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Report on low-cost collection/harvesting, pre-processing and handling strategies tailored for biomass/waste feedstocks of FlexSNG

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Table of Content

1 Executive summary

This report relates to Task 2.2 of the FlexSNG project and describes feedstock handling and activities needed to produce a feedstock suitable for the FlexSNG process. In a preceding project report, several different streams of forest and agriculture biomass residues and biogenic waste feedstock were evaluated (*Report on biomass residue and waste feedstock potential assessment in Europe and Canada*). The feedstock activities for the most promising alternatives are described in this report. The report also gives and overview of feedstock requirement in the FlexSNG process. Possible adaptions to better cope with the FlexSNG requirements are highlighted. The results presented give necessary input to subsequent Tasks 2.3-2.5 as well as to the decisions on which feedstock assortments to be modelled in the case studies of the project. The conclusion is that there is a possibility to arrange and modify the feedstock activities to better suit the FlexSNG process. In the later demonstration of a 20% supply cost reduction these aspects must be considered since they influence both quality and cost. Therefore, an optimization model that can handle different designs and orders of activates must be developed to fully explore this potential.

2 Introduction

The overall objective of the FlexSNG project is to develop a flexible and cost-effective gasification-based process for the production of pipeline-quality biomethane, high-value biochar, and renewable heat from low-quality biomass residues and biogenic waste feedstocks. The flexibility of the gasification process lies in the ability to switch between two operation modes to produce a mix of end-products (biomethane, biochar and heat) that meets current price signals and market demand. At the same time, cost-effectiveness compared to state-of-the-art biomass-to-SNG technologies is expected by the combining of gasification process development and feedstock supply chain optimization.

This report relates to Task 2.2 of the FlexSNG project and describes methods and systems for supply chain activities of feedstock suitable for FlexSNG gasification. In a preceding project report, several different streams of forest and agriculture biomass residues and biogenic waste feedstock were evaluated based on their availability, thermochemical or quality aspects, and market price (D2.1 "*Report on biomass residue and waste feedstock potential assessment in Europe and Canada*"). The highest-potential subset of evaluated assortments is the target of this report. Figure 1 gives an illustration of these specific assortments.

Efficient methods and systems are key to preserving feedstock quality and value throughout the supply chain. Tailored supply systems that exploit the trade-off between feedstock quality, handling costs, and end-users' needs can open opportunities to use assortments that aren't available by standard methods. The goal of this report is to provide a better understanding of essential activities of a tailored supply system for each of the targeted feedstock assortments with respect to the specific needs of the FlexSNG gasification process.

The results presented give necessary input to subsequent Tasks 2.3-2.5 as well as to the decisions on which feedstock assortments to be modelled in the case studies of the project.

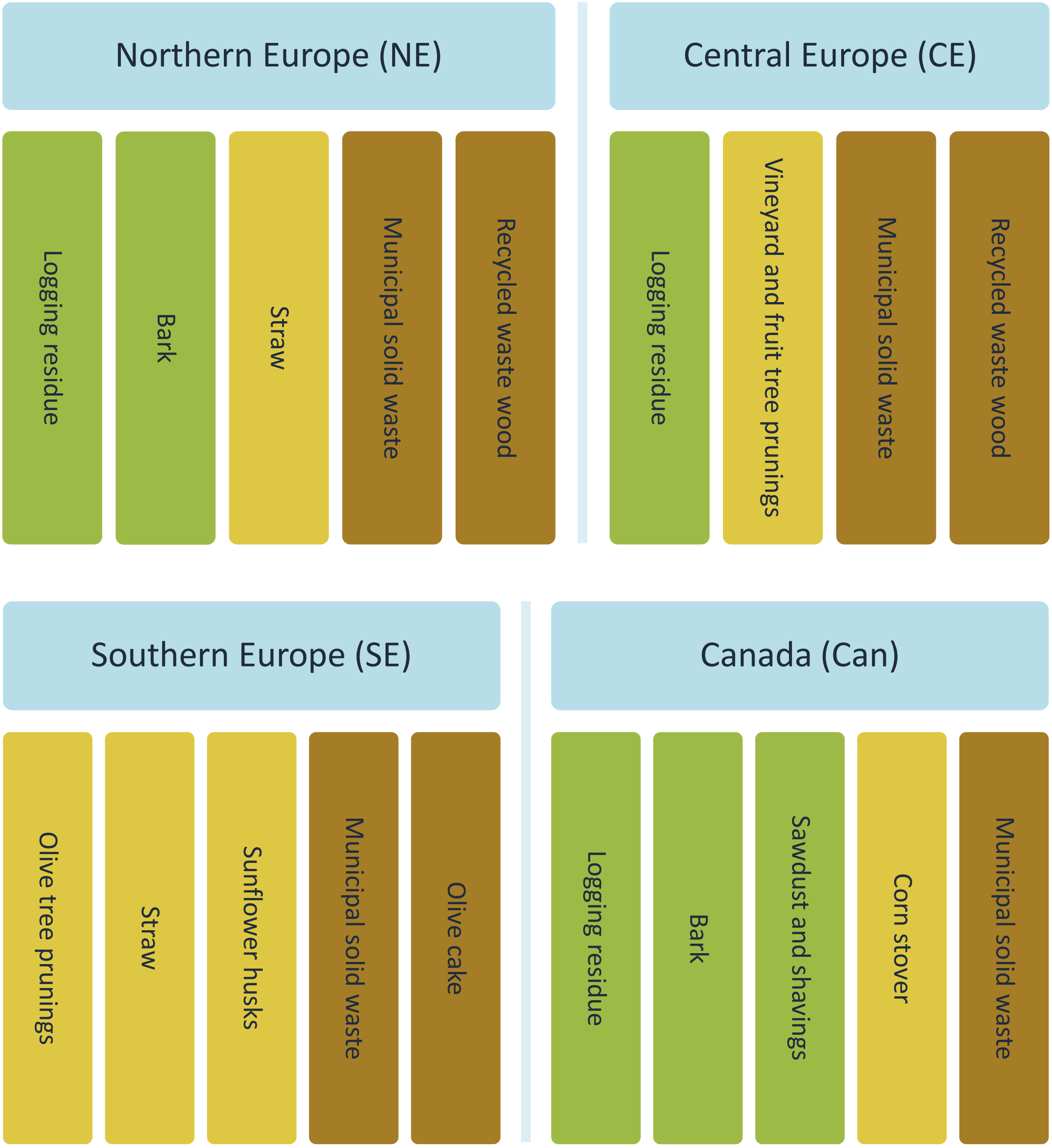

Figure 1. Overview of feedstock assortments covered in this report, illustrated by region. Feedstock origins are forest sector residues and by-products (green), agriculture residues and by-products (yellow), and biogenic waste (brown).

3 Feedstock requirements for the FlexSNG gasification process

Gasification can be used to convert virtually any carbon-containing feedstock to syngas, and the FlexSNG gasification technology is in general less sensitive to feedstock properties than other conversion technologies. There are, nevertheless, some requirements on the feedstock quality that are imposed by the specific gasification process design and selected reactor type. Fulfilling the feedstock requirements is expected to result in reliable and efficient operation of the FlexSNG plant.

The two factors of highest importance for optimal functioning of the process are the feedstock moisture content and the particle size. When entering the gasifier, the feedstock should have a moisture content of about 10-20 wt% to prevent excessive energy consumption for water evaporation. Surplus heat produced as a by-product at the plant can be exploited for feedstock drying, but a low moisture content upon delivery at the plant is better for the system efficiency. As to the particle size, a too heterogenic material is problematic for both the drier and the feeding system. The particles must not be larger than 100 millimeters, and a maximum of 20 wt% of the material can have a particle size less than 1 millimeter. The preferred range of particle sizes is between 5 and 50 millimeters.

The FlexSNG gasification process uses atmospheric pressure which allows conveying the feedstock into the reactor pneumatically. Consequently, and in contrast to other techniques for the final feeding step, densification of low-density feedstock is not necessary in the FlexSNG case.

The FlexSNG gasification technology sets no further strict requirements on feedstock quality of relevance for the forestry and agricultural assortments given in Figure 1. Therefore, cost-effectiveness of any quality-improving processing related to aspects other than moisture content or particle size, such as heating value (LHV) or ash content, is important to motivate use of such activities in a tailored supply system. Regarding the waste streams, some extra pre-treatment may be required to handle the relatively high presence of metals, inert materials, and other problematic elements in these assortments (see 5.9).

4 Overview of supply chain activities

An overview of common supply chain activities required for the use of the assortments in Figure 1 as feedstock in the FlexSNG process is given below.

Collection. A collection activity usually defines the start of the FlexSNG supply chain. Clarity on where, when, and in what form the feedstock becomes accessible and enters the supply system is important to understand what following steps are needed.

Storage. Storage is characterized by limitations on when, where, and how it takes place, and by any implications on the feedstock quality it may have, the latter normally dependent on storage time and conditions.

Comminution. Comminution is used when a reduction in feedstock particle size is needed. Reasons could be fulfilling the end-user's needs or facilitating transport. Common techniques are chipping, crushing, grinding, and shredding; the choice of technique is influenced by the specific characteristics of the material.

Compaction. Compaction is used to facilitate transport, storage, or handling of a loose, bulky, or fluffy material. Bundling, baling, briquetting, and pelletizing are examples of compaction activities.

Sorting. Sorting is used when an 'accept' fraction must be separated from a 'reject' fraction in the feedstock material. An example of a sorting activity is sieving, which is used if adjustments in the particle size distribution are needed. Another example is reduction of contaminants.

Transport. Transport of the feedstock is characterized by available modalities (road, rail, or sea) and by any limitations or restrictions on the means of transport. For some assortments, specialized equipment for loading and unloading may be needed.

5 Supply chains of low-cost assortments tailored for FlexSNG

5.1 Logging residue (NE, CE, Can)

Logging residue consists of the treetops and branches generated in the forest as a by-product from forest harvesting. The material becomes accessible for transport (or processing) after being collected from the forest site and stacked in windrows at roadside landings.

The logging residue must be comminuted to meet the requirements on the feedstock particle size. Mobile comminution systems can be relocated between roadside landings to process the material just before, or simultaneously as being loaded onto trucks. Comminution close to the forest site is desirable with respect to transport cost since bulkiness of the material is reduced. As an alternative, stationary or semi-mobile processing systems with higher capacity can be used at terminals; however, to the expense of an added first-leg transport of the bulky raw product to the terminal.

Comminution at the FlexSNG plant site has the potential of requiring fewer systems but implies transport of the bulky raw product all the way from the forest.

The choice between comminution systems depends on the presence of soil contaminants. In general, logging residue is a clean material and is therefore often processed by chippers. Chipping at roadside landings is either by combined chipper-trucks or by separate chippers, the former implying less available cargo volume and the latter requiring coordination with arriving trucks.

Uncomminuted logging residue can be stored at any location in the supply chain: at roadside landings, terminals, and plant sites. Normally, a first storage period takes place already in the harvesting area prior to forwarding the material to the roadside landings. Long-term storage of the comminuted material should be avoided since biodegradation is faster than in the uncomminuted raw product, resulting in a larger reduction in bioenergy content as well as risk of spontaneous ignition. Short-term storage in large piles at a terminal or plant site is on the other hand possible.

Storage of logging residue not only works as feedstock buffer, but also acts as a drying process of the freshly cut material that typically has a moisture content above 60 wt%. Long-term stored logging residue reaches a moisture content between 30-50 wt% and is in general drier during summer and moister during winter. The moisture content seldom or never falls within the required interval of 10-20 wt%. Knowledge on the variation in moisture content by season, local climate, or storage conditions can be helpful in minimizing the need of pre-drying at the plant site using surplus heat.

Transport of logging residue from the forest roadside landings is always by road; however, in the Canadian case, the transport is sometimes by barges directly from the forest. The most common means of road transport are ordinary chip truck and trailer, self-loading chip truck and trailer, or container truck and trailer. Changes in transport modality or means of transport are possible at terminals after a long or short period of storage.

Sieving can be used to adjust the particle size distribution in the comminuted material at any location in the supply chain, although at a terminal or plant site would be the more rational choice. The expected improvement in the gasification process by using a more homogeneous material needs to be balanced with both sieving cost and the loss in bioenergy content corresponding to the rejected fraction.

5.2 Bark (NE, Can)

Bark is the by-product generated from the debarking of sawlogs at sawmills, or pulpwood at pulp mills, and becomes accessible for transport at the industry yard where it is stacked in piles suing a wheel loader. The debarking technique may differ between industries, but the characteristics and composition of the output bark fraction is similar independent of used technique.

The debarking process outputs bark particles with sizes ranging from very fine (less than 2 millimeters) to very coarse (larger than 90 millimeters) [1]. The large-fraction particles have a sleeve-like shape known to be problematic for feeding systems of the screw conveyor type. Further comminution and sieving may therefore be needed to decrease the particle sizes and narrow the particle size distribution. Due to high levels of soil contamination (stones and gravel), less wear-sensitive shredders or crushers are used before knife-mounted chippers. Comminution and sieving can take place at any location in the supply chain.

Long-term storage of bark should be avoided to prevent bioenergy losses from faster biodegradation or spontaneous ignition. Short-term storage at the debarking industry, terminal or plant site is on the other hand possible.

Being produced from freshly cut wood, bark has a high moisture content (55-60 wt%) and is, in contrast to logging residue, not undergoing any natural drying processes since long-term storage is avoided. Current use of bark in bioenergy production is therefore often as a component in a feedstock mix with drier assortments.

Transport of bark is usually by road. The most common means of road transport is container truck and side tipper trailer that enables easy unloading at the plant site. The loading into trucks can be done whit a wheel loader.

5.3 Sawdust and shavings (Can)

Sawdust and shavings are by-products generated from the sawmills and can become accessible to the FlexSNG system at the mill. The only process that at minimum must be at place is a transportation and possibly storage phase. Sawdust and shavings can be used without pelletizing them first which means that only a bulk transport is needed. However, the fines can be challenging. Transport modes such as trucks, trains and barges can be considered. Storage of large quantities of sawdust and shavings is not unproblematic and dry sawdust can also be challenging in an industrial environment with risks of e.g., dust explosions.

5.4 Vineyard and fruit tree prunings (CE)

Vineyard and fruit tree prunings is the residue generated from the removal of certain parts of a vine or fruit tree using different techniques to increase fruit production.

The development of energy recovery processes from prunings is a complex and tense issue in Central Europe. Some farmers are against the use of these debris outside of their farms. In these regions, soils are mostly poor in organic matter and allowing prunings to decompose *in situ* contributes significantly to the renewal of this organic material.

Pruning is done in the winter season (mainly January and February). If used for ground fertilizing purposes, the pruning residues are stored in windrows and thereafter crushed in the following month. Farmers then use a mulcher attached to a tractor to crush the prunings directly on the ground. However, a minority of farmers use prunings for energy production already today (in most cases in a boiler for own heating needs). The pruning residues are then stored in windrows for a few months to dry; fresh prunings have a high moisture content (50-60 wt%).

Prunings need to be shredded, chipped, or crushed to meet the requirements on the FlexSNG feedstock particle size. Like forestry residues, comminution should not take place before the material has dried or before long-term storage due the high humidity rate combined with the accelerated decomposition induced by the smaller particle size. Comminution of the dried material can be done directly at the farm or at the FlexSNG plant site. In general, the most effective way is to process the residues at the farm using a mobile machine such as the SILVATORE from SUD ENERGY – comminution prior to transport has the potential to significantly increase the transported weight. If comminuted at the FlexSNG plant site, the pruning residues should first be baled. Baling is done in the field and usually require specialized machines to cope with the limited space between plant rows, but also to efficiently load, unload, and transport the bales further down the supply chain (similar as for straw). An advantage of baling is the possibility to control the moisture content – baled and dried pruning residues can be stocked for several months with only minor changes in quality.

Once comminuted, the pruning residues can be sorted to reduce contaminants such as stones and soil residues, and to remove the finest particle fraction obtained during comminution. In general, the crushing and subsequent sorting process result in a reject fraction corresponding to a 45 wt% mass loss that can be used as organic matter and fertilizer. The sorting process can take place on the farm or at the FlexSNG site, however, sorting at the FlexSNG plant site requires an additional transport of the reject fraction back to the farms.

5.5 Olive tree prunings (SE)

Pruning is a standard agronomic practice for olive trees that is used to control the plant growth and keep it healthy and productive. For many olive farmers, pruning is seen as a form of art and its implementation varies depending on personal preferences, but also on climate conditions and traditional practices. In mature olive trees, *maintenance pruning* is practiced and takes place either every year or once every two years. In principle, olive tree pruning can be done in the period starting from autumn until the first months of spring, but it should be avoided during the winter months in areas with a chance of frost. Hence, the pruning window varies between locations.

Olive tree prunings are the branches that are cut from the olive trees during the pruning process. Larger and thicker branches are almost always collected by the farmers themselves and used as firewood. For a FlexSNG process – or any other type of biomass conversion – the key feedstock is the smaller branches that usually remain unexploited. Unfortunately, open-field burning of those smaller olive tree prunings is still a widespread practice in several areas. Alternative treatment methods, such as mulching or chipping, in which the material is left on the soil as a type of organic fertilizer are gaining in popularity. However, some farmers – as well as some scientists – remain skeptical of these practices, fearing increased phytopathological risks. Removal of the prunings for use in bioenergy production applications can be a viable alternative in such cases.

Olives are an evergreen tree species which means that the leaves are on the branches when they are pruned. The chemical properties of leaves are not ideal for thermochemical conversion processes (relatively high ash, nitrogen, and alkali contents). Therefore, ideally, the prunings should be left on the field for a period of time (roughly one month) so that the leaves can dry and fall off naturally.

There are different alternatives for harvesting of the olive tree prunings. For smaller value chains or when the terrain does not allow mechanized harvesting, an acceptable method is manual collection and subsequent size reduction in small, manually fed chippers. For larger supply systems, a more efficient method is manual or mechanized windrowing and integrated harvesting and shredding with a specialized machine. Most commercial integrated harvesters use hammers for comminution, thus producing hog fuel. Different systems for the collection of the shredded material exist, including big bags and direct discharge in trailers or tiltable bins. An optional method is forwarding of the prunings to the field side or another open location (e.g., using a tractor) and subsequent shredding or chipping with a larger, stationary machine. Forwarding and stationary shredding could be effective in larger fields but the forwarding step increases contact of the prunings with the soil, typically resulting in higher degrees of contamination with inorganic materials. Baling – the harvesting method used for many other agricultural assortments – has not been extensively tested for olive tree prunings and is probably difficult due to the size of the branches.

After comminution on or near the field, olive tree prunings can be handled in the same way as forest wood chips in terms of storage, transport, pre-treatment, et c. Typically, they exhibit higher values of ash, nitrogen, chlorine, alkalis and other compounds than forest chips due to their composition or the employed harvesting or logistics operations (presence of leaves, soil contamination, smaller branches, et c.). Since they are most often available in the form of hog fuel, some type of sorting pre-treatment may be needed to reach a more uniform particle size. If justified by the economics, olive tree prunings can also be processed and upgraded into pellets.

At the moment, there are only few examples of bioenergy value chains based on olive tree prunings. Lack of incentives or motivation for the farmers is one reason. The fact that olive trees grow mostly in warmer climates, in which heating demand is lower seems to also play a role. In some areas, olive groves are often found in difficult terrains, such as fields with slopes, where mechanized collection is difficult. At the same time, the average holding size may be small, meaning that the amount of prunings that a single farmer can mobilize is also small. An example of energetic utilization of olive tree prunings is FIUSIS [1] – a 1 MWe biomass power plant in Puglia, Italy fueled exclusively by olive tree prunings from local groves (10 000 tons per year). Experiences from FIUSIS have been transferred to Greece within the AGROinLOG project[2]. Other examples of

[1] https://circulareconomy.europa.eu/platform/en/good-practices/fiusis-energy-and-fuel-pruning-olive-trees.

[2] http://agroinlog-h2020.eu/en/2020/01/20/olive-tree-pruning-harvesting/.

energetic utilization include some larger biomass power plants and other industrial facilities in Spain.

More information on agricultural pruning to energy value chains can be found in the monograph "Biomass from agricultural pruning and plantation removals" developed by CIRCE and CERTH within the framework of the uP_running project [2].

5.6 Straw (NE, SE)

Straw is the agricultural by-product consisting of dry stalks from cereal or legume production. It is the remaining part after the grain or chaff has been removed.

Straw is produced during the relatively short period when crops (e.g., oat, wheat, barley, and rye) are harvested. The material becomes accessible for transport once baled in the field, collected, and usually stacked in a storage area at the farm.

Like vineyard and fruit tree prunings, straw is often used for soil quality improvement. The straw is then chopped directly after harvest and never leaves the field. If to be used for energy production, farmers first leave the (unchopped) straw in the field a few days to allow it to dry to what is commonly referred to as *gray* straw. Leaving the straw in the field a few days is also important to reduce the alkali content in the material, as contaminants can be washed off by dew (or possibly by rain).

The moisture content of straw is generally below 18-20 wt% at time of harvest [3]. The fluffy, dried straw is then compacted into bales. Baling is done directly in the field by specialized contractors or by the farmers themselves. The bales are large, usually several hundreds of kilograms each, but their form varies depending on the baling technique. The bales are collected by a wheel loader or other tractor-pulled machine and loaded onto a trailer, and thereafter transported out from the field to a storage area at the farm. The bales could also be transported directly to the end-user.

Given the short production window, the straw bales must be long-term stored at some point to be able offer an even supply to the end-user. Indoor storage is recommended to avoid rewetting of the material. Covered outdoor storage is possible, but the risk of rewetting from the ground needs to be considered. In general, proper storage of straw does not significantly affect its moisture content. As with many biomass assortments, however, long-term storage eventually leads to degradation in quality and dry matter losses.

Short-distance transport of straw can be done by a farm tractor and trailer. Long-distance transport (farther than 30-50 kilometers) is more cost-efficient if done by a truck and trailer. Special equipment for efficient loading/unloading of several bales at a time onto/from the trailer can be used. A loader with long reach or a traverse system is used in large-scale applications, while a conventional farm tractor with front loader usually is sufficient for small-scale applications.

Straw bales must be shredded before entering the feeding system at the FlexSNG plant. The shredding process should take place at, or very close to, the FlexSNG plant to avoid transport of a bulky material.

More information on straw can be found in the "Straw to Energy" guide developed by Food & Bio Cluster Denmark within the framework of the AgroBioHeat project [4].

5.7 Sunflower husks (SE)

Sunflower husks are the outer shell of the sunflower seeds and represent around 20-30 % of the total seed weight. It is the by-product from the production of sunflower oil, a process that takes places in dedicated extraction plants and which relates to most of the global sunflower production.

In most sunflower oil production plants, the separation of the husks from the seeds is one of the first steps undertaken (preceded by a drying step, which makes the removal easier), since the presence of husks during the sunflower oil extraction has a negative impact on the quality of oil and of the residual meal, increasing the concentration of waxes in the former and reducing the content of protein in the latter. Thus, sunflower husks are available as a separate fraction. They are characterized by medium ash content and quite high calorific value. They have very low content of protein and therefore are not suitable as an animal feed, unlike the sunflower meal.

A significant share of the sunflower husk production is self-consumed by the sunflower oil production plants for their own thermal energy needs. Some of the larger plants have also implemented investments in biomass CHP systems and can cover part of their electricity consumption as well. The quantities that remain are generally made available to the market; a pelletization step is employed, since the bulk density of the unprocessed husks is very low.

After pelletization, the logistics for sunflower husks are quite similar as that employed for industrial wood pellets. Sunflower husk pellets can be transported over long distances via truck, train, or vessels. During storage and transportation considerations to avoid contact with rain should be employed in order not to degrade the pellet quality.

Sunflower husk pellets are a competitive type of agropellet and they are used as a fuel in various applications: space heating of greenhouses, co-firing fuel in power plants, or for other industrial processes.

More information on sunflower husks can be found in the "Agroindustrial residues to energy" guide developed by AVEBIOM (Spanish Biomass Association) and CERTH (Centre for Research and Technology Hellas) with contributions from UABIO (Bioenergy Association of Ukraine) within the framework of the AgroBioHeat project [5].

5.8 Corn stover (Can)

In the bioenergy systems, corn stover is one of the raw materials from the agricultural biomass value chain. Because of some considerable features of corn stover like the easy accessibility to it, use of it in ethanol production is on the rise [6]. The composition of this biomass can vary based on different factors, for instance, the harvest method, the fraction collected, and the time of year.

The most challenging parts of using corn stover in the bioenergy system are the time of harvesting and the storage method. Corn stover can be harvested in low moisture content (20 wt%) and then baled or in higher moisture content (40 wt%) and ensiled in bags or in wrapped bales. The efficiency of processing biomass for energy product via thermochemical processes is lower for high moisture content. It is observed that corn stover are utilized as animal bedding in the agrifood industry. Subsequent use of this biomass in a bioenergy system can be challenging. Arising issues can consist of contamination of bales with dirt and plastic, a low labor efficiency of the process, bale breakage, and consistency of the product [7].

A corn stover harvesting operation usually use either "combine" or "forage" harvesters in the corn fields. Harvesters produce corn stover bales, which can be found in different shapes and sizes such as small or large, round, or square bales. After on-site harvesting, square bales are often stored in covered-storage centers. Round bales of corn stover may be stored inside or outside. The round bales also can be wrapped in a polyethylene film to protect them from additional moisture and avoid losses. The transportation of the corn stover in different shapes of bales can be done in various capacities by trucks or rail when available [8].

5.9 Municipal solid waste (NE, CE, SE, Can)

Municipal solid waste refers to waste generated by households except hazardous, electrical, or bulky waste. It is generally managed by the respective municipality where the waste is generated.

Household food and residual waste can be collected as a mixed fraction intended for energy recovery or divided into a food waste fraction and a combustible fraction. The waste collection takes place either via recycling stations or close to the household properties. In some cities, manual handling of bins has been replaced by vacuum systems and underground containers to avoid both odors and heavy manual handling, and to reduce the need for transport. The containers are collected by freight exchange vehicles. A trend in Europe is the increased control and responsibility among municipalities of the collection of waste – about one third of municipalities manage the waste collection within the own municipal organization.

Storage and other handling of municipal solid waste are in general more regulated than for the forestry and agricultural assortments. For example, long-term storage of large amounts of waste may require a separate permit. The pre-treatment requirements for waste streams when used as a feedstock for the FlexSNG gasification process are also more demanding. The goal of these pre-treatments is primarily to separate metals, inert materials, and fines to produce the high-quality waste assortment solid recovered fuel (SRF). Since the composition of municipal solid waste varies greatly between countries or municipalities, (mostly depending on the recycling activity at the source encouraged by the local environmental plans or regulations) different degrees and methods of separation may be required after collection to recover recyclable materials. In general, more than 60 percent of the household waste can be recycled (e.g., glass, paper or plastic packaging, cardboard, newspapers, and food waste). Separation of paper and plastic fractions lowers the calorific value per kilogram of the residual waste, while separation of the food waste fraction increases the calorific value. Separation of metals can be done with magnetic or eddy current separators, and removal of heavy objects (e.g., stones or other inert materials) and fines (e.g., soil, sand, and glass) with drum screening and air classification.

The moisture content of municipal solid waste varies depending on its composition. Mixed, unsorted household waste has an average moisture content in the range 30-45 wt% (in general wetter during winter) and needs to be dried to meet the requirements of the FlexSNG gasification process. The food waste fraction has a moisture content above 65 wt% (up to 80 wt%) and its energy content is better extracted with anaerobic digestion.

Long-distance transport of municipal solid waste requires some type of compaction of the material, such as pressing and baling. As a final step, shredding or crushing is needed (irrespective of baling) to improve the particle size distribution prior to entering the FlexSNG feeding system.

5.10 Recycled waste wood (NE, CE)

Recycled waste wood consists of wood from packaging and pallets, demolition wood, and chipped wood waste from the industry. Recycled waste wood is collected at recycling centers or via container and big bag systems used at construction sites.

The material needs to be crushed to meet the requirement on particle size. Crushing is usually done at the recycling stations or sorting facilities with a hammer-crusher technique. The wood chips are often sorted into separate qualities to be able to meet specific requirements of the end-users. There are several techniques available to remove the finest fraction, plastics, and light metals (e.g., using a wind sifter), as well as heavier metals (e.g., using strong magnets). Regarding the requirement on moisture content, the need for pre-treatment drying at the FlexSNG plant is minimal as the average moisture content is around 25 wt%.

Storage of recycled waste wood is in loose outdoor piles. Different qualities should be stored separately to minimize the risk of dry material losses and self-ignition. If compacted into bales and coated in plastic, outdoor storage for up to three months is common. Available transport modalities depend on the transport distance, but road, rail, and sea are technically possible.

5.11 Olive cake (SE)

The olive oil value chain produces several types of solid residues which can be used as biomass fuels. Olive mills treat the olive fruits and, apart from the olive oil, also produce olive pomace. Depending on the production technology, olive pomace can be wet (moisture content of around 70 %, from two-phase technology) or dry (moisture content of around 50 %, from three-phase technology). The olive pomace contains residual oil, which is extracted in larger facilities, known as olive pomace mills. The olive cake, also known as extracted olive pomace, is the solid residue resulting this extraction process. Essentially, the olive cake includes the processed residues of the olive fruit:

flesh, skin and any amount of olive stones that may not have been removed as a separate fraction.

The olive stones themselves are a very interesting biomass assortment. They have an ash content of around 1 % weight and a moisture content of 20 - 22% weight when separated. Their calorific value is high and their quality can be further improved through valorization: drying and removal of the fines via sieving. In certain markets, such as the Spanish one, separation and valorization of olive stones is more frequent and the assortment is available for residential / small-scale heating applications and as a product analogous to wood pellets. In other olive oil production regions, separation of olive stones is less frequent and the assortment is essentially integrated with the olive cake.

The olive cake is a granular material and fairly dry after its production, with a moisture content of around 20 %. However, it can be dried naturally even a little further, so it is usually found with moisture content of around 15 %. On the other hand, its ash content is quite high (typically between 5 – 10 % wt dry basis). Its calorific value is high and since it does not require a separate processing step, it has a competitive price, which makes it quite attractive for industrial applications.

Ultimately, the olive cake represents around 20 % of the weight of the olive fruits processed for olive oil production. A significant part of the olive cake production during each campaign is used internally by the olive pomace mills (for drying the incoming pomace and for generating steam for the extraction), as well as by olive mills (for hot water production). The volume of leftover quantities – as well as their price – depends on how good the olive oil season was. Generally olive cake is made available for various applications: greenhouse heating, lime production, power generation and others, even residential heating in some cases.

Since it includes the residue of the olive fruit flesh, olive cake has very distinct and often quite strong smell (compared to olive stones). It is also more prone to biological degradation than the stone fraction.

In local markets, olive cake is usually transported via trucks in bulk and handled like any other kind of bulk biomass material. Roofed storage is ideal but not always the case. For longer transport to long distances (e.g. power production plants in West/North Europe), olive cake can be transported via ship as well.

The geographical areas for olive cake production are obviously connected to the main centers of olive oil production: Spain, Italy, Greece and Portugal are the main EU producers, while Tunisia, Turkey, Morocco and other Mediterranean countries are also important producers.

More information on olive cake can be found on the Guide: "Agroindustrial residues to Energy3" developed by AVEBIOM (Spanish Biomass Association) and CERTH (Centre for Research and Technology Hellas) in the framework of the AgroBioHeat project.

6 Concluding remarks

The conclusion is that there is a possibility to arrange and modify the feedstock activities to better suit the FlexSNG process. In the later demonstration of a 20% supply cost reduction these aspects must be considered since they influence both quality and cost. Therefore, an optimization model that can handle different designs and orders of activates must be developed to fully explore this potential in the later optimization tasks.

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7 References

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