Heating energy [kW]	137	685

Table 5: Design of the biogas plant and CHP plant with 2 options: 1000 t/y and 5000 t/y of pruning residues (PFI)

The introduction of the 800 t of extraction residues would produce 312.800 m³ of biogas per year. This biogas could feed the CHP plant and produce 1.7 GWh of electricity and 1.7 GWh of heat. The power of the CHP plant required for this would be 137 kW (table 5).

For 4000 t of extraction residues biogas production would increase to 1.564.000 m³, produce 8,5 GWh of electricity and 8,5 GWh of heat energy. The recommended power of the CHP plant to install is 685 kW (table 5). The operation of the biogas plant would consume a small part of the electricity and heat generated.

DIGESTATE AFTER BIOGAS PRODUCTION

After the production of biogas in the digester, the remaining waste inside the digester is called the digestate. It is also considered as a by-product which can be put to good use as an organic fertiliser.

The digestate of the extraction residues following biogas production has the following chemical analysis (table 6).

PARAMETER	CONCENTRATION AND/OR PERCENTAGE OF BIOMASS BASED ON DRY MATTER
Dry matter content	13,2 %
Loss on ignition	98,2 %
Total nitrogen amount	3243 mg/kg
Ammonium nitrogen	1280 mg/kg
Calcium	17480 mg/kg
Potassium	15460 mg/kg
Phosphorous	7620 mg/kg
**Sodium*	698 mg/kg
Zinc	165 mg/kg
Mangan	169 mg/kg
Nickel	9 mg/kg

Table 6: Composition of the digestate after biogas production from the residues of extraction

As much as 90% of the extraction residues entering the digester could be converted into digestate. Approximately 720 tonnes of digestate would be produced every year for the 1000 t plant and 3.600 t/y for the 5000 t plant.

The digestate has the perfect composition to be used as a fertiliser. This is the last step in the cycle as farmers would be able to use the digestate to fertilise the orchards that the primary matter came from.

The NPK ratio of the digestate composition described in Table 6 is: 3.2/7.6/15.5. Table 7 shows the calculation for potential cost savings using the digestate as a fertiliser compared to buying chemical fertiliser.

With the hypothesis presented in table 7, the cost of spreading chemical fertiliser is estimated to be 310 euros per hectare. In comparison, the cost of spreading digestate from the biogas plant is 240 euros per hectare. This means that it is 70 euros/ha cheaper to spread digestate.

HYPOTHESIS OF CROP REQUIREMENT AND DIGESTATE N CONTENT	
Total nitrogen requirement of the crop (organic + mineral)	150 kg N/ha
Digestate N content	3,2 kg N/gross ton

Hypothesis: an equivalent contribution in total nitrogen was considered. The organic nitrogen fraction of the digestate will act more slowly than chemical nitrogen but the crop can still use what remains albeit a little later in the season.

SPREADING CHEMICAL FERTILISER	
Mineral nitrogen price (August 2022)	2 €/kg N
Price of the chemical fertiliser distributor	10 €/ha
Total cost per hectare for spreading chemical fertiliser	**310 €/ha**

SPREADING DIGESTATE	
Total nitrogen price (organic + mineral) in digestate	0,8 €/kg N
Digestate price	2,56 €/tonne of raw digestate
Quantity of digestate needed	46,875 tonnes of raw digestate/ha
Digestate price per hectare	120 €/ha
Price for spreading in barrels	120 €/ha
Total cost per hectare for spreading digestate	**240 €/ha**
Savings made by spreading digestate	**70 €/ha**

Table 7: Calculation for the cost savings of applying digestate compared to organic fertiliser (Valbiom)

With the financial support of the European Regional Development Fund and Wallonia

ADVANTAGES

One advantage of this configuration is the "on site" production of the molecules of interest. This production would diversify the activity of the farmer thereby generating extra revenue.

As this would take place during the autumn and the winter, an option could be to use the heat and electricity generated for greenhouses in the orchards and would also be another reason to keep production to the winter period. Depending on its overall electricity and heat consumption, the owner may also become self-sufficient in terms of energy or at least reduce their need to pay for electricity.

The digestate is also a valuable by-product of biogas production. Indeed, the farmer can spread the digestate back on the fields which provided the pruning residues at the beginning of the cycle. This represents additional cost savings as it would reduce the need for organic fertiliser. Moreover, with the price of chemical fertiliser increasing significantly at the present time, the use of digestate means price fluctuations can be avoided.

LIMITATIONS

There are two limitations to take into consideration:

- The biogas unit will only be operational for 6 months of the year in line with the period for which heat is required. However, it would be preferable to find outlets with a high heat demand and keep the biogas plant operational all year round.
- The power of the unit (137 kW) is not particularly important when processing small volumes of dry matter in the region of only 1000 tonnes per year. However, when volume increases to 5000 t per year it could be worth investing in a larger 685 kW unit. The extraction unit would be able to handle more volume with 5000 t of pruning residues which is another reason for considering the investment.

It seems that the scale of the plant is a crucial factor. The investment cost for a biogas unit operating 6 months of the year with 1000 t of dry matter is significant but would be difficult to benefit from an economy of scale. The estimated investment for a 137 kW unit is in the region of 1 to 1.5 million euros. However, increased volumes of biomass, for example 5000 t per year, would increase the estimated power and the economic situation could be far better as it would be possible to have an economy of scale in the total investment of the biogas plant.

In general, the size of the biogas plant could be increased by adding other matter with good methanogenic power such as fruit residues that go to waste or crop residues from other fields or farms in close proximity to the orchards.

It should be borne in mind with the numbers presented above that some field validation may be required regarding potential methanogenic power of the extraction residues. This number (391 Nm³/t) was defined under laboratory conditions but it needs confirming in real conditions as other factors such as storage effects or matter homogeneity could modify the potential production of the biogas.

Scenario 2: Build an extraction unit and sell extraction residues to an existing biogas plant

Due to the limitation listed in scenario 1 and depending on the quantity of pruning residues collected, an alternative scenario which is presented here is the potential for selling the extraction residues (or the pruning residues if there is no extraction unit) to an existing biogas plant.

In fact, it would seem prudent to begin by selling the dry matter to an up and running biogas plant to make sure the matter is suitable for biogas production before making investments in the equipment.

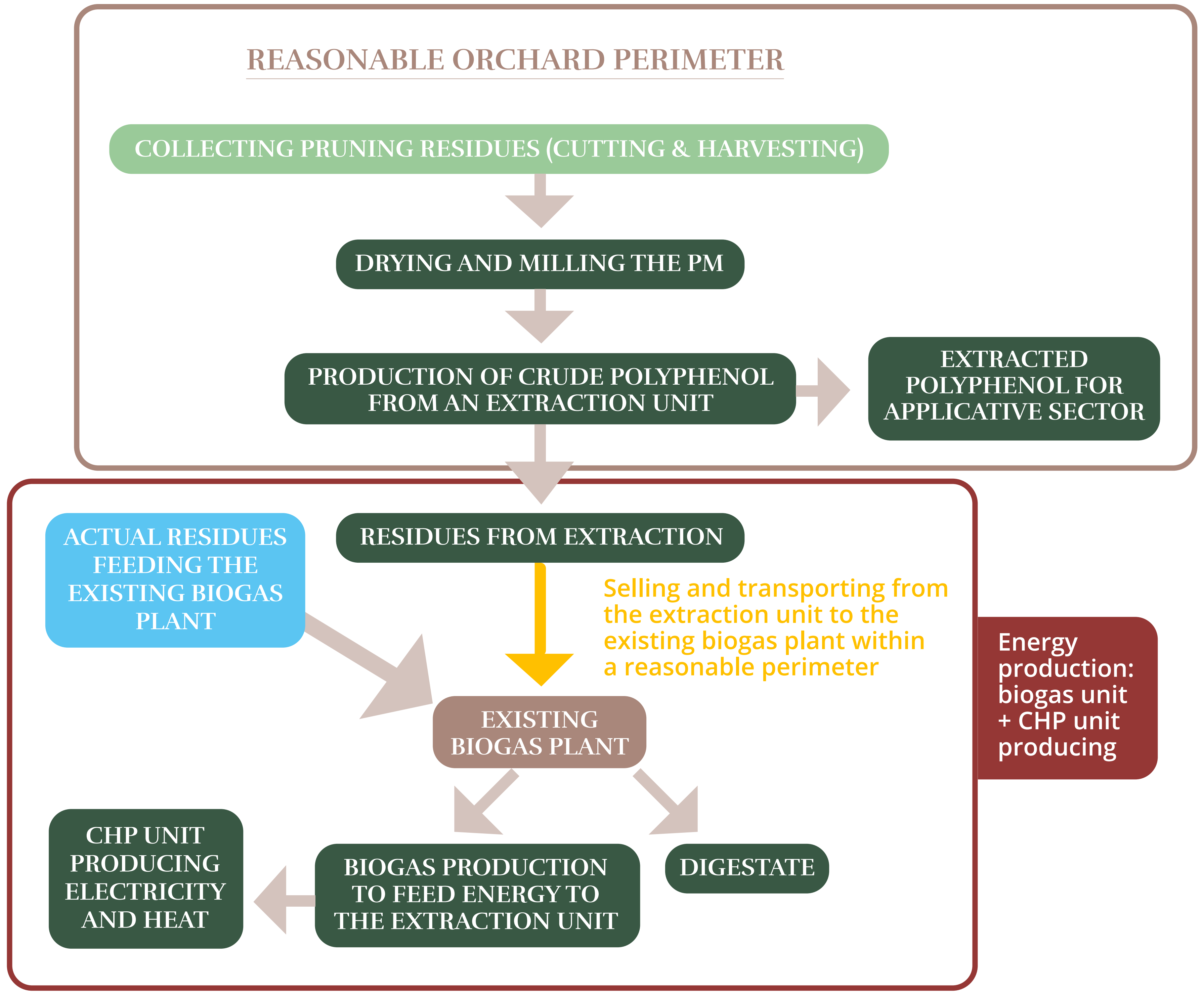

Figure 5: Diagram representing scenario 2

Interreg North-West Europe AgriWasteValue

With the financial support of the European Regional Development Fund and Wallonia

If the composition of the dry matter is found to be suitable for biogas production, it would be then reasonable to evaluate the building of a new biogas unit in an area where there is a high density of orchards and high demand for heat during the winter.

Looking at the existing biogas plant close to Sint-Truiden – where there is a high density of orchards, a potential buyer could be the Haut Geer biogas unit. In fact the biogas unit is located at 20 km from Sint-Truiden and has a power of 1500 kW. The unit has several types of inputs: livestock effluent, crops, crop residues and industrial by-product from a frozen vegetable company. Pruning residues could be of interest to them to complete their residues. In Haut Geer, the biogas obtained is used to run 2 CHP unit. The electricity produced covers the needs of the cooperative and the surplus is sold to a neighbouring company.

Based on the BMP of the residues of extraction compared to the BMP of the corn and purchase price of corn for biogas production, it is possible to estimate the purchase price of extraction residues for biogas production. The table below summarises this calculation. The purchase price of the extraction residues is estimated to be 89 euros/t of dry matter (DM). The total revenue generated by selling the extraction residues will then depend on the quantity of the residues. This could generate a revenue of 71.200 euros/years if selling 800 tonnes of extraction residues and as much as 356.000 euros if selling 4000 tonnes of extraction residues.

PARAMETER	1000 T BIOGAS PLANT	5000 T BIOGAS PLANT
Purchase price of corn for biogas production [€/t MF]	48	48
Methane potential of corn [Nm^3/t MF]	116,4	116
Price of corn per Nm^3 of methane [€/Nm^3]	0,41	0,41
Methane potential of residues after extraction [Nm^3/t MF/MS]	215	215
Purchase price of residues of extraction for biogas production [€/t MS]	89	89
Quantity of residues of extraction for biogas production (t MS)	800	4000
Total price of residues safter extraction for biogas production [€/an]	71.200	356.000

Table 8: Price estimation of the residues of extraction if sold to an operational biogas plant (Valbiom)

Conclusion and elements to consider

This case study has reviewed the potential of a cycle for the AgriWasteValue project. The study compared two scenarios with two potential amounts of biomass (1000 tonnes and 5000 tonnes of pruning residues collected).

If some farmers or actors in the orchards sector are considering investing in an extraction unit coupled with a biogas plant and CHU unit, they need to carefully consider some elements:

- Verify in real conditions the methanogenic power of the input matter of the bio-digester. For the purposes of this case study, input matter analysed was extraction residues with a high content of cellulose and lignin.
- Ensure that the matter fed into the digester is reasonably homogenous in terms of the storage and potential degradation time.
- Have enough matter to feed the digester to be sure that the size is optimum and have a good return of investment. The best is to have homogenous matter available in sufficient quantity to operate all year.
- Analyse the heating and electricity needs of the industry or orchards to be sure that all energy produced is put to good use.
- Analyse the technical feasibility of how making the best inoculation of the residues when entering into the digestate.

As illustrated in the case study, before making a significant investment in an energy production unit and wherever possible, the matter should be first tested in an existing biogas unit to confirm its suitability for energy production.

Interreg North-West Europe AgriWasteValue

With the financial support of the European Regional Development Fund and Wallonia

AgriWasteValue project

The majority of natural actives used in cosmetic or nutraceutical formulations are currently imported to Europe, although a huge diversity of resources is present in North-West Europe. This means that a large amount of residues in covered areas, known for their arboriculture and viticulture sectors, are not being fully exploited for the sourcing of natural actives and are therefore going to waste.

The AgriWasteValue project aims to take agricultural residues from the European North-West regions and to transform them into bioactive compounds. These will be used, initially in key industrial sectors such as cosmetic and nutraceutical fields and then, in a second phase, in the energy, chemical and agricultural fields.

The agricultural residues and biomass that will be used for this project come principally from pruning vines and apple and pear trees.

The project is possible thanks to the financial support of the European Regional Development Fund (ERDF) and Wallonia.

Budget of the project :

- Global budget : 3.193.157,19€
- Fund ERDF : 1.744.580,84€

The AgriWasteValue project is a transnational cooperation that will open up new ways of recycling residues from the agricultural, viticulture and arboriculture sectors.

Contact

Do not hesitate to contact **Flora Mer (f.mer@valbiom.be)** or **Patrick Ballmann (patrick.ballmann@pfi-biotechnology.de)** if you are interested to know more about the case study or AgriWasteValue project.

info@agriwastevalue.eu
www.agriwastevalue.eu

@AgriWasteValue Interreg NWE
@AgriWasteValue

Project under the program

With the financial support of the European Regional Development Fund and Wallonia

9 partners in Europe