PROJECT FINAL REPORT

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Table of Contents

1. Final Publishable Summary Report 3

1.1. Executive summary 3

1.2. Project context and objectives. 4

1.3. Main S&T results/foregrounds 8
1.3.1. Pruning harvesting equipment 8
1.3.2. EuroPruning's Logistics Smart System 11
1.3.3. Pruning to energy logistics chains demonstration and monitoring 15
1.3.4. Changes in prunings quality specifications along the logistics chain 20
1.3.5. Pruning to energy logistics chains and soil management 24
1.3.6. Environmental and socioeconomic assessments 26
1.3.7. Business Models, Policy implications 30

1.4. Potential impact and the main dissemination activities and exploitation of results. 31
1.4.1. Potential socio-economic impact 31
1.4.2. Main Dissemination activities 36
1.4.3. Exploitation of results 38
1.4.4. Project contact details 40

1. Final Publishable Summary Report

1.1. Executive summary

EuroPruning aimed to optimise biomass from pruning logistics chain to make it cost-effective and to ensure quality adequacy to final consumer needs. To define the quality specifications of the materials to be produced, an intensive survey to gather quality requirements from European consumers was carried out. The conclusions drew the requirements to be achieved: M35 (moisture content ≤ 35 w-% ar); P45 particle size distribution (EN ISO 17225-4:2014) or D1 bales (1.2 m diameter, 1.2 m length) and A3 (ash content ≤ 3 w-% db) material.

Europruning has developed specific equipment able to achieve those quality requirements, filling a technology gap and contributing to satisfy chain's economic feasibility. On the one hand, a chipper (towed by a tractor) has been designed, constructed, tested and optimized for windrowing, picking, conveying, chipping and collecting the final P45 product in a single pass. Additionally, a system concept (baler and windrower) able to collect and compact pruning was also developed. The baler, trailed to the tractor, and the windrower, to be mounted on its front, windrow, rake and press pruning into D1 bales in a single pass. On the other hand, the project has developed an innovative logistics tool for optimising the pruning handling along the value chain. This Complete Logistics Smart System, which comprises a Smart Box and a Web-Based Information system, sets a specific lot number, implements a label code, and gives a product delivery identification number allowing pruning traceability definition.

The performance of all the equipment has been demonstrated under real environmental conditions working with different species and climate and procurement situations in demos performed in Spain, France and Germany. They included specific trainings for local farmers and some performance tests to accurately determine the equipment working operation conditions. Within the demos the material required for outdoor storage assessments was produced. These storage trials were carried out in three different climate conditions representing real situations of possible logistics centres based on pruning final products. Demos also included products validation in existing biomass boilers to complete the logistics chain.

Demos were also used to evaluate quality along all the stages of the logistics chain. Moisture content decreased in the chain but in some cases, ash content increased in some stages. Rain, soil conditions, equipment collection system or loss of dry matter due to biological activity during storage were some of the causes. In order reduce quality degradation, favour drying process and reduce material losses along the whole value chain, several working recommendations were disseminated to all the stakeholders involved in the chain.

The effect of wood pruning on soil chemistry, GHG emissions, nitrate leaching and soil erosion was also studied under a wide range of field conditions. Though several factors have to be taken into account, results showed at all demo sites that the use of pruning for energy purposes is not opposed to a sustainable soil management and long term soil fertility. Additionally, environmental, economic and social aspects impacts on the whole biomass from prunings logistics chain were analysed. Results allow stating that biomass from prunings could be placed in the market at competitive prices leading to positive environmental and social impacts, especially for certain yields, species and logistics chain.

1.2. Project context and objectives.

Agricultural residues from tree crops are one of the major source of woody biomass, which offers a strategic benefit wherever it is non appropriate to convert cropland to energy crop cultivation[1] and the disposal of such residue is expensive or problematic[2]. Besides, residues from pruning do not accrue any growing costs and could be tapped at a relatively low price if effective collection systems were deployed. Fruit growing represents a global business and generates substantial wealth. Grapes, apples and pears are some of the most common fruit crops in the temperate regions, and on a global scale they cover 7.4, 4.9 and 1.7 millions of hectares, respectively[3]. A further 9 million hectares are occupied by olive groves, whereas many other fruit crops exist and could be easily tapped for biomass. Finding some use for orchard pruning residues would allow transforming a disposal problem into a collateral production, with a potential for revenues or reduced management cost. Annual pruning yields vary with crop type and cropping system, but in general terms, they range from 1 to over 4 t_{fm}[4]$\cdot ha^{-1} \cdot year^{-1}$ (even more in some cases). The typical multi-year pruning intervals of some species (for instance olive groves) are bound to offer higher yields when the pruning is done, often in the range of 5 or more $t_{fm} \cdot ha^{-1}$.

Considering EuroPruning results, it can be stated that wood prunings from permanent crops essentially are unexploited biomass resources in the EU28 despite currently more than 13 million tonnes (over dry basis) of pruning are generated every year. Several reasons are behind this fact: cultural heritage, lack of awareness of their potential use or some logistics barriers that usually appear with these resources (*i.e.*, geographical dispersion, seasonality, inhomogeneity production, bulk density, etc.).

With the aim of promoting a change towards a larger utilisation of biomass from prunings, new logistics chains need to be developed to make pruning procurement (harvesting, pre-treatment and transport) and use economically, technically and environmentally feasible. The overall objective of the project was the development and implementation of a new and non-existent logistics chain for biomass from pruning by providing technical solutions for the fruit tree, vineyards and olive grove prunings as well as branches from up-rooted trees harvesting, transport and storage activities. Following epigraphs detail the specific objectives of each workpackage (WP) (without including WP1 management and administrative issues).

- **WP2.- Biomass requirements and specifications for the biomass in the whole value chain**

Since fulfilling consumers' quality requirements is one of the main constraints for the success of this type of resource in the market, the project has dedicated an intensive effort on the assessment of regular consumers' requirements and on the evaluation of the changes on the fuel quality along the whole logistics chain. Within WP2 the properties that should be

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1 Li L., Ya T., Jia-sui X., Yuan-liang Y. (2009). The role of marginal agricultural land-based mulberry planting in biomass energy production. Renewable Energy 34: 1789-1794

2 ARSIA, (2009). The wood-energy chain. Final results from the interregional project Woodland Energy. Regione Toscana, Firenze, Italy. 160 p (in Italian). ISBN 978-88-8295- 106-1

3 FAOSTAT, (2009) – consulted on-line 25th March, 2010.

4 t_{fm}: tonnes of fresh matter (tonnes at the moisture content over a wet basis which is obtained on site)

measured to describe and evaluate the pruning material as a fuel were defined. The main goal of this WP was to assess the quality of the pruning residues as feedstock for energy production at each step of the supply chain. To fulfill this goal, the specifications that should be monitored were identified and a set of criteria were chosen to assess the fuel quality at each step of the logistics chain. The protocols and the methodology necessary to accurately determine these characteristics and to compile a common methodology, both standard methods and other common methods, required for the evaluation of biomass specifications and monitoring of the demonstration activities along the supply chain (harvesting, processing (chipping & baling) and storage of pruning residues) were defined. Possible measures to minimize the changes in the final product quality were identified and guidelines and best practice for improving the quality of pruning residues along the whole value chain, taking into consideration geographical variations and end user demands, were proposed.

- **WP3.- Harvesting methods and machinery**

Harvesting represents a key point that influences the product quality, the type and the economic sustainability of the biomass from pruning logistics chain. One of the main goals of the Europruning project was to develop specific equipment able to chip or bale pruning residues filling a technology gap achieving quality requirements set in WP2 while satisfying economic sustainability of the chain. The objectives of WP3 were divided in three main tasks:

- to analyse and identify the current methods and best available technology (BAT) applied nowadays to harvest the pruning of permanent crops;
- to map and analyse the pruning biomass potential in Europe;
- to design, develop and build two new prototypes for a sustainable large or little scale feasible wood pruning logistics:
    - a chipper able to harvest and chip the prunings, according to the transport distance and necessities of the final user;
    - a prototype for baling prunings.

- **WP4.- Management of storage**

Special importance was given to the storage process resting in the fact that it is the step of the logistics chain where the quality of the material is likely to suffer the highest variation. Biological, physical and chemical processes which take place during storage may have positive or negative effects on quality parameters. Substance losses are likely to occur. The process depends on biomass fuel characteristics (species, composition, initial moisture content and particle size distribution in case of chips or bulk density in case of bales), the storage characteristics (dimensions and shape of the pile) and the external climate conditions. The optimisation of the storage by promoting the reduction of moisture content through natural drying and limiting the substance losses, minimising health risk due to exposure to air-borne microbial particles, risk of self-ignition in chip piles and the emissions of greenhouse gases (GHG) is challenging to achieve a cost-effective supply chain.

Considering these issues, the objectives of this workpackage were:

- to set-up the protocols for the construction and monitoring of the storing piles/stack and prepare the equipment and facilities needed to monitor the storage trials and to carry out the storage demonstration tests;
- to perform sampling and monitoring of the storages to determine quality evaluation, assessing dry matter losses and energy variation, to evaluate the risks on self-ignition

and health aspects and to assess the environmental impact of large-scale storages of prunings through their GHG emissions;
- to elaborate guidelines for stakeholders attending to biomass quality as well as to environmental, safety and economic concerns.

- **WP5.- Integrated Logistics and Development of Smart System**

This WP focused on developing and implementing an innovative logistics tools in order to optimize environmentally and economically efficient and effective handling of agricultural residues along the whole supply chain from their harvesting to their transport to a power plant (end users). The organization, management, handlings, storage, packaging, transport, and the associated information and financial flows are addressed by these tools. The traceability for monitoring from the harvest to the final user had to be included to assure the quality of the prunings. WP5 specific objectives were:

- to describe the logistics activities along the biomass logistics chain and conducting logistics audit analysis to assess the knowledge gaps of pruning biomass value chain;
- to develop the traceability system to assure the biomass quality and its integration into logistics smart system;
- to analyse the requirements and specifications required and the final development of the Smart logistics system (Smart Box and web-based information Platform (website)) for biomass from pruning;
- to test the Smart logistics system at different DEMO sites, conducting performance analysis of the smart system, improving its performance and preparing reports.

- **WP6.- Demonstration and monitoring**

EuroPruning demonstrations aimed to test in real operational environment the logistic chain of agricultural pruning. Demonstrations took place at three demo sites: Aragón (Spain), Medoc (France) and Potsdam (Germany). This selection was established aiming to reproduce the pruning logistics chain into three climatic areas simulating multiple different logistic chains.

The demonstrations had three main goals: test EuroPruning prototypes in real operational environment; produce sufficient material for carrying out research on the storage and handling of pruning biomass (carried out in WP4) and gather information from local participants needed for other EuroPruning tasks, like economic, environmental and local impacts assessment, logistics chains configuration, for example.

- **WP7.- Soil management**

The main goal of WP7 was to estimate the effects of wood prunings either left on the soil in order to save mineral fertilizers and to sustain the soil organic carbon content or removed from orchards for energy use. Nutrient content and soil organic carbon are indicators for soil fertility, which is essential for constantly high yields and fruit quality in orchards. In addition, WP7 aimed to investigate environmental side effects of pruning usage such as greenhouse gas emissions, nitrate leaching from soil and soil erosion. The effects related to the pruning addition or their removal on soil fertility and on different environmental impacts depend on the soil type, the water availability and the crop itself. Therefore, 3 sites were selected in Spain, 1 in France and 2 in Germany. For each of the 6 orchards the soil type was characterized and their limitations for agricultural production were identified. Soil was sampled in order to quantify the content of nutrients and organic carbon. Furthermore, the leaching rates of nitrogen were measured in the orchard soils. In 4 of the 6 orchards greenhouse gas emissions were measured additionally to the monitoring of soil moisture and temperature. In one additional orchard in Spain, soil erosion was studied. An extensive literature review added some insight into long-term effects of wood chips or other mulch addition to orchards on the parameters under study. At the end of the project some recommendations for pruning management were given from the soil fertility and from an environmental perspective.

- **WP8.- Environmental, economic and social issues**

The main goal of WP8 was to carry out a complex analysis of economic, environmental and social aspects involved in the biomass supply chain proposed within EuroPruning project. All analyses gave positive results pointing out that pruning residues are a proper renewable and competitive energy source to partially replace conventional fossil fuels and to limit CO_2 emissions to the atmosphere. Additionally, it was concluded that pruning residues from orchards and other plantations may play a significant role in the sustainable development of the region supporting local energy market and social integration between the local market players.

One of the most important activities performed within this work package was the assessment of local impacts derived from each operation (like harvesting, transport, storage etc.) supported by the opinions of local communities and farmers expressed in the specially prepared questionnaires. Other assessments that were carried out were an environmental evaluation of the supply chain and the technically feasible sustainable potential of agricultural pruning residues. Furthermore, the economic and social impacts assessments of the proposed pruning to energy (PtE) strategy have been carried out. Several exemplified scenarios in selected fruit orchards/plantations were analysed and compared. Additionally, the comparison of two basic possibilities of pruning residues treatment, namely their utilisation for energy purposes (PtE) and/or leaving the branches in the soil have been done (pruning to soil, PtS). Finally, the best practice brochure for a sustainable utilization of wood pruning residues was elaborated.

- **WP9.- Business models, Dissemination and Exploitation**

WP9 aimed to support focused dissemination actions towards the key players of the value chain and the general public, as well as develop business plans, and provide recommendations for market uptake for EuroPruning developments. Broadly, the Work Package sought to pave the way for further use of EuroPruning results beyond the end of the project.

Concerning dissemination, the project sought to ensure effective EuroPruning branding, and communicate key results and messages to policy-makers, investors, professionals, farmers and researchers. Public communication was focused primarily on online communication, as well as through articles and videos, whilst industry and scientific audiences were targeted through participation in over 50 events through the course of the project. In order to ensure policy-makers were actively informed, a series of policy events were held, one in the European Parliament, and three in Spain and France, making recommendations on how to support the emergence of pruning value chains.

Specific aims in the topic of business models and exploitation included reviewing current market trends on biomass, defining business models for market take-up of the project results, and developing an overall project exploitation strategy including valorisation, SWOT analysis, exploitation roadmaps and value innovation analysis of individual projects results. Within the project, each of the SME partners in the consortium were assisted to develop business plans, to ensure that they can exploit their developments beyond the end of the project.

1.3. Main S&T results/foregrounds

1.3.1. Pruning harvesting equipment

One of the main goals of the Europruning project was to develop specific equipment able to chip or bale pruning residues filling a technology gap, achieving the fulfillment of the quality requirements set while satisfying economic sustainability of the whole chain. Hereafter are listed the main characteristics that the equipment needed to fulfil:

- to be compatible with different crops layouts (able to collect pruning in different inter-row widths, maximum width 2 m);
- to be versatile enough to be able to adapt to the different characteristics of most common crops pruning (diameter, length, hardness, etc.);
- to be mounted on regular agricultural tractors;
- to imply low operation cost (carrying out all the operations -windrowing, picking up and treating- in a single pass);
- to be able to produce a homogeneous chipped product from most common agricultural woody crops, cut but not frayed as made by the forage harvesters already in the market;
- to be able to achieve chip particle distribution P45 [EN ISO 17225-4:2014], from most common agricultural woody crops;
- to produce D1 bales (1.2 m diameter, 1.2 m length) for an efficient handling and storage of harvested biomass.

ONG together with CRA-ING designed, constructed, tested and optimized the configuration of a chipper to be towed by a tractor with a minimum power of 45 kW (Figure 1). The chipper has been designed for windrowing, picking, conveying, chipping and collecting the final product and has been developed to be able to work on four harvesting configurations:

- Configuration "A": pruning harvester+chipper and parallel trailer to unload the chips.
- Configuration "B": pruning harvester+chipper with a trailer drawn back.
- Configuration "C": pruning harvester+chipper with unload in big bags and hydraulic operated tractor loader to remove the filled big bags from the field (Figure 1).
- Configuration "D": pruning harvester+chipper provided with a specific own container for the wood chips.

Figure 1: PC50 chipper, configuration C.

In order to give a clear description of the machine, the main components are commented according to their position and function:

1. *Windrowing rollers*: designed to gather the scattered pruning in a central windrow to facilitate their collection. According to the demonstration tests carried out in Germany and Spain (WP6) and the additional tests near ONG's headquarters, these windrowers

cannot be adapted to all kind of field characteristics and pruning types. For this reason, a specific robust windrower is necessary to windrow the branches. ONG has developed and built one with iron teeth towed by the tractor that can work with all kind of pruning reducing losses and saving time (Figure 2).

Figure 2: ONG pruning windrower

2. *Pick-up*: The pick-up system is formed by a toothed roller (to ensure performance with all the pruning typology) with the working height adjustable from the control panel on the tractor. The purpose of the device is to pick up the windrowed pruning in order to favour their conveying toward the chipping apparatus. It includes a system to stop the machine if anything might affect driver`s safety.
3. *In-feed conveyors*: The conveying system has to feed branches into the chipping device, ensuring that they will enter in the longitudinal chopper, in order to have a homogeneous product, unlike the machines available on the market. This is composed by a central chain and by 2 toothed counter-rotating rollers (Figure 3). The studied system forces the entry of the product in the longitudinal chopper. This guarantees a more homogeneous cutting unlike the machines already in the market, where the feeding is free, and the product is frayed into particles of variable sizes. The chain is placed centrally in the upper part of the feeding channel, while the rollers are located in the lower part immediately behind the pick-up system. Branches of hard wood, and with a diameter bigger than 40 mm, that are picked up in a perpendicular way respect to the conveying system, can clog the motion of the chain because impossible to break. In case of clogging the motion of the chain, the rollers, the pick-up, and the chain itself, can be inverted in motion in order to restore the operability. The speed rotation of the roller can be varied according the dimension of the chipped product to be obtained.

   During the project various modifications have been implemented in order to improve branches conveying to the chipping device, and the final version of the central chain of the conveying system is stronger and more robust. Furthermore, ONG has performed trials on different kind of chain teeth, so to understand which type was better. Finally, ONG has set two augers at the sides of the "mouth" of the machinery to help convey branches to the chipper. This modification has significantly contributed to the machinery performance improvement.
4. *Chopper with helicoidal knifes*: The chipping of pruning is performed by a double-auger mounting blades (Figure 3). Such solution was implemented to obtain a clean cut and a minimum use of tractor's power. With this special cutting system attaining a good quality product from pruning residues is possible. The motion of the double auger is generated mechanically by the PTO of the tractor with a ratio ½ , meaning that each round of the cardan shaft corresponds to two rounds of the augers. The chopper is able to operate on products with different diameters, up to a maximum of 80 mm of woody material (in a single or multiple branches), and with different wood consistencies. Two different types of knives have been set up in order to test them: helicoidal knives with

continuous cut and helicoidal hoes. Results have showed that the initial type of knives is suitable to cut branches with a higher diameter, while knives with helicoidal hoes are more efficient with branches with a lower diameter.

5. *Discharging and collection system*: The discharging system consists of a gooseneck that rotates with an electro hydraulic command from the tractor's cabin. The system was designed to have the maximum versatility in relation to different handling options (configurations A, B, C and D). After the test provided by the project and additional tests carried out with CREA-ING on vineyards near ONG's headquarter, final improvements were carried out in order to speed up the discharging and collecting phase.

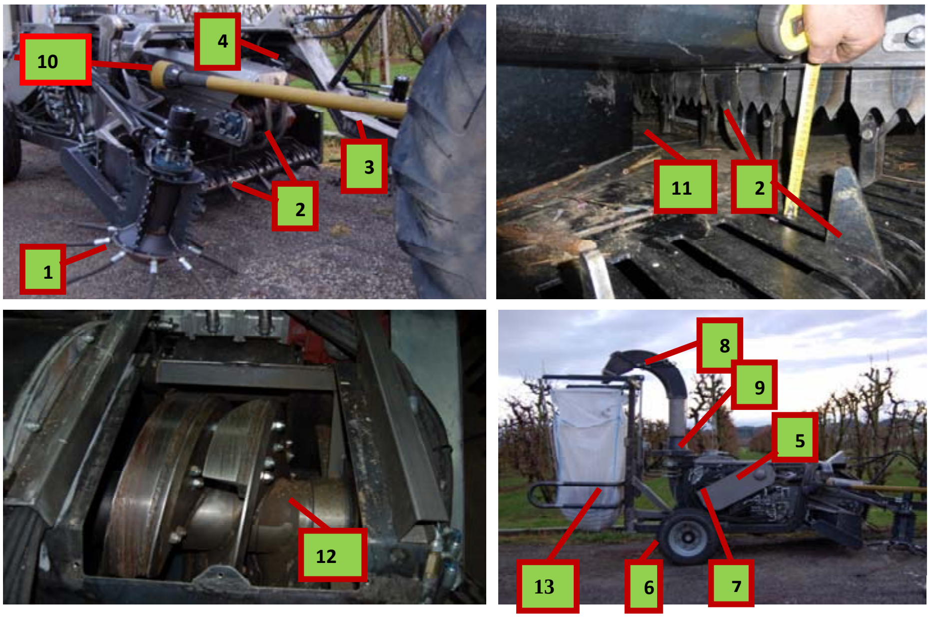


Figure 3: 1) Windrowing Rollers (Optional), 2) Pick-up Roller and Chain, 3) Front Drawbar, 4) Harvest Height Adjusting Cylinder, 5) Hydraulic Oil Heat Exchanger with Electric Fan, 6) Tires, 7) Chipper Screw and Thrower Fan Shaft, 8) Thrower Duct with Adjustable Top, 9) Thrower Duct Slewing Ring, 10) Power Take Off, 11) Feed Rollers, 12) Chipper Screw with Blades, 13) Rear Attachment (Optional).

On the other hand, PIMR developed a system concept to collect and compact branches from pruning which included two equipment: the baler itself and a windrower. The baler (Figure 4), trailed to the tractor (minimum power of 40 kW), has been designed to rake and press into bales pruning in different format and produced on different soil conditions. It includes a pick-up system (Figure 5) in which height is controlled by a wheel or anti-sinking skids systems. Material is picked-up by an over-ground rotating raking device which can be completed with tines in stony soils.

Figure 4: PRB 1,75 baler.

The windrower (Figure 5), mounted on the front of the tractor (minimum power of 25 kW), has been designed to windrow the pruning to the centre of the row by two hydraulically driven rotary heads equipped with two different types of working elements, nylon bristles and rubber flaps.

Figure 5: PRB 1,75 baler raking equipment (left) and one of the windrowing configurations systems (right).

In order to optimise windrowing, PIMR also developed a windrower which could be placed as an independent equipment, the Pruning Windrower PW 6,0 (Figure 6). The PW 6.0 windrower has a double fully adjustable telescope arm which allows operating from 1.8 up to 6.0 m width.

Figure 6: Pruning Windrower PW 6,0.

Besides carrying out several performance tests to assess the equipment performance under well-controlled conditions, the baler has been tested under real working operation conditions. The results obtained allowed improving the baler by means of redesigning windrowers which are mounted on the baler pick-up's assembly, implementing and using a working angle adjustment of tines for branches collection, optimizing the use of rotating discs in the interior of the baling chamber, implementing four wheels baler underbody, and increasing the possibility of power transfer through the drivetrain.

1.3.2. EuroPruning's Logistics Smart System

Another EuroPruning's main goal was the development and implementation of an innovative logistics tool in order to optimize the handling of agricultural residues along the whole supply chain, from harvesting to the final transport to the end user. In order to properly define the tool, a comprehensive data survey format was prepared and used to gather information regarding 26 existing and potential pruning supply chains mainly in Germany, Spain, Poland, Italy and Denmark. Figure 7 presents the typical pruning biomass logistics configuration.

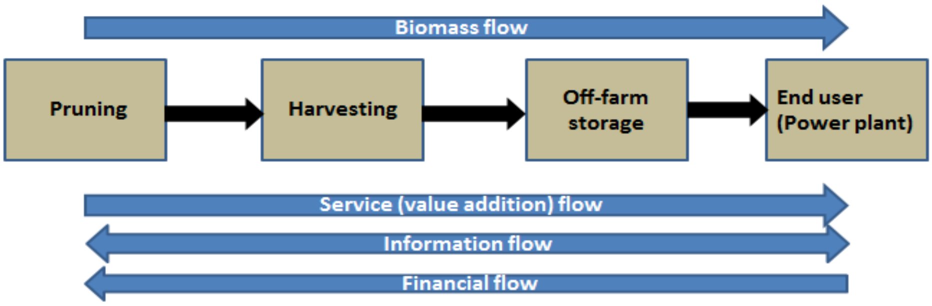


Figure 7. Concept of a typical Pruning to energy logistics chain

In addition, several logistics-audit analyses were carried out. The logistics-audit check list was prepared to include the major characteristics of biomass from pruning in the assessment: fruit tree pruning activities and characteristics; pruning biomass sources (species) and productivities; harvesting systems; storage characteristics and biomass treatment (drying, chipping, etc.) activities at storage; biomass transport; biomass quality and traceability information flow along logistics chain; biomass procurement and system cost; and sustainability of pruning to energy (PtE) chains. Although the investigated biomass from pruning value chains have different logistics configurations and operate in different regions, the study indicated that:

- Biomass losses (at harvesting, storage, and transport) varies from 0.5 % to 37 % for chips and 1.20 % to 32 % for bales
- Estimated total operational cost (at harvesting, storage, and transport stages) ranges between 27 €/t and 149 €/t (*i.e.*, at wet base, t_{wb}) when supplied in form of bales and 32 €/t_{wb} to 123 €/t_{wb} for case of chips.

Based on the assessment of the existing and potential pruning biomass supply chains, the main problems identified (critical issues) included: lack of adequate and appropriate harvesting, storage, and transport system and related high investment and operational costs; biomass losses at harvesting and storage site; contamination of biomass with impurities such as soil, stones, and metals; increased transport cost due to increased transport distance, lack of appropriate trucks and/or loading/unloading system; less trust of final consumers on quality and quantity of pruning biomass supply for existing boilers or to invest in new power plants.

Using this information, identifying major actors involved in pruning biomass supply chain and identifying biomass quality requirements for traceability of pruning products for energy sources a biomass from pruning traceability system was developed to provide sufficient information for all the stakeholders in the chain and to promote inspection for pruning biomass quality and sustainability issues. In Europruning's traceability system, a company name, quick response (QR) code, Lot number, and unique label code (assigned to an actor or label owner) are the key data elements indicated on the label. The detailed information flow can be obtained using the product delivery identification number together with products lot number. In general, there are three different codes used:

- Lot number: each batch of product should be assigned a unique lot number by the actor who produces the product.
- Label code: each registered actor (*e.g.*, farmer, distributer, etc.) involved in the product delivery will be given a specific label code.
- Product delivery identification number: unique identification number is created for each product delivery (along the biomass supply chain), identifying stages and actors involved in the supply chain.

The continuity of traceability information flow can be confirmed using the centralized information (Europruning application) platform (Figure 8). This is effective platform where each actor can play its role using the interface created for different actors (see Figure 13).

Figure 8. Sample of EuroPruning Label indicating company name with its identification code (FSWE022) and Lot number of biomass product (151129B01R1)

By determining the potential users of the EuroPruning logistics Smart System, defining the technical and functional requirements and specifications for the development of the smart logistics system, and determining relevant information/data to be documented and managed by the smart logistics system, the EuroPruning Logistics Smart System was designed by MOBITRON and SLU to be formed by four major components (Figure 9):

- Sensor unit (Smart Box): this enables to measure relative humidity, temperature, geographic positions and route tracking, truck speed, and information associated with Quick Read (QR) codes.
- On-board control unit: this enables to perform route planning, monitor the recordings by the Cargolog, and control information flow between SmartBox and web-based EuroPruning information platform.
- Information platform: this allows all recognized actors of biomass supply chain to have a centralized platform for performing documentation and data sharing, and facilitating biomass trading and management of pruning supply chain and traceability.
- Central control unit: this provides an interface linking the Information platform and On-board control unit and serves as a point of administration for the whole biomass trading and logistics system.

Based on the identified functional requirements, the smart box prototype and the web-based information platform were developed and integrated with the biomass product traceability system (see Figure 9) by MOBITRON and SLU. Using the modern Telematics technologies such as wireless devices and 'black box' technologies for transmitting real time data during transport, the EuroPruning Smart Box prototype was developed (see Figure 10 and Figure 11).

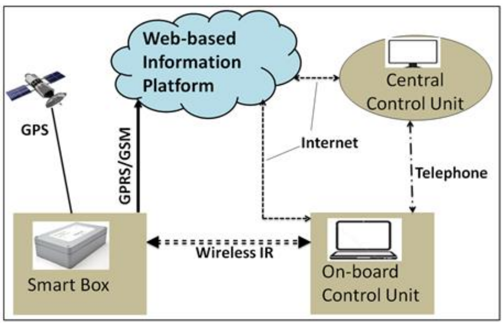


Figure 9. Linkage between different units of EuroPruning smart system

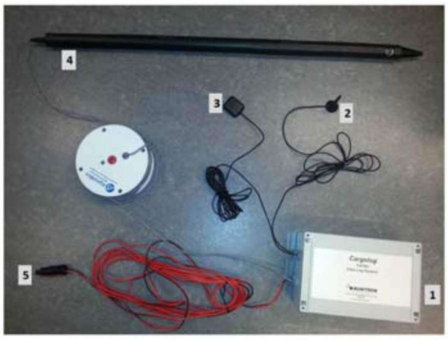


Figure 10. Smart Box system assembly: [1] smart box protected with Metal case; [2] GPRS/GSM antenna; [3] GPS Antenna; [4] Temperature and humidity measuring sensor probe; [5] Power cable.

Figure 11. Power™ 9500 scanner with its components

The web-based EuroPruning information platform is a central platform for application of logistics Smart System (see Figure 12) where different actors of the biomass supply chain interact effectively and efficiently (see Figure 13). It services as a center where data regarding biomass is gathered, stored, filtered, and transferred. It also provides an e-trading platform for effective marketing of pruning biomass. Figure 12 depicts an example of first page display where different actors can login and use it.

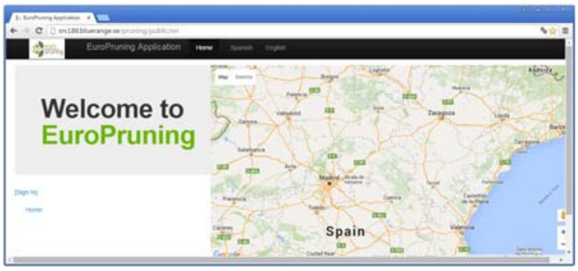


Figure 12. EuroPruning Application platform displaying Home page with interface for signing in. URL: http://europruning.mobitron.se/public/en .

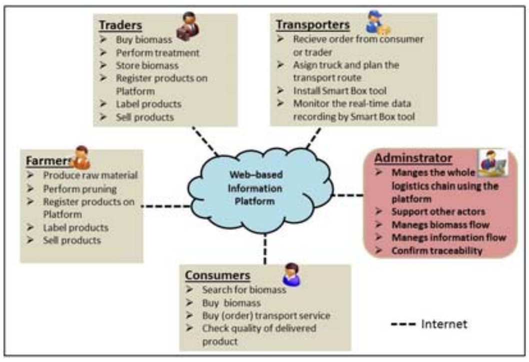


Figure 13. Major activities of different users of the platform

1.3.3. Pruning to energy logistics chains demonstration and monitoring

EuroPruning demonstrations aimed to test in real operational environment the logistics chain of agricultural pruning. They took place at three demo sites: Aragón (Spain), Mèdoc (France) and Brandenburg (Germany) that were selected in order to reproduce the pruning logistics chain into three climatic areas as well as to simulate multiple different logistics chains. Demos have been carried out along the 39 months of the project lifetime. They started with multiple contacts with actors involved in the pruning harvest operations and in the transports to the intermediate storage sites. The preparation stage ended in Oct 2014 with the preparation of a handbook for the demos describing demo stages, roles and responsibilities to be undertaken by partners and other demo participants. Demonstrations were carried out from Oct 2014 to April 2016, including: pruning quality prior harvest, machinery training and performance tests, full-scale harvest of pruning, transport and storage, and a delivery to final consumption centres (called here validators). The timeline is summarised in Figure 14.

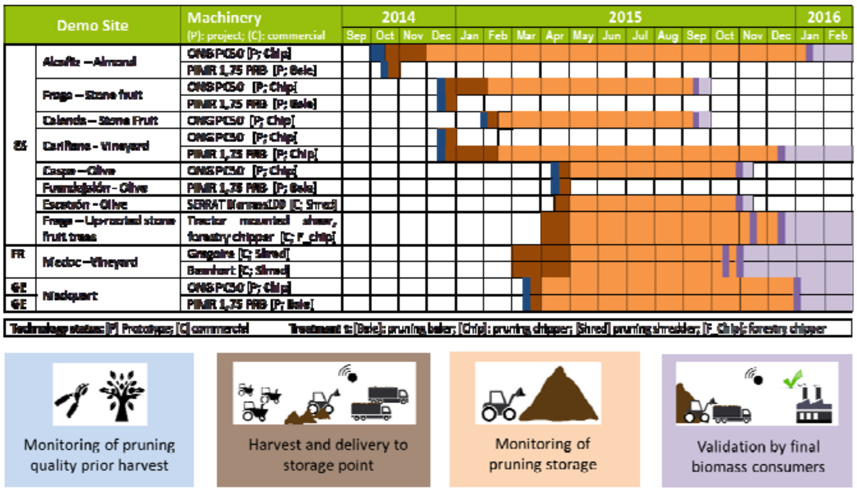


Figure 14. Timeline of EuroPruning demonstrations carried out in Spain, France and Germany

Machinery performance and full-scale harvest

The two EuroPruning pruning harvesters were developed from a low TRL (Technology Readiness Level) as neither ONG nor PIMR had a pre-existent prototype built. Carrying tests of performance was a necessary step programmed in each demo, as they should provide the figure of the machinery actual working capacity in each case. The prototypes operated properly in the performance tests, even in fields with very difficult conditions. Prototypes were tested in small parcels (few hectares) during 1 or 2 days; tests included multiple crop species, both narrow and wide crop layouts, diverse soil coverages (bare soil, stony, grass cover) and different amounts and shapes of the pruning wood. They were fully monitored by machinery builders (ONG-SNC and PIMR) and the coordinator of the machinery building and performance (CREA-ING). The summary of tests carried out is provided in Table 1.

Performance tests and full-scale harvest operations were carried out until April 2015. Demonstration tests have tested the capability of the prototypes to operate in different operative condition and with various types of pruning. Even if the species on which the tests have been carried out have different morphologies of twigs and branches, both machineries operated in proper conditions. Field conditions affected the machinery performance. In general terms, the maximum material capacity (MC) attained was achieved in fields with high pruning yields per hectare. This is a key factor, as the costs per tonne depend on the processing capacity. If MC is smaller than 1 t_{fm}/h the viability of the chain might be jeopardised, for example. The best results were obtained in Italy and Poland in February and March 2016. These tests were done with the retrofitted prototypes (including improvements) and in fields with good harvesting conditions (no constraints).

Table 1. Summary of results of the performance tests carried out for PC50 chipper and PRB1,75 baler.

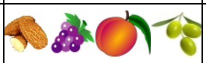
Machine/	Country	Nr tests	Crops	Ave. diamet (mm)	Ave. Length (m)	Yield (t_{fm}/ha)	EFC (ha/h)	MC (t_{fm}/h)	Losses (%)	Fuel cons. (l/t_{fm})	Moist. (%)	Bulk density (kg_{fm}/m^3)
PC50 chipper	ES	6		20-30	1-1.3	0.37-3.22	0.31-1.66	0.4-1.6	11-25%	8.5-15.8	30-40%	178-256
	DE	4		17-33	1.1-2.4	2.8-9.5	0.11-0.51	1.05-2.08	8-20%	10.1-14.0	40-44%	263-280
	IT	4		--	--	1.59-3.26	0.63-1.28	1.97-2.18	11.4-16.2%	3.8-5.2	37%	199-224
PRB 1.75 baler	ES	4		10-35	0,87-1.5	0.2-3.96	0.27-3.1	0.62-1.06	6.4-24.6%	3.2-18.6	28-32%	138-210
	DE	1		19	1.1	3.31	0.92	3.05	22.1-37.3	4.9	32%	213
	PO	2		8-12	0.58-0.77	4.15-8.08	0.38-0.73	3.03-3.05	2.8-3.3%	2.9-2.8	32-34%	162-180

Table Headers: *Sp.: species; Config: machinery configuration; EFC: effective Field Capacity; MC: material capacity: Fuel cons: tractor fuel consumption; Moist.: moisture.*

For the ONG's PC50 chipper results indicated that the bulk density is larger by using the helicoidal knives than with the new separated knives (two different implements of the cutting system). Bulk density was always lower for olive pruning, probably because it incorporated a significant amount of leaves. It was pointed out that the high values of moisture content (30 to 40 %, wet basis) may have compromise a good dimensional distribution, because the thinner branches are still flexible and become difficult to be processed with clear cuts. The machine was capable to produce P45 wood chips. Results were improved by including knives in the thrower blades for conveying chips downstream the chipping stage. The mass fraction of chips in the class 3.15-45 mm increased, the large pieces fraction decreased, and bulk density rose.

PRB 1,75 baler prototype 1 was tested in Spain, showing in all cases a lower material capacity. Prototype 2, tested in Germany (March 2015) and Poland (February 2016) achieved much higher field capacities, showing the evolution in the technology achieved by PIMR.

Built-in windrowers of the PC50 chipper showed not to be useful to convey pruning branches towards the machinery inlet in the initial tests. After retrofitting the system was found to be adequate depending on the pruning type. The hydraulic mechanism that reverses the direction of the feeding chain and the pick-up system allowed to unlocking material blockages without the need for direct intervention of the operator. The PRB 1,75 baler windrowers were able to conduct the branches to the centre of the interrow area (from 1.8 m minimum to 6 m width maximum).

After each performance test, the EuroPruning prototypes were used in a "full scale" pruning harvest, with the objective of testing the endurance and performance of the machinery in real conditions when driven by local farmers or service companies as well as to provide sufficient amounts of biomass to carry out EuroPruning storage research. The main figures of the demonstrations are shown in Table 2. It was expected that the prototypes may require repairs and fixing during the "full scale" demonstrations, and therefore other alternative machineries were contacted and utilised when the EuroPruning prototypes required repairs or when the amounts to be collected exceeded prototypes working possibilities. In Spain the SERRAT Biomass 200 shredder was used to harvest olive pruning resides. Other implements utilised were 2 regular pruning mulchers (Gregoire and Bernhart) in France. In Spain the collection of tree wood from peach up-rooted plantation was also carried out, using a mechanised tree-cutting system and a conventional forestry wood chipper.

Table 2. Summary of pruning harvesting operations in Spain, Germany and France

Demo	Crop	Farmers involved	Equipment	Products	t_{fm} produced
Spain	almond	5	ONG PC50 + PIMR PRB 1,75	65 big-bags + 3 bales	12.2
	peach	7	ONG PC50 + PIMR PRB 1,75	250 big-bags, 8 bales,	48.5
	peach	1	Auxiliary: Shear in front of truck and regular forestry chipper	Bulk woodchips	164.0
	vineyard	6	PIMR PRB 1,75	70 bales-	11.9
	olive	1 + 1	ONG PC50+ PRB 1,75	42 big bags and 1 bale	7.4
	olive	1	Auxiliary (SERRAT Biomass 100)	Bulk woodchips	136.0
Germany	apple	3	ONG PC50 + PRB 1,75	2 big-bags 164 bales	> 33
	plum	1	ONG PC50	7 big-bags	≈1.2
	cherry	2	PRB 1,75	12 bales	≈2.0
France	vineyard	18	Auxiliary (Gregoire & Bernhart)	bulk shredded wood	154.0
46 farmers involved			≈ 570 t_{fm} produced		

The observation of the full scale work leaded to obtain recommendations depicted in Table 3.

Table 3. Summary of observations and recommendations at harvesting stage

FACTS	RECOMMENDATIONS
Commercial machineries endured the full scale demos. EuroPruning prototypes required adjustments along the demos, which allowed achieving pre-commercial status.	Use proved technology when starting new business on pruning biomass.
Commercial machineries underwent clogging and operational difficulties.	Harvesting pruning is more costly in time than just driving over the pruning with a mulcher/chopper that leaves branches as pieces on the soil. This is needed to be known beforehand to avoid farmers disappointment.
Farmers tend to try finding the easiest solution. One of them is to just push the branches outside the field. This practice is simple, fast, and requires low investment.	Soil and lot of stones can be incorporated with the biomass placed at side of field. Only possible under two conditions: farmer does it with care (then the time savings are not that much); the final consumer knows it and is eager to accept the biomass.
Performance of harvesting depends quite on crop layout, pruning amounts and shape, pre-alignment of pruning, field headland space and drivers ability. There is not a “best” machinery and implement.	Do tests with preferred machinery when preparing your business plan. Do not build your plans based on thumb rule estimations
Performance of full scale demonstrations was lower than during performance tests, mainly due to drivers ability and inappropriate use of the machinery.	Try the system on field, but assume a performance reduction in future when harvesting more under more uncontrolled conditions
Built-in windrowers facilitate branches conveying towards harvesters inlet. However, previous pre-alignment is much more effective to reduce losses and increase speed.	Avoid farmers to just leave branches on soil as they fall. Encourage and agree they participate as part of the chain. This is a key point. All actors benefit: Fewer losses of branches remain on the field; the harvesting is faster and more effective.
On field losses reduced if pick-up height is lowered, but increases grass and stones collection	Use harvesters able to adapt pick-up height and revolutions. Adapt to your own field.
Both fines and large pieces cause problems in handling, storage and use. Finer dos not mean better	Choose chipping to reduce particle size of the wood to an appropriate size.

Transport and handling

A total of 25 transports were necessary to bring all the material to the storage site in Spain, mostly using mobile floor trucks and container trucks. After the storage stage, biomass was sent to validators with the same type of trucks. In France tippers towed by tractors had to be used to transport the produced materials to the centralised storage site adding a total of 60 transports to the intermediate storage, with average weight per trip of 2.5 tonnes. Three trucks were sent to validators and more than 10 to a composting plant. In Germany transports from the field to the intermediate storage site were carried out with a standard agricultural HW80 trailer towed by tractor transporting pruning bales. The delivery to final consumers after the storage stage were done with a Mercedes Vario (7.5 tonnes) and in a 8 tonnes dump truck.

The observation of the whole operative of biomass handling and transport lead to several recommendations, summarized in Table 4.

Table 4. Summary of observations and recommendations at transport and handling stage.

FACTS	RECOMMENDATIONS
Pruning harvest coordination among different farmers was extremely difficult. Each famer has a different timing and preference.	When multiple farmers aiming to participate as providers, it is necessary they to be flexible. Do not try to impose a unique supply scheme. Several supply schemes may be the key to obtain sufficient amounts of biomass.
Format affects quite a lot handling costs. The loading of big-bags and bales on a truck required 30 min/t whereas bulk chips required 5 to 7 min/t.	In large scale avoid big-bags. They may be suitable in local scale markets, or for self consumption instead. For large scale bulk material easies handling.
Discharge bulk material on soil causes about 10% d.m. loss, and increases introduction of soil particles and stones.	Promote discharge of pruning woodchips harvested (either in built-in container, or in a towed agrarian trailer) directly on containers or trailers placed at field side. This option reduces handling time and avoids contamination.
Farmers, machinery operators (to load trucks) etc. tend to compile everything from soil to leave their parcel soil "clean". In non paved soils it causes lots of soil and stones to be incorporated.	These actors are crucial. The whole value chain is in compromise if stones, plastics, etc are incorporated. These actor must be aware, and then they will avoid the "wrong practices" mentioned.
Some logistics operators use the same truck for multiple purposes: transporting rubbish, plastic residues, construction debris, etc. They may tend to use same dump truck without cleaning.	Intermediaries must be aware and committed to guarantee no pollution of biomass with inorganics due to multimodal transport. It is advisable to make them aware, and to include as part of the transport contract.
Drying of pruning prior being collected reduce problem in storage.	When aimed to obtain woodchips / shredded material, leave the branches as long as possible on plantation soil. They will loss moisture, and the losses of matter during storage will decrease.
Organising delivery with multiple actors is time consuming and source of miss-understanding. Centralised platform allowed better follow-up.	Large scale: use advanced systems to register the pruning harvest and mobilisation. Promote multi-users platform in local markets.

Validation

Pruning biomass obtained during the demonstrations was sent to final consumers after its storage of at least 6 months in open air conditions. These final consumers provided their opinion and collaborated with EuroPruning as "validators" of the pruning biomass collected. A total of 15 validators were identified in Spain, 8 in Germany and 4 in France (one of them refers to multiple small scale heating systems). Not all of them finally participated in the validation, due to they had some incompatibilities with the product, mainly because of the particle size distribution.

A total of 13 validators collaborated with EuroPruning (7 in Spain, 4 in Germany and 2 in France). The facilities had the following characteristics: in Spain 3 boilers were larger than 5 MW_{th}, 3 boilers had an output smaller than 500 kW_{th} (one of them for bales), and one was a pellet producer; in Germany 4 heating systems from 30 to 800 kW were tested (both heat an CHP applications); in France a boiler for industrial heat production in a winery and a CHP plant (both were larger than 10 MW_{th}).

Not all the cases showed completely satisfactory results, however, it can be stated that products from prunings fulfilled the expectations. Nearly in all the cases in which pruning was not suitable. The reason behind was that the feeding system could not deal with large pieces or particles (a single large piece was able to block the system). Even the material complying P45 showed more difficulties to flow than the regular woodchips, due to the more elongated shape of the particles. Fines in the woodchips produced out of pruning bales were a problem in Germany. In France the too large and uneven particle size was an end-track for consumers. The lessons learnt are presented in Table 5.

Table 5. Summary of observations and recommendations for fuel quality

FACTS	RECOMMENDATIONS
Vineyard pruning has lower ash content in general (about 4% (w-% db). Others typically under 5 (w-% db) at storage stage.	ISO17225-4 sets limits of 3% for less restrictive woodchip class (B2). Woo h certification.
During validation by final consumers the constraint was in most cases the feeding system, even if accomplishing P45 or P63.	Pruning wood value chains should be designed taking into account they will have to feed a much irregular wood chip type than usual. Either the consumers adapt their feeders, or a intermediate treatment (chipping and screening) must be considered.
Conventional mulchers produce hog material (braches broken in pieces, no clean cuts, high living tissues opened to air). They are not at all woodchips	Choosing mulcher instead chippers for carrying out the harvest may compromise biomass marketing. Consider when designing the chain
Shredders able to produce very fine shredding material expose the whole fibers to air. Particle size distribution include still few large pieces.	The material tends to degrade rapidly when stored in piles. Even in small piles it tends to degradation very soon. A just in time delivery, or a drying stage may cope with the problem.
It was observed exogenous material (soil, dust, stones) can rise 1 percentile due to improper handling. Stones may be delivered to final consumers.	Take much care to avoid further impoverishing biomass quality. Regulate the height of the harvester pick-up.
Final consumers declared intend to pay less than forest woodchips. Highest purchase prices found for medium scale facilities.	Target medium sized consumers willing to lower their biomass bill.
When plantation soil is covered with grass exogenous material is reduced. Under wet conditions more soil and sand particles are collected.	Promote farmers to leave grass cover before executing pruning. Avoid collection of prunings after rains.
Quality was better preserved when pruning was baled.	Bales are the best option to preserve quality.
Difficult to find bale consumers. They needed an extra operation for converting into woodchips.	Take care when designing the chain. Ensure intermediaries can handle and treat bales. Ensure costs still make the initiative feasible.

Evaluation of existing pruning value chains

As part of the monitoring of the demonstration an activity was agreed among multiple partners to widen the data available as base of other activities in EuroPruning: supply chain analysis, economic, social and environmental assessments, business models understanding, *e.g.* A total of 6 value chains representing the demos were documented. Additionally 19 real pruning value chains were described, by contacting directly the stakeholder participating in it. Existing value chains were reported in Spain, Italy, France, Germany, Poland and Denmark. It was stated other value chains were already set-up, especially in Italy and Spain. The result of this activity was the information itself, later on utilised by multiple EuroPruning activities.

As a summary, it was stated that large biomass chains were only detected in Spain, even though it is know that some large scale pruning biomass utilisation is already being carried out in Italy. In the rest of experiences the biomass was mostly being utilised by farmers, caves or fruit producers for self-consumption in their own facilities. However other interesting models were detected. It is worth to mention these 19 value chains, which description is fully available in EuroPruning reports:

- pruning collection as part of waste management plans from local orchards in Nuertingen (Southwest of Germany) and Serra (Valencia, Spain);
- self-consumption of plantation pruning wood in Vesterled frugtplant (Fejø, Denmark), AGRIFRANJA (Fraga, Spain), Château Poupille and Château Haut Peyrat (Aquitaine, France), Cantine Giorgio Lungarotti (Torgiano, Italy) and Stefano Barbieri (Riolo Terme, Italy), Agriculture and Pomology Research Farm in Przybroda (Rokietnica, Poland);
- olive mill waste and pruning wood large scale plants of El Tejar and Valoriza (Andalusia, Spain);
- pruning wood marketed locally to consumers of conventional biomass by intermediaries who carry out the collection, treatment and distribution, like
    - AREX Medio Ambiente distributing olive pruning as co-feedstock to a straw/wood power plant (Miajadas, Spain);
    - the agricultural service of Timo Kirn in Serheim (Germany) performing pruning and marketing it as firewood;
    - Green Forest who recoveres the pruning from PPHU “SADY TRZEBNICA ” Sp.z and markets it (Trzebnica, Poland);
    - GOSPODARSTWO SADOWNICZE fruit company, who bales their own pruning and provides to a couple of local heat plants;
- coordinated action of multiple actors, service company, council and multiple farmers and caves for local heating demands (Vineyards4heat Life+ project, Vilafranca del Penedes, Spain);
- mobile pelleting unit providing pelting service to neighbouring plantations by a Xavier Muller Domain cave (Marlenhein in Alsace, France);
- production of wood pellets from olive pruning in a cooperative (Jabalquinto, Spain) and in a large centralised pellet plant (Pellets de la Mancha, in pruning offers tree care service and compiles pruning).

1.3.4. Changes in prunings quality specifications along the logistics chain

The demonstration activities showed that each stage of the logistics chain has an effect on the biomass from prunings properties which in turn affect the subsequent processes. The results showed that taking into consideration quality specifications, particularly moisture content and ash content, should be prioritised already at the early stage of pruning. The material has to be kept dry and free from contamination, soil or sand, until the next process takes place since higher moisture and ash contents negatively affect the heating value and, in the second case, can also lead to slagging problems in the combustion systems.

The evaluation of pruning stage, for the studied crops, at different locations showed variations in moisture content, gross calorific value and ash content that are partly related to geographical effects. Variations among quality of the different crops were evident.

The quality parameters vary along the logistics chain depending on the type of the biomass (stem, branches, with or without leaves) and the time between pruning, harvesting and storage. Local weather conditions clearly affect the changes, especially during the period between pruning and harvesting stages compared to harvesting and storage. For this reason, the collection of prunings from the field should be delayed as much as possible. High proportion of leaves in prunings residue should be avoided when possible, promoting their falling before being chipped, since they lead to an increment of ash and chlorine contents and can facilitate degradation during storage.

Pre-treatment involves either baling the prunings to be stored in a stack, or reducing particle size of the material by chipping or shredding before storing it in a pile. The evaluation of the storage process in bales and chip piles at the dismantling stage showed that bales, in general, maintained better quality than chips or hog fuel after storage. Baling pruning resources of apple tree (Germany) and vineyard (Spain) showed minimal dry matter losses and positive energy change up to +7.4 % (Figure 15), due to a remarkable drying effect favoured by the low density of bales. However, the total cost of such handling method has to be considered across the whole supply chain before choosing this type of logistics chain. Chips storage, on the other hand, led to considerable dry matter losses and inhomogeneous fuel quality with regards to particle size distribution and moisture content. Chipped material was found to be less prone to microbial degradation, *i.e.*, less dry matter loss, compared to the shredded pruning (hog fuel) which was used in the French storage trial, that showed a decrease in net energy of 8.8 % (Figure 15). The deterioration of prunings quality at the dismantling stage was indicated by a reduction in the calorific value and increased ash content. The total net energy changes in most of the comminuted prunings after storage were negative, to different degrees, depending on the type of the stored material, particle size distribution/percentage of fines, initial moisture content, comminution machinery (using sharp knives for chipping and blunt tools for shredding) and presence of leaf fraction in the prunings material. Geographical influence during the storage of chip piles was not clear as in bales storage.

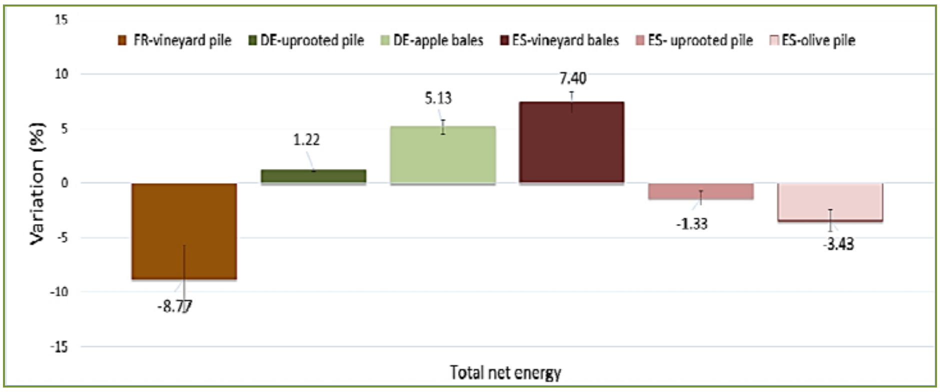


Figure 15. The total net energy variations in the prunings of different species after 6 months of storage in France, Germany and Spain.

Storing pruning residues as branches has less negative impact on fuel quality than storage of chips, being the drying process more effective and the quality deterioration minimal. When comminution of prunings is due, choosing the larger particle sizes acceptable to the consumer, and using sharp knives to chip the fuel with low fraction of fine particles, will considerably improve storage conditions and reduce quality deterioration.

Analysis of mineral components in ash showed some rise in silicon values during the logistics stages of many crops, which confirms the need to keep the prunings as clean as possible. The rest of major minerals of biomass ash showed no major changes in their concentrations between pruning and dismantling stages and had average concentrations similar to those reported in the literature in all the studied species. Contents of chlorine were acceptable according to the limits stated by ISO 17225-4:2014 (Solid biofuels - Fuel specifications and classes - Part 4: Graded wood chips), except for chlorine in the case of olive tree prunings.The presence of certain heavy metals, such as copper and chromium, in some material at high levels should be considered. Measures such as mixing the unacceptable fuel with cleaner biomass can reduce these average values to levels below the maximum limits allowed for wood fuel chips according to ISO 17225-4:2014.

The assessments of health risks connected with exposure to high concentrations of air-borne fungal spores or microbial particles were found to be close to values reported for agricultural or waste disposal areas. The demonstration of storage trials showed no indication of possible risk of self-ignition. Due to the limited quantities of prunings available at a single site, storage piles are not expected to be high or large, thus reducing the potential of such risk. Similarly, emissions of GHG (CO_2, N_2O and CH_4) during construction and dismantling stages were considered to be low.

The results of EuroPruning project highlight the fact that the knowledge on what happens to the quality of a certain raw material during the supply chain under specific climate conditions is essential in order to guarantee the required quantity and fuel quality to the consumer. Specific study of each case should be performed since no rules of thumb can be applied. However, the information obtained experimentally has enabled the project to provide guidelines of interest for future stakeholders dealing with the storage of prunings resources.

At the pruning stage, the inclusion of contaminants in the harvested material is an important problem that has to be addressed at early stage to avoid reducing the fuel quality. In this sense, main recommendations in this stage are:

- Collect the pruning without picking contaminating material such as stones and soil, which will increase the ash content and silica concentration. If the field is not covered with vegetation or grass try to place a plastic sheet on the ground before pruning. A balance with the effects on machinery performance should be assessed from the economic point of view in this case.
- The pick-up system of the collection machinery should be positioned few cm from the soil in order to avoid the collection of stones and sand. On the other hand, losses of material should be evaluated during machinery performance.
- Actions should be carried out to ensure that the pruning residue is kept as dry as possible to avoid any increase in moisture content. If possible, choose a rain-free day to perform the pruning stage. Make sure that the material is kept dry (not under the rainfall) at all stages of the logistics chain.
- When collecting the material, try to avoid the bottom layer close to the soil or the very fine material collected on the plastic sheet. Large proportion of fines has negative effect on natural drying process during storage and usually increases ash content.
- Although moisture content of prunings residues rarely exceed 50 % (w-% ar) at the pruning stage, the collection of prunings from the field should be delayed as much as possible. This will decrease the moisture content significantly on the field with no important substance losses. Additionally, leaves (when existing at the pruning stage) will be allowed to dry and fall down into the soil, improving the quality of the material in terms of ash and chlorine content.
- If biomass from pruning has to be stored at field side before or after pre-treatment, avoid increase of exogenous material and optimize the process for better drying.

The size of prunings particles will be normally reduced to chips or hog fuel before combustion. This process has significant effect on many parameters in the storage stage. Main recommendations in this stage are:

- When comminution of prunings is due, choose chipping process, which imply clean cuts with sharp tools. Avoid shredders since they use blunt tools to crush the material into irregular size, easily compacted and more susceptible for biological degradation.
- The material should be chipped to the highest possible particle size that is acceptable to the consumer. This will improve the storage conditions and reduce quality deterioration.
- The presence of high percentage of fines has a negative effect on chips during storage such as pile permeability and compaction. Moreover, it provides larger surface area for microbial growth.
- Once the material is chipped, the period between chipping and storage should be kept to a minimum.

The storage stage was thoroughly evaluated between construction and dismantling stage. Due to the type of logistics chain associated with prunings, governed by scarcity and local availability, large scale storage is not considered to be the most common practice. For this reason, it is highly recommended to:

- Promote the construction of large piles (high core to surface ratio) in areas characterised by non-favourable weather conditions (rainfall and low temperatures). Small piles are more convenient under favourable conditions if space is not a limitation.
- If possible, store the pruning material as branches in bale format instead of chipping and storing it in a pile to ensure the preservation of the material quality. In any case, it has to be ensured that the whole supply chain still is cost-effective.
- Storage should be done on dry surface (paved or asphalted ground) to avoid additional contamination with exogenous matter e.g. soil and stones.
- When possible, sieving the material after comminution is a good practice to avoid large percentage of fines in the fuel which can lead to many undesirable effects on fuel quality during storage.
- Do not compact the material during the storage construction.
- Ensure an even surface of the pile to avoid accumulation of water in pits or pockets.
- Ensure that transport trailers and trucks are clean before loading and delivering the fuel to consumer.

General recommendations to prevent occupational health risk and self-ignition during storage are:

- As in the handling of any other stored chip piles, breathing masks (with protection limit of at least 5 μm) are highly recommended to avoid respiratory diseases. Health risks are normally higher in comminuted material than in bales (unless they are highly densified).
- Due to the relatively low initial moisture content of the pruning before storage, temperature development inside the piles, caused by microbial activity, is not expected to reach high levels. Self-ignition is therefore less likely to occur during storage. However, frequent visual inspection is highly recommended.
- Loading and unloading of the material should be done in a well-ventilated area.
- Storage indoors should be performed in a well-ventilated area equipped with temperature sensors and, whenever possible, CO sensors.
- Material received with pockets of high temperature should be separately stored and allowed to cool before further handling. Metal pieces in comminuted pruning should be

extracted, since they could act as a catalyst in heated piles.
- Mixing of fuels from different qualities (species, particle size distribution, and moisture content) should be avoided.

1.3.5. Pruning to energy logistics chains and soil management

Taking advantage of biomass prom prunings in the energy sector also requires ensuring whole process sustainability. This implies that all the issues which might affect future yields have to be considered. High yields and fruit quality in orchards are dependent on many factors. Orchard farmers are used to focus on plant choice and treatment, pests and diseases, fertilization and water supply. While all these factors are decisive for successful farming, farmers tend to neglect soil fertility, which is just as important to their success as the others. The effect of wood pruning on soil chemistry, GHG emissions, nitrate leaching and soil erosion was also studied under a wide range of field conditions. Six different study sites were selected in Spain, Germany and France in which mulched pruning plots and not-mulched pruning plots (uses of pruning for energy purposes) were monitored and assessed during the length of the project.

Soil organic carbon

The carbon removal through prunings was relatively low (Table 6) compared to removal in agriculture through straw of cereals (Poaceae, 4,000 kg C ha^{-1} $year^{-1}$) or of corn (*Zea mays*, 10,000-15,000 kg C ha^{-1} $year^{-1}$). These results may explain that the removal of prunings from orchards did not affect the content of soil organic carbon at the 6 study sites except for the tree row in the cherry orchard (Brandenburg/ Germany). Grass cover in the interrow can be regarded as an alternative carbon source for soil microorganisms. Consequently pruning effects can be more pronounced in herbicide treated and therefore grass-free tree rows. The effects increased with increasing amounts of pruning left on the soil.

Table 6. Study sites and their estimated carbon removal through pruning extraction from orchards for energy production.

Study site	*Carbon removal by pruning (kg·ha^{-1}·$year^{-1}$)*
Peach, drip irrigation/Aragón (ES)	1628
Peach, flood irrigation/Aragón (ES)	1110
Almond, drip irrigation/Aragón (ES)	724
Vineyard, no irrigation/Mèdoc (FR)	518
Cherry, no irrigation/Bradenburg (DE)	1747
Apple, drip irrigation/Brandenburg (DE)	1021

Fertilizer savings

In order to assess the potential of fertilizer savings by leaving prunings on the orchard soil, a balance between nutrient input by fertilization and output by removal of harvested fruits and collected prunings was established, taking the nutrient content of the soil into account. Two peach sites were heavily over fertilized and therefore pruning removal would have no impact on soil nutrient contents. For almond the nutrient removal from the orchard by harvest highly exceeded that of pruning removal and, hence, the impact of pruning removal on soil nutrient content should be rather small for almond. For the French vineyard and the German cherry and apple orchards a removal of prunings would change the balance to nutrient losses from the system, but on a low level, which can also be compensated by fertilization.

No significant effects of pruning removal on soil nutrient content could be detected after two years in the 6 study sites, but according to our literature review, in the long term it can be expected that soil nutrient levels decrease due to pruning removal without compensation by fertilizers.

Environmental effects

The emission of greenhouse gases (GHG) such as CO_2, CH_4 and N_2O is a land use specific indicator, which describes the environmental impact of an agricultural practice and which plays an important role in the assessment of the life cycle of a product. In this study no significant difference of GHG emissions was found for pruning removal compared to leaving it in the orchard. When only considering fluxes from the tree row, CO_2 emissions tended to be higher with pruning left in almond and cherry orchards compared to pruning removal. But differences between sites were much greater than those between pruning treatments in tree rows. In general, CO_2 emissions were higher in orchard soils with enhanced moisture content due to climate or flood irrigation. Mean annual emission rates of N_2O and CH_4 were very low.

The export of nitrogen (N) from orchards to groundwater is a risk to the environment. Groundwater can drain into surface water bodies and trigger eutrophication in slow flowing rivers or lakes. In addition, excessive concentration of nitrate in drinking water is considered a health risk. Nitrate leaching losses were, however, low for all study sites except for the peach drip irrigation in Spain. The loss of 24 - 33 kg N ha^{-1} $year^{-1}$ in the peach drip irrigation orchard can be explained by the over-fertilization mentioned above. Pruning removal did not change the rate of nitrogen leaching in any of the study sites.

Soil erosion is a major problem especially in drier climates as it is typical in Aragon/Spain. Fertile soil is normally restricted to the top soil layer (0-30 cm) and losses of fertile top soil through erosion can be compensated only slowly in some cases, but not if erosion exposes hard rock. Erosion was not found to be a problem in any of the experimental sites listed in table 1 as field inclination was low for all of them. But for one additional almond orchard on sloping land in the Spanish demo region annual top soil losses amounted to ~ 190 t ha^{-1}.

Since in this case the upper slope has a maximum depth of only 60 cm, exposition of the hard rock can be expected within the next 42 years. This would not allow the growth of trees anymore, if the management does not change.

Soil management recommendations

Detailed recommendations of this work about conditions when prunings should not be removed from orchards have been formulated and published on the project webpage (http://www.europruning.eu/web/data/new.aspx?source=topic&id=1984). The main recommendations are: for the use of prunings to energy instead of prunings to soil, the paramount importance of an established grass or vegetation cover has been identified. All sites with a well-established grass / vegetation cover did not show negative effects with regard to the indicators of soil fertility as discussed in the above epigraphs. Therefore, prunings can be removed, if other carbon sources such as a grass cover are present and nutrient export is compensated *e.g.*, by fertilization.

Soil management contraindications

Prunings should ***not*** be removed, if

- **vegetation cover > 80 %** between trees (interrows) **cannot** 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 *or*
- **vegetation cover with > 15 t ha^{-1} year^{-1}** fresh biomass (3 t ha^{-1} year^{-1} dry mass) **cannot** be established *and* soil carbon content is low.

If one or more of the cases (a) – (c) apply, the dominant problem should be treated as follows:
If (a) or (b): Prunings should be chipped and *used as cover mulch.*
If (c): Prunings should be chipped and *worked into the soil.*

This general advice may be modified according to local environmental characteristics. No general number can be given for a low carbon content, nor general advice for a treatment, because both are strongly dependent on multiple environmental and management factors.

1.3.6. Environmental and socioeconomic assessments

Assessment of local impacts derived from each operation

Environmental Impact Assessment (EIA) is a procedure required under the terms of European Union Directives 85/337/EEC and 97/11/EC on assessment of the effects of certain public and private projects on the environment. As the EuroPruning project contained few steps in the whole logistics chain focused on Pruning to Energy (PtE) strategy (which may be replicated in different places), the EIA scoping and screening issues were evaluated according to three main selected parts:

- harvesting process (in the orchard),
- transportation of the harvested biomass (transport outside orchards),
- biomass storage (open air conditions).

The analysis was supported additionally by the questionnaires (fulfilled by the farmers) and observation of the activities during the whole PtE logistics chain. As a result, some potential negative environmental impacts of the PtE strategy have been determined and prevention actions have been recommended. The performed EIA analysis revealed that the potential negative impact of PtE strategy on the local environment is marginal and may be neglected.

LCA analysis of the supply chain

To determine the general environmental consequences of the Pruning-to-Energy (PtE) logistics chain, a Life Cycle Assessment (LCA) was conducted for an apple and cherry plantation in Germany, peaches, almonds and olives in Spain and grapes in France. Moreover, the Pruning to Energy scenarios have been compared to the *status quo* of mulching and leaving the pruning residues on the field after pruning pPruning to soil scenarios, PtS). The scenarios assessed were based on the demonstration logistic chains, which included newly developed pruning residue harvesting machinery. In order to get a better overview of the impacts in the minor stages, the results for the category Climate Changes were provided for the 'Field to Gate' stages, excluding the combustion of the pruning residues in the 50 kW furnace, which is dominating in the overall results for PtE. Consequently, also the coal substitution was not considered, which is dominating the PtS results. This resulted to imply certain impacts on the environment. Based on the conducted assessments it was concluded that:

- considering the Climate Change category, the impacts of Pruning-to-Energy are in any case and under all circumstances much smaller than when the pruning residues remain in the orchards.
- the PtE chain leads to a reduction of CO_2 from 500 kg/ha (almond) to 2500 kg/ha (apple) or from 94 kg/GJ (apple) to 105 kg/GJ (almond) of generated heat.
- for most the other impact categories, Pruning-to-Soil shows better results.
- the impacts of the transport and storage of pruning residues are very small compared to other stages.
- the impacts of harvesting of the pruning residues in case of the PtE chain are generally comparable to the mulching operation in the PtS case. Compared to the impacts of combustion of pruning residues or coal they are small.
- the use of the baling machinery leads to smaller impacts in the harvesting stage, but higher impacts in the transport and storage stage, when compared to the baling machinery.
- assuming a larger furnace for heat production, the chips produced from pruning residues lead to considerable lower environmental impacts, especially the amount of fine dust will be decreased.

Assessment of the technically feasible and sustainable potential of agricultural prunings

In order to obtain the sustainable potential pruning residues in Europe, a set of coefficients of reduction have been developed to account for the constraints that limit the use of the pruning wood. As a result, different pruning potentials have been determined, from theoretical potential, technical potential (considering losses during harvesting process, slope, accessibility to fields), economic potential (taking into account the minimum field size and density of plantations in the territory) up to sustainable potential (assuming competition with other current uses of the pruning wood, and default use as soil amendment to the pruning in organic farming, special protected areas and preservation of the soil organic carbon in the long term). The performed analysis revealed high theoretical potential for Europe (Figure 16), of about 13.7 Mt of dry matter per year of wood from pruning.

It was shown that the technical limitations do not significantly affect the potential, causing a small reduction of about 10 %. The economic scenarios have revealed that pruning has an important potential not only for small consumption in closed loops, but also an economic potential for exploiting in commercial basis of about 8.7 Mt of dry matter per year. The implementation constraints have also revealed to not affect severely the pruning wood potential. The main limitation, or at least the main concern, has been detected when analysing the sustainability in terms of preserving the soil organic carbon in the long term. The potentials can drop down to 30 % if the soil management is not adequately carried out. The results revealed that pruning can have a relevant role especially in areas where the annual carbon returns to the soil are limited. This is the case of dry Mediterranean areas, where the permanent crops are prevailing in Europe. However, the results did not mismatch the recommendations obtained from EuroPruning's work on soil management, which suggest that in overall, the energy use of pruning residues is not opposed to a sustainable soil management and long term soil fertility.

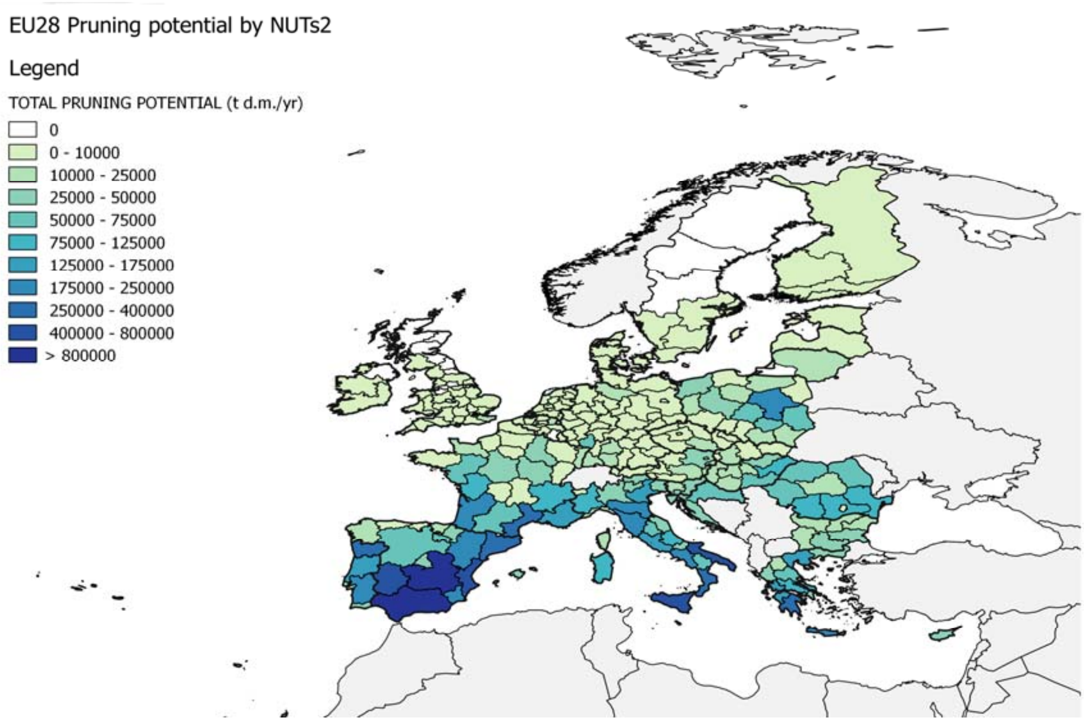


Figure 16.- Regional pruning potential for NUTS2 level in EU28

Report on economic evaluation of biomass supply chain

From practical point view, the economic evaluation is crucial in the decision making. Therefore, the work was focused on logistics costs at different stages of supply chain considering harvesting, storage, and transport stages as well as management costs. The analysis included life cycle cost analysis (LCCA) over the life span of 10 years.

The logistics cost assessment results indicated that the collection/harvesting stage is the most expensive step of the pruning logistics chain followed by the storage stage when only operational costs are considered. On average, the distribution of operational costs is 68 %, 13 %, 9 %, and 10 % for harvesting, storage, transport, and management levels respectively at basic scenario with 50 km transport distance, and 90 m^3 truck capacities.

The unit operating harvesting cost ranged between 29.60 €/$t_{w.b.}$ and 82.60 €/$t_{w.b.}$ which indicated that the final machinery developed from the prototypes of EuroPruning project could have good performance. LCCA results showed that the operational cost was about 73 % of total life cycle cost. Therefore, it was suggested that at strategic level, more attention should be given to the improvement of the logistics operations and management than to the investment cost which was only about 27 % of total cost. The LCCA varied from 108.90 €/$t_{w.b.}$ (almond chips) to 50.06 €/$t_{w.b.}$ (vineyard chips). The sensitivity analysis indicated that excepting for the almond chips case, the remaining PtE scenarios can be attractive at least within 200 km limit of transport distance between farm and power plant. The case of best scenario (vineyard chips) can be effective over transport distance up to 500 km. Except almond chips case, for remaining 5 scenarios, the estimated net benefit at basic scenario varies from 12.50 €/$t_{w.b.}$ (Peach chips) to 59.25 €/$t_{w.b.}$ (vineyard chips).

Considering the yearly harvestable potential under basic scenario (*i.e.*, 50 km distance and 90 m^3 truck), LCCA results indicated that vineyard chips can generate net benefit up to 97,169 €/yr, followed by olive chips and apple bales (*i.e.*, chipped at Storage site) could generate net benefit up to 70,870 €/yr and 62,541 €/yr, respectively. Therefore, where adequate pruning potential of Vineyard, Olive, and Apple trees exist, the PtE initiative on these varieties can be more attractive with these harvesting machine prototypes developed in EuroPruning project.

Report with the determination of social impact

In the scope of sustainable development, the social acceptance is crucial. To reflect the opinion of the society the social return of investment (SROI) assessment was proposed and calculated for different scenarios. The review of existing and chosen methodologies was the basement for the elaboration of the SROI analysis methodology used for calculations. For the SROI analysis the indicators like: product impact on farmer and energy producer, product responsibility, job creation and greenhouse gases reduction, have been applied. As a result, the SROI analysis for different case studies has been performed. Additionally, the comparison of SROI effects for mulching and pruning to energy (PtE) were made. It was shown that mulching brings almost no social benefits, in turns, the PtE scenario creates positive social value.

To examine which parameters are vital for the SROI result a sensitivity analysis was performed, as well. It was proven that orchards area, local pruning potential, lower caloric value of pruning residues, cost of CO_2 emission, and yearly investment, influenced the most the social benefits. Additionally, the social analysis was supported by questionnaires fulfilled by the farmers and EU authorities who pointed out a positive attitude towards PtE strategy.

The social analysis for scenarios in which a farmer collects the branches as a hobby (unpaid labor) gave the highest values of social indicator (SROI). Scenarios with market wages for a handmade collection gave also positive, but not so high SROI results. They also generated high incomes for local energy producers. The scenarios assessed were based on the demonstration logistic chains, which included newly developed pruning residue harvesting machineries (pruning baler and pruning chipper).

Finally, main conclusions from the social assessment were defined:

- The comprehensive analysis of the PtE strategy is complex and some indicators are not always applicable in all considered aspects.
- Some of the indicators are common among the environmental, economic and social analyses. For instance, CO_2 reduction influences the environmental effect (*i.e.*, decrease

of global warming), the economic analysis (cost of 1 Mg of CO_2 emission to the atmosphere), and the social one (*i.e.*, health of society).

- In a specific case study (the use of machinery is impossible, trees are located quite randomly, pruning potential is very low, and the only possibility is a use of man power for pruning collection), it is possible to obtain the negative economic result (NPV<0, no profits for entrepreneurs without the external support) whereas the social analysis may bring very positive social effects (*i.e.*, SROI=24, which means that one EUR spent on EuroPruning business model implementation gives 24 EUR of social benefits). In such case, if social benefits are more crucial for local community, the subsidies might be recommended and justified.
- For typical cases analysed (when NPV>0, and the machineries are in use) the SROI indicator is positive and its value is in the range between 0.5÷7.

Best practice brochure

To promote the sustainable pruning to energy (PtE) strategy amongst all the market players involved in the local biomass from pruning utilization for energy purposes, a best practices brochure has been elaborated. In the brochure many aspects dealing with PtE strategy have been described, including: a good start of the business, biomass harvesting in the orchard, harvesting machine safety information and devices, pruned biomass storage, pruned biomass logistics and transportation, fuel quality and its combustion in the boilers, environmental and social aspects. Based on project results and on observations during the demo tests, some recommendations, suggestions and remarks to work effectively and produce successful outcomes have been determined, that should be respectively adopted depending on the considered case, characterization of the orchard/plantation, transportation and storage possibilities as well as final consumer demands.

1.3.7. Business Models, Policy implications

Policy Implications arising from the project have been drawn up and presented to policy-makers at the European level through a final Policy Event in the European Parliament, as well as to regional and national policy makers in workshops held in France and Spain (countries with large pruning potentials). The background research found that as a marginal biomass resource, policy often does not reflect the specific characteristics of prunings, resulting in a lack of supporting frameworks at regional, national and supranational levels, and the emergence of a number of regulatory barriers. For example, provisions of the Common Agricultural Policy, such as Good Agricultural & Environmental Conditions (GAECs) were found to encourage non-optimal use of prunings as a soil amendment rather than a biomass resource, and that eco-design requirements for small stoves and boilers could prohibit the use of prunings as an energy resource. Further, recommendations were made on how to overcome non-technical barriers to pruning use, such as low awareness amongst farmers, and it was argued that EU funding (ERDF and EAFRD) could be used to support regional value chain creation.

Business models were developed to enable the commercial exploitation of the technical innovations made within the project. These business models were different for each organization partner and individual technology.

Finally, a value chain approach was used to show theoretically, and with identified real life examples, how to make the prunings chain viable. The absolute key conclusion drawn from EuroPruning's models and examples is that there is a clear need for one or two key organizations, with clear goals and interests, to be in charge of initiating and running the pruning value chains, before it is viable to use pruning for energy production beyond the level of self-consumption.

1.4. Potential impact and the main dissemination activities and exploitation of results.

1.4.1. Potential socio-economic impact

The opportunity to use biomass from pruning residues for energy purposes or other applications creates a potential for a new business for farmers and related companies. Moreover, it enables the development of the local community and taking advantage of regional renewable energy sources which is important in terms of environmental protection, reduction of carbon dioxide emission as well as limitation of fossil fuels combustion, especially in medium and small scale domestic boilers.

To follow the pruning-to-energy (PtE) strategy in the economic, environmental and social area, EuroPruning has proposed some recommendations and advices and has pointed out risks and sensitive points. These actions should help and support the farmers and other market players in their decision and further activity in this area of interest. The proper understanding of the dependences in this logistics chain leads to the improvement of the process and elimination of the weak points, building a new market for such type of local biomass, like pruning residues. If new biomass logistics chains grow, the local economy will be stronger and the policy of district or local heating with local resources will be easily implemented helping circular economy schemes to emerge.

Social Impacts

In the EuroPrunung project many SROI analyses have been carried out to determine the validity and added value of the pruning-to-energy (PtE) logistics chain considering social aspects. Social assessment studies were also performed to compare the PtE scenario to the current practice: mulching and leaving the branches on the field (pruning-to-soil schemes, PtS).

In most of the cases (when NPV>0, and the machineries were in use) the typical SROI result was in the range 2÷8 (one EUR spent on EuroPruning business model implementation gives from 2 to 8 EUR of social benefits).

If the specific case where the economic analysis had negative results (NPV<0, no profits for entrepreneurs without the external support), the social analysis revealed very positive effects (SROI=70). It raised from the fact, that no machineries were in use (trees were located quite randomly, pruning potential was very low, and the only possibility was to use of man power for pruning collection). Therefore, the economic result was very poor (manpower was more expensive than machinery) but social factor was very high (thanks to the positive factors of "additional workplaces" and "product responsibility"). In such case the subsidies might be recommended and justified, but social benefits remain only a decision-supporting factor. Considering these results it can be stated that taking advantage of biomass from pruning for energy purposes has a significant socio-economic impact.

Impacts on economy

Although communication efforts will support future development of pruning value chains, the four business plans and the overall exploitation plan developed should actively encourage the emergence of new products and services arising from the EuroPruning project. In particular, three aspects might increase EuroPruning's impacts on economy:

- **Technologies** – The technologies developed in the project not only provide the stakeholders involved in exploiting the pruning with the necessary tools for doing so; but on the same time will lead to job creation in the future, alternative ways of using prunings as well as straighten the competitiveness of the European Union with new and more efficient ways of harvesting, optimized logistics and quality control tools.
- **Value Chain Model –** The value chain model developed in the project, can calculate whether is financially viable or not to use prunings for biomass. It can be made for the whole chain or be adapted for the individual company, to calculate if it is profitable. The model can be expanded or simplified as needed, but can be a strong tool for evaluating if it is a good idea to initiate a pruning chain. This model can be used beyond the scope of the project as it can be adapted to work with other things than pruning and represents a unique and valuable tool.
- **Business Models –** The different models to follow for exploiting the prunings were identified in the market analysis conducted during the project with a number of key stakeholders. The real life models can be duplicated across the European Union, leading to job creation in terms of several businesses that will identify an opportunity in exploiting prunings; resource optimisation by using prunings as self-consumption as well as sale of the pruning machineries and services needed.

EuroPruning's life cycle costs analyses estimated that net benefit at basic logistics scenario (*i.e.*, 50 km distance from producer to end user and 90 m^3 truck) varies from 12.50 €/$t_{w.b.}$ (peach chips) to 59.25 €/$t_{w.b.}$ (vineyard chips). EuroPruning's results have also revealed that pruning has an important economic potential for exploiting PtE chains in commercial basis of about 8.7 Mt of dry matter per year in Europe. Considering an average net benefit (35.9 €/$t_{w.b}$) and a pruning average moisture content of 35 % over a wet basis, if the exploitation of the already mentioned 8.7 Mt of dry matter per year was achieved, this fact could lead to attain 478.5 M€ net benefits directly distributed among the European Primary Sector. This figure just exemplifies the significant potential of PtE chains to create added value in the EU's rural area.

Pruning value chains are inherently local, and as such, measures to encourage their development should occur at the regional level. The development of such value chains can be encouraged using the Regional Development Pillar of the CAP, and the finance provided through the European Agricultural Fund for Rural Development (EAFRD). The Rural Development pillar can fund knowledge transfer, training and skills acquisition; support non-agricultural activities for farm and business development; and promote co-operation amongst value chain actors for biomass provision and energy production. The EAFRD also funds basic services and village renewal in rural areas, which can be used for renewable energy infrastructures. These measures can be supported in Rural Development Plans, which can be amended by the relevant Managing Authorities.

The European Commission's Farm Advisory Services and the European Innovation Partnership on Agriculture (EIP-Agri) should promote the use of prunings as a biomass resource, giving guidance also on how to remain within Cross Compliance criteria and on the use of the EAFRD measures. These actors can rely on the best practices created by the EuroPruning project, make use of a value chain calculator created within the project to demonstrate profit potential, and use EuroPruning results as validation of the potentials of new value chains.

At the regional level, policy-makers need to consider every stage in the value chain, and recognise that every actor needs to benefit. It must also be recognised that, of course, not every region has sufficient resources for developing a market. Regions should be encouraged to perform resource assessments, and stakeholder mappings, to better understand their regional potentials. Bioenergy and pruning harvesting can be placed within a broader regional strategy for rural development, to highlight that benefits are regional and not only for the involved actors.

For promoting business development, green public procurement can be a powerful economic tool, with public facilities making use of pruning biomass. Co-operative structures should be promoted as the most suitable for overcoming scale and investment barriers, with co-ownership of harvesting machineries, and storage and logistics platforms assisted by CAP Rural Development funding. Where a region does not have suitable end-users, collective end-use of prunings should be encouraged through community operated medium-, to large-scale applications in rural areas.

Project results enabled to identify the best performing alternatives of pruning biomass supply chains, which may be an important reference for firms dealing with biomass based energy generation, agricultural machineries or for municipalities and government agents promoting renewable energy production, and finally for farmers to implement best harvesting and transport systems. Project results are also an important resource for researchers and practitioners working in biomass production and trading. For actors of biomass supply chains (*e.g.*, farmers, traders, and consumers), Europruning's documents provide good understanding and valuable economic data at different logistics stages.

Impacts on sustainability and environment

Besides considering socio-economic impacts of the whole PtE logistics chain, specific impacts of some stages have been specifically drawn since they could endanger success or sustainability of future biomass from pruning chains. This is the case of the possible affections of pruning energy use to soil management sustainability.

Most prunings generated within the EU are either burnt in open-air fires or are shredded as a soil amendment. Whilst the former entails no net-environmental benefits, the latter can improve soil conditions, but can also be a vector for disease. As a result, some regions ban or strongly recommend against mulching of biomass and use as a fertiliser, whilst others recommend it, often accompanied by pesticides. When farmers integrate prunings into the soil, frequently they do so not because it is the best use of the material, but because it is the simplest waste management method. The main driving force that determines whether burning or soil amendment is predominant is whether there is a regional or national ban on burning prunings in open-air fires. EuroPruning went deep into in these issues. Though both the short experimental period and local sites factors have to be taken into account and reminded and further analyses are recommended evaluating the same aspects during a longer period of time, important results have been attained.

In general terms, EuroPruning results allow stating that the energy use of residues from pruning is not opposed to a sustainable soil management and long term soil fertility. However, some local factors, like soil erosion control or alternative carbon inputs by other plant materials (*e.g.*, grass covers) should be taken into consideration to counteract potential problems and ensure sustainable functioning of the orchard/plantation. As most of the nutrients accumulate in the leaves and not in the wood, nutrient loss through pruning removal after the fall of leaves is low and can be compensated by fertilization. In contrast, pruning removal from orchards can also counteract the spread of diseases and, hence, decrease costs for pesticide application or tree substitution. If farmers, however, opt for leaving chipped prunings in the field, no negative effects in terms of increased greenhouse gas emissions or of enhanced nitrogen leaching are to be feared. Land degradation due to erosion proceeds relatively slow and has only a small negative economic effect on the short term, but it steadily increases with time. It has social impacts as future generations may suffer from the loss of arable land.

While managing soil and fruit trees productivity in a sustainable way, GHG emissions may be reduced by PtE chains. If the exploitation of the already mentioned 8.7 Mt of dry matter per year was achieved as well as if an average of 100 kg CO_{2_eq}/GJ savings could be attained by PtE chains compared to heat produced in coal boilers (EuroPruning LCA results), up to 16.53 Mt CO_{2_eq} could be avoided per year in Europe.

Impacts on agriculture

Results of EuroPruning, as they have been obtained under real environmental working conditions and directly by farmers, may have a significant impact as showing a vast amount of information on pruning harvest, quality, and utilisation of these resources like an energy feedstock. EuroPruning's demonstrations were carried out in real conditions, and biomass produced utilised by consumers of regular biomass, so that the information attained is highly valuable for all the actors involved. Demos have served to back-up the EuroPruning assessments (their impact is partly relying in the work done in the demos) and also were fundamental to detect gaps for implementing pruning value chains. The needs for further knowledge, machinery or other technologies has led to point out niches for improvement of the chain, and niches for developing new technologies and services. Demos even went a step forward by describing not only the hypothetical value chains that could be promoted in the demo areas, but also registered, analysed and reported 19 existing value chains. The scarce knowledge on pruning biomass chains has been explored and made public. This fact can have a high impact, as one of the non-technical barriers detected, is the unawareness of stakeholders on potential models to be followed. Demonstrations have served to obtain recommendations for the value chain implementation, which have been publicly available and will lead to a significant socio-economic impact as they are fundamental to avoid wrong handling and risks that could endanger future initiatives.

One important factor that EuroPruning has shown with all the work carried out under reals field conditions is the potential for increased collaboration between farmers. Collaboration can entail sharing of machinery to increase its operation time. Local collaborative efforts have a number of socio-economic advantages, including learning (*e.g.*, exchanging practical experiences), and also in the scale of economies in cooperation between farmers. Collaboration can also enhance the capacity to empower the rural population, as well as building the foundation for stabilisation and continuity. The establishment of supply chains for pruning residues can also lay the foundation for new activities or work opportunities; as an example the enhancement of small local enterprises such as transport companies.

As it has been stated in the project context epigraph more than 23 million hectares are potential beneficiaries of EuroPruning's results. By adapting existing agricultural practices to the lessons learned within EuroPruning, 13.7 Mt of dry matter per year of wood from pruning could reach the energy market.

Impacts on the biomass logistics

Life cycle costs analyses carried out in the project showed that considering particular yields and constraints PtE chain costs varied from 50.06 €/$t_{w.b.}$ (vineyard chips) to 108.90 €/$t_{w.b.}$ (almond chips). Despite costs vary with yields, specific logistics characteristics, end user requirements, etc., it can be stated that biomass from pruning may compete in the market if the whole process is optimised. Another important economic factor, common to all indigenous renewable energy sources, is the decrease in dependency on uncertain and unsecure energy sources, in contrast the access to locally produced and owned energy. By extension this local source of energy can lead to economic benefits and local job opportunities within the region, as well as diversification of economic activities.

EuroPruning enabled to identify the knowledge gaps and necessary interventions to promote sustainable initiatives of renewable energy production from pruining residues. The major knowledge gaps include:

- lack of adequate knowledge on the profitability of the pruning value chain;
- limited awareness of people regarding the economic and environmental values of biomass from pruning based energy generation;
- difficulty to get reliable data on pruning biomass quality parameters and availability of biomass;
- lack of well-organized information flow and system to manage the pruning supply chain effectively and efficiently;
- and difficulty to know if leaving pruning on soil as organic fertilizer has more value than using pruning biomass as energy source.

Biomass from pruning can be produced for self-consumption or can be commercialized. Therefore, the results of this study identified important issues needed to be addressed to promote the pruning residues based energy production. This in turn promotes the environmental, social, and economic sustainability. Within EuroPruning different harvesting and logistics equipment have been developed to promote the sustainability of renewable energy production from pruning residues. In the EuroPrunin's Logistics Smart System the data recording and storing, and the capability to support product traceability and supply chain management are found to be very effective to ensure successfulness of future chains. The Smart System can be improved and upgraded to a marketable tool that can promote sustainable renewable energy value chains from pruning residues, as well as from other biomass sources also characterised by being scattered.

Impacts on the energy sector

Project results enabled to identify the best performing alternatives of pruning biomass supply chains, which may be an important reference for firms dealing with biomass based energy generation, agricultural machineries or for municipalities and government agents promoting renewable energy production, and finally for farmers to implement best harvesting and transport systems. Public documents, best practices brochures and recommendations are an important resource for researchers and practitioners working in biomass production and trading. For actors of biomass supply chains (*e.g.*, farmers, traders, and consumers), these documents provide good understanding and valuable economic data at different logistics stages.

Considering EurObserv'ER 2015 figures[5], solid biomass primary energy production in the EU in 2013 was 87.710 Mtoe and the solid biomass consumption reached 91.756 Mtoe. As it has been already mentioned, pruning has an important economic potential for exploiting in commercial basis round 8.7 Mt of dry matter per year in Europe. If this potential was finally placed in the biomass market, approximately 3.95 additional Mtoe of renewable primary energy per year would be used in Europe. This potential would allow decreasing solid biomass imports in Europe while reaching 4.3 % of all the solid biomass energy consumed in 2013. If the whole biomass potential from pruning (13.7 Mt of dry matter per year) could be placed into the market, 6.22 additional Mtoe of renewable primary energy per year would be used in Europe, which might lead to reach almost 7 % all the biomass energy consumed in 2013. This figure is higher than the difference between solid biomass consumption and the solid biomass primary energy production in Europe, which was 4 Mtoe in 2014[5].

1.4.2. Main Dissemination activities

Communication and Dissemination activities have been ongoing since the beginning of the project, to ensure that stakeholders have been informed about the developments and to support post-project exploitation. The project has been presented at over 50 events and has had substantial promotion online via the project website, social media, news and videos. Early

[5] EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2015 EDITION. Available at: http://www.eurobserv-er.org

on in the project a visual and written identity was created for consistency of communication, and integrated into a broader communication plan to ensure that as many stakeholders could be reached as possible.

To communicate project aims, a website was established, as well as a leaflet, poster and project videos. Press Releases have been produced and distributed throughout the course of the project, at important milestones. Handouts have also been produced for key events, such as the European Commission’s Bioeconomy Investment Summit, where EuroPruning had a stand, and the final Policy Event, held in the European Parliament. Substantial effort was made to present the results of EuroPruning at the European Biomass Conference & Exhibition in June 2016, as Europe’s largest biomass event. In total, ten poster presentations and four oral presentations were given.

Policy Implications arising from the project have been drawn up and presented to policy-makers at the European level through a final Policy Event in the European Parliament, as well as to regional and national policy makers in workshops held in France and Spain (two countries with large pruning potentials).

The Dissemination and Communication work of the project should actively support the future exploitation of the project results, by raising awareness of the work that has been done and promoting the use of prunings as a biomass resource. The project identified low awareness, regulatory barriers and a lack of models to follow as major barriers to the use of prunings. The dissemination work both promoted EuroPruning’s technical developments, as well as promoting new value chains in general. Specific effort was made to communicate with policy-makers, to make the case for future policy support and for recognition of agrarian wastes as a biomass resource. The policy recommendations of the project can be further exploited in future and could be best used by the European Innovation Partnership on Agriculture, the Commission’s Farm Advisory Services and the European Network for Rural Development.

Figure 17: Dissemination activities in EuroPruning

1.4.3. Exploitation of results

Alongside Communication to stakeholders and interested parties, EuroPruning has also made substantial efforts to support exploitation. The goal of the exploitation tasks in EuroPruning was to identify if, and how, the results of the EuroPruning project could be used to support the uptake of prunings for energy, and for commercial exploitation of the technical innovations made within the project. In order to do so, an exploitation plan was created to show, step-by-step, how the knowledge and technologies created in EuroPruning potentially help to close existing gaps in the logistics chain for use of prunings. However, it is important to emphasize, that focus has been on the technologies created and on supporting the companies/organizations behind them, as they have the largest potential to use the project results for significant commercial impact.

The first step was to identify the market barriers for the use of prunings. EuroPruning had prior knowledge and assumptions before starting the project, and made a large qualitative market analysis, with input from 27 actors from across the value chain, to validate and substantiate these. Using the data collected, the project was able to narrow in on six main barriers:

- Can prunings be used for energy production, if so, how?
- Is it financially attractive to use prunings for energy production?
- Is the right harvesting machinery available to effectively harvest prunings?
- Is it viable to use prunings for energy with a low and uncertain production volume per unit?
- Is the quality of the pruning material high enough?
- Are there no use cases, best practice and models to follow?

EuroPruning partners identified PtE chains barriers and identified gaps in the pruning logistic chain, such as: lack of the right harvesting machinery, optimized logistics for small volumes, best practice and quality control, etc. EuroPruning partners have tried to solve these gaps by actually creating the technology needed to fill those gaps with more efficient harvesting, optimized logistics, better quality control and an alternative higher value use for pruning than energy.

- **First gap to close:** the right harvesting machinery, and the need for specialized, cheap harvesting equipment to make it faster, easier and cheaper to collect the pruning material from the field in a transport ready state. Two machines (a chipper and a baler) were created by the Italian SME ONG and the Polish agricultural institute PIMR.
- **Second gap to close**: optimized logistics for small volumes, to make it economically viable to actually source prunings from many smaller producers and optimize the transportation of the prunings. The solution created by EuroPruning partners Swedish SME Mobitron and the Swedish agricultural university SLU, can be used to optimize the sourcing and transportation of prunings material using a central web-based logistics platform.

- **Third gap to close**: is quality control of the pruning material, which also can be done using the platform developed by Mobitron and SLU.

For each of the technologies, a business plan has been created, each with its own business model to follow, in order to enable the commercial exploitation of the technologies going beyond EuroPruning. The development of the business plans was done in larger exploitation workshops, and in one on one coaching sessions. The business model for each partner is different, but made to fit the individual technology and organization in a manner that are realistic and viable, and can help them exploit their innovations going forward.

Building on the individual business plans, an overall exploitation plan was created. It described how the technologies created in EuroPruning can potentially help to close the described gaps, and create a viable complete logistics chain for prunings. Furthermore, how the knowledge created in the project supports this.

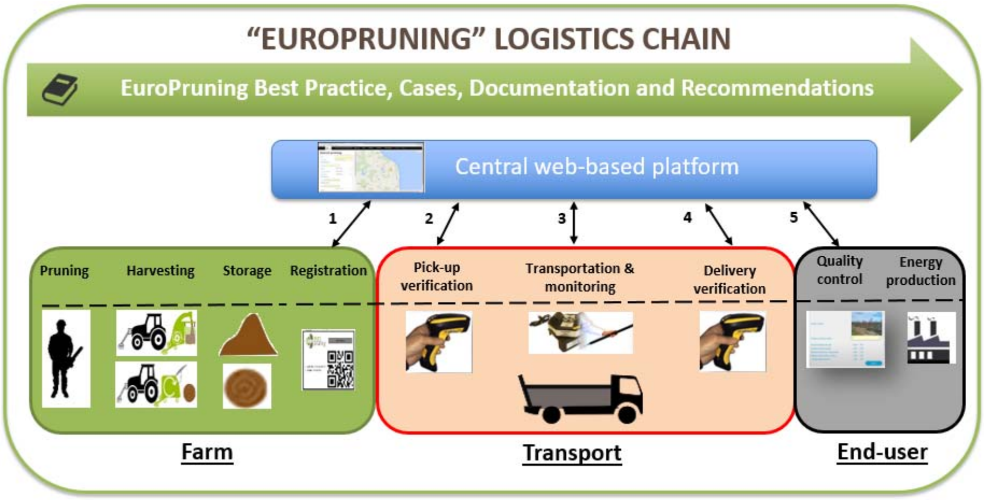


Figure 18. EuroPruning's value chain approach

Finally, a value chain approach was used to show theoretically, and with identified real life examples, how to make the prunings chain viable (Figure 18). The absolute key conclusion drawn from EuroPruning's models and examples is that there is a clear need for one or two key organizations, with clear goals and interests, to be in charge of initiating and running the pruning value chains, before it is viable to use pruning for energy production beyond the level of self-consumption.

1.4.4. Project contact details

Table 7: Project contact details

No.	Participant name		Country	Website	Contact
1	circe	Fundación CIRCE - Centro De Investigación de Recursos Y Consumos Energéticos (CIRCE)	Spain	www.fcirce.es	Fernando Sebastián *fersebas@fcirce.es*
2	SLU	Sveriges Lantbruksuniversitet (SLU)	Sweden	www.slu.se	Girma Gebresenbet *girma.gebresenbet@slu.se*
3	ATB Agrartechnik Bornim	Leibniz-Institut Fuer Agrartechnik Potsdam-Bornim Ev (ATB)	Germany	www.atb-potsdam.de	Jürgen Kern *jkern@atb-potsdam.de*
4	crea	Consiglio per la Ricerca In Agricoltura e L´Analisi dell´Economia Agraria	Italy	www.crea.gov.it	Luigi Pari *luigi.pari@crea.gov.it*
5		Uniwersytet Przyrodniczy We Wroclawiu (WUELS)	Poland	www.up.wroc.pl	Arkadiusz Dyjakon *arkadiusz.dyjakon@up.wroc.pl*
6	Greenovate!	Greenovate! Europe (G!E)	Belgium	www.greenovate-europe.eu	Astrid Severin *astrid.severin@greenovate.eu*
7	cooperativas agro-alimentarias	Cooperativas Agro-Alimentarias De España U. De Coop. (CAAE)	Spain	www.agro-alimentarias.coop	Juan Sagarna *sagarna@agro-alimentarias.coop*
8	GRU&SER	Grúas y Servicios GRUYSER S.L (GRUYSER)	Spain	www.gruyser.net	Adrián Lapeña *logistica@gruyser.net*
9	PIMR	Przemyslowy Instytut Maszyn Rolniczych W Poznaniu (PIMR)	Poland	www.pimr.poznan.pl	Pawel Frackowiak *pawfrack@pimr.poznan.pl*
11	ONG	ONG di Naldoni Domenico & C. (ONG)	Italy	www.ongsnc.com	Domenico Naldoni *ongsnc@tiscali.it*
12	TerrAquat	Wolf-Anno Bischoff – TerrAquat (TQT)	Germany	www.terraquat.com	Wolf-Anno Bischoff *w.bischoff@terraquat.com*
13	MOBITRON	Mobitron AB (MOB)	Sweden	www.mobitron.com	Sven-Olof Olsson *soo@mobitron.se*
15	Obstgut Marquardt GbR	Obstgut Marquardt GbR (MQT)	Germany	www.obstgut.de	Lutz Kleinert *obstgut@t-online.de*
16	cooperativas agro-alimentarias	Federación Aragonesa de Cooperativas Agrarias (FACA)	Spain	www.faca.es	José López-Duplá *jlopez@aragon.coop*
17	UNI-MEDOC	Societé Cooperative Agricole et Vinicole Intercommunale les Vignerons d' Unimedoc (UNIM)	France	www.unimedoc.com	Laurent Crespy *laurent.crespy@uni-medoc.com*
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