Italian import flows of woody biomasses for energy use: a sustainable supply?

MATTEO FAVERO, DAVIDE PETTENELLA

Jel Classification: F14, L73, Q42

Abstract

Despite the inaccuracy of the official estimates, it is commonly recognised that wood biomasses play a relevant role in the Italian renewable energy production. Moreover, the Italian dependence on the international biomass market has significantly increased over the time. This trend seems to be the antithesis of the "short value chain" objective that is a leitmotif of renewable energy and rural development domestic policies. Starting from this evidence, Italian import flows of woody biomasses for energy use were analyzed over the period 1991-2011 both in quantitative and economic terms. Then, the environmental impacts of these flows have been estimated by means of a Life-Cycle Analysis to determine whether, and to what extent, the increased transport distance reduces the environmental sustainability of these materials with respect to conventional fossil fuels. Some policy considerations concerning the opportunity of further developing local supply chains are finally provided.

***Key words**: biomass, imports, fuel wood, wood residues, Italy, LCA.*

Résumé

Malgré la fiabilité réduite des estimations officielles, il est communément admis que les biomasses de bois jouent un rôle important dans la production d'énergie renouvelable en Italie. En outre, la dépendance italienne du marché international de biomasse a augmenté de façon significative au cours du temps. Cette tendance semble être l'antithèse de l'objectif d'une «chaîne de valeur réduite» qui est un leitmotiv des énergies renouvelables et des politiques nationales de développement rural. A partir de ces éléments, les flux d'importations italiennes de biomasses sur base de bois pour la consommation d'énergie ont été analysés pour la période 1991-2011 en termes quantitatifs et économiques. Ensuite, les impacts environnementaux de ces flux ont été estimés au moyen d'une analyse du cycle de vie pour déterminer si, et dans quelle mesure, la distance de transport accrue réduit la durabilité environnementale de ces matériaux par rapport aux combustibles fossiles traditionnels. Quelques considérations de politique sur l'opportunité de poursuivre le développement des chaînes d'approvisionnement locales sont enfin fournies

***Mots- clés:** Biomasse, importations, bois de chauffage, résidus de bois, Italie, ACV.*

1. Introduction

In 2010, the Italian Ministry of Economic Development published the National Action Plan (PAN) for Renewable Energy Sources (RES). According to the PAN, by the year 2020 a share of 17% of the total gross energy production in Italy has to be obtained by RES, for a total amount of 22,6 Mtep (MSE, 2010). The Plan assigns a key role in achieving the national target to solid biomasses: about 8% of electricity production and 50% of thermal energy production, of the total RES, will be related to solid biomasses. Among solid biomasses, woody biomasses are indicated as the major component.

The quality of data on which PAN estimations are based is uncertain: indeed, several surveys suggested that the Italian amount of energy-wood consumption is much higher than that indicated by official sources (Gerardi *et al.*, 1998; Gerardi and Perrella, 2001; APAT-ARPA, 2008; ARPA Emilia Romagna, 2011). Moreover, the PAN provides no information on biomasses import and export flows.

Two recent surveys came to the same conclusion: it is likely that bioenergy production in 2010 was already higher than 5.25 Mtep, i.e. the 2020 target stated in the PAN (Tomassetti, 2010; Pettenella and Andrighetto, 2010). The underestimation of the actual biomass production is due mainly to three reasons: (1) domestic firewood harvested amounts are not correctly calculated; (2) import and export flows of chips and particles, firewood and wood residues are not computed, also because it is difficult to separate the various final uses of chips and residues (energy, panel production or pulp for paper) and (3) recycled biomass from post-consumer products and industrial residues used for energy purposes are not taken into consideration by PAN.

Due to its increasing dependence on the international biomasses market, in 2010-2011 Italy became the top worldwide firewood importer and the fourth country for the importing of chips and particles and wood residues. In addition, it is the main European importer of pellets for residential use (Paniz, 2012). This situation leads to a variety of issues and uncertainties arising with respect to environmental, economic and social impacts of bioenergy domestic market development, which seems to be the antithesis of the "short value chain" that is a *leitmotif* of renewable energy and rural development policies. In particular, doubts arose about the environmental sustainability of imported energy-wood from countries like Australia, Argentina or Brazil, just to mention some of the exports of such products to Italy.

Moving from this empirical evidence, concerns arouse about the sustainability of such import flows, both in economic (e.g. dependence upon foreign sources, incentives inducing market distortions) and in environmental terms.

University of Padova - Department of Land, Environment, Agriculture and Forestry, Padua, Italy

The latter, particularly, regarded the possibility that the energy consumption due to the import chain could exceed the benefits, namely the substitution of fossil fuels with more eco-friendly solid wood biomasses. It has also been argued that, for some flows, the capability to check whether those timber resources originate from illegal sources is weak. Similar concerns spread out among the public, reaching a vast audience (Casalini, 2010; Rowe, 2013).

At the same time, the "short supply chain" concept has been increasing its relevance in the last years, with special reference to the agricultural and food sector. The European Commission (2011) proposed to define it as "*a supply chain involving a limited number of economic operators, committed to co-operation, local economic development, and close geographical and social relations between producers and consumers*", whereas Fondse *et al*. (2012) identified four main criteria encompassing most of the existing definitions. These are the following: (i) geographical proximity between suppliers and consumers, (ii) capacity to generate added value and profit at the local scale; (iii) social equity and balanced redistribution of revenues across the chain, and (iv) environmental sustainability.

Thus, although a single definition doesn't exist yet, the theoretical framework is complex and goes beyond the mere geographical criterion, and includes the sustainability concept as well. This, again, is further split in its various dimensions, spanning from the legal, social, and environmental ones. Meaningfully, also the main forest certification schemes, e.g. the *Forest Stewardship Council*® (FSC) and the *Programme for the Endorsement of Forest Certification*™ (PEFC) *schemes*. Particularly, FSC scheme states that a responsible forest management shall be "*environmentally responsible, socially beneficial and economically viable*" (Forest Stewardship Council, 2009).

In Italy, Ministerial Decree DM 02/03/2010 states that, in order to consider the supply chain "short", the final energy plant should not be located more than 70 km far away from the biomasses production site, as the crow flies. Nevertheless, the only geographical criterion still does not seem sufficient to describe the multitude concerning the social dimension, governance dynamics and the public utility, all of them related to the short – and sustainable, supply chain concept (Masiero *et al.*, 2013).

2. Objectives

Starting from this framework, this paper is organized in two parts aimed at providing complementary information.

In the first part, Italian import flows of woody biomasses suitable for energy use are analyzed over the period 1991-2011. Here, the main objective consists in giving detailed information on current and past import trends, since these data had not been analysed and presented in such a format so far.

In the second part the environmental impact of the import flows has been estimated in terms of CO_2 and CO_2 equivalent (CO_2, CH_4 and N_2O) emissions. This estimation has been limited to 2010. A Life-Cycle Analysis (LCA) has been performed, considering all life-cycle phases of the imported woody material, combustion for energy production (heat or electricity) included. The aim of this analysis is to determine whether, and to what extent, the increased transport distance reduces the environmental sustainability of these materials with respect to conventional fossil fuels. Finally, a comparative LCA has also been made considering the ongoing import flows and a hypothetical local supply chain.

The main goal of this section is to finally reject the pretended unsustainability of imported woody biomasses in comparison with traditional fossil fuels, even though they originate from Countries far away from final consumption sites. Secondly, the analysis aims to estimate the possible further lowering of green-house gases (GHG) emissions that a shorter transportation system would allow, compared with the current longer ones. A qualitative discussion concerning some issues that should induce the policy system to prefer and implement short supply chain comes along with these quantitative estimations.

3. Material and Methods

3.1. Import flows

For the import flows analysis, data were taken from the ISTAT (Italian National Institute of Statistics) website and more precisely from Coeweb, the section dedicated to statistical data related to the Italian trade with foreign countries. Five good-categories were identified[1] but they were grouped in three different categories for easier understanding: chips and particles, wood fuel (firewood) and wood residues.

Coeweb database was queried to obtain for every year of the 1991-2011 period the list of exporting countries and, for each of them, the volume and the value of that flow. Temporal patterns of these trade flows were also investigated, both in a category-specific and in an aggregated way. Furthermore, quantitative flows were divided according to the geographical supply area: European Union countries (EU-27) or extra-EU countries. In order to homogenize the series, EU-27 data have been considered since 1993, namely before the actual entry into the Union of certain countries (EU-25 in 2004, EU-27 in 2007). Economic values have been expressed in real terms, referred to the year 2011, using annual coefficients provided by ISTAT on consumer prices for families of workers and employees. The average unit price of the imported materials has been obtained from the ratio between economic values and quantitative amounts.

Temporal patterns (quantitative stability, duration, diversification) of supplying countries have been investigated. Only the most interesting results will be discussed: among others, the recent appearance of "anomalous" quantitative

[1] We considered the products classified under the "Harmonized System" (HS) with the codes: 440121, 440122, 440110, 440130 and 440500.

flows and the progressive increase in the number of countries exporting woody biomasses to Italy, both occasionally and stably (namely, on the basis of an empirical criterion, those countries supplying material for ≥ 4 consecutive years).

Throughout the 1991-2011 period, for every quantitative flow of each good-category, the Gini index and Herfindahl-Hirschman index have been calculated. Values of both concentration indexes range from 0 to 1. The Gini index measures the quantitative homogeneity between different flows: value 0 indicates an equidistributed situation, i.e. when every supplying country exports the same amount; value 1, instead, proves the maximum possible dishomogeneity, i.e. just one exporting country. The Herfindahl-Hirschman index is usually used to express the market power of firms, in relation to the size of the market, as an indicator of their competitiveness. In this case, the index is defined as the sum of squared market shares of each exporting country, where shares are expressed as a fraction of the total. Note that, by squaring market shares, the final index value is strongly affected by countries with high export amounts. Low index values mean a large number of supplying countries with small market shares, whereas values close to 1 indicate high concentration levels, up to the single exporting country situation (value = 1).

3.2. Life-Cycle Analysis

Emissions of greenhouse gases (CO_2 and CO_2 eq.) related to woody biomasses importation have been estimated for the year 2010; the analysis has been limited to flows responsible for 95% of the total imported volume, for each good-category: therefore, countries from which Italy imports very small amounts of the total were excluded.

In order to perform the life-cycle analysis, the software "GEMIS" (Global Emission Model for Integrated Systems, implemented by Öko-Institute.V. Darmstadt), version 4.7, has been used. Some data and coefficients reported in the literature have also been used. Analyses were carried out by using already defined flows, processes and their combinations (systems) available in the GEMIS database. When necessary, links between different processes and system boundaries have been modified, in order to obtain specific emission values for each life-cycle phase, instead of a single final aggregated value.

With regards to wood fuel, emissions related to silvicultural treatments, cutting and storage were considered. In this case, in GEMIS emissions are expressed as CO_2 and CO_2eq. kilograms emitted per unit (1 kg) of produced dry matter (d.m.). Emissions also differ according to the tree species. So, beech and spruce were selected as representative of deciduous and coniferous species, respectively. Therefore, the quantitative shares of hardwood and softwood were assumed to be equal to those precisely provided by ISTAT for chips and particles (HS codes: 440121 and 440122). In order to calculate the exact amount of dry matter, it was assumed that the imported wood fuel had a 20% moisture content.

The same processes were considered for chips and particles and a 30% moisture content was assumed. In addition, emissions related to the chipping process (99% efficiency) were calculated. In this case, emissions in GEMIS are expressed as CO_2 and CO_2eq. kilograms produced per unit of processed energy (1 MWh), in relation to the low heating value of wood chips (kWh/kg).

Emissions related to wood residues can be split in two parts, namely those identified by the two HS codes adopted (440500 and 440130). No emissions have been referred to sawdust production (440500). Instead, for the other part (440130), emission coefficients indicated by Elsayed*et al.* (2003) in *Carbon and energy balances for a range of biofuel options* were used (transport share has been subtracted). The cited work doesn't provide emission coefficients for gases other than CO_2. So CO_2 eq. emissions were obtained assuming CO_2 emissions equal to 91.9% of the total amount; this share was chosen in analogy with the chipping process.

Various combustion processes were used that differ by their efficiency rate, fuel needed, output provided and process power: 10 kW for wood fuel or 1 MW for chips and wood residues for thermal energy production and 30 MW for chips and wood residues for electricity production. In addition, CO_2 eq. emissions were estimated for a cogeneration process (51.3% thermal energy and 48.7% electricity as outputs): in this case power equals 14 MW and chips and particles and wood residues are used as fuels.

Then, for each good-category, emissions related to the transportation phase were added. In order to make the estimation possible, it was necessary to identify and/or to hypothesize some basic variables, like the departure point within the national boundaries of each exporting country, the final (arrival) destination in Italy, the distance covered and the means of transport.

Due to the impossibility of having a detailed map that identifies timber-supplying areas for every country, the departure point of wood produced in European countries (extensive geographical criterion) was assumed as corresponding to the geographical barycentre of each country. In order to individuate geographical coordinates, the GIS-software AdBToolBox, Version 1.6.4., was used. If necessary, the departure point has been approximated to the nearest available roadway (maximum distance as the crow flies: approx. 5 km). In the case of extra-European origins, a departure port has been identified for each country on the basis of geographical criteria and with regard to the prominence of the eligible ports in the national maritime trade. In this case geographical barycentric coordinates were not adopted due to the high probability that chips and wood residues production takes place in facilities located near the port, while firewood export flows to Europe are close to zero.

Geographical barycentric coordinates were used also to identify the final destination in Italy, on a regional basis, in order to allocate imported quantities among the Regions.

Table 1 - *Combination between ports and Italian Regions in case of maritime transport.*

Regions	Harbours	Railway terminals
Valle d'Aosta, Piemonte, Liguria	Genova	Torino Orbassano
Lombardia	Genova	Milano Certosa
Trentino Alto Adige, Veneto	Venezia	Verona Quad. Eur.
Friuli Venezia Giulia	Trieste	Verona Quad. Eur.
Emilia Romagna	Ravenna	Bologna Interporto
Toscana	Piombino	Livorno Guasticce
Umbria	Ancona	Livorno Guasticce
Marche	Ancona	Bologna Interporto
Abruzzo	Ancona	Pescara PortaNuova
Molise	Napoli	Pescara PortaNuova
Lazio	Civitavecchia	Roma Smistamento
Campania	Napoli	MaddaloniMarcianise
Basilicata	Taranto	MaddaloniMarcianise
Puglia, Calabria	Taranto	Bari Ferruccio
Sardegna	Olbia	Livorno Guasticce
Sicilia	Messina	Gela

Firewood distribution was based on data provided by the *Final report on estimated firewood consumption for heating and domestic use in Italy* (APAT-ARPA, 2009) and, in the case of values referred to macro-regions (e.g. Triveneto), the individual regional values were obtained by weighing Regions according to their population (data provided by I-STAT, 2010). The regional distribution of chips and particles and wood residues was instead based on the "Import of wood and wood products" index, provided by ISTAT and updated to 2007. For maritime transport, arrival ports have been chosen as those with the greatest "solid bulk goods" flows (data provided by CONFETRA, 2009) and assuming that they should be reasonably close to the final regional destination. Applying these two criteria, the port-Regions combinations shown in Table 1 were found.

The overall transportation distance has been calculated on the basis of the means of transport presumably used. According to a study conducted by the *Fraunhofer Institute for Material Flow and Logistics*, "road-rail" intermodal transportation is cost-effective (and convenient) for distances above 300 km (Eiband, 2009). Assuming this break-even point as reliable, we evaluated each flow to identify which transportations would be intermodal, by using common distance-calculator tools available on-line. So, with transportation distances below 300 km, only road-transport has been considered, whereas with longer distances an intermodal road-rail transport has been considered. Table 1 shows a combination between rail terminals and Italian Regions, identified on the basis of geographical proximity. In the case of maritime transport, the transportation distance has been estimated as the shortest route between the departure and arrival ports. Both for rail and maritime transport, the final transportation by truck from the arrival port or rail terminal to the final regional destination has been added, increased by a fixed 50 km value in order to account for the initial collocation of the material at the departure terminal. Table 2 summarizes the procedure adopted in the transport distance identification for each import flow and the respective means of transport considered. In order to calculate emissions related to the material transportation, coefficients provided in 2010 by the British *Department for Environment, Food and Rural Affairs* (DEFRA) were used. They indicate the CO_2 and CO_2 eq. amount (kg) emitted carrying one material unit (1 ton) for one kilometre, with respect to different means of transport. They refer to a >10,000 tons deadweight cargo ship, a diesel/electric train and to an articulated truck whose emissions correspond to the mean of emissions produced by articulated vehicles of different tonnages (from 3.5 to 33 t). All coefficients express the sum of direct and indirect transport-related emissions ("all scopes" option).

The same road-transport emission coefficient has been used to estimate how many emissions would be produced by transporting the same biomass amount over a 100 km distance. The difference between the emission amounts related to the long- and short-distance transportation corresponds to the emission increase due to importing biomasses over long distances, instead of implementing local supply systems and short distribution chains.

Finally, the differences between the emissions produced by using fossil fuels and imported woody biomasses, for the same amount of energy production, have been estimated. This comparison has been performed both for thermal energy and electricity production, by making use of appropriate processes available in GEMIS database. Oil and natural gas were the fossil fuels considered for the thermal energy production processes, while coal and natural gas were adopted in the electricity production processes. Cogeneration process has been excluded in this evaluation due to the lack of similar or comparable processes involving biomasses and fossil fuels in GEMIS.

Table 2 - *Summary of adopted transport-related assumptions.*

Departure Continents, geographical areas and Countries	Distance	Transport vehicle	Departure place	Fixed distance (Km)	Intermediate destination	Arrival destination
America (N/S), Africa, Australia, Albania, Serbia, Bosnia-H,Spain to Sardinia/Sicily	Whatever	Ship	Port *(ad hoc)*	50	Italian port *(ad hoc)*	Regional geographic barycentre
Europe	>300 km	Train	National geographic barycentre	50	Railway terminal *(ad hoc)*	Regional geographic barycentre
	<300 km	Truck	National geographic barycentre	0	-	Regional geographic barycentre

4. Results

4.1. Import flows

Temporal patterns and trends of quantitative Italian imports of firewood, wood residues, and chips and particles show that flows of each category have strongly increased since the beginning of the investigated period. They also suffered an appreciable drop between 2005 and 2008 (Figure 1). After that rapid

Figure 1 - *Imported quantities for each product-category.*

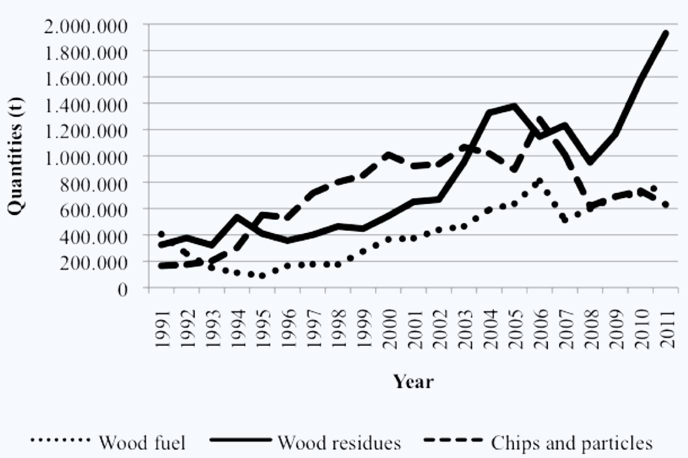


Figure 3 - *Italian imports: cumulated quantities and economic values.*

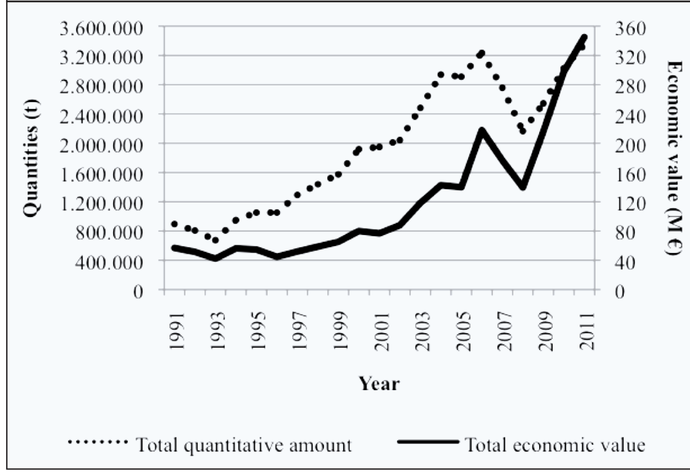


Figure 2 - *Imported economic values (in 2011 real terms).*

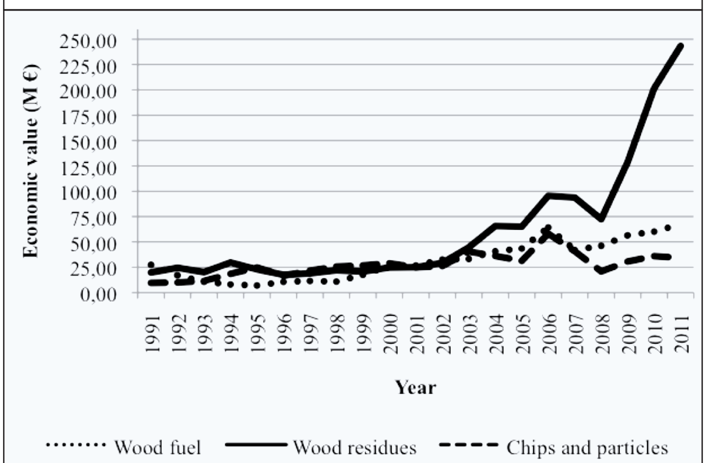
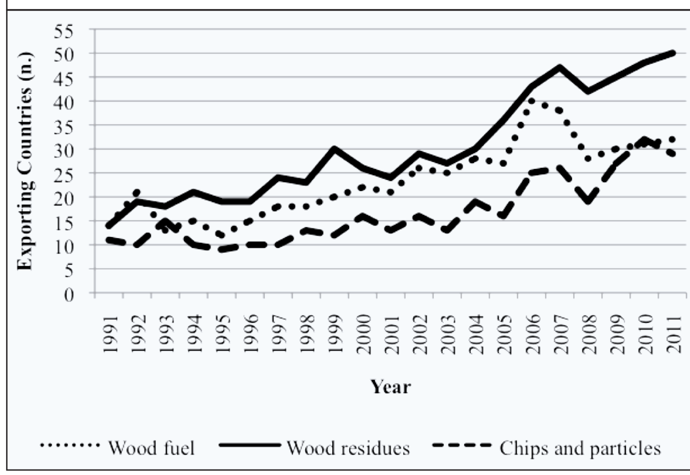


Figure 4 - *No. of countries supplying solid bioenergy products.*



decrease, wood residues and firewood had a new positive growth trend. Wood residues import flows increased in a particularly marked way: indeed, in 2010 and 2011 they reached their maximum historical value. The increase of wood fuel import flows was less marked, nevertheless the current import volumes are close to the maximum value recorded in 2006. The recovery of a growth trend appears more uncertain for wood chips and particles imports.

Some explanations of these trends include the increasing costs of conventional fossil fuels and the public incentive policies to support the use of renewables. Furthermore, biomass-based energy plants and stoves are becoming more competitive thanks to the developments of burning technologies and more advanced distribution channels. Also the long-term trend in cost reduction through substitution of solid wood with reconstructed panels is stimulating the demand for chips and low-quality wood raw material.

Similarly to the quantitative flows, economic import values (expressed in real terms referred to the year 2011) also significantly increased over the period (Figure 2). Economic values of wood residues started to sharply increase after the 2006-2008 downturn; in 2011 they reached their highest historical value; the highest value was also recorded for firewood but, in this case, the increase was less marked. Also for economic values, recovery after the 2006-2008 decrease is more uncertain for chips and particles than for the other two good-categories.

The average unit values (€/t) of imported materials (2011 real-term values) increased for each good-category: this means that the growth of unit values was faster than the increase in imported quantities. This current trend is the opposite to that for chips and particles and wood residues in the first half of the time series. The fact that the economic increase has been more significant than the quantitative one is demonstrated by Figure 3. The historical peaks of both economic and quantitative aggregated values were registered in 2011.

It is interesting to analyse the concentration and diversification processes of Italian trading partners: the number of supplying countries increased over the time series (Figure 4). The share of woody biomasses imported from EU-27 countries has a negative trend, as shown in Figure 5: the average value decreased from about 90% of the total amount in

Figure 5 - *Imports from EU-27 Countries in respect to the total import: product-categories (black lines) and total average value (grey line).*

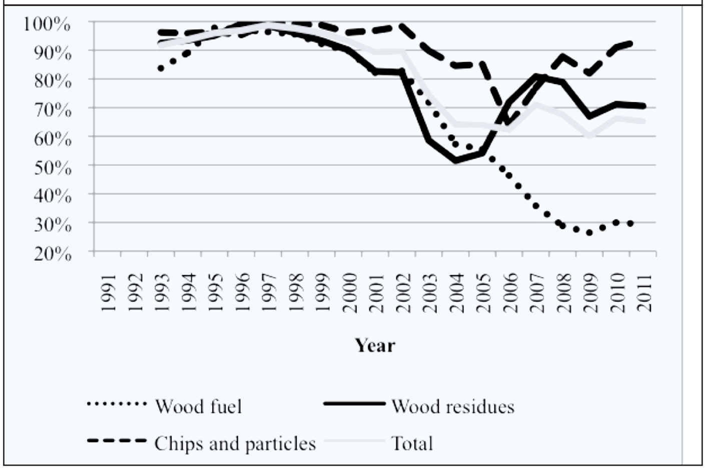
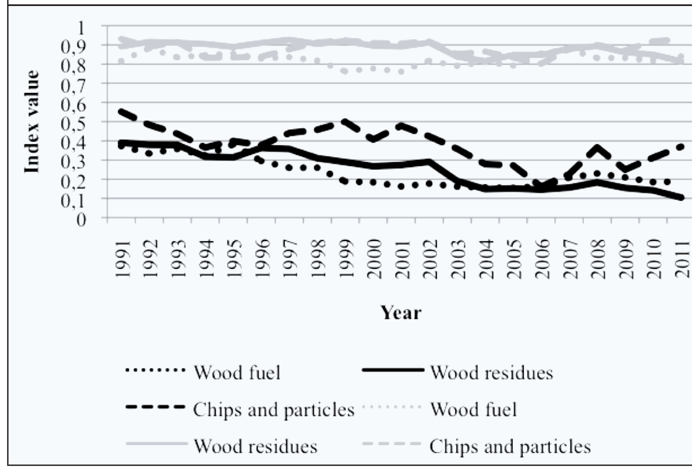


Figure 6 - *Trends by each product-category of the value of Gini Index (grey lines) and Herfindahl-Hirschman (black lines).*



the early 1990s to the present value of about 65%. However, the overall trend is influenced by the good-category specific ones: a progressive decline is particularly noticeable for firewood.

The Herfindahl-Hirschman Index and Gini Index displayed different trends over time, as shown in Figure 6: Gini Index, although fluctuating, remained broadly stable over the time series, whereas Herfindahl-Hirschman Index actually dropped, rising again recently to an appreciable extent only for chips and particles.

With regard to the duration of trade relationships between Italy and each supplying country, an increase in "stable" relations (lasting for ≥ 4 consecutive years) has been detected for wood residues and chips and particles. In the meantime, the total number of countries from which Italy imports the woody biomasses also gradually increased. A quite relevant turnover in business partners has only been found for wood fuel: their number globally increased, but several past partnerships have been discontinued and new ones established.

An interesting phenomenon has been detected concerning the quantitative flow stability of each exporting country over time. Since 2003, several countries have had sudden "peaks" in export flows, especially with regard to wood residues and chips and particles. The "average flow" of these countries is usually characterized by low quantities and economic value. Nevertheless, they have suddenly increased their exports for a single year or for a maximum of two consecutive years, then immediately returned to the usual low quantities. In some cases, these peaks were sufficiently abnormal to make the respective flow first for importance in that single year, in both quantitative and economic terms. For example, in 2005 the United States provided 24.4% of total Italian wood residues imports, but no more than 0.1% in 2006. It has been noted that this phenomenon usually occurs for extra-European countries.

4.2. Estimation of emissions

For each good-category, CO_2 and CO_2 eq. emissions (t) produced during the life-cycle were estimated. These estimations refer to the phases prior to combustion (Table 3 – section A) in addition to the combustion phase, considering both thermal energy and electricity production processes and also a cogeneration process (Table 3 – section B). Emissions related to the entire life-cycle of different fossil fuels are listed in Table 4.

Comparisons were made between life-cycle emissions of fossil fuels and woody biomasses; they seem to be particularly favourable to the latter, as shown in Table 5.

Finally, emissions related to the biomasses supply were estimated, both in the situation of long-distance import and assuming that the same amount of imported material was subject to a 100 km transport distance, covered by truck. In the first case total emissions amounted to 132,704 CO_2 eq. tons and 124,932 CO_2 tons, whereas in the case of local supply chain these amounts lowered to 31,037CO_2 eq. tons and 30,684 CO_2 tons (Table 3 – section C).

Table 3 - *Emissions produced by each biomas life-cycle phase.*

Section A – Emissions produced prior to combustion (t)					
	Kind of emissions	**Sylvicultural operations**	**Chipping process**	**Transport**	**Total amount prior to combustion**
Wood fuel	CO_2 eq.	9,076	-	30,962	40.038
	CO_2	8,715	-	29,205	37.920
Chips and particles	CO_2 eq.	8,521	9,234	36,138	53.893
	CO_2	8,182	8,491	34,039	50.712
Wood residues	CO_2 eq.	27,086		65,603	92,689
	CO_2	25,067		61,688	86,755
Cogeneration (Chips + Residues)	CO_2 eq.	44,841		101,741	146,582
Section B – Biomasses: combustion phase-related emissions					
Fuel	**Energy produced**	**Low heating value (kWh/kg)**	**Power**	**Efficiency (%)**	**CO_2 eq. emiss. (t)** / **CO_2 emiss. (t)**
Wood fuel	Heat	4,033	10 kW	67.0	38,465
					10,882
Chips + Residues	Heat	3,496	1 MW	85.0	92,856
					76,812
Chips + Residues	Electricity	3,496	30 MW	34.9	29,257
					10,146
Chips + Residues	Cogeneration	3,496	14 MW	59.9	36,273

Section C – Emissions related to biomasses transportation (t)					
	Kind of emissions	**Wood fuel**	**Wood residues**	**Chips and particles**	**Biomasses total amount**
Real assumed transport. (ship, train, truck)	CO_2eq.	30,962	65,603	36,138	132,704
	CO_2	29,205	61,688	34,039	124,932
Short transportation (100 km by truck)	CO_2eq.	7,323	16,120	7,594	31,037
	CO_2	7,240	15,937	7,507	30,684
Difference (Real T. – Short T)	CO_2eq.	23,639	49,483	28,545	101,666
	CO_2	21,965	45,751	26,532	94,248

Table 4 - *Fossil fuels and energy typology: emissions across the whole life-cycle.*

Fossil fuels: complete life-cycle emissions					
Energy produced	**Fuel**	**Low heating value (kWh/kg)**	**Power**	**Efficiency (%)**	**CO_2 eq. emiss. (t)** **CO_2 emiss. (t)**
Heat	Methane	(35,584)	10 kW	(86.0)	548,311 486,189
	Gas oil	(11,842)	10 kW	(85.0)	699,067 691,295
	Methane	(35,584)	1 MW	(87.5)	2,009,220 1,793,243
	Gas oil	(11,842)	1 MW	(85.0)	2,597,952 2,563,348
Electricity	Coal	(7,639)	700 MW	(45.4)	2,491,714 2,347,682
	Methane	(33,801)	450 MW	(57.0)	1,159,254 1,072,711

Table 5 - *Emissions produced by fossil fuels and woody biomasses during their entire life-cycle.*

Comparison between life-cycle emissions: fossil fuels vs. biomasses		
Energy produced	**Comparison**	**Δ CO_2eq. emissions (t)** **Δ CO_2 emissions (t)**
Heat	Σ(methane emissions) – Σ(biomasses emissions)	2,239,590 2,016,351
	Σ(oil emissions) – Σ(biomasses emissions)	2,979,078 2,991,562
Electricity	Coal emissions – Σ(chips + residues emissions)	2,275,837 2,162,149
	Methane emissions – Σ(chips + residues emissions)	943,377 887,178

5. Discussion

5.1. Import flows

The data clearly indicate a strong increase in Italian import flows of woody biomasses suitable for energy purposes: their total amount, both quantitatively and economically, is currently at the highest historical value. Nevertheless, in the first five years of the last decade, import economic values increased more than quantitative flows, so the average unit value increased. Wood residues had the strongest increase: the trend is still rising, as well as the trend for firewood. Increase of chips and particles imports has been on high levels until 2005 but, contrary to what happened to the other two good-categories, chips and particles did not establish a new, well-defined growth trend after the 2006-2008 drop.

The number of supplying countries also increased over the period and, moreover, trade partnerships were established with new countries. The Gini Index indicates that import flows continued to differ a lot in quantitative (and economic) terms over the time. In other words, different flows in homogeneity remained high. In the meantime, as suggested by the Herfindahl–Hirschman Index trend, the market share of the main supplying countries reduced over time.

A significant increase of woody biomasses imports from foreign countries raises doubts about the ability of Italy to secure economically and quantitatively stable supplies in the medium and long term. In fact, it has been suggested that European timber demand could exceed the internal supply capacity by 2025 (Mantau *et al*, 2010). As a consequence, the biomasses amount placed on the international market could reduce, due to the priority of some currently exporting countries to satisfy their own domestic needs: the competition in the purchase of materials could increase, as well as prices, resulting in a further escalation of the existing conflict between the wood processing industry and energy sector.

Data provided by EUROSTAT in 2009 also contribute to raising concerns about the increasing Italian imports from foreign countries: in 2005, forest areas available in Italy for wood supply covered 8,922 M ha, with an estimated annual increase of 38,320 M m^3 (average: 4.3 m^3/ha). At the same time, wood harvested amounts were found to be 10,105 M m^3, equivalent to only 26.4% of the annual increase. Even in the case of a marked underestimation of forest operations with respect to those actually carried out (Corona *et al*, 2007), margins for increasing domestic wood supply would remain very wide.

5.2. Estimation of emissions

The results suggest that the use of the total woody biomasses amount in energy production processes would be responsible for the emission of 317,941 CO_2 eq. tons, of which 263,081 t referred to CO_2. By using chips and particles and wood residues in the cogeneration process, despite the lower efficiency, 182,855 CO_2 eq. tons would be emitted, namely 56,583 tons less than using those biomasses just for thermal energy production. At the same time, using them in an electricity production process would cause the emission of 175,839 CO_2 eq. t (147,613 CO_2 t): in this case, the emission value is particularly low thanks to the emission-reduction systems required for and implemented by such power plants.

Estimates indicate that the use of imported biomasses, rather than traditional fossil fuels, permits an emission-saving value between 0.88 and 2.9 M CO_2eq. tons, depending on different energy-generating processes and the elements of comparison adopted. Therefore, the emission-saving value resulting from the replacement of fossil fuels is well able to justify the woody biomasses importation, regardless of the transportation distance.

The difference between emissions produced under the supposed import conditions (distance, means of transport) and those related to a transport distance of just 100 km equals 101,666 CO_2 eq. tons (94,248 CO_2 t). This value indicates that the longer transport distance of imported biomasses than that of a local supply chain, has a major impact on the total life-cycle emission amount. However, this effect is not significant in relation to the emission saving achieved by replacing fossil fuels with imported woody biomasses in energy production processes: the order of magnitude of this saving alone is in fact generally higher than that of the increased environmental burden due to the longer transport distance.

6. Conclusions

This paper highlights that Italian import of woody biomasses for energy purposes strongly increased over the period 1991-2011, in both quantitative and economic terms. Wood residues is the good-category most affected by the import increase. The number of supplying countries gradually increased, while the share of imports from EU-27 countries has been shrinking. Recently, single exporting countries, particularly non-EU ones, have shown abnormal export activities. Some forecasts for the European woody biomasses market predict a demand exceeding available domestic supply by 2025 (Mantau *et al*, 2010). This fact and other economic, social and environmental considerations suggest that the increasing Italian dependence on foreign supplies for its own woody biomass procurements is inappropriate.

Estimates indicate that longer transportation distances greatly affect the total CO_2 and CO_2 eq. emission amounts with respect to those produced by a shorter supply chain. However, in the case of imported biomasses, this heavier environmental burden is not sufficient to conclude that replacing traditional fossil fuels with biomasses in energy production processes is not environmentally sustainable. These results suggest that, in the debate concerning imported biomasses, perhaps excessive attention is given to the "ecological footprint" of the transportation phase. In fact, the energy efficiency (in addition to the economic efficiency) of some transportation systems, e.g. maritime transport, usually on specialized cargo ships, enables transport over long distances with no strong effects on transport-related emissions. Truck transportation is instead characterized by the opposite situation: increasing transport distances lead to higher emissions. Thus, in promoting short supply chains, it seems preferable to place stress on different considerations related to wood supply security in the medium- and long-term.

First of all, the advisability of improving internal, small-scale supply has to be considered, since the domestic wood harvesting rate is by far lower than the annual increment – as already mentioned in this paper. In addition, it is worth to recall that domestic timber resources are mainly located in marginal rural areas, with frequent processes of land abandonment. In these areas, the development of integrated strategies based on a more intensive use of forest resources is most needed, so as to mitigate the severe issues due to wildfire recurrence, insect outbreaks, snow and wind throws.

Interestingly, the Italian Framework Programme for the Forestry Sector (MIPAAF-INEA, 2008) already considers many of these matters. Nevertheless, the Plan represents a theoretical document aiming to make different regional policies uniform and homogeneous. However, it does not have a binding nature, and the lack of a consistent and harmonized strategic vision still remains a weakness of the Italian forestry sector policy. The on-going programming exercise for the Rural Development Plans (2014-2020) of the Italian Regions and Autonomous Provinces is a challenging opportunity to achieve a better coordination of targets and measures. The forthcoming new European Union Forest Strategy and solid biomass supply criteria will create an improved and more concrete policy frame for this much needed coordination.

Finally, it should be stressed that 345.08 M € (2011 value) could be saved in the national economic balance if local supply chains would be activated, thus replacing current biomasses importation flows. Unfortunately, a lot of energy plants (even the recent ones) that use biomasses in their energy production processes are located in close proximity to port facilities: this fact seems not to be in line with the abovementioned considerations.

References

APAT-ARPA Lombardia, 2008. *Stima dei consumi di legna da ardere per riscaldamento ed uso domestico in Italia. Final Report*. Agenzia per la Protezione dell'Ambiente e i Servizi Tecnici-Agenzia Regionale per la Protezione dell'Ambiente della Lombardia Milano. ARPA Emilia-Romagna, 2011. *Risultati dell'indagine sul consumo domestico di biomassa legnosa in Emilia-Romagna e valutazione delle emissioni in atmosfera*. Agenzia Regionale per la Protezione dell'Ambiente, Bologna.

Casalini E., 2010. *Biomasse di massa*. Reportage, "REPORT" broadcast, Rai 3 channel, 31/10/2010. http://www.report.rai.it/ dl/Report/pun tata/ContentItem-9dbca710-20ea-42d0-b4c4-2cf34c2f54c0.html

CONFETRA, 2009. *Traffici merci nei principali porti italiani 2008-2009 (Assoporti data-source).*

Corona P., Giuliarelli D., Lamonaca A., Mattioli W., Tonti D., Chirici G., Marchetti M., 2007. Confronto sperimentale tra superfici a ceduo tagliate a raso osservate mediante immagini satellitari ad alta risoluzione e tagliate riscontrate amministrativamente. *Forest@*, 4(3): 324-332.

DEFRA, 2010. *2010 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting.*

Eiband A., 2009. *Market analysis for shifting of goods from road to rail by means of combined transport in Germany*. Fraunhofer Institute for Material Flow and Logistics. Prien am Chiemsee, Germany.

Elsayed M.A., Matthews R., Mortimer N.D., 2003. *Carbon and energy balances for a range of biofuels options.* Sheffield Hallam University, Sheffield. European Commission, 2011. *Proposal for a regulation of the European Parliament and of the Council on support for rural development by the European agricultural fund for rural development (EAFRD).*Brussels, Com(2011) 627final.

Fondse M., Wubben E., Korstee H., Pascucci S., 2012.The economic organizations of short supply chains. *126thEaae Seminar "New challenges for EU agricultural sector and rural areas. Which role for public policy?", 27-29/06/2012, Capri.*

Forest Stewardship Council, 2009. *FSC Glossary of Terms.*

Standard FSC-STD-01-002 (V1-0) EN. https://ic.fsc.org/down load.fsc-std-01-002-v1-0-en-fsc-glossary-of-terms.a-1129.pdf.

Gerardi V., Perrella G., 2001. *I consumi energetici di biomasse nel settore residenziale in Italia nel 1999*. Roma: ENEA.

Gerardi V., Perrella G., Masia F., 1998. *Il consumo di biomassa a fini energetici nel settore domestico.*RT/ERG/98/9. Roma: ENEA.

Mantau U. (ed.), 2010. *Real potential for changes in growth and use of EU forests*. *Final report.* Hamburg, Germany: EU wood Project.

Masiero M., Andrighetto N., Pettenella D., 2013. Lineeguida per la valutazione sistematica della filiera corta delle biomasse legnose a fini energetici. *Agriregionieuropa*, 9(33): 74-78. http://www.agriregionieu ropa.univpm.it/dettart.php?id_articolo =1048

MIPAAF-INEA, 2008. *Programma quadro per il settore forestale*. Roma. http://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/ID Pagina/416

MSE, 2010. *Piano di azione nazionale per le energie rinnovabili dell'Italia (conforme alla direttiva 2009/28/CE e alla decisione della Commissione del 30 giugno 2009)*. Roma: Ministero dello Sviluppo Economico.

Paniz A., 2012. Italia: leader europeo per produzione e vendita di stufe a pellet. *Agriforenergy*, 4(1): 17-19.

Pettenella D., Andrighetto N., 2011. Le biomasse legnose a fini energetici in Italia: uno sleeping giant? *Agriregionieuropa*, 7 (24).

Rowe R., 2013. *Has the EU fallen for Congo rainforest logging scam?* Reportage on BBC website. http://www.bbc.co.uk/ news/world-africa-23358055

Tomassetti G., 2010. Dati ufficiali, ufficiosi, prevedibili sulle biomasse ad uso energetico in Italia a fine 2010 e sulla copertura degli impegni al 2020. *Economics and Policy of Energy and the Environment*, 3: 45-60.