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## Article

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# Mixed biomass pelleting potential for Portugal, step forward to circular use of biomass residues

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## Abstract

Densification of the biomass residues as an efficient method to produce a renewable and CO<sub>2</sub> neutral energy resource has been in consideration in recent years. However, according to a recent boost in the European wood pellet demand, the importance of R&D studies for substitution and enhancement of current raw materials for pelleting purposes has been increased. A large amount of annual garden waste and agricultural residues in Portugal causes that so-called Mixed Biomass Pelleting (MBP) method becomes a promising approach of the future that by closing the cycles in the agro-economic environments of Portugal, enhances the socio-economic conditions in the rural areas. This itself will have one more important consequence of wildfire prevention in the Portuguese forests. This work as a subset of a broader study that aims to develop an evaluation tool for circular economies will cover the information required for a techno-economic analysis of mixed biomass pelleting by a review on potential assessment methods, a rough-cut assessment of agro-residues potential for Portugal and gathering the required information about pellets origin, characteristics and legislative frames.

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*Keywords:* Biomass residues; Circular economy; Mixed biomass pelleting; Portugal; Potential assessment

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## 1. Introduction

Densification is an effective approach for efficient use of the biomass residues that facilitates the handling and transportation of the biomass, that can be used as a fuel in combustion systems. In fact, densification of the biomass residues resources, or that of pelletizing them, reduces the moisture content, increases the energy content and combustion efficiency and by enhancing homogeneity of composition eliminates problems caused by physical

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heterogeneity, size and the low specific weight of biomass [1,2]. The concentration of the biomass increases its specific weight from 40–200 kg m<sup>-3</sup> to 600–800 kg m<sup>-3</sup> [1].

Two major constraints of the Portuguese pellets market are: primarily the lack of internal consumption and dependence on exportation, and secondly shortage of raw material mainly due to the competition with the biomass power plants. Portugal has been produced in lower cost range than internationally traded pellets price due to the lower labor cost and raw material cost among European pellets producers [2]. Although large amounts of agro-residues and garden waste annually are produced in Portugal, it seems that their contribution to meet national energy demand has remained rather low and it requires more efficient and planned use. However, due to inefficiency of these raw materials for biofuel purposes in ‘used as received’ condition, considering their seasonality above other common disadvantages of solid biofuels, and on the other hand for the purpose of growing demand for the pellet resources, R&D investigations for Mixed Biomass Pellets (MBP) and their supply will gain importance [1,3]. As a consequence, the socio-economic improvement of Portuguese rural life can contribute to prevent wildfire directly by applying forest cleaning collection and indirectly by prevention of rural migration and so by keeping the cleanness of rural areas near forests. This work is aligned with a broader study on techno-economic analysis of MBP based on agro-residues (basically grapevine pruning) mingled with other wooden or non-wooden biomass residues, defining it in a circular economy (CE) context and developing an evaluation tool to CE analysis of the specific management of these wastes. This work as a subset tries to cover the required information for a more precise techno-economic and environmental feasibility analysis of the MBP industry for the Portugal case.

## 2. Classification of origin, properties and legislation frame

Since for quality certification, the fuel production chain of fuels is required to be clearly traceable over the whole chain, In European EN 14961 standard for the wood pellets, the solid biofuels are divided into four classification sub-categories of woody biomass, that comes from trees, thickets and bushes (e.g. chips, hog-fuel, firewood, wood pellets and briquettes), herbaceous biomass, that are plants without woody stem and wither at the end of the growing season (e.g. straw, grass, miscanthus, reed canary grass, etc.), fruit biomass, corresponding plants with seeds (e.g. Kernels, stones like olive stones, cherry pips, grape waste, nut shells, husks etc.) and blends and mixtures [4,5].

Another classification for solid biomass with one more sub-category of aquatic biomass, that are related to the plants from aquatic environment (e.g. algae, seaweeds), has been used by European ENplus based on international ISO 17225-2 standard [6], and also by EN ISO standard from 2014 under EN ISO 17225-1. These sub-categories are listed in the first column of classification table for origin and sources in the EN ISO 17225-1 when in other columns their origin is referred in more detail [7]. This standard obligates stating origin and source for all biofuels [8]. Generally speaking, according to the indicated origin for “blends and mixtures” biomass sub-category in the EN ISO 17225, when biofuels are mixed unintentionally they are categorized to be “mixed biomass” whereas, “blended biomass” is intentionally mixed biofuel [8].

It has to be noted that solid biofuel excludes all animal-based biomass (manure, meat and bone meal and such-like materials); these fuels will be dealt with by other standardization committees. Also demolition timber is classified as hazardous waste and is not included in the solid biofuel category [7]. In the EN ISO series two standard parts of “graded wood pellets” and “graded non-woody pellets” cover the quality requirements for wood pellets. Graded wood pellets are included in the EN ISO 17225-2 and are divided into two sub-categories based on their use as pellets for small-scaled “non-industrial use”, which is classified in to property classes of A1, A2, and B, and for larger “industrial use” classified by I1, I2, and I3 [8]. Non-woody pellets on the other hand are included in ISO 17225-6 and are originated in the blends and mixtures of herbaceous, fruit or aquatic biomass. Woody biomass also can be included in these blends and mixtures. Regarding the pellets classification, ISO 17225-6 includes two classification tables [8]: 1. A and B class pellets produced from herbaceous and fruit biomass and blends and mixtures. 2. Those made from straw, miscanthus and reed canary grass pellets. Typically, these pellets have high ash, chlorine, nitrogen and sulphur contents, as well as major element contents, so they are recommended to be used in appliances which are specially designed or adjusted to use them.

Another standard that might be related to the MBP is properties standard of upstream products like torrefied pellets characterized by EN ISO 17225-8 (Graded thermally treated and densified biomass fuels). However, mandatory property classes in EN ISO standard that can be subjected to the optimization for BBP are [8]: diameter (D), length (L), moisture (M on wet basis, w-%), ash (A, on dry basis w-&, ashing temperature 550 °C), mechanical durability (DU, w-% pellets after drum testing), amount of fines (F < 3.15 mm), bulk density (BD) and net calorific

value as received (Q) [7]. Obviously, when defining a fuel to be used in an eco-industrial zone (based on circularity of the economy), near or in the pelleting site, the applicability of other form of the biomasses should be compared whether in mechanically compressed form or without. So that in that case other parts related to the graded briquettes, graded wood chips, or graded firewood (and their quality classifications) may be of interest [9].

Another important consideration regarding MBPs should be the effect of the lignin content of the raw materials in enhancing the mechanical durability of the pellets produced. As the amount of the lignin varies from trees to trees, and hard wood normally has a lower content of lignin than soft wood, it is very important to mix several kind of raw materials after their cleaning stage, to ensure that the mix is as even and homogeneous as possible to avoid the risk of interruptions during the pressing process and to keep to the strict limit for ash content [4]. When using raw materials with relatively low lignin content, like recycled wood or depolymerized raw materials, an additive augmentation ensures that pellets do not crumble into fines [10]. Furthermore, additives can significantly improve pelleting performance when using herbaceous raw materials like straw and whole crops. The improvements by additives are seen in stable density and shatter index of the wood pellets, increasing the heating value, reduction of ash content, reduction of compaction pressure requirement and consequently improvement of the energy performance [11]. However, there are regulations regarding the use of additives, even biological ones [12].

### 3. Biomass potential assessment for Portugal

For potential assessments of biomass residues for energy purposes to Portugal the classification chart of Fig. 1 is simplified based on recent studies with some alterations for MBP purpose [4,9]. Forest residues, agricultural residues and, under some conditions, industrial residues due to vicinity for wooden sources in Portugal are in more interest for this study. However, the possibility of blending municipal solid residues depending on pelleting site position and potential can be subject of future assessments.

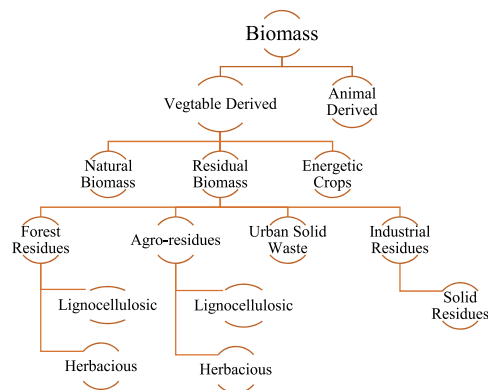


Fig. 1. Biomass classification based on feedstock origin for MBP [4,10].

According to the Monteiro et al. [2], nearly one third of the Portuguese territory is forests and the mixture of the forest waste cut-down with cleaning residues of the bushes can be considered as biomass source for pellet production. However, three determinant factors in the forest residues share in the total above ground biomass are the age of the tree, the species, and the wood assortment harvested [13]. However, in this scope sustainability pros, like fire prevention and valuable energy resource obtaining, along with cons, affecting biodiversity, aspects should be considered.

Activities like furniture production, carpentry, veneer panels, parquets, saw-mills and impregnation include the wood industry residues in Portugal that can be used as biomass for pellet production. Since the sawmill residues have other customers (e.g. for three panel board mills, horse trails, walking trails and garden mulch), the economic factor is the main limiting factor for the use of such residues for energy purposes. Moreover, most of the residues from the cork industry in the Portugal are recovered and used for reintegration into the process or heat generation [2].

In Portugal pruning of vineyards, olive groves and fruit trees, wastes resulting from production of olive oil, olive husk and its seed can be mentioned as some agricultural wastes that can be used for pelleting purposes. Also, waste from the production of corn and maize, as the largest agricultural potential, and cereals such as straws and stalks

among others can be recovered for this purpose. However, the main factors that reduce the interests in this residue for pellets production is its low density, difficulties in collection and uncertainty in quantifying the available waste. Furthermore, there are some technical problems in transformation process. Biomass should be clean, without the presence of land or other elements that may damage the production machinery. The higher emissions of the pellets resulting from agricultural residues and their higher quantity of ash production than pellets resulting from forest or industrial residues is another constraining factor for them that puts an obligation in verification of threshold limitations in EN ISO property classes for small-scale or industrial use [2,8].

### 3.1. A rough-cut potential assessment for agro-residues in Portugal

Portugal with 199 000 ha of grapevine cultivated area [14] seems to have a significant potential for garden waste pelleting. Besides, viticulture has socio-economic context in Portugal [15]. In order to calculate the mass potential of the agricultural waste based on an energy content forecast that took place in 2000 through the Swedish National Board for Industrial and Technical development in 1993, that is shown by Table 2, the energy content of the table is divided by the respected higher heating value (HHV) of the species according to the HHV values shown in Table 1. It has to be considered that the wheat straw in this table represents the cereal straw of Table 2. Moreover, the average HHV of the olive husk is considered to be 19.5 MJ/kg [16].

**Table 1.** HHV data used in this article [17].

Species	HHV [MJ/kg]	Species	HHV [MJ/kg]
Almond shell	18.275	Grape stalk	18.809
Cherry-tree chips	17.595	Hazelnut + alder chips	17.555
Chestnut tree chips	17.485	Horse chestnut burr	17.165
Corn cob	17.344	Mimosa branches	16.237
Dried oil mill stone	18.092	Oil-mill stone	16.484
Eucalyptus bark	17.752	Olive stone	17.884
Extracted olive pomace	18.186	Olive tree pruning pellets	18.720
Extracted olive pomace pellets	18.182	Olive-pomace oil-extractor	18.687
Grape pomace	17.019	Poplar branches	18.411
Grape seed flour	16.467	Wheat straw	17.692

**Table 2.** Estimate of potential energy in agricultural waste of Portugal [18], and potential derived from agriculture residues in Portugal.

Species	Energy [PJ]	Alcohol equivalent [ML]	Residues potential [kton/year]
Cereal straw	5.4	227 270	305
Olive husk	0.6	25 250	31
Pruning residues from vineyard, fruit-trees and olives	8.5	357 740	452
Almond residues	1.8	75 760	96
Total	16.3	686 020	884

Also the result of calculation, the last column of the Table 2, shows that pruning residues of the vineyard, fruit trees, and olives overall have the largest share of the agricultural residues in Portugal with annual potential of 452 000 tons of residues. Cereal straw with 305 000 tones, and with smaller proportion, almond residues and olive husk are in the proceeding levels of the significance for annual residues share in Portugal. However, it should be considered that this calculation helps for a rough-cut potential assessment, and for more updated and precise results there are other assessment pattern based on a comprehensive literature analysis. This assessment is based on applying coefficients drawn from literature for agricultural [9,19–22], forestry or bio based industry production data [21,23] giving the biomass yield from unit agricultural area or production [9]. Yet, there might be available some data for Portuguese residues statistics that help verification and confirmation of the calculations [24].

For MBP, the introduced method, among other potential assessment studies [25–27], can be applied for potential assessment of residues of fruit tree pruning [28], residues of cereal harvesting, forest wooden and herbaceous residues, industrial residues (wood based industry, solid food and agro-products, etc.) and other sectors like

municipal residues. For the lignocellulosic residues the annual potential amount of fresh residues,  $RL$  (t/year), is the product of the cultivated area,  $Ac$  (ha), by the “residue-to-area rate”,  $RAR$  (t/ha-year). While for having the corresponding dry amount of lignocellulosic residues,  $RL, d$  (t/year), the moisture content of the fresh residues,  $\varphi$  (%) should be considered [9]. Straw is the residue that is available after grain harvesting from cereal crops. In order to calculate required annual dried cereal residues for pelleting purposes,  $RC, d$  (t/year), primarily annual straw production quantity,  $RC$  (t/year), should be estimated by multiplying the crop production,  $PC$  (t/year), by the “residue-to-product rate”,  $RPR$  (–) [29–33]. In this stage the evaluated amount of  $RL, d$  (t/year) would be achievable by considering their average value of total solid concentration,  $TS$  (%), that is, the quantity of feedstock that can be theoretically converted into energy, excluding water. In these calculations the  $RPR$ ,  $TS$  coefficients should be drawn from literature [9].

One important factor that should be considered in estimating available biomass residues for energy purposes is the alternative use of residues [29,34]. For this purpose, an availability factor,  $a_f$  (%), will be multiplied by the already calculated residues estimation and the corresponding energy content would be available by multiplying the result by Lower Heating Value (LHV) of the biomass. The evaluated energy content also can be used for evaluating the corresponding power potential [9].

#### 4. Discussion and conclusion

To make the long story short, this study based on a vast literature review that started from August 2018 by the aim of MBP techno-economic assessment for Portugal, gathered to gather fundamental and important information about different aspects of pelleting, mainly related to the potential assessment and quality properties and standards that BBP researchers and practitioners may encounter. However, due to the intrinsic time consuming nature of a complete assessment study, lack of data in the literature for Portugal and character limitation imposed for the paper, the techno-economic considerations and more detailed assessments regarding agro-residues, other potential raw materials and energy exploitation are the missing rings of this study. In terms of legislative frame, it should be noticed that a pellet decision maker or practitioner should consider besides the other aspects, any other regulation and legislative frame that becomes subjected in different conditions like important international coding systems or quality assurances in different countries and regions. The international coding systems are important tools that are applied to harmonize commodity description containing also trading rules and regulations as well as vital statistics worldwide. Safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping is also aimed to be covered by international coding systems. Furthermore, this work introduced a pathway for detailed potential assessments for raw materials and corresponding energy content based on previous studies that show respectively the considerable potential of pruning residues from vineyard, fruit-trees and olives, cereal straw, almond residues and olive husk for MBP.

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