Universidade de Aveiro
2022

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ESTUDO DA BIOMASSA AGROFLORESTAL RESIDUAL EM PORTUGAL: MERCADO, VALORIZAÇÃO E POLÍTICAS

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ESTUDO DA BIOMASSA AGROFLORESTAL RESIDUAL EM PORTUGAL: MERCADO, VALORIZAÇÃO E POLÍTICAS

STUDY OF THE RESIDUAL AGROFORESTRY BIOMASS IN PORTUGAL: MARKET, VALORIZATION, AND POLICIES

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Economia, realizada sob a orientação científica da Professora Doutora Marta Alexandra da Costa Ferreira Dias, Professora Auxiliar do Departamento de Economia, Gestão e Engenharia Industrial e Turismo da Universidade de Aveiro, e sob a co-orientação científica do Professor Doutor Leonel Nunes, Investigador Auxiliar no Instituto Politécnico de Viana do Castelo.

Apoio financeiro da FCT no âmbito do projeto PCIF/GVB/0083/2019.

Dedico este trabalho ao João, o meu co-construtor de sonhos, e à Sofia, o nosso maior sonho concretizado.

o júri

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agradecimentos

Agradeço à minha família, a raiz de tudo aquilo que sou.

Agradeço a todos os meus professores, que me fizeram uma estudante apaixonada. Um agradecimento especial à Professora Marta e ao Professor Leonel, que não só me guiaram nesta caminhada, como caminharam comigo lado a lado. Obrigada pelo vosso exemplo de perseverança, dedicação e alegria constante em todas as reuniões que tivemos. Tornaram esta tarefa num prazer!

Agradeço também à FCT pelo apoio financeiro a este trabalho, no âmbito do projeto de I&D “BioAgroFloRes - Modelo Sustentável de Gestão da Cadeia de Abastecimento da Biomassa Agroflorestal Residual suportado numa Plataforma Web” (PCIF/GVB/0083/2019).

palavras-chave

Biomassa residual, biomassa agroflorestal, bioeconomia, economia circular, fogos rurais.

resumo

A biomassa do setor florestal e agrícola fornece uma importante contribuição para cumprir as metas nacionais para aumentar a produção e utilização de bioenergia. A caracterização de resíduos agrícolas e florestais é fundamental para a sua exploração e utilização para fins energéticos. Com esta investigação, pretende-se dar uma visão mais ampla desta temática, compreender o potencial de criação de mercado para a biomassa agroflorestal residual, os stakeholders envolvidos, de que forma é possível valorizar este tipo de resíduos, quais as políticas que podem ser implementadas para solucionar os diversos problemas relacionados com estas operações, bem como compreender os seus impactos socioeconómicos, particularmente no que concerne o problema dos fogos florestais. Vale a pena notar que embora Portugal tenha uma vasta área florestal e agrícola, estas áreas são altamente fragmentadas, o que é um problema que terá de ser superado para maximizar o potencial de valorização dos resíduos agroflorestais. Estas são as principais questões envolvidas que tentaremos explorar, a fim de encontrar possíveis soluções.

Com este trabalho foi possível perceber o potencial da biomassa agroflorestal residual na região centro de Portugal bem como os pontos de vista de diferentes grupos de *stakeholders* e como um modelo de negócio suportado numa plataforma web poderia funcionar na prática.

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keywords Residual biomass, agroforestry biomass, bioeconomy, circular economy, rural fires.

abstract

Biomass from the forestry and agricultural sectors contributes significantly to meeting the targets presented by the government for increasing bioenergy production and utilization. Characterization of agricultural and forest wastes are critical for exploiting and utilizing them for energy purposes. This research aims to give a broader view of this thematic, understand the market potential for residual agroforestry biomass, the stakeholders involved, how is it possible to valorize this type of waste, and which policies could be implemented to solve the logistics and other problems involved in these operations, as well as understanding its socio-economic impacts, particularly regarding the problem of wildfires. It is worth noting that although Portugal has a vast area of forest and agriculture, these areas are highly fragmented, which is a problem that would have to be overcome to maximize the potential for biomass waste recovery. These are the main issues involved that we will explore in order to find possible solutions.

With the present work we were able to understand the potential of RAFB in the central region of Portugal as well as the points of view from different groups of stakeholders and how the business model though a web platform could work in practice.

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Acronym List

AAEM - Alkali and alkaline earth metal

AFB – Agroforestry Biomass

AREAC - Agência Regional de Energia e Ambiente do Centro [Regional Agency for Energy and Environment of the Center (of Portugal)]

CHP - Combined heat and power

CO_2 - Carbon dioxide

FCT - Fundação para a Ciência e Tecnologia [Science and Technology Foundation]

GPP – Gabinete de Planeamento, Políticas e Administração Geral [Planning, Policies and General Administration Office]

HT – Hydrothermal

ICNF - Instituto de Conservação da Natureza e das Florestas [Institute for Nature and Forest Conservation]

ID – Identification

IFN – Inventário Florestal Nacional [National Forest Inventory]

INE - Instituto Nacional de Estatística [National Institute of Statistics]

INIAV - Instituto Nacional de Investigação Agrária e Veterinária [National Institute for Agricultural and Veterinary Research]

IRENA - International Renewable Energy Agency

MDF - Medium-density fibreboard

NGO – Non Governamental Organisation

NO_x - Nitrogen Oxides

NUTS - Nomenclatura das Unidades Territoriais para Fins Estatísticos [Nomenclature of Territorial Units for Statistics]

PAC - Política Agrícola Comum [CAP - Common Agrarian Policy]

PALOPs - Países Africanos de Língua Oficial Portuguesa [African Countries of Portuguese Language]

RAFB – Residual Agroforestry Biomass

SA - Stakeholder analysis

SC – Supply Chain

SOC - Soil organic carbon

1. Introduction

The increasing environmental challenges that humans are facing are propelling research and innovations towards a more sustainable future. The continuous economic and energy consumption growth that we have seen in the last few decades have a cost in terms of environmental pollution. We are seeing a rapid increase in greenhouse gas emissions, namely CO_2. It was estimated that world energy-related CO_2 emissions increased from 32.3 billion metric tons (2012) to 35.6 billion metric tons (2020), and this number will reach 43.2 billion metric tons (2040) (Li et al., 2017). This means that global warming is a threat that urges for solutions in different fields, but especially in the energy sector, with the development of renewable energy, to control CO_2 emissions and energy efficiency, to achieve a low-carbon society.

International institutions are committed to a transition towards more sustainable systems of production and consumption. In this transition, innovations promoting sustainability are going to be fundamental. In particular, the production of bio-based products, which are wholly or partly derived from biological materials or from innovative production processes, and/or innovative biomass such as food waste or forest residuals, will be part of this process (Falcone et al., 2019). European Union is committed to its bioeconomy policy. Advancements in bioeconomy research and innovation uptake will allow Europe to improve the management of its renewable biological resources and to open new and diversified markets in food and bio-based products (European Commission, 2012; Hamelin et al., 2019).

To be effectively sustainable, development must be based on three pillars: environment, economy, and society. New business models, that are economically affordable, environmentally respectful, and socially responsible (Falcone et al., 2019), are crucial to achieve a truly circular bioeconomy. The concept of circular bioeconomy is recent and emerged among academic, political, and industrial circles. It conjugates the concepts of green economy, bioeconomy and circular economy (Gregg et al., 2020).

Bioeconomy means, according to the European Commission (2012), "the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy." Regarding the concept of circular economy, it's main goal is to capitalize on material flow recycling and to balance economic growth and development with environmental and resource use (Winans et al., 2017). Green Economy acts as an 'umbrella' concept, including elements from circular economy and bioeconomy concepts (e.g. eco-efficiency; renewables), as well as additional ideas, e.g. nature-based solutions (D'Amato et al., 2017).

Circular bioeconomy includes the use of biomass in a sustainable way and the valorisation of biomass resources efficiently. It also incentivizes the use of residues and post-consumption wastes and the use of circular biomass (Gonçalves et al., 2021; Gregg et al., 2020). Advancements in bioeconomy research and innovation uptake will allow Europe to improve the management of its renewable biological resources and to open new and diversified markets in food and bio-based products (European Commission, 2012; Hamelin et al., 2019).

Biomass, in its broadest definition, refers to all material that was or is a part of a living organism (Hames, 2009). Although, when considering its use as feedstock, biomass refers to all organic material that is plant derived. Through the photosynthetic process, green plants convert sunlight into carbohydrates, which makes biomass a stored source of solar energy in the form of chemical energy. This energy can be released by various biological and thermo-chemical processes, when the chemical bonds between adjacent oxygen, carbon, and hydrogen molecules are broken (McKendry, 2002; L. Zhang et al., 2010).

Biomass wastes from forestry and agriculture are expected to fuel part of the increasing demand for biomass. Biomass residues stand out as potential raw materials to produce renewable fuels, chemicals and energy (Ferreira-Leitao et al., 2010). In fact, forest residues are getting more attention as an energy source. Instead of disposing of them by on-site, in-woods burning, there is growing interest in expanding the use of forest treatment residues as feedstock for energy production, with the added benefit of promoting rural employment and economic development as well as improving forest restoration treatments (Guilhermino et al., 2018).

The valorisation of biomass residuals allows for a higher degree of closure in the biomass utilization loop and consequently, more efficient use of nutrients and resources (Gregg et al., 2020). Compared with the cultivation of energy crops, the use of biomass residues and waste for bioenergy generation is considered a more sustainable approach in biomass research (Baasch, 2021). Every process involving wood transformation generates residues. However only 40 to 60% of the total volume of logs harvested is used. The processing of agricultural crops also generates large amounts of residues (de Ramos e Paula et al., 2011).

According to McKendry (2002), “when low cost biomass residues are used for fuel, the cost of electricity is already often competitive with fossil fuel-based power generation”. This leads to the expectation of a very promising future in relation to the exploitation of biomass residues. Although, we must keep in mind that the cost of recovery and delivery relative to the value of residual biomass as a raw material for producing energy, liquid fuels and bio-based products is a challenge (Jones et al., 2013).

Besides the economic advantages of using residual agroforestry biomass, there are very important social and environmental advantages, particularly related to rural fires. In fact, mitigating the risk of rural fires is so crucial in Portugal that the Fundação para a Ciência e Tecnologia (FCT), which is the government institute that selects and finances scientific research projects, launched a call for funding scientific research and technological development projects in the field of fire prevention, with 10 of the 56 projects focusing on rural biomass utilization.

This dissertation is part of the first phase (of four) of the project BioAgroFloRes - Sustainable Model for the Management of the Residual Agro-Forest Biomass Supply Chain supported on a Web Platform, financed by the FCT, and it falls within the subject area of Biomass Management and Enhancement Projects in Rural Areas. This project pretends to develop and offer operational solutions to increase the efficiency and effectiveness of the residual agroforestry biomass (RAFB) supply chain (SC). The main motivation of BioAgroFloRes project is to propose solutions to foster the use of RAFB in the production of thermal/electric energy or as raw material for other kinds of industries, such as pellets or fertilizer products, through the enhancement of the RAFB-SC. A functional prototype of an intelligent Web platform will be developed to assist biomass SC stakeholders, as the final output of the project.

This project is unique in that it would both reduce biomass in rural environments and the risky burning practices of rural industries that start many rural fires. In other words, the reduction in risk is not based solely on removing the fuel load but essentially on the reduction/ elimination of the burning of leftovers, traditionally used by forestry operators and farmers to eliminate the residues resulting from their activity, which is one of the main causes of rural fire ignition in Portugal. Thus, this dissertation intends to show the importance of recovering residual agroforestry biomass, to reduce the risk of rural fires in Portugal and thus contribute to a more fire resilient landscape, but also to understand the market space for a platform that will promote the collection and recovery of agroforestry residual biomass and contribute to reducing rural fire risk in the central region of Portugal. At the same time, it is intended to contribute to creating new value chains for residual agroforestry materials from a circular bioeconomy perspective.

This work is based on the characterization of the residual agroforestry biomass that flows from the source to the end users (thermoelectric power plants or other industries), and it covers the following six main goals:

- Current state of the art regarding residues from agroforestry biomass (AFB) and their characterization.
- Identification of environmental problems caused by the incorrect disposal of AFB waste, with particular emphasis on forest fires.
- Stakeholders identification (Landowner, Farmer/Forester, Transportation, Pre-processing and Final users as Energy Facility or other interested industries).
- Understanding the market space for AFB waste through surveys, interviews to experts and focus groups.
- Conception of a generic business model through the implementation of a web platform.
- Economic and social advantages of the circular economy applied to biomass waste, in Portugal.

The primary research method selected was qualitative research, to understand and analyse the role of different actors within the system. Within the qualitative research methods, we used the stakeholder's analysis and market research.

This dissertation follows a scientific paper structure: literature review, methodology, results, discussion, and conclusions.

Within the scope of our work in the first phase of the BioAgroFloRes project, four different papers have already been published, and one is submitted:

- Casau, M., Cancela, D. C. M., Matias, J. C. O., Dias, M. F., & Nunes, L. J. R. (2021). Coal to Biomass Conversion as a Path to Sustainability: A Hypothetical Scenario at Pego Power Plant (Abrantes, Portugal). Resources 2021, Vol. 10, Page 84, 10(8), 84. https://doi.org/10.3390/RESOURCES10080084
- Casau, M., Dias, M. F., Matias, J. C. O., & Nunes, L. J. R. (2022). Residual Biomass: A Comprehensive Review on the Importance, Uses and Potential in a Circular Bioeconomy Approach. Resources 2022, Vol. 11, Page 35, 11(4), 35. https://doi.org/10.3390/RESOURCES11040035
- Nunes, Leonel J.R., Casau, M., & Dias, M. F. (2021). Portuguese Wood Pellets Market: Organization, Production and Consumption Analysis. Resources 2021, Vol. 10, Page 130, 10(12), 130. https://doi.org/10.3390/RESOURCES10120130
- Casau, M., Dias, M. F., Teixeira, L., Matias, J. C. O., & Nunes, L. J. R. (2022). Reducing Rural Fire Risk through the Development of a Sustainable Supply Chain Model for Residual Agroforestry Biomass Supported in a Web Platform: A Case Study in Portugal Central Region with the Project BioAgroFloRes. Fire 2022, Vol. 5, Page 61, 5(3), 61. https://doi.org/10.3390/FIRE5030061
- Nunes, Leonel J.R., Casau, M., Matias, J. C. O, Dias, M. F. (under review). Assessment of the Woody Residual Biomass Generation Capacity in the Central Region of Portugal: Analysis of the Power Production Potential

Two of these papers have been incorporated partially for this dissertation - “Residual Biomass: A Comprehensive Review on the Importance, Uses and Potential in a Circular Bioeconomy Approach” has been used in the literature review (sections 2.1., 2.2. and 2.3.), and “Reducing Rural Fire Risk through the Development of a Sustainable Supply Chain Model for Residual Agroforestry Biomass Supported in a Web Platform: A Case Study in Portugal Central Region with the Project BioAgroFloRes” has been adapted to the last part of the literature review (section 2.4.), first part of the results (sections 4.1. until 4.5.) and first part of the discussion (section 5.1.).

2. Literature Review

2.1. Biomass for energy production

Biomass is the oldest source of energy that humans use, since the discover of fire. In fact, in 1850 biomass represented 85% of the energy consumption worldwide, and before that is was practically the only source of energy used by Men, besides wind (for sailing), domesticated animals (in agriculture) and small amounts of coal for heating (Goldemberg, 2009). There are many biomass energy sources, being wood and wood wastes the most important, but also agricultural crops and their waste byproducts, municipal solid waste, animal wastes, waste from food processing, and aquatic plants and algae (Balat, 2006; M. F. Demirbas et al., 2009).

As it is well known and widely studied, there is a narrow relationship between energy consumption and economic development (Bekun et al., 2019; Ozturk, 2010; Yumashev et al., 2020). The access to energy is becoming more important than ever, due to economic development and population expansion, but the concerns regarding climate change and sustainable development have also gained much attention. Worldwide, new types of sustainable and clean energy are being implemented and developed, to replace fossil fuels. According to Wu et al. (2019), about 20% of global energy is supplied by renewable energy sources and the remaining 80% comes from fossil fuels. The search for substitutes to fossil fuels that are capable of decarbonizing the economy and supplying large amounts of energy has been one of the greatest objectives in science and technology (Leonel J. R. Nunes, 2020).

Biomass has gained attention in recent years, since it is a renewable source, and it can be used directly by combustion or transformed into a liquid or gaseous fuel (Balat, 2006; Mao et al., 2018). Biomass energy (bioenergy) is already essential in the energy supply worldwide, widely recognized as an effective alternative to fossil fuels, but with more importance in developing countries, where it is mostly used through direct combustion for cooking and heating, representing approximately 35% of energy demand (M. F. Demirbas et al., 2009; Wu et al., 2019).

According to the IRENA statistics (available at https://irena.org/publications/2021/Aug/Renewa-169 ble-energy-statistics-2021, accessed on 05 January 2022), in 2019, the total amount of electricity generated from renewables was 6963 TWh. Renewable hydro accounted for about 61% of this (4207 TWh), followed by wind energy (1412 TWh), solar energy (693 TWh), bioenergy (558 TWh), geothermal energy (92 TWh) and marine energy (1 TWh). Bioenergy generation was divided as follows: 389 TWh (69%) from solid biofuels; 92 TWh (20%) from biogas; 69 TWh (10%) from renewable municipal waste; and 8 TWh (1%) from liquid biofuels.

According to the International Energy Agency report (2020), biofuel production was strongly impacted by the Covid crisis, with an estimated decline of 12% from the record occurred in 2019. The report emphasizes that this is the first reduction in annual production in two decades, driven by both lower transport fuel demand and lower fossil fuel prices diminishing the economic attractiveness of biofuels.

In the European Union, biomass for energy (bioenergy) is the main source of renewable energy in terms of gross final consumption, with a share of almost 60% (European Commission, 2019). Despite the Covid-19 crisis, the demand trend for biomass in the EU and world-wide is increasing. Although, the plantation of energy crops in fertile, arable lands increasingly results in new land use conflicts with food production and cannot be considered as sustainable (Gerwin et al., 2018; Giuntoli et al., 2016). Forest biomass is the main source of biomass not competing with food supply in Continental Europe. The high demand for forest biomass as a material and energy resource led to a competition between industries and the need to improve circularity/ resource efficiency (Gonçalves et al., 2021). In this regard, European forest are essential for supplying biomass to a growing bio-economy (Verkerk et al., 2019).

2.2. Biomass conversion technologies

2.2.1. Framework

There are numerous technologies of biomass conversion to produce a variety of energy forms including heat, steam, electricity, ethanol, hydrogen, methanol, and methane, but also to produce fertilizers, value-added chemicals and functional materials (Cherubini, 2010; Leonel J R Nunes et al., 2021). Selecting a product for conversion depends on several factors such as need for direct heat or steam, conversion efficiencies, energy transport, conversion and use hardware, economies of scale, and environmental impact of conversion process waste streams and product use (Chynoweth et al., 2001). In this section, these modern conversion technologies will be approached succinctly.

2.2.2. Physicochemical conversion

Regarding the physicochemical conversion, which includes particle size reduction, drying, densification, and solvent fractionalization, it is often used as a pre-treatment before other conversion steps. This allows density increase, reduction of the feedstock inhomogeneity, and it makes transportation and storage more manageable (Kang et al., 2021). Through pressing/ solvent extraction, oilseeds can be recovered and converted to esters, which are able to replace diesel (Faaij, 2006)

Organic solvent pre-treatment of lignocellulosic biomass has been utilized for more than 100 years, and several solvents have been studied in order to isolate different components from biomass such as cellulose, lignin and hemicellulose (K. Zhang et al., 2016). The densification processing allows the development of uniformly formatted, densified feedstock from lignocellulosic biomass, which is important to achieve consistent physical properties such as size and shape, bulk and unit density, and durability (Tumuluru et al., 2011). Through the achievement of this consistency, transportation logistics, storability and combustion properties are improved, comparing to raw biomass (Kang et al., 2019). Diverse densification systems (e.g. pellet mill, briquette press) can be used to produce a homogeneous format feedstock commodity for bioenergy applications, that will influence the feedstock chemical and physical properties, and energy consumption (Tumuluru et al., 2011).

2.2.3. Thermochemical conversion

Biomass can be converted to bioenergy through two main processes: thermo-chemical and biological processes, with the first having higher efficiencies in terms of reaction time and ability to destroy most of the organic compounds (L. Zhang et al., 2010). Thermochemical conversion technologies applied to biomass have been extensively studied, and include combustion, torrefaction, pyrolysis, liquefaction, and gasification. As stated before, combustion is the most used conversion method, but gasification and pyrolysis are also very used, since we can obtain high grade energy products, like charcoal, tar and combustible gas (Li et al., 2017). The oldest method for using biomass energy is direct combustion, and it is the process of using biomass as a fuel to produce energy without the use of chemical conversion. The combustion method can be divided into three main evolutionary paths: stove combustion, boiler combustion, and biomass briquette combustion (Bajwa et al., 2018; Miller et al., 2012; K. Zhang et al., 2016).

Pyrolysis is a thermal destruction of organic materials that takes place in the absence of oxygen to convert biomass to a more useful fuel in the form of solid charcoal, liquid (bio-oil), and gases at elevated temperatures, being the most efficient process for biomass conversion (A. Demirbas, 2004; L. Zhang et al., 2010). Torrefaction is a biomass conversion technology that allows the reduction of major limitations of biomass such as heterogeneity, lower bulk density, lower energy density, hygroscopic behaviour, and fibrous nature, improving biomass properties for fuel application (Nhuchhen, 2014; L.J.R. Nunes et al., 2018). The torrefaction process consist on slowly heating the biomass through a range of temperatures between 200 and 300◦C in a controlled atmosphere without the presence of oxygen (Ribeiro et al., 2018).

Direct liquefaction or hydrothermal liquefaction of biomass is a thermochemical conversion process that converts biomass into liquid fuels by processing in a hot, pressurized water environment for enough time to break down the solid bio polymeric structure to mainly liquid components (Gollakota et al., 2018).

Gasification can be defined as the thermochemical conversion of a solid or liquid carbon-based material (feedstock) into gaseous products (CO_2, water, carbon monoxide, hydrogen and gaseous hydrocarbons), small quantities of char (solid product), ash, and condensable compounds (tars and oils), by the supply of a gasification agent (another gaseous compound) (Belgiorno et al., 2003; Puig-Arnavat et al., 2010). The conversion of the feedstock into fuel gas takes place in the gasifier, which can be categorized into three fundamental types: fixed bed, fluidised bed and indirect gasifier (Belgiorno et al., 2003). Gasification can be considered a form of pyrolysis that is carried out at high temperatures in order to optimize the gas production, being considered one of the most efficient ways of converting the energy embedded in biomass, and it is becoming one of the best alternatives for the reuse of waste solids (A. Demirbas, 2004; Puig-Arnavat et al., 2010).

2.2.4. Biological conversion

Biological conversion of biomass still faces challenges related to its low efficiency (Puig-Arnavat et al., 2010). Different biological processes have been studied to produce biofuels, value-added products, and other chemical building blocks. These processes are mainly fermentative although some special conditions might be needed, such as anaerobic environment, specific illumination, different microorganisms (bacteria , yeasts , cyanobacteria , algae) (Gouveia & Passarinho, 2017). Bioethanol can be produced from different biomass sources such as wood and agroforestry residues such as corn stover (corn cobs and stalks), sugarcane waste, wheat or rice straw, forestry, and paper mill discards, the paper portion of municipal waste and dedicated energy crop, but nearly all fuel ethanol is produced by fermentation of corn glucose in the US or sucrose in Brazil (Lin & Tanaka, 2006). This process comprises the following main steps: "hydrolysis of cellulose and hemicellulose to fermentable reducing sugars, fermentation of sugars to ethanol, separation of lignin residue, and finally, recovery and purification of ethanol to meet fuel specifications. The hydrolysis is usually done by lignocellulosic enzymes and the fermentation is carried out by yeasts or bacteria" (Maurya et al., 2015).

Anaerobic digestion is a natural biological pre-treatment of organic substrates carried out in the absence of oxygen by robust, mixed culture microbial communities. This process, applied to biomass allows the recovery of biogas, being methane the most studied, to provide a clean fuel from renewable feedstocks. Lignocellulosic biomass provides an excellent opportunity to convert abundant resources to renewable energy, but its structure is complex due to the lignin content, which inhibits the anaerobic digestion process (Sawatdeenarunat et al., 2015). To overcome this problem, various pre-treatment methods are available. Hydrothermal (HT) pre-treatment of lignocellulosic biomass is a promising approach to increase biogas production in anaerobic digestion (Paul & Dutta, 2018). The use of organic wastes to produce methane through the anaerobic digestion process would benefit society by the replacement of fossil fuel-derived energy (Chynoweth et al., 2001).

2.3. Agroforestry biomass wastes

2.3.1. Framework

Agroforestry biomass wastes have been converted to energy for centuries through combustion, and more recently, through other technologies such as gasification, liquification and pyrolysis. There is not a single technology that can be characterized as the best or most promising for conversion of agricultural and forestry residues into energy (Harper et al., 1979). Bioenergy produced from the residues of forests and agriculture has gained renewed attention in the context of carbon emissions reduction and climate change mitigation strategies, through sustainable and short-distance supply chains of agroforestry residual biomass (Bascietto et al., 2020). Besides the pollution reduction and improvement of the ecological environment, using agroforestry wastes in a reasonable and effective manner, can have a huge regional impact, with the development of rural regions and reduction of forest fires (Leonel J. R. Nunes, 2020; Wu et al., 2019). In fact, according to L. J.R. Nunes et al. (2016) most of biomass waste products actually available are not valorised and may potentially be used as an energy source. This means that we have a viable resource that can be valorised for energy production or other products such as chemicals.

The use of agroforestry waste biomass is of particular importance, especially when there is a large quantity available, since it contributes to the circular economy and to decarbonization (Leonel J. R. Nunes, 2020). Recovering, transforming, and valorising agroforestry waste biomass has many benefits. As referred above, some of these benefits include rural development, wildfires reduction thanks to the clearing of forests and not burning these wastes on site. But there are many other benefits, namely regarding human health, since unregulated land disposal pollutes surface and ground waters, inducing eutrophication and emission of greenhouse gases (Tripathi et al., 2019).

It is estimated that biomass wastes originated within the different economic activities, are in the order of 140 Gt, with more than 120 million tons per year corresponding to crop residues, and approximately 40 million tons per year are originated from the forestry industry, with these two sectors being responsible for 30% of the waste produced in Europe (Gaspar et al., 2019; Tripathi et al., 2019). This means that currently there is a huge potential for using agroforestry biomass wastes while at the same time solving significant management problems, as discarded biomass can have negative environmental impacts. In terms of agriculture biomass sources, worldwide, it is estimated that 66% of the residual plant biomass comes from cereal straw (stem, leaf's, and sheath material), and the large majority (60%) is produced in low-income countries. The second largest source of biomass are sugarcane stems and leaves, and other important wastes come from 'oil crops', roots and tubers, nuts, fruits, and vegetables. Regarding the forestry sector, most biomass wastes come from timber logging. We can differentiate forestry residues as primary and secondary. The first classification includes include logging residues, stumps, and early thinning (e.g., branches) while the second includes residues from wood processing (Tripathi et al., 2019).

According to Gaspar et al. (2019), the forestry residues have adequate heating value to produce thermal energy, and hemicelluloses and lignin content make this type of materials suitable for obtaining second-generation biofuels, such as biogas and bioethanol. To this author, cellulose and hemicelluloses can be used in food, textile, paper, petroleum, and mining industries, among others, and other less explored products may be obtained from pine residues, especially for food and pharmaceutical applications, due to their phenolic content and antioxidant activity.

Agroforestry residues can, within the context of bioeconomy, be used as feedstock for high added-value materials and products, serving as main sources of the basic building blocks for chemicals and materials (Thorenz et al., 2018).

In the following subsections, the literature review on the valorisation of residual agroforestry biomass is presented per decade, since the 70s, to understand the main research focuses on the subject over the last decades and also identifying the most recent trends.

2.3.2. The decade 1970-1979

Saeman (1977) discussed the use of wood residues as fuel and the transformation of forest products to ethanol, furfural, methanol, formaldehyde and phenol. Indirect savings from using forest products instead of other alternatives more energy-intensive are presented, and the author states that the “environmental problems associated with the handling and burning of wood residues are held to be minimal. However, the chemical or biochemical conversion of forest biomass appears at present to involve high capital costs and low profits.”

Gopalakrishnan et al.(1979) reviews the processes for the production of liquid and gaseous fuels from biomass and wastes by fermentation, enzymatic hydrolysis, and hybrid processes, and discusses the suitability of these fuels for internal combustion engines.

In another study (Timbers & Downing, 1977), different forms of biomass wastes produced by Canadian agriculture were estimated. Already at this time, the authors worried about an ‘energy-conscious society’, and demanded an urgent investigation regarding anaerobic digestion, pyrolysis and hydrolysis for utilizing biomass wastes from agriculture.

Hileman et al. (1976) argue that there was not any technology available at that time that would allow an economic recovery from biomass, despite the possibility of recovery for energy. Despite the problems related to agricultural residues named by the authors, regarding the high moisture content, difficult feedstock handling and low tonnage biomass availability at any one location, they describe a process to enable the achievement of an economical potential through a simple, low-cost production of medium-Btu gas from biomass in modest sized plants.

In a study conducted by Harper et al. (1979), the authors describe different biomass energy production systems, involving diverse conversion methods (hydrolysis, pyrolysis, and combustion) and agroforestry residues (corn residues, molasses, pulp and papermill wastes), and they estimated material and energy flows, capital, operating and maintenance costs as well as environmental impacts.

2.3.3. The decade 1980-1989

Wilke et al. (1981) designed a process for conversion of biomass to sugars and ethanol, and did an economic assessment of this production, using corn stover as a representative raw material, showing that the cost of ethanol is mostly dependent upon: (1) the cost of the biomass, (2) the extent of conversion to glucose, (3) enzyme recovery and production cost, and (4) potential utilization of xylose. In another study from the same year, the authors analysed the production of ethanol as a liquid fuel by microbial process from sugars, starches, agricultural and forestry cellulosic materials and urban and industrial wastes, concluding that pre-treatment processes would have an impact on the competitive industrial production of this fuel (Kosaric et al., 1981).

In a techno-economic study from 1986 (Klyosov, 1986) the production of sugars and alcohols from cellulosic materials is approached more deeply, with a special focus on developing countries. The authors argue that sugar-containing plants such as sugarcane, sweet sorghum, and nipa palm are the best candidates for the high-yield production of alcohol fuel, but they emphasize on biomass containing cellulose, which implies a special treatment before use to produce glucose and alcohols. This treatment is described as follows: (1) Growth, harvest, and delivery of raw materials to processing plants; or, alternatively, the collection and delivery of cellulosic "waste" products. (2) Pre-treatment or conversion of the raw material by mechanical, physical, chemical, or enzymatic methods to break down the cellulose to sugars and to modify or remove unwanted side-products, usually lignin and hemicellulose. (3) Recovery and purification of sugars from reaction mixture. (4) Fermentation of sugars to alcohol and purification by distillation. (5) Treatment of process residues to reduce pollution and to recover potentially valuable side-products. Despite all the potential, the authors conclude that at that time the production of alcohol from cellulosic materials is not economically favourable, but they encourage further research because the advantages for developing countries would be many (e.g., increase energetic self-sufficiency, increase employment, higher technical competence in biotechnology and related areas, increase chemical industries).

Radhika et al. (1984) carried out a study regarding the United States. According to the authors, the US planned to achieve a 4.2-5.2% of biomass and wastes to primary energy consumption within the first decade of the 2000’s. At that time, wood and wood-waste combustion systems were the main sources of energy from biomass and wastes in the United States, being mostly used for industrial purposes, despite the increase in residential use. The authors discuss other technologies that were gaining attention, anaerobic digestion of farm and industrial wastes for methane, thermochemical gasification of wood and wood wastes for fuel gases, mass-burning of municipal solid wastes and combustion or co-firing of refuse-derived fuel for steam and electricity, landfill gas recovery for medium- and high-calorific-content gas, and biomass-derived ethanol fuel. Nevertheless, they argue that small scale plants would predominate in the future because of the limitation of biomass (mostly related to the logistics problem). The article from Radhika et al. (1984) is specific for agricultural wastes, and the authors classify the processes for energy recover from these wastes as follows: aqueous or biological processes, and dry chemical or thermochemical processes, stating that within the biological processes, the one with most potential is anaerobic digestion.

2.3.4. The decade 1990-1999

The bioconversion of biomass to fuel ethanol keeps being studied in the 90’s. In a study carried out by Duff & Murray (1996), the authors examine the efficacy of converting waste wood cellulosic materials into fuel ethanol, from a technological and economical points of view. The concerns regarding biomass production, wood pre-treatment, enzyme production, hydrolysis, fermentation and product recovery are reviewed. The authors conclude that wastes from the forest products industry could reduce the costs of ethanol production which together with the advantages of a pre-treated, cellulose-enriched substrate and existing material handling equipment, would make this an ideal industry for integrated ethanol production.

In another article from 1996 (Easterly & Burnham, 1996), electric power generation from biomass and waste fuels was addressed. This article starts by characterizing important physical characteristics of biomass and waste fuels, classifying biomass into four categories: wood residues; agricultural residues (from crops, food processing and animals), dedicated energy crops; and municipal solid waste. The authors continue, emphasizing the importance of biomass wastes, given the large volumes that are generated by the wood products industry, as well as by the forestry and agricultural sectors. The authors propose that these residues could be gathered in regional biomass power facilities. Although, the problems related to logistic have prevented its growth of using these residues for fuel production. Wood residues and waste materials were the primary source of biomass used for power production, and the authors expected an increase over the following 5-10 years, but a stagnation from the year 2000, since they expected a substitution from energy crops. Importance is given to the stimulation of rural areas through jobs creation, but also to the fact that it would be a source of renewable energy and environmentally friendly. A comparison between biomass with conventional fossil fuels, especially coal is also done.

Obernberger (1998) did a review regarding combustion as the most mature conversion technology utilized for biomass. The authors addressed different technologies (underfeed stoker furnaces, moving grate firings, bubbling and fluidized beds), and different biomass fuels (sawdust, wood chips, bark, straw, cereals, and grass). Developments regarding NO_x reduction and higher plant efficiencies were already ongoing, and the problems related to the reactions that take place in the hot flue gas that cause depositions and corrosion in furnaces and boilers needed further research.

In a review article from 1997 (Hughes & Benemann, 1997), the importance of managing the carbon cycle in order to mitigate the emission of greenhouse gas is addressed. The authors stated that electric power generation is responsible for roughly one third of fossil CO_2 emissions, which implies the need for reducing CO_2 emissions from power plants, through different technologies such as cultivation of microalgae on flue-gas or captured CO_2, and the cofiring of wood with fossil fuels. The authors also suggest the use of indirect biological processes like growing trees. Besides that, they argue that biofuels could potentially replace a large part of fossil fuels, and that cofiring biomass wastes and residues with coal is one of the lowest-cost, nearest-term options for reducing fossil CO_2 emissions at existing power plants, concluding that wastes and residues form the forestry and agriculture sectors could have a major positive impact.

2.3.5. The decade 2000-2009

Within the first decade of the new millennium, the research trends focused on new biomass conversion technologies such as gasification, pyrolysis, torrefaction, and not just combustion, which is the oldest way of using biomass and according to A. Demirbas (2004), responsible for over 97% of the world's bio-energy production. As we have seen before, already in previous decades, processes such as pyrolysis, gasification, anaerobic digestion, and alcohol production had been applied to biomass for energetic valorisation, as well as cofiring biomass with coal.

Although, within the beginning of the 2000's, these modern conversion technologies have been further researched. The environmental concerns regarding biomass, namely its availability and sustainability are a major focus in scientific studies since the new millennium because the prospects for replacing fossil fuels are more real than ever.

Demirbas et al. (2009) advocate that biomass is the best option and with the largest potential to substitute fossil fuels. The authors conclude that the "utilization of biomass resources will be one of the most important factors for environmental protection in the 21st century", since it helps the atmospheric CO_2 recycling, not contributing to the greenhouse effect. Biomass can be continually regenerated, since it is a renewable resource, which leads to a sustainable and dependable supply. Besides that, the net production of CO_2, the major greenhouse gas, from wood combustion is very reduced (~5%) because the CO_2 generated during combustion of the wood equals the CO_2 consumed during the lifecycle of the tree (Balat, 2006).

Belgiorno et al. (2003) give an overview of the gasification conversion technology applied to biomass solid wastes. Since the gasification process need a sufficiently homogeneous carbon-based material, many kinds of wastes cannot be included, but this is not the case for agroforestry residues. The authors argue that gasification would be a good "alternative to the waste incinerator for the thermal treatment of homogeneous carbon-based waste and for pre-treated heterogeneous waste".

Gómez-Barea et al. (2009) studied the gasification of two wastes ("orujillo", which is a solid waste coming from olive oil manufacturing and meat and bone meal waste) in a fluidised-bed pilot plant. The authors wanted to optimize the industrial process obtaining better ash quality and higher energy efficiency, as well as finding ways of recycling the ash produced. Since the ash produced contained compounds harmful to the environment, pre-treatment is necessary to use them in agriculture and construction, but it is not necessary if using it for cement kilns. The authors researched other uses that would not require pre-treatment – manufacture of lightweight board and bricks -, stating that this is a low-cost process but that generates high-value products.

In a study conducted by Sadhukhan et al. (2009), the authors searched for an economically viable combined heat and power (CHP) generation plant, using biomass waste as feedstock, allowing a cost-effective and cleaner industrial process. The authors chose as low-cost feedstock agricultural wastes, and as a more predominant biomass feedstock, wood, since it has been extensively used as standard fuel for electricity generation. Biomass gasification for CHP generation was studied in order to maximize heat recovery and subsequently improving the sustainability of the process. The authors predicted the cost of electricity generation as well as the cost of carbon capture using discounted cash flow and operating cost analyses, and they concluded that CHP generation from biomass is economically viable if low carbon initiatives are in place, and that agricultural wastes would be the ideal feedstock.

Skodras et al. (2006) studied the pyrolysis and combustion behaviour of 10 biomass and waste materials (two agricultural residues – almond shell and olive kernel -, and six wood-processing byproducts - MDF, saw dust, willow, waste wood, forest residue, and demolition wood), in a perspective of greenhouse gases reduction. They concluded that all samples were found to be good fuels, reflecting their high volatiles and low ash contents.

2.3.6. From 2010 to present

According to Guilhermino et al. (2018), the main challenge regarding biomass exploitation seems to be in its viable and sustainable use and not in its availability per se. Although, academics are not consensual regarding the sustainability of biomass for energy, with some authors pointing mostly to its benefits, while others conclude that this is not such a “green” source of energy as it may seem at first view. Generally, biomass is considered a good source for energy production because it is renewable and distributed all around the globe. Besides its abundance, biomass has low sulphur and nitrogen (relative to coal) content and nearly zero net CO_2 emission levels (Li et al., 2017).

Proto et al. (2014) present biomass as being an important alternative to fossil fuels, but also as a potential source for the socio-economic development of various marginal areas. Although, these authors point out some environmental risks regarding the intensification of its use, which justifies the importance of a sustainable biomass supply chain. The low environmental impact of biomass and its contribution to improving competitiveness, employment and regional development are named by Torreiro et al. (2020), concluding that biomass is an important element to fight climate change. In a study conducted by Kang et al. (2021), the authors state that “energy production from biomass can reduce greenhouse gas (GHG) emissions, mitigate climate change, promote environmental sustainability, and improve human health and wealth”.

On the other hand, the logistics problems represent one of the main drawbacks for biomass use. “The uncertainties of supply-side externalities (e.g., collection and logistics) represent the key challenges in bioenergy supply chains and lead to reduce cross-cutting sustainability benefits” (Mirkouei et al., 2017). Regarding this issue, large volumes with low density must be moved from largely spread production and collection sites to centralized processing facilities, then delivered in its final form to consumers (L. J.R. Nunes et al., 2020). Kang et al. (2021) points out some disadvantages regarding bioenergy that are not solved yet, such as the lower fuel quality of raw biomass when compared with fossil fuels, including low bulk density and grindability, hydrophilic and perishable nature, low calorific value, and high alkali and alkaline earth metal (AAEM), oxygen and moisture content. The same authors emphasize as well that although biomass can be considered carbon neutral, the harvesting, transportation, conversion, product separation, purification, and even utilization are all often coupled with high energy demand and may cause various levels of indirect carbon emissions and release of other contaminants. Furthermore, the vast diversity of plant species, the inhomogeneity of their chemical composition, the seasonal, and the uneven geographical distribution collectively increase the cost of biomass utilization.

In short, all the economic, environmental, and social aspects of a biomass-based supply chain must be considered to truly understand the sustainability performance of biomass as a bioenergy resource (Mirkouei et al., 2017). Despite some disagreements on the literature, one thing is mostly consensual: the use of biomass wastes from forestry and agriculture to produce energy or other valuable products, in a perspective of the bioeconomy, is sustainable, and should be further studied and implemented. Using biomass waste solves problems related to competition with other land-uses (Leonel J. R. Nunes, 2020).

As a land system, agroforestry biomass has a great potential for carbon sequestration beyond the production of biomass for energy. Sequestering carbon in the soil organic carbon (SOC) is seen as one way to mitigate climate change by reducing atmospheric carbon dioxide, and this can be deliberately enhanced by agroforestry practices (Jose & Bardhan, 2012; Lorenz & Lal, 2014). Obviously, there are some inherent characteristics from agroforestry biomass that need to be overcome in order to fully exploit its potential, such as "poor grindability, high moisture content, a poor energy density and calorific value, perishability, and difficult to collect, store, and transport properties" (Jiang et al., 2021). Fortunately, there are different biomass pre-treatment technologies that already solve most of these problems.

Tuck et al. (2012) reviewed the potential of biomass wastes to produce chemicals, fuels and solvents. According to these authors, the amount of lignocellulosic biomass residues is estimated to exceed $2x10^{11}$ $t{\cdot}yr^{-1}$ and they classify them into two groups: one related to residues left in the field after harvest of crops and other related to product processing. The authors focused on agricultural and food wastes, describing some uses beyond energy valorisation, especially large-volume chemicals such as lubricants, surfactants, monomers for plastics and fibres, and industrial solvents. Sheldon (2014) also reviews the use of waste biomass as feedstock for chemical production, focusing on green chemistry, which is defined as the production and application of chemical products using (preferably renewable) raw materials, eliminating waste and avoiding the use of toxic and/ or hazardous solvents and reagents.

Regarding the use of biomass waste to produce high value chemicals, Cho et al. (2020) reviewed the application of biochemical processes to various types of biomass wastes that exist in high quantities, namely from agricultural and forestry activities, but also from food processing and other sector of industry. The authors demonstrate that enzymatic technology allows a more efficient process of biomass waste conversion into valuable products, that can be applied in chemical, pharmaceutical, cosmetic and food industries. Although, they point out to the fact that this valorisation is not yet competitive against petroleum-based products.

The production of biofuels is extensively reviewed by Limayem & Ricke (2012), that point out for the fact that the interest in biomass derived fuels increases every time there is a price peak in petroleum derived fuels. The authors state that "industrial research efforts have become more focused on low-cost large-scale processes for lignocellulosic feedstocks originating mainly from agricultural and forest residues along with herbaceous materials and municipal wastes". This goes in line with another article (Saini et al., 2015) that advocate the use of agriculture residues for bioethanol production, since they are renewable, lignocellulose-rich and available in large amounts. Upgrading techniques to produce gas and/ or diesel and chemicals from biomass and waste biomass is reviewed by Jacobson et al. (2013), that state that there is a great potential for conversion to transportation fuels.

Foong et al. (2020) argue that biomass waste is promising substitute of fossil fuels, not only for energy purposes but also value-added products. According to the authors, pyrolysis seems to be the best thermochemical conversion process applied to biomass, thanks to low pollutant emissions and residues formation. The different pyrolysis processes are review, namely fast, slow, and flash pyrolysis, which originates as main products bio-oil, solid char and syngas, respectively. Different types of pyrolysis are also explained: solar pyrolysis, which uses solar energy as the heating source; vacuum pyrolysis, where the pyrolysis is conducted under vacuum to replicate an inert environment; conventional pyrolysis, which is the most common pyrolysis technique in waste transformation and recovery.

Donner et al. (2020) focused their research on business models that create value from agricultural waste and by-products through a perspective of the circular economy. Trough the analysis of 39 cases, and semi-structured interviews, the authors identified six types of circular business models: “biogas plant, upcycling entrepreneurship, environmental biorefinery, agricultural cooperative, agropark and support structure”. The differences between these business models are discussed, as well as their similarities, being the most important the fact that all these businesses depend on partnerships and their ability to adapt to changing external conditions. The authors conclude that there is a great potential of using biomass for higher added-value products and that the “cascading biomass valorisation at a territorial level will increasingly be important for locally cooperating actors within a circular bioeconomy approach”.

2.4. The incorrect disposal of RAFB and rural fires

In the Southern European region, rural fires are a widely known problem causing socio-economic losses and undesirable environmental consequences, including loss of lives, infrastructures, cultural heritage, and ecosystem services (Joana Parente & Pereira, 2016; Turco et al., 2018). Different authors point out to the fact that rural fires have been increasing in extent and severity over the last decades (Chapin et al., 2008; Leonel J.R. Nunes, Raposo, et al., 2021; Pereira et al., 2013). Natural rural fires are important for the ecosystems since they are responsible for renewing the vegetation and recycling available nutrients (Pyne, 2017). However, in the last decades, rural fires have become larger and more severe, causing profound changes in the structural and functional processes of ecosystems (Adélia N. Nunes, 2012; M. Oliveira et al., 2020).

In recent years, weather conditions have become the warmest on record, impacting many countries (Molina-Terrén et al., 2019). Historically, increased temperatures create the perfect scenario for extreme fires, as demonstrated by the events in Portugal in 2017, and more recently in Australia and California (Keeley & Syphard, 2021; M. Oliveira et al., 2020; Wintle et al., 2020). Climate change impacts rural fire regimes in different ways such as longer fire seasons and newly vulnerable ecosystems, such as occurring in Central and Northern Europe (M. D. Flannigan et al., 2000; Frank et al., 2015). New potentially catastrophic fire regimes are emerging from these dynamics, while impacts become harder to predict once fire regime changes have occurred

(Wunder et al., 2021). In fact, megafires (fires burning areas higher than 10,000 ha) have been affecting some European countries, namely, Portugal (M. Oliveira et al., 2020; Scotto et al., 2014). The capacity of the countries to control these megafires can be considered a challenge, as stated by Oliveira et al. (2020) regarding Portugal, which registered 1,158,175 ha of burnt area between 2010 and 2017, representing a cumulative loss of 37% of the total forest area, with the northern and central regions being the most affected areas. Despite climate change being associated with the increase in the number of fires and their intensity by several authors, it is also of great importance to understand that although climatic and meteorological parameters are key elements in the occurrence of fires, these factors do not totally justify the increase in the burnt area registered in recent years in Portugal (Alcasena et al., 2021; Adélia N. Nunes, 2012; Pereira et al., 2005).

Changes associated with demography and land use, namely, the rural exodus that is occurring since a few decades ago, changed the landscape, with the abandonment of the agro-silvo-pastoral activity, contributing to the accumulation of large amounts of biomass likely to burn when weather conditions are favourable (Enes et al., 2019; Félix & Lourenço, 2019; Wunder, Calkin, Charlton, Feder, Martínez de Arano, et al., 2021). Since the climate and the weather cannot be controlled, the root causes of fires and other factors associated with demography and land use must be addressed (Fernandes et al., 2013; Meira Castro et al., 2020). In fact, many studies suggest that the increasing incidence and impact of fires in Mediterranean environments can be mainly attributed to the decline in the landscape mosaic that has historically characterized Mediterranean rural areas (Badia et al., 2002; Hill et al., 2008; Moreira et al., 2001; Salis et al., 2018).

According to Wunder et al., in the European Mediterranean region, around two thirds of all fires are originated in agricultural practices, since farmers still use fire to remove crop residues or rejuvenate pastures (Wunder et al., 2021). In Portugal, the misuse of fire and negligent attitudes towards it, mainly associated with the burning of leftovers resulting from agricultural activity or forestry operations, are the leading causes behind rural fires (Leonel J.R. Nunes, Raposo, et al., 2021). Agroforestry residuals are currently dealt with through burning because there is not a market and functioning supply chain for the biomass. This burning reduces fuels in rural environments but also causes many wildfires. As stated by Leonel J.R. Nunes, Raposo, et al. (2021), the data made available by ICNF (Instituto da Conservação da Natureza e das Florestas) show that up to 27% of fires, of a total of 41% attributed to all negligent causes, were caused by this misuse of fire in 2020. This scenario remains in line with the data available for the 2010–2019 decade. This traditional use of fire to dispose of waste materials from agriculture and forestry practices, eliminating leftovers, contribute to increase the risk of fire occurrence but also present an opportunity for new options to manage agroforestry residues (Adegbeye et al., 2020; Catry et al., 2009; J Parente et al., 2018). In this same line, Wunder et al. stated that instead of reinforcing the efforts in fire suppression-centred strategies, the author defends the idea that it is of utmost importance to develop new approaches that shift emphasis towards the root causes of fires, along the entire risk management cycle of prevention, preparedness, response, and recovery (Wunder et al., 2021). Reducing the risk of occurrence of rural fires can be analysed from several perspectives. For example, Martin et al. analysed the risk of rural fires from the perspective of the factors influencing the reduction in risk behaviours on the part of populations that inhabit rural areas, with the authors concluding that populations often do not have a direct perception of how their traditional practices influence rural fire risk and what mitigation practices they should adopt (Martin et al., 2009). Brenkert-Smith et al. (2012), on the other hand, in their analysis of the behaviour of rural populations regarding the risk of rural fires occurrence, concluded that these populations, when they perceive high levels of risk, tend to acquire behaviours to mitigate this risk, that is, strengthening the biomass marketplace through improved supply chain management. This should replace the fuel reduction efforts of current burning practices while reducing rural ignition sources.

3. Methodology

3.1. Data Sources

The present work was very dependent on data and their availability. Different database sources were used, all available on the internet:

- ICNF (https://www.icnf.pt/, accessed on 15 February 2022) - Instituto de Conservação da Natureza e das Florestas - provides a data bank (http://www.icnf.pt/portal/florestas/dfci/estatisticas, accessed on 15 February 2022) regarding all fires that have occurred in Portugal, from 1980 until 2015, but it is only from 2001 that the tables have more detailed information. Each record contains certain relevant information, such as geographic location, date, burned area in hectares and cause of the ignition, reported after the fire investigation by the competent authorities. Since 2001, this Institute releases an annual report regarding the Portuguese forest fires.
- PORDATA (https://www.pordata.pt, accessed on 15 February 2022) is a statistical database that collects, compiles, systematizes, and disseminates data on multiple areas of society for Portugal and its municipalities, namely, demographic, and socioeconomic information.
- INE (https://www.ine.pt, accessed on 15 February 2022)—Instituto Nacional de Estatística, is the national statistical survey, namely, concerning demographic and socioeconomic information.

Besides the public data that was gathered, in order to apply the stakeholder analysis methodology and conduct the research about the market, we conducted two different surveys, six semi-structured interviews and one focus groups session. These methodologies will be explained in more detail in the following section.

3.2. Stakeholder analysis and market research

3.2.1. Definitions

Stakeholder analysis (SA) is a holistic approach for gaining an understanding of a system, characterized by identifying key actors or stakeholders and assessing their respective interests in the system. This methodology has been developed in response to multiple objectives, but more particularly in the search for efficient, equitable and environmentally sustainable development strategies (Grimble & Wellard, 1997). By “stakeholders” it is meant any group of people, organized or not, that share common interests or stake in a particular issue or system; they can be at any level or position in society, from global, national, and regional concerns down to the level of household. The root of SA lie in political economy and its areas of concern overlap with cost-benefit analysis and environmental economics. The term Stakeholder Analysis, however, was first used in management science as a method for identifying and addressing the interests of different stakeholders in business.

This seemed the most appropriate methodology for this thesis, since we wanted to acquire empirical knowledge, understand the key stakeholders involved in a RAFB market, develop a generic business model while incorporating stakeholder and institutional concerns, and develop knowledge of the opportunities and scope for action by policymakers. It is important to notice that SA may be applied at different levels and in different degrees of detail, depending on the needs and resources.

Since one of the main goals for this work was understanding the market space for AFB waste, we decided to include the market research methodology, as a mean of determining the viability of the web platform proposed here. Market research allows to discover the target market and get opinions and other feedback from stakeholders about their interests. The process of market research can be done through deploying surveys, interacting with a group of people also known as sample, conducting interviews and other similar processes, which is in line with the methods used in stakeholder analysis.

3.2.2. Stakeholder Survey

Online surveys in other scientific research areas other than economics already have an extensive background, as highlighted by the work of Ilieva et al (2002), in which the authors classified online surveys as a new kind of data collection. Regarding the biomass market, Leonel J.R. Nunes, Casau, et al. (2021) used online surveys to stakeholders in order to understand the wood pellets market's dynamics, evolution and prospects in Portugal.

For this work, after the stakeholder's identification, information was collected through surveys to stakeholders in the agroforestry biomass sector, namely producers, logistic operators and transformers. This survey was developed using Google Forms in the Portuguese language, and after being pre-tested, was made available through social and professional networks such as Facebook and LinkedIn, and through direct contact by email. In any case, the link provided let to the survey form, and was anonymous, since no personal data that could lead to the identification of the enquired was asked. Inquiries to producers were also conducted by face-to-face administration, in order to have more answers, since agroforestry producers are often not familiar with digital technologies. The data was collected from April 1st until May 15th, 2022.

Following the same survey structure as Solomon & Johnson (2009), after a first section with demographic questions, there was a second section with a set of questions on environmental problems, namely climate change, wildfires and incorrect disposal of agroforestry biomass wastes. This allowed to open the survey to the general public and assess their perception regarding these topics. This section on environmental problems, measured agreement/ disagreement using the Likert scale, from 1 (strongly disagree) to 5 (strongly agree) with 15 statements. At the end of this section, a question regarding the respondent role in RAFB determined the following section – if there was no role, the survey ended, but if the respondents were producers, logistic operators or transformers, there was a different section for each one, and then the survey ended.

The survey is presented in Annex 1. The main goal of the last section was to understand the potential market for RAFB among the different stakeholders, as well as their willingness to pay for this resource and their openness to use a web platform to coordinate supply and demand and their willingness to participate in this market.

3.2.3. Municipalities survey and focus groups

The main goal of the project BioAgroFloRes is to implement a web platform for the RAFB market. For this, the governmental agencies must be included in the process. It is expected that such a kind of platform benefits not only the stakeholders directly involved, but also the municipalities and the local agencies. That is why AREAC [Agência Regional de Energia e Ambiente do Centro – Regional Agency for Energy and Environment of the Center (of Portugal)] was involved since the beginning of the project BioAgroFloRes. This Regional Agency mission is "*to contribute to energy efficiency and to the best use of endogenous energy resources, through the development of projects and methods that allow the dissemination of the best techniques and procedures, (…) with the main objective of promoting sustainable local development*" (http://www.areac.pt/pt/quem-somos/missao, accessed in 9/5/2022), which is in line with the goals for this project. Therefore, an event for the municipalities that are AREAC's associates was conducted on the 3rd of May of 2022 at 10 a.m., in the Municipal library of Lousã.

Figure 1 - Presentation and discussion of the BioAgroFloRes project in Lousã, 3/5/2022.

Figure 2 - Presentation and discussion of the BioAgroFloRes project in Lousã, 3/5/2022.

From the 12 municipalities that are part of the AREAC's associates (*figure 3*), six were represented either by an assemblyman or by an environmental or forestry technician – Cantanhede, Figueira da Foz, Góis, Lousã, Pedrógão Grande and Vila Nova de Poiares. Some municipalities had more than one representative, so in total there were eleven participants.

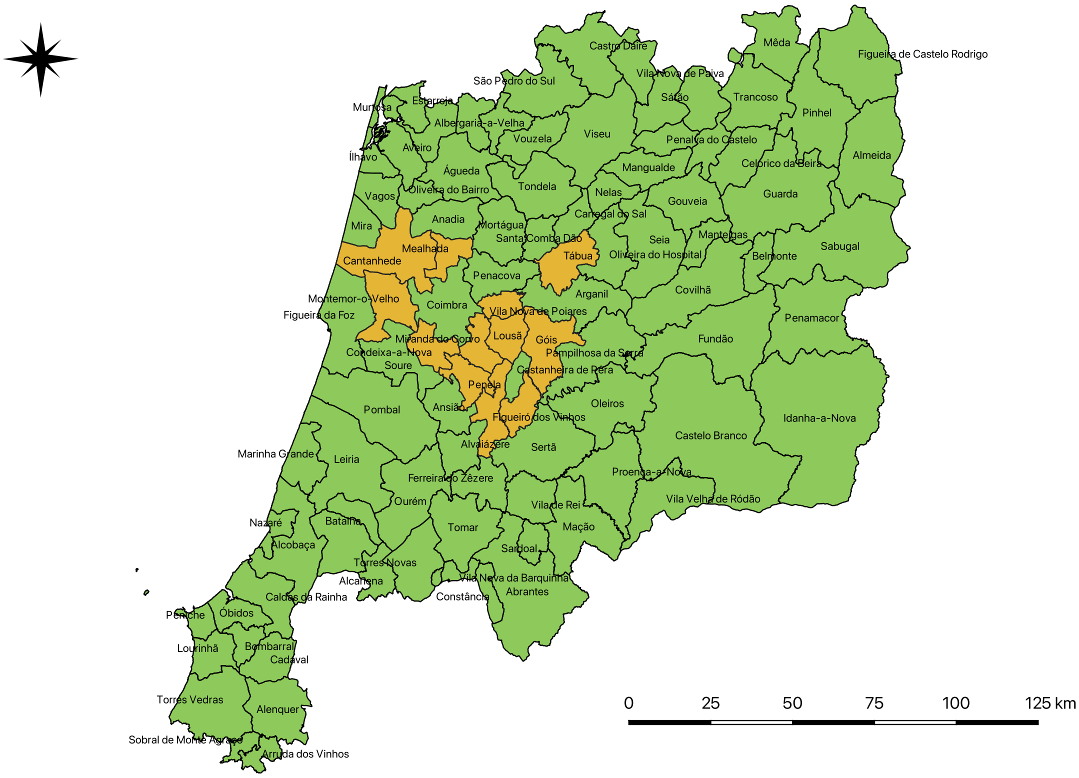


Figure 3 – Municipalities part of the AREAC in Portugal central region.

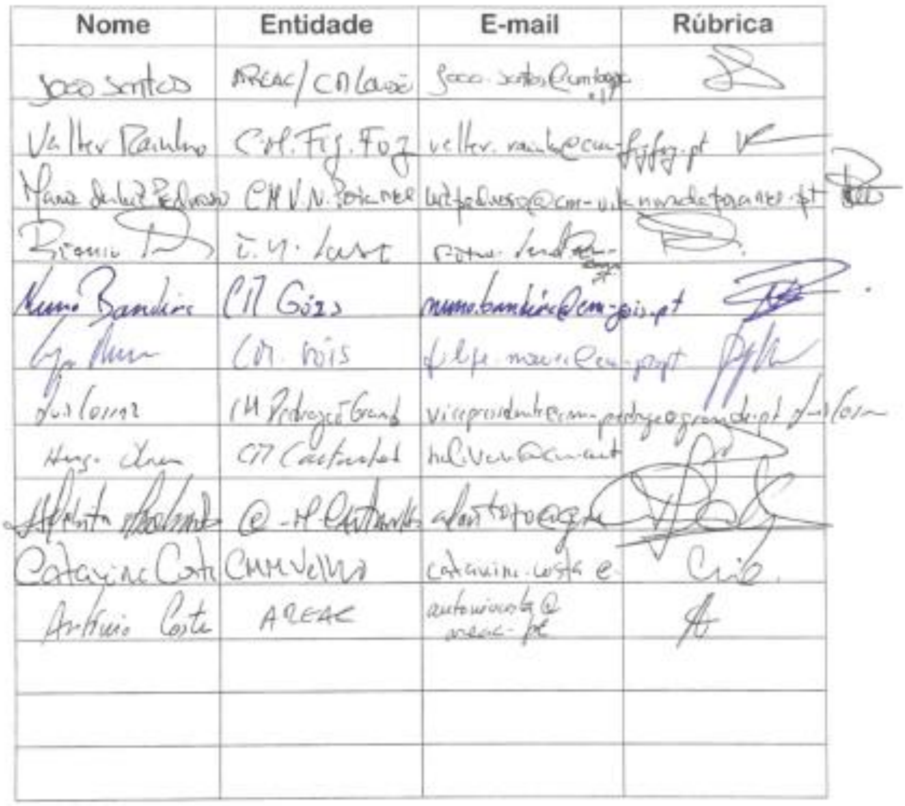


Figure 4 - Presence list.

The session went accordingly to the following schedule:

- 10:00 a.m. - Opening Session
- 10:10 a.m. - Project Presentation
- 10:40 a.m. - Completion of the surveys
- 11:00 a.m. - Focus groups
- 12:00 a.m. - Closing of the Session

The municipalities survey is presented in Annex 2, and it had as main goal to enable an individual reflection on the topic, to prepare the focus groups discussion. It was a short survey, that had questions regarding the interest in the project, and the level of knowledge on agroforestry biomass wastes within the municipality of the respondent.

After this survey, two focus groups were formed, one with five persons and the other with six. There was one mediator per group, that kept the focus on the main questions and wrote down the main ideas of the participants. This is, in fact, one of the main points regarding focus groups - the researcher facilitates or moderates a group discussion between participants and not between the researcher and the participants. Unlike interviews, the researcher thereby takes a peripheral, rather than a center-stage role in a focus group discussion (O. Nyumba et al., 2018).

The focus group methodology has been extensively applied in social sciences, for data collection within qualitative research settings (Parker & Tritter, 2006). Focus groups can be distinguished from the broader category of group interviews by the explicit use of group interaction as research data, and they are first mentioned in the 1920's as a market research technique (Kitzinger, 1994).

For the purposes of this dissertation, five main topics were the guidelines for the focus groups discussion:

1. What is the best way to get agricultural/forestry producers, logistics/forestry operators and processing industries (i.e. biomass plants, pellet factories, etc.) to use the platform? – JOINING THE PLATFORM

2. How to reach small producers, who often do not master new technologies? – CONTACT WITH PRODUCERS

3. What are the biggest obstacles to implementing this project on the ground? How to overcome them? What are the biggest benefits of implementing it? How to potentiate them? – OBSTACLES AND BENEFITS

4. What do you consider to be the ideal business model regarding the use of residual agroforestry biomass? – BUSINESS MODEL

5. What are your expectations regarding this project – EXPECTATIONS

There was also space for other comments.

3.2.3. One-to-one interviews

Interviews are also a valid method of qualitative research. According to Bewley (2002), "*the task of interviewing is to learn as much as possible about decision making, despite people's reluctance to discuss it*", and it is a particularly important mean of research within the field of economics, since the most fundamental elements of economic life are the decisions made by its participants, and the basic components of these decisions are people's motives, the constraints they face, and how they go about achieving their objectives, given the constraints.

The choice of conversational and semi-structured interviews was decided based on the possibility of allowing for questions to be revised based on what the interviewees revealed by speaking with a broad and representative range of actors. This degree of flexibility was very important since it allowed to understand better the interviewees roles, activities, procedures, and perspectives on the topic.

Different organizations and stakeholders related to agroforestry biomass were contacted, and a total of 6 interviews were conducted with participants, five in an online format and one face-to-face, and were spread out from March until April 2022. *Table 2* presents an overview of the participants according to the type of their organization and level of activity. Besides these interviews, we had the opportunity to have informal talks with seven farmers when we applied the face-to-face survey to producers.

Table 1 - Generic description of interviewees.

Date	ID	Participant role	Type of organisation	Level of action	Interview method
22/3/2022	I1L	Technical coordinator	Forestry NGO	Local	Conversational (online)
7/4/2022	I2R	Head of the forestry department	Logistics Company	Regional	Semi-structured (online)
7/4/2022	I3N	Project Manager	NGO	National	Semi-structured (online)
8/4/2022	I4R	Commercial	Agricultural Cooperative	Regional	Conversational (presential)
21/4/2022	I5N	Chief of department	Governmental Agency	National	Semi-structured (online)
28/4/2022	I6N	Forestry technician	Forestry Company	National	Semi-structured (online)

The first interview was conversational, characterized by an informal talk and flexibility, which contributed to a better understanding of the topic and helped narrowing the questions for the semi-structured interviews.

In the semi-structured interviews format, there was more control over the interview topics, and the questions were tailored according to the type of organization. Although, the set of questions was not rigid, offering the interviewees the chance to explore issues they felt that were important. These interviews contributed to getting multiple perspectives on how governmental agencies, NGOs and private sector organizations collaborate and which are their views regarding the residual biomass market.

Two of the interviews were recorded, with the permission of the interviewees. The main points and statements were extracted from all the interviews. Through the data retrieved from the interviews, it was possible to deconstruct the current perception regarding the residual biomass market.

4. Results

4.1. Study area

Portugal, officially the Portuguese Republic, is a State of Southern Europe, covering a total area of 92,225 km^2. Mainland Portugal (89,102 km^2) is located on the Iberian Peninsula, in the extreme Southwest of Europe, bordering Spain to the North and East, and the Atlantic Ocean to the West and South. The Portuguese territory also includes two autonomous regions: the archipelagos of Madeira (801 km^2) and the Azores (2322 km^2), located in the Atlantic Ocean, which were not included in this study. Regarding mainland Portugal, despite its modest land area, the physical environment varies significantly from North to South. The northwest landscape is mountainous and is characterized by the abundance of water and existence of fertile soils, and property is structured around the minifundium. In the southern interior, open rolling plains and smooth hills characterize the relief, with water scarcity, poor soils, and agriculture that developed around the latifundium. In terms of territorial organization, the Portuguese government uses the NUTS system (Nomenclature of Territorial Units for Statistics – which subdivides the economic territory of the European Union into three different levels, NUTS I, II, and III, moving from larger to smaller territorial units, respectively). In 2015, a new regional division came into practice in Portugal – NUTS 2013. Compared to the previous version – NUTS 2002 –, this brought significant changes in the number and municipal composition of NUTS III, which went from 30 to 25 territorial units, now called 'administrative units'. Currently, the 308 municipalities in Portugal are grouped into 25 NUTS III, 7 NUTS II and 3 NUTS I, as can be observed in *Figure 5*. This is important because it means that there is an administrative unit variation of data, that difficult the task of gathering and organizing the data. In this work, we use the last regional division (NUTS 2013), knowing that the limitation is that we will use the most recent years only.

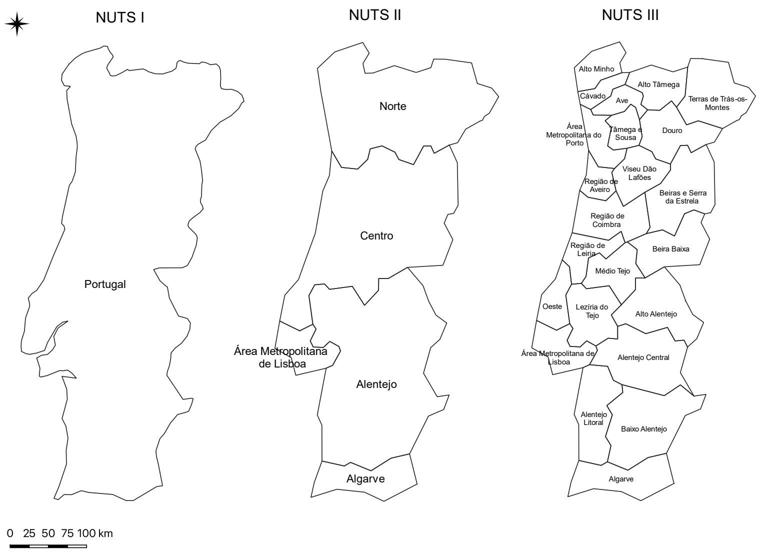


Figure 5 - Mainland Portugal NUTS subdivision.

Table 2 - Demography and land use characteristics of the sub-regions of Portugal (Portugal mainland NUTS III - PV [Population Variation]; DP [Density of Population]; AI [Ageing Index]; AA [Agriculture Area]; and Portugal mainland NUTS II – FA [Forest Area]). Data source: PORDATA and INE.

NUTS III	Demography				Land use			
	PV	DP	AI		AA		FA	
	1981-2020 (%)	2020 (Inhab./km^2)	1981 (%)	2021 (%)	1989 (ha)	2019 (ha)	2005 (km^2)	2015 (km^2)
Alto Minho	-11.2	103.2	51.7	252	87,077	70898	5664	5849
Cávado	21.6	324.2	27	146.5	43,719	29554		
Ave	10.6	282.6	26.3	167.3	53,414	40419		
Área Metropolitana do Porto	13.1	846.4	32.1	174.7	45,143	No data		
Alto Tâmega	-35	29.3	43.4	383.9	105,485	No data		
Tâmega e Sousa	3.4	225.8	28.2	149.5	56,640	No data		
Douro	-27.5	47.1	44.4	274.4	147,687	No data		
Terras de Trás-os-Montes	16.2	163.2	51.9	185.4	106,495	69416		
Oeste	15.1	216.9	41.7	185.6	36,963	21492	10817	10931
Região de Aveiro	-7	100.5	60.6	243.9	80,120	44272		
Região de Coimbra	9.1	117.1	46.2	201.7	37,297	24568		
Região de Leiria	-11.4	78	53.1	246.3	76,882	39516		
Viseu Dão Lafões	-26	17.3	108.1	330.9	155,389	164985		
Beira Baixa	-12.4	69.8	69.1	253.8	67,862	48136		
Médio Tejo	-26.4	33.5	75.7	337.9	266,232	220914		
Beiras e Serra da Estrela	15	951.5	41.4	150.9	97,243	90733		
Área Metropolitana de Lisboa	-9.9	17.5	66.9	223.5	267,172	318161	670	663
Alentejo Litoral	-27.6	13.5	79.1	217.9	586,063	698507	13544	13346
Baixo Alentejo	1	55.4	61.1	199.6	186,236	206666		
Lezíria do Tejo	-27.8	17	93.3	253.6	419,671	473272		
Alto Alentejo	-16.5	20.4	71.8	224.1	580,222	654126		
Alentejo Central	35.1	87.7	75.2	176.7	136,779	100605		
Algarve	35.1	87.7	75.2	176.7	136,779	100605	1424	1453

The exodus of the Portuguese rural population may be explained by many factors, such as a lack of employment options; uncompetitive farm structures, characterized by small plots; remoteness of the centers of consumption and services; and encouragement by the European Union of Common Agrarian Policy (CAP) to withdraw agriculture activity, especially cereal crops, through the payment of subsidies (A N Nunes & Lourenço, 2017). Exception can be highlighted for the northernmost regions and the southernmost regions of the country, namely, Alentejo Central and Algarve. The central region has a mixed trend, with some NUTS III regions growing. In contrast, others decrease in population, most likely due to regional migration, with populations originating from NUTS III regions, such as Viseu Dão Lafões, Beira Baixa, or Médio Tejo, looking for better living conditions in NUTS III regions, such as Oeste, Coimbra, or Beiras e Serra da Estrela. From the point of view of the Aging Index, in the last 40 years, there has been generalized ageing of the population in all regions, and even the external migratory flows coming from the PALOPs (African Countries of Portuguese Language), Eastern Europe, Southeast Asia, and South America have not managed to counteract it. The agricultural area decreased in all NUTS III regions, except those included in the Alentejo (NUTS II region). Even here, the Alentejo Central region decreased. In the central region of the country, Viseu Dão Lafões is the only one that grows in terms of population in the area. If, in the case of Alentejo, the growth of the agricultural area is related to the increase in the areas of intensive and super-intensive production of almond and olive groves. In the case of the Viseu Dão Lafões region, the growth of the agricultural area is related to the increase in vineyard area. Regarding the evolution of the forest area for the years 2005 and 2015 (which corresponds to the most recent data provided by the IFN6), there is a stabilization since the differences verified in the total area for each NUTS II region are not significant. In the northern region an increase of 185 km^2 is verified; in the central region, there is an increase of 114 km^2; in the Metropolitan Area of Lisbon, there is a decrease of 7 km^2; in Alentejo, there is a decrease of 198 km^2; and in Algarve, there is an increase of 29 km^2.

All these factors contributed to the abandonment of large areas of land, which is covered mostly by shrubs and herbaceous vegetation, which are favorable to fire occurrence. In 2015, Portugal had 3305 Mha of forest land, 2241 Mha of agriculture land, and 2818 Mha of shrubs and pastureland. Water, urban area, and unproductive land account for the remaining 859 Mha. The 35.8% of forest area places Portugal within the average of the 28 EU countries (38.3%). According to the IFN6, the national forest is mostly constituted by indigenous forest species (72%). In structural, functional, and landscape terms, the forest can be organized into four major groups: pine and other softwood forests; evergreen hardwood forests; deciduous hardwood forests; industrial productive hardwood forests; and other species (Casau et al., 2021).

4.2. The European Context

As stated previously, the wildfire occurrence in the Mediterranean region is a well-known problem. A comparative analysis of the most affected southern countries of this region (Spain, France, Greece, Italy, and Portugal) should be considered. As presented in *Table 3*, Portugal is the smallest of this group. It is therefore surprising that the burnt area is so significant (*Figure 6*).

Table 3 - Comparative Southern European countries area (adapted from http://www.pordata.pt, accessed on 14 December 2021).

Country	Spain	France	Greece	Italy	Portugal
Area (km^2)	505,983	638,475	131,694	302,073	92,227

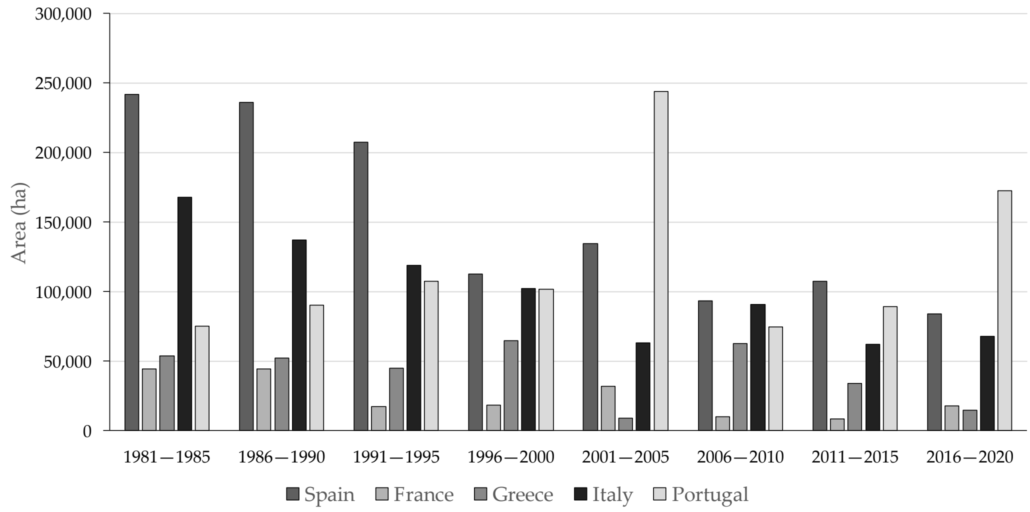


Figure 6 - Average burnt area (hectares) per five-year period in five southern European countries (adapted from http://www.pordata.pt, accessed on 14 December 2021).

It is possible to observe a decreasing trend in the average burnt area from 1981 until 2020 in Spain, France, Greece, and Italy. On the contrary, in Portugal, an almost continuous increase in the average burnt area within each subsequent five-year period can be observed, mainly caused in 2001–2005 and 2016 to 2020.

4.3. The Portuguese Context

Although the statistics show that the average burnt area in Europe decreased in the last 35 years, Portugal presents the opposite trend, being the European country more affected by rural fires, with countless ecological, social, and economic losses (Magalhães et al., 2021). The problem related to wildfires in Portugal has evolved very rapidly over the last decades. According to Félix & Lourenço (2019), until the 1970s, large forest fires were considered to be all those whose burned area was equal to or greater than 10 hectares, while nowadays, to be considered large, a forest fire must have 50 times more burned area. Over time, the Portuguese population has become used to the occurrence of wildfires, while at the same time, the public policies seem to have no real effect on reducing the problem. The yearly burnt area shows a high annual variability, reaching maximum levels in the years 2003, 2005, and 2017, when the total burned area reached 471,750 ha, 346,718 ha, and 539,921 ha, respectively. Between 1980 and 2020, there was an average of 19,202 forest fires per year, corresponding to 117,433 hectares of burnt area per year, but looking to the last decade (2011–2020), this average increases up to 130,706 ha.

Considering the type of land cover burnt, from 2011 to 2020, an average of 63,809 ha (49%) corresponded to forest stands, 58,004 ha (44%) corresponded to bushes and natural pastures, while 8893 ha (7%) corresponded to agricultural land. Maritime pine and eucalyptus are the species which have suffered most severely, corresponding to 83% of the area of forest burnt in the aforementioned period. This situation has been contributing, in mainland Portugal, to a sharp reduction in the area of maritime pine (273,700 ha less between 1995 and 2015) and to an increase in the area of bushes (226,600 ha), according to data of the IFN6 (6th National Forest Inventory, released in 2019). On the other hand, the agriculture area lost 314,400 ha within the same period and according to the same inventory.

Another important aspect to consider is the distribution of fires within the different regions of Portugal. *Figure 7* presents the distribution of burnt area according to the NUTS II subdivision in mainland Portugal. On average, between 2001 and 2020, the north and center regions of Portugal were responsible for 43% and 39% of the total burnt area in mainland Portugal, respectively. Although the north and center regions account for 81% of the fires in mainland Portugal, these subregions occupy only 55% of the territory.

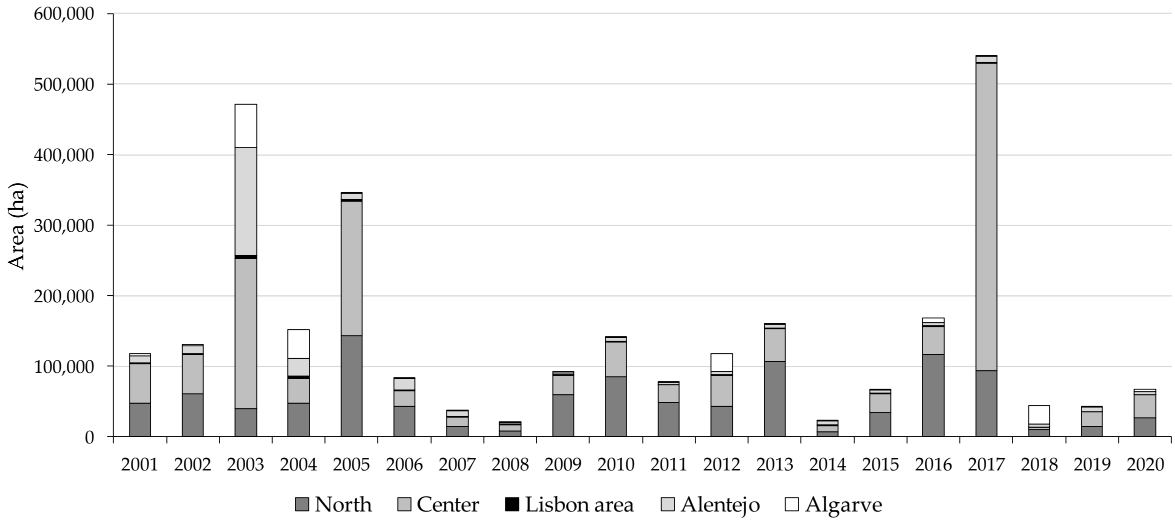


Figure 7 - Distribution of burnt area according to the NUTS II subdivision in mainland Portugal (adapted from http://www.ine.pt, accessed on 14 December 2021).

4.4. Causes of Rural Fires

ICNF lists the causes of rural fires in five categories: intentional (incendiarism and arson, mainly resulting from behaviors and attitudes reacting to the constraints of agroforestry management systems and conflicts related to land use), neglectful (the misguided use of fire in activities such as burning trash, mass burning of agricultural and forest fuels, fun and leisure activities; failure to extinguish cigarettes by smokers properly; the dispersal and transport of incandescent particles from chimneys, among others); unknown (absence of sufficient objective evidence to determine the cause of the ignition); natural (lightning generated in thunderstorms); and reactivations (burning of an area over which a fire has previously passed, but where fuel has been left that is later ignited by latent heat, sparks, or embers). As shown in *Figure 8*, the causes of rural fires in Portugal are mainly anthropogenic.

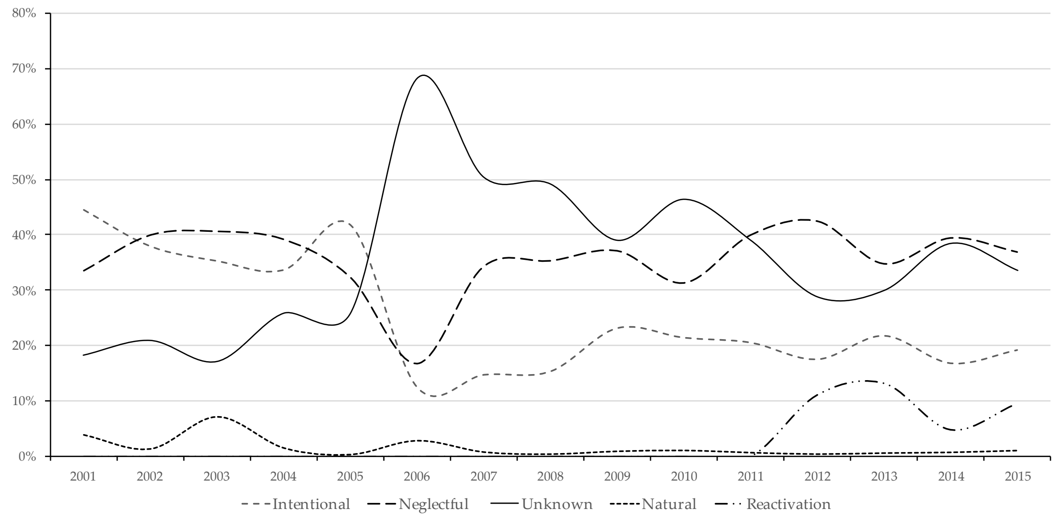


Figure 8 - Causes of rural fires in Portugal between 2001 and 2015 (adapted from http://www.icnf.pt/, accessed on 12 January 2022).

Efforts have been made to identify the causes of fires within the last years. However, only a small proportion of fires were investigated to identify their causes prior to 2007. From 2016 and onward, the ICNF has ceased to provide such detailed information in the form of Excel spreadsheets, but the data on each fire are available through their GIS platform (https://geocatalogo.icnf.pt/websig/, accessed on 12 January 2022), but there is not information regarding the specific causes for each fire. However, the global percentages can be seen in the Annual Rural Fires Report (http://www2.icnf.pt/portal/florestas/dfci/relat/rel-if, accessed on 12 January 2022). Within the accidental causes, "*transports and communication*" and "*machinery use*" are included, while the category "*fire use*" includes "*extensive fires for pasture management*", "*extensive fires of agroforestry wastes*", "*burning of piles of agroforestry wastes*", "*garbage burns*", and "*making bonfires*". On average, from 2011 until 2020, within the successfully investigated causes, the use of fire was responsible for 40.1%. The use of fire to dispose agroforestry waste represents 27% of the ignitions occurred in the same period.

4.5. Biomass

There are many biomass energy sources, with wood and wood waste being the most important. The National Forestry Inventory (IFN), in addition to evaluating the areas occupied by the forest and its species, also presents statistics on biomass production, which are fundamental for planning and regulating the exploitation of this resource. According to the IFN6, in 2015, Portugal had 172 Mm^3 of wood growing, an identical result to what was found in the IFN5 (2005), showing a balance, with woodcuts and losses due to fires or pests being compensated by the growth of the forest. However, the IFN6 characterizes the state of the forest in 2015, which is different from its current situation in 2022, especially considering the consequence of the severe rural fires of 2017 and 2018. *Table 4* displays the total volume (including growing and dead biomass) by species in mainland Portugal and the central region.

Table 4 - Total existing volume by species, in mainland Portugal, in 2015 (adapted from http://www.icnf.pt, accessed on 18 December 2021).

Species	Total Volume (Mm^3)	
	Mainland Portugal	**Portugal Central Region**
Maritime pine	68.06	43.99
Eucalyptus	43.78	24.39
Cork oak	25.76	2.14
Holm oak	7.08	0.4
Oaks	5.78	1.94
Stone pine	5.25	0.87
Chestnut	3.22	0.56
Carob tree	0.2	-
Acacias	2.07	1.07
Other hardwoods	9.08	4.03
Other softwoods	5.39	2.06

The analysis of the data regarding the estimation of agroforestry biomass is very important, since the on-site burning of these wastes is one of the main causes of fires in Portugal. This means that there is a real potential for fire risk reduction if solutions for collecting, distributing, and valorizing residual agroforestry biomass are implemented. In this way, the solution presented by the project BioAgroFloRes can contribute to reduce the risk of rural fire occurrence.

The residual biomass production potential of a given region is directly related to the biomass types available and the areas occupied by these biomass sources. In this way, it is possible to estimate the amount of residual biomass generated by a type of source, provided that the coefficients of production/generation of residual biomass for each specific type are known. It is also expected that these coefficients may present a perfect fit for a given region, but they present a poor fit for another. However, for a larger-scale assessment, for example, at the national territory level or even at the level of large regions (NUTS II), the results obtained can give a valid estimate of the potential for generating residual biomass. Recently, the Planning, Policies and General Administration Office (GPP), in partnership with the National Institute for Agricultural and Veterinary Research IP (INIAV), presented the “Strategic Lines of the Primary Production Sectors in the Context of the Development of the National Strategy for the Sustainable Bioeconomy 2030”, wherein a series of volumes dedicated to different sub-themes, they present a characterization of the primary sector in Portugal, in a bioeconomy context. In addition to the more general aspects, the framework of public policies for the sector is presented through the systematization of the available information regarding the primary production of biological resources and assets, which includes the potential for the generation of residual woody biomass.

Through the data presented by the GPP in the previous work, it is possible to quantify the residual woody biomass existing in Portugal, which is summarized in *Table 5*.

Table 5 - Residual woody biomass available in mainland Portugal (t·yr-1).

NUTS II	Pruning Residues	Forest Residual Biomass	Total
Northern region	963,472	751,695	1,715,167
Central region	590,661	960,708	1,551,369
Lisbon and Tagus Valley region	660,477	55,310	715,787
Alentejo region	715,505	555,790	1,271,295
Algarve region	58,996	210,817	269,813
Mainland Portugal	**3,007,071**	**2,543,320**	**5,541,391**

As mentioned, not all biomass sources contribute in the same way and do not present the same potential. The study presented by the GPP includes in the category "Left Pruning" the materials resulting from the pruning of fresh fruit orchards, citrus, subtropical fruits, almond trees, chestnut trees, walnut trees, carob trees, other nuts, olive groves and vineyards. However, some of these sources occur exclusively in certain regions, as is the case of the carob tree, and others are closely associated with strips of territory due to the climate, as is the case of the almond tree or citrus.

Table 6 presents the quantification results of residual biomass for the six categories defined as being the most relevant for the Central region of mainland Portugal, namely, orchards, olive groves, vineyards, maritime pine, eucalyptus, and bushes.

Table 6 - Quantification of residual biomass originating from leftovers from pruning, forestry operation and management and woody scrubland in the Central region of mainland Portugal (t·yr-1).

Biomass sources	Area (%)	Relative area (%)	Quantity ($t \cdot yr^{-1}$)
Orchards	37,021	1.3	35,540
Olive groves	104,491	3.7	177,635
Vineyards	50,143	1.8	175,501
Maritime pine	620,195	22.2	331,474
Eucalyptus	482,542	17.2	216,733
Scrubland	374,537	13.4	342,613
Total	**2,800,127**	**59.6**	**1,279,495**

As can be seen from the results obtained, the area occupied by sources potentially generating residual biomass corresponds to 59.6% of the territory of the Central region of mainland Portugal. However, the total residual woody biomass estimated for the region, 1,279,495 t·yr^{-1}, corresponds to 82.5% of the total residual woody biomass estimated for the region.

4.6. Stakeholders' analysis and market research

4.6.1. Stakeholders survey

Section 1 – Demographic data

In the stakeholders' survey, a total of 113 responses were obtained from all regions (NUTS II) of mainland Portugal, distributed as shown in *Table 7*. As expected, and wanted, most of the respondents live in the center region of Portugal (66.4%), and predominantly from rural areas (54%).

Table 7 - Demographic characteristics of the stakeholder's survey respondents.

Survey question		Percent of respondents
Gender		
	Male	54.9%
	Female	45.1%
Age		
	18-30	0.0%
	31-40	34.5%
	18-30	31.0%
	41-50	15.9%
	51-60	8.8%
	61+	9.7%
Area of residence		
	North	18.6%
	Center	66.4%
	Lisbon Metropolitan area	13.3%
	Alentejo	0.9%
	Algarve	0.9%
The area of residence is predominantly		
	Rural	54.0%
	Urban	46.0%
Education		
	Less than basic school degree	4.4%
	Basic school degree	0.0%
	High school degree	9.7%
	College or advanced degree	85.8%

Regarding gender distribution it is relatively well balanced, with a share of 54.9% for male respondents and 45.1% for female respondents. In what concerns the education level, the vast majority (85.8%) of the respondents had a college or advanced degree (bachelor, master or PhD), with only 4.4% not having finished the basic school (9th grade), and 9.7% having finished high school.

Section 2 – Environmental problems

Attitudes about environmental problems indicated that most people in the sample think that climate change is happening and is being caused by the increase in GHG emissions. At the same time, the majority of the respondents disagree that they cannot do anything individually to mitigate climate change. It is also almost consensual that environmental disasters are increasing because of climate change, and rural fires are a disaster that worries a lot almost all of the respondents. Although, regarding the causes of rural fires, the perception of the respondents is not so much consensual, with answers that are more disperse in the Likert scale, when some possible causes are named – climate change, malpractice (i.e. agroforestry wastes burnt), rural exodus. Another interesting finding is that we also have more dispersed answers regarding the statement: "I think I cannot do anything to avoid forest fires", when compared to the equivalent sentence for climate change.

Despite the fact that forest fires are a problem that worries to a great extent the respondents, approximately 46% answered that they strongly disagree or disagree with the possibility of paying 3€ more in the electricity bill if that money would be used to reinforce the prevention of forest fires. Regarding the three statements that were related to agroforestry biomass wastes, most of the respondents agrees that the recovery of these residues would help decrease the forest fires occurrence, and that this would be good for the local economy. This shows an interest, at least at environmental level, in the RAFB market. The results to this section, in terms of the mean in the Likert scale are shown in *Table 8*.

Table 8 - Survey responses to environmental questions (section 2).

Survey statement	Mean on the Likert scale*
Climate change is not going to happen	1.65
The so-called ecological crisis facing humans has been greatly exaggerated	2.02
Rapid increases in greenhouse gases are causing climate change	4.19
I cannot do anything individually to mitigate climate change.	1.76
Environmental disasters are increasing due to climate change.	4.20
Forest fires are a problem that worries me greatly.	4.53
The increase in the number of forest fires in Portugal is due to climate change.	3.07
The increase in the number of forest fires in Portugal is due to bad practices, namely the burning of agroforestry residues.	3.55
The forest fires are closely linked to the rural exodus.	3.70
Among the known causes of forest fires in Portugal, the burning of agroforestry residues is the most important.	2.82
I don't think I can do anything to prevent forest fires.	2.11
I would be willing to pay a monthly fee of €3 added to the electricity bill if that money was intended to reinforce forest fire prevention.	2.77

Agroforestry residues are of no importance in the problem of forest fires.	1.99
The recovery of agroforestry residues would be good for the economy of my area of residence.	3.82
The recovery of agroforestry residues would reduce the occurrence of forest fires.	3.70

*1=strongly disagree; 2=somewhat disagree; 3=neither agree nor disagree; 4=somewhat agree; 5=strongly agree.

The last question of this section determined the following section – 67.3% of the respondents had no role regarding RAFB, and for these the survey ended at this point. Regarding the stakeholders in the RAFB market, we received a total of 26 answers (23%) from producers, 6 answers (5.3%) from collectors/ transporters, and 5 answers (4.4%) from processors, as shown in figure 9.

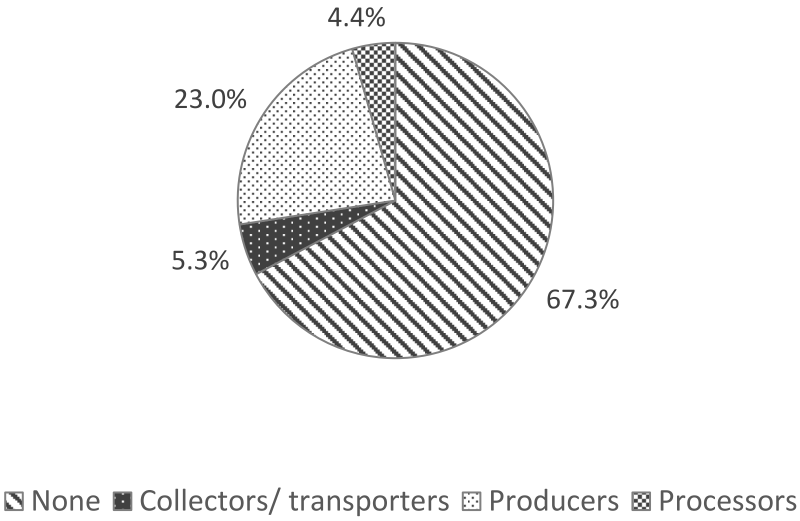


Figure 9 - Role of respondents regarding RAFB.

<u>Section 3.1. – Producers</u>

From the 26 answers obtained from producers, the vast majority (88.5%) is individual owner, with only 2 (7.7%) being entrepreneur and 1 (3.8%) answering as being forest manager. The second question of this section asked about the type of RAFB produced – 57.7% produces pruning firewood, 50% produces branches and tree peckings, and 42,3% produces woody undergrowth. There were 4 producers that answered openly, stating that they had other residues – vegetable residues and manure. It is important to notice that two of the respondents were vegetable producers, and they answered that they have no residues.

Regarding the production area, from the three possible answers, the majority (65,4%) of the producers has a small area (<5 ha), which is in line with the type of land organization in Portugal, characterized by smallholding properties.

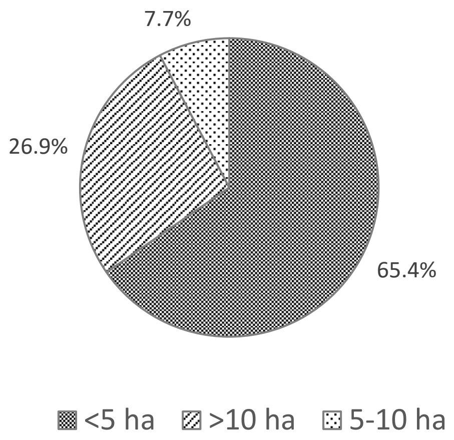


Figure 10 - Production area of the respondents.

The following question asked about the treatment given to RAFB, and the respondents had six possible answers, including an open answer. Twenty-four aswers were obtained in this question. The majority (66,7%) shreds and leaves on the ground, while 45,8% answered that they burn the residues. Only 12,5% says that sell the AFB residues, and 8,3% pays to someone to do the proper treatment. Nobody leaves in a pile for future recovery. From the open aswers, different destinations were pointed out: use in traditional cooking stoves, animal feeding and bedding, recovery by the logger.

Regarding the willingness to pay for the RAFB recovery by producers, results are presented in *Figure 11* (24 aswers).

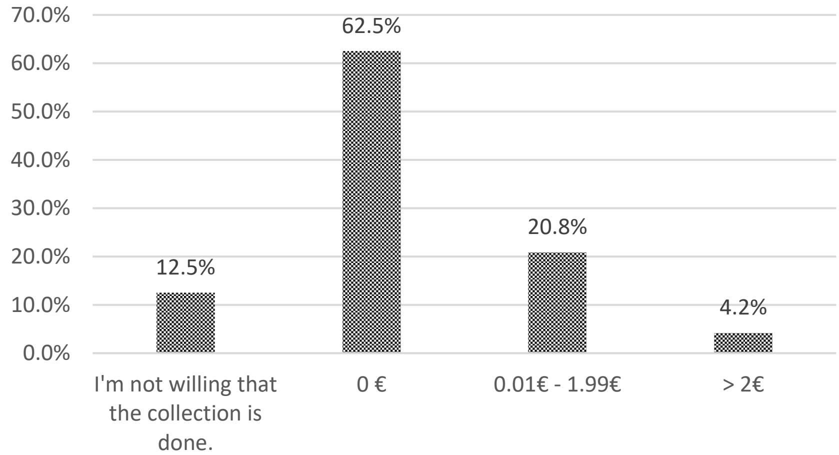


Figure 11 - Willingness to pay for the RAFB recovery by producers.

The following question, asked if the producer would be willing to give away for free the RAFB. From the 24 answers obtained for this question, 45,8% would give away for free their residues, 29,2% might give and 25% would not give away for free at all. Sixteen open answers were obtained regarding the reasons for the aswer to that question, and they are presented as follows:

- Not to burn the surplus.
- It's a lot of work to remove [RAFB], especially horse manure. I already give it to some people who go there to collect.
- It depends on the situation, in the case of the forest, biomass should be more valued since it is also a product to be removed from the forest.
- For safety reasons I prefer to prevent and give the biomass; although, having to pay to shred is expensive.
- To decrease fuel load
- If it doesn't generate income, it's better to stay on the ground
- If I can't use it or shred it, if anyone is interested, I think I should allow them to use it, as long as it doesn't impact the [soil] properties.
- It is necessary to leave the biomass on the ground to be incorporated into the soils. Biomass contains many nutrients.
- Because it is very important to keep it for the soil sustainability.
- Waste should stay in the soil to protect it.
- Depends on the end that it would have.
- Prevent the accumulation of undergrowth weeds.
- It depends on certain criteria: who collects? How is it collected?
- Because I currently have an expense.
- Burning forest biomass can lead to soil impoverishment.
- Reuse.

Regarding the minimum value (in euros) that the respondent would be willing to sell their RAFB, aswers are distributed as shown in *Figure 12*.

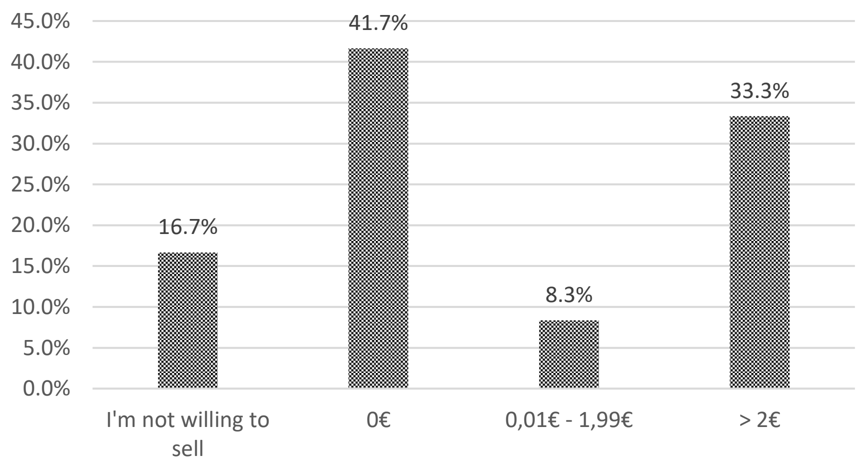


Figure 12 - Minimum value (in euros) that the respondent would be willing to sell their RAFB.

The following question was about the willingness to use a web platform to signal their RAFB for future recovery. The vast majority (75%) answered yes, and 25% said they would not be willing to use such platform.

The two last questions asked about wildfires. One measured the level of agreement from 1 (strongly disagree) to 5 (strongly agree) regarding the following sentence: “I believe that a web platform that allows the collection and subsequent treatment/recovery of agroforestry residues could contribute to minimize the problem of forest fires”. Results are presented in *Figure 13*.

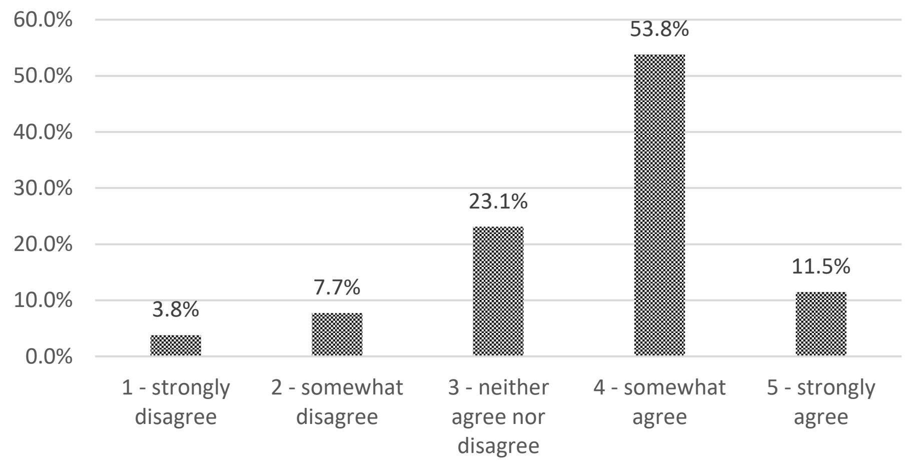


Figure 13 - Level of agreement with the sentence: “I believe that a web platform that allows the collection and subsequent treatment/recovery of agroforestry residues could contribute to minimize the problem of forest fires”.

At last, the answers to the question “What do you think is the average percentage of forest fires that are caused by the burning of agroforestry residues?” are presented in *Figure 14*.

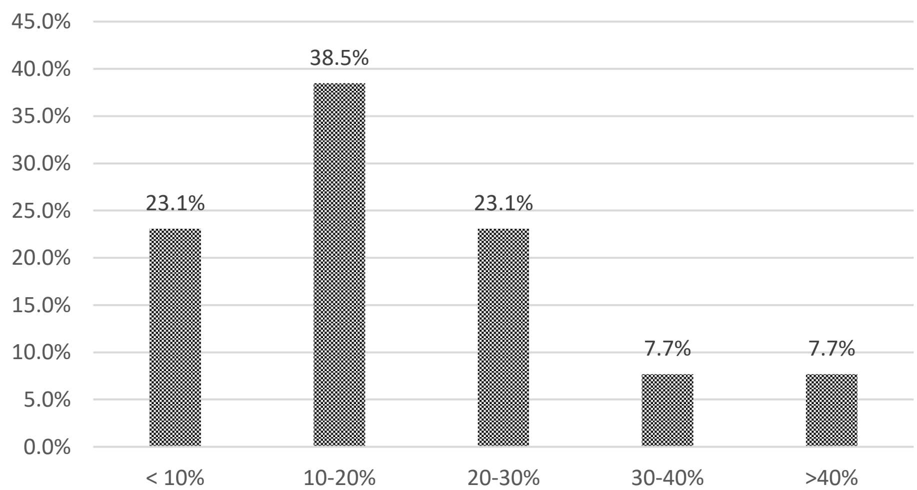


Figure 14 - Answers to the question “What do you think is the average percentage of forest fires that are caused by the burning of agroforestry residues?” .

Section 3.2. – Collectors/ transporters

The section destined to forestry and/or logistics operators was much shorter, with only four questions, and was answered by six persons, all of which were employees in a company in this sector of activity. Regarding the main cost for recovery and transportation of RAFB, from the 3 possible answers that were given, the results are split 50/50 between fuel and maintenance of machinery and vehicles. No one selected “labor” as the main cost.

Regarding the question: “Would you be willing to use a web platform that allows you to collect residual agroforestry biomass?” the answers were also split 50/50 between yes and maybe, as highlighted in *Figure 15*.

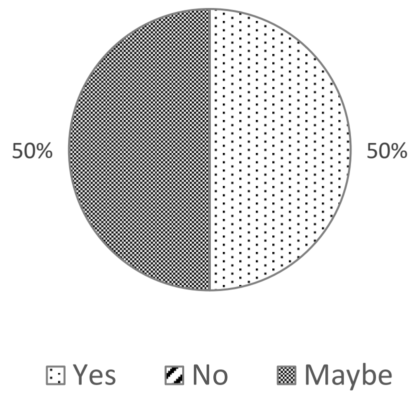


Figure 15 - Answers to the question: “Would you be willing to use a web platform that allows you to collect residual agroforestry biomass?”.

The last question in this section was not mandatory, and it was an open question that asked the reason for the previous answer. The two answers obtained were:

- It would allow a better logistics operation regarding the means allocated to this (these) work(s).
- Yes, it would be easier to collect biomass.

Section 3.3. – Processors

The section destined to processors of biomass had seven questions, and was answered by 5 persons, distributed according to *Figure 16* between entrepreneurs and employees.

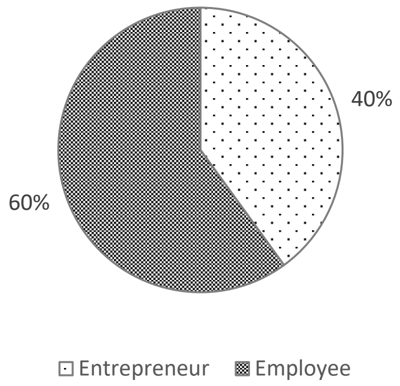


Figure 16 - Percentage of respondents that were owners or employees in a biomass processing company.

Regarding the type of biomass that they processed, 60% (3) process biomass from the forestry sector, 20% (1) from the agricultural sector, and 20% (1) process both types. The following question was about the type of transformation given to RAFB, and the answers are presented in *Figure 17*.

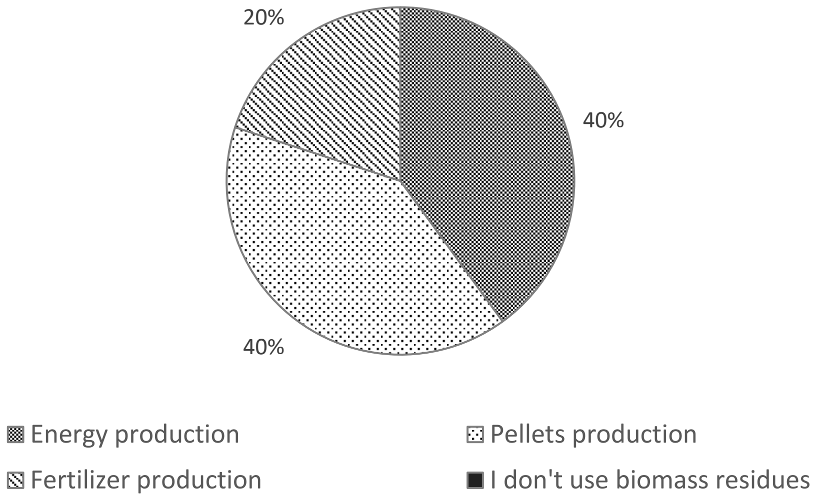


Figure 17 - Types of biomass processed by the respondents.

Regarding the price paid for RAFB, from the four possible answers (0€/ 0,01€ - 1,99€/ >2€/ the producer pays me to collect the wastes), 60% (3) don't pay anything, 20% (1) pays between 0,01€ and 1,99€, and 20% (1) pays more than 2€.

All of the respondents in this section answered that they would use or might consider using a web platform that would allow them to receive RAFB. Nobody selected the answer "no" to this question.

The following question, "What benefits and/or disadvantages do you see in a web platform that allows the signaling, collection and delivery for processing of residual agroforestry biomass?" was open and not mandatory. The two answers obtained were:

- Logistics
- Better efficiency

The last question was: “Given the potential environmental benefits, would you be willing to increase the amount of residual biomass you use as a raw material, keeping everything else the same?”. Here again there were no negative answers, and 60% (3) answered “maybe”, and 40% (2) answered “yes”, as highlighted in *Figure 18*.

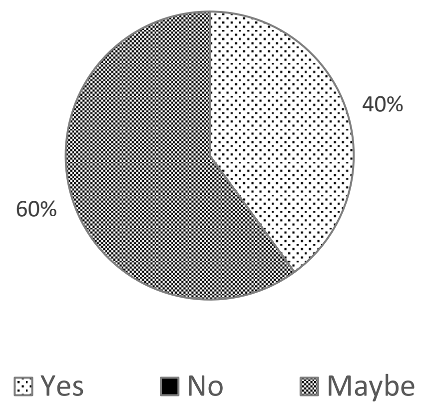


Figure 18 - Answers to the question: “Given the potential environmental benefits, would you be willing to increase the amount of residual biomass you use as a raw material, keeping everything else the same?”.

4.5.2. Municipalities surveys and focus groups

From the event aimed at the municipalities that are AREAC’s associates, which was conducted on the 3rd of May of 2022, we tried to obtain as much information as possible, through the implementation of a specific survey, followed by the discussion in focus groups.

From the 11 persons that attended the event, the municipalities of Cantanhede and Lousã were represented by three people, the municipality of Vila Nova de Poiares was represented by two, and the municipalities of Figueira da Foz, Góis and Pedrógão Grande had one representative each. The results of the survey are presented as follows.

Regarding the problem of rural fires, only one person did not consider this a serious problem in his/her municipality, while all the others (90,9%) answered positively. This question was followed by a set of three sentences, in which was asked to point out the level of agreement from 1 (strongly disagree) to 5 (strongly agree). The results are presented in *figure 19*.

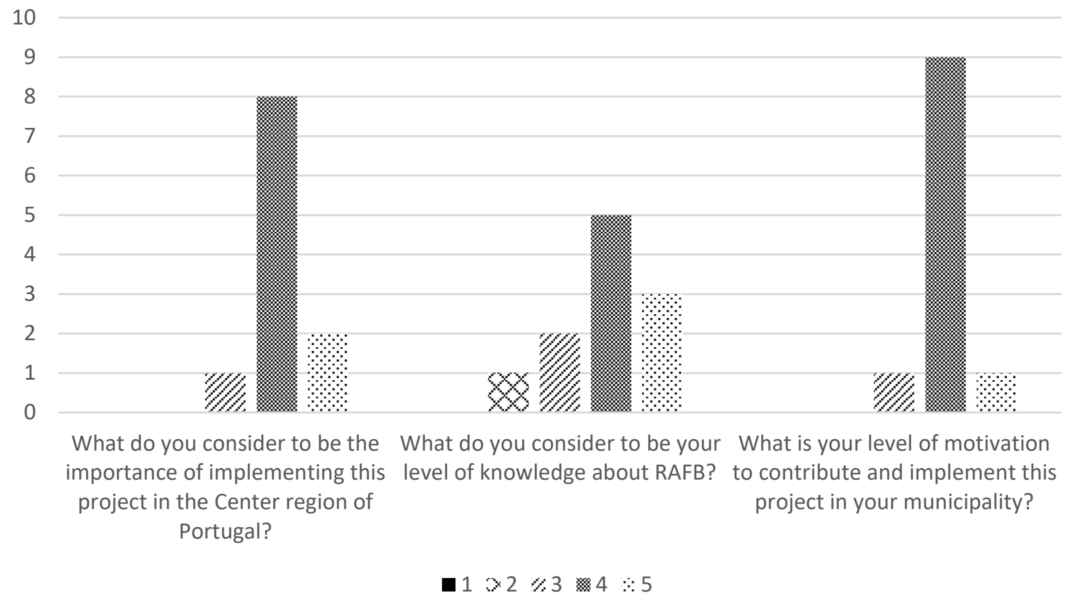


Figure 19 - Level of agreement - from 1 (strongly disagree) to 5 (strongly agree) - regarding three different sentences.

Regarding the most produced agroforestry residues within each municipality, the results obtained were:

- Pruning, green waste
- Vineyard and olive grove
- Branches, bushes, burnt trees
- Forest biomass
- Pine / eucalyptus
- Eucalyptus and various leftovers
- Pruning of olive and fruit trees
- Vines, pruning of fruit trees, forest remnants
- Pruning orchards, olive groves, bushes
- Pruning (mostly olive groves)
- Pruning, land clearing

Two of the respondents did not have knowledge of what happens with these residues, while the other nine answered positively, and they were then asked which was the main destination given to these residues. Answers are presented in *Figure 20*.

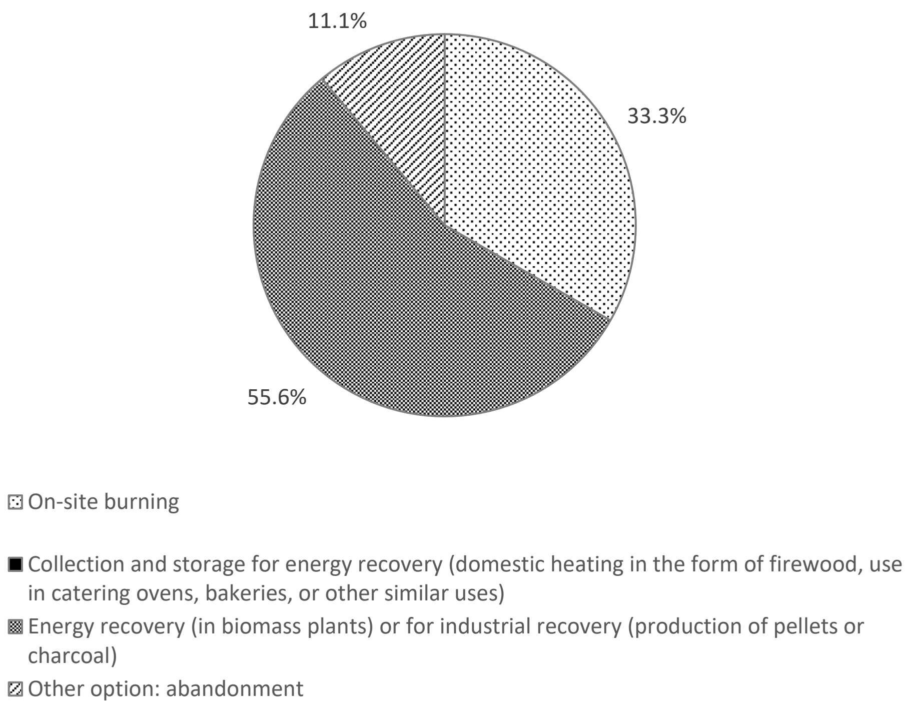
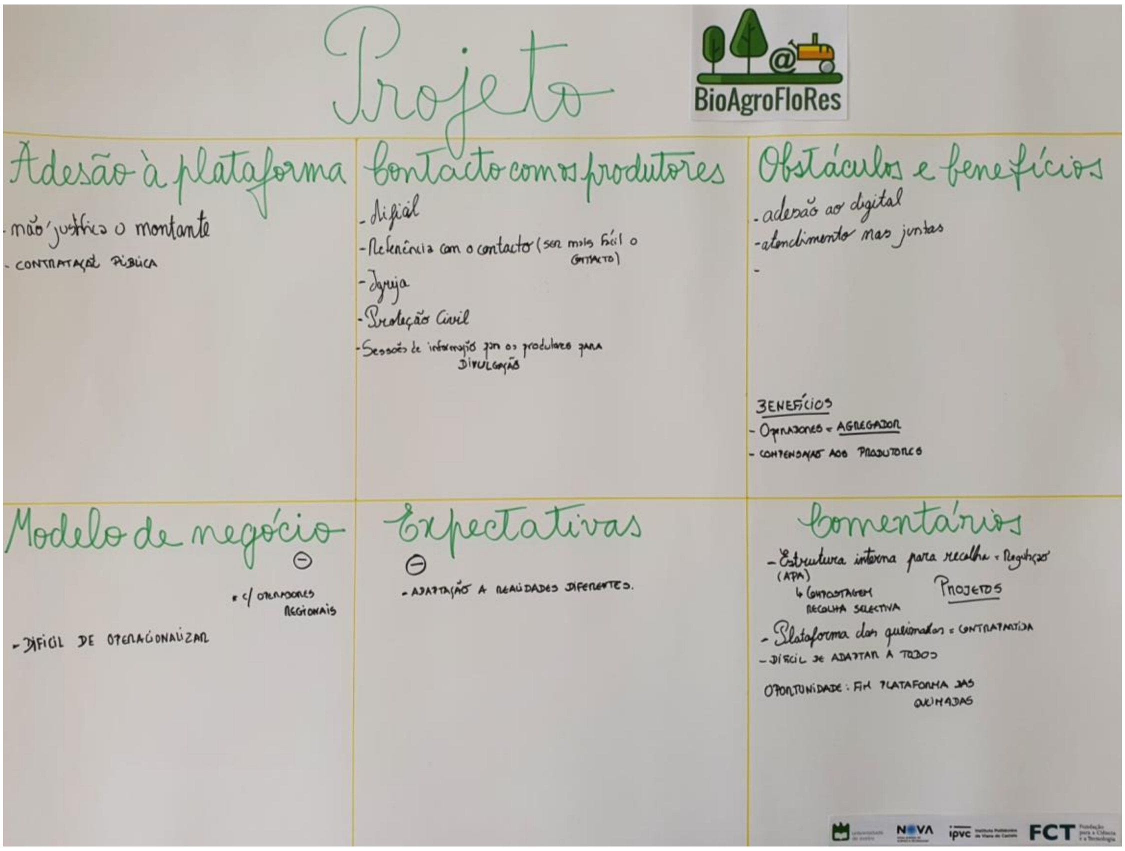


Figure 20 - Destination given to RAFB within the municipalities.

The last question was “How do you think your municipality can contribute to the implementation of this project?”, and the answers obtained were as follows:

- Actively participating and publicizing the initiative.
- In the dissemination and insertion of data on the platform.
- Articulation with APFLOR (Association of Forestry Producers). Awareness.
- Establishing contact with local loggers
- Articulation with partners
- We are available to help spread the word.
- Create a public center to collect forest leftovers
- Project dissemination and promotion
- Advertise the platform to citizens.
- Dissemination
- Dissemination / information

This was a short survey that allowed a personal reflection on the subject, in order to facilitate the discussion within the focus groups. As explained in the methodology section, two groups were formed, one with 5 persons and the other with 6 persons, and each group had a mediator. The pictures of the two posters at the end of the session are presented in F*igure 21*.



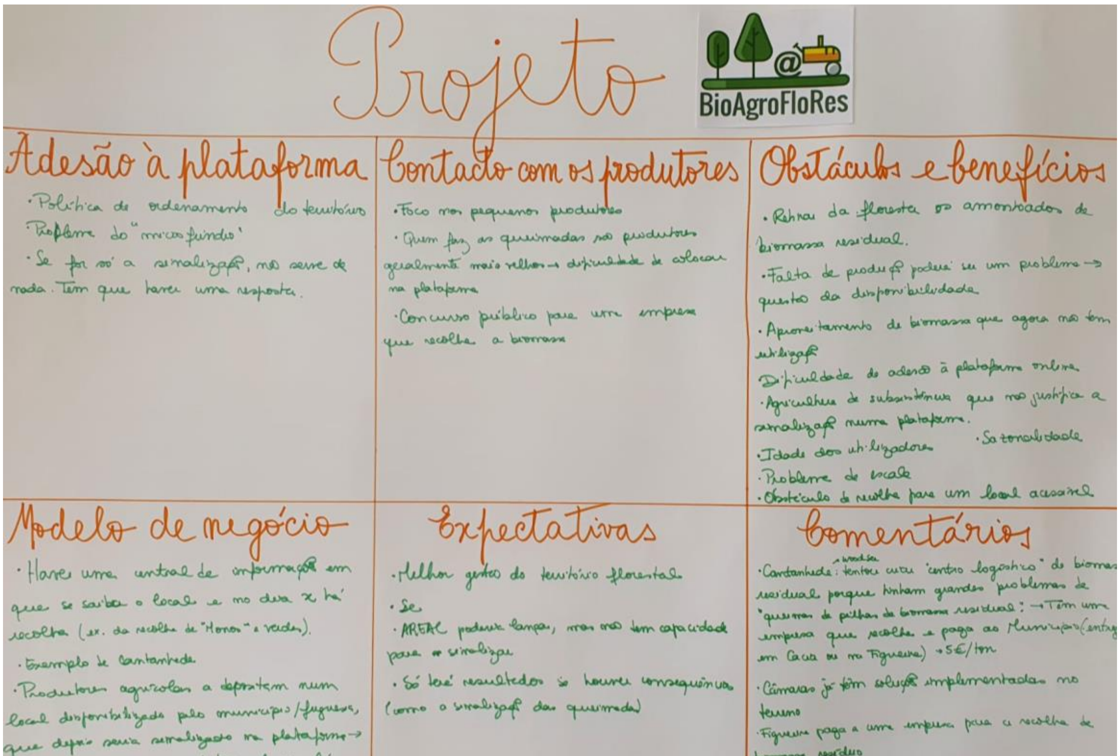


Figure 21 - Posters with the answers/ comments that each focus group gave during the session.

Shortly, the main ideas within each topic of discussion were:

1. JOINING THE PLATFORM

- It was consensual that Portugal suffers from a problem of territorial planning, that is characterized by the minifundium. This makes very difficult the acceptance to join and use the platform.
- If the platform is only to signal de RAFB, it will be useless. If it works from the producer until the final processor, then there will be a chance of success.
- Subsistence farming does not justify the adherence to the platform.
- Public procurement to find companies that can collect and deliver the RAFB.
- All the process will be too costly to be profitable.

2. CONTACT WITH PRODUCERS

- The focus of the platform should be the small producers.
- Usually it is the older people that burns the RAFB, and they will not use a web platform.
- It will be difficult, but it could be done through the civil protection, the local church, dissemination sessions and direct contact with the producers.

3. OBSTACLES AND BENEFITS

- Recovery of the residual biomass piles from the forests it's a big benefit.
- Possible lack of supply.
- Valorize biomass residues that now are just waste.
- Difficulties in getting people to adhere to the platform.
- Age of the producers.
- Seasonality.
- Difficulties in transferring the biomass to an accessible location.
- Scale problem.
- Compensation to farmers.

4. BUSINESS MODEL

- Example of collection of "monos[1]" and green wastes within the municipalities. There is an information center where the location of the RAFB pile is known and on certain day there is the collection.
- Producers deposit in a place provided by the municipality/parish, which would later be signaled on the platform, but there is the difficulty for producers to take them there (it is easier to signal fires!).

[1] "Monos" is the name commonly used to define useless bulky waste. This is the case of old furniture, appliances (fridges, televisions, etc.), mattresses, among others.

- It should include regional operator.
- It will be hard to make operational.

5. EXPECTATIONS

- Better territorial management.
- AREAC could launch the platform but does not have capacity to keep it working.
- The platform will only have results if there are consequences (like the fires signaling).

Other comments that were obtained within the groups:

- Cantanhede municipality had a big problem related to the burning of RAFB piles, and to solve this, in a first phase they created a logistic center for this residual biomass, but this was not working well. They decided to launch a public procurement, and now they have a company that collects these RAFB piles, that are signaled by the municipality. The municipality receives 5€ per ton and the company delivers in the biomass power plants of Cacia or Figueira da Foz.
- The municipalities have already some solutions implemented.
- The municipality of Figueira da Foz pays to a company to make the recovery of biomass residues.
- An opportunity is to replace the fires platform (Plataforma das Queimas e Queimadas - https://fogos.icnf.pt/InfoQueimasQueimadas/QUEIMASQUEIMADAS.aspx.).

4.5.3. One-to-one interviews

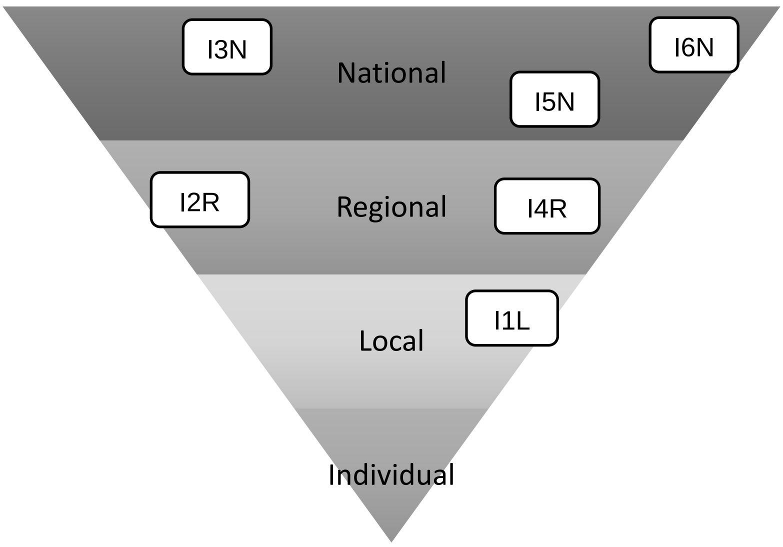


Figure 22 - Visual representation of the level of action of interviewees.

A potential RAFB market involves many actors, with different skills and opinions. The result from the interviews shows that different stakeholders have different roles and responsibilities within the market and the value chain of biomass. Those responsibilities may be divided into four levels of action: the individual, the local, the regional and the national. *Figure 22* represents the level of action of the interviewees. Regarding the individual level, there were no formal interviews, but there was the opportunity to have an informal talk with seven different farmers and landowners.

Individual level

The individual level includes the general population, particularly landowners, that usually live in rural areas. Their role is crucial in the land management, and in this case, in the management of RAFB. They are responsible not only for the reduction of fuel load to mitigate the risk of rural fires, but also to ensure the productivity and income from what is planted. Although, landowners may leave their lands abandoned, without adequate management. This is understandable when we consider the problem of the land fragmentation that exists in Portugal, where each owner has generally small and dispersed land plots. The producers to whom we talked to, referred the high costs of managing and removing the residual biomass. This economic factor contributes to the low level of commitment of the landowners in protecting their assets and generating new incomes, namely though the recovery of RAFB.

Another interesting finding among the landowners is their perception regarding the causes of rural fires. When this problematic arose during the conversations, there was a consensual cause for the high number of wildfires in Portugal: “That is because of arson!”. There is a feeling that all the fires in Portugal are caused by incendiarism, and there is a sense that the justice is not working. Although, when reminded of other causes, like the rural exodus, or the burning of RAFB, they generally agreed that these could also be responsible for the problem.

Local level - I1L

The local level relates to the implementation of policies and operations on a local level. The actors range from local governments to NGOs. Within this level we conducted an interview with the technical coordinator of a local forestry NGO. The most important idea from this interview, and that resumes it the best, is:

“There is no market space [for residual biomass] in the forestry sector.”

According to him, this is because the residual biomass that has already some economic value (branches and pecking) is already collected at the time of cutting by medium and large companies. Regarding the small companies of the forestry sector, when they have no capacity for transportation of this residual biomass, they ask to larger ones.

“The final destination [for this residual biomass that is already recovered] is thermoelectric plants.”

“Regarding bushes I find really hard that the logistics costs compensate the extra income.”

Although, it was mentioned the high thermal capacity of bushes, but also the problem of silica deposits in the boilers. In addition, he highlighted the fact that when the bushes are destroyed and remain on the ground, this allows it to be enriched in nutrients.

“Regarding the possibility of recovery of residual biomass that results from forest clearing operations, this occurs only in very small and limited areas.”

In the view of this technical coordinator, even the RAFB that results from these clearing operations has not the economic potential for being recovered, since the amount is very limited, and the cost of recovery would be very high.

Regarding the local governments, such as municipalities and parishes, no interviews were conducted, since their ideas were already discussed in the focus groups.

Regional level – I2R

Regarding the stakeholders that operate at a regional level we conducted two interviews. The main ideas obtained from the interview with the head of the forestry department within a logistics company are presented as follows.

This logistics company **“receives the forest biomass, crushes it, and sends it to energy recovery plants. However, our main objective was to find a solution to reduce the risk of fire.”**

Their main areas of intervention are the north and central regions of Portugal, and they receive all kinds of biomass wastes, not only from the forestry sector, but also from industries, as well as demolishing and carpentry operations.

“We collect agroforestry biomass up to a maximum distance of 25km. More than that is not worth it.”

In terms of the value that they receive per m3 of residual biomass, “**it depends on several factors but on average it is around 10€·m^3.**” Regarding this, it was explained that they have different schemes, namely:

- They transport to the plant, they do the chipping and deliver to the final destination;
- They transport to the plant and then it’s the biomass power plant that collects the biomass.
- They transport the residual biomass from the production site and deliver it right after.

Their main costumer is a biomass power plant, but it is also the client that pays worst:

“…as it is the only one located within a feasible distance in terms of business, they end up having the monopoly and they are the ones who determine the price they pay.”

Besides this biomass power plant, they also deliver to a compost plant, and in terms of the residual biomass market, they only operate in the north region of Portugal. It was highlighted that the pellets industry has no interest in their product, because they have a mix of different species.

“It is hard to enter in the paper pulp market: they have a monopoly!”

Their main suppliers are loggers, but they also have small producers. In particular, there has been a demand for kiwifruit pruning and vines.

“If it is a quantity [of RAFB] that justifies the collection, we do it, but if not, we receive it for free.”

“I really think there is a market space for residual biomass, but there should be smaller and more dispersed biomass power plants. Now, there are only a few, and they act like a monopoly.”

According to the interviewee, the operations related to RAFB started only in 2020 (the company has already 25 years’ operating), and they only represent around 2% of the business, but it has been growing consistently, and the company is really committed to this circular economy approach.

“In 2021 we collected 7000 tn of residual biomass.”

Regarding the costs and benefits, it was pointed out that:

- “This operation avoids burning in forest areas”;
- “Since it’s going to be burnt anyway, at least there is an economic benefit”;
- “The main cost is the transportation”.

“People [producers] are very impatient! They want an immediate collection [of their RAFB]!”

“A web platform would only make sense for us if there is signaling from the final receptors, because we already have a lot of supply. Sometimes even more than we can manage!”

<u>Regional level – I4R</u>

At the regional level we had another interview, with a commercial within an agricultural cooperative. This interview was shorter than the previous one, and in a conversational style. Since this cooperative only receives vegetables, the amount of residues is not significative. Even though, they have found a solution at a local level.

“**The people around here come to get these residues to give as food for their animals.”**

“We give these [vegetable] wastes for free, except the potatoes that are rejected [for the market]. These have a symbolic cost.”

When asked about the matching between supply and demand, they have found an equilibrium. It is important to notice that this kind of agricultural residues can be recovered within a short period of time, so the solution found works perfectly for the cooperative as for the farmers that are close to their logistic center.

National Level – I3N

Regarding the organizations that operate or have impact at the national level we had the opportunity to interview a project manager from an NGO related to biomass for energy. The following sentence summarizes very well the whole interview:

“There is market space [for RAFB], especially within the center region of Portugal.”

This NGO has worked with several projects related to residual biomass, and they shared with us a project that is currently in development, with Altri, a portuguese company that operates in wood pulp production, cultivation of forests for the timber and paper industry and co-generation of energy, including energy production from renewable resources. Within that project, municipalities around the Mortágua biomass plant, provide a place for the small forestry producers to deliver their residues. When they have enough residual forestry biomass, they produce to the chipping and transport until the biomass plant, for energy valorization.

Regarding the idea of the web platform to match supply and demand of RAFB, despite being a good idea, and despite believing that there is a market space, it was stated that:

“It will be very hard that such a platform will work in practice.”

When asked why, the reasons ranged from the difficulty of acceptance from small producers, until the solutions that are already working, as well as the secrecy of prices.

National level – I5N

A governmental agency related to the Agricultural Ministry was also interviewed through the agricultural and sustainable growth chief of department. This was a very enriching interview in terms of public policies.

The "plan of action for the sustainable bioeconomy" was approached as being extremely connected to biomass with an economic end, and as being the most focused document regarding this area and has the strategies to be implemented in the short term (until 2025).

Another topic was the agricultural policies:

"The PAC [Política Agrícola Comum – Common Agrarian Policy] was launched in 1962 and it is a partnership between the agricultural sector and society, and between Europe and its farmers. The goals are: supporting the farmers and improve the productivity of the agricultural sector, ensuring a stable supply of food at affordable prices."

It was shared a study that this governmental organization developed, regarding the priorities for the bioeconomy, which has estimates of the residual biomass from the agricultural and forestry sectors.

"I consider that there is a potential emerging market [regarding RAFB], through the focus on innovation."

Adding the idea that if the final destination of the RAFB is related to value added products, these will be in a 'higher level' in terms of European incentives, when compared to simple energetic valorization.

"The potential of agricultural biomass is something that needs to consider the balance between advantages and disadvantages. It is not obvious. Even if there is potential for economic recovery, farmers may prefer to continue incorporating the residual biomass in the soils, for the advantages it brings and for being the way they are already used to."

"It is important to create governance that is attentive to these issues."

At last, it was highlighted that it will be very important to invest in a good base of information about the availability of residual biomass and its different uses according to its quality.

National level – I6N

We had the chance to interview one forest technician from one of the biggest players of the forestry sector in Portugal. Within this sector, the opinion regarding the web platform for RAFB was very clear: it will be very hard for the stakeholders within the forestry sector to adhere to such platform.

"A producer doesn't have an idea of how much biomass he produces. Who knows is the logger."

"Creating something without taking into account what already exists will be very difficult."

Within the forestry sector, the loggers have an expectation of how much forest biomass they will need for the year, based on the demand from the companies.

"It is a very dynamic sector."

"The biomass market is very different from other energetic sources."

It was highlighted the secrecy problem – companies will not want to put the price they are willing to pay for residual biomass in a web platform.

"At this moment, everything is working in a very empirical way."

In this way, he sees a possibility for the web platform to work and to be very useful, if it optimizes not only the routes, but also the machinery that should be used in each case, and if it helps the users to know if in the end, they really had a benefit (cost/ benefits analysis).

"Sometimes they [forestry operators] don't even know if they are having profit from their work. They buy the machinery because the neighbor bought it and had a subsidy for it!".

The interviewee also showed his concern regarding the overexploitation of the forestry sector in Portugal:

"I think that the [Portuguese] forest is in danger of being annihilated because everything [forestry biomass] is going for energetic purposes."

When asked about the treatment they currently give to the residual biomass, he answered that it goes to biomass plants and to the pellets industry. Regarding the bushes:

“It is not economically viable. We should forget it! And if the bushes are removed, there are other problems: removing fertility from soils and the ability for the soil to mitigate erosion.”

Although, the interviewee emphasized that a logistics study regarding forest biomass would be useful, with the most important costs being shredding and transportation.

“There exists a market for residual biomass that is still not explored, but it should be removed cautiously!”

Regarding the wildfires problem, in the opinion of the interviewee, it is not the residual biomass that is responsible for it, but the poor land management.

“Forest management is essential to allow firefighters to act within the forest in case there are fires. The removal of biomass contributes to the proliferation of invasive species.”

Finally, in terms of price range for residual forestry biomass, it goes from 16€/tn until 30€/ton, if the residues are already crushed.

5. Discussion

5.1. The BioAgroFloRes web platform

Within Europe, Portugal is the country most affected by rural fires (Marques et al., 2011). This trend has been accentuated in the recent decades and is likely due to the transformation of the Portuguese landscape in the last century (S. Oliveira et al., 2017). Afforestation and rural abandonment transformed the rural landscape that once was multifunctional, integrating agriculture, shrublands, and forests in a complementary way (Vizinho et al., 2021). With this mosaic-like landscape, rural fires had smaller dimensions and were rapidly extinguished (Magalhães et al., 2021). According to Gomes (2006), the land cover has progressively changed to the monoculture of fast-growing species, first (mid-19th century) with *Pinus pinaster* Aiton. and later (since the 1950s of the 20th century) with *Eucalyptus globulus* Labill.

Despite the rural exodus that has been happening since the second half of the 20th century, ancient traditional agricultural practices keep being used, such as the use of fire to prepare the soil for new crops, acting also as a waste elimination procedure, and to promote the growing of grass to be used for cattle feedstock (Kasimis, 2010). This practices, if not correctly managed, can induce forest fires (Bento-Gonçalves et al., 2019). In addition to this, another factor that aggravates the problem of forest fires in Portugal is the inadequate management of forests, such as the lack of bush and forest wastes collection and the lack of economic resources for prevention and firefighting (Villagra & Paula, 2021; Xie & Peng, 2019). Although fire is one natural aspect of Mediterranean forests, the structural, social, and political aspects are more significant, making this a public calamity and ecological disaster in Portugal (Górriz-Mifsud et al., 2019).

In fact, the government's periodic structural reforms have not been able to reverse the rural fire crisis, and its capacity to intervene is very reduced in the absence of a private-sector counterpart. The fact that private ownership of land extends over 94.3% of Portugal makes structural forest reforms very difficult to achieve by the state (Mateus & Fernandes, 2014; Tedim et al., 2016). Fire management policies have strengthened fire control capacities instead of focusing on timber and land conservation and agriculture, energy, and soil regulation (Pereira et al., 2005). Fire prevention measures have been left to second plan, while the focus of the national strategy has been on firefighting capacity, showing striking similarities to the US approach to forest fire prevention over the past century, with similarly ineffective results (M. Flannigan et al., 2009; Joana Parente et al., 2016; Reinhardt et al., 2008). Without addressing fuel loads management, a firefighting-only approach leads to larger conflagrations with exponentially greater economic and societal costs (Tedim et al., 2015).

Over the last decades, different management, control, and financial measures have been implemented, with constant revisions, sometimes with conflicting results, which can be counterproductive (Pinto-Correia & Vos, 2004). The constant regulatory changes, the difficulty to control and apply those rules due to the lack of resources, and the failure to take a consistent direction towards a successful performance has led to what seems like a dead end (Navalho et al., 2017). The constant revisions and the quantity of strategic documents is indicative of this uncertainty in the system (*Table 9*).

Table 9 - Portuguese forest strategies (adapted from Magalhães et al., 2021).

Year	Plan
1996	Forest Policy Bases Law
1999	Portuguese Forest Sustainable Development Plan
2003	Action Plan for the Forest Sector
2003	Forest Sector Structural Reform
2005	Operational Plan of Forest Fires Prevention and Suppression
2006	National Plan of Forest Defense Against Fires (2006–2018)
2006	National Forest Strategy
2020	National Plan for Integrated Fire Management
2020	National Forestry Accounting Plan—Portugal 2021–2025

The national system for forest fire protection was established in 2006 (Decree-Law 124/2006, of 28 June), including the definition of fuel management criteria (Magalhães et al., 2021). Although it is mentioned that the problem of rural fires must be tackled with structural prevention measures, mainly related to the reorganization of the existing landscape, this has not been the case. In addition to the national regulation, there are also forest fire protection plans at the regional, municipal, and local scales, but their framework is complex, without criteria and scale integration and with simultaneous negative consequences in forest governance efficiency. In 2019, the regional forest landscape plans were revised, which was an opportunity to change towards a structural transformation in the land-use planning system, including new targets to fire-resilient landscapes, tree species, and other sustainable land-uses. However, the revised plans still consider a policy target for 2050 with a dominant and high *Pinus pinaster* and *Eucalyptus globus* forest cover area, representing between 60% and 90% of the total forest area (Magalhães et al., 2021).

From the data gathered, it is possible to conclude that there are multiple causes for the forest fires in Portugal, and most of them are structural, which means that there is still a long way to go. First, the Portuguese forest is characterized by the monoculture of highly flammable species—pine and eucalyptus—due to their essential oils, instead of autochthonous species that are fire-resistant such as oaks (*Quercus sp*.), cork oak (*Quercus suber*), and holm oak (*Quercus rotundifolia*). Secondly, the rural exodus that led the rural populations to the cities had multiple effects: the abandonment of land that was previously used for non-intensive agriculture and now is occupied by fire-prone vegetation, the agroforestry residues are no longer used for heating or cooking purposes, and the fire prevention capability formed by village inhabitants disappeared. Another structural and significant issue is the fragmentation of land holdings into small plots, with the state only owning around 3% of the Portuguese forest and 12% of the area with no landowner and, thus, not subject to any management system. Although, there has been a great effort from the government to identify the landowners through the BUPi (Balcão Único do Prédio) platform.

There is also a lack of human and material resources dedicated to managing and coordinating the forests. As previously stated, the policies have been directed towards increasing firefighting capacity instead of prevention, educational programs, and reducing the use of forest fuels. From the known causes of forest fires in Portugal, it becomes obvious that it is crucial to educate people to end risky behaviors such as the burning of agroforestry residues, which accounts for 27% of the fires in Portugal each year. These negligent behaviors are also very seldom penalized, contributing to their continuation. Arson is also common but also infrequently penalized.

The use of agroforestry waste biomass increases rural development and reduces rural fires thanks to clearing forests and not burning these wastes on-site. These wastes are particularly important, especially when a large quantity is available, since it contributes to the circular economy and decarbonization.

The estimates presented point to a high capacity to generate residual woody biomass throughout the territory of mainland Portugal, with emphasis on the Northern and Central regions, although with distinctive characteristics between them, since the Northern region dominates the biomass resulting from the leftovers of pruning. In contrast, the residual biomass resulting from forest management dominates in the Central region. This situation is easily understandable, given the enormous contribution of the vineyard area to this region, where some of the most important wine regions of the country are located, namely, the Vinho Verde region and the Douro region.

Portugal does not yet have logistical support structures functioning as collection and pre-processing centers for subsequent dispatch. For example, places where residual biomass can dry before being destroyed for later shipment to the energy recovery destination, optimizing transport as much as possible. These centers would have as their primary function the correction of the main disadvantages associated with residual biomass, which are its low density, heterogeneity, high humidity, and low heating value.

Despite the existing possibility and the fact that the estimated consumption is practically equivalent to the estimated availability (at least in its lower limit), this scenario would make unfeasible an entire existing network of plants dedicated to biomass, which at this moment already totalizes an installed power of 523.79 MW, as shown in *Table 10*, corresponding to an annual consumption of residual woody biomass of approximately 1,800,000 $t \cdot yr^{-1}$.

Table 10 - Biomass power plants in operation in Portugal (adapted from https://florestas.pt, accessed on 12 April 2022).

Biomass Power Plant	**Location**	**Installed Power (MW)**	**In operation since**
Cogeração Amorim	Aveiro	1	2004
Cogeração de Cacia	Aveiro	35.1	2005
Termoelétrica de Cacia	Aveiro	12.5	2009

Termoelétrica Terras de Sta. Maria	Aveiro	10.75	2008
Central a Biomassa de Vila Nova de Famalicão	Braga	10.8	2018
Central de Biomassa de Corga de Fradelos	Braga	10	2017
Cogeação Celtejo	Castelo Branco	23.69	1992
Termoelétrica Centroliva	Castelo Branco	5.63	1998
Termoelétrica da Palser	Castelo Branco	3.3	2010
Termoelétrica de Belmonte	Castelo Branco	2.53	2010
Termoelétrica de Rodão	Castelo Branco	12.5	2007
Cogeração Celbi	Coimbra	70.96	1987
Cogeração da Figueira da Foz (Lavos)	Coimbra	95	2004
Termoelétrica Celbi	Coimbra	6.26	1987
Biomassa Caima	Santarém	7.04	-
Cogeração Caima	Santarém	8	2001
Termoelétrica de Constância	Santarém	13.23	2009
Cogeração de Setúbal	Setúbal	53.9	2004
Termoelétrica de Setúbal	Setúbal	12.5	2009
Cogeração Europac Energia Viana	Viana do Castelo	103.7	2002
Cogeração SIAF	Viseu	3.8	1996
Mangualde	Viseu	12.6	2019
Termoelétrica de Mortágua	Viseu	9	1999

As can be seen, of the 23 biomass power plants existing in mainland Portugal, only five are not located in the Central region, so it can be inferred that the pressure on the resource is exerted more intensely precisely in this region. However, as shown in *Table 10*, some of the units belong to groups in the pulp and paper industry, so they are energy recovery units that have access to other types of residual biomass, namely black liquor and other residues resulting in from the production of paper pulp. In this way, the estimated biomass consumption may be significantly lower in terms of residual biomass needs.

As stated before, the central region of Portugal is rich in agroforestry waste, and until now, it is usually left on-site or burnt since the costs for collecting them are high. The development and implementation of a web platform that will foster the use of RAFB in the production of energy or as raw material for other industries, such as biomass pellets, charcoal, or fertilizers, through the enhancement of the RAFB supply-chain, linking supply and demand. Small farmers and landowners that nowadays leave the residual biomass on the ground or burn it will be able to find a destination for the RAFB produced, while the logistics operation will be optimized through the platform. This will solve the problem caused by the burning of leftovers, reducing the risk of rural fire occurrence while closing the loop in the biomass waste recovery.

Due to its territorial organization and the type of land cover and use, the central region of mainland Portugal presents a high propensity for the occurrence of rural fires. This has been the most recurrent scenario in recent years, with the region checking year after year, the top places in terms of the number of occurrences and burnt areas. Using a tool like the one being developed in the BioAgroFloRes project comes as an option, in fact, without presenting a significant change in the existing mandatory by law procedure for recording the burning of leftovers and piles. In other words, residual biomass producers must register whenever they intend to dispose of this biomass waste, so this platform gives residual biomass producers the possibility of having an alternative to the usual procedure. The development of a campaign focused on aspects related to the origin of rural fires and the negative impacts caused could constitute a launching pad for creating a collective awareness that leads to a change in habits.

The project BioAgroFloRes intends to develop an operational solution to increase the efficiency and effectiveness of the RAFB supply chain. The logistic costs, the low heating value, and the lack of collaboration among entities can inhibit the RAFB valorization as a natural resource and hold back the disposal of these wastes. In this way, a platform that promotes the information management between all the actors involved in the supply chain, bringing supply and demand needs closer together may be a solution. This platform will enable the contact between all stakeholders and subsequently will present optimized suggestions to the necessary logistics operations in the central region of Portugal (NUTS II). Thus, *Figure 23* presents the operational framework of the web-based platform.

As shown, the operational framework of the web platform aims to promote communication between the stakeholders belonging to the RAFB supply chain, as well as information management on the amounts of residual biomass that may have resulted from agricultural and forestry activities, such as, for example, pruning fruit trees, or the residues of forest clearing operations.

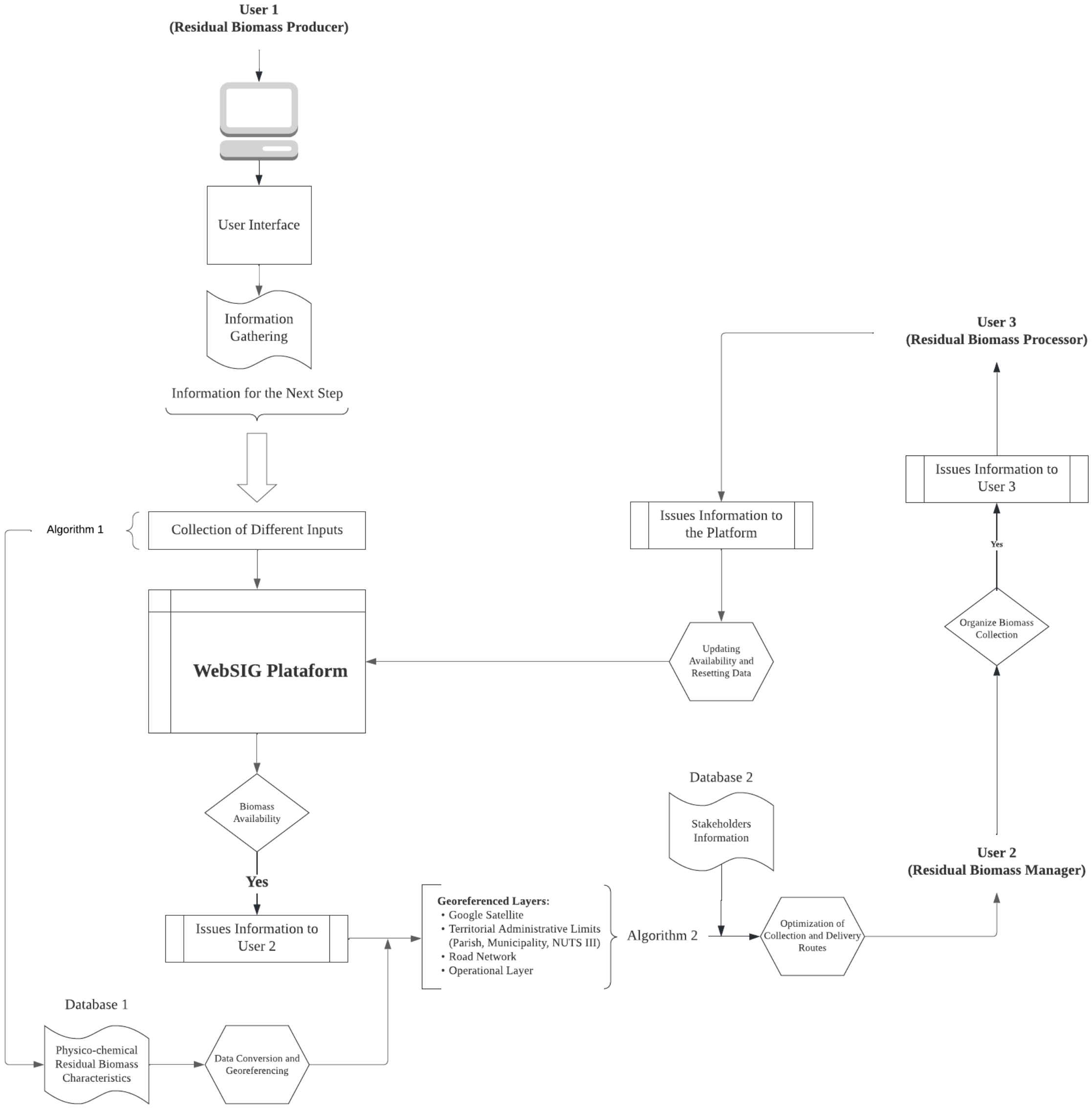


Figure 23 - Operational framework of the residual biomass management platform to support the BioAgroFloRes project.

The BioAgroFloRes platform presupposes the identification of stakeholders with potential intervention in the platform, which are distributed across different levels of interaction, usually known as actors of the system, as shown in *Figure 24*.

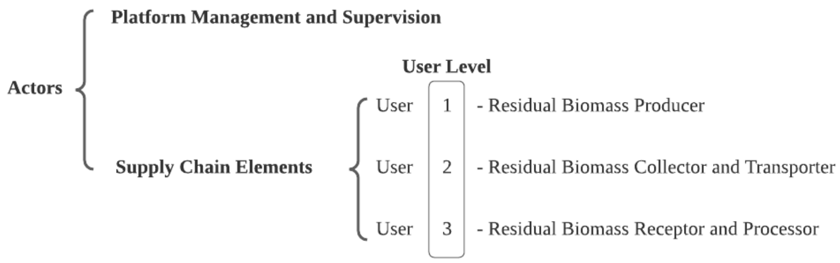


Figure 24 - Definition of actors and different levels of intervention.

In this way, the Administration/Management of the Platform corresponds to the profile (or actor) responsible for managing the platform's content and ensuring and monitoring its operation by assigning access permissions to other actors. This can be defined or selected according to the scale of operation level and the geographic scope of the platform, ranging from the scale of parish, municipality, association of municipalities, and NUTS III or NUTS II regions, for example. On the other hand, the actors related to the supply chain are distributed over three access levels representing three different types of user profiles that perform a set of functionalities according to their role in the biomass supply chain.

Table 11 details some characteristics of the platform actors, representing stakeholders with additional characteristics of users, contributing with data input and/or information visualization. Some high-level functionalities, which these actors can carry out, are also presented.

Table 11 - Types of stakeholders and their functionalities.

Stakeholder Type	Description	Actors	Roles
Platform Administration/Management	Parish, Municipality, Association of Municipalities, NUTS III, NUTS II, …	Administrator	• Validate pre-registrations of the potential producer (User 1); • Validate pre-registration of potential receivers (User 3); • Register producers; • Register receivers; • Introduce auxiliary information to support the management of the platform; • View indicators; • Measuring and disseminating results.
Supply Chain Elements	Residual Biomass Producer	User 1	• Pre-register as a potential producer (User 1); • Record information on the residual biomass produced; • Register availability and conditions for collection.
	Waste Biomass Collector and Transporter	User 2	• View collection points; • View characteristics of the waste material to be collected; • Introduce the characteristics of transport; • Register the check-in of the cargo (status is in transit); • Register the check-out of the cargo (status is captive).
	Residual Biomass Receiver/Processor	User 3	• Validate the check-out status to the carrier; • Validate the check-in as a receiver (status is captive); • Reset the platform.

In this way, the platform can manage the supply chain, presenting notifications to the stakeholders from when residual biomass is produced until the moment it is transported to a point where it is processed/recovered. The platform starts from some assumptions, namely, through the mapping of supply and demand, the characterization of the types of biomass available and their origins, and the analysis of the different possible supply chains. For example, the supply chain can be of a simple linear type, such as Producer → Transporter → Receiver, or it can be of a complex type, presenting intermediate stages/processes of value adding before reaching the destination, such as Producer → Transporter 1 → Receiver 1 → … → Transporter n → Final Receiver.

The characterization of different types of consumption also emerges as an important assumption since different types of biomass can be sent to different destinations and uses. The collection of information by the platform, which is provided by the users (each one with different levels of interaction), and the essential information that supports the functioning of the decision-making support algorithms, are essential aspects of the functioning of the platform since the quality of the information generated and transmitted to the next level of users depends on them. *Figure 25* presents the information flow for the different stages of the process.

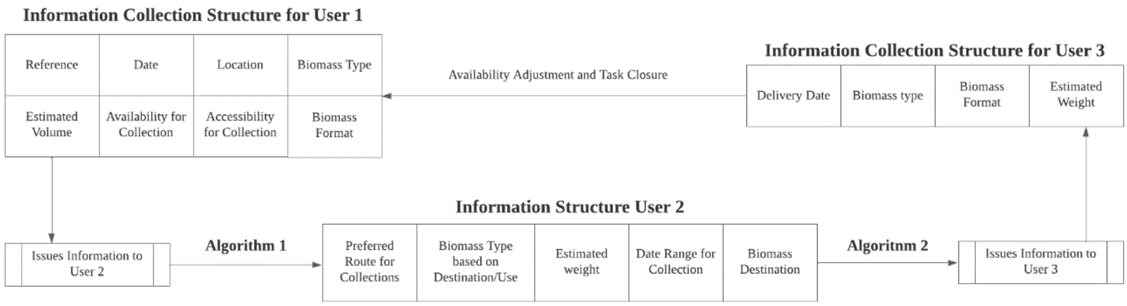


Figure 25 - Information flow and information collection tables in the user-friendly interface.

The type of interaction required between level 1 users (User 1) must occur in a simple and direct way. Similar to what already happens with other platforms, namely, with the platform where these residual biomass producers already carry out the mandatory registration of the burning of leftovers (https://fogos.icnf.pt:8443/queimasqueimadas/QueimaSeguraRapidaadd.asp#, accessed on 27 March 2022). In other words, the objective of the platform proposed by the BioAgroFloRes project is to replace the process of burning the leftover waste materials, by introducing them into the supply chain of biomass derivatives, through the creation of a process similar to the one that already exists today, in a platform of mandatory registration, and in this way contribute to reducing the risk of rural fires. As already seen in section 4.4. – Causes of rural fires, the negligent and accidental use of fire represents a very significant percentage of the known/investigated causes of rural fires.

5.2. Stakeholder analysis and market research

Although stakeholder analysis is an important tool for problem analysis and for considering the interests of all actors, it cannot provide answers to problems or guarantee representation. Therefore, we have used different qualitative methodologies within this work.

Regarding the stakeholders' survey, there was a big difficulty obtaining answers from the specific groups of stakeholders. Despite that online surveys are a commonly used tool in academic research, there was a sample bias, that was highlighted by the fact that 85,8% of the respondents had a university degree. This obviously does not reflect the agroforestry sector, especially regarding the producers, characterized by lower education level, and lower use of the information technologies. This is probably one of the biggest reasons for the difficulty in disseminating this online survey, despite the contact of producers and governmental organizations that were willing to diffuse the survey but stated since the beginning that the response rate would be close to zero. One of these organizations suggested to apply the survey face-to-face, which was done during one day. This allowed for a closer perspective from farmers, and a more unbiased sample.

Within the second section of the survey, related to environmental problems, it is possible to stand out some interesting findings from the results presented on *Table 8*.

- The lowest mean value on the Likert scale was obtained (1.65) was for the first statement: "Climate change is no going to happen", which means that people strongly disagree with this statement, and understand that climate change is a reality.
- On the other hand, the highest mean value obtained (4.53) was for the statement "Forest fires are a problem that worries me greatly", showing that this is a problem that is a problem that greatly concerns all respondents.
- Another interesting finding is related to the willingness to pay for fires prevention: the mean value obtained was 2.77, which is almost in the middle of the Likert scale, showing a division among respondents regarding the statement "I would be willing to pay a monthly fee of €3 added to the electricity bill if that money was intended to reinforce forest fire prevention.".
- Regarding the agroforestry residues, the results shows that people agree that this kind of residues constitutes a problem for forest fires, but it is not very consensual that the recovery of agroforestry residues would reduce the occurrence of forest fires (the mean on the Likert scale that was obtained regarding the sentence: "The recovery of agroforestry residues would reduce the occurrence of forest fires" was 3.70).

Despite the limitations previously pointed out regarding this survey, we managed to have answers from all groups of stakeholders, that can give us some interesting insights regarding RAFB and the web platform proposed in this work.

First, from the producer's perspective, which represent the biggest share of stakeholders, most of them (75%) would or might be willing to give away for free their RAFB, but 16,7% would not be willing to sell for any value their residues. This reflects the fact that the producers value their residues and believe that keeping them on the ground enriches the soil, as stated by several respondents. On the other hand, producers understand the impact of RAFB in wildfires, with 65,3% strongly agreeing or agreeing that a web platform that allows the collection and subsequent treatment/recovery of agroforestry residues could contribute to minimize the problem of forest fires, and 75% of the respondents would be willing to use such platform.

From the collectors/ transporters and processors perspectives, it is a good sign that nobody excluded the possibility of using the web platform, and they pointed out some advantages, namely better efficiency, and better logistic operation. Despite the low number of respondents, it was possible to have at least one representing each category – energy, pellets and fertilizers. This was possible thanks to direct contact with companies.

The results and conclusions obtained in the stakeholder's survey were in line with the opinions from different actors of the system, in the one-to-one interviews. From these interviews, it was mostly consensual that despite the possibility that there is a market space for RAFB, and that these residues can be valorized from an economic point of view, the barriers to the adherence from the stakeholders are so vast, that the chance that the BioAgroFloRes platform will work in a territorial area as vast as the center of Portugal is very reduced. Despite this generalized "negativity" from the interviewees, there were also more constructive points that stood out:

- Within the forestry sector there is already in place a market for the residual biomass, that is dominated by big companies. In this way, there is the possibility to enter through the smaller producers/ companies.
- There are companies that are already doing what the BioAgroFloRes platform aims to do, but at a local level and in a more empirical way. This can work as proof of concept.
- Trying to create something from scratch without considering what is already in place in terms of the RAFB market will doom the project to failure.
- The cost of logistics doesn't allow a range of collection much bigger than 25km. So il will be very important to find delivery points that are close to the picking points, and to optimize the routes. So, the operation at a local level would be possibly the best solution.
- There is a market space for RAFB.
- The platform would need to have in account the problem of price secrecy that exists, especially in the wood sector.
- There would be socio-economic benefits if this platform would work.

Even the more critique interviewees agreed that the idea of a constitution of a market for RAFB through a web platform is good, and it has potential, if solutions for its implementation can be found, and if all the stakeholders involved gain from using it.

Similar findings were those of the focus groups. The municipalities already must deal with the problem of residual biomass. Some have found better solutions than others. For example, the municipality of Figueira da Foz pays for the collection of RAFB, while the municipality of Cantanhede is paid by a company for the residues that are produced within their area. This shows how important is to consider that each municipality or region has its own characteristics, and a solution “fit-it-all” might not be the best. In this sense, working together with the local government will be very important for the platform to work. The biggest difficulty, as in almost all projects, will be the adherence to the platform by all three levels of actors, as presented previously, but the opportunity that constitutes the replacement of the fires platform for this one is huge, and has to be taken advantage of.

6. Conclusions

Until the Industrial Revolution, practically all the energy consumed by Man was from renewable sources. However, industrialization started a process of exploration of non-renewable fossil resources for energy production, which has been growing exponentially in recent decades. Economic development had obvious positive improvements in the living conditions and general well-being of populations, although, the consequent increase in population and standard of living is generating increased pressure on ecosystems and emission of greenhouse gases, that are already causing changes in the climate.

The energy crisis in the 70's, due to excess of demand over supply with consequently increasing prices which, coupled with the possible depletion of fossil fuels, led to a rapid search for alternative energy supplies with emphasis on renewable sources such as biomass. The discoveries of new reserves of fossil fuels allied to conservation policies relieved the problem, and the oil crises disappeared in the late 1980's. Nowadays we are facing a more urgent need for the development of sustainable energy sources, given the increase of greenhouse gases emitted to the atmosphere resulting from anthropogenic activity that are causing climate change.

The great interest of the scientific community concerns research on environmentally sustainable alternatives to respond to the increasing pollution from the society. Renewable energies are taking a central role not only for environmental preservation, but also for economic and social development. In fact, the demand for renewable energy sources has acquired increasing importance in recent years, with the emergence of numerous investments aimed at producing energy from different sources. In this way, biomass was identified as an alternative capable of contributing to the diversification of the energy mix and to the decarbonization of the economy and the energy independence of the countries. In the specific case of Portugal, the use of biomass already has a relevant history.

The interest in biomass and, more particularly in agroforestry waste biomass is growing. Even though biomass is the oldest energy source managed by Men, the technologies related to its valorisation are still developing. We have observed that most studies have been focused on sustainable energy from biomass to replace conventional fossil fuels, since biomass has many advantages, being considered the best alternative. Biomass has the largest potential to meet requirements and insure fuel supplies in the future. Different types of biomasses can be used to produce fuels, chemicals, and energy, such as plants, agricultural and forestry residues, organic components of garbage (municipal solid waste), and algae. This diversity of biomass sources as well as the driving forces of market demand and industrial competition, led to the development of different technologies within the last decades.

The path in agroforestry waste biomass is not yet finished. The developments of the last decades have significantly improved the conversion processes, leading to greener solutions, but there is still much to be studied and to put into practice. Closing the loop into biomass waste recovery will be essential to achieve a truly circular bioeconomy.

The valorization of the existing energy potential in the lignocellulosic biomass of agroforestry residues favors the reduction in the probability of rural fires because of the cleaning of the forests from these residues that constitute a high fuel load that, in hot and dry weather, can fuel rural fires. By removing these forest residues, cleaning forests will benefit forest ecosystems, preserving them as an essential carbon dioxide sink. On the other hand, it instils economic dynamism in inland regions that have suffered from the rural exodus being the most disadvantaged and isolated in Portugal, contributing to the minimization of the depopulation of these territories. The use of tools such as the one being developed in the BioAgroFloRes project presents itself as a contribution to reducing the risk of rural fires by mitigating the well-known causes of these occurrences.

Although, this work had several limitations, particularly in what concerns the stakeholder's survey sample, which was very reduced and biased, since the diffusion of the study was through personal social media. Despite this fact, since different methodologies were applied, the findings were still representative.

With the present work we were able to understand the potential of RAFB in the central region of Portugal as well as the points of view from different groups of stakeholders and how the business model though a web platform could work in practice. Despite the barriers to use of such a platform, namely low level of use of the information technologies by the producers, high logistics costs, monopoly-like markets already established in the biomass sector, secrecy of prices, among others, the potential for a RAFB market exists, and the socio-economic benefits that could result from it, of which the most important is the possibility of fires reduction, compensates the efforts of implementing this project.

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Annexes

Annex 1 – Stakeholders survey

The following survey is the original one, in Portuguese, retrieved directly from GoogleForms.

Modelo Sustentável de Gestão da Biomassa Agroflorestal Residual - Inquérito aos stakeholders

O presente inquérito destina-se à recolha de dados para posterior análise, no âmbito do projeto "Modelo Sustentável de Gestão da Cadeia de Abastecimento da Biomassa Agroflorestal Residual Suportado numa Plataforma Web" (PCIF/GVB/0083/2019)

A informação recolhida será tratada e divulgada de forma agregada e unicamente para fins de investigação científica, respeitando as regras de privacidade dos inquiridos, garantindo a segurança e a confidencialidade das informações recolhidas, em estrito cumprimento com o Regulamento Geral de Proteção de Dados (RGPD).

Para qualquer esclarecimento ou contributo adicionais contacte através do email: amcasau@ua.pt

Desde já, obrigado pela colaboração!

*Obrigatório

Objetivo, destinatários e conceitos-chave

O objetivo deste inquérito é determinar a disponibilidade de os intervenientes fazerem parte de um mercado de biomassa agroflorestal residual, como um meio de avaliar os valores ambientais não comerciais, para mitigar as consequências dos fogos florestais em Portugal.

Este inquérito destina-se à população em geral com maioridade, particularmente a:
- produtores
- operadores florestais/ logísticos
- e transformadores de biomassa agroflorestal residual.

O que é biomassa agroflorestal residual?
É todo o material oriundo da gestão de florestas e campos agrícolas tais como ramos, bicadas, lenhas de poda, matos, material queimado que não apresenta valor comercial bem como resíduos gerados pelas transformações pelas quais a madeira ou os produtos agrícolas passam para serem comercializados.

1. Género *

Marcar apenas uma oval.

- ◯ Feminino
- ◯ Masculino

2. Idade *

Marcar apenas uma oval.

- 18-30
- 31-40
- 41-50
- 51-60
- 61+

3. Região de residência *

Marcar apenas uma oval.

- Norte
- Centro
- Área Metropolitana de Lisboa
- Alentejo
- Algarve
- Região Autónoma dos Açores
- Região Autónoma da Madeira

4. Qual o município onde reside? *

____

5. A sua zona de residência é predominantemente: *

Marcar apenas uma oval.

- Citadina
- Rural

6. Qual o seu nível de escolaridade completo? *

Marcar apenas uma oval.

- Inferior ao 9º ano
- Ensino básico (9º ano)
- Ensino secundário (12º ano)
- Ensino superior (licenciatura, mestrado, doutoramento)

Problemas ambientais

7. Esta secção contém frases relacionadas com problemas ambientais. Selecione o seu grau de concordância relativamente a cada afirmação referida, numa escala de 1 a 5. *

Marcar apenas uma oval por linha.

	1 - Discordo fortemente	2 - Discordo	3 - Indiferente	4 - Concordo	5 - Concordo fortemente
As alterações climáticas não vão acontecer.	⬭	⬭	⬭	⬭	⬭
A crise ecológica que estamos a enfrentar tem sido muito exagerada.	⬭	⬭	⬭	⬭	⬭
Um aumento acentuado nas emissões de gases com efeito de estufa está a provocar alterações climáticas.	⬭	⬭	⬭	⬭	⬭
Não posso fazer nada individualmente para mitigar as alterações climáticas.	⬭	⬭	⬭	⬭	⬭
Os desastres ambientais estão a aumentar devido às alterações climáticas.	⬭	⬭	⬭	⬭	⬭
Os fogos florestais são um problema que me preocupa muito.	⬭	⬭	⬭	⬭	⬭
O aumento dos fogos florestais em Portugal deve-se às alterações climáticas.	⬭	⬭	⬭	⬭	⬭
O aumento dos fogos florestais em Portugal deve-se a más práticas, nomeadamente queima de resíduos agroflorestais.	⬭	⬭	⬭	⬭	⬭

Os fogos florestais estão muito ligados ao êxodo rural.	◯	◯	◯	◯	◯
De entre as causas conhecidas dos fogos florestais em Portugal, a queima de resíduos agroflorestais é a mais importante.	◯	◯	◯	◯	◯
Acho que não posso fazer nada para evitar os fogos florestais.	◯	◯	◯	◯	◯
Estaria disposto a pagar uma taxa mensal de 3€ acrescida na fatura da eletricidade se esse dinheiro se destinasse a reforçar a prevenção dos fogos florestais.	◯	◯	◯	◯	◯
Os resíduos agroflorestais não têm qualquer importância no problema dos fogos florestais.	◯	◯	◯	◯	◯
Reaproveitar os resíduos agroflorestais seria bom para a economia da minha área de residência.	◯	◯	◯	◯	◯
Reaproveitar os resíduos agroflorestais faria diminuir a ocorrência de fogos florestais.	◯	◯	◯	◯	◯

8. Que papel assume relativamente à biomassa agroflorestal residual? *

Marcar apenas uma oval.

- ( ) Produtor *Avançar para a pergunta 9*
- ( ) Operador florestal/ logístico *Avançar para a pergunta 28*
- ( ) Transformador *Avançar para a pergunta 21*
- ( ) Nenhum *Avançar para a secção 6 (Obrigada pela sua participação!)*

Esta secção destina-se aos produtores

9. Enquadra-se em que categoria? *

Marcar apenas uma oval.

- ( ) Proprietário individual
- ( ) Empresário
- ( ) Outra: ____________________

10. Que tipo de biomassa agroflorestal residual produz? *

Marcar tudo o que for aplicável.

- [ ] Lenhas de poda
- [ ] Ramos e bicadas
- [ ] Matos

Outra: [ ] ____________________

11. Das biomassas referidas anteriormente, quais as que costuma aproveitar? *

____

12. Qual a sua área de produção aproximadamente? *

Marcar apenas uma oval.

- ( ) <5 ha
- ( ) 5-10 ha
- ( ) >10 ha

13. Qual o tratamento que dá atualmente à biomassa agroflorestal residual que produz? *

Marcar tudo o que for aplicável.

- [ ] Queimo
- [ ] Destroço e espalho pelo terreno para servir de fertilizante
- [ ] Deixo numa pilha para recolha por terceiros
- [ ] Pago para fazerem o devido tratamento
- [ ] Vendo

Outra: [ ] ____________________

14. Até quanto estaria disposto a pagar pela recolha de biomassa agroflorestal residual (por m3)? *

Marcar apenas uma oval.

- ( ) 0€
- ( ) 0,01€ - 1,99€
- ( ) > 2€

15. Estaria disposto a ceder gratuitamente a biomassa agroflorestal residual? *

Marcar apenas uma oval.

- Sim
- Não
- Talvez

16. Porquê?

____

17. Qual o mínimo (em euros) por m3 de biomassa agroflorestal residual, pelo qual estaria disposto(a) a vender? *

Marcar apenas uma oval.

- 0€
- 0,01€ - 1,99€
- > 2€

18. Estaria disposto(a) a utilizar uma plataforma online para sinalizar e disponibilizar a sua biomassa agroflorestal residual? *

Marcar apenas uma oval.

- Sim
- Não

19. Qual o seu nível de concordância relativamente à frase: considero que uma plataforma que permita a recolha e subsequente tratamento/ valorização de resíduos agroflorestais poderia contribuir para minimizar o problema dos fogos florestais. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo fortemente	◯	◯	◯	◯	◯	Concordo fortemente

20. Qual acha que é a percentagem média de fogos florestais que é causada por queima de resíduos agroflorestais? *

Marcar apenas uma oval.

◯ < 10%
◯ 10-20%
◯ 20-30%
◯ 30-40%
◯ >40%

Avançar para a secção 6 (Obrigada pela sua participação!)

Esta secção destina-se aos transformadores

21. Enquadra-se em que categoria? *

Marcar apenas uma oval.

◯ Empresário
◯ Colaborador numa empresa ligada à transformação de biomassa

22. Que tipo de biomassa é que transforma? *

Marcar apenas uma oval.

- Florestal
- Agrícola
- Outra: ____________________

23. Qual o tipo de transformação que dá à biomassa agroflorestal residual? *

Marcar apenas uma oval.

- Produção de energia
- Produção de pellets
- Produção de fertilizantes
- Não utilizo resíduos, apenas rolaria
- Outra: ____________________

24. Qual o preço médio que paga por m3 de biomassa agroflorestal residual? *

Marcar apenas uma oval.

- 0€
- 0,01€ - 1,99€
- > 2€
- O produtor paga-me para eu recolher os resíduos

25. Estaria disposto a utilizar uma plataforma web que lhe permita receber biomassa agroflorestal residual? *

Marcar apenas uma oval.

- Sim
- Não
- Talvez

26. Que benefícios e/ ou desvantagens vê numa plataforma web que permita a sinalização, recolha e entrega para transformação da biomassa agroflorestal residual?

27. Tendo em conta os potenciais benefícios ambientais, estaria disposto a aumentar a quantidade de biomassa residual que utiliza como matéria-prima, mantendo tudo o resto constante? *

Marcar apenas uma oval.

- Sim
- Não
- Talvez

Avançar para a secção 6 (Obrigada pela sua participação!)

Esta secção destina-se aos operadores florestais/logísticos

28. Enquadra-se em que categoria? *

Marcar apenas uma oval.

- ◯ Empresário
- ◯ Colaborador numa empresa de gestão florestal e/ou logística

29. Qual considera ser o maior custo na recolha e transporte de biomassa agroflorestal residual? *

Marcar apenas uma oval.

- ◯ Mão-de-obra
- ◯ Manutenção de maquinaria e veículos
- ◯ Combustível
- ◯ Outra: ____________________

30. Estaria disposto a utilizar uma plataforma web que lhe permita recolher biomassa agroflorestal residual? *

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não
- ◯ Talvez

31. Porquê?

____

Obrigada pela sua participação!

Annex 2- Municipalities survey

The following survey is the original one, in Portuguese.

Modelo Sustentável de Gestão da Cadeia de Abastecimento da Biomassa Agroflorestal Residual Suportado numa Plataforma Web

O presente inquérito destina-se à recolha de dados para posterior análise, no âmbito do projeto PCIF/GVB/0083/2019 - Modelo Sustentável de Gestão da Cadeia de Abastecimento da Biomassa Agroflorestal Residual Suportado numa Plataforma Web. O objetivo principal é o de recolher informação acerca das preocupações e expectativas dos *stakeholders*, assim como recolher ideias práticas que possam vir a ser úteis na implementação do projeto.

A informação recolhida será tratada e divulgada de forma agregada e unicamente para fins de investigação científica, respeitando as regras de privacidade dos inquiridos, garantindo a segurança e a confidencialidade das informações recolhidas, em estrito cumprimento com o Regulamento Geral de Proteção de Dados (RGPD).

Desde já, obrigado pela colaboração!

1. Qual o seu concelho de residência?

____

2. Qual o seu cargo no município onde exerce funções?

____

3. Considera os fogos rurais um problema sério no seu município?

☐ Sim ☐ Não

4. Numa escala de 1 a 5, onde 1 é nada e 5 é muito:

4.1. Qual considera ser a importância da implementação deste projeto na região Centro?

____

4.2. Qual considera ser o seu nível de conhecimento acerca da biomassa residual agroflorestal?

____

4.3. Qual o seu nível de motivação para contribuir e implementar este projeto no seu município?

____

5. No seu município qual o tipo de resíduos agroflorestais mais frequentes?

____
____

6. Tem conhecimento do que acontece aos resíduos de biomassa sobrantes no seu município?

☐ Sim ☐ Não

7. Caso tenha respondido afirmativamente à questão anterior, indique qual o principal destino dado a esses resíduos:

☐ Queima no local

☐ Recolha e armazenamento para valorização energética (aquecimento doméstico sob a forma de lenhas, utilização em fornos de restauração, padarias, ou outras utilizações semelhantes)

☐ Encaminhamento para valorização energética (em centrais de biomassa) ou para valorização industrial (produção de pellets ou carvão vegetal)

☐ Outro. Qual? ____

8. De que modo considera que o seu município poderá contribuir para a implementação deste projeto?

____
____
____
____

Muito obrigado pela sua participação.