Biomass from agricultural pruning and plantation removals

A FEASIBLE PRACTICE PROMOTED BY THE UP_RUNNING PROJECT

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CONTENTS

This is the first of a series of three monographs to be released by uP_running. This monograph provides an insight to the current status of use of APPR biomass, its difficulties, the possible alternatives to organize a value chain, and some practical recommendations to do it. Still two additional monographs are to be produced. The second will verse on the existing framework conditions in Europe, main barriers, opportunities, and strategies that can be followed to release the large endogenous European APPR biomass potential. The third monograph will summarize the keys for success to develop a new APPR biomass initiative, based on the analysis of multiple existing cases, and on the specific lessons learned from the entrepreneurs accompanied by uP_running.

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1. Introduction

1 INTRODUCTION

The utilization of agro-residues as a source of biomass is an opportunity for supporting the expansion of the bioeconomy in Europe. Among the multiple agro-residues, those produced from vineyards, olive groves and fruit plantations represent a significant potential for many EU countries. Specifically, the woody biomass residues from **A**gricultural **P**runing and **P**lantation **R**emoval (**APPR** from now onwards) is a paradigm of agro-residues being produced year after year, and, in the vast majority of the cases, not utilized as a resource for added value activities like the production of energy, biochemical or other biocommodities.

The use of APPR biomass is possible. It is a fact. There are multiple examples along Europe that prove it can be utilized. However, even though there is a large potential in Europe to be exploited (estimated more than 25 Mt of dry matter per year [1]), the cases of success in establishing a value chain for APPR biomass are scarce, occurring isolated. At the moment, the wide spreading of the utilization of APPR biomass appears stuck. There are multiple reasons for it, which are related to technical barriers, but also - and more importantly - to non-technical constraints such as cultural attitude, current regulatory framework, market prices of fossil or other biomass fuels.

The uP_running project (www.up-running.eu) is an Horizon 2020 initiative bringing together 11 partners from 7 European countries, allied with the same objective: to promote the take-off of APPR biomass in Europe. uP_running illustrates the collaboration between technology and research centres, universities, agrarian associations, agrarian chambers and clusters to drive a real change towards an increased utilization of APPR biomass, by promoting the start-up of new initiatives, but also by promoting a more favorable framework and social perception.

The present document is the first monograph produced by the uP_running project. It aims to provide the reader with a general overview on the difficulties to start up new initiatives and with a specific insight into the organization of the value chain operations: how the different stages of the value chain and logistics can be carried out, how to preserve the value and characteristic of the APPR biomass, and what should be regarded when facing its utilization to produce heat and/or electricity. Two more monographs are expected to be produced by the uP_running project until 2019. The second one will focus on the existing framework conditions in Europe, main barriers, opportunities, and strategies that can be followed to release the large indigenous European APPR biomass potential. The third monograph will summarize the keys for success to develop a new APPR biomass initiative, based on the analysis of multiple existing cases, and on the specific lessons learned from the entrepreneurs accompanied by uP_running from 2017 till 2019.

2. Status of APPR biomass in Europe

2 STATUS OF APPR BIOMASS IN EUROPE

2.1 The fact: energetic utilization of APPR biomass is possible

The use of APPR biomass is already a fact. Multiple private initiatives or projects promoted by municipalities provide evidence for it.

The degree of penetration of the APPR biomass on the European market is, in general, much lower than conventional biomass like forestry wood or even other agro-residues like straw, despite the fact that the wood from APPR is being produced periodically and it is subject of agronomic practices for its use or disposal.

The case of annual, biennial, or periodic prunings, the energy use of agricultural pruning is rather low in Europe [2]. The energetic utilization of APPR biomass in modern energy conversion system (e.g. efficient furnaces, boilers or gasifiers) usually corresponds to less than 5 % of the management practices. The use of firewood can be relevant locally in some rural areas where thick parts of pruning wood are valorized by part of local inhabitants, generally not an extended practice, thus in general lower than 20% of final use), but in general its use can be considered small at EU scale. The main management of the pruning biomass is its open-air burning, its disposal at field side where it is abandoned, or its use in form of shredded pieces widespread on the soil plantation (see section 3.6.2 for further details).

About wood from plantation removal, it is usually produced when vines, olive or fruit trees are cleared out at the end of the lifetime of a plantation. In some cases, the termination of a plantation is driven by changes in the food market (in order to grow a new fruit or grape variety), by agricultural policies (for modernization and reconversion of plantations) or by other particular reasons (plague/disease, farmer or exploitation manager). As for prunings, the wood from plantation removals is mostly under-utilized in Europe [3,4], although traditional use of firewood from the aerial part of the tree may be usual in some areas. In such cases, the stump and roots, as well as thin branches remain unutilized. In many cases, the whole tree is just up-rooted, piled with others, and fired in the open air.

Notwithstanding this general situation, there are successful cases of modern value chains at local or regional level based totally or partially on APPR biomass. More than 20 cases have already been identified by the uP_running project and are recorded in the uP_running "Observatory", the web-based tool developed for recording APPR experiences [5] (see a screenshot in Figure 1).

Figure 1 Screenshot of uP_running Observatory [5] displaying identified APPR biomass value chains and flagship cases (until April 2018) - http://www.up-running-observatory.eu/.

In all of the value chains identified, a major issue has been solved: a change in the management of the residues. This is the masterpiece when facing the use of any type of APPR: the producer of the residue (that is a farmer, a cooperative, a company dedicated to produce fruit/olive/grape) deals with a change in the current method to perform the crop agronomics and its timing. This change is not always easy and requires a coordination with the other value chain actors downstream (see Figure 2). On the other side, the value chain actors like biomass suppliers, managers of residues, or other intermediaries, are usually unaware of the needs of farmers and companies, and see the APPR biomass as a market product, without considering the effort needed downstream to drive the change in the residues management.

Therefore, even if there are multiple barriers and difficulties retaining the take-off in the use of these agro-biomass woody residues, the first issue to address is to find a way to modify the current management of the residue in a way that is beneficial for all the value chain actors, from farmer to consumer. The dialogue and mutual understanding is precise, especially where a new value chain is still not established. This fact is remarked in Figure 2, where the key roles of the different value chain participants are specified.

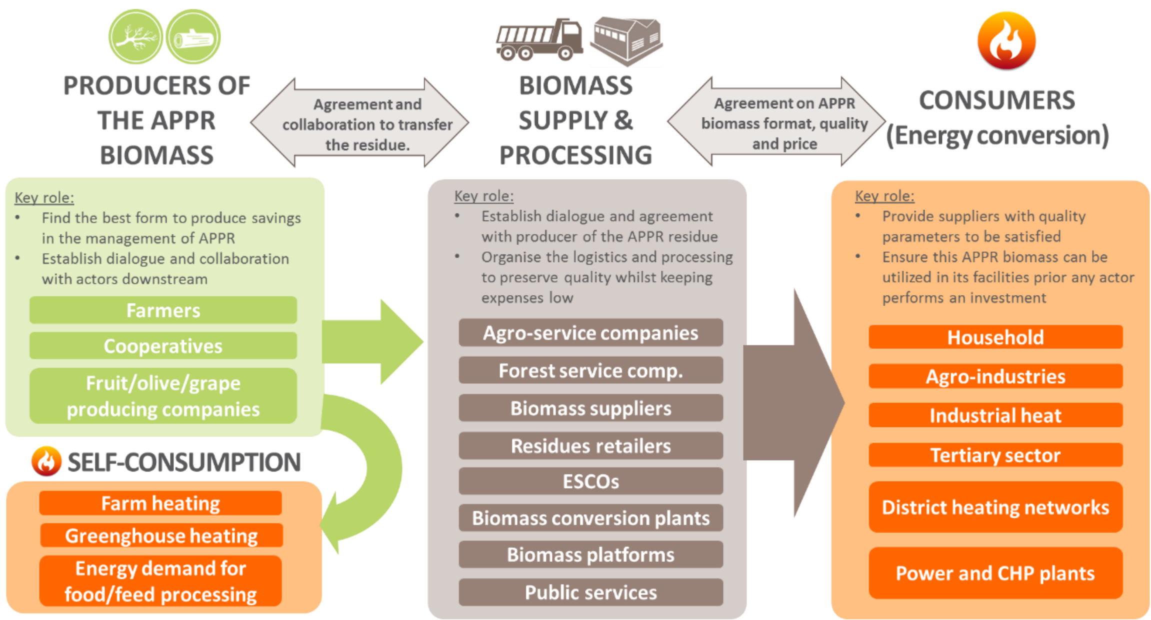

Figure 2: The three groups of key actors participating in the APPR biomass value chain: types of actors, interrelations and main roles.

Derived from this fact, an important part of the current APPR biomass use remains in self-consumption practices (marked in Figure 2 with a green curved arrow), or as APPR firewood produced and consumed locally in traditional stoves or boilers. Both cases represent the largest volume of APPR biomass consumed in Europe. Modern value chains, like those presented in Fig. 1 (*e.g.*, power plants running on APPR biomass), are much less extended. The next sections are intended to highlight the usual barriers and the lessons learned, especially with respect to the organization of the value chain operations. Moreover, further insight will be provided in the second and third uP_running monographs, which will describe the existing framework conditions in Europe and the keys for success to develop a new APPR biomass initiative respectively.

2.2 If it is possible… why doesn't it expand more? Barriers and driving forces detected

It is true that there are several successful cases of APPR biomass use to energy, although it is equally true that promoting new value chains based on APPR biomass is absolutely more difficult than starting new value chains based on forestry wood, or even other biomass types. On one side, there are diverse technical factors that may limit or bring difficulties when starting a new initiative to use APPR biomass, as for example: availability of mature, efficient and adapted machinery, logistic and monitoring systems prepared to the usually disperse source of APPR biomass or availability of boilers ready to use APPR wood). However, under the vision of uP_running project, beyond these technical issues **what really retains the huge, unexploited APPR biomass potential in Europe are non-technical barriers.**

These non-technical barriers have been revealed through **direct consultations with more than 600 stakeholders** in workshops celebrated in Spain, Italy, Greece and Ukraine. uP_running has already gained much knowledge on the barriers constraining the development of APPR biomass sector, but also about the driving forces capable of unblocking the current situation. The analysis started from the local dimension of the problem by performing 19 workshops and 36 direct interviews held in several European regions: Aragon (Spain), Apulia (Italy), Macedonia and Trace (Greece), Peloponnese (Greece) and Vinnytsia (Ukraine). The different information and visions collected were integrated in form of 4 Regional Action Plans, accompanied by an aggregated document from a wider European perspective [3]. Additionally, uP_running has performed 7 national country analyses based on collected information and visions of numerous national players, finally leading to 7 national strategic plans and a European integrated plan for the promotion of APPR biomass [4].

In principle, when considering the sector (see stakeholders type in Figure 2) with respect the use of APPR biomass, it is observed that there are **much more weaknesses than strengths**, or in other words, that the position of value chain actors to participate in new value chains is not well developed, and that the sector has more deficits than capacities. In contrast, when observing the external factors (opportunities and threats), the **opportunities stood over the threats**. This talks of multiples successful and unsuccessful stories. At the light of the multiple opportunities, an entrepreneur in an area shall take action guided by its intuition. Then the entrepreneurs will look for other cases they can replicate or shall ask for technical advice. Prospering or not depends on the capacity of the entrepreneur to successfully design and set into gear the new APPR biomass value chain and business. If the decisions are adequate, and if constant care is taken to steer the initiative and adapt to changes, then the new value chain will prosper. The new value chain will bring the expected benefits to the value chain actors involved, generally tangible (economic saving, incomes) and intangible (brand, image, strengthen position), and thus the opportunity that guided the entrepreneur, will become materialized.

From a global point of view, both the barriers and the driving forces may be related to (a) cultural attitude, (b) know-how and technology, (c) economic and finance, or (d) governance and policy. Figure 3 depicts few of the most relevant barriers and driving forces identified in the national framework of multiple EU countries. What can be found in most countries is a general interest in some of the driving forces depicted whereas in practical terms there are no mechanisms or instruments actually favoring APPR use as one of the alternatives in line with such general interests. Some of the driving forces could trigger by themselves a sudden change in the national paradigms, e.g., a sustained increase of the fossil fuels prices or a public initiative to use APPR biomass through public procurement.

Figure 3: Summary of potential driving forces and barriers affecting the development of the APPR biomass use in a national framework [3]

Under the absence of relevant driving forces, APPR biomass remains underdeveloped. Breaking the situation at national scale becomes complex, as the situation is stuck in a vicious circle, as depicted in Figure 4. At local scale, when trying to start a new value chain, a “chicken and egg” problem has also to be solved: a consumer is interested in APPR biomass will usually find no providers and lots of uncertainties and risks to be faced. When a biomass producer decides to collect APPR wood he finds usually no consumer, and much distrust about the quality and properties of the APPR biomass. Additionally, they find no example or model to follow, while informed counsel is also difficult to be obtained.

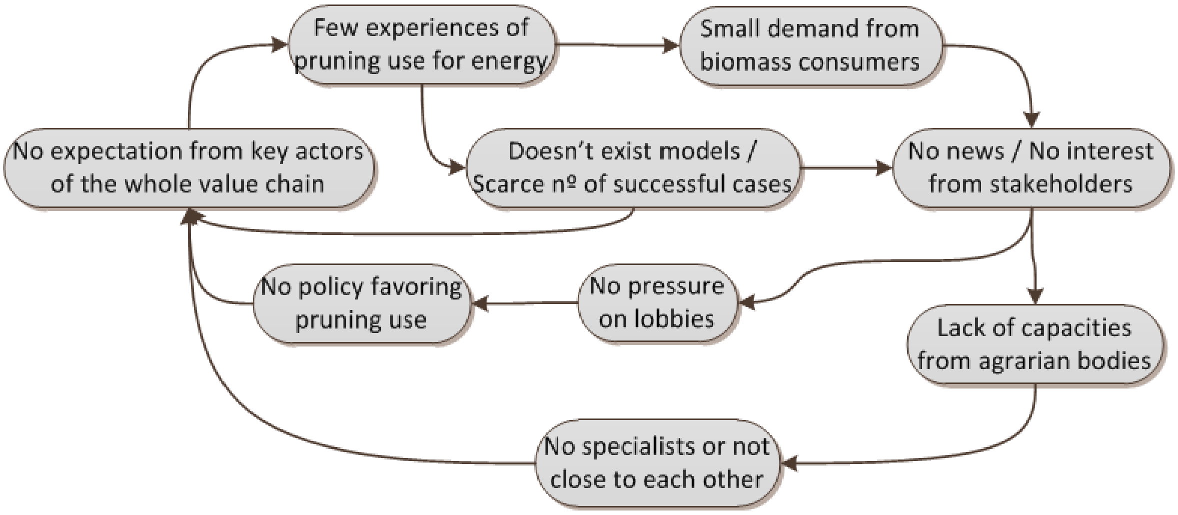

Figure 4: The circular problem found at national scale when APPR biomass is intended to be promoted (based on [1])

3. Understanding APPR value chains

3 UNDERSTANDING APPR VALUE CHAINS

3.1 APPR biomass dispersion and productivity

Collecting the wood from pruning or from the trees of plantations to be terminated poses a series of difficulties to the logistics due to several factors:

1) its dispersion in the territory,
2) the size and layout of the plantations;

Size and layout of the plantations as well as their territorial dispersion are the first two factors to be considered. In many cases, vineyards, olive and fruit plantations are organized in small parcels and distributed in the territory. In several cases (for example, several olive groves and vineyards in Southern Europe) the terrain has high slopes and features that may limit the capacity of a machinery to operate. Excessive maneuvering time can also occur due to the simple fact that a machine needs to operate in a field with a presence of trees that should not be damaged. Finally, moving machines from field to field requires additional time. All these aspects impose limitations on the types of collection systems that can be utilized and can increase operational costs. Moreover, in order to mobilize large volumes of biomass, an involvement of a large number of farmers and plantations is necessary, which increases the coordination and logistics costs. Farmers usually want to dispose residues from their fields quickly; the risk is that, when delays occur due to weather, or to unavailability of a service for APPR biomass collection, farmers or plantation managers may opt for disposing the residues as usual, e.g. through open air burning, mulching, etc.

A third factor conditioning the organization of the biomass supply from APPR residues is the fact that production of biomass per hectare is low in comparison to forestry wood, and thus operations of collection, handling and processing at field are usually subject of relevant costs per unit of material processed. The APPR biomass productivity ranges from 0.5 to 10 t/ha (dry matter). The lowest productions correspond to annual pruning of crops grown in dry areas without irrigation, or in areas of poor soils under low input agronomics. Annual pruning from crops in good climatic and agronomic conditions can usually produce from 0.5 to 2.0 t/ha (dry matter). Biennial pruning, as in case of olive groves can range from 2 to 4 t/ha (dry matter), whereas less frequent operations like toppings or re-shaping of tree forms can produce even larger amounts. The biomass productivity from plantation removals can reach 5 to 10 t/ha dry matter or even exceed it. In comparison, forestry exploitations can easily reach above 40 t/ha dry matter of stem-based wood.

APPR productivity depends on multiple factors, as described by García et al. 2016 [6]: type of crop, variety and age, form of the tree, density, type of pruning (pre-pruning, graft pruning, maintenance, topping, etc.), climate and soil conditions, and other agronomic operations relevant. As a result, it is inadvisable to use standard literature values of APPR biomass productivity when scoping a new initiative. Evaluation through direct measurements is always recommended and a manual is already available on the uP_running Observatory [5]. Alternatively, data from the Observatory tool can be useful for a first guess as this google maps platform collects biomass productivity values from hundreds of field measurements in relation to the aforementioned factors.

3.2 APPR biomass as fuel

APPR from vineyard, olive groves and fruit trees are a woody biomass with good energy content, but with some particular differences in comparison to forest biomass. It is worth mentioning that several projects have provided evidences of these particularities. For example, according to the results of EuroPruning [7], one kilogram of APPR biomass is equivalent to 1.03 kg of forestry wood, at same water content (see Table 1). The main difference lies in homogeneity of particle size and shape, as well as in ash content (see section 4.2).

Forestry stem-based wood chips, which represents the best quality and are a “reference” fuel for several installations, usually have an ash content around 1 % on dry basis. This type of biomass is not contaminated with soil, dust or stones and does not contain twigs, pieces of branches, leaves or bark, which have a higher ash content than pure stem-based wood. Accordingly, APPR biomass therefore requires boilers with higher requirements in the systems dedicated to withdrawing ashes or to clean the flue gases.

Inadequate management of APPR biomass can cause a biomass initially below 5 % of ash to have more than 10 %, including gravel or stones, which difficult the operation for most boilers.

According to EuroPruning [7], S2Biom [8] and Biomasud Plus [9] APPR wood ash content usually ranges from 3 to 5 % of ashes (dry basis). However, depending on the management operations, their ash content may reach levels of 10 % in dry basis, or even more. This is the case of prunings that are hauled out of the fields with tractors equipped with front forks. Then, the content of inorganic matter increases due to incorporation of soil and stones and may cause problems to the operation of a combustion systems (e.g. blockages of grates, increased particle matter emissions, etc.).

Table 1 Characteristics of different types of APPR biomass after mechanical collection (by harvesting with integrated shredder) and processing (data from EuroPruning [7]). Comparison with pine wood chips of class B (norm EN-ISO 17225). ar: as received. db: dry base.

COMBUSTIBLE	Pine chips Class B	Almond pruning	Peach tree pruning	Olive pruning	Vineyard pruning
Water (% wt, ar)	**≤ 35.0**	34.4	37.5	27.6	41.5
Ash (% wt, db)	**≤ 3.0**	4.6	3.7	4.8	3.5
LHV (MJ/kg, ar)	**-**	10.6	10.5	12.5	9.2
LHV (MJ/kg,db)	**18.2**	17.4	18.3	18.2	17.4

3.3 How to collect and mobilize pruning wood

One of the main challenges for using the pruning biomass to energy consists in finding the most appropriate system to collect the APPR biomass. Collection systems affect the APPR biomass quality, and thus its value, but also have a direct influence in the organization of the logistics and handling operations downstream. Furthermore, collection is a critical stage as it can have an impact up to 60 % in the total costs for APPR mobilization, based on some preliminary economic analysis by uP_running project.

For the collection of wood produced from pruning operations, three main configurations can be proposed:

1. Hauling branches and shredding/chipping/baling at field side
2. Collection integrated with shredding/chipping/baling
3. Pre-pruning with integrated shredding/chipping

In the two first methods, the pruning wood is collected from the soil, whereas the third case allows a direct collection from the tree during the mechanical pruning operations. In the next sections, more details are given for each one of these collection methods.

3.3.1 Preparing the pruning wood before collection

When pruning operations are performed, the branches removed fall on the plantation soil, in a circle around the tree trunk. Three main scenarios exist, depending on how the prunings are then arranged:

1. to windrow or to organize them in the center of the lane between tree rows; this is the ideal option in cases of pruning collection or even when a mulcher is used, since it minimizes the working time of the tractor;
2. to leave them as they are and pass with the treating machinery nearby, even though it may require passing with the machinery 2 or 3 times along each lane. This option is also more complicated since the presence of branches on the standing trees may limit the movement of tractors / machinery.
3. to collect them in piles in the middle of the rows; this option could be acceptable if a static chipper is employed.

The preparation of the prunings is not technically complex. It can be carried out manually or mechanically (by means of windrowers). Windrowers or pruning sweepers are usually coupled to the hydraulic circuit of tractors, mounted in front or at rear, either in both or in one side, depending (respectively) if they work to bring all pruning to center or only work nearby one of the tree rows. The sweepers are usually made of flexible, but highly resistant plastic bars, rubber blades or wires. Some examples are provided in Figure 5.

Windrower with plastic bars (image from EuroPruning project [11])

Windrower with rubber blades (image from EuroPruning project)

Windrower with wires (*acordonador-girolivo.blogspot.com*)

Figure 5: Different types of windrowers

The preparation of the pruning is a crucial part of the work. Firstly, this operation can be partly facilitated by the farmer or plantation manager. The preparation or windrowing needed may differ from the usual methods of the farmer; therefore, a negotiation may be needed. The correct preparation of the branches (alignment, width of the windrows) has a direct impact on: the performance in ha/h (and thus on economics) and on losses (amount of material not collected). It is to be highlighted that high losses have a double impact in the viability of the biomass collection: firstly, the costs per ton obtained are higher; and secondly, the farmer or plantation will have to perform an additional, probably manual, operation for removing the branches remaining. This causes an additional cost to the plantation owner and thus, put in risk the economic savings of the biomass producer. Or, it may result in an arrangement that is simply not agreeable with the farmer.

3.3.2 Hauling the branches and shredding/chipping/baling at field side

This method consists in hauling the branches out of the field, where they stay temporary piled. The branches can be moved manually in case of small orchards. In such cases, the branches shall be only partially contaminated with soil particles and stones. When the haulage is performed mechanically (tractors equipped with a rake or a fork), then more inorganic materials is collected. In case of vineyards, the amount of stones can be particularly large. Figure 6 provides an example of this problem.

Figure 6: Haulage of branches shall cause relevant incorporation of stones and soil. Example of vineyard pruning after withdrawal, with stones (uP_running demonstrations in Spain).

After the haulage to the side of the field, the branches can be directly loaded on a truck to be transported to the final consumer or to a biomass hub or logistic platform. This alternative is feasible in local uses and short distances, since the branches inside a truck occupy an important volume[1] and the final weight transported is low in comparison to chips or bales (which density is much higher). An alternative is to perform the processing at the field side with implements of different size and power, depending on the volumes to be processed and the availability of machinery or companies ready to provide the service. The material can be shredded into pieces of

[1] Bulk density of branches may range 90-120 kg/m^3 (dry basis), while bulk density of chips uses to range 200-300 kg/m^3 (dry basis).

large size (*e.g.*, G150 or G300), can be shredded in form of heterogeneous material (usually called hog fuel, G100 or smaller), or it can be baled. The different options are depicted in Figure 7.

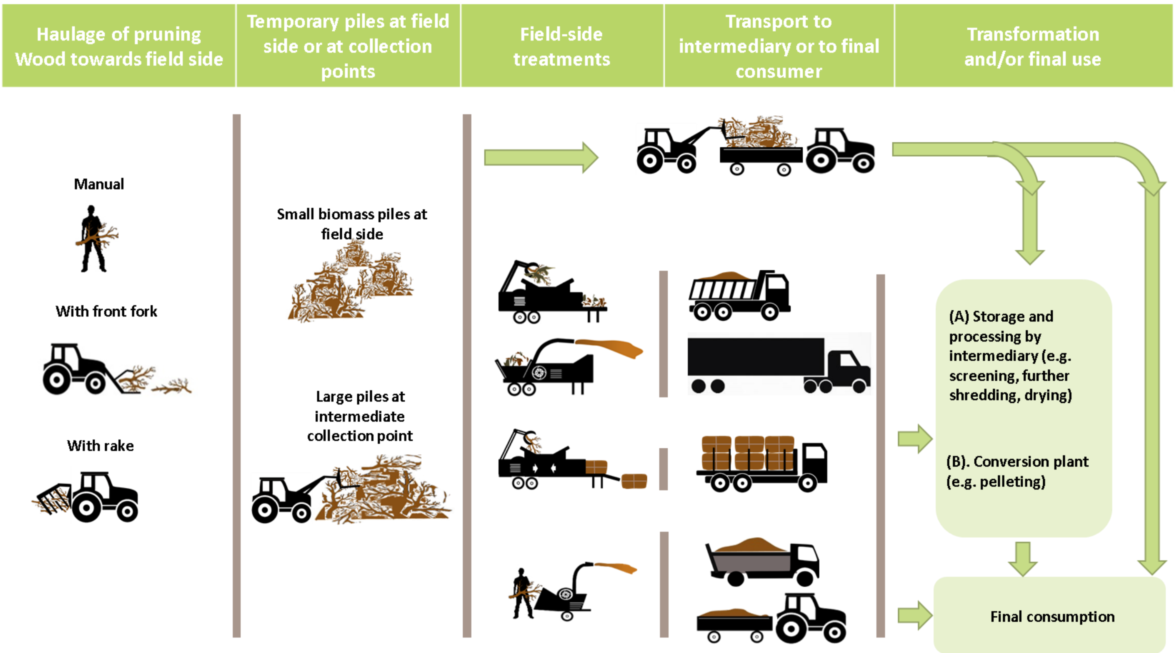

Figure 7: Alternatives for implementing the supply chain when prunings are hauled to the field side.

Chipping machinery includes blades or knifes that can be rapidly deteriorated if they process wood with abrasive inorganics, such as stones and soil particles. Since branches are usually contaminated with such inorganics, the application of chipping is not typical for the handling of prunings. Shredders with hammers are preferable, since they are better suited to the comminution of unclean wood.

As case example, uP_running performed several demonstrations of pruning collection, showing that the haulage can be performed appropriately. In Spain, both cases of appropriate and inappropriate haulage took place. Pruning from large branches taken from peach tree plantations were hauled with tractor, and piled manually, and its final ash content was as low as 1.5% (d.b.). This percentage is really low as compared to the values presented in Table 1. However, in another experience with vineyards the amount of stones inside the piles of pruning shoots collected were so high, that it was needed several cleaning operations before the prunings collected could be processed with a large shredder able to cope with contaminated wood, but not with such large amount of stones.

According to uP_running experience, farmers are usually eager to suggest this method, as it implies lower costs for them, no investment, and no need to negotiate or coordinate with an external company to enter in the field (as the material remains outside in piles). However, when the haulage incorporates important amounts of inorganics, the material obtained is not of good quality and may need additional operations to separate stones, gravels or soil. An additional advice is to leave the biomass drying in piles before the treatment, as it will get drier and facilitate its handling. Additionally, rains shall partially contribute to remove part of the inorganics collected.

3.3.3 Harvesting with integrated shredding/chipping/baling

In this case, the branches are collected from the soil, within each field row. An effective operation with these types of implements requires that the prunings are aligned in windrows (either manually or mechanically prepared, as discussed in 3.3.1). These machineries integrate the collection and the treatment, that can be a shredding, a chipping or a baling of the branches collected. The system can be mounted in front of the tractor and then it avoids driving over the branches (see Figure 8 cases ‘a’ and ‘b’). However, when mounted at the rear, the tractor drives over the branches (see Figure 8 cases ‘c’ to ‘f’). In such cases, it is recommended to adapt the tractor with some protections underneath to avoid damages in electric connections, hydraulic systems or other systems exposed to the contact with the branches. There exist few self-propelled machinery, even though they are unusual, and thus not depicted in Figure 8.

The material collected and transformed into shredded wood or woodchips is sent either to a trailer towed behind (cases ‘a’ to ‘c’), to a big-bag (case ‘d’) or to an integrated deposit (able to tilt and discharge, as cases ‘e’ and ‘f’). In these last cases, it is important to avoid forming a pile of chips and letting it on soil (case ‘e’): it negatively affects quality and costs, as it will need an operation of loading to a trailer or truck. The preferred practice should be the direct discharge on trailer, container or truck.

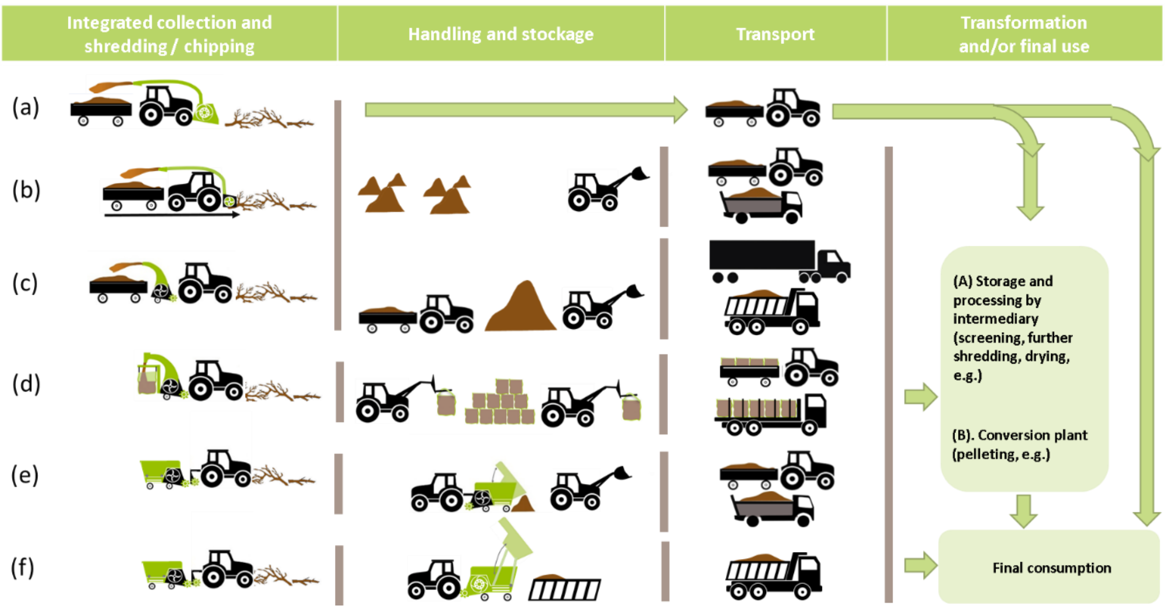

Figure 8: Alternative paths for implementing the supply chain when collection and shredding/chipping of prunings is integrated in the same machinery.

The different implements shown in Figure 8 are offered by multiple brands with shredding technologies. The simplest shredding systems utilize hammers without any sieves, and thus produce an inhomogeneous woody material consisting on pieces of branches partially defibered, as they are comminuted by impacts of the hammers. More evolved shredders combine hammers with sieves and other teeth shredding or cutting systems, producing a very fine shredded material. This type of systems is less common, usually more sensitive to stones and with higher maintenance costs. On the positive side, the material produced, still not comparable in shape to woodchips, is more homogeneous and thus it is more likely to find direct consumers for it.

Another option of the integrated systems is to collect the pruning branches from the soil and baling them in form of round or square bales, as can be seen in Figure 9. The baling operation is as quick and effective as shredding or chipping (allows a similar velocity of advance). There exist already commercial balers for prunings able to produce either round or squared bales. Balers for pruning are colored green in Figure 9. In some cases, the prunings can be baled with regular hay balers by incorporating some modifications. These implements are shown colored in black in Figure 9. Normally the bales are more irregular, less compressed and more instable than bales produced with specific pruning balers, though this is not necessary a main issue, depending on how the value chain is organized.

In respect Figure 9 t, as observed, the principal differences are the bale size and the shape, either squared or round. In case of small bales, the loading, transport, storage operations are more time consuming. The use of forks, shovel or grabber to handle the bales usually cause them to partially change in shape, especially when handling bunches of small bales. The systems denoted with (a) are small round bales prepared for pruning, especially for vineyards. Its use has been demonstrated to be appropriate for self-consumption and local consumption (with particular advantage that bales can be handled manually). Small squared balers (b) are also usually prepared for vineyard pruning. Large balers producing round (c) and squared (d) bales are more appropriate for producing larger volumes of biomass or in farms where there is already a boiler capable of handling large bales.

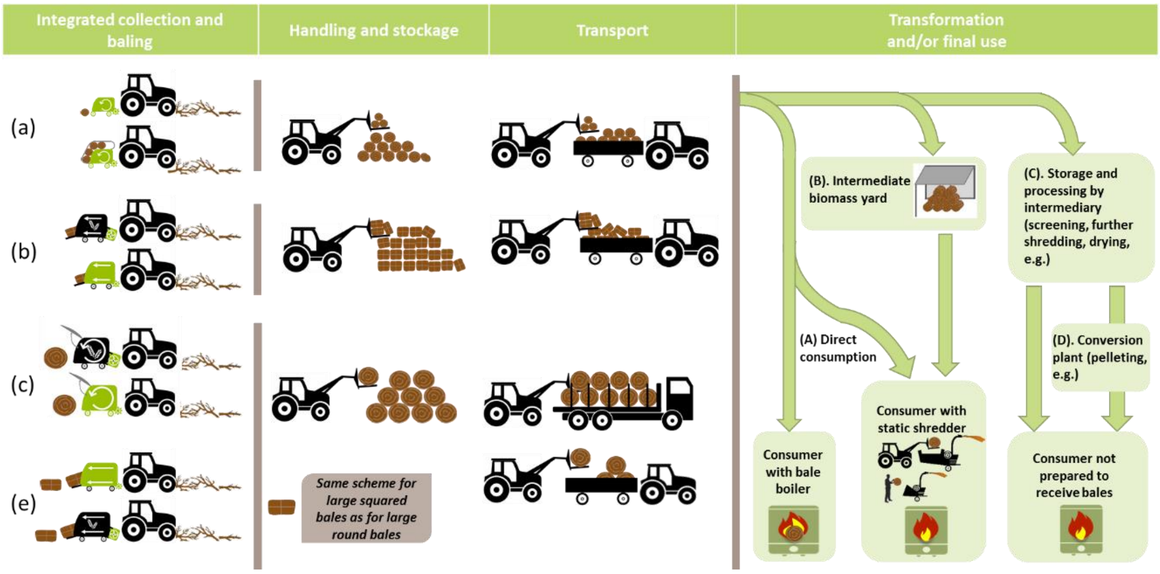

Figure 9: Alternative paths for implementing the supply chain when collection and baling of prunings is integrated in the same machinery.

The advantage with bales is the better storage and the lower tendency of the wood to decompose when stored. However it involves a series of disadvantages to be taken into account, as they condition the subsequent logistic operations and costs: after being produced, bales have to be picked-up and hauled to a place at plantation side; loading and unloading involves longer time and additional costs than bulk shredded wood or woodchips; the pruning bales tend to be less stable than straw bales, and usually lose its initial shape; finally, unless the final user already has a baler boiler, the bales have to be shredded before consumption. Baling is, however, a practice carried out already in some success cases like in Domaine Muller (France), Cantine Giorgio Lungarotti (Italy) or Wienawia (Poland). Further details on these cases can be found in the uP_running observatory.

3.3.4 Pre-pruning with integrated shredding/chipping

Although this last option has not been implemented until now in existing chains, it is introduced in this monograph due to its great potential to reduce costs and collection performance. As the modernization of fruit, olive and grape plantations proceeds, the mechanization is penetrating and incorporated more in the agronomical practices [2]. The mechanized pruning is a method quite extended for vineyards, which allows a cutting of a relevant part of the vineyard shoots. An attempt to implement a vineyard pre-pruner integrated with biomass collection has been already carried out in the framework of the Life+ project Vinyards4heat [10].

Another existing implement is a self-propelled integrated harvester capable of performing both pruning and pruning residue harvesting in a single pass in tree alignments, and thus applicable to reconverted intensive fruit and olive plantations. A multiple-disc cutting bar is mounted on a hydraulic boom hinged on the right side of the carrier, which performs the cutting, and the pieces fall on a belt conveyor that feeds the shredder.

The implements mentioned, and briefly described Figure 10, are technical solutions that are either in development or not very widespread yet (although commercially available, in case of Favaretto). Therefore, as for the moment, no pruning biomass value chain based in this collection method has been detected.

	*Vineyard pre-pruning integrated with collection and mulching/chipping* A prototype has been developed and tested in the framework of the Vineyards4heat project. Source: Vineyard4heat [10]	
	*Pre-pruning integrated with collection and mulching/chipping in an automotive machine* A commercial machine (Speedy cut) is offered by the Italian manufacturer Favaretto. Source: EuroPruning [11]	

Figure 10: Examples of implements designed to perform the integrated pre-pruning, collection and treatment the biomass

3.3.5 Pros and cons of the different pruning collection methods

Table 2 is given in order to get a better overview of the different methods available to collect and treat the pruning wood from olive, vineyards and fruit trees. A comparison of advantages and disadvantages is illustrated, as well as some existing value chain cases which apply each collection method.

Table 2 Comparison of the three pruning collection methods.

	Hauling branches and shredding at field side	Harvester with integrated shredding/chipping	Harvester with integrated baling	Pre-pruner with integrated shredder
Machinery needed	• Simple fork, rake, grabber coupled to tractor. • Static shredder / chipper (fed manually or with hydraulic arm).	• Shredder or chipper coupled to the tractor (mounted in front or behind)	• Baler coupled to the tractor at the rear • Tractor with fork / grabber to handle the bales	Pre-pruner adapted to be able to launch / convey pruning to gathering system
Pros	• Easiness for the farmer	• Limited contamination of the biomass with exogenous (stones, soil, etc.)		

<table>
<tr><th></th><th>Hauling branches and shredding at field side</th><th>Harvester with integrated shredding/chipping</th><th>Harvester with integrated baling</th><th>Pre-pruner with integrated shredder</th></tr>
<tr><td></td><td>• Branches can dry out without fermentation
• A local company shall provide the shredding/ chipping service.</td><td>• Material already processed (some consumers may be capable of using it directly)</td><td>• Storage is simple
• Wet branches dry properly in form of bales</td><td>• No additional cost (pre-pruning + collection integrated)
• No contamination (biomass does not touch the soil)</td></tr>
<tr><td rowspan="2">Cons</td><td rowspan="2">• Usually significant contamination of biomass during hauling (stones, soil, etc).</td><td colspan="2">• Windrowing / pruning preparation necessary
• Collection time may be large
• Driving over pruning requires installing tractor protections</td><td rowspan="2">• Non-existing value chains. Few prototypes / implements available
• Percentage of losses may be high during collection</td></tr>
<tr><td>• Moist shred material undergoes degradation during storage
• Chipping sensitive to stones
• Shredding usually not fine and needs further processing
• Case of big-bags: additional handling time, cost of big bags</td><td>• Bales tend to change shape with time
• Lower density than straw bales
• Handling is time consuming
• Need to shred if final consumer cannot burn bales</td></tr>
<tr><td>Existing value chain cases[2]</td><td>• Pelets de la Mancha (ES)
• Acciona Miajadas (ES)</td><td>• Biotoños (ES)
• Vilafranca del Penedés (ES)
• Fiusis (IT)
• La loma (ES)
• Sacyr Energía (ES)</td><td>• Domaine Xavier Muller (FR)
• Cantine Giorgio Lungarotti (IT)
• Wienawia (PL)</td><td>• Vilafranca del Penedés (ES)</td></tr>
</table>

3.4 How to collect and mobilize wood from plantations removals

The vineyard, olive and fruit trees plantation have to be renovated with a certain frequency. Whereas fruit tree plantations are usually subject of a shorter lifetime (10 to 20 years in market orientated plantations), vineyards and olives usually have a longer lifetime (circa 30 years for modern vineyards, 40 for olive intensive, or about 15 for olive under super-intensive management).

From a global point of view, the methods to collect and mobilize wood from plantations removal may be classified into three different approaches:

1. Whole tree uprooting, shredding and further processing
2. Felling the trees to be processed by crushing, shredding or chipping
3. Integrated felling with shredding / chipping

In all of them a cornerstone is the shredding or chipping device. As these systems must process a tree in a piece, they are systems of large power, either forestry chippers of large capacity, or large crushers or shredders as those generally utilized by treating industrial/demolition wood or other residues. When selecting a system, it is fundamental to take into account the following items:

(1) Transporting the whole tree is not efficient, and thus, except for short distances, the solution is to perform a first comminution of the material at field side. In contrast, the logistics and operation of chippers and shredders of large capacity is not always possible or simple. Moreover, the costs involved are high. Thus, a first decision is whether to perform the comminution at field side or to transport the bulk unprocessed trees to an intermediate facility where it can be more optimally processed.

(2) Degree of contamination with soil and stones: chippers are only adequate when processing the aerial part of the tree. Its roots and stumps are included, then a crusher or a shredder should be utilized.

[2] More information for each case can be found in the Observatory (http://www.up-running-observatory.eu)

(3) The balance between particle size and processing performance: even though it is interesting to perform as few processing steps as possible, processing whole trees into fine and regular material implies longer time and processing costs. Therefore, whenever the material produced is not transferred directly to a final consumer, but to an intermediate biomass hub or logistic centre, an option is to save time and costs in the operations at field side, meaning that the objective is to perform the comminution as rapid as possible.

(4) Feeding the crusher/shredder/chipper: the form of fruit and olive trees, with branches expanded in form of vase or fan, and with a short stem (in comparison to forest trees) makes difficult the feeding and the conveying at the inlet of the machinery. Feeding is usually the bottleneck for the performance. An ineffective feeding lead to very low performances, and thus to large costs per unit of biomass processed.

(5) Outlet system: ideally the best solution at field side is to discharge on a container or on a truck. Even though the processing is slow, the cost associated to waiting time of the transport should be considered. Discharging on soil implies two drawbacks: the material should be loaded afterwards (need of a shovel or telehandler) as well as the further contamination with soil.

In the next section, more details are given for each one of the different collection methods.

3.4.1 Whole tree uprooting, shredding and further processing

The typical operation when a plantation is terminated consists in up-rooting with bulldozers or excavators. The residues are usually piled to be dumped or burnt in the open air to be eliminated. When aiming to make a change in the final fate for these residues in coordination with the farmers or plantation owners, it should be considered that they usually prefer to perform the practice as usual. The challenge is then to obtain a biomass with sufficient quality for the consumers.

This practice obtains together the whole tree wood (both the aerial part, and stump with part of the roots). The material must be piled at the field side, and then either transported bulk to the processing plant (Figure 11.a) or treated “in situ” (Figure 11.b). As the material contains substantial amounts of soil and stones stuck to the roots, and due to the haulage carried out, it is recommended to shake the uprooted trees before its comminution. The mechanical systems better adapted to treat the biomass are crushers (low rotating velocity) or shredders (hammer shredding at high rotating velocity). Both produce respectively large pieces and inhomogeneous shredded material.

Except for the case that the material processed is directly sent to a final consumer with capacity to directly use or process it (Figure 11.c) the material should be transported to an intermediate point (biomass hub or logistic platform) where it can be object of screening and further shredding/chipping. In general, the wood produced from such a scheme is of lower quality in comparison to the methods where the aerial part of the tree is treated separately.

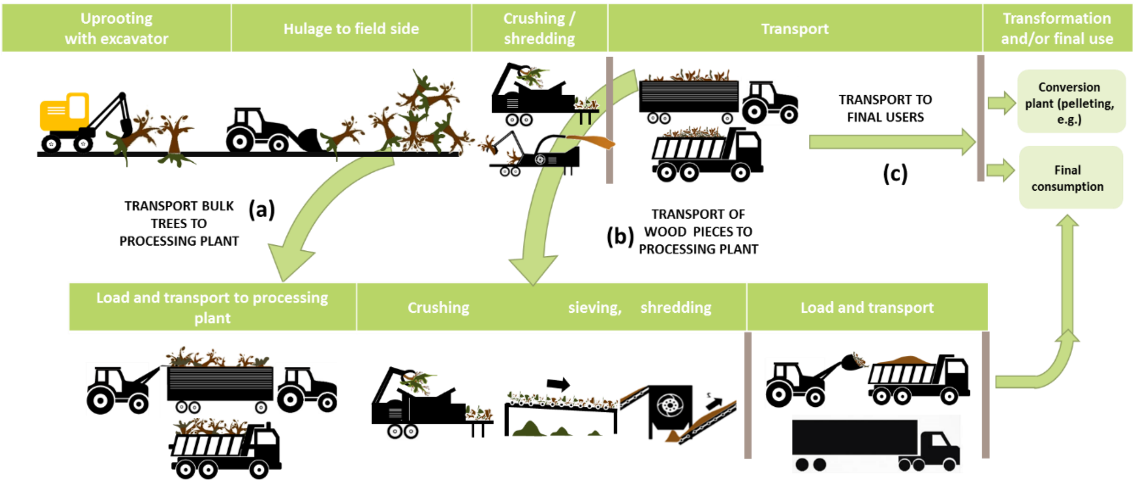

Figure 11: Alternative paths for implementing the supply chain of plantation removal wood when the whole tree is up-rooted and processed.

3.4.2 Felling the trees to be processed by crushing, shredding or chipping

An option to reduce the need of processing downstream the field side operations, improve the biomass quality, and thus, have a more competitive feedstock, consists in the processing of the aerial part of the tree. Trees can be felled manually by farmers or workers with chainsaws, or mechanically, with cutting discs or shears mounted on a hydraulic arm (see Figure 12). This method leaves stumps on the field. It has the disadvantage of the felling operation, which is an additional cost compared to the plantation up-rooting operation described in the previous section.

As observed in Figure 12 three principal alternatives can be discerned:

(a) Once the trees are felled, they can be treated directly without haulage. The main advantage is the better quality of the wood, as it has not been hauled along the field. Option (a.1) consist on a shredder/chipper of high power coupled to the power take-off of a large tractor. The system may need in some cases an alignment of trees, which involves some additional costs in the preparation. Case (a.2) consists in a kind of processing train, where a tractor pulls the forestry chipper and a large trailer. The implement moves alongside the trees felled and feed the shredder or chipper with an arm. The main trouble is to find a shredder able to convey the whole tree. The arm needs to push the tree at the inlet, and thus the feeding and final performance (measured in t/h) will be low. Both systems obtain a material that can be sent directly to final consumers; an alternative is to send it to an intermediate storage and processing plant for further treatment.

(b) Another option is the direct transportation of whole aerial part of the trees to the processing plant. This practice is possible in short distances. Whole trees are usually partly broken and loose their original shape when hauled with shovel or bulldozers, and thus, they fit and fill better the trailers or containers utilized. The processing centre carries out directly shredding or chipping. Alternatively, it performs a rushing operation. Sieving is not necessary unless the haulage has caused the wood to get polluted with soil and stones. Therefore, the means of haulage is a key issue.

(c) A third option is performing a chipping or shredding (c.1) or crushing (c.2) at field side. Chipping should be considered only when the haulage has been carefully performed, and stones or soil are absent. The material could be sent to final consumers, or alternatively, b sent to an intermediate centre for storage and further processing.

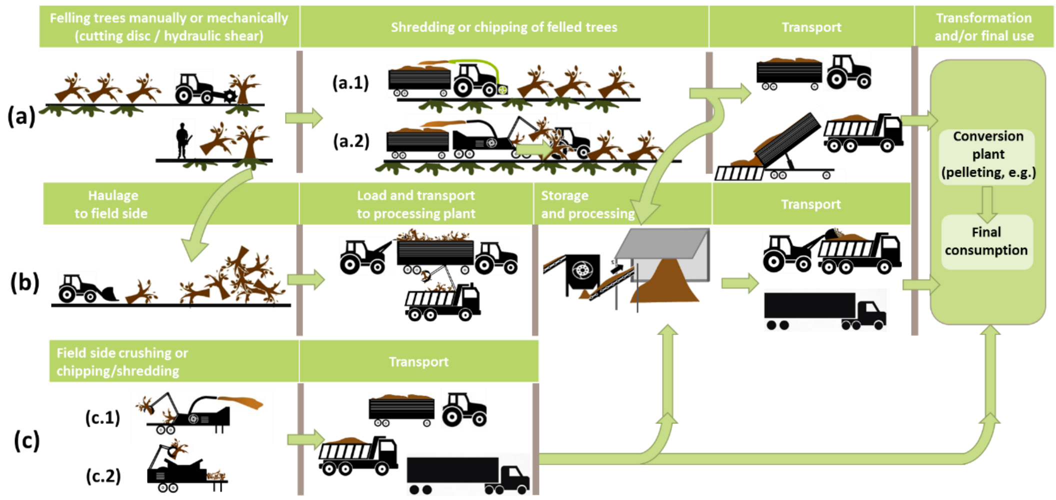

Figure 12: Alternative paths for implementing the supply chain of plantation removal wood when the trees are felled to obtain the aerial part of the tree.

3.4.3 Integrated felling with shredding or chipping

An alternative to optimize the processing is to carry out the operations in a single stage (see Figure 13). The process requires a tractor of high power with a large shredder installed in front. As the tractor advances in the line of trees, these are bended and/or cut and as they fall the shredder/chipper reaches the stem and start processing. Similarly to the operation with forestry chippers or large shredders or crushers, the investment is high. The main difference is that in the 2-stages process, the value chain actors to be involved in the area may already possess with the necessary machinery, and thus the use for plantation removals is a way to extend the hours that the machinery is utilized every year (and accordingly, to reduce the amortization costs). In the case of a single pass, it may be rare to find a local actor that owns the required high-power tractor and front shredders; therefore, the investment usually is totally on purpose to obtain the plantation removal wood. This is a main bottleneck for the deployment of this system.

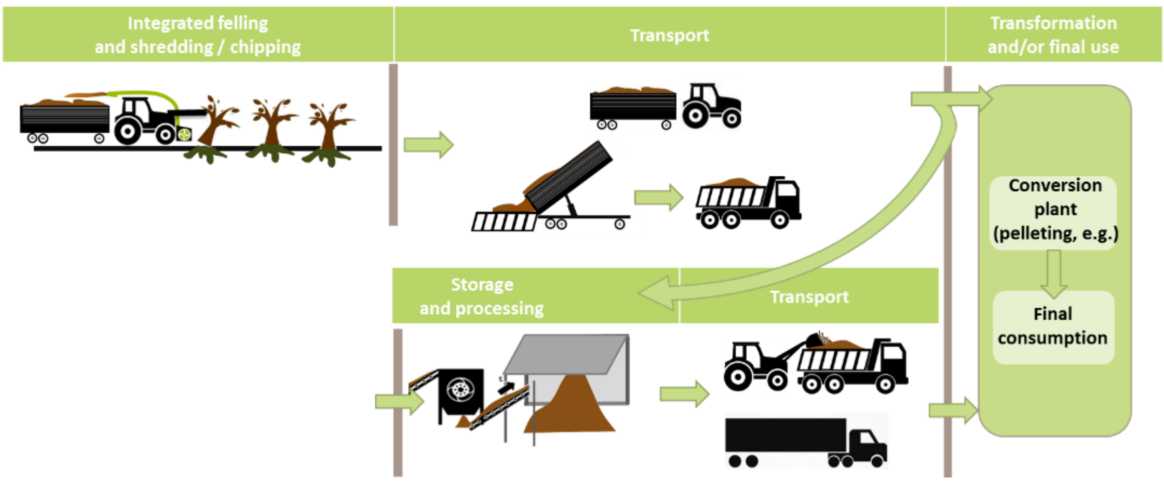

Figure 13: Alternative paths for implementing the supply chain of plantation removal wood when an integrated felling and shredding / chipping is performed.

3.4.4 Management of stumps

Stumps and roots remain in the field when only the aboveground part of the biomass is processed. Farmers usually need to clean these remaining parts of the tree in order to start a new plantation cycle. Wherever the burning in piles on the open air is the usual practice to manage the residues of plantations removed, farmers are reluctant to agree upon a new management where a third actor gathers the aboveground part of the tree. The reason is that stumps and roots do not burn properly, and thus, the disposing method fails. In such areas farmers prefer to uproot the whole tree, since then all residues (above and underground parts) are burned and converted to ash.

An option is to integrate a service of felling and obtaining the aboveground part of the tree, with the up-rooting of stumps and roots, and restoration of field soil. In such case, the farmer is completely released from the management operations of the plantation removal residues. The costs are then increased for the company providing the service, and thus a fee or money transfer is asked to the farmer (who should still save money with respect the as-usual costs). In other words, a service company could organize a service of plantation removal, leaving the field clean of residues to the farmer, but at a lower cost for him, given the fact that part of the biomass can be utilized to cover partly the plantation removal costs.

The diagram is similar to the case of up-rooting the whole tree, as explained in section 3.4.1. Figure 14 depicts the value chain organization.

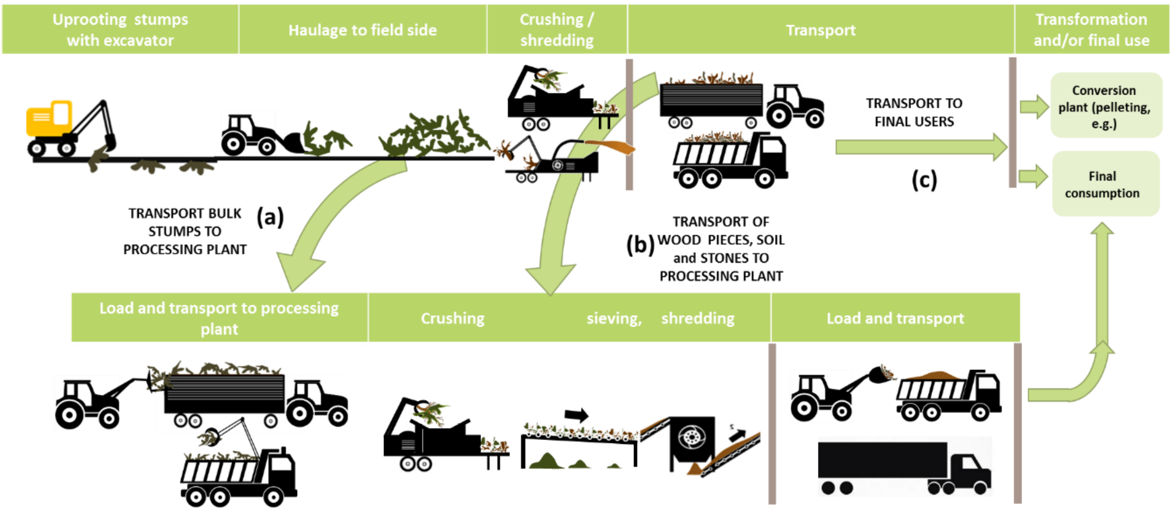

Figure 14: Alternative paths for obtaining stumps and roots and provide them to a final consumer.

3.4.5 Pros and cons of the alternatives to obtain the woody residues form plantations removed

The advantages and disadvantages of the different methods have been presented in the previous sections. Here a summary is provided in Table 3. As observed in Figure 11 to Figure 13, there are several options to arrange each supply. Table 3 presents the general advantages and disadvantages, excluding a specific option that has been presented in for the three different supply methods: the direct transport of trees (or aerial part of the tree) to a local processing plant.

Table 3: Comparison of the three pruning collection methods.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Whole tree uprooting, shredding and further processing</th><th colspan="2">Felling the trees to be processed by crushing, shredding or chipping</th><th rowspan="2">Integrated felling with shredding or chipping</th></tr>
<tr><th>(a) Chipping / shredding without previous haulage</th><th>(c) Field side processing with crusher, shredder or chipper</th></tr>
<tr><td rowspan="2">Machinery needed</td><td rowspan="2">• Retro-excavator / shovel / bulldozer for uprooting and haulage
• Large crusher / shredder to be operated at field side</td><td colspan="2">• Felling: Chainsaw (manual felling) or tractor / spider with cutting device (cutting discs or hydraulic shear)</td><td rowspan="2">• Tractor of high power and large shredder / chipper mounted in front</td></tr>
<tr><td>• (a.1): Tractor of high power and large shredder / chipper mounted in front
• (a.2): Tractor and forestry chipper with hydraulic arm</td><td>• Shovel / bulldozer for uprooting and haulage
• Large chipper / shredder to operate at field side</td></tr>
<tr><td rowspan="2">Pros</td><td rowspan="2">• Uprooting and haulage with normal machinery and “as usual” practice
• Simple to be performed</td><td colspan="2">• Trees not contaminated with soil/stones</td><td rowspan="2">• A single step operation is carried out
• Performance in t/h is high
• Material obtained is not contaminated with soil/stones</td></tr>
<tr><td>• (a.1) Does not need hydraulic arm to feed the shredder
• (a.2) Can adopt existing forestry chippers / shredders available in the zone</td><td>• Can adopt existing forestry chippers / shredders available in the zone
• Field side operation feeding from a large pile optimizes the performance (t/h)
• If stumps are requested to be eliminated, those could be processed at field side</td></tr>
<tr><td rowspan="2">Cons</td><td rowspan="2">• Biomass contaminated with stones and soil
• A process of sieving/cleaning usually necessary. Usually also further shredding needed
• The processing of a material with soil and stones leads to a faster deterioration of consumables in hammers / mills
• If haulage carried out carefully, to detach soil and stones, costs increase</td><td colspan="2">• Felling implies a significant cost
• Stumps are left on field. Owner may require them to be also withdrawn</td><td rowspan="2">• Stumps are left on field. Owner may require them to be also withdrawn
• The investment is high: tractor of large power and large shredder/chipper
• No commercial system available. Depending the type of trees to be treated the cutting / bending system may need adaptation</td></tr>
<tr><td>• (a.1) requires investment in a shredder / chipper or high cost
• (a.1) shall require an alignment of trees prior to processing
• (a.2) forestry chipper or shredder not always well prepared to be fed with fruit trees
• (a.2) the processing train may be too long and difficult maneuver
• (a.2)
• If stumps have to be treated, an additional machinery may be necessary</td><td>• Biomass has been hauled, and usually chipping is not possible (as it damages the chipper knifes)
• Material may require further processing (screening, sieving, further shredding)
• The processing of a material with soil and stones leads to a faster deterioration of consumables in hammers / mills
• In case the biomass is launched to soil, it requires extra operation of loading, and biomass quality impoverishes</td></tr>
<tr><td>Existing value chain cases[3]</td><td>• ENCE (ES)
• SOLAMUR (ES)</td><td>• EuroPruning demo [19]</td><td>• NUFRI (ES)</td><td></td></tr>
<tr><td>uP_running demos</td><td>• GRUYSER-ECOADESO (ES)</td><td></td><td>• GRUYSER-ECOADESO (ES)</td><td></td></tr>
</table>

In summary, the option of performing a direct transport of whole tree or aerial part of the tree bulk to the processing plant, the advantages are: avoiding displacement of expensive machinery to field side, simplification of operations at field, simple to be performed (farmers or local companies can perform the work). But it also implies a series of restrictions: inefficient transport and high costs involved. This practice can be considered as one of the possible alternatives for local supply of a biomass logistic centre or a processing plant in the proximity.

[3] More information for each case can be found in the Observatory (http://www.up-running-observatory.eu).

The processing of stumps and roots has also to be taken into account. The methods collecting the aerial part, as observed in Table 3, have as a drawback the lack of removal and treatment of stumps. Farmers or field owners may require a complete removal of all the plantation, not just the aerial part. In such up-rooting the stumps, haulage and treatment or disposing involve additional costs. If no benefit can be obtained by marketing this material, all costs should be covered by the incomes of marketing the biomass from aerial part, and from the service fee.

3.5 Transforming APPR biomass into energy

The last step for producing energy from APPR biomass is the final transformation of the fuel to useful heat and/or electricity. The chemical energy contained in the APPR biomass is usually obtained through thermo-chemical conversion in systems like furnaces, boilers, gasifiers, etc. The traditional use of APPR biomass was constrained usually to self-consumption in small heating devices. Although still relevant, new modern applications and niche markets have emerged in certain locations: heating of municipal buildings, farm heating or industrial processes. Moreover, the APPR biomass may also be co-fired in large thermoelectric plants to replace part of the biomass or fossil fuels currently used, as can be seen with more detail in the value chains reported by the uP_running project [12-13]. Usually, a combustion process using grate-fired systems or fluidized bed technologies is employed in such cases.

Such combustion installations typically have the following distinct components, as shown in Figure 15: biomass supply; biomass storage; feeding system; energy conversion system (burner and heat exchanger); ash collection; gas cleaning; chimney; control panel and safety system. Compared to biomass installations based on forest wood pellets or chips, systems ready to use APPR biomass are different in the following three aspects: the feeding system, the burner technology and the ash collection system. More details are given later in section 4.4.4.

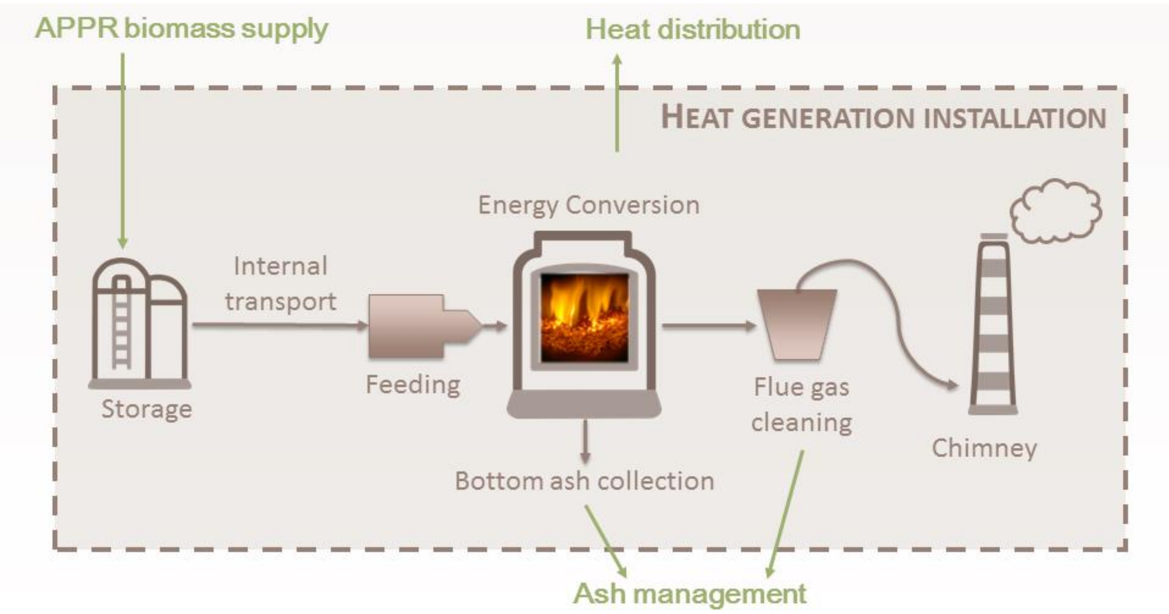

Figure 15: Scheme of a biomass installation for heat generation

As a summary of the conversion systems utilized in initiatives described by EuroPruning and uP_running projects, the different technologies that have been applied up to now are summarized hereinafter:

- Small-scale biomass boilers, with fixed and stainless-steel grate: one example is the 45 kW Guntamatic POWERCORN that operates with vineyards prunings pellets and chips in “Domaine Xavier Muller” (France).
- Medium-scale boilers, with fixed grate and robust feeding system: several boilers from Heizomat operate with municipal pruning residues in Calpe (see Figure 16), vineyards prunings in Vilafranca del Penedés (Spain) or other prunings residues in Germany.
- Medium-scale boilers, with moving grates and fully automatized operation: one example is 130 kW_{th} HERZ Firematic, operating with a mix of standard chips and vineyard prunings chips at Cavas Vilarnau. As can be seen in Figure 17, the overall installation is placed in a container, next to the winery. In Ukraine the company ITC Shaboo produces steam out of vineyard pruning in a 1.16 MW_{th} boiler of the Ukranian manufacturer Kriger.
- Large boilers with reciprocating or inclined grates and flexible operation: different examples arise, as those ones of L.Solé 4 MW_{th} steam boiler installed at Bodegas Torres (Spain), which operates with a mix of standard chips and vineyards prunings; the ORC (Organic Rankine Cycle) installed at Fiusis power plant (Italy) that fires olive trees prunings in a Uniconfort boiler (see Figure 18) and produces electricity with a 1 MW_e turbine from Turboden; and the Standardkessel boilers operating in Sacyr Energía power plants with olive pomace and olive prunings (Spain).
- Other many grate biomass boiler manufacturers like OKO-THERM, LASIAN, Hargassner or Fröhling (at small-to-medium scale) and BINDER, Compte-R, SUGIMAT or LIN-KA (at medium-to-large scale) also claim that they can produce boilers capable of burning burn APPR biomass.
- Finally, APPR may also be co-fired with other biomass in fluidized beds, as it is the case at ENCE power plant (Huelva, Spain).

To a minor or major extent, the biomass combustion technologies initially designed and developed to work with conventional biomass fuels (*i.e.*, forest wood pellets or chips) have been modified in order to operate with high ash content and heterogeneous biofuels. Nonetheless, these modifications and/or retrofit have not compromised the techno-economic feasibility of these installations, as demonstrated by the existence of the aforementioned initiatives.

Figure 16: Heating of a swimming pool in Calpe (Spain) with pruning residues. Boiler model: RHK AK300 from Heizomat.

Figure 17: Container with a HERZ Firematic biomass boiler (130 kW) placed at Cavas Vilarnau to supply heat to the winery.

Figure 18 Uniconfort boiler installed at Fiusis power plant (Italy) that fires olive trees prunings for CHP production.

3.6 Pruning use and sustainability

The utilization of APPR biomass for energy involves a series of advantages in respect the use of fossil fuels that are evident: reduction of pressure on fossil fuel reserves, reduction of energy dependence, and positive impact in reducing GHG emissions among others.

However, the actual use of APPR biomass for energy may be subject of distrust because of some environmental issues like: generation of air emissions and local pollution, displacing the use as organic input for soils, or insufficient capacity to abate CO_2 emissions. Even though these concerns rely on some funded argumentations, their generalization is usually incorrect. Next sections try to provide clarity on the actual sustainability of APPR biomass for energy.

3.6.1 Air quality and pollutants from APPR biomass

Biomass use can be a source of air pollution when rudimentary and obsolete combustion systems are utilized. For example, the traditional use of APPR biomass as a firewood can be a source of pollution. Moreover, obsolete boilers or heating systems in farms, agro-industries or other non-regulated and non-monitored sectors can be a source of air pollution. However, modern combustion systems are developed to perform an appropriate combustion of biomass. Furthermore, APPR biomass can be burnt in devices already prepared for it. In large scale systems the air emissions are monitored and the units are equipped with flue gas cleaning systems.

It is also argued that due to the pesticides and other phytosanitary products, APPR wood is contaminated with dangerous elements, and thus it should not be combusted. Findings from the Biomasud Plus project [9], in which an extensive sampling of olive tree and vineyard prunings was performed, verify that the only minor element that can be found in higher quantities in APPR biomass compared to "standard" forest wood is copper[4], which is coming from fungicides used in permanent crops. However, it can be argued that the increased presence of copper does not have a significant impact on the air emissions for the following reasons:

- Copper is a non-volatile element, so it is not expected to contribute to increased particulate matter (PM) emissions (in particular PM1 or PM2.5).
- Copper generally facilitates the formation of dioxins when chlorine is present. However, in modern biomass boilers, the temperature that flue gases reach is sufficient for destruction of any dioxins formed.
- Finally, the ash content of APPR biomass is generally higher than that of forest wood. Therefore, the percentage of copper in the bottom ash would not be as high as the percentage of copper in the fuel suggests.

The copper content of APPR biomass can be reduced if the material is washed out via rains when left on the field.

3.6.2 Use as soil organic amendment

The utilization of pruning wood as organic amendment to improve the properties of the soil is an extended practice in several areas in Europe, principally in non-Mediterranean countries (Germany, France, Slovenia, Slovakia, Poland or Ukraine) as example [2]. A change from a pruning-to-soil to a

[4] The average copper content of olive tree prunings and vineyard prunings samples analyzed was found to be 20 and 16 mg/kg on a fuel dry basis, compared to 10 mg/kg which is the limit set in the ISO standards for wood pellets and wood chips.

pruning-to-energy practice may seem unsustainable from a soil quality preservation perspective. In order to bring some light to this issue, next facts should be considered:

- APPR wood is imbalanced in its composition of C/N: soils are a living ecosystem. Adding organic matter involves an activation of the soil. The organic matter is assimilated by the soil living organisms and transformed into new products; part of the metabolized carbon is released in the atmosphere while another part is stabilized and contributes to the humus and improves soil structure and fertility. However, given the C/N imbalance, integrating APPR wood can cause a temporary blockage of the available nitrogen of the soil, which is utilized by microorganisms in order to assimilate the added organic matter.
- APPR wood transformed causes CO_2 and N_2O emissions to the atmosphere: the APPR wood integrated into the soil decomposes and causes emissions (see more details in section 3.6.3). From the total dry matter about 15 % may become humus (according to typical humification coefficients).
- Adding APPR biomass as soil cover, without integrating it into the soil, only has a residual effect on the SOM (Soil Organic Matter).
- The utilization of APPR biomass as soil amendment is not by itself the solution to rise the SOM pool of soils, or to improve its quality. Other agronomic practices are complementary, and even more relevant: application of manure or compost, keeping a green cover mowed several times per year, or reduction of tillage.
- APPR biomass utilized as soil amendment is only possible if there is no risk of disease and pest propagation. If the area under consideration is being threatened by the olive tree borer, *Xylella fastidiosa* (affecting olive but also almond) or vineyard fungal diseases (e.g. mildiu, botrytis, oidium) then removal of APPR from the field is a one-way street for the farmers.

Notwithstanding the previous arguments APPR biomass can play a role in preserving and improving the characteristics of the agricultural soils. Some indications that can be followed have been provided by EuroPruning project [14-15] as expressed in Table 4.

Table 4: Recommendations from EuroPruning where pruning wood should be left at plantation soil according to the results obtained in its research on soils in Spain, France and Germany.

Prunings should not be removed if:	• no vegetation cover > 80 % between trees (inter-rows) can be established and (a) soil structure is weak and tends to compaction / silting / surface runoff or (b) the orchards are prone to erosion and there are no alternative erosion protection measures or (c) top soil tends to water logging / anoxic conditions
	• no vegetation cover with > 15 t ha-1 year-1 fresh biomass (3 t ha-1 year-1 dry mass) can be established and soil carbon content is low.
Specific measures	• case (a) or (b): Prunings should be chipped and used as cover mulch. • Case (c): Prunings should be chipped and worked into the soil.

Special mention should be paid to Mediterranean countries where in areas of low annual rainfalls the spontaneous grass cover is absent or partial, and where agricultural soils tend to be object of tillage (to avoid competitiveness for water between grass and crop). This fact causes soils to be traditionally more exposed to erosion, and to a decrease in its organic matter. Therefore, these areas should be object of special care. EuroPruning [16] in collaboration with the S2Biom project [17] and its assessment on soil sustainability at European scale, established that Mediterranean soils in permanent crop plantations presented poor organic carbon contents. In such cases, a grass coverage can be a very effective method to preserve and grow the SOM in soils.

3.6.3 The GHG emissions

The use of APPR biomass for energy brings a question in comparison to its use as organic amendment: is it really an environmentally friendly practice considering the actual effect on GHG emissions from a life cycle perspective? It is usually argued that the use of APPR wood as soil amendment recycles nutrients with the organic matter; thus, the use of synthetic fertilizers can be reduced. For this perspective it can be argued that, whenever the biomass is utilized for energy, the opportunity to reduce the use of fertilizers is missed.

Life Cycle Assessment (LCA) is a methodology developed for comparing the environmental impacts of several products or services, counting all their lifetime: from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. In the case of pruning wood, an assessment was performed by EuroPruning project [16], by comparing the LCA of pruning-to-energy with the pruning-to-soil.

The results of EuroPruning (see Figure 19) revealed that in terms of climate change impacts, the pruning-to-energy path performed better. The reason is that the pruning-to-soil path also involves a series of emissions (as measured by EuroPruning parcels in 3 countries). In the case of pruning-to-energy path it is needed to compensate the soil effects that would have obtained through the alternative pruning-to-soil. As observed the impact is low, since the contribution to nutrients to the soil is very low, and thus, the replacement rate of synthetic fertilizers is also low. In contrast, pruning-to-energy leads to reduced consumption of fossil fuels, and thus a direct and large reduction of GHG takes place. In the case of olive tree prunings, the use for energy is 6 times more effective in terms of GHG emission reduction compared to their use as soil amendment. In other words, from the viewpoint of global emissions, the use of pruning for energy is very effective.

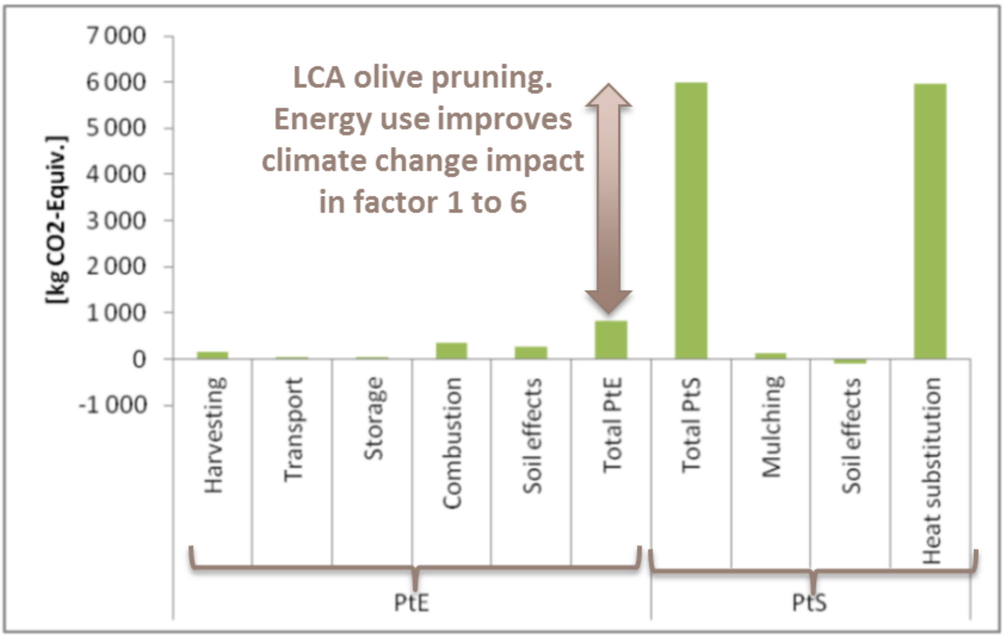

Figure 19: Results climate change impacts obtained by EuroPruning for olive prunings through LCA methodology (adapted from [16]). PtE: Pruning to Energy. PtS: Pruning to Soil.

3.6.4 Final remarks for decision making

Sustainability in the use of APPR wood cannot be just simplified by stating that the best use is as organic input or soils. An effective increase of SOM requires several practices and is not CO_2 neutral. It should be performed there where it is a best practice from an agronomic perspective and is risks-free in terms of disease propagation.

uP_running has developed a simple methodology to frame the use of APPR for energy. The document describes a simple assessment of sustainable soil conditions to remove fruit tree residues from pruning and uprooting operations, and a “traffic light” method for decision-making [18][5]. This method considers four parameters (SOM content, slope, texture and climatic conditions) and provides as output a traffic light categorization for pruning-to-energy potential (red, yellow, green), as well as recommendations for preserving the conditions of soil in each case.

In terms of biomass availability, it should be noted that shredding the pruning biomass to be left as an organic input for the soil plantation, is in many cases carried out by farmers just because it is the simplest system to manage and dispose the APPR biomass. In other words, it is not always performed as best practice, but as most practical or economic method. Therefore, in areas of Europe where the current management of APPR wood is its integration as soil amendment, the **change of agronomics from pruning-to-soil to pruning-to-energy is possible**. Unavailability of APPR biomass for energy uses should be considered only in the cases where soil conditions are poor, where farmers are convinced of the practice, or where a regulation makes soil incorporation compulsory.

[5] *This method has been utilized in uP_running during the selection of beneficiaries to be accompanied by uP_running. The method was useful to detect cases of initiatives where the soils sustainability was in compromise.*

4. Recommendations to set-up new chain based on APPR biomass

4 RECOMMENDATIONS TO SET-UP NEW CHAIN BASED ON APPR BIOMASS

Thanks to previous projects, to the identification of existing cases in Europe, and the practical knowledge gained by performing pilot scale demonstration of APPR value chains, uP_running consortium has already been able to detect some success keys for the development of new initiatives based on APPR wood. In the next paragraphs, specific recommendations and keys for success are introduced, so that an understanding of the most critical steps be considered when initiating a new value chain based on APPR biomass is established.

4.1 Organization of the value chain actors: foster collaborative relationships and mutual benefits

A basic key is to recognize that the management of APPR residues involve costs, and that in some cases implies a problem for the farmer. When this fact is acknowledged by the producer of the residue, then this actor is more prone **to collaborate and cover part of the costs or efforts to facilitate its extraction**. A second premise is that both the supplier and the other agents of the value chain have to understand and perceive that the **overall chain profitability is quite adjusted**. Contrary to conventional products sell-buy mechanisms (*e.g.* for acquiring shoes, computers or food), APPR value chains usually require **collaboration agreements between the actors**, especially for the organization of pruning and plantation removal operations, from one hand, and their harvesting operations, on the other hand.

There are multiple ways to organize an APPR value chain, but in all of them there is the **win-win aspect** between the supplier of APPR wood (*e.g.* the farmer or cooperative) and the intermediary company or the consumer and this **mutual benefit relationship** does not always imply a simple economic transaction.

That is why **replicability is more complex**. Creating the demand for APPR biomass does not ensure its effective mobilization. It is necessary to coordinate all the agents involved in those steps between the collection and the consumption, which requires intense local work and bilateral meetings.

Example

Existing plants like "Pellets of La Mancha" or those of "Valoriza Energía" in Andalusia exemplify the need to foster collaborative relationships. There is no single chain of biomass sourcing, simply because every farmer, owner or cooperative can find a different way of managing their APPR residues, depending on their interests, available machinery, staff resources, etc. These conversion plants, which consume thousands of tons of pruning annually, are supplied through agro-services companies already established in the area. These extend their services to offer the collection of the pruning to the farmers, who save time and costs. However, the farmers must also adapt the way they leave prunings on the soil to facilitate their collection. In parallel, the biomass plants also offer to receive individuals biomass lots/loads/batches, previously chipped or shredded, or even raw, untreated, piled up on the farm with tractors and transported by the farmers themselves in their agricultural trailers, without the need to purchase machinery. **Each chain implies different transactions, sometimes in the form of payments, and sometimes in the form of contributions**.

4.2 The intangible value, a typical ingredient for the success

The narrow profit margin for APPR value chains is usually regarded as a risk by entrepreneurs, a weak driving force for starting a new value chain. Why to bet for APPR biomass if other biomass resources, with comparable or even better quality, are locally available at a better or reasonable price?

There are multiple ways to organize the chain, but in all of them there is the win-win aspect between the farmer and the intermediary company or the consumer.

Beyond basic economic aspects the **intangible value of APPR biomass** may be the key for activating the implementation of a new chain. Not everything is money, and some actors may find a real appealing value in saving time, avoiding annoying operations for the residue management, reducing fires risk, branding they are "green" and contributing to the wealth of the local community, among others.

The intangible values are very varied, but a lesson learned through uP_running is that in all the cases analyzed the intangible gains were an essential driving force for some actors, and lead to a successful and steady use of APPR biomass. It has also been observed that some initiatives based on economics, stuck and turned to an alternative biomass resources when the market conditions changed. In such cases the intangible benefits were conjectural. Some of these key factors are presented in Figure 20.

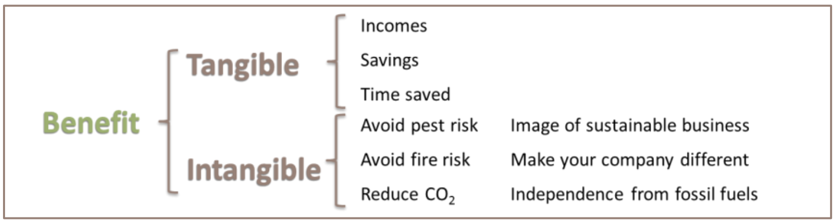

Figure 20: Examples of tangible and intangible benefits that can play a role to trigger new APPR initiatives

4.3 What is the market value of the APPR biomass: it's all about quality

Understanding the final consumer needs in terms of fuel quality is fundamental when designing APPR biomass sourcing schemes. In the "ideal" case, future consumers invest in combustion facilities that are able to handle this kind of biomass. However, when it is intended to put APPR biomass as an alternative fuel in an existing biomass market, the value the APPR biomass can reach depends on the market prices of the biomass resources utilized currently by the targeted segment (e.g. forestry woodchips, straw, almond shells, etc.). Each market segment is particular, and whereas the APPR biomass properties are in some cases a drawback, its price can be adjusted to become competitive. Finding buyers of APPR biomass can be complex, since most of the existing biomass facilities are prepared for the specific fuel they consume, and then they may fail in the attempt to burn APPR wood (see section 4.4.4), generating the erroneous belief that this type of biomass cannot be used to energy.

The challenge is to find **a good fit between the characteristics of the APPR biomass generated and the quality demanded by the final consumer.** In other terms, the logistic path through which APPR biomass is harvested, treated and transported must be performed taking into account the requisites of the energy system that will convert APPR biomass to energy. Two parameters are the most complex: the maximum particle size and the maximum ash content that the boiler or gasifier is able to handle. The moisture content of the harvested APPR biomass may also pose limitations; however, there are more possibilities to find low or no cost alternatives to reduce the water content of the fuel, e.g. by leaving piles of pruning wood on the field to dry before harvesting.

Example

Through the EuroPruning project D6.2 [19], a total of 570 tons of fruit, vineyard and olive pruning were collected in multiple demonstrations carried out in Spain, France and Germany. In Spain a total of 380 tons were collected with four different systems, and after a storage of six months, were distributed to seven consumers. **The biggest problem identified was the particle size distribution**. Many of the potential consumers discarded the possibility of using the APPR biomass produced simply because too long pieces were present in the lots, which would block their feeding systems, their screens or their hoppers. The problems were evidenced even by some of the demonstrators who carried out additional grinding or screening operations.

It is important to underline that there exist many logistic paths and ways to harvest and treat APPR biomass and that none of them is “the best one”. Each path has its own pros and cons, specific costs and a different quality level of the final product (as presented in sections 3.3 and 3.4). The **right treatment is the one that allows optimizing operation costs and generating a product that is accepted by the end-user** or the intermediaries. In that sense, for some initiatives it may be more appropriate perform more costly field operations and avoid problems later in the value chain (biomass fermentation, additional screening, erosion or fires in mills due to stones, etc.); in other cases, it may be better to work quickly and at low cost in the field and then treat the biomass in an intermediate platform.

The biomass collected with shredders is more difficult to store and place directly on the market. Chippers may be more suitable for this purpose.

In the case the APPR biomass will be put on conventional biomass market, the APPR biomass produced has to fulfill some quality criteria that allow its combustion in conventional boilers. This is particularly relevant for the size distribution, as described before (see Figure 21). The problem is that current pruning harvesting systems are principally shredders, which were initially designed for other purposes, generally to leave pruning on the plantation soil either in form of pieces, or in form of very thin shredded wood. In the last years, these machines have been adapted by manufacturers to propel these small pieces to a self-loaded bin, a big bag or to a towed agricultural trailer, instead letting them on soil. The work performed, which can be satisfactory in terms of yield per hectare, nevertheless obtains a type of biomass incompatible with most current combustion facilities, even in large boiler plants of more than 10 MW (as attested by three EuroPruning demonstrations in Spain and France). Similar is the case with plantation removal shredders. They are prepared for larger pieces of wood, and thus the material produced out of vines, olive or fruit trees tends to have a very heterogeneous particle size. Treating this biomass may entail additional costs of around 5 - 10 €/t, which can be a death track for the chain's profitability.

Figure 21 Left: Hog fuel from vineyard pruning (obtained by Cobra Colina shredder [10]); Right: Conventional stem-based wood chips.

This is why, when the objective is to put APPR biomass directly on the market, an alternative can be the use machines capable of producing more homogeneous biomass in a single operation. The possibility can be performed with shredders combining hammers with a second cutting system and a sieve (some models are already available in the market). **Chipping is another alternative.** The clean cut produced by the chipper shape blades improve the shape of the biomass particle. The homogeneity may improve substantially, even though also it depends on the sieving system at the outlet of the chipping systems, and the inter-spaces between the knifes and the sieve. Static chippers are available in the form of small units (coupled to a tractor PTO or powered by their own engine), where the branches have to be fed manually, or large forestry chippers prepared for comminuting thick stems from forestry logging. Mobile chippers integrated with the gathering of prunings are rare, and only few commercial models are available. Two Italian companies have recently developed them: Nazzareno (Marev Alba) and ONG-SNC (PC50); both models were implemented as a result of national or European R&D programs, like EuroPrunning [11], illustrating their degree of innovation compared to conventional shredders.

Finally**, another option that may allow improving the quality of APPR wood is the baling** (see Figure 22). Up to nine models are marketed in Europe, although the most recent innovations consist of the Wolagri (Italy) and PIMR (Poland) round balers that allow obtaining standard bales (1.2 m wide and diameter). Also, the T2400 head of SERRAT (Spain) coupled in conventional hay balers allows to obtain high density square bales. Bales after storage can be chipped or shredded to be used as fuel.

Figure 22: Two examples of innovative solutions for harvesting wood from agricultural prunings developed through the EuroPruning project: ONG-SNC chipper PC50 capable of discharging on big-bags, trailer circulating in parallel, or on a built-in container with capacity to tilt and discharge (left); Round baler PIMR PC50 (right).

4.4 Facts and recommendations in the implementation of new APPR biomass value chains

4.4.1 Organizing the APPR biomass supply

The organization of the value chain is crucial. It involves not only the practical means and operations (see next sections) but also the agreement between actors. In this respect Table 5 summarizes the main lessons learned from uP_running.

Table 5: Facts and recommendations for organizing the biomass value chains

	Facts and Risks	RECOMMENDATIONS
1	APPR biomass is currently managed as a residue. Using for energy production it involves a change in the current disposal practices.	It is important to establish a dialogue with farmers to find the way how the APPR biomass can be managed in a way that benefits the farmers (reduce costs, simplify their work, release time)
2	The principal product of the farmer/plantation owner is the fruit, grape, olive. The residue is not a principal feedstock, and the principal need is its adequate management and disposal.	The new management of the residue allowing the gathering of APPR biomass should allow a normal execution of the farmer /plantation owner agronomics. The dialogue is crucial prior selecting any organization of the value chain.
3	When organizing the supply from multiple plantations, each farmer finds a best option for pruning withdrawal: *e.g.* some may prefer external company to do harvest while others would prefer pushing pruning branches out of the field.	Check preferred options, negotiate and involve farmers as much as possible, allowing different harvesting methods. Allowing different harvesting methods will increases the sourcing flexibility.
4	Coordinating timing of collecting and/or field side operations is a major issue. During the pruning or plantation removal seasons the services / machinery of APPR biomass collection may be overbooked.	It is crucial to organize the collection in an area with sufficient means to cope with peaks. Allowing different collection methods brings more flexibility to the timing and organization of the supply.
5	APPR biomass from scattered plantations in an area and from multiple owners makes the organization difficult.	For large scale value chains, the use of advanced systems to register the providers, record the status of their APPR, and to register the request for a service may facilitate the organization of a centralized collection of APPR biomass in an area.
6	The benefits of every actor involved in the value chain are different. When starting a new APPR biomass business distrust between producer of residue and other actors may occur.	The business model, the difficulties and a transparent communication of the benefits of each actor allows a better understanding and trust.
7	APPR biomass profit margin is usually tight. Investments may be risky.	Unnecessary operations should be avoided: the lesser the steps in the value chain, the lower costs. Whenever a local actor can provide a service with an existing machine, it may be more economic than setting-up a new service and perform a new investment.
8	APPR biomass value chains are usually inexistent, and subject of uncertainty in terms of costs, biomass quality, performance, or biomass handling.	Pilot scale tests of the different operations to be adopted is recommended prior to initiating any investment.

4.4.2 Collecting and treating at field: select the appropriate machine, not the “best” one

The different ways to collect agricultural pruning and plantation removal have been described in sections 3.3 and 3.4, respectively. In this section, some practical recommendations are provided in Table 6 based on lessons learnt from uP_running and also based on results from previous projects and experiences.

Table 6: Facts and recommendations for operations of pruning harvesting or at field side

	Facts and Risks	RECOMMENDATIONS
1	Treating APPR biomass in newly developed machineries brings uncertainty. Every wood type is different, as well as pruning and tree shape.	**Use proved technology** when starting new business on pruning biomass
2	Performance of the treatments (t/h or ha/h) and quality of wood obtained depends on multiple factors. In particular for integrated pruning harvest and treating crop layout, pruning amounts and shape, pre-alignment of pruning, and field headland space have to be considered	**There is not a perfect machine for everything**. Select the solution that better adapts to the APPR and/or field. Take into account the investment needed as well as the logistics operations required downstream.
3	Operations of harvesting prunings, or treating wood at field side often add up to more than 50 % of the total costs for APPR wood supply	**Carry out tests with the selected machinery** before any investment. Consider the results and variability, and performance reduction (idle times, repairs) to tune your business plan Do not build your plans based on thumb rule estimations or general data (usually provided by salesmen).
4	The knifes and hammers of processing machinery undergo deterioration, especially when APPR wood contain soil and stones. It affects performance and lifetime of other subsystems (or tractor PTO).	**Preventive maintenance** and appropriate handling reduce the medium and long term costs and avoid failure and interruption during the APPR collection campaign.
5	Preparing the APPR wood before harvesting / treating at field side is crucial to improve performance of APPR collection. This operation may involve an additional cost.	It is essential an **agreement between company harvesting / treating the APPR wood and the farmer**. Since farmers should save some costs in management of their APPR residues, it is crucial to involve them partly in these operations.
6	On field losses (% of APPR wood not collected) involve economic losses. Moreover, the farmers may consider that the service has not been performed properly and that they should still invest time and money on managing the material remaining on the field.	It is essential to agree upon maximum losses. In case of pruning collection, it is suggested the use **harvesters able to adapt pick-up height and revolutions**. In case of plantation removals, it is suggested to use of systems able to collect all wood, but with low amounts of soil and stones.
7	Both fines and large pieces usually cause problems in handling, storage and final use. On-field operations are not always able to process the biomass with the appropriate quality as demanded.	Select the **operation** mode capable to **produce the quality demanded**. **Or alternatively perform a simple and low-cost operation** on field and perform a second processing in a processing plant.
8	Producing bales (of pruning wood) brings advantages for handling and storage for long time. However, it involves higher handling and processing costs.	Select **baling especially when final consumer has a bale boiler**. Alternatively, when biomass has to be preserved long time at field side, or in open air.

9	Quality is quite affected depending on the conditions of how the APPR biomass is harvested – hauled.	Select haulage of APPR wood with systems able to reduce soil incorporation (fork, grabber instead of shovel). Work on compacted soil or with grass cover. Avoid working during and after rains.

4.4.3 APPR biomass transport and storage: take care to maintain the product quality

During transport and storage of APPR biomass, there exists an important risk of biomass degradation or biomass contamination due to improper loading/unloading, inadequate particle size during storage, etc. This may entail a **strong impact on the quality of the biomass product** and, consequently, a **substantial effect on the feasibility** of the value chain. In some cases, the biomass degradation and/or contamination may even ”kill” the economic profitability of the initiative. For this reason, particular care should be given to the operations performed during the transport and the storage of the APPR biomass. In Table 7, some recommendations and lessons learnt about transport and storage are summarized based on experience gained through uP_running and other previous projects like EuroPruning [19-21].

Particularly, the lessons learnt have shown that a value chain based on APPR biomass cannot succeed unless all actors are well involved and understand their role and responsibility. In the side of farmers, they should understand they may have to perform some operations differently from their usual methods, in case these tend result in contamination of the biomass (e.g. the method to rake, windrow, or prepare the biomass). Downstream, if the logistics are not well organized or if the actors do not execute their work properly, APPR biomass quality can easily decay. Then its potential market value, or the satisfaction of the final user, can be seriously compromised.

Table 7: Facts and recommendations about transport and storage of APPR biomass.

	FACTS and Risks	RECOMMENDATIONS
1	Handling costs are directly related with format of APPR biomass produced at field side, and value chain organization. Every load/discharge, and storage operation involve costs.	Adopt bulk biomass format for large scale, as it reduces handling costs. Biomass in big-bags only for self-consumption, and bales for long term storage or consumption in bale boilers.
2	Discharge APPR biomass on soil may cause about 10 % dry matter loss and increases introduction of soil particles and stones (the effect on the ash content can vary from a value of 1-2 % in dry basis to 10 % or more).	Promote discharge of biomass bins directly on containers or trailers or paved soils to reduce handling time, losses and contamination.
3	Moist biomass in form of woodchips or hog fuel tends to degrade during its storage. The drier the APPR, the easiest the leaves and dust detaches during handling and processing.	Leave APPR wood untreated at field soil or field side for natural drying prior the processing at field.
4	Piles of moist APPR wood containing fines and pieces of irregular size (hog fuel) tend to get compacted and reduce internal aeration, thus causing biological degradation.	Avoid storage of APPR wood in form of hog fuel. Promote previous reduction of moisture, or alternatively foresee frequent aeration of piles by disassembling with shovels for first weeks.
5	APPR wood stored on open air is subject of weathering. Rains and exposition to air and sun causes degradation and losses of quality and matter.	Storage under cover, in barns without walls. When stored on open air, prepare larger pile in wet

		climates (external part protects the inside part of pile).
6	Along the value chain biomass can get contaminated with plastics, wires, rubbish, etc. if the transport vehicles, storages areas, etc. have been utilized for other uses.	Every actor participating should assure the use of appropriate methods in handling / transport. Specifically avoid transport in trucks which box has been utilized previously for transport of other residues.
7	Mixing APPR biomass with other biomass resources (like forestry wood) may improve the quality of the material.	When preparing the supply, it should be considered if the mix with other biomass could facilitate the penetration of APPR wood in the market. It can mark the difference.
8	APPR wood is natural wood, even though its quality is usually lower, or different from other usual wood fuels. But it can be also better in respect to other low-cost and low-quality fuels.	Mixing APPR biomass with another fuel to improve quality is a good strategy. However, it should be controlled to avoid mixture with non-biomass residues like demolition wood or wood with impregnations.

4.4.4 APPR biomass use to energy: conversion systems fitted to APPR characteristics

The use of APPR biomass can be carried out in existing facilities not initially designed for APPR biomass; alternatively, it can be utilized in facilities initially designed and prepared with this fuel in mind. Penetrating in a conventional biomass market is usually not easy, as the APPR biomass characteristics are different from other biomass already in use. Mixing the APPR biomass with other biomass types is an alternative. Another alternative is to offer a substantial reduction in the biomass supply that balances the costs of any retrofitting investment that a final consumer may have to adopt. Additionally, the boiler manufacturer or maintenance service should agree to keep the product and service warrantee.

When a new consumer adopts APPR biomass it is strongly suggested to adopt mature and proved technologies able to use the APPR biomass in form of heterogeneous material, as it will allow a cost reduction of the on-field and field side operations, and thus will reduce the final cost of the APPR supply. It is relevant to realize the different type of properties that determine the behavior of the biomass, as summarized in Table 8. As shown in the previous sections, the biomass from APPR residues are characterized by a wider particle size distribution, even with the presence of some long pieces, and by a higher ash content. In order to adapt to these properties, therefore the combustion systems adapted to APPR biomass usually include improvements in three essential aspects: a **feeding system** able to break the larger pieces, a **combustion system** (usually a fixed or moving **grate**) that can handle heterogeneous biomass, and an **ash cleaning** system that may work with high ash content biomass.

Table 8: Thermochemical and physical parameters of biomass and influence on its energy conversion

Biomass parameter	Characteristics	Effect
Chemical parameters	Ultimate analysis	Determine the biomass behavior during combustion/gasification
	Proximate analysis	
	Ash composition	
	Ash fusion temperatures	

Energy parameters	Heating value	Determine the maximum energy usable
Physical parameters	Bulk and particle densities	Determine the selection of feeding systems, the necessity of pretreatments and the conversion behavior
	Water content	
	Size and shape	

Firstly, it is crucial that the feeding system can work continuously with heterogeneous chips or shreds without clogging. For this, both augers and rotary valves are more robust than conventional systems and specifically designed to break the longest pieces. Secondly, the combustion chamber must have an automatic adjustment of primary and secondary air and a combustion system able to burn the largest particles (in case of grates, sufficient area and time of residence). Finally, the ash removal system of the furnace must allow the evacuation of the relatively high amount of these combustion residues, which may also present some sintered material or stones. The ash bin, usually located next to the boiler, must have a sufficiently large volume to ensure the autonomy of the system.

Based on uP_running experiences, on EuroPruning results [18] and on CIRCE and CERTH (authors) expertise, some recommendations are provided in Table 9.

Table 9: Facts and recommendations about APPR biomass quality and use.

	FACTS and risks	RECOMMENDATIONS
1	APPR wood can have ash content as low as 1-2 %, e.g. in case of large branches obtained by graft pruning. Nonetheless, for most APPR biomass the ash content uses to be larger than 4% (weight in dry basis).	ISO17225-4 sets limits of 3 % for less restrictive woodchip class (B2). Wood pruning marketing should not try (by default) to achieve such quality levels.
2	Feeding systems are usually a bottleneck for the use of APPR biomass in existing facilities.	APPR wood value chains should be designed taking into account they will have to feed a much irregular wood chip type than usual. Mixing APPR biomass with other types may buffer this drawback and permit an appropriate operation.
3	Heterogeneous biomass usually makes difficult the conveying and feeding systems may fail	Use robust screw feeders (more resistant and thicker material), redlers, hydraulic pushers instead of conventional screw feeders.
4	Final consumers would usually pay less for APPR chips than for forest wood chips. Medium sized facilities usually can pay higher price than large scale facilities	Targeting medium sized consumers willing to lower their biomass bill or to consume local biomass may be a strategy to make APPR value chain feasible in terms of economics.
5	Pelletization converts APPR into more homogeneous biomass, even though they usually cannot be used in small –medium sized pellet boilers prepared for EN-Plus pellets.	Producing pellets should be considered only when the boilers are prepared for industrial pellets. In such case the achievable market price depends on the prices of the current biomass utilized.
6	APPR wood present high ash content, which may sintered on the grate	Use water-refrigerated and moving grate. Investment is higher, but O&M will be lower and the grate will last more time.
7	APPR wood present high ash content, which causes fouling of heat exchangers surfaces (and decrease efficiency)	Select technologies that are able to increase the cleaning frequency of the fumes tubes and the frequency of the ash bin discharge.

5. Conclusions

5 CONCLUSIONS

This document has presented the status of value chains based on APPR biomass at European level and has described the main operations that are needed for extracting APPR wood and using it for energy production. Moreover, specific recommendations for implementing new APPR biomass value chains have been provided, with special focus on the operations of the supply chain, the organizational aspects, the dialogue and needs of the different value chains actors, and the importance to keep in mind quality issues during each step of the chain.

In addition, the existing barriers that block the expansion of APPR-to-energy chains have been briefly presented; they are principally non-technical, e.g. related to social aspects, economic framework, existing regulations and energy, environment and agriculture policies.

Beyond this article, uP_running continues carrying out a series of actions in order to tackle some of the non-technical barriers and unlock the APPR biomass potential in Europe (more information is available through the uP_running website, http://www.up-running.eu/). Two additional monographs to be produced by the project will provide further insights into the barriers, opportunities and strategies to promote the use of APPR biomass, and on the existing success stories and the lessons learned from them.

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