The role of indirect woody biomass sources in the Italian energy sector

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Summary

This paper aims to describe and analyse available data on the main components stages of the wood energy value chain in Italy, highlighting discrepancies between data about woody biomass consumption and domestic supply. Discrepancies are probably connected to informal harvesting, historically a source if raw material not easily captured by official statistics, and to the lack of information regarding the energy utilization of sources not directly connected to forest operations, like, for example, residues from industrial processing, post-consumer recovered wood and biomass from urban forests. The paper focuses on the role played by these non-forest sources. In other European countries such as Germany, France and the United Kingdom, available information gives evidence that these resources cover an important share of woody biomass sources used for energy production, while in Italy, until now, there are no reliable data on the global availability of non-forest wood resources or their utilization for energy purposes. This paper aims to understand the main factors that can influence the utilization of these sources in Italy, analysing the legislative framework and competition with other market sectors for the same raw material. At the Italian level, the competition with panel production seems to strongly limit the use of recovered material for energy purposes. As in other EU countries, data on wood processing residues are scarce and not well organized, even if the utilization of woody biomass for energy production appears to be a rather common practice.

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INTRODUCTION

In 2009, the European Union adopted climate and energy guidelines to cut greenhouse gas (GHG) emissions by at least 20% by 2020 compared to levels in 1990, by increasing the share of renewable energy sources (RES) to at least 20% of total consumption and saving 20% of energy consumption through energy efficiency improvement. The Renewable Energy Directive (2009/28/EC) established an overall policy for the production and promotion of renewable energy in the EU through identification of specific national targets for each Member State. These targets could differ based on the differing starting points of each country. They vary from 10% in Malta to 49% in Sweden (Gerigk *et al.*, 2012). To support the diffusion of renewable energies, EU Member States have implemented their own support schemes, mainly based on two feed-in tariff schemes: (i) the fixed-price scheme, based on long-term purchase agreements of power at fixed prices, and (ii) the premium-price scheme, which offers a premium above the average market price of electricity. Thanks to the stability of incentives that the fixed price tariff scheme can ensure, fixed-price feed-in tariffs are by far the most widespread tool for supporting RES worldwide. However, numerous countries currently operate both tariff schemes, depending on the plant size and the type of renewable energies (NREL, 2010).

Thanks to the support schemes implemented in most European countries, bioenergy consumption in EU-28 has more than doubled between 2000 and 2015 and, in the same period, 46% of all existing EU plants (equal to 42% of all bioenergy production capacity) were constructed (AEBIOM, 2015). The role of bioenergy is most important in the heating and cooling sectors, which alone are responsible for almost half of final RES consumption in the EU (World Energy Council, 2016). Solid biomass, mainly constituted by woody biomass, is by far the most important bioenergy source and represents the main single source of renewable energy (IRENA, 2016). In 2015, woody biomass became by far the largest source of renewable energy in the EU-28, accounting for almost 50% of the EU-28's renewable energy consumption (Pelkonen *et al.*, 2014). Projections included in the European Forest Sector Outlook Study II (UN, 2011) have assumed that, if woody biomass for energy has to play the role laid out for it in each nation's energy plans to reach their renewable energy targets, the supply of woody biomass to the EU-28 will have to increase by around 50%. Given the expected increase in demand and the potential gap between demand and in internal supply, an important issue to consider is whether this increase in demand could be met without strong distortion effects in the market of forest products (Bodstedt *et al.*, 2015). In this scenario, indirect sources of woody biomass such as recovered wood and wood processing residues are going to play an important role in meeting the growing demand of woody biomass for energy (Standing Forestry Committee, 2008).

2. WOODY BIOMASS FOR ENERGY - AN OVERVIEW

The term wood energy refers to any energy source that comes from woody biomass, including fuelwood, charcoal, industrial wood residues, wood pellets, cellulosic ethanol and other advanced forms of bioenergy. These different types of woody biomass can be collected from (Trossero, 2002):

I. forests (trunks, dead trees, and other woody waste materials),
II. trees planted in marginal and farming lands (trunks and prunings)
III. recoresidues from wood processing industries (material from pre-and post-processing)
IV. waste wood (post-consumer wood)

According to Steierer (2010), around two thirds of woody biomass used in the countries included in the United Nations Economic Commission for Europe (UNECE) came from direct sources, such as forests, while one third of woody biomass used for energy in these countries came from non-forest sources, such as recovered material from wood processing industries and waste wood. Both types of supply chain, those utilizing direct and indirect sources, consist of a varying number of stages, and in many cases, they are scharacterized by a high level of informality (Mantau *et al*., 2010). Different actors may be involved in production at each stage, with numerous and relevant interlinks in wood use and flows among them. As a result, supplying a detail picture of wood energy sector, estimating the amount of woody biomass consumed for each steps of supply chain, could represent a real complex process. This issue of multidisciplinarity is gaining increasing attention not only from policy makers, scientists and stakeholders in the energy sector, but also from stakeholders and interest groups representing other sectors like agriculture, forestry, the environment, industry and consumption (Ferranti, 2014).

2.1 THE ROLE OF WOODY BIOMASS FOR ENERGY AT ITALIAN LEVEL

In the context of the European Directive 2009/28/EC, the National Renewable Energy Action Plan, developed by the Italian Ministry of Economic Development (2010) assigns a key role to solid biomass in achieving targets for 2020. Indeed, solid biomass should become the largest source of renewable energy in Italy by 2020, accounting for 8% of electricity production and 50% of heating and cooling production supplied by renewable energies. In 2015, according to data supplied by "*Gestore dei Servizi Energetici*", in its "*Yearly Statistical Report*" (GSE, 2017), a total of 23,7 million (M) tons of wood was used in primary energy production. Within the total consumption, the total amount of woody biomass used for residential purposes was 19,2 million tons, which can further be divided into 16,7 million tons of firewood and 1,9 million tons of wood pellets. This significant role covered by residential use is mainly motivated by the common practice of utilizing woody biomass as heating sources, especially in rural contexts. In fact, according to a research carried out by ISTAT (2014), more than 20% of Italian households used woody biomass as their main heating source. These numbers would make woody biomass the second largest heating source for Italian households, just after methane. In addition to the residential consumption, in the Italian territory there were 300 electricity production plants using solid biomass in 2015 (either directly or by CHP), although this number does not include urban wastes. Their average power capacity was equal to 2.1 MW. With regard to electricity produced from woody biomass, it's interesting to note that Italy has no electric plants that run on wood pellets (AEBIOM, 2015); all of the country's plants run using woodchips. In southern regions, some plants may use solid biomass from Mediterranean farm products (e.g., olive pomace, pits and grape residues) to integrate woodchips. Table 1 presents the different uses of woody biomass for energy in Italy.[1]

[1] The table and its related data will also be utilized in the Joint Wood Energy Enquiry 2017 for Italy.

Table 1. Consumption of woody biomass for energy in Italy in 2015[2]

	Quantity (1000 ton)	Energy produced (Tj)
HEATING PRODUCTION		
Fuelwood	**16709**	**232409**
First home	16532	229973
Second house	177	2436
Pellet	**1938**	**33490**
First home	1919	33161
Second house	19	329
Woodchips/post consumer material	**1674**	**19103**
Industry	536	6110
Agriculture	125	1431
Trade and service	185	2119
ELECTRICITY		
Woodchips	**3382**	**68986**
CHP	**2124**	43337
Only electricity	**1257**	25649
Total consumption (1000 ton)	**23703**	

According to GSE and ISTAT data elaborated in the table 1, residential consumption represents more than 70% of the total consumption of woody biomass, while industrial sector doesn't cover more than of 20% of consumption. In any case, if GSE, thanks also to ISTAT data, is able to give a rough overview of woody biomass consumption in Italy, answering to the question about the origin of this woody biomass remains a real challenge. In order to answer this question, different potential sources of biomass shall be analysed, such as:

- *Domestic forest removals*: according to the most recent available data, in 2012, forest removals for energy purposes in Italy amounted to 5.4 million m^3 (2.7 million tons), or about 70% of total roundwood removals on a national scale[3];
- *Removals of trees outside forest areas (Other Wooded Land, in the FAO terminology)*: there are no official statistics regarding domestic wood production from trees not included in forest area. However, the Italian Producer of Renewable Energy Federation (FIPER, 2013) indicates that at least three or four million tons of woody biomass are potentially available from these sources every year. In case of energy utilization, this amount of material can generate a yearly income for Italian municipalities of around 60-100 millions of Euro;
- *Imports*: in 2015, Italy imported 3.8 million tons of woody material (firewood, chips and pellets) to be used for energy purposes[4];
- *Wood processing residues from forest-based industries*: according to the estimation made by the initiatives "Extravalori" carried on by the Italian Ministry of Agricultural, Food and Forestry Policies, Italian companies, involved in first and second timber transformation, produce yearly around 3,1 millions of tons[5] of woody by-products, such as shavings and sawdust. At the moment, there aren't any estimation concerning the real utilization of this source for energy purposes;

[2] Conversion factors utilized are included in the "*Manual for statistics on energy consumption in households"*, published by International Energy Agency in 2005.

[3] Source: Eurostat, 2017. Forestry statistics. Eurostat statistics explained. Last access: 10th August 2017. Link: http://ec.europa.eu/eurostat/statistics-explained/index.php/Forestry_statistics

[4] Source: Comtrade Database. Last access: 10th May 2018. Link: https://comtrade.un.org/

[5] This estimation is based on the assumption that each 1 m^3 of roundwood worked produces 0.3 m^3 of wood processing residues.

- *Post-consumer recycled wood*: wood waste, including packaging and urban waste, collected in Italy every year was estimated to 1,4 around million tons in 2016, 50% of which was utilized for energy purposes (Fondazione per lo Sviluppo Sostenibile and FISE UNIRE, 2014)**.**

Table 2 summarizes the estimated contribution made by different sources to national supplies of woody biomass, together with data on total and domestic consumption at the national level.

Table 2. Different sources and their annual contribution (estimated) of woody biomass for energy.

Annual supplies	Quantities (M tons)[6]	Data sources
Forest removals for energy purposes	2.7	Eurostat, 2014
Woody material from trees from outside the forest	3 to 4	Fiper, 2013
Wood processing industries from forest-based industries	3.1 Mt	Extravalori, 2013
Import	3.8 Mt	Comtrade, 2016
Recycled wood utilized for energy purposes	0.7	Fise Unire, 2014
Total sources	**13.3 -14.3**	

Even though data regarding woody biomass sources reported in table 2 refer to annual values in the period 2013 to 2016 rather than a single year, a rough comparison between supply and demand is possible and the gap between the consumption of woody biomass for energy and the related supply appears relevant. In this overall picture, we have also to consider that the panel production covers an important share in the utilization of wood residues from primary and secondary industrial transformation and in the wood chips imported. Even if we assumed that all of the potential woody biomass was destined for energy production, the total amount would cover less than 70% of household consumption of woody biomass, and only 55% of total consumption. Therefore, we can assume that no less than 30% of the total woody biomass used for energy in Italy comes from unknown sources, which might include: (i) trees outside forests located in rural context, (ii) wood processing industries residues and (iii) wood from illegal activities such as irregularly harvested/traded wood. About that, in 2012 in Italy, 823 cases of wood theft were reported by the State Forestry Corps (CFS, 2013). In addition to wood theft, empirical experience indicates that the Italian wood energy sector is characterized by an informal market, with consequences in terms of Value Added Tax (VAT) fraud.

2.2 THE ROLE OF WOODY BIOMASS FOR ENERGY IN THE MAJOR EU ECONOMIES

To assess the consistency of Italian data, we have compared them with the data of the wood energy sector of the three major European economies, namely: Germany, the United Kingdom and France[7]. We have chosen to utilize data included in the Joint Wood Energy Enquiry (JWEE), an initiative launched in 2006 by UNECE, FAO (Timber Section) and the International Energy Agency (IEA) to improve knowledge about woody biomass use for energy. The JWEE is based on active data collection via a detailed grid to collect precise and disaggregated national data of woody biomass for energy from different sources.

Just as in Italy, other countries reported gaps between total woody biomass consumption and recorded supplies. In fact, in general, wood consumption is higher than wood supply. These differences can be explained by weaknesses, especially in data, concerning: (i) harvested woody biomass outside the forest, (ii)

[6] Assuming 1 m³ corresponds to 0,5 t, as suggested by Mantau *et al.* (2010).

[7] Germany, United Kingdom and France report the highest Gross Domestic Production in 2016, according to Eurostat statistics. Link: http://ec.europa.eu/eurostat/statistics-explained/index.php/National_accounts_and_GDP. Last access on 20th May.

post-consumer recovered wood and (iii) logging residues. Furthermore, problems related to underestimation of forest removals are reported in other EU countries such as Germany (Jochem *et al*., 2015). To make the global picture more difficult to analyse, important products related to the wood energy sector, such as chipwood, can have, as already mentioned, different final destinations besides energy utilization, such as panel production.

Table 3 presents data on total consumption of woody biomass for energy for France, Germany and the United Kingdom for 2013, which are the last data published by JWEE. These data are compared with the total woody biomass consumption at the Italian level, presented in Table 2. To make data more comparable, the third column reports the ratio between total consumption and population, according to World Bank.

Table 3. Total consumption of woody biomass for energy for the major EU economies and Italy. Data source for Germany, United Kingdom and France is the results of JWEE and data are referred to 2013, whereas data for Italy are referred to 2015

	Total consumption (M m^3)	Total population (M)[8]	Consumption per inhabitant (m^3/inhabitant)
Germany	65.9	80.6	0.81
United Kingdom	13.3	64.1	0.20
France	46.6	65.9	0.70
Italy[9]	47.4	60.2	0.78

Table 3 shows that total Italian consumption is similar to that of France and Germany, whereas the UK reports much lower total woody biomass consumption for energy. This is mainly due to the limited percentage of Britain households that utilize wood as the main source of energy for heating. According to Waters (2016), around 2% of the English population uses solid biomass as the principal source for heating their houses, while in Germany, France and Italy, these figures exceed 15%. In Britain, most woody biomass is consumed in big energy plants that generate electricity and are located near important harbours, since these plants are fed mainly by imported material. As Pearce (2015) notes, this tendency of building big plants fed with imported material could be considered a distortion effect of the large economic incentives granted in the EU's biomass strategy, which covers the cost for importing large amounts of raw material from far away.

Table 4. Role of residential consumption of woody biomass for energy in three major EU economies and Italy

	Role of residential consumption in the context of total consumption	% households that utilize wood for heating own house
Germany	49%	19.1% (source: Mantau, 2012)
France	70%	16.4% (Source: Cotoure *et al*., 2009)
United Kingdom	29%	2.3 % (Source: Waters, 2016)
Italy	78%	21.4%

With regard to possible sources of wood biomass, countries with a high share of residential consumption usually rely heavily on direct supplies of wood fibres, such as woody biomass from forests. In contrast, countries with large industrial sectors rely mainly on wood supply from indirect sources, such as products and residues from forest-based industries. JWEE classifies four different typologies of sources:

[8] Source: World Bank. Link = https://data.worldbank.org/indicator/SP.POP.TOTL?end=2013&name_desc=false&start=1960. Data are referred to 2013

[9] As we have reported in table 1 the Italian consumption of woody biomass in 2013 was around 23.7 M t. Assuming that 1 $m^3$is equivalent to 0.5 ton, the Italian woodfuel consumption is around 47.4 M.

- *Direct source*: woody biomass from forests and other wooded land, including logging residues. This category includes the net trade;
- *Indirect sources:* co-products and residues from forest-based industries, including processed wood fuels with improved energy content such as wood pellets, briquettes and charcoal;
- *Recovered wood:* post-consumer wood wastes such as wastes from construction, but also packaging and old furniture;
- *Unknown sources*: the difference between the total consumption and the rest of the sources.

Table 5 presents the role covered by direct/indirect sources and recovered wood in total woody biomass consumption in Germany, France and the United Kingdom. At the moment, there are no data for Italy. However, given the very important role of residential consumption, it is possible to assume that direct sources, including woody biomass from non-forest areas and woody biomass imports, account for at least half of final consumption.

Table 5. The role covered by direct/indirect source and recovered wood

	Direct sources	**Indirect sources**	**Recovered wood**	**Unknown sources**
Germany	47.8%	29.5%	20.4%	2.3%
France	58.7%	33.2%	8.1%	0%
United Kingdom	28.5%	69.4%	2.1%	0%

In the next chapters, we will analyse in detail important aspects of indirect and recovered sources such as the legislative framework at the EU and Italian level and the competition with other industrial sector.

3. THE SECONDARY SOURCES OF WOODY BIOMASS, AN OVERVIEW

In the last decade some gaps and inconsistencies in statistics about non-forest sources of biomass, such as co-products and residues from forest-based industries and recovered wood such as waste wood, are becoming important elements in woody biomass flows for energy production. According to JWEE, between 2007-2013, the energy consumption of non-forest sources and recovered wood in the UNECE region increased by 51%. In the near future, the role of these sources will increase due to the growing demand for bio-based products and energy (Standing Forestry Committee, 2008).

According to Mantau *et al.* (2010), in EU-28, 26 million tons of post-consumer wood (i.e., wood products such as discarded furniture) were generated in 2010. Around one-third of this material was recycled into other products, one-third was converted to energy and one-third was permanently disposed or incinerated. Mantau estimated that almost all wood processing residues are utilized in some way, with 59% being burned for energy and 41% recycled into other products.

Generally, industrialized countries with a limited amount of forest removals and strong wood industries have long been forced to re-use wood processing residues and recovered wood in their industrial sectors. Countries with large forest resources have a relatively high provision rate because they have large sawmill industries (i.e. large amount of sawmill residues), but the utilization rate of wood processing residues and recovered wood is relatively limited (Mantau *et al.* 2010).

In addition to technical and logistic barriers, the main factors that limit the use of indirect secondary sources for energy purposes are related to policies concerning waste management and the competition of the industrial sector for the same raw material. In terms of waste management policies, EU strategies have aimed to reduce the environmental and health impacts of waste by improving resource efficiency and reducing the

emissions of air pollutants from the incineration (Keegan *et al.*, 2013). With regard to competition with the industrial sector, particleboard production competes directly with the energy sector, in particular for the use of non-coniferous chips. In the last twenty years, policy-makers have tended to deal with this competition separately, resulting in a lack of integrated policies that do not consider any potential synergies between them. While voluntary or binding targets exist for bioenergy or renewables, with accompanying support mechanisms, similar support schemes for utilizing indirect wood sources are lacking (Vis *et al.*, 2016). According to the European Panel Federation (2017), this tendency has created, in the last decade, a market distortion with a concrete risk that the wood material was not used efficiently. A clear sign of competition between energy and material utilization is the price trend for non-coniferous woodchips (i.e. the material most suitable for panel production). According to Eurostat data[10], real prices for non-coniferous chips have increased by more than 70%, while prices of coniferous chips have increased by around 10%.

3.1 POST CONSUMER WOOD - A LEGISLATIVE FRAMEWORK

According to the definition used by UNECE/FAO Forestry and Timber Section, post-consumer wood is any waste wood fibre after at least one life cycle, including wood from construction, renovation, demolition, packaging and old furniture. Therefore, wood waste can come from numerous and different sources, such as municipal, commercial and construction sectors, in different forms with different characteristics (virgin or contaminated with glue and paints). According to this definition, post-consumer wood should be considered waste, since, in a legislative context, waste refers to any substance or object that the holder discards or intends to discard (Defra, 2012). With regard to legal framework, Directive 2008/98/EC on waste (Waste Framework Directive) has set the basic concepts and definitions and laid down some waste management principles within the EU, with the main objective of protecting the environment and human health from the possible harmful effects of waste**.** The Waste Framework Directive includes two specific targets to be achieved in EU-28 by 2020: 50% reuse and recycling of waste generated by household and 70% reuse and recycle of non-hazardous waste in the construction and demolition sectors.

The European Union Waste Framework Directive requires that each Member State adopts national measures to realize self-sufficient waste disposal through a specific waste management plan that considers the type, quantity and source of waste and existing collection systems. In Article 4, the EU Waste Directive prioritizes waste handling through a five-stage waste hierarchy: (a) prevention; (b) preparing for re-use; (c) recycling, defined as any recovery operation by which waste materials are reprocessed into products, materials or substances for the original or other purposes; (d) recovery, defined as any operation the principal result of which is waste serving a useful purpose by replacing other materials that would otherwise have been used to fulfil a particular function, e.g., energy recovery); and (e) disposal (Fugure 1).

[10] Data source: http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Wood_as_a_source_of_energy&oldid=375661. Last access = 23rd May 2018

Figure 1. Waste management hierarchy according to EU Waste Directive. Source = European Commission

Figure 1 shows that energy production from waste is only appropriate for waste that cannot be prevented, reused or recycled. Therefore, the EU Waste Directive implies reuse and recycling of materials before energy recovery. The necessity for prioritizing between different potential uses of raw material along the value chain is a type of approach supposed by the cascading principle. The cascade approach implies the use of wood according to a priority based on the added value that can be potentially created, so woody raw material should be used for building, furniture and other products with long life span, while the energy use of wood should be considered the least valuable option (Ciccarese *et al*., 2014).

The cascading concept has already been emphasized in other EU policies and strategies, such as the EU Bioeconomy Strategy, the EU Circular Economy Package and the EU Forest Strategy. As of September 2015, the cascading principle is also an important element of the indirect Land Use Change (iLUC) Directive that largely governs the role of biofuels in the EU's climate change mitigation policies up until 2020.

In addition to the European Waste Directive, another important legislative reference for the sector is the Packaging and Packaging Waste Directive (Directive 2004/12/EC). The Directive aims to minimize the creation of packaging waste through promotion of reuse, recycling and energy recovery. The Directive set a recycling target of 15% for wood, which was to be attained in 2008. All Member States that were subject to targets met them. In 2014, the European Commission began reviewing waste-related and other recycling targets in the context of the circular economy package, which included a proposed recycling target of 80% for wooden packaging waste to be met in 2030 (Mantau *et al*., 2016).

3.2 POST CONSUMER WOOD - SOME DATA FROM THE MAJOR EU ECONOMIES

Table 6 presents the total wood waste production for EU-28 and the four countries considered in this study according to Eurostat. Compared to Mantau's (2010) estimations, Eurostat supplies a higher value of wood wastes generated in EU-28, about 50 million tons. Part of this discrepancy is likely because Eurostat data include processing wastes from forestry. Germany is by far the most important EU producer of wood waste. However, due to strict existing regulations, with the related controls, adopted to limit the use of contaminated waste wood, the ratio between hazardous and non-hazardous waste in Germany is lower compared to other countries (Garcia and Hora, 2017).

According to Eurostat data, at the European level, around 40% of wood waste is re-used for energy production and roughly the same share is used for the production of other material, especially panel. Among the four countries considered, these figures are very different. In Italy and France, 67% of wood waste is re-used for the production of other materials, whereas in Germany, more than 60% of wood waste collected is re-utilized for energy production. These figures are partially confirmed by the analysis of the origin of

material for particleboard production (Table 8). In fact, as Meinslschimdt *et al.* (2015) report, the Italian particleboard sector, the largest in EU-28, relies mainly on recovered wood, whereas French and German particleboard producers prefer to rely only partly on recycled wood. Vis *et al.* (2016) have attempted to identify a series of motivations, in terms of prospective panel consumers, of these different pictures of wood waste input for particleboard production (Table 9).

Table 6. Wood waste generated in 2014 according to Eurostat (1000 ton)

	Total wood wastes generated	Hazardous waste	Not hazardous waste	Not hazardous /hazardous
EU-28	50280	1720	48560	96.5%
Germany	11932	1069	10863	91.0%
France	6154	32	6122	99.4%
United Kingdom	4505	33	4472	99.2%
Italy	4420	6	4414	99.8%

Table 7. Treatment of wood waste generated according to Eurostat (2014)

	Recovery for energy	Recovery for the production of other material	Other (landfill - incineration)
EU-28	43.4%	41.4%	15.2%
Germany	63.5%	0%	36.5%
France	26.9%	67.0%	6.1%
United Kingdom	14.0%	38.8%	47.2%
Italy	15.6%	67.0%	17.3%

Table 8. Use of wood and waste wood in the production of particle boards in main EU economies (Meinlschmidt *et al*., 2015)

	Share of roundwood	Share of woody by-products	Share of recovered wood
Germany	20%	46%	34%
France	41%	37%	22%
United Kingdom	16%	31%	53%
Italy	0%	5%	95%

Table 9. Consolidation of features describing particleboard production and customer habits (Vis *et al*., 2016)

	Recycled content in particleboard	Consumers' behaviour	Users' orientation
Germany	Particleboard is made with a maximum share of recovered wood of 30-40%, the usual ratio is 15-20%	Furniture buyers look first and foremost for highest quality and "healthy" material	Public and particleboard users have a somewhat negative view of particleboard with recycled content and preconceived opinion that it is of less good quality
France	Particleboard is made with differing shares of recovered wood	No special customs of the consumers are mentioned	Public and particleboard users have a somewhat negative image of the use of recycled material
United Kingdom	Particleboard is made with a maximum share of 50-60% of recovered wood	Furniture buyers are either very design and fashion oriented or behave very conservative	Furniture makers (particleboard users) use to combine modern design and marketing ideas
Italy	Particleboard is made with high shares of recovered wood, up to 100% of total wood input	Furniture buyers focus more design than on the content of material used	Particleboard users have adjusted to products made from 100% recycled wood

3.3. POST CONSUMER WOOD - THE ITALIAN CONTEXT

The EU Waste Framework Directive (WFD) was transposed in Italy by Legislative Decree 205/2010 (modified in 2012), amending Legislative Decree 152/2006 (the consolidated act on the environment). In particular, article 179 contains the technical criteria for the determination of end-of-waste material flows that need to be disciplined and priorities of procedures to be followed for the adoption of the implementing regulations. Italy has not developed a national waste management plan, since the national legislation requires that plans should be developed at regional level. Therefore, the regional authorities have the task of drafting waste management plans to organize and integrate waste collection, treatment and disposal within the Optimal Management Areas.

Rilegno is the national consortium for the collection, recovery and recycling of wood packaging in Italy. It has been active since 1998, when Legislative Decree 22/1997 (Ronchi Decree) became law. Rilegno is one of the six consortia included in the packaging sector that is cooperating with Conai (the national packaging consortium) (Garcia and Hora, 2017). According to the statute, Rilegno's main task is to ensure the achievement of the objectives set by law for the overall recovery of the packaging timber after consumption such as pallets, crates, boxes, cages and cable reels. The consortium includes companies that produce wood, suppliers of new materials for the production of packaging, importers of materials or wood packaging and companies that recycle wood packaging waste. Rilegno has a well-established transportation network to collect wood wastes in different municipalities from deposits by private operators in the industry as well as retailers. At the end of 2017, the consortium had 2367 members and manages around 400 recovery platforms and supplies its services to 4437 Italian municipalities, around two-thirds of the Italian population. Rilegno's services to Italian municipalities have been fixed by an agreement between the consortium and the National Association of Italian Municipalities (ANCI). This agreement states that Rilegno is also responsible of collection of bulky wood waste, besides wood packaging waste. At the end of 2017, consortium members included:

- 328 wooden packaging producers;
- 2029 wooden packaging transformers and
- 10 companies specialized in recycling.

In terms of numbers of associates, the recyclers play an extremely marginal role. Within them, there are seven panel producers, one paper producer, one producer of building materials and one producer of pallets realized with post-consumer wood. There are no recyclers specializing in wood energy recovery, whereas there are very important panel producers in Italy such as Saviola and Fantoni. For this reason, almost the total of the wooden packaging Rilegno recovers is destined for the production of other wood materials. In fact, out of the total wood waste generated in Italy and managed by Rilegno, around 2.9 million tons, around 60.1% is recovered or recycled for the production of other products, whereas waste wood destined for energy recovery does not amount to more than 80000 tons (2.5%) (Rilegno, 2018).

3.4 WOODY PROCESSING RESIDUES—A LEGISLATIVE FRAMEWORK AND SOME DATA AT THE EU LEVEL

Wood processing residues (by products) can be accumulated during all mechanical production processes in the forest-based industries. For a long time, wood processing residues were considered waste or remnant biomass without any further use. After the demand for woody biomass for energy increased, wood processing residues, especially sawmill residues, became a by-product with competitive product features (Saal *et al*., 2017).

However, wood processing residues very often are not well defined or harmonized among EU legislations and scientific literature. In fact, frequently, wood processing residues appear with similar features as forest residues or waste wood, with the risk of confusing these materials. By-products, according to Article 5 of the EU Waste Framework Directive, are substances or objects, resulting from a production process, the primary aim of which is not the production of that item. In particular, by-products must meet these conditions:

- further use of the substance or object is certain;
- the substance or object can be used directly without any further processing other than normal industrial practice and
- the substance or object is produced as an integral part of a production process.

Despite it is known that wood processing residues are becoming a significant share of woody biomass in the wood energy sector, by-products from forest-based industries are not still covered comprehensively by official statistics at the global level or in single countries. The main reasons for this lack of statistical data are the huge variety of wood processing residues and the numerous and different parameters available at the international level to estimate the potential availability of woody by-products. The parameters differ from methodological approaches, data units, type of manufacturing process and the kind of wood product used as input to the respective production process (Sall *et al.*, 2017). For instance, sawmill residue can range from 35% to 45% depending on species, log dimensions and technical processes (FAO/UNECE, 2010), while shares of wood processing residues from wood-based panel production can vary from 4 to 12%. In plywood production, woody by-products results in higher shares (45%) because of lower material efficiency (Table 10).

Table 10. Rate of wood residues generated for some timber products[11] proposed at international level

Product	Share of wood residues per m³ roundwood input
Particle board production	3.9%
OSB/MDF	9.7%
Hardboard	11.6%
Veneer/Plywood	45%
Sawmill residues	35-45%

3.5 WOODY PROCESSING RESIDUES - SOME DATA AT ITALIAN LEVEL

Italy is one of the world's leading consumers of timber in Europe. The Italian wood supply chain is very complex and fragmented, and the different processes generate different types of by-products, which are often used directly (as self-consumption) for energy production, while residues with glues or varnishes are sent to landfills. No official data are available for Italy on the available quantity of residues from wood processing that can be used for defining an bioenergy budget (Gallo, 2013). At the international level, in the last twenty years, numerous studies have attempted to identify parameters for estimating wood residues from different processes. These parameters, summarized in Table 11, appear very different, with different units of measurement. However, two studies reported that in two Italian regions (Friuli Venezia-Giulia and Lombardy, i.e. two relevant timber consumer areas), the practice to use wood processing residues for energy production for self-consumption is quite common. Of course, since the energy utilization is mainly internal to the companies, estimating amounts of wood processing residues used for energy appear very complex.

Table 11. Rate of wood residues generated for some timber products[12] proposed at national level

Author/organization responsible for the study	Area of the study	Parameters identified	Note

[11] Source: Mantau & Bilitewski (2010), Fonseca, (2010), FAO/UNECE, (2010)
[12] Source: Mantau & Bilitewski (2010), Fonseca, (2010), FAO/UNECE, (2010)

ISPRA (2010)	Italy	11.8 e 20.6 t/year for employee	Data resulting from elaboration of previous studies
FLA (2010)	Italy	21.25 kg/m^3 roundwood input	
CTI (2005)	Lombardy	11.8 tons/year for employee	54% of forest-based companies utilize its processing residues for heating
Udine University (2002)	Friuli	8 tons/year for employee	The energy utilization of wood processing residues covers around 40% of the total heating needs of companies that produce residues
Notargenlo *et al.* (2015)	Trento	30% per m^3 roundwood input	6% of wood processing residues are used internally for heating companies that produces them. The rest of the residues are sold

4. CONCLUSIONS

The rapid increase in the use of woody biomass for energy in Italy and other European countries should be supported by a well-coordinated, intersectorial policy strategy. Until now, in some EU countries with large wood-based sectors such as Italy, one of the main limiting factors for implementing an effective strategy is the lack of data and statistics on the woody biomass supply. In fact, in addition to informal removals that historically represent sources not easily captured by official statistics, other important woody biomass sources such as wood residues and recycled wood are not still reported with reliable statistics. With regard to recovered wood, at the Italian level, it is evident that the main destination of post-consumer wood is the production of panels. The market of recovered wood is still dominated by large companies specializing in panel production. It means that in Italy, until now, the distortive effects of economic support of bioenergy are still marginal for this kind of resource and, for this aspect, the Italian wood energy sector seems in line with the hierarchy proposed by the Waste EU Framework and the concept of cascading use of wood. Regarding wood processing residues, detecting reliable data on the availability of this resources and their utilization for energy production appears very complex. Nevertheless, the utilization of these wood processing residues appears to be common practice. The wood residues generated by forest-based companies are mostly used for internal energy production. Generally, improving data collection could help the understanding of the potentials from increased cascading of wood and the links between the different wood using sectors, with positive impacts in policy making both for the energy sector and the bio-industry.

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