Energy wood: A challenge for European forests

Potentials, environmental implications, policy integration and related conflicts

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Aim, methods and structure of the report

This report is based on the state-of-the-art review developed by the author for the project titled "COmpeting uses of fOrest Land-COOL" (http://content.cool-project.org/). The COOL project focussed on challenges and new demands on the European forest sector derived from the increasing attention towards energy wood produced by forests, and on the consequent forest use competition, as well as on the future of integrative and segregative policy and forest management approaches developed to deal with such competition. The collection of information by the author of the current report was aimed at building up a background information-base for the international team of the project (http://content.cool-project.org/partner) and in particular for the peer review publications which are produced as outputs. The information included in this report provides an overview on current trends in European forests with respect to the production and use of woody biomass for bioenergy production, on the related policy framework, and on the competition with other forest ecosystem services.

This report was drafted after an in-depth literature review of i) EU legislation, policy documents and guidance manuals, ii) reports and websites of research projects and studies carried out at the European and national levels, iii) peer review articles, iv) monographs, and iv) published communications from stakeholders involved in the environmental, forest and energy sectors. In analysing these data sources, attention was focussed on the elements which characterize the context of bioenergy production from wood sources in Europe, as well as on factors determining other forest-related factors. Examples of these factors are: forest biodiversity conservation, forest environment protection, tourism in forests, role of forests in tackling climate change, rural economic development, and wood market. The analysis of these factors gives an insight into the economic, ecological and social functions of European forests and their interrelations; the analysis is used in this report to identify trends in the broad scenario of bioenergy production from forest wood sources. Moreover, this report was informed by interviews carried out with European level stakeholders including policy makers, representatives of Non-Governmental Organizations and scientists (see the Acknowledgements section for more details). The interviews were aimed at identifying and documenting the personal and institutional opinion of relevant actors with respect to several issues related to the production and use of forest energy wood, including: current and future trends and perceived changes, trade-offs and synergies between energy wood production and other forest ecosystem services, and the legislative and policy framework regulating the context at stake.

The report is structured as follows: Section 1 includes background information which introduces the renewable energy theme and it locates the use of woody biomass for bioenergy in the context of renewable energies; Section 2 describes and discusses several studies on forest energy wood potentials; Section 3 focuses on the trade-offs and synergies associated with the production and use of forest energy wood; Section 4 illustrates the legislative and policy framework affecting the forest energy wood context; Section 5 discusses the integration of forest energy wood and biodiversity conservation policy goals in the European

Union’s policy; Section 6 reports general conclusions on the challenges presented by the production and use of forest energy wood. The attachments list references, acronyms, figures, tables and boxes used in the report, and describe the expertise of the reviewers which validated the information included in the report.

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- Forest Research Institute Baden-Württemberg, Germany
- EFICENT, Germany
- Finnish Forest Research Institute (METLA), Finland
- Department of Forestry and Renewable Forest Resources, Biotechnical faculty, University of Ljubljana (ULJ), Slovenia
- Forest Sciences Center of Catalonia (CTFC), Spain
- Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences (UMB), Norway

This report benefited from insights provided in six interviews carried out with key actors involved in the forest and energy sectors at the European level, and representing important stakeholders affected by or interested in the forest energy wood topic. The actors interviewed are:

- Robert Flies (European Commission, Directorate General Environment)
- Tatu Liimatainen (CEPF- Confédération Européenne des Propriétaires Forestiers)
- Veerle Dossche (FERN- European level forest environmental Non-Governmental Organization)
- Hans Verkerk (European Forest Institute)
- Ernst-Detlef Schulze (Max-Planck-Institute for Biogeochemistry)

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Executive Summary

The production and use of forest energy wood are amongst the topics that receive increasing attention in the renewable energy context, not only from policy makers, scientists and stakeholders of the energy sector, but also from stakeholders and interest groups representing other sectors like agriculture, forestry, environment, industry and consumers. Indeed, forest biomass is characterized by several features which can be considered beneficial in the European context. These include security of domestic supply, more limited reliance on fossil energy source imports, as well as the possibility to diversify the energy mix in the European Union.

From a policy perspective, forest biomass – as a renewable source of energy which is able to reduce greenhouse gas emissions compared to fossil fuels – is one of the strongholds of the strive towards the policy targets established by the European Union within the so-called "2020 climate and energy package": increasing the share of renewable energy to 20% of gross domestic energy consumption (10% of the share of renewable energy should be made up by biofuels); and reducing greenhouse gas emissions by 20% with respect to 1990 levels by the year 2020. The idea that energy wood reduces greenhouse gas emissions is called the "carbon neutrality" assumption and it holds true when considering that the biomass extracted from the forest and burned in the energy generation process is in the long run replaced by new biomass growth in the forest, which re-absorbs the carbon emitted by the energy generation process. In this sense, the carbon emitted when generating energy from wood is perceived as staying in the atmosphere for a rather short time frame. Instead, the carbon emitted when using fossil fuels is destined to stay in the atmosphere for a very long time because its recovery time is much slower. From an economic perspective, forest energy wood allows for a diversification of forestry production, for the creation of a market for low value wood, and for the increase of forest owners' income. From a social perspective, forest biomass for energy is a means to improve the development of rural areas and to increase employment rates.

As well as the positive features characterizing the production and use of energy wood from forests, important negative implications can be identified. For example, the production of forest energy wood may conflict with forest biodiversity conservation and nature protection goals. This is because the intensified forest management approaches needed for forest energy wood production are likely to negatively affect specific features of the forest environment which are important for the achievement of environmental goals (e.g. deadwood availability in the forest, length of rotation periods, forest soil status and nutrients, water quality, forest composition). The production of forest energy wood may also conflict with social issues related to the forest environment. These can include the presence of tourism and recreational activities and the reliance by forest owners on traditional forest management approaches and wood mobilization patterns. Finally, the use of energy wood as a renewable source of energy may conflict with climate change mitigation goals when considering the effects of burning wood on greenhouse gas emissions. These effects may exceed those of using fossil energy sources in the short term. Indeed, the climate neutrality assumption described in the previous paragraph is considered by many to be valid only in the long term, while in the short term the

extraction of forest biomass and related carbon from the forest temporarily reduces the amount of carbon immobilized in European forests – representing a “carbon debt” which needs to be repaid. Also, when emitted during energy generation processes, the carbon will spend some time (even if short) in the atmosphere contributing to exacerbating climate change effects.

This description shows that the production and use of energy wood are at a cross-roads amongst different interests. They are associated with economic, social and environmental trade-offs and synergies. These features contribute to the description of the forest energy wood topic as complex and intricate. This complexity has resulted in a complex and intricate policy and legislative framework affecting the forest energy wood context. At EU level, renewable energy, climate, biodiversity, forest, agricultural and resource efficiency policies and policy instruments influence the production and use of energy wood, and try to steer an increase in both demand and supply of this energy source. The overlapping of sectoral policy objectives in the forest energy wood context results in a complicated matrix of policy goals which in some cases generates policy conflicts which need to be dealt with.

This report aims to shed light on the above described context, and it is made up of five interconnected sections directed at investigating relevant issues for a better understanding of the challenge represented by forest energy wood in Europe. Section 1 reports background information on forest energy wood, locating it in the more general energy context. It makes clear that the increasing attention towards forest energy wood is due to the fact that this energy source allows reduces reliance on non-renewable energy production and use paths, while being characterized by some disadvantages which make its production and use controversial in some instances. This section introduces the EU 2020 climate and energy targets, and the main rationales behind the reliance on forest energy wood in the strive towards these targets, which for example comprise the availability of an unutilized wood reservoir in European forests due to wood extraction rates below forest annual increment. Moreover, this section generally addresses the technologies employed for the production of energy from forest biomass, picturing this energy source as an important element of diversification for all three energy sectors (heath, electricity and transport).

Section 2 addresses the European Union’s forest energy wood potential, by presenting an overview on the most outstanding studies which calculate and estimate current and future potentials. These include for example the BioFuture, the EUwood, and the EFORWOOD studies. The section makes clear that great differences exist among the estimates, which for example for the year 2020 range between about 0.9 and 3.9 EJ/year for the 27 states of the European Union. These large differences in estimates are due to varying methods used in the studies, for example: different definitions of forest energy wood, and different wood assortments included in these definitions; the different aims of the studies and in particular their varying focus on either the energy wood demand side or the supply side or the “wood resource balance” (the last one assessing both production and consumption and taking into account inter-sectoral trade flows and cascade uses of wood); the different measurement units employed; and the different time periods for which the energy wood potential estimation is calculated. The differences amongst the estimates are also due to different assumptions and uncertainties taken into account. These assumptions may include e.g. increased emphasis on nature-oriented forest management approaches, nature conservation or the protection of the water-soil system in forests. These are accounted for as potentially limiting the area available for energy wood production. Uncertainties concern, for example, the effects of climate change on European forests' productivity and the market competition of energy wood with other wood uses and with other renewable energy sources. Section 2 also reflects on the fact that the limitations to forest energy wood production and use and the uncertainties affecting the studies of energy wood potential well mirror the intricacy of the forest energy wood topic. Moreover, these limitations and uncertainties well characterize the drawbacks of producing and using forest energy wood, which in Section 1 are set against the advantages of relying on this energy source. It is concluded that studies on forest energy wood potential in the European Union should adopt precautionary approaches when accounting for uncertainties, and prefer a focus on the supply rather than on the demand side. This would allow avoiding negative consequences of overestimating such a potential. An overestimation could translate in the need to import wood from countries outside the EU- potentially reducing the role of wood in increasing security of energy supply, reducing energy imports and developing sustainable energy paths.

Section 3 deepens the reasoning on the limitations to and implications of energy wood from forests, by investigating the social, economic and environmental trade-offs and synergies associated with energy wood. It describes the production and use of energy wood as two-fold issues: on the one hand, they present opportunities for economic growth, social development and environmental protection; on the other hand they have negative implications, which affect the importance of forest energy wood as a valuable alternative to fossil fuels. From an economic perspective, for example, forest energy wood allows differentiating rural economy and represents a chance for forest owners to increase their income. However, an increased production of energy wood might generate a competition with pulp and paper industries for low value wood assortments which could indirectly and negatively affect the economy of rural areas. From a social point of view, energy wood production might increase employment opportunities but could reduce the touristic attractiveness of forests.

Section 3 also focuses in particular on the analysis of the environmental trade-offs and synergies linked to energy wood production and use. The relations between energy wood production and use and environmental forest functions (like biodiversity conservation, soil and water protection, climate change mitigation and forest fire management) are analyzed to identify mutual beneficial or negative effects, and to propose possible solutions for the conflicts that are detected. It is highlighted that forest management approaches aimed at the production of energy wood should focus on strengthening existing environmental synergies between this production and the other forest functions. These synergies include for example forest fire protection, safeguard from attacks by forest pests and pathogens, conservation of a balance in soil nutrients (for example in soils with high nitrogen deposition), and in some instances support of biodiversity and water quality. Also, forest energy wood related practices should aim at embedding different forest functions and ecosystem services in order to address environmental conflicts and consequent trade-offs associated with forest energy wood production. This can be accomplished by compromising between economic and environmental interests, for example: avoiding energy wood production in sensitive forests characterized by poor soils or high biodiversity levels; leaving adequate amounts of deadwood and trees with cavities in forests to support biodiversity; avoiding soil compaction by carrying out energy wood extraction at the same time as other traditional forestry operations, and by preferring periods in which the soil is dry or frozen to enter the forest with heavy machinery. The pursuit of such compromises in the European context should be supported also in the face of increasing demand for energy wood and possible intensification of forestry activities.

Section 4 addresses the policy framework which represents the legislative and policy background to the forest energy wood topic. The section first presents an extensive overview of the legislation and instruments affecting the production and use of energy wood from forests, which touches several policy areas amongst which forest, agriculture, resource efficiency, construction and building, energy, industry, and environment. Subsequently, the section presents an in-depth analysis of four main EU policy areas that affect the forest energy wood context, namely a) the policy efforts which in this report are joined under the label "forest policy", b) agricultural policy, c) energy policy and d) biodiversity policy. Even if the European Union has no legislative competences in forest-related matters, it has produced non-legally binding policy instruments like the Forest Strategy and the Forest Action Plan which potentially affect the production of forest energy wood. Instead, the other policy areas addressed are mainly exogenous to the strict forest context, but are as influencing for the forest energy wood topic. In particular, the Common Agricultural Policy through its Rural Development Regulation finances forestry measures and forestry-related activities involved in the production of wood for energy, and it ultimately determines the availability, types and costs of forest woody biomass. Renewable energy policy deploys its main effects on the forest energy wood context through the EU Renewable Energy Directive 2009/28/EC, which stimulates demand for this energy source. Finally, biodiversity policy affects the production of energy wood from forests by limiting the production of forest energy wood to the extent to which this production does not affect the conservation of endangered habitats and species. The analysis of these policy areas shows that the topic of forest energy wood is given increasing attention in the instruments and legislations characterizing them, especially after the establishment of the 2020 climate and energy targets by the European Union. Agriculture and energy policies are the areas where references to forest energy wood have appeared most frequently. These two policy sectors nowadays address forest energy wood rather broadly and meaningfully, even if space for improvement can be detected in both contexts. "Forest policy" is also currently taking forest energy wood into account to a considerable extent, but the frequency with which this topic is mentioned is lower than in agriculture and energy policies. Finally, biodiversity policy presents a rather low consideration of forest energy wood topics. This is surprising in particular when considering that forest ecosystems are the ones hosting higher levels of biodiversity in Europe, and they are therefore the most abundant habitat types represented within the ecological network Natura 2000. The low consideration of forest energy wood in biodiversity policy is not commensurate to the importance of the conflicts identified in Section 3 between biodiversity conservation and energy wood production.

Section 5 examines in particular the case of biodiversity policy and its corresponding legislation, in order to shed light on the reasons behind a low consideration of the energy wood topic in this body of legislation. The aim is to identify the extent to which biodiversity policy sectoral goals like the conservation of endangered habitats and species in a favourable status are integrated with forest energy wood production goals at European level. In particular, this section focuses on the persisting policy conflicts between energy wood production and biodiversity conservation in the forest environment, which are perceived as potential precursors of problems in the simultaneous achievement of biodiversity conservation and energy wood production goals in forest management. Section 5 concludes that the lack of prioritization of potentially competing policy goals at European level is likely to exacerbate exiting policy conflicts and forest management trade-offs. This can be linked to the functioning of the subsidiarity principle on which relations between European Union and Member States are based, and which prescribes that Member States take policy actions in all matters (such as biodiversity conservation and forest management) which are not the direct competence of the European Union. In such a context, the leeway to integrate biodiversity policy goals into objectives of the economic use of forests remains with the Member States. It is concluded that in the face of the current economic crisis that there is a risk that the environmental functions of the forest may be given a lower emphasis than the economic functions in development of forest policy and in forest management objectives.

Section 6 reports the general conclusions on the issues treated by the current report. It reflects on the complexity of the forest energy wood topic by presenting the implications of the environmental considerations and policy concerns raised. The section contributes to describe the forest energy wood topic as a controversial issue which is not free from policy and practical conflicts. It raises attention towards the precautions that need to be taken when focussing on energy wood as a possible substitute for fossil energy sources. Recommendations are listed which can be employed when undertaking energy production and utilization paths based on forest energy wood as source of energy. These recommendations are directed towards scientists and policy makers who deal with the forest energy wood topic, and include suggestions for scientific research on the topic and on policy decision making. Examples are the need to focus studies on forest energy wood potential on sustainable implementation potentials, which reflect the main practical limitations to forest energy wood production and use; and on the mutual relations between various synergies and trade-offs associated with forest energy wood production and use, in order to better understand the underlying relations amongst competing and synergistic forest functions. With respect to policy making, coherence and coordination should be improved amongst policies affecting the forest energy wood context at the EU level, by a) prioritizing competing policy objectives at EU level, and by b) better including forest energy wood related matters in policies which are relevant for the energy wood context. Emphasis should be given to biodiversity policy. The policy enthusiasm towards the opportunities offered by forest energy wood will need to be weighed against the likely negative implications linked to the practical matters of forest energy wood production and use, in order not to substitute a currently unsustainable fossil based energy path with similarly unsustainable renewable energy solutions.

1. Background information

Reviewed by Benjamin Engler

During the last decades, the renewable energy topic has received increasing attention not only from policy makers, scientists and stakeholders from the energy sector, but also from stakeholders and interest groups representing other sectors like agriculture, forestry, environment, industry and consumers (UNECE/FAO 2012; AEBIOM 2014; Union of Concerned Scientists 2012; Coolproducts 2014; International Energy Agency 2011). The main reason for this widespread interest is that different stakeholders perceive as problematic the implications of the path undertaken by modern societies with respect to energy use, which is based on a very high consumption of energy often retrieved from non-renewable energy sources or imported, and on a limited efficiency of energy use (Birdlife, Greenpeace, EEB, Client Earth and Fern 2012). Global energy consumption grew by 15% between 1990 and 2000 and it is expected to grow with higher rates in the future, exacerbating the negative consequences of the undertaken energy path (EC 2004). For the European context, the European Commission (EC) listed a set of challenges regarding the current situation of energy use in the European Union (EU) (EC 2006):

- Need of strong investments to replace ageing infrastructures;
- Need to increase energy efficiency (to slow down increasing energy demand);
- Rising energy import dependency;
- Increasing demand for energy which is expected to result in increased carbon dioxide (CO_2) emissions and intensification of climate change effects;
- Rising oil, gas and electricity prices;
- Lack of a fully competitive EU internal energy markets, which hampers the possibility of enjoying security of energy supply and low prices.

These pressing issues, together with the dangers linked to nuclear energy, have fostered the need to reduce dependency on non-renewable energy sources (including coal, oil, natural gas and nuclear energy) and substituting these sources with renewable ones, and namely i) biomass, ii) solar power (thermal, photovoltaic and concentrated), iii) hydro-electric power, iv) tidal power, v) geothermal energy, and vi) wind power (onshore and offshore) (EC 2011b). Despite the numerous advantages offered by the use of renewable energy, e.g. diversifying the energy mix and reducing greenhouse gas (GHG) emissions, there are also several drawbacks. Those include the need to adjust infrastructures and to deal with limitations to available biomass. Table 1 presents a comparison of some of the pros and cons of renewable versus non-renewable energies.

Table 1. Pros and cons of using non-renewable versus renewable energy sources. Sources: EC, 2004; 2012; Ragwitz et al. 2006; Muench and Guenther, 2013.

	Non-renewable energy sources	Renewable energy sources
Pros	• Infrastructures are already in place and suppliers and distributors are already organized. This generates low extraction and distribution costs • Existing infrastructures guarantee broad geographical availability • The possibility to have continuous energy supply attributes ability to satisfy the base load of energy plants • Plants are mostly set where the energy is demanded, so the produced energy is transported over relatively short distances	• Worldwide more homogenously distributed • With the right precautions it is easier to generate sustainable paths of energy use and endless energy provision • Contribution to ensuring security of supply by diversifying energy mix • By reducing greenhouse gas emissions, they contribute to tackling climate change and improving air quality • Creation of new job opportunities • Increase of export possibilities • Plants are mostly set where the energy source is located or available and the input resources are subject to short transportation distances
Cons	• Limited availability, which makes it hard to establish sustainable energy utilization paths • Limited geographical distribution of the energy sources • Pollution, greenhouse gas emission and negative consequences for environment and health • Import dependency • Plants are mostly set where the energy is demanded and the resource/energy carrier (e.g. crude oil or coal) is mostly transported over long distances	• Need to update infrastructure and re-organize suppliers and distributors to allow a broad geographical diffusion • Expensive extraction • Energy provision is widely dependent on time of the day, time of the year and weather conditions. Energy can therefore not be produced constantly and there are constraints in the ability to satisfy the base load of energy plants • Small amount of biomass energy sources available, especially under northern continental climate where most industrialized countries are located • Often energy cannot be generated where it is demanded. Plants are mostly set where the energy source is located or available and the output energy needs to be transported over rather long distances to the place of utilization.

In the face of the unavoidable environmental and social dangers posed by non-renewable energy sources, the EU embraced the responsibility of increasing the share of renewable energy in its territories (EC 1997). Amongst the other renewable energy sources, the exploitation of biomass – and of woody biomass in particular – attracted policy attention for being one of the most important factors of energy consumption mix diversification in the EU (EC 2004; EC 2009; International Energy Agency 2011). The importance of biomass in the energy context is due especially to its security of supply. Biomass has been described as "the largest single renewable energy source in absolute terms" (EC 2009, p.9), counting for 84% of gross domestic consumption of renewable energy in the early 2000s (Karjalainen et al. 2004). In 2005 biomass constituted the largest source of renewable energy in the EU-25, accounting for about 66%, and wood represented 89% of the biomass (Hetsch et al. 2008). In 2012, the total supply of wood for energy in the EU was about 1 billion m^3, corresponding to 8500 PJ (Petajoule; $1PJ=1\times10^{15}$ joules). About 70% of this amount came from forests and 30% from outside forests (Mantau et al. 2010). With respect to woody biomass, different categories of resources can contribute to the supply of renewable energy: i) industrial wood residues, ii) forestry residues – including woody material left in the forests during roundwood removals, iii) complementary fellings – stemwood biomass from maintenance operations such as thinning and their residues, iv) short rotation forestry plantations, v) wood from trees outside the forests and vi) recycled wood (EEA 2007). Forestry residues, wood industry residues and short rotation energy crops are the most important energy sources for the production of solid fuels. Complementary fellings could also represent a substantial source of bioenergy, but their utilization suffers from the competition from other more traditional uses of wood such as construction wood (Karjalainen et al. 2004; EEA 2007).

Policy attention toward woody biomass from forests as a resource which can help reaching EU energy targets is justified by the fact that the EU forest area has increased by 8% in the 50 years prior to 2004 (Gold cited in Karjalainen et al. 2004). Moreover, the roundwood balance – defined as difference between net annual increment in forest wood (total increase of stem volume during a year minus natural losses) and actual fellings – has been positive during this time period, suggesting that European forests host a reservoir of wood which could be used in the future (Karjalainen et al. 2004). This wood reservoir in past and present time was and is mostly left in the forest due to technical (e.g. excessive slopes and lack of efficient mechanization) and non-technical (e.g. missing forest owners' willingness to extract increased wood volumes) barriers to its mobilization (UNECE/FAO 2007; Schmithüsen and Hirsch 2010). At present, only 60–70% of the annual increment is being harvested, and the remaining amount could be made partly available for satisfying increasing and competing demands for wood (EEA 2005; EEA 2007). Projections reveal that wood harvest rates are expected to increase by about 30% by 2020 as compared to 2010 (EC 2013b), in order to satisfy the multiple and multifaceted demands towards this resource. Nowadays wood remains the main source of income for forest owners around Europe. Forest-based industries represent 7% of added value of total manufacturing in the EU and provide around 3 million jobs (EC 2013c). Next to being a source for bioenergy, wood from forests is a renewable material for construction, it is used to produce paper, it has positive effects for nature conservation representing important habitats for biodiversity maintenance, and it provides opportunities for recreation increasing forests' likability to visitors (Mantau et al. 2010; EEA 2005, 2007). Therefore forests are an important resource which are often underestimated (EC 2013b). The above highlights the future likely competition between the sectors that will contend the wood reservoir hosted in European forests. The industrial sectors that will compete for this resource are represented in Figure 1. It is noted that, for example, for the energy sector wood resources come partially from forests and partially from industrial residues and wastes (cascade use). Moreover, other sectors will enter the competition such as forest biodiversity conservation and forest recreation.

Despite this competition, research suggests that it will be possible to sustain the future needs of woody biomass if policy principles will be applied to foster efficiency of use, reduction of wastes, mobilization of resources and respect for the environment (Hall 1997; Larson and Kartha 2000; EEA 2006; Ragwitz et al. 2006; Cornelissen et al. 2012).

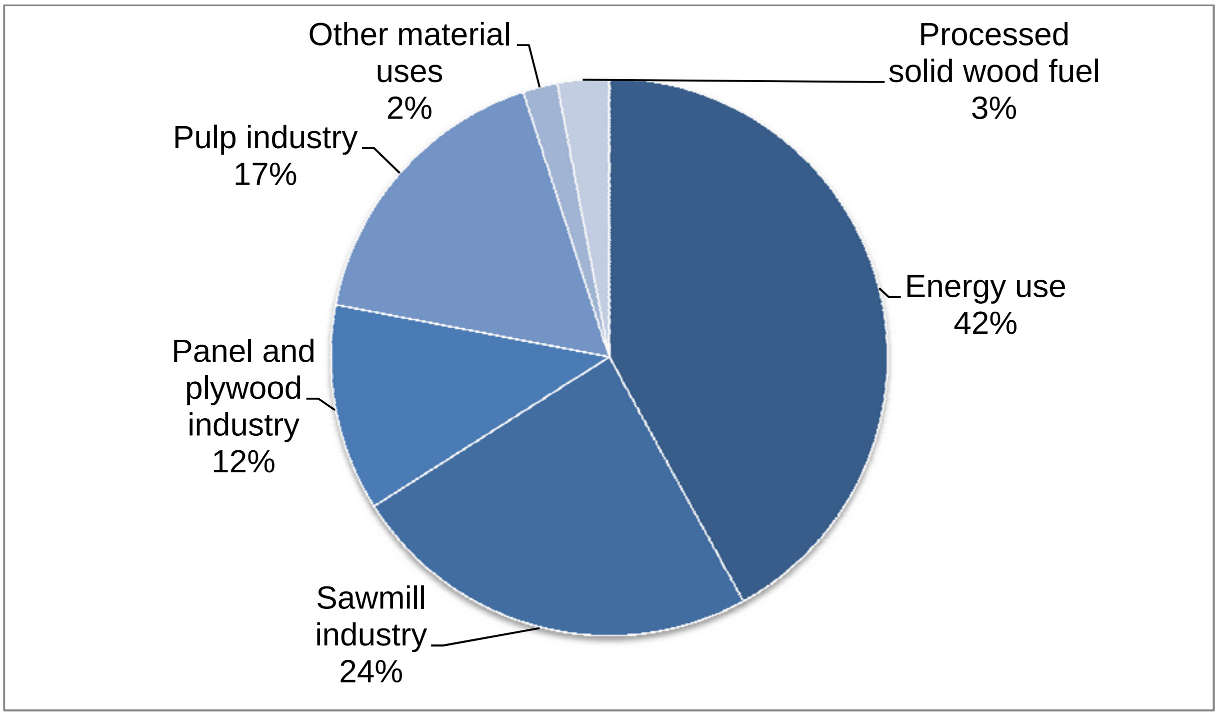

Figure 1. Wood use in EU27 in the year 2010, including cascade use. Adapted from Mantau et al. 2010.

The contribution of wood to the total renewable energy consumption in the EU amounted to around half in 2005, and it is expected to increase to about two-thirds in the future (EEA 2005). In particular, the EU Member States (MSs) expect to mobilize extra domestic biomass resources for heating and electricity generation and to increase the amount of biomass destined to these industries from 76 Mtoe in 2006 to 113 Mtoe in 2020. It is expected that forests will remain the main source of wood in this context (as shown in Figure 2) and that in the same time-frame wood contribution would increase from 62 Mtoe to 75 Mtoe (EC 2013c).

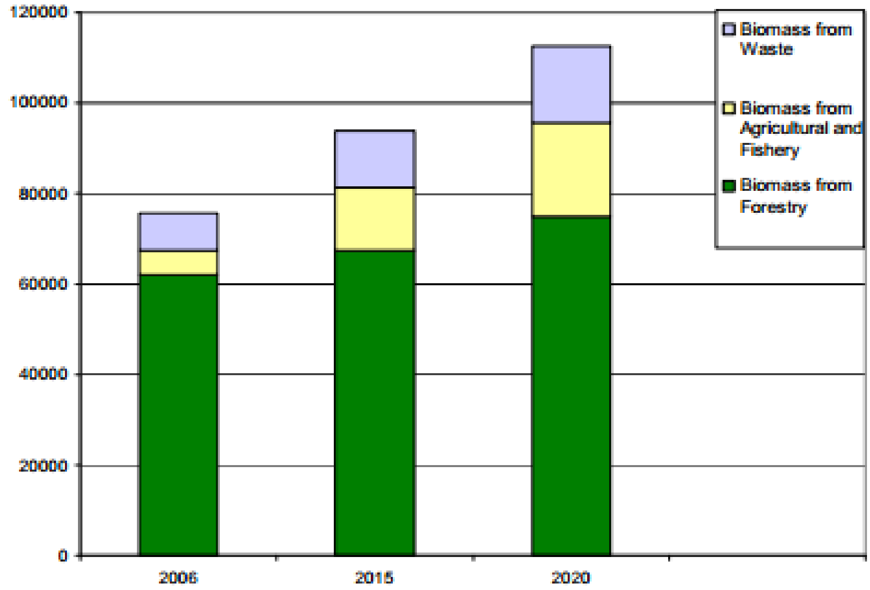

Figure 2. EU domestic biomass supply (in ktoe) for heating and electricity calculated for the year 2006 and estimated for the years 2015 and 2020. Source: EC, 2013c p. 38

Current technology provides several options for conversion of woody biomass into energy, including direct combustion for power generation, repackaging of biomass in pellets to use for private heating, or co-firing for power generation in combination with large-scale district heating (Faaij 2006). Moreover emerging technologies like biomass pyrolysis and gasification stimulate interest in the production of methanol, ethanol, syngas and biodiesel from wood (Fernholz et al. 2009; Van Loo and Koppejan 2008). As can be deduced from this description, woody biomass can be employed in all three energy sectors (electricity, heating and transport). Wood currently dominates the heating sector, but its importance is destined to grow also in the transportation sector (through second generation biofuels made from lignocellulosic biomass or woody crops, agricultural residues or waste) and in the electricity sector (through diffusion of district heating and Combined Heat and Power (CHP) plants, and the use of wood to produce methanol as a hydrogen source for hydrogen fuel cells generated electricity) (EC 2005; Vogt et al. 2005). For the electricity sector, district heating works with rather low emissions compared to other heating technologies, combust more types of fuel and can therefore be alimented with different types of wood resources. If a heat sink is available in the plant, CHP plants can provide heating and electricity at the same time, optimizing the use of wood for bioenergy production and reducing environmental impacts (EC 2005).

For the transportation sector, second generation biofuels have a better quality than conventional diesel since the fuel characteristics can be designed according to the requirements of the activity in which the fuel is used. They can secure a higher market share for biofuels by allowing a wider variety of raw material as source, and potentially reduce GHG emissions by limiting the inputs necessary to the cultivation of the prime cellulosic material (if compared to traditional agriculture and first generation biofuels) (EC 2005). With respect to the production of methanol and other biofuels, “wood is a higher-quality starting material” compared to other agricultural crops because of wood’s more consistent chemical composition, which results in high efficiency of conversion to by-products (Vogt et al. 2005). For example, about 40-50% of the initial energy stored in the biomass can be converted to biofuels, e.g. via Fischer-Tropsch- or Methanol-Synthesis (Dahmen et al. 2012). The process efficiency strongly depends on the by-products use, and can be increased by e.g. included heat and power generation (Dahmen et al. 2012). Moreover, compared to energy crops, wood has the advantage of not competing with food resources. This holds true if considering existing forests or afforestation of non-arable lands, but not in the case in which arable lands are afforested and managed with short rotation forestry approaches (see also Box 2 in Section 2.1 for more details on short rotation forestry).

In 1997 the EU made the commitment of increasing the share of renewable energy to 12% of gross domestic energy consumption by 2010. This objective was entitled the “2010 renewable energy target” (EC 1997). This target was not achieved at the EU level in the set time-frame. The contribution of the EU MSs to the achievement of the target has been variable (see Box 1). According to the EC (2004), one of the reasons for not achieving the 2010 renewable energy target is that the production of electricity from biomass was not as high as foreseen in the studies underpinning the target. While wind and solar energy grew rapidly between 1996 and 2004, energy from biomass and in particular biomass electricity grew slowly and intermittently. Other reasons are the limited number of MSs having invested in renewable energy, and the limited variety of technology used to achieve the 2010 target (EC 2009). Moreover, the existence of non-technical and non-market barriers (e.g. the lack of consumer information on the origin of renewable energy sources, the complexity of administrative procedures and the lack of connection of the renewable energy systems to the traditional electricity grid) hampered EU efforts to increase the percentage of renewable energy used in its territory. Finally, the lack of a strong regulatory framework for renewable energy in the European context also played a role (EC 2011c).

Box 1. Contribution of selected EU MSs to the 2010 renewable energy target. (EC, 2009)

Only a few EU MSs reached the 2010 renewable energy target in their national contexts within the due time-frame (e.g. Germany, Hungary, Spain and Finland). None of these countries experienced biomass as driver of the growth in renewable energy share. Only in Finland, Denmark and Germany did biomass grow steadily in the analyzed period. For all the other EU countries the contribution of biomass to the share of renewable energy was intermittent or very slow. The unexploited biomass potential is especially relevant for countries from Central East Europe like Hungary, Czech Republic and Slovakia.

In response to the failure to reach the 2010 renewable energy target, the EU committed to a more rigorous and ambitious goal: increasing the share of renewable energy to 20% of gross domestic energy consumption by 2020 (Directive 2009/28/EC). The "2020 renewable energy target" is part of a robust regulatory framework for renewable energy sources, the so-called Renewable Energy Directive (EU-RED) (Directive 2009/28/EC). The EU-RED imposes legally binding national targets which support the achievement of the communitarian 2020 renewable energy target. These compulsory targets substitute the voluntary character of the 2010 target, which have been detected as one of the reasons for not having achieved the renewable energy goals. Recent communications by the EC (2011c; 2012) report that MSs are on track with respect to the 2020 renewable energy target, as also shown in Figure 3.

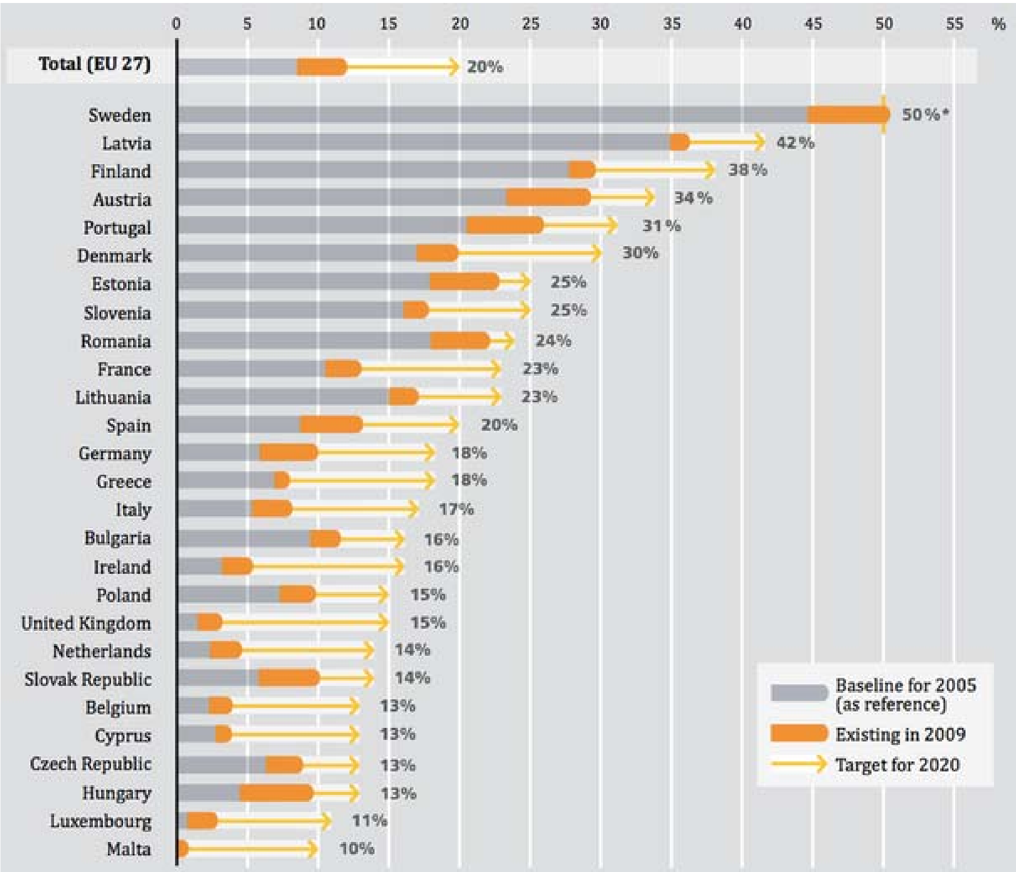

Figure 3. EU renewable energy shares for the years 2005 and 2009, with targets for 2020. Source: REN21 2014

According to an assessment of the forecasts included in the national Renewable Energy Action Plans developed by MSs to comply with the EU-RED, all MSs will reach the 2020 national targets. Some will even exceed the targets thus being able to export renewable energy to other EU MSs (EC 2011c). In the 2020 projections, biomass will remain the dominant renewable source of energy in the heating sector, and will account for 50% of the growth.

Despite the positive projections of EU MSs and the actual increase in the share of renewable energy between 1999 and 2009 (growing from 5% to 9%; EC 2011d), the EC warns about gaps in the renewable energy context which still need to be addressed, and which might represent an obstacle to achieving the 2020 renewable energy target. Examples of these gaps are the fragmentation of internal energy markets, the existence of different national laws and state support schemes for renewable energy sources which hamper market harmonization, and delays in investments and technological progress (EC 2010). A strong commitment by MSs and the application of their national Renewable Energy Action Plans will be instrumental to implementing the national projections on renewable energy share and achieving the 2020 renewable energy target, insofar as "the price of failure is too high" (EC 2010 p. 2).

Notwithstanding the political commitment of the EU in reforming the energy policy context, the financial support provided for supporting the achievement of the 2020 renewable energy target is rather low. The EU dedicated €9.8 billion in the period 2007–2009 to this sector. A big portion of this amount has been provided as loans from the European Investment Bank (EC 2011c). Here follows a list of some of the funds made available by the EU to co-finance the renewable energy sector and in particular energy wood production and use (EC 2011c; EC 2013c):

- European Energy Programme for Recovery which, in light of the economic crisis, financially assists the energy sector through grants especially dedicated to the use of renewable sources, increased carbon sequestration and promotion of energy efficiency (Regulation EC No 663/2009).
- European Research and Technological Development programmes, funding and supporting research in the EU. These funds can be used to finance technological research progress in the bioenergy field.
- EU Strategic Energy Technology Plan expenditures, which promote investments in renewable, safe and sustainable low carbon technologies through a well organized plan of actions.
- Horizon 2020 and the European Innovation Partnership which support the development of research and innovation actions.
- Intelligent Energy Europe Programme which supports sustainable projects in the bioenergy sector.
- Structural Funds and Cohesion Funds, which support regional development in the EU reducing disparities amongst EU regions.
- Rural Development Fund, which is a tool to rural development in the EU.
- Revenues derived from the EU Emission Trading Scheme.
- Funds managed in collaboration with the European Bank for Reconstruction and Development and the European Investment Bank.

Due to requests by stakeholders involved in the energy sector for receiving information on the "after 2020" scenario (EC 2012), the EU elaborated an Energy Roadmap 2050 (EC 2011). The Roadmap conveys a low carbon economy based society for the period after 2020, which is built on the single energy market. Current state financial help to renewable energy producers will be gradually reduced. State incentives to renewable energy producers are seen to be essential for building a renewable energy market in the EU. Once this market is established, however, state incentives to producers might undermine investor confidence in the energy sector, and for this reason need to be gradually reduced in order to reach a single energy market in the EU. Moreover, state support provided by MSs creates a complex picture of incentives. It makes the renewable energy context different in each EU country. This situation prevents market operators from one MS from investing in another MS, and prevents market operators from border countries investing in the EU energy sector (EC 2012). The reduction of state incentives will have the goal of exposing investors to market prices and increasing market competition. Energy efficiency will regulate the market, with the producers of most efficient technologies leading the scene, and consumer choice making a difference (EC 2012). However, for the period after 2020 some state support will still be needed in order to support the establishment of a strong market. The EC is proposing the New Entrants Reserve (NER) 300 scheme, which employs auction revenues from the EU emission trading scheme to finance innovative renewable technologies (EC 2012). NER 300 is so named because it is funded from the sale of 300 million emission allowances held in the NER of the EU Emissions Trading Scheme (EU-ETS) – for more information on this EU policy see Table 14 in Section 4.1. The carbon market and the renewable energy market, which already now present strong linkages, will become more and more entangled in the post 2020 scenario. In general, the EU-ETS (Directive 2003/87/EC), which sets the target of reducing GHG emissions by 20% by 2020, is described as an important driver promoting renewable energy (EC 2011c).

2. Energy wood potential in Europe

Reviewed by Tobias Cremer

2.1 Introduction to the study of energy wood potential

The achievement of EU policy goals for the coming years requires a more intensive and efficient utilization of woody resources in order to strengthen the contribution of energy wood to the European energy share (EC 2005; EC 2006b). Even though several studies show that European forests include a reservoir of wood that is currently unexploited (Karjalainen et al. 2004; Asikainen et al. 2008; Verkerk et al. 2011), it is essential to know how much of this reservoir is potentially and realistically available in the EU for energy generation. EU energy wood potential is conditioned by environmental, social and economic issues that vary according to the types of woody biomass considered and the types of assessments carried out. This section aims at providing an overview of the most recent studies on energy wood potential in Europe, and to draw conclusions based on their lessons learned. The studies have been selected based on their frequent citations in the broad array of literature on the topic.

An overview of relevant studies on energy wood potential has been carried out by the Biomass Energy Europe project (http://www.eu-bee.com/). The project dealt with studies estimating the potential of all biomass sources at the global, European, national and regional levels (Rettenmaier et al. 2010). Its scope goes beyond mere energy wood potential but the project provides interesting considerations. For example, Rettenmaier et al. (2010) identified four different types of biomass potential for energy production that can be taken into account when assessing resource availability:

- "Theoretical potential": maximum amount of terrestrial biomass theoretically available for energy production within bio-physical limits;
- "Technical potential": fraction of theoretical potential available under technologic and structural possibilities (which also consider competition with other land uses and ecological constraints);
- "Economic potential": share of technical potential which is economically profitable;
- "Implementation potential": fraction of economic potential implementable under concrete socio-political conditions (which also take policy incentives into account).

It goes without saying that assessments of differently defined biomass potentials give different quantitative results. The choice of the biomass potential to estimate depends on the objectives of the study which is being carried out, and on the users of the resource assessment (Rettenmaier et al. 2010).

In addition, a fifth type of biomass potential has been identified by the Biomass Energy Europe project, namely the "sustainable implementation potential", corresponding to the fraction of the technical biomass potential which can be developed without opposing the general principles of sustainable development – for example, without causing social or ecological damage (Rettenmaier et al. 2010). Different sustainability criteria and limitations can be applied in the definition of this type of potential, and even if the sustainable implementation potential would be relevant for the sustainable achievement of the EU 2020 target (Rettenmaier et al. 2010), its determination remains rather arbitrary and can increasingly complicate the picture of the existing biomass resource assessments.

Among the studies analyzed in the Biomass Energy Europe project, several deal in particular with energy wood potential. They apply a great variety of approaches and come to very different quantifications of the above-mentioned potential. For example, some studies use a resource-based approach, focussing on total resource availability and competition among different resource uses. Other studies use a demand-based approach, estimating for example the amount of biomass needed to reach renewable energy targets. Finally, a recently introduced approach called “wood resource balance” assesses production and consumption and takes into account inter-sectoral trade flows and cascade uses of wood (Smeets et al. 2010). Next to the variability in approaches, also a variety of methods can be identified. Indeed, some of the studies on EU energy wood potential use estimates based on mathematic functions, others use literature review methods, and again others use modelling techniques. All these methods take into account different economic, social and environmental factors for the calculation of the energy wood potential.

Available studies on energy wood potential differ also with respect to aspects such as (Rettenmaier et al. 2010):

- The geographic scale taken into account. With respect to Europe, some of the studies focus on national contexts, while others focus on EU-15, EU-25 or EU-27 contexts.
- The type of wood resource assessed and the definition of woody biomass categories. In the specific case of energy wood, some of the studies include all wood sources while others include only the wood retrievable from forests. Some studies consider short rotation forestry (SRF) and short rotation coppice (SRC) areas in the analysis of forest energy wood potential, while others exclude them. SRF and SRC are described in Box 2 together with some information on their role in the calculation of energy wood potentials.
- The time scale considered. Some studies focus on current potential while others estimate future wood potentials for the years 2020, 2030, 2040 or 2050.
- The terminologies and quantitative units used.

Box 2. Short Rotation Forestry, Short Rotation Coppice and energy wood potential. Sources: Kärkkäinen et al. 2013; McKay 2011; Dallemand et al. 2007; de Wit and Faaij 2010; Berndes et al. 2003; Mantau et al. 2010; LTS International 2006

SRF consists in the establishment of a forest plantation of fast-growing trees at such a spacing that it quickly fill the available space, and then felling the trees when they reach an easily harvestable size (between 10 and 20 cm). Similar plantations rely on short tree growth cycles and trees reach their economically optimum size between 8- and 20-years-old. Managing SRF plantations requires highly mechanized and frequent interventions in the plantations. SRF is usually carried out on lower-grade agricultural land, previously forested land or reclaimed land. Because of its similarities with agriculture (it needs closer management interventions than regular forestry and stronger anthropogenic inputs like fertilizers), SRF is often labelled as agricultural activity and in many EU MSs it is not addressed by forest policies and guidelines but rather by documents developed for the agricultural sector. As a consequence, also many studies on energy wood potential exclude SRF and SRC wood from the quantification of the forest resources available for energy generation.

SRC is a sub-type of short rotation forestry encompassing woody species (especially willow, poplar, robinia and eucalyptus which are the most suitable) to be cut down at the stem and re-sprout. The stands are harvested several times (every 2 to 6 years) in a short rotation regime of 20-30 years.

SRF and SRC are an important source of wood material which is often chipped and used for energy generation.

SRF and SRC currently cover a rather limited portion of European land (in 2010 these plantations covered about 30 000 ha), but their coverage is expected to increase as is their contribution to the energy industry. SRF is described as one of the wood related sectors with the greatest potential for expansion The combined potentials of three SRF and SRC species (poplar, willow and eucalyptus) were estimated to be 4.4 EJ/y, 7.2 EJ/y and 9.5 EJ/y for the years 2010, 2020 and 2030, respectively.

Because of these important differences, energy wood estimates can differ visibly amongst studies. For example maximum estimates of energy wood potential in one study can be several times higher than the minimum estimates in other studies (Rettenmaier et al. 2010). Table 2 shows the ranges of estimates reported by different studies focussing on energy wood potential from forestry and forestry residues. It gives an indication of the range of variations among estimates.

Table 2. Range of estimates of energy wood potential reported in selected studies applying different approaches, methods and assumptions. Numbers are expressed in EJ/year. Adapted from Rettenmaier et al. (2008) p. 128.

	2000	2010	2020	2030	2040
EU27					
Forestry and forestry residues	1.0-3.9	1.0-3.2	0.9-3.9	0.9-2.4	2.4
EU15					
Forestry and forestry residues	0.5-3.2	0.5-2.8	0.6-4.8	1.3-1.7	1.3-5.0

In order to facilitate the comparison of the energy wood potentials identified by the different studies included in the next section of the report, Table 3 presents the conversion factors amongst the various measure units used in the studies.

Table 3. Conversion factors amongst the measure units used in the selected studies. EJ (Exajoule) equals 1018 joules (measure unit for energy). Mtoe stands for million tons of equivalent oil, being a toe the amount of energy released by burning one ton of crude oil. As different crude oils have different calorific values, the exact value of the toe is defined by convention and there are several slightly different definitions. TWh stands for terawatt hours, being watt the measure unit for power. Mm3 stands for million cubic meters, being cubic meter a unit measure for volume. Oven dry tonnes measure the dried weight of the wood. For all units, a water content of 0% is assumed.

	EJ	Mtoe	TWh	Oven dry tons
Mm^3 of softwood	$7.56\ 10^{-3}$	0.18	2.1	400 000
Mm^3 of hardwood	$10.1\ 10^{-3}$	0.24	2.8	550 000

2.2 Review of selected studies on energy wood potential

2.2.1 BioFuture study

In 2004 the Finnish Forest Research Institute published the results of the BioFuture study (http://www.bioenergy-noe.com/?_id=146&showArticle=75), which analyzed the "roundwood balance" of European forests (difference between net annual increment and fellings) as an indicator of the amount of wood potentially available for energy production or other purposes (Karjalainen et al. 2004). The study focussed on forests available for wood supply namely areas where technical, social or environmental factors do not (significantly) limit wood extraction.

In 2004, standing volume (growing stock of living trees and dead trees in the forests) in the EU25 forests was approximately 18 144 million m^3. About 1% of this volume is represented by dead trees. Forest cover in the EU has been steadily increasing in the 50 years before 2004. In particular, forest cover has increased by about 8%, average growing stock by about 10% and average net annual increment by about 25% (Karjalainen et al. 2004). Karjalainen et al. hold that developments in forest resources and forest cover are influenced by policy and market, as well as by the way society relates to forests. For example, forest treatments such as cuttings and afforestation can influence the age class structure of forests, which on its turn influences average growing stock and increment. Moreover, growing stock is influenced by thinning and final fellings, which are mostly market driven but also depend on silvicultural constraints. Finally, growth in forest stands depend on factors like air pollution and climate change (Karjalainen et al. 2004). Changes in land-use history and afforestation, felling activities not exceeding the increment in forest volume, nitrogen deposition and increasing temperatures are amongst the factors that contributed to the increase of the EU forest area. Indeed, roundwood balance in EU forests has been positive for a long time, and this balance can be considered as a reserve of wood that could be used for different purposes. In particular, net annual increment in the EU25 was calculated to be about 576 million m^3 per year, while fellings were approximately 390 million m^3 per year (about 68% of the net annual increment). These data allow calculating the roundwood balance which is about 186 million m^3 per year (32% of net annual increment). This corresponds to the theoretical amount of wood that is annually left in European forests (Karjalainen et al. 2004). Due to technical constraints such as excessive slopes or unsuitability of the ground to stand the impact of heavy machinery, only a part of the roundwood balance is actually available for exploitation. Such constraints are difficult to estimate as they will depend on local conditions. However, they need to be taken into account as they will determine the actual percentage of wood which is available for harvesting (Karjalainen et al. 2004).

The study of Karjalainen et al. (2004) was updated in 2008 (Asikainen et al. 2008), analyzing forest energy wood potential from forests available for wood supply in the EU27. The analysis was carried out using data available in January 2007 for the 27 EU countries and relying in particular on the FAO Global Forest Resources Assessment 2005 report (FAO 2014). Forest energy wood potential was divided between the estimation of the annual change rate of European forests and the amount of felling residues. The annual change rate is an indicator of the long-term sustainability of wood supply which represents the difference between the net annual increment and fellings. This rate has been positive in the last five decades, and quantified at approximately 238.6 million m^3 constituting a potential wood reservoir (Asikainen et al. 2008). It is challenging to predict how much of such a reservoir would find use for energy, since the competition with other wood uses such as material ones will play a crucial role. In this context, not only the straightforward competition between energy and material sectors for the available reservoir of wood play a role, but also the mutual relations between the sectors which compete for the wood. For example, because industrial wood residues can be used for energy production, increased material use of wood would increase the availability of energy wood from waste, and potentially reduce the need of using the wood reservoir for energy generation. This makes clear that not only competing but also synergistic relations can be established among the material and energy uses of wood (Karjalainen et al. 2004). The line of reasoning is different when dealing with the competition between energy use of wood and biodiversity conservation, soil protection and recreation. Demands for these forest services are increasing, and the compromises between nature protection and energy sector will have to be more substantial, making it even harder to actually estimate how much of the unutilized wood increment will actually be used for energy (Asikainen et al. 2008).

Roundwood production in the EU was on average 473.1 million m^3 per year in the period 2000-2004 (Asikainen et al. 2008), i.e. 3% higher than in the year 2000. About 77% of the

European roundwood production was softwood. In some EU countries a substantial share of roundwood was used for energy generation (for example it was above 60% in Italy and Greece). Askikainen et al. concluded that the use of roundwood directly for energy purposes depends on different factors that are hard to quantify, such as the prices of roundwood, sawnwood, pulp and paper, other energy sources and carbon emission allowances. The study reported forestry residues as the most likely sources for energy wood (Asikainen et al. 2008). In particular, Asikainen et al. considered three categories of forestry residues as building up the European energy wood potential: 1) logging residues from the removals of roundwood (branches, needles, top stemwood, off-cuts of stems), 2) annual change rate of growing stock and 3) stumps and coarse roots of trees. The role of stumps extraction in contributing to the energy wood potential is described in Box 3.

Box 3. Stump removal and its contribution to energy wood potential. Sources: Walmsley and Godbold 2010; Karjalainen et al. 2004; Richardson et al. 2002; Vasaitis et al. 2008

Stump extraction consists of the lifting of the tree stumps after felling using excavators equipped with a special stump removal head. Before extraction, stumps are cut into smaller pieces to break off fine roots, and shaken to remove excessive soil residuals. Stump pieces are transported through forwarders modified for handling the stumps. Stump extraction is mainly carried out for sanitary purposes (to combat tree root rot) and for energy production. Since demand for forest fuels continued to grow during the 20th and 21st century, stump wood started to attract the attention of forest researchers and practitioners. Scientific studies over the use of stumps as source of energy have been carried out almost exclusively in Scandinavian countries. In 2004 it was estimated that stumps could potentially source up to 9 million m^3/year of forest chips. Stump extraction is one of the activities which is believed to contribute the most to the increase of energy wood provision to satisfy growing energy demands. In 2002 it was reported that the biomass available from the stump-roots potentially allows 20% extra biomass with respect to the volume of wood obtainable from stems. Stump extraction poses a series of environmental implications which most of all regard soil disturbance. Good practices for stump removal suggest that this operation should take place as soon as possible after clearfelling, so that the foliage and branches are in the right condition to support the movement of harvesting and forwarding machines and consequently avoiding excessive soil disturbance.

Tree species were divided into three groups: spruces, pines and broadleaves. Figure 4 illustrates the theoretical energy wood potential in EU27, which amounts to 785 million m^3 per year and has been significantly reduced in the study, because of constraints that were identified by the authors and that underpin the definition of technically harvestable potential (Asikainen et al. 2008). For example, the impact of mountains on the availability of harvestable energy wood has been taken into account to a certain degree, even if such an impact is difficult to estimate. In particular, this impact was not considered as a factor to reduce technically harvestable residues in the calculations, since the relevance of mountainous areas is different for various European regions. Instead the mountainous terrains were considered as elements which extend the time employed for forwarding and as an element which reduces the possibility to harvest belowground biomass. Moreover other reduction factors have been applied to calculate the technically harvestable potential from the theoretical potential, for example linked to the mechanization degree. Another limitation considered was the possibility to recover stumps only from spruce stands (Asikainen et al. 2008).

Felling residues were estimated to be 211 million m^3 in 2007, but only 76.5 million m^3 of felling residues and 7.4 million m^3 of stump wood per year were defined as technically harvestable making a total of 83.9 million m^3 of annually harvestable residues). If complementary fellings were to be 25% of the annual change rate surplus and directly used for energy, 101.6 million m^3 of aboveground biomass and about 1.2 million m^3 of stump wood could be used for energy production each year (Asikainen et al. 2008). Therefore, the total potential of forest energy wood which is technically harvestable is about 187 million m^3 per year (see Figure 4).

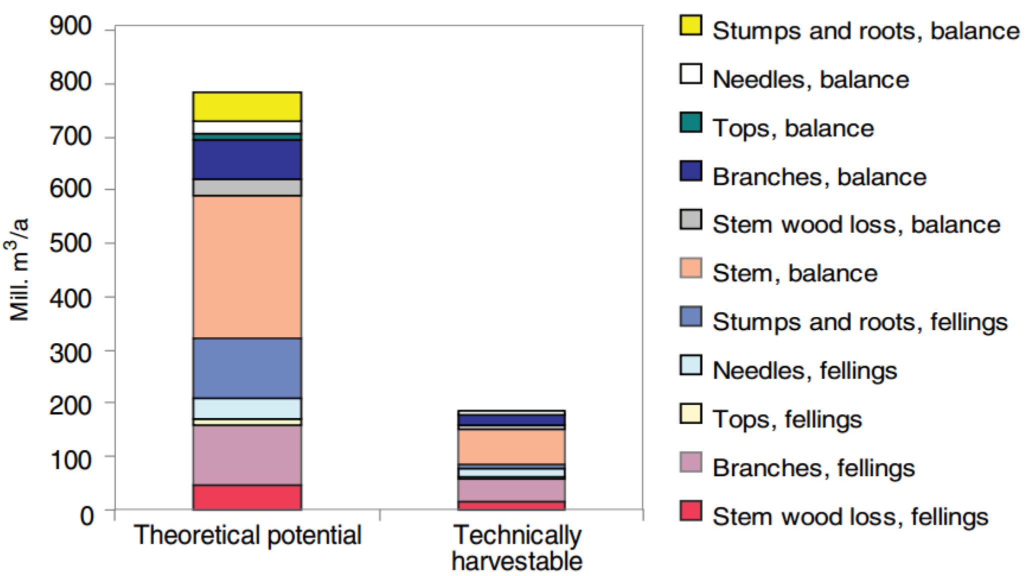

Figure 4. Theoretical and technically harvestable energy wood potential in the EU27. Source: Asikainen et al. 2008 p. 6

The potential calculated by Asikainen et al. (2008) is higher than the one calculated by Karjalainen et al. (2004), even if the methods used are the same – except for the mountainous factor employed for stump recovery calculations. Reasons for this difference are the facts that two new countries have been included in the 2008 study, and that the number of harvester machines has increased in Europe during the time that passed between the two studies, raising the mechanization level.

2.2.2 Estimates by the UNECE/FAO and Hamburg University consortium

In order to assess how in the future multiple interests toward wood will relate to each other and to the European wood reservoir, it is necessary to develop and discuss assessments and forecasts on the (future) wood supply and demand, considering also uses of wood other than energy generation. In 2007 a consortium between UNECE/FAO and the University of Hamburg carried out a study on the current wood supply and consumption in 29 EU/EFTA countries, based on the "wood resource balance" (Mantau et al. 2007). The scientific consortium also published a new version of the study in 2008 (Hetsch et al. 2008), where data are slightly adjusted compared to the 2007 version but which reports the same conclusions. With respect to the advantages of using a wood resource balance approach for estimating energy wood potential, the authors underline the fact that this type of assessment allows accounting for the versatile character of wood. Wood can indeed be reused and processed several times, and not only forests but also wood by-products and the residues from industrial processes can be considered as wood sources (Mantau et al. 2007). Tables 4 and 5 present the wood supply and use in 2005, while Table 6 gives insight on the supply-use balance.

Table 4. Wood supply in 2005 from forests and other sources. Other sources include for example recycled wood and industrial wood wastes. Source: Mantau et al. (2007)

	Wood supply from forest (million m^3)	Total wood supply (including internal sources) (million m3)
EU-27	499	748
EU/EFTA	518	775

Table 5. Wood use in 2005. Source: Mantau et al. (2007)

	Material use		Energy use		Total use
	million m^3	%	million m^3	%	million m^3
EU-27	460	58%	333	42%	793
EU/EFTA	478	58%	343	42%	821

Table 6. Wood supply-use balance in 2005. Source: Mantau et al. (2007) p. 13

	Total wood supply (million m^3)	Difference (million m^3)	Total use (million m^3)
EU/EFTA	775	47	821

Moreover, the study estimated wood requirements for the years 2010 and 2020, based on the results of the 2005 UNECE European Forest Sector Outlook Study (EFSOS) (UNECE/FAO 2005) and combined these results with an assessment of national and EU policy targets for renewable energy, bioenergy and wood energy (Mantau et al. 2007). EFSOS presents long-term trends for supply and demand of forest products (roundwood, sawnwood, panels, pulp, paper, non-wood products) to the year 2020. It reviews trends for the forest resource, trade, markets and recycling elaborating a baseline scenario, a conservation scenario (shift toward environmentally friendly land management) and an integration scenario (shift toward economic growth). When assessing the results of EFSOS 2005, Mantau et al. noticed that despite the proved accurateness of the proposed scenarios, wood production in some countries had increased substantially more than within the EFSOS forecasts. Therefore updates were made to encompass more recent trends (Mantau et al. 2007). Moreover, since EFSOS did not specifically model energy wood but wood potential in general, the authors integrated the EFSOS data with consideration of renewable energy policy as a driver for future energy wood potential in the EU. According to Hetsch et al. (2008), renewable energy policies are of high priority for all countries and strongly influence the forestry related sectors, while forest policies often play a minor role in policy making. This approach allowed for a better understanding of both the energy and forest sectors (Hetsch et al. 2008).

Mantau et al. aimed to present the consequences of current energy policy for wood demand, and the possible implications for the forest sector (Mantau et al. 2007). They emphasize that the figures presented in their study cannot be considered as realistic forecasts, since the study relies on assumptions like the relative share of wood as renewable energy which cannot be exactly determined. Moreover, the authors did not present an econometric model, but rather a "crude scenario" (Mantau et al. 2007 p. 19) that displays how much wood is needed if wood consumption develops as forecasted by EFSOS, and if renewable energy targets are to be met. Table 7 shows the results of the study by Mantau et al. (2007).

Table 7. Wood required to fulfil EFSOS scenarios and renewable policy objectives in the EU/EFTA countries. The last row reports data based on the assumption that in 2020 the relative share of wood compared to other renewable energy sources might decrease to 75% of the relative share in the year 2005. This assumption considers the likely faster growth of other energy sources compared to energy wood. Source: Hetsch et al. 2008 p. 11

	Material use (EFSOS calculation) (million m^3)	Energy goals (policy objectives) (million m^3)	Total use (million m^3)
2005	478*	343*	821*
2010	495	481	976
2020	536	738	1274
2020 "75% scenario"	536	620	1156

* actual figure

Mantau et al. (2007) identified a substantial difference between the wood requirements needed to fulfil the EFSOS scenario and the ones needed to meet the policy targets. In particular, foreseeable demand for wood is considerably higher than the supply forecast by EFSOS. Therefore Mantau et al. concluded that one of the following developments will be likely to take place:

1) Wood supply will be increased.
2) Policy targets will not be met, or at least will not be met through the contribution of wood resources.
3) Wood-based industry will not develop as forecasted by EFSOS.

Mantau et al. (2007) also state that it will become necessary to increase wood supply from new sources, for example by further expanding the forest area available for wood supply and/or the wood supply from existing sources. Moreover, wood imports will have to be intensified, likely leading to problems such as food-energy competition in developing countries. In order to fulfil the increasing demands of wood, energy efficiency will need to be drastically improved, as well as the wood use efficiency (fostering cascade-uses of wood).

2.2.3 The EUwood project

The scientific consortium established by UNECE/FAO and Hamburg University was later expanded to include other important forest research institutions that collaborated in the EUwood project (http://www.managenergy.net/news/articles/36). Despite the fact that the EUwood study did not obtain concrete results on the EU energy wood potential but concentrated on the total wood potential, Verkerk et al. (2011) underline the advantages of the approach adopted, which avoids double counting that cannot be circumvented when focussing only on energy wood potential. The project carried out an in-depth analysis of the wood resource balance in the EU, studying the gap between wood supply and demand based on the European Forest Information SCENario (EFISCEN) model. This model describes the forest as an area distribution over age and volume classes in matrices. Data for the model were taken from national forest inventories on forests available for wood supply (Verkerk et al. 2011). The authors present historical balances for the years 2005 and 2007, and projection balances for the years 2010, 2020 and 2030. In order to obtain reliable data for the years 2020 and 2030, the authors applied several assumptions to the study of wood supply and demand, including for example EU policy targets for renewable energies, technical issues related to wood extraction, and environmental and socio-economic constraints (Mantau et al. 2010). For example, the project took into account technical risks related to ground compaction and it included limits imposed by the small size of forest properties. Table 8 reports the constraints utilized in EU Wood.

Table 8. Constraints on forest wood supply considered in the EUwood project. Adapted from: Verkerk et al. 2011 p. 2009.

Constraint	Type	Explanation
Soil productivity	Environmental	The nutritional impact of biomass harvesting in forests is influenced by the degree to which foliage and small branches are extracted from a site. If soils are more productive, they can tolerate a higher degree of biomass extraction.
Soil and water protection	Environmental	Removal of forest biomass inevitably involves vehicle operations and soil disturbances. The extraction of forest residues and stumps increases the risk for erosion, especially on steep slopes Forests have an important role in the protection of watersheds. Intensive logging and residue extraction may result in a degradation of water quality. The extraction of forest residues on sites with shallow soils could increase erosion risk. Using heavy machinery for extracting biomass can lead to soil compaction, particularly in wet soil.
Biodiversity protection	Environmental	To prevent loss of biodiversity a significant percentage of the European forests area is protected or managed for conservation purposes with constraints on harvesting activities. An exception could be made on in areas with high or very high forest fire risk.
Recovery rate	Technical	Part of the woody biomass from forest is lost before reaching the point of utilisation due to, e.g., loss or damage of biomass during harvesting. The technical recovery rate depends on the used harvesting technology.
Soil bearing capacity	Technical	On soft soils the bearing capacity of soil can reduce the amount of harvestable biomass, e.g., because logging residues are used to strengthen the bearing capacity of the soil on the forwarding trail.
Distributed forest ownership	Social/economical	Private owners with small properties may be less motivated to sell wood as harvesting may not be economically significant, transaction costs too high, or due to other management objectives than wood production.

These assumptions allowed Verkerk et al. to refer to the "potential" rather than to the "theoretical" supply and demand. Indeed, different types of constraints to the extraction of wood from forests have been identified in the project. These constraints reduce the theoretical supply of wood from forests to an extent proportional to the intensity of the constraints. The EUwood project refers to three wood mobilization scenarios (Mantau et al. 2010):

- In the high mobilization scenario forest owners associations are established and working, strong mechanization takes place, biomass harvesting guidelines are less strict than at present, and environmental damage associated with intensified biomass extraction are considered less negative than environmental problems caused by use of traditional energy.
- In the medium mobilization scenario the recommendations expressed in the high mobilization scenario are not applied or do not have the desired effects, and current patterns in forest management are considered as adequate.
- In the low mobilization scenario the recommendations of the high mobilization scenario do not have the desired effects and environmental concerns strongly limit woody biomass extraction (the forest area available for wood supply is reduced by 5%).

The quantitative data presented hereafter all refer to the medium mobilization scenario.

Like the study presented in Section 2.2.2, EUwood was not only limited to the analysis of wood from forests, but also considered that different wood sources build up the total EU 27 potential wood supply: stemwood, forest residues, bark, landscape wood, sawmill by-products and other industrial residues, black liquor, solid wood fuels and post consumer wood. The study excluded the wood supply obtainable from SRF, since these plantations only cover about 30 000 ha in the EU in 2010 and their expansion in the future is subject to influence of socio-economic factors that are difficult to quantify. For the demand side, the study considered the following sectors as contributing to determine the potential demand of wood in the EU: sawmill industry, veneer plywood industry, pulp industry, panel industry, other material uses, solid wood fuel producers, forest sector internal use, biomass power plants, households (pellets and other wood sources) and liquid biofuels (Mantau et al. 2010).

In 2010 total wood supply in the EU27 was about 1 billion m^3 (corresponding to 8500 PJ), of which 70% is extracted from forests and 30% from woody biomass outside the forests. In the same year, wood demand amounted to about 800 million m^3, of which 57% came from material uses, while 43% from energy purposes (Mantau et al. 2010). The estimation of the energy use of wood included assumptions on the household use of fuelwood, which is often not recorded in official statistics on energy wood. Table 9 shows the relative contribution of the various wood sources and wood-depending sectors, respectively to the potential supply (left side of the table) and potential demand of wood (right side of the table) in 2010. Table 9 makes clear that in 2010 wood supply was considerably higher than potential demand, and that about 170 million m^3 of wood reserve was theoretically stored in European forests. The authors emphasize however that the reservoir of wood could have been entirely used only in the case in which a successful mobilization of the total volume had taken place (Mantau et al. 2010).

Table 9. Potential supply and potential demand of wood in 2010 for EU 27. The abbreviations should be read as follows: C= coniferous softwood; NC= non-coniferous hardwood; ME= potential characteristic of the medium mobilization scenario; USE= potential that is or will be used. Source: Mantau et al. 2010, p. 21

Potential in M m^3	**2010**	**In %**	**2010**	**In %**	**Demand in M m^3**
Stemwood C, ME	362	36.4	196	23.8	Sawmill industry
Stemwood NC, ME	182	18.3	11	1.3	Veneer plywood industry
Forest residues, ME	118	11.9	143	17.3	Pulp industry
Bark, ME	24	2.4	92	11.1	Panel industry
Landscape c.w. (USE) ME	59	5.9	15	1.8	Other materials use
Short rotation plantation	-	-	21	2.5	Producer solid wood fuels
Sawmill by products	87	8.8	86	10.4	Forest sector intern. use
Other industrial residues	30	3.0	83	10.1	Biomass power plants
Black liquor	60	6.0	23	2.8	Household (pellets)
Solid wood fuels	21	2.1	155	18.8	Household (other)
Post consumer wood	52	5.2	0	0.0	Liquid biofuels
Total	**994**	**100**	**825**	**100.0**	**Total**

Excluding wood sources from outside forests, EUwood concluded that the realistic potential from European forests could be estimated at 747 million m^3 per year in 2010 and could range from 625 to 898 million m^3 per year in 2030, according to the considered mobilization scenario. Also, the amount of wood harvested will depend on the demand.

According to the forecasts, between 2015 and 2020 the potential demand of wood will exceed the potential supply, mostly as a consequence of the increased demand of energy wood that comes with the assumed achievement of the 2020 renewable energy target. As shown by Figure 5, if the 2020 renewable energy target will be actually achieved, the demand of energy wood will more than double by the year 2020. Instead, considering current environmental and technical constraints, the supply potential will remain rather constant. A small increase in the potential supply can be foreseen reflecting the future increase of the contribution of non-forest biomass to the European wood supply. However, the EUwood project assumes that if the mobilization of wood from forests will be intensified and will strongly contribute to the European wood supply, less effort will be put on intensifying the use of wood from outside forests. The study reveals that, according to current forest management practices, domestic sources will not be able to support the achievement of this target (Mantau et al. 2010).

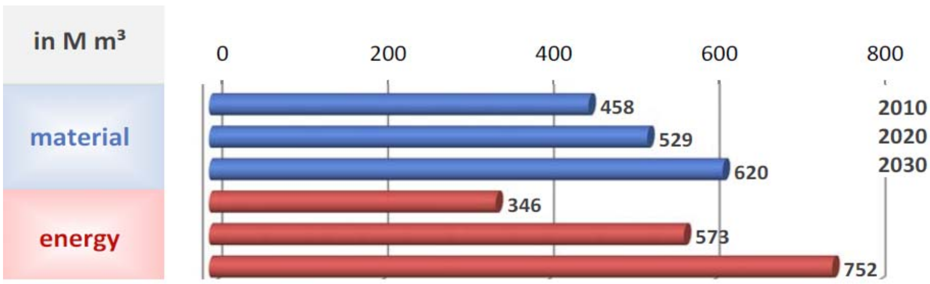

Figure 5. Developments of material and energy wood demands. Adapted from Mantau et al. 2010, p. 23

In general terms, the EUwood project concluded that a large unutilized wood supply potential is available in European forests. However, due to many environmental, technical, social and economic exogenous factors that influence the extraction, mobilization and use of wood, the project did not assess the economical availability of this unutilized potential. The project noted that the least strong constraints are identified for stemwood from early thinning and logging residues from final fellings, while conspicuous constraints are detected for the use of stumps. Moreover, it was not possible to establish if the types of wood supplied will suit the future needs of material and energy wood demands. The results of the EUwood project also make clear that a large share of the potential wood supply lies outside forests, and the utilization of this portion of wood can increase the European wood potential and help reaching the 2020 renewable energy target (Mantau et al. 2010).

A peer reviewed article that discusses the results of the EUwood has been published (Verkerk et al. 2011). They underline that important factors difficult to quantify represent uncertainties to the study. Some of these uncertainties regard socio-economic developments. For example, forest owner attitudes toward the energy wood context can have relevant effects on wood mobilization, but this attitude is difficult to quantify. Other socio-economic constraints like the size of forest holding were taken into account in the study, but their consideration is hampered by the lack of empirical data on the correlation between property size and wood harvesting (Verkerk et al. 2011). Moreover the authors reflect on the effects of the market on wood potential. High mobilization efforts could increase the realizable wood potential to 71% of the theoretical potential (i.e. the amount of wood that could be harvested without taking into account ecological and socio-economic constraints). If the supply would exceed the demand for wood, part of the EU wood potential would remain in the forest and would be available in later times. In this sense Verkerk et al. conclude that current studies on wood potential might underestimate the potential for the post-2020 period (Verkerk et al. 2011).

Finally, Verkerk et al. (2011) discuss the uncertainties related to the ecological and socio-economic impacts of climate change. Climate change might affect forest growth and increase natural disturbances in ways that are difficult to quantify. For example, it could reduce water availability in Southern Europe therefore limiting tree growth, and extend growing seasons in Northern Europe consequently favouring tree growth. It might reduce harvest potentials by exacerbating forest fires, or increase harvest potential by making available large amounts of wood after increasing storm frequency.

2.2.4 The study by the European Environmental Agency

In 2007 the European Environmental Agency (EEA) published a study on the environmentally compatible energy wood potential from European forests (EEA 2007). The estimates focussed on forest residues and complementary fellings (and their residues). Other wood sources are excluded like industrial wood residues, SRF, trees grown outside the forest and recycled wood. EEA quantified forest energy wood potential for the years 2005, 2010, 2020 and 2030 under a range of constraints and scenarios that restrict or increase the theoretical potential. Complete data were available for 21 European countries (EEA 2007).

The EEA study used the projections developed with the EFISCEN model, and applied environmental considerations to a “baseline” scenario and a “maximum sustainable harvest scenario”. In the baseline scenario, wood demand was the most recently reported stemwood allocation to wood industry (corresponding to the data registered in 2005). It increased slowly from 2006 onwards based on demand projections taken from those European countries belonging to the Organisation for Economic Co-operation and Development (OECD). In this scenario only the baseline forest residues were made available. In the maximum sustainable harvest scenario, wood demand was increased to reach the maximum sustainable harvest level. In addition to the baseline residues, complementary fellings and their residues were also made available (EEA 2007). To define complementary fellings the EEA (2007 p.7) referred to the fact that “the present harvest levels in Europe use less than the sustainable wood harvest potential”. For this reason, “it would be possible to use complementary fellings to increase the supply of bio-energy from forest biomass” (EEA 2007 p.7) by carrying out additional thinnings and stemwood removals and use these as well as their residues for the energy industry.

The EEA study also compared the EFISCEN results with a classification of suitability for residue extraction provided by the forest map of Europe developed by Schuck et al. in 2002. Finally, in order to take into account the demands of stakeholders for additional restrictions on the utilization of forest resources, the authors of the study developed two additional scenarios. They were defined as “increase in protected areas” and “biodiversity” scenarios. In the increase in protected areas scenario the area available for wood supply was reduced by 5%, while in the biodiversity scenario the 5% area reduction was applied, together with an additional reduction of 5% for the standing volume of trees that was left in the forest after harvest.

The study by EEA applies different types of environmental criteria to determine the environmentally compatible energy wood potential from European forests (EEA 2007). Table 10 reports these criteria. An in-depth description of these and other environmental criteria and reflections on the implications these have for energy wood extraction principles are included in the discussion of the trade-offs and synergies between the energy use of wood and environmental forest functions (see Section 3.2).

Table 10. Summary of the environmental criteria considered by the EEA and of information on their implementation. Source: EEA (2007) p. 12

Constraint/indicator	**Implementation**		
	Forest residues from regular fellings	**Forest residues from complementary fellings**	**Complementary fellings**
Conservation and protection of biodiversity			
Protected area	Not applicable	Scenario with – 5 % of total potential	Scenario with – 5 % of total potential
Biodiversity	Not applicable	Scenario with – 5 % of total potential	Scenario with – 5 % of total potential
Site fertility			
Soil type	Suitability classification	Suitability classification	Not applicable
Base saturation	Suitability classification	Suitability classification	Not applicable
Soil erosion			
Slope and elevation	Suitability classification	Suitability classification	Not applicable
Soil compaction			
Peat land	Suitability classification	Suitability classification	Not applicable
Soil water regime	Suitability classification	Suitability classification	Not applicable
Nitrogen inputs			
Nitrogen deposition	Suitability classification	Suitability classification	Not applicable
Nitrogen fertilisation	Suitability classification	Suitability classification	Not applicable

The application of these criteria to the study of forest energy wood potential allowed EEA deriving the potential that could be harvested if no socio-economic or technical constraints would occur (EEA 2007). Table 11 reports the results of the EEA study.

Table 11. Annual energy potentials from complementary fellings in 2010–2030 and felling residues in 2005–2030. Total values (Mtoe) for 21 EU Member States under different scenarios. Source: EEA (2007) p. 22

Scenario	Total potential			
	2005	2010	2020	2030
Energy potential (Mtoe) from forest residues resulting from:				
Regular fellings (baseline)	14.3	14.9	15.9	16.3
Complementary fellings — protected area and deadwood scenario	–	4.8	4.2	4.2
Complementary fellings — protected area scenario	–	5.7	5.0	5.1
Complementary fellings	–	6.7	6.0	6.1
Energy from complementary fellings, Mtoe				
Max — protected area and biodiversity scenario	–	22.9	19.1	18.5
Max — protected area scenario	–	27.1	22.7	22.5
Max scenario	–	31.9	27.1	27.0
Summary energy potential from felling residues and complementary fellings, Mtoe				
Max — protected area and biodiversity scenario		42.5	39.2	39.0
Max — protected area scenario		47.6	43.6	43.9
Max scenario		53.4	48.9	49.4

The study addressed the fact that the exclusion of afforestation and SRF from the analysis may lead to an underestimation of the EU forest energy wood potential. Moreover, the limited time horizon of the study did not allow for consideration of the implications of forest management changes. Phenomena like the conversion of even-aged forest stands, or changes toward nature oriented forest management, are likely to affect species composition and wood potential in the long term. Also, when considering energy wood potential it is important to take socio-economic and infrastructural aspects into account, since these could affect the availability of wood for energy generation both negatively or positively. However, socio-economic and technical factors were outside the scope of the study (EEA 2007). The consequences of applying environmental constraints to the estimation of the EU forest energy wood potential were also addressed. The application of these constraints might have led to an over- or underestimation of the potential, according to the constraint considered. For example, the study assumed that currently protected forests fall under the category of forests not available for wood supply, but this is not always the case. Also, almost 20% of the forest area taken into account was classified as moderately suitable for residue extraction due to the low base saturation of the soils. However, part of this forest area could actually be suitable for residue extraction. These two elements are examples of factors that can lead to an underestimation of energy wood potential in the EU (EEA 2007).

2.2.5 The EFORWOOD project

In 2007 Nabuurs et al. published a paper reporting on a study partially commissioned by the Confederation of European Paper Industries and partly linked to the EC funded EFORWOOD project (http://87.192.2.62/eforwood/Home/tabid/36/Default.aspx). The paper projects future wood supply from 27 European countries until 2060. The study does not report specific data on forest energy wood, but focuses on the total wood resource extractable from European forests. However, it is included in this report insofar as it presents interesting reflections on the timber resource available in Europe also (but not solely) considering the increased demand of energy wood as one of the factors conditioning future wood supply. For example, the paper reflects on existing concerns on the long-term availability of wood as raw material that can be extracted from European forests. These concerns are driven by different factors (Nabuurs et al. 2007):

- The expected demand increases in the pulp and paper industries.
- The increases in consumption expected especially in Central European countries with economies in transition.
- Current developments in forest management which reveal that supply to wood-based industries might be reduced in the future due to: (1) trends towards nature oriented forest management, (2) EU policies leading to an increased demand for energy wood, and (3) the Kyoto Protocol rewarding carbon credits for further build-up of forest growing stock. If policy makers will opt for the continuation of these trends, European forests might include a vast resource characterized by high rates of mortality, a decreasing net increment, and a higher biodiversity due to the older age classes and to the higher amount of deadwood left in the forest.

The study adopts a resource approach and it uses the EFISCEN forest resource model to calculate results following three scenarios (Nabuurs et al. 2007):

A) Benchmark scenario with stable fellings, in which the total national fellings level is fixed at the level of the year 1990s until 2060.
B) Projection of historical management scenario, in which the fellings rise until the year 2060 while species composition and forest area remain the same. In this scenario no strict forest reserves are established.
C) New management trends scenario, in which the basic fellings develop as in the B scenario, plus an extra annual total fellings of 80 million m^3 of wood that satisfies increasing demand for energy wood in Europe. In this scenario the assumption is made that important exogenous trends affecting forest owner preferences, denominated “nature oriented management”, “bio-energy” and “carbon credits”, will translate into changes affecting species composition and forest area, as well as management strategies. In this scenario, for example, it is expected that environmental consideration will take a broader space in forest management and important forest reserves will be established all around Europe as a reflection of the acquisition by forest owners of nature oriented management principles.

The results of the study by Nabuurs et al. (2007) show that a large increase in wood supply in European forests can be achieved sustainably in the period 2005–2060. In particular, in scenario A the average growing stock of European forests rises from 188 to 287 m^3/ha. In scenario B the supply increased to 729 million m^3/year in 2060, while in scenario C it increased from 409 million m^3/year in 2005 to 647 million m^3/year in 2060. Despite the 80 million m^3 higher demand associated with scenario C, this scenario gives a reduction in fellings of 82 million m^3 and thus a reduced supply of 162 million m^3/year (despite an increased forest area of 16 million ha over a period of 55 years). The high supply levels of scenario B are mostly due to overharvesting that exceeds the increment. Instead, in scenario C, overharvesting occurs in the period 2030–2040 but decreases in 2050. Scenarios B and C show only a small difference between average growing stock developments (in scenario B growing stock increases faster, peaks around 2040 at 221 m^3/ha and then declines, while in scenario C growing stock keeps on increasing to 221 m^3/ha in 2060). So, despite different scenario assumptions and stringent management rules in scenario C, the average growing stock is hardly affected. For example, in scenario C harvesting is less and one would expect a consequent higher average growing stock. However, this is counteracted by new afforestation with very low standing volumes. The study concludes that large increases in supply are possible also keeping harvesting rates higher that the net increment for some time, insofar as this hardly affects the growing stock. If we do not want to breech the sustainability index by harvesting more than the increment, we need to take into account serious limits to the availability of wood resources (Nabuurs et al. 2007).

2.3 Reflections on the selected studies on energy wood potential

As mentioned in the Biomass Energy Europe project and Section 2.1, the results of available studies on energy wood potential differ significantly amongst each other. The discrepancy among the estimates is partially due to the different methodological approaches adopted by the studies. For example, the EEA study and the EFORWOOD project use a resource-based approach while the BioFuture study, the project by UNECE/FAO and Hamburg University consortium and the EUwood study use a wood resource balance approach (the first one focussing on roundwood balance and the other two on total wood resource balance). BioFuture and the project by UNECE/FAO and Hamburg University consortium calculated current energy wood potential based on a literature review method, the second combining it with EFSOS model results. EUwood, the EEA study and the EFORWOOD projects adapted model results from EFISCEN to project energy wood potential in the coming decades.

When considering projects which use similar methodological approaches, such as the EUwood, the EEA study and the EFORWOOD project it is still possible to identify great variations amongst results. This is due to the fact that the different studies consider varying socio-economic, ecological and technical limitations to the realization of EU energy wood potential. For example, the EUwood project considers energy wood potential only from land areas which are currently classified as “available for wood supply” and it takes into account the necessity to maintain soil productivity, soil bearing capacity as well as biomass recovery rate; the need to protect water, soil and biodiversity; and the effects of the low motivation of private forest owners to sell wood to the energy industry (Mantau et al. 2010). It developed three mobilization scenarios where factors like the functioning of forest owners associations, the level of mechanization and the societal acceptance and management of trade-offs between energy wood production and forest environmental functions determine the availability of energy wood in different contexts. In the lowest mobilization scenario, environmental concerns are perceived as a strong determinant by society, and consequently the area available for wood supply is further reduced by 5% (Mantau et al. 2010). The EEA study focussed on the environmentally realizable energy wood potential and therefore excludes social and economic drivers by considering limitations like soil type, base saturation, erosion, slope, elevation and compaction, as well as water regime, nitrogen deposition and fertilization (EEA 2007). The acknowledgment of these limiting factors exemplifies the difficult interactions between energy wood production and use and other forest ecosystem services, as well as underlines the potential conflicts which influence energy wood potentials and are complex to take into account (McCormik 2005).

Moreover, the difference among the estimates is also due to influencing elements that are difficult to quantify because affected by important uncertainties. Some of these elements are either excluded from the studies, or considered as constant variables or non-influencing variables for the energy wood context. Here follows a list of the uncertainties which emerge from the analysis of energy wood potential research projects, and which are taken into account in very different ways by the projects included in Section 2.2 of this report. These uncertainties are variously affecting demand and supply of forest energy wood as well as the resources balance of this energy source (Karjalainen et al. 2004; Mantau et al. 2007; 2010; Hetsch et al. 2008; Nabuurs et al. 2007; EEA 2007):

- Increasing CO_2 concentrations and climatic changes that might affect forest growth and disturbances in ways that are not possible to quantify. Climate change might reduce water availability in Southern Europe therefore limiting tree growth, and extend growing seasons in Northern Europe consequently favouring tree growth. Climate change may reduce harvest potentials by exacerbating forest fires, and increase harvest potential by making available large amounts of wood after increasing storm frequency.
- Land conversions that could change the amount of land currently taken into account in the estimates. In the future areas considered as available for wood supply might be expanded or reduced according to policy priorities and societal needs of resources.
- Implications of forest management changes due to policy requirements, market effects or to societal preferences. Phenomena such as the conversion of even-aged forest stands, or changes toward nature oriented management, are likely to affect species composition and wood potential in the long term.
- Competition with biodiversity conservation, soil protection, nature and landscape conservation, which may affect the demand of energy wood and ultimately the

wood mobilized from forests. Societal acceptance of energy risks plays a role in this context, for example environmental damages associated to intensified biomass extraction in the future might be less negatively perceived than environmental problems caused by use of traditional energy, at the benefit of energy wood production. Or, society might favour more deadwood in forests for addressing biodiversity conservation as compared to the amount forecast by the studies on energy wood potential.

- Competition with recreational and tourist activities which could limit forest practices in terms of time and place of application, and accepted forest management measures.
- Market competition of energy wood with other wood uses and other renewable energy sources. The first type of competition is determined by the development of wood industries in the future. For example, the current low demand of wood by the pulp and paper industries is likely to rise, resulting in fewer resources available for the energy industry. The second type of competition is determined by the growth of other renewable energy sources. If they would provide a high share of energy in the future to satisfy EU energy targets, a considerable growth of energy wood provision might not be needed and it might not take place.
- Effects of developing economies on the availability of wood. For example, increases in wood consumption are expected especially in Central European countries with economies in transition.
- Effects of policy instruments on market prices of lands and resources. For example, stringent CO_2 control policies and payments for ecosystem services could reduce the availability of wood, increase the competition among wood uses, increase wood prices and ultimately reduce the wood available for energy generation. Also, energy policies will have a growing but undetermined effect on the forest sector as striving towards EU energy targets may stimulate varying degrees of increase in energy wood demand and provision.
- The development in the production and energy utilization of industrial wood residues and of cascade wood processes. Increasing industrial use of wood may increase the availability of residual wood, potentially reducing the need of using wood directly extracted from the forest. The same can be caused by the re-use and re-processing of wood in cascade.
- Developments in the energy wood provision from SRF and SRC plantations, as well as from stump extraction and trees outside forests. These wood sources are normally excluded from the studies on energy wood potential. This is either due to the low data availability or to the fact that these sources are not very important at present. The importance of SRF and SRC may change in the future and the underestimation caused by the exclusion of these wood sources in the calculation of the energy wood potential might result in the need to correct the estimates.
- Energy wood imports might be decreased according to the willingness of the EU to reduce import dependencies. They also might be increased following the recognition of not being able to reach EU 2020 energy targets with EU domestic

wood sources. Energy wood imports also depend on food-energy land competition in developing countries.
- Technological developments in efficiency of energy processes and their future developments which are undetermined.
- Correlation between forest property size and wood harvesting which is affected by lack of empirical data.
- Household use of fuelwood, which is often not recorded in official statistics on energy wood.

All these uncertainties can negatively affect the reliability of estimates on energy wood potential, and the geographic scale of the estimates is one of the elements that amplifies or reduces the magnitude of the uncertainties. The choice of the project/study results to select depend most of all on the type of user and on the purpose for which results are used. Despite the uncertainties and variations affecting the calculations and results on energy wood potential, important lessons can be learned from the analysis of the studies in Section 2.2. This is particularly true for the recognition and consideration of various challenges for increasing the production of energy wood to satisfy the increasing demand with which we will be confronted in the near future, and we partially already have to deal with. Taking into account the type of potential the study deals with, and namely the theoretical, technical, economic, implementation or sustainable implementation potentials, is of great support to deciding the type of energy wood potential study which is more suitable for a specific purpose. If the emphasis is on energy wood potential in economic or social terms, studies that are of particular interest include those that calculate the portion of energy wood potential which is economically profitable to exploit, or the implementation potential (Rettenmaier et al. 2010) – the fraction of economic potential implementable under specific socio-political conditions and also takes policy incentives into account. If environmental considerations are important, it is useful to select studies dealing with sustainable implementation potential (Rettenmaier et al. 2010) – the fraction of the technical biomass potential which can be developed without opposing the general principles of sustainable development and, for example, without causing social or ecological damage.

The analysis of the studies in Section 2.2 illustrates that energy wood potentially plays a substantial role when striving towards the EU 2020 energy and climate targets. However, to fully realize its potential, the provision of woody biomass from European forests should grow at a faster pace than today. Indeed, the current growth rate in the biomass sector is just a third of the scenario forecasts, and it amounts to about 25 TWh/year. With the current trajectory, the total growth until 2020 would be about 300 TWh, which represents a significant amount but it is about 550 TWh shorter than the expected levels (Hogan et al. 2010). The envisaged acceleration in the development of the woody biomass sector will only be possible if significant growth barriers are removed and if an enforced environmental framework is built, including, for example, industry standards and legislative processes (Hogan et al. 2010). In order to boost the contribution of woody biomass to achieve the 2020 energy targets there will also be a need to make use of woody biomass cost competitive, for example, by capturing the cost improvements needed in the heating and electricity sectors. Biomass should be considered as a "proven but underdeveloped renewable energy technology in need of scale-up rather than as a mature industry" (Hogan et al. 2010 p. 3). In this sense, companies and policy makers should recognize that the current value chain is immature and that investments are not happening at the expected pace. The scaling-up in the energy wood context could be achieved by increasing the number of pellets mills with a high production capacity, or by increasing and up-scaling the retrieval of forestry residues after forestry operations. With respect to scaling-up, woody biomass from forests is the energy source which is more problematic. Indeed, cost decreases from up-scaling operations might be outweighed by cost increases of capturing more challenging forestry fractions. Also, at present there is no demand for forest woody biomass at the price levels needed by producers to achieve profitability and this generates high uncertainty with regard to the role of biomass in the long-term energy context (Hogan et al. 2010).

The uncertainty in the role of woody biomass is currently addressed by state subsides which are stimulating demand for energy wood. However, it is important to highlight that if demand is stimulated without fairly stimulating supply, this could lead to a decrease in biomass production and/or an increase in biomass imports in Europe (Hogan et al. 2010). This shows in the forecasts of the EUwood project, which identified that between 2015 and 2020 the potential demand of wood will exceed the potential supply, mostly as a consequence of the increased demand of energy wood that comes with the assumed successful achievement of the 2020 renewable energy target. Instead, considering current environmental and technical constraints, the supply potential will remain rather constant, since just a small increase in the potential supply can be foreseen reflecting the future increase of the contribution of non-forest biomass to the European wood supply (Mantau et al. 2010). However, the EUwood project assumes that if the mobilization of wood from forests is intensified and will strongly contribute to the European wood supply, less effort will be put on intensifying the use of wood from outside forests. The study also revealed that, according to current forest management practices, domestic sources will not be able to support the achievement of this target (Mantau et al. 2010). In this sense, woody biomass might contribute to satisfy the renewable energy needs of the EU, but without actually performing its role to enhance energy supply security.

3. Trade-offs and synergies associated with the production and use of forest energy wood

Reviewed by Stefano Carnicelli, Alexander Held and Till Pistorius

3.1 Overview on the trade-offs and synergies associated with forest energy wood

Despite the policy emphasis on the use of wood for energy purposes as a contribution to the achievement of the EU 2020 targets in the contexts of climate change and renewable energies described in Section 1, it is important to highlight that the production and use of forest energy wood will have many associated implications (Abbas et al. 2011; EEA 2007; Schulze 2012). Indeed, European forests are multifunctional, and aside from energy wood they provide a varied set of goods and services which are essential for human life and livelihood. They include important natural habitats for a very broad variety of species which rely on the forest ecosystem for their shelter and nourishment (Dudley and Vallauri 2004; Bengtsson et al. 2000; Verkerk et al. 2011). Forest ecosystems also host the highest level of biodiversity if compared with other natural and semi-natural land uses (N2K Group 2012; Winkel et al. 2009). Further, forest biodiversity is characterized by a better conservation status than the biodiversity hosted by other land uses (EC 2003; Winkel et al. 2009). Next to biodiversity, forest ecosystems are important for other environmental services, including the protection of the soil nutrient capacity and structure, the safeguard of the hydrologic system, the purification of the air from pollution, and the absorption of CO_2 from the air with positive consequences for climate change mitigation (Adams 1981; Laudon et al. 2011; Ciais et al. 2008; EEA 2007; Jackson et al. 2008; Bonan 2008; Copa-Cogeca 2012). Forests also provide a wide variety of goods and materials which, like wood for construction, are commercially produced, cork, pulp for paper production and non-timber forest products (NTFPs) like mushrooms, berries, herbs, resins and essential oils (Mantau et al. 2007; 2010; EC 1997; EC 2009c). The management of the forest for the provision of these goods and materials is an activity which provides employment in a variety of industries and companies, making the forest an essential element of job diversification and rural development (EC 2013b; EC 2013c). Forests in particular provide a location for recreation and tourism (Elands 2004; Edwards et al. 2011; Rametsteiner et al. 2009).

The multifunctionality of European forests is also addressed in Section 2 of this report which is dedicated to the study of energy wood potential in Europe. The studies took into account different demands towards forests and different factors of competition between energy wood and social, economic and environmental issues. That allowed the studies to differentiate between "theoretical potential", defined as the maximum amount of terrestrial biomass theoretically available for energy production within bio-physical limits, and "technical potential", namely the fraction of theoretical potential available under technological and structural possibilities which also considers competition with other land uses and ecological constraints (Rettenmaier et al. 2010). The exploitation of the technical potential should be weighed against economic profitability in order to calculate the "economic potential". Again, the economic potential should be weighed against the socio-economic conditions that determine its extraction, to give life to the concept of “implementation potential” and of “sustainable implementation potential” – the last being the fraction of the technical biomass potential which can be developed without opposing the general principles of sustainable development (Rettenmaier et al. 2010). The reasoning developed around these different definitions of energy wood potential are particularly relevant in the current and future contexts of energy wood production and use, in which intensification of forestry activities is expected to be necessary and to become a reality to allow the growth in importance of energy wood (EC 2005).

The mutual implications between on the one side the environmental, social and economic issues, and on the other side the production of energy wood which are addressed by the studies on energy wood potential all represent constraints which can reduce the amount of energy wood retrievable from European forests (Sacchelli et al. 2010).

These constraints result in trade-offs which need to be addressed (Behan 1990; Hesselink 2010; Mckechnie et al. 2011). The Oxford English Dictionary defines trade-offs as “a balance achieved between two desirable but incompatible features; a compromise”. This definition makes clear that in order to increase the production and use of energy wood, compromises will need to be made among environmental, social and economic issues affecting and affected by the energy wood context. Precautions will have to be taken e.g. when establishing SRF plantations for the production of energy wood because as their landscape characteristics may be regarded as unattractive by tourists (especially when located nearby) natural forests, and negatively affect rural economy. When establishing plantations nearby natural and frequently visited forests, compromises for increasing the social acceptance of the plantation might entail keeping coherence of colours, shapes and tree composition with nearby wooded lands, and creating plantations with varied age structures for hosting a wider diversity of environments (LTS International 2006). Also, shifts towards forest management practices characterized by shorter rotation periods and more intensive wood extraction to satisfy increasing energy demands may alter ecological parameters in the forest, like soil nutrient content and soil structure, potentially negatively affecting forest productivity and wood provision in the long run (Schulze et al. 2012; Walmsley and Godbold 2010). On the other hand SRF with high yield and economic return may discourage forest owners to pursue longer rotations in forestry possibly resulting in a shortage of high quality timber (Schulze et al. 2012). A balance will have to be established between on the one side the implementation of sustainable forest management practices which proved to support the forest ecosystem and associated economic activities (Bollmann and Braunisch 2013) and on the other side intensified forest management approaches for energy wood production.

The character of the mutual implications between social, environmental and economic issues and the production and use of energy wood vary according to the issues analyzed: not only trade-offs can be identified, but also the production and use of energy wood can have positive implications for other forest functions and society. Such positive implications represent important synergies which are often highlighted as benefits and opportunities offered by the production and utilization of energy wood (EC 2005; Yablecki et al. 2011). For example, using energy wood reduces GHG emissions in comparison to fossil fuels; the establishment of

SRF plantations for bioenergy production on previously cultivated land increases the level of biodiversity in the area (LTS International 2006). In the same way, some forest ecosystems characterized by high nitrogen deposition, can benefit from forest residue extraction since some of the excess nitrogen in the residues is thus extracted, potentially affecting forest productivity (Abbas et al. 2011). Also, establishing forestry plantations for bioenergy in areas with low levels of employment can increase job opportunities (LTS International 2006). Tables 12, 13 and 14 give examples of environmental, social and economic trade-offs and synergies associated with the production and use of energy wood. They also list possible solutions to the trade-offs based on the principle of compromise. The environmental trade-offs and synergies associated to the production and use of energy wood are addressed in more detail in the following section of the report.

Table 12. Examples of environmental synergies and trade-offs (with respective possible solutions) associated to the production and use of forest energy wood.

Environmental synergies associated with forest energy wood	Environmental trade-offs associated with forest energy wood	Potential optimization of trade-offs
Conversion of lands in SRF areas can benefit biodiversity when SRF reduces the input of chemicals in the ecosystems for example when it substitutes intensive agriculture.	Conversion of natural forests in SRF areas to increase the amount of energy wood produced reduces the level of biodiversity.	Conversion of areas in SRF should be avoided when it worsens the environmental condition of the area, for example by requiring higher water and fertilizer inputs.
The use of energy wood reduces the amount of carbon emissions in the atmosphere respect to the use of fossil energy sources. Therefore enhancing energy wood uses helps tackling climate change. Moreover, producing biofuels and methanol from wood results in lower CO_2 emissions during the energy generation process compared to traditional fuel sources.	Conversion of lands with high carbon stocks in the soil or in the vegetation (e.g. peatlands, wetlands and continuously forested areas) into lands managed to produce biomass for energy (e.g. SRF areas) leads to a release of carbon into the atmosphere. This conversion can hamper the carbon storage function of forests and increase the effects of climate change.	Avoiding conversion of lands that represent sensitive carbon stocks can buffer risks of releasing carbon in the atmosphere.
Removing forest residues has positive effects on the reduction of insect and diseases outbreaks, by reducing the amount of wood that can be attacked by insects and diseases. In Mediterranean countries removal of forest residues can decrease the risk of forest fires by decreasing the amount of wood that can fuel the fire brakes. Finally, some forest ecosystems are characterized by high nitrogen deposition, due for example to atmospheric conditions, or biologic factors like in the podzols. Forest residue extraction can benefit the nitrogen balance of these territories, and potentially increase forest productivity.	Removal of forestry residues is associated with export of nutrients, which is detrimental for poor soils (e.g. peatlands). Also, increasing forest residues extraction increases the frequency of changes to the soil structure caused by heavy machinery compared to traditional forestry.	Negative impacts of biomass extraction on soil nutrients can be reduced by leaving in the forest tree parts with higher nutrient concentration (e.g. foliage, needles and small branches), or by applying compensatory fertilization. Using a portion of branches as “mats” during wood extraction activities, extracting forest residues when the soil is frozen and avoiding wood extraction in wet soils can reduce the impact of extraction activities on the soil structure.

Table 13. Examples of social synergies and trade-offs (with respective possible solutions) associated to the production and use of forest energy wood.

Social synergies associated with forest energy wood	Social trade-offs associated with forest energy wood	Potential optimization of the trade-offs
Employment rates associated with the production of biofuels and methanol from wood are much higher than the rates associated with other renewable energy production processes, like wind and solar energy production. In particular, the use of wood for the production of biofuels and methanol can create new specialized jobs in the engineering, informatics, economy and trade sectors.	Amenity values and protection of traditional landscapes can be negatively affected by intensive biomass extraction from forests to satisfy the growing energy demands. These intensive extraction activities are indeed likely to transform forest landscapes in a way that might not be appreciated by recreational stakeholders.	Discouraging bioenergy extraction from areas where stakeholders have strong cultural and recreational interests can reduce the negative perception of bioenergy impact on traditional forest landscapes. Instead, favouring the establishment of an energy biomass value chain in rural areas with low employment rates can increase job opportunities and consequently the local acceptance of the plantations.
Establishing a SRF plantation in previously unutilized agricultural lands can benefit the tourism of the area, since some categories of recreationists (e.g. dog owners, horse riders) might prefer the newly introduced landscape to the already existing one.	Conversion of arable lands in SRF areas can create competition with food production.	Discouraging the establishment of SRF areas on fertile arable lands can decrease the competition between bioenergy use of wood and food production. Instead, abandoned agricultural areas represent an opportunity to increase the likability of SRF plantations.

Table 14. Examples of social synergies and trade-offs (with respective possible solutions) associated to the production and use of forest energy wood.

Economic synergies associated with forest energy wood	Economic trade-offs associated with forest energy wood	Potential optimization of trade-offs
The production of bioenergy from wood would establish a market for small diameter wood, contributing to the rural economy.	Competition between energy use and pulp and paper use for the use of small value wood can make pulp and paper production costs rise, and result in decreased competitiveness of the pulp and fibre market.	A balance should be kept between energy and other uses of small diameter and low value wood.
The use wood as renewable energy source classifies as market tradable carbon credits under the EU-ETS.	The use of wood to generate energy in CHP plants and in biofuels refineries employ innovative technologies that have to compete with existing and cheaper technologies linked to the use of fossil and other non-renewable sources of energy. For this reason, increasing the use of energy wood needs to be supported by subsidies and this might lead to an increase in wood prices on the market, in particular with respect to those wood fractions destined to the energy industry, discouraging the production of quality timber and increasing the acceptance of unfriendly management practices.	The reliance on market based instruments which do not have important negative drawbacks for the energy wood context like the trading of carbon credits is recommended, while the reliance on state subsides which are likely to alter the market should be limited.

3.2 In-depth analysis of environmental trade-offs and synergies associated with forest energy wood

The production and use of forest woody biomass for energy purposes has associated environmental trade-offs and synergies. This section examines the trade-offs and synergies with various environmental functions offered by forests and namely biodiversity conservation, climate change mitigation, soil protection, water protection and forest fire protection. Moreover, it examines the effects of biomass removal on two factors that are intrinsic to the development of the forest ecosystem and environment, i.e. forest productivity and forest health. These two aspects strongly influence – and on their turn are strongly influenced by – the environmental services provided by forests. For all the environmental forest functions and related to forests besides climate change mitigation and forest fire protection, trade-offs and synergies are highlighted with respect to the sole production of energy wood. For climate change mitigation and forest fire protection trade-offs and synergies related to energy wood use are also described, as these are affected by discussions on emissions caused by the utilization of wood for energy.

In the context of energy wood production, it is important to take into account considerations referring to specific types of forest soils and tree species, and cannot be generalized but need to be considered in the context in which they are addressed. The following sub-sections refer to several forestry operations that are carried out with the main purpose of extracting energy wood (e.g. collection of forest residues and extraction of stumps), but also mention basic forest practices applied in most forestry approaches aimed at the economic exploitation of the wood coming from the forest (e.g. soil scarification and mounding, thinning, and clearcutting). The last types of forestry operations are addressed because currently forest energy wood is a side-product of traditional forestry operations (Kärkkäinen et al. 2014), and therefore traditional forestry activities are also playing a role in the determination of the impacts of forest energy wood extraction. It is however important to recognize that forestry operations focussed at removing biomass for energy, especially if intensified in respect to the current situation, may have stronger environmental impacts on the forest ecosystem than traditional practices, especially for the effects on soil productivity, water and habitat quality (Abbas et al. 2011). The literature stresses the fact that nature conservation practices in forest management are intrinsically not associated with practices that "would repeatedly allow the harvest, re-growth and production of biomass for energy" (Abbas et al. 2011). These considerations are at the basis of the broad discussions taking place in relation to the negative environmental effects of producing energy wood, which are considered in literature as the main drawbacks of using wood for energy generation.

3.2.1 Trade-offs and synergies between forest energy wood production and biodiversity conservation

Forests possess one of the highest levels of all habitats in Europe (Winkel et al. 2009). Such high levels of biodiversity can be maintained because of the low intensity that characterizes the most commonly applied forestry treatments, if compared with other human activities like agricultural practices or urban development. In Europe natural and unmanaged forests are virtually inexistent, constituting less than 1% of the forest cover (Paillet et al. 2010). Most European forests can be considered as "semi-natural" habitats, resulting from the interaction of humans with the environment and characterized by high degrees of naturalness. These forests provide products and services that can be economically exploited, but at the same time host a wide variety of species and habitats (EC 2003).

Forest management has effects on forest biodiversity, as it affects essential characteristics of the forest habitats like age structure, vertical stratification, tree species composition, light temperature, moisture, litter and soil conditions (Paillet et al. 2010). When comparing species richness of managed and unmanaged forests, the literature reports varying information on the effects of forest management on biodiversity. Effects are described as depending on different factors including the species taken into account, the intensity of forest practices and the forest environment considered. In general, managed forests are characterized by frequent and rather uniform disturbances caused by regular forestry operations, which compared to natural disturbances occurring in unmanaged forests do not allow the same development of some habitat features that support biodiversity. Examples of these features are large amounts of deadwood and decaying trees, old and large trees, and pits and mounds in the roots area (Paillet et al. 2010). Paillet et al. (2010) came to the conclusion that unmanaged forests host a higher species richness than managed forests, especially when considering species like saproxylic beetles, bryophytes, lichens and fungi. In this context one should take into account that "species richness" is not a synonym for "biodiversity", but rather one of the factors of biodiversity. Biodiversity indeed includes also factors like ecosystem functions and biological processes, and limiting the meaning of this term to the richness of hotspot species can be a simplistic way to reduce its broad significance (Paillet et al. 2010).

There are other opinions which support the idea that forestry can be beneficial to forest biodiversity, especially in the case of practices that allow the maintenance of habitat diversity and resemble natural forests to as great an extent as possible (Ammer 1992; Bengtsson et al. 2000). In the case of species and habitats that depend on human activities, actively managing forest stands can address habitat fragmentation issues – for example, by providing a continuity of forest habitats, and promoting habitat maintenance and restoration, consequently allowing species to reproduce and find food (Oregon Department of Forestry 2008). Species richness of vascular plants was proven to be higher in managed forests, and this is especially true for understory shade intolerant plants, ruderal and competitive species as well as stress-tolerant species (Paillet et al. 2010). Instead, forestry practices that reduce habitat variability, like the creation of homogenous forests managed with short rotation treatments to enhance wood production, can be detrimental to biodiversity (Schulze et al. 2012). In general, considerations on the benefits of forestry practices for biodiversity are linked to the forest environment taken into consideration. For example, mountain forests and other fragile forest ecosystems are likely to be negatively influenced by intensive management (Linares et al. 2011), and thus often cannot support a continuous demand of biomass by energy plants, for example due to seasonal management constraints.

The effects of management practices on biodiversity are positively correlated with the intensity of management practices. For example, thinning operations are relatively low-intensity practices and are often beneficial to forest biodiversity (Oregon Department of Forestry 2008). Since overstory stand structure strongly influences understory plant communities by determining the amount of light that penetrates the canopy, the opening of dense stands through thinning increases the understory biomass (Hartmann et al. 2010). Moreover, thinning facilitates the development of dense herbaceous understory vegetation by increasing nutrient availability (Hartmann et al. 2010), a benefit which would disappear with the energy use of thinning residues. By increasing microhabitats and creating new germination sites, thinning favours tree species that can rapidly colonize available space by seed or vegetative propagation (Oregon Department of Forestry 2008). With respect to wildlife, thinning benefits animal species that prefer open habitats. This is the case for predators like hawks, owls and eagles, which can more easily prey on small mammals. Instead, animals that prefer closed-canopy or dense understories can be negatively affected by thinning operations (Oregon Department of Forestry 2008). These positive and negative effects of thinning on forest biodiversity demonstrate the variable impact of forestry practices on biodiversity conservation (Paillet et al. 2010).

The same variability of effects can be identified for clearcutting practices, which are a more intensive operation than thinning and therefore result in more intense impacts on forest biodiversity. The information below needs to be considered in light of the fact that clearcutting is not a very common forestry practice in the EU, being allowed only in few EU MSs including some Scandinavian countries and France. It is forbidden in other countries like Spain. Clearcutting is generally considered to have negative effects on biodiversity, for example when the portion of forest that has been cleared is then re-colonized by invasive or exotic plants (Oregon Department of Forestry 2008), or when the size of the clearcutting does not allow natural regeneration (Potvi et al. 1999). Clearcutting is also detrimental to biodiversity when the forest area is replanted with a different tree species (Paillet et al. 2010). Further, clearcutting operations are considered to be detrimental for invertebrates of soils and organic layers, because of the soil compaction and loss of organic layers associated with the heavy machinery used in these forest practices. These considerations can also be considered to be true for other forestry practices like thinning and logging (Walmsley and Godbold 2010; Hartmann 2010). However, clearcutting of small portions of forest can be beneficial to forest biodiversity, since it creates a diversity of environments and a variety of microhabitats that favour both animal and plant species (Camprodon and Plana Bachs 2007). For example, plants which rapidly colonize available space in the forest are advantaged by clearcutting over an area that allows their reproductive methods to be effective. In the same way, animal species that are associated with early successional vegetation can benefit from clearcutting of small portions of forests that allow the area to regenerate (Oregon Department of Forestry 2008).

Site preparation practices like scarification, ploughing, tilling and crushing can have a negative impact on species associated with the forest floor like salamanders and invertebrates. These practices especially impact the availability of soil organic matter, since they negatively affect the presence of coarse wood debris which is an important component of the forest organic material. Fertilization can temporarily increase the richness of plant species, but the duration of its effects are temporary (Hartmann et al. 2012). Actions aimed at eliminating the understory and reducing the lower structural complexity in forests to facilitate silvicultural operations can result in loss of biodiversity, and conflict with the biodiversity conservation principle of preserving a suitable amount of deadwood to sustain the species that depend on it (Schulze et al. 2012). This type of practice is particularly relevant for the energy wood context insofar as wood energy is mainly produced from the wood that is not used in material production processes (Asikainen et al. 2008). The considerations on deadwood and forestry residues are therefore very important for assessing the impact of the production of wood for energy generation and the function of conserving biodiversity performed by forests.

Deadwood is the non-living biomass which is left in the forest after harvesting has taken place, and it includes dead trees, lying deadwood and stumps (Sacchelli et al. 2013). Both the quantity and quality of deadwood in the forest are key factors for biodiversity conservation and determinants of the suitability of a forest habitat for species and species assemblages (Jonsson et al. 2005). Deadwood is indeed thus an important indicator of forest biodiversity: it is considered as the foundation of the food cycle in forest ecosystems and it offers a habitat to several species like fungi, lichens, bryophytes, arthropods, mammals and birds (Jonsson et al. 2005). With respect to the amount of deadwood, it has been estimated that in 2005 the forests of 24 European countries included an average of 12.3 ton/ha of deadwood (Verkerk et al. 2011). In literature this amount of deadwood has been considered as low (Verkerk et al. 2011; Schulze et al. 2012), and EU biodiversity policy recognizes this by fostering the increase of the amount of deadwood in European forests (EC 2003; EEA2007; Standing Forestry Committee 2012). WWF recommends striving for a target of 20-30 m^3 of deadwood per hectare, which should be left in the forest to favour biodiversity (Dudley and Vallauri 2004). The UK Forestry Commission (2002) suggests leaving a minimum of at least three standing and three fallen pieces of deadwood per hectare, or a volume of 5 m^3 of deadwood pieces bigger than 15-20 cm^2 of diameter. Managed forests most often include a much lower amount of deadwood, especially if compared to natural forests, since current forest management aims at reducing the impacts of forest disturbances (such as fires, storms or insect attacks) mainly to limit economic losses (Walmsley and Godbold 2010; Verkerk et al. 2011). The amount of deadwood is positively correlated with older forest age structures (Jonsson et al. 2005), and since managed forests in Europe are rather young, the amount of deadwood they include is lower compared to a situation in which forests might have aged without management (Verkerk et al. 2011).

With respect to the types of deadwood and their relations with forest biodiversity, a difference can be made among standing deadwood (e.g. stumps and standing dead trees), downed deadwood (mostly generated from standing dead trees which fell) and forestry residues (e.g. stem residues). Each one of these types can support different species living in the forest. Downed deadwood is more species-rich than the other types, but it has been demonstrated that some species are confined to standing deadwood or small forestry residues. This makes it important to conserve all three types of deadwood to enhance biological diversity in the forest (Verkerk et al. 2011). Downed deadwood can be classified in coarse woody debris and fine woody debris, according to the size of the deadwood material. Coarse deadwood is generally bigger than 10cm in diameter, while fine woody debris is below that size threshold (Sacchelli et al. 2013). The two fractions of deadwood have different relevance in terms of habitat and biodiversity conservation. In particular, coarse woody debris represent a habitat for the fauna, a reserve of water and a substrate for seedlings, while fine woody debris are more suitable for hosting saprobic and mycorrhizal fungi. The relative importance of fine wood debris for biodiversity is higher in managed than in unmanaged forests (Sacchelli et al. 2013).

Concerning the effect of forest practices on the availability of deadwood, traditional forest practices like stem-only harvesting leave large amounts of deadwood – mainly residues, stumps and roots. In managed forests, where the amount of deadwood is generally quite low, removing deadwood to use for energy generation can have severe consequences for wood-inhabiting species (Sacchelli et al. 2012). The maintenance of tops and branches in the forest has been declared as very important for the support of forest biodiversity (Abbas et al. 2011). It has been estimated that the extraction from the forest of both forestry residues and stumps can remove up to 70% of the wood that would otherwise be left in situ, negatively impacting the availability of deadwood. Stumps in particular represent a significant component of the deadwood in harvested sites (especially where residue harvesting is carried out) and are therefore an essential factor to forest biodiversity (Walmsley and Godbold 2010). It is therefore logical to believe that an intensive extraction of stumps for energy wood production can negatively affect this biodiversity.

Different studies addressed ways to increase the amount of deadwood in the forests (Bütler and Schlaepfer 2009; Müller and Bütler 2010), but generally the suggested options reduce the amount of biomass that can be extracted, making clear that trade-offs exist between the exploitation of woody biomass and the conservation of forest biodiversity (Verkerk et al. 2011). The extraction of higher amounts of deadwood from the forest to satisfy increasing demands of energy wood presents a variety of possible outcomes on forest biodiversity. These outcomes are mostly negative, but in the case of some animal species they could present synergies with the conservation of animal populations (Oregon Department of Forestry 2008). Studies have been carried out on the effects of forestry residue extraction on invertebrates, demonstrating that leaving stumps in the forests can benefit this animal group. The same is true for lichens, fungi and mosses (Moning et al. 2009; Bradtka et al. 2010). Invertebrates that feed on deadwood and wood-living invertebrates are negatively affected by the extraction of stumps and forestry residues, and this is a particular reason for concern as invertebrates are crucial for nutrient cycling and maintenance of site productivity (Walmsley and Godbold 2010).

Verkerk et al. (2011) carried out a model study on 24 EU countries using the EFISCEN model, and predicted the possible effects of intensification of biomass extraction to satisfy increasing bioenergy demands by comparing a “baseline” and a “bioenergy” scenario. In the baseline scenario no changes in policies or management of European forests occur compared to the year 2005, and the extraction of woody biomass from forests is modelled on projections of wood demand based on historical development and economic growth. In the bioenergy scenario forestry residues are extracted and fellings are increased to the maximum potential from 2010 onwards (Verkerk et al. 2011). The study concluded that in the baseline scenario the amount of deadwood increased in most European regions, partly as a consequence of the shift in forest area over age classes in the period 2005-2030, and partly as a result of the increased availability of felling residues resulting from the increased harvesting occurring as a result of economic growth. This scenario suggests that the amount of deadwood in 2030 could be increased by 6.4% with respect to 2005 levels. Instead, the bioenergy scenario suggests that increased levels of biomass extraction to satisfy bioenergy demands result in an average reduction of deadwood by 5.5% compared to 2005 levels. Stem residues were most strongly reduced (8.8% on average compared to 2005 levels), even if they remained the most common type of deadwood in the forests. These were followed by standing residues, which were reduced by 5.5% compared to 2005 levels. The amount of downed deadwood was estimated to remain the same (Verkerk et al. 2011). Consequently, species depending on large-diameter deadwood might be more strongly affected by increased biomass extraction to satisfy bioenergy demands, if compared with species that depend on small deadwood fractions like stem residues. In the same way, species depending on standing deadwood might be more negatively affected by the production of energy wood than species depending on standing deadwood (Verkerk et al. 2011).

Other important factors to forest biodiversity are cavities in large diameter trees, insofar as these offer nesting, roosting and shelter habitat for bats, birds and small mammals, as well as a source of food (Camprodon et al. 2008). If forestry practices do not take into account the need to keep in the forest trees which might develop or have already developed cavities, they can negatively affect the biodiversity conservation function of forests (Oregon Department of Forestry 2008). Just as for deadwood, quantity and quality of tree cavities are important in determining the level of biodiversity hosted by a forest. However, with respect to the quality, not all cavities are optimal for supporting biodiversity and therefore in forestry practices it is important to acknowledge the favourable characteristics of cavities for the selection of trees to leave in the forest for biodiversity conservation purposes (Camprodon et al. 2008). With respect to the quantity, forest management approaches allow the development of different amounts of cavities. In Mediterranean beech forests mature forest stands present a higher amount of cavities, high stem forests present an intermediate amount of cavities, while stands managed with coppice techniques present the lower amount of cavities (Camprodon et al. 2008). In general the intensity of forest management is negatively correlated with the quantity of tree cavities in the forest (Camprodon et al. 2008).

This section also examines the impact of forest plantations managed through intensive approaches like SRF and SRC on forest biodiversity. Box 2 in Section 2.1 describes these management approaches in more detail. These approaches deserve particular attention in the energy wood context insofar as they are mentioned among the possibilities to obtain a larger amount of wood to use for energy generation (EEA 2007). With respect to the effects on biodiversity, forest plantations have been defined in literature as “biological deserts” (Dyck 1997), since they present less diversified species composition than forests especially with respect to birds, arthropods and plants (Hartmann et al. 2010). For example, apart from a small number of bryophytes, no particularly rare or threatened plants are likely to benefit from the establishment of a tree plantation (LTS international 2006).

The considerations above however vary with the tree species that are used for the plantation (LTS international 2006). For example, it has been demonstrated that pure stands can support a richer understory vegetation than mixed species stands, and that biodiversity is generally higher in deciduous than in coniferous stands (Hartmann et al. 2010). Moreover, native species host a higher species richness than exotic species, especially with respect to arthropods which are an important basis of the food chain. Also, compared to exotic plantations, the litter of native forest plantations is more rapidly decomposed by micro-organisms which are adapted to it, and it carries higher number of phytophages – therefore being able to support higher levels of plant diversity (LTS international 2006). It has been demonstrated that the different density of the canopy associated with different tree species is strongly related to the levels of biodiversity hosted in the plantations, determining the amount of light reaching the soil, the abundance of understory vegetation and the rate of litter breakdown (LTS International 2006). Also, the lack of available surface water caused by the high water interception of the plantation canopy may render understory conditions too dry for some herbaceous species. This can economically benefit the success of the plantation because of reduced competition between planted trees and naturally regenerated species, but it negatively affects biodiversity (LTS International 2006).

Next to the tree species, differences with respect to the impact of plantations on biodiversity arise when considering the scale of the plantations. For example, smaller blocks of plantations have a higher proportion of edges than large blocks, therefore being able to host a wider diversity of species adapted to edge habitats (LTS International 2006). Moreover, when considering forest plantations, it is important to take into account some factors that allow assessment of their effects on biodiversity without being influenced by the negative reputation of this forest management practice. Examples of these factors are i) the land use or vegetation that the plantations replace, ii) the possible alternative land uses to the plantations and their impacts on biodiversity, and iii) the time span local species have to adapt to the habitat of the plantation (Brockerhoff et al. 2008). Indeed, some synergies exist between the establishment of forestry plantations and the enhancement of biodiversity, for example when plantations substitute more intensive land uses like agriculture, polluted, degraded or abandoned lands, and treeless landscapes (LTS International 2006; Hartmann et al. 2010; Abbas et al. 2011; Pedroli et al. 2013). Potentially, the establishment of plantations in agricultural areas benefits most species of mammals and birds by providing additional cover by the tree crop (LTS

International 2006). In general however, a too abundant population of mammals like rabbits and deer is undesirable in trees plantations due to potential damage to young trees (LTS International 2006). Plantations also facilitate the colonization of early and even late successional tree species from the forests in the surroundings, when the distance from these forests is not too great (Hartmann et al; 2010). In cases in which plantations are established between isolated stands of existing forests, biodiversity could be enhanced thanks to the corridor role played by the plantations (LTS International 2006).

3.2.2 Trade-offs and synergies between production and use of forest energy wood and climate change mitigation

Forests store CO_2 in living biomass, dead organic matter and soil and for this reason they constitute "carbon pools". Depending on whether the carbon pool grows by absorbing more carbon from the atmosphere, or decreases by liberating carbon to the atmosphere, forests are defined respectively as "carbon sinks" or "carbon sources" (Luyssaert et al. 2008; Schulze et al. 2012). The absorption and immobilization of carbon in the forest pool represents an important ecosystem service offered by forests, contributing to the mitigation of climate change by reducing the concentration of CO_2 in the atmosphere (Mckechnie et al. 2011). The literature on the flows of carbon in forest ecosystems shows that in many parts of Europe forests are currently particularly active in sequestrating carbon from the atmosphere, and this is linked to the ongoing recovery of forest ecosystems after the land abandonments of the last century (Schulze et al. 2012). Indeed, the European forest area is increasing, as is the carbon stock included in the forests and the capacity of forests to accumulate more carbon (Schulze et al. 2012; Copa-Cogeca 2012). According to Ciais et al. (2008), during the last fifty years European forests multiplied their biomass carbon stock per hectare by 1.75. This sustained carbon accumulation is due to several reasons like 1) the fact that harvesting levels have been lower than the biomass increments for several decades, 2) the increased fertility of forest soils due to reduction of nutrient export by grazing, and 3) the increasing atmospheric CO_2 concentration which acts as a sort of fertilizer for plant growth (Ciais et al. 2008). The capacity of forests to sequester carbon can be further enhanced by favouring rapid growth and long-term site retention, maintaining healthy and vigorous trees and minimizing disturbances by fires and insects (Millar et al. 2007). Other options are storing carbon in wood products and using wood to create energy through fossil fuel substitution (Millar et al. 2007; Mckechnie et al. 2011).

These two last options are based on the assumption of "carbon neutrality" of wood as an energy source and as material. In other words, they rely on the idea that the carbon stored in wood represents a reservoir that has been built up by absorbing CO_2 from the atmosphere. When wood is extracted from the forest and used as material for construction, furniture and other wood-based products the carbon is immobilized in the timber and its emission in the atmosphere is in this way avoided at least for the life duration of the wood product (Law and Harmon 2011). When using wood as a material, the carbon reservoir of the forest from which the wood has been extracted decreases, but the carbon emissions from the wood product are postponed in time (Law and Harmon 2011). When the wood is burned, the carbon emissions derived are balanced by the carbon absorption that took place when the trees generating the wood were growing (Bright et al. 2012). In this perspective, burning wood is considered as having a neutral effect on the atmospheric CO_2, since, if applying a long time frame of analysis, the balance between the CO_2 absorbed by trees and the CO_2 released in the combustion is considered to be zero (Czeskleba-Dupont 2012). It follows that whatever use is made of wood – if material or energy – it allows in any case to reduce carbon emissions in the long run, if its use is compared with fossil fuel sources. This shows the potential of forest biomass in mitigating climate change, which is particularly strong if soil carbon losses are avoided. However a difference should be made among various wood fractions since harvesting, forwarding and processing stump wood fuel is estimated to produce larger carbon emissions if compared with small roundwood or forestry residues bundles. This is mainly due to the great soil disturbances caused by the extraction of stumps (Walmsley and Godbold 2010).

As "carbon sources", forests emit carbon to the atmosphere either due to natural causes or when management practices result in emissions from the different pools (e.g. forest soil), therefore worsening the impacts of global warming (Luyssaert et al. 2008; Law and Harmon 2011). For example, respiration plays a role in this context when large amounts of dead biomass decompose after a storm, and the carbon losses are considered over a long time frame. Again, slow releases of carbon can take place as a result of insects and diseases attacks. Instead, in the case of phenomena like wildfires, land-use change and management practices which disturb the soil carbon pool, carbon losses are rather immediate (Czeskleba-Dupont 2012). As stated above, carbon release to the atmosphere also occurs when burning forest wood. In particular, forest wood used as an energy source emits more carbon per unit of energy produced than natural gas, coal or gasoline (Czeskleba-Dupont 2012). If considering the emissions derived from the energy use of wood in a short time frame, it is possible to affirm that the "carbon neutrality" assumption is not universally valid, and it is rather a convention used in carbon accounting in order to avoid double counting in carbon fluxes. With respect to this point, several studies have demonstrated in different ways that the "carbon neutrality" assumption does not apply indiscriminately to all bioenergy projects, but rather its validity depends on different factors like the time frame considered, the fossil fuel alternative taken into account, and the whole value chain of the forest-based bioenergy product (Law and Harmon 2011).

For example, Schulze et al. (2012) hold that the strategy to extract woody biomass from forests to generate bioenergy that can substitute fossil fuels is likely to miss its main objective to reduce GHG emissions, since, when wood consumption would exceed tree growth, this might result in a reduction of the carbon pools included in the forests that might take a long time to be paid back by fossil fuel substitution. Indeed, the assumption that burning wood to generate energy is carbon neutral does not take into account carbon emissions caused by the decrease in standing biomass. In other words, extracting wood from forests to produce bioenergy generates carbon emissions because of the consumption of current carbon pools and of the permanent reduction of the forest carbon stock that took centuries to accumulate.

Schulze et al. (2012 p. 164) refer to this process as "slow in and fast out". This is confirmed by studies which show that in productive temperate forests lower carbon emissions are achieved by sequestering carbon in forests rather than producing bioenergy from wood sources (Hudiburg et al. 2011).

In the same way, by allowing forests to grow older it would be possible to generate richer carbon sinks if compared with the management of young forests with short rotation periods to produce more wood for energy purposes. Indeed, old growth forests show lower net primary production (NPP), i.e. increase in plant biomass per unit area and unit time, but store larger amounts of carbon. The combination of fast rotation management approaches and use of wood to substitute fossil fuels reduces the ability of forests to sequester carbon (Schulze et al. 2012). Moreover, the assumption that burning wood to generate energy is carbon neutral ignores the fact that fossil fuels are used for land management, wood harvest and transportation and for bioenergy processing, and that increasing the production of bioenergy from wood sources is likely to indirectly increase carbon emissions (Schulze et al. 2012). Another argument against the carbon neutrality of wood as an energy source is that the carbon emitted during biomass harvest, processing and combustion stays in the atmosphere for decades before being absorbed by growing forests. In a scenario of increased woody biomass utilization for energy purposes, a "pulse of warming" (Schulze et al. 2012 p. 164) is likely to occur in the first years of intensified bioenergy production. This idea conflicts with the concept of a rapid reduction of climate change effects following the substitution of fossil fuels with biomass based energy that are the basis of bioenergy and biomass policies in the EU.

Despite the considerations above, when considering the effects of producing bioenergy from wood on climate change, part of the scientific community supporting the carbon neutrality assumption underlines that burning wood produces CO_2 emissions that remain only temporarily in the atmosphere, because if the forest sink is fully regenerated the CO_2 will be once again absorbed by tree growth and accumulated in the wood (Bright et al. 2012). Instead, fossil fuels generate emissions that are theoretically remaining in the atmosphere for millennia. The substitution effect of wood toward fossil fuels should therefore be considered when discussing the role of bioenergy from woody biomass in mitigating climate change. This is the main theoretical basis which supports the climate neutrality assumption (Bright et al. 2012). In carrying out this reasoning Bright et al. (2012) distinguish between CO_2 emissions from wood and those from fossil fuels. In practice the effects of carbon emissions on climate change however do not depend on the emitting source (Schulze et al. 2012). Moreover, relying on the capacity of future forests to absorb the carbon emitted by burning wood today can be considered as a "carbon debt" that will need to be repaid (Czeskleba-Dupont 2012). Since measures like fertilization that aim at speeding tree growth increase the amount of wood produced but not necessarily the amount of CO_2 absorbed, the carbon debt might take much longer than expected to be paid back, resulting in permanent rather than temporary carbon emissions in the atmosphere (Schulze et al. 2012). Often, in the use of biomass for energy generation a "payback time" can be identified, before which GHG emissions increase, and only after which the system actually decreases GHG emissions (Cherubini et al. 2011).

The discussions taking place in the scientific arena show the complexity of the relations between the production and use of forest-based bioenergy and the climate change mitigation function of forests. The stronger argument used against the assumption of carbon neutrality of bioenergy from biomass is based on a temporal perspective, and it claims that this assumption does not well represent the carbon cycling of biomass growth, especially with respect to slow growing ecosystems like forests. This is mostly due to the time dependency of carbon impact caused by forest harvest for bioenergy (Mckechnie et al. 2011; Law and Harmon 2011), and it is explained by the fact that carbon emissions from combustion of forest biomass occur at a single point in time, while carbon absorption by forests takes from decades to centuries. Assimilations and emissions diverge in time, resulting in the fact that prior to being captured by biomass re-growth, CO_2 molecules emitted while burning biomass spend time in the atmosphere and contribute to global warming (Cherubini et al. 2011; Czeskleba-Dupont 2012). In temperate and boreal forests for example, harvest cycles range from 60 to 100 or more years (Czeskleba-Dupont 2012). This means that it could take a century for carbon stocks to be replaced (Cherubini et al. 2011), especially under a clearcutting management approach (Mckechnie et al. 2011). These long time frames generate uncertainties on future forest conditions, markets and performance of investigated bioenergy systems, which drastically reduce the confidence in the immediate carbon neutrality of energy wood (Mckechnie et al. 2011). In conclusion, carbon neutrality is a valid assumption for fast growing biomass species, but should be carefully applied to forest biomass value chains, by considering the specific characteristics of the bioenergy products and their use (Cherubini et al. 2011).

The capacity of forests to contribute to climate change mitigation and the specific flows of carbon in a forest depend on different factors like forest type and age of the forest, but also on anthropogenic factors like forest management (Hudiburg et al. 2009). For example, with respect to forest types, Bonan et al. (2008) and Jackson et al. (2008) report differences between boreal and tropical forests, explaining that tropical forests store carbon especially in the living biomass, while boreal forests store carbon mostly in the soil and in dead biomass because of the slow decomposition rates of these ecosystems. Also, with respect to forest age, the literature is divided between those who consider that only young forests are able to actively accumulate carbon (van Tuyl et al. 2005), and those who consider that also old-growth forests are carbon sinks (Carey et al. 2001; Luyssaert et al. 2008). The first group of authors suggests that old-growth forests are carbon neutral, i.e. that the CO_2 uptake by assimilation is balanced by soil and plants respiration. This leads to the consideration that old-growth forests are redundant in the global carbon cycle, and that therefore their economic exploitation for extraction of timber does not affect this cycle. The second group of authors asserts that carbon accumulation continues in forests that are centuries old (Luyssaert et al. 2008). This is explained by the fact that the creation of new forests frequently follows disturbance to soil and previously existing vegetation, which result in the decomposition of coarse wood debris, litter and soil organic matter which exceeds the NPP of the forest ecosystem (Luyssaert et al. 2008). Instead, when the forest ages, decomposition stops exceeding the NPP, and forest biomass can increase for centuries while accumulating carbon. During the succession, plant competition leads to self-thinning in natural forests or is induced by thinning in managed forests, so that older stands host a relatively small number of trees which tend to be quite large (Luyssaert et al. 2008). When high aboveground biomass is reached, generally new recruitment occurs, or abundant second canopy layers can develop, which take over and maintain productivity. Even though tree mortality can occur rapidly, or over several years, tree stem decomposition can take decades, while again regeneration occurs in a shorter time frame continuing the carbon absorption from the atmosphere. These authors conclude that in most forests between 15- and 800-years-old the net carbon balance of the forest, including soil, is positive (Luyssaert et al. 2008).

Different studies assessed the effects of forest management practices and wood utilization options on the role of forests in emitting or absorbing carbon. Some forest management practices have been defined as enhancing the absorption of CO_2 by forests therefore building up synergies between the economic exploitation and the climate change mitigation function of forests. For example, common forest practices like thinning and stem-only harvesting can enhance soil carbon pools (Walmsley and Godbold 2010; Law and Harmon 2011). In particular, sawlog harvesting in coniferous forests allows the amount of carbon stored in the forest soil to increase (Johnson and Curtis 2001). Other practices have been instead defined as reducing the capacity of forests to store carbon or even contributing to carbon emissions. These practices generate trade-offs between forest exploitation and climate change mitigation functions. This is for example the case for whole-tree harvesting which leads to substantial losses in soil carbon (Johnson and Curtis 2001; Walmsley and Godbold 2010). This last consideration is particularly relevant for the extraction of wood for energy generation, which mostly relies on the collection of forestry residues after stem harvest. Indeed, if left uncollected, forestry residues would continue to store carbon until decomposition (Mckechnie et al. 2011). Moreover, considering that forests are able to store important quantities of carbon in the forest soil is important when assessing the impact of energy wood extraction on carbon fluxes in the forest ecosystem (Law and Harmon 2011). The organic matter in the soil is present as stable and labile pools. Stable pools have turnover times of weeks or months, while labile pools have turnover times of decades or longer. Stable pools represent the long-term carbon sequestration pools, while labile pools are decomposed by microbes and this constitutes a major carbon flux in the forest ecosystem (Walmsley and Godbold 2010). Disturbances to forest soil can enhance the turnover of labile and stable organic matter, increasing heterotrophic respiration (the decomposition of litter and soil – a major process releasing carbon to the atmosphere) and potentially leading to a release of carbon from the soil into the atmosphere (Walmsley and Godbold 2010). This situation can occur, for example, when lands with high carbon stocks in the soil like continuously forested areas are converted into lands managed to produce biomass for energy like SRF areas (LTS International 2006).

It is possible to state that in general losses of forest carbon are reduced when effort is put in minimizing disturbances to forest soil (Walmsley and Godbold 2010). As a consequence, management approaches that include mechanical preparation of the forest soil cause elevated rates of soil carbon decomposition and loss of soil carbon (Walmsley and Godbold 2010). Also stump harvesting leads to important soil carbon emissions due to the relevant disturbances caused in the forest soil and in particular to the decomposition of soil organic matter. Moreover stump extraction causes leaching of dissolved organic carbon, further contributing to the impoverishment of the carbon pools included in forest soils (Walmsley and Godbold 2010). However, uncertainties affect studies carried out in this field, and it is not possible to conclude whether the exacerbation of carbon soil losses caused by stump harvesting is outweighed by the potential reductions in carbon emissions caused by the effect of substituting fossil fuels with the wood derived from stumps. In general, there is a lack of scientific data on the effects of stumps on the soil carbon pools (Walmsley and Godbold 2010).

Next to these studies, a part of the scientific community reflects on the fact that when assessing trade-offs and synergies associated with climate change it is important to consider not only forestry aspects, but also the whole life cycle of the product (Law and Harmon 2011). For example, aspects like the transportation of the wood resource for long distances to produce energy might contribute to, rather than help to mitigate, climate change (Schulze et al. 2012). Also, taking another energy source as means of comparison can help assessing the mutual effects of energy wood production and climate change mitigation functions. For example, producing biofuels and methanol from wood results in lower CO_2 emissions during the energy generation process compared to traditional fuel sources. If these sources are substituted with wood, potential synergies can arise between energy wood use and climate change mitigation.

When looking at the total carbon fluxes in the forest, it is important to take into account not only forest practices but also the uses of forest products and a specific non-renewable energy as reference for the calculations. Walmsley and Godbold (2010) report that the greatest reduction in net carbon emissions occurs in a scenario in which forests are fertilized, residues and stumps are harvested, wood is used as construction material, and the reference fossil fuel is coal. Indeed, fertilization allows the amount of wood that can be extracted from the forest to be increased, and the material use of wood strengthens the climate related advantages of substituting fossil fuels by storing the carbon in wood products. Wood is a renewable material and its use in construction reduces the need to produce other construction materials that heavily rely on fossil fuels for their production (Walmsley and Godbold 2010). Instead, the lowest reduction in net carbon emissions occurs in a scenario in which traditional forest management is put in place, forest residues are left in situ, and the wood is used as an energy source to replace natural gas (Walmsley and Godbold 2010). This second approach does not exploit the potential of forests to provide wood to its greatest extent, for example because forest residues are left unutilized. Also, wood is burned rather than used as a material, therefore causing more carbon emissions than the previously described scenario. Moreover, the non-renewable energy source taken into account is characterized by a lower carbon emission rate than the one considered in the first scenario, indirectly reducing the carbon emissions in the second scenario (Walmsley and Godbold 2010).

Mckechnie et al. (2011) carried out a case study over two energy wood products (wood pellet and ethanol) and two forest management practices (harvesting of standing trees and residue collection). They used a Life Cycle Assessment approach to identify the impacts of the different bioenergy options on the carbon emissions to the atmosphere. For the two products, two fossil fuels are used as references, i.e. coal for the pellets and gasoline for ethanol. The authors evaluate forest carbon stocks and their changes for three potential scenarios: 1) "current harvest" baseline scenario where wood is not extracted for bioenergy but only for traditional timber markets; 2) "current + residue harvest" scenario where residues are removed for bioenergy production; and 3) "maximum allowable harvest" with harvest of additional standing trees, without collection of residues (Mckechnie et al. 2011). Mckechnie et al. (2011) report that the climate change mitigation potential of bioenergy products depends on the activities carried out through the whole life cycle of the product taken into account, which needs to be considered in a cradle-to-grave perspective. The results of the study show that emissions are greater when biomass is sourced from standing trees than from residues, primarily because live trees would continue to sequester carbon if not harvested, while carbon in uncollected residues declines over time (Mckechnie et al. 2011). The authors make clear that increasing biomass removals from the forest significantly reduces forest carbon stocks, and delays and lessens the carbon mitigation potential of biomass solutions. They also show that it is erroneous to assume that extracting biomass from the forest and using it to produce energy has an immediate neutral effect on atmospheric CO_2 (Mckechnie et al. 2011). Excluding changes in forest carbon and therefore assuming the immediate carbon neutrality of bioenergy options, the emissions reduction associated with using bioenergy in place of fossil alternatives increases steadily over time. During the 100 years time frame considered in the study, using pellets reduces emissions of 18% with respect to the use of coal whether standing trees or residues are used, while the use of an ethanol/gasoline blended fuel reduces emissions by 57% with respect to the use of pure gasoline. Substituting coal with pellets provides a greater mitigation benefit than substituting gasoline with the ethanol/gasoline blended fuel, mainly because of the higher carbon intensity of coal (Mckechnie et al. 2011).

When reductions in forest carbon are taken into account and the carbon neutrality of wood is bounded to time rather than being assumed as immediate, emission reduction is delayed and reduced (Law and Harmon 2011). For example, excluding changes in forest carbon when assessing the production of pellets from standing trees leads to an overestimation of total emissions reduction equal to 56% (Mckechnie et al. 2011). This shows the negative consequences of assuming the immediate carbon neutrality of forest wood. All scenarios show that bioenergy options produce emissions which initially exceed the emissions from the reference fossil fuel. This increase in emissions is however temporary, since the rate of forest carbon loss decreases with time, while the emissions produced by the fossil fuels alternative continue to increase steadily (Mckechnie et al. 2011). A break-even point exists for every bioenergy pathway, in which total emissions from the bioenergy products and the fossil fuels are equal. This point is time dependent, and only after this point net emission reductions are achieved through the bioenergy options. For example, compared to the production of electricity with pellets, using residues for ethanol production is more affected by changes in forest carbon due to the lower carbon intensity of gasoline compared to coal. Ethanol from residues has its break-even point after 74 years of continuous production. Pellets from standing trees reach the break-even point after 38 years (Mckechnie et al. 2011). As a conclusion, when forest carbon dynamics are considered, the use of forest-based bioenergy increases overall emissions for several years, and in the worst case scenario of using standing trees to produce ethanol, they might not yield climate change benefits over the 100 years period studied. Residue collection is therefore a better option to reach the climate mitigation goal (Mckechnie et al. 2011).

The study of Cherubini et al. (2011) examines the effects of forest management practices in boreal forests on the climate impact of CO_2 emissions from forest-based bioenergy. The different forest management strategies are exemplified with the changes in growth rates and year of harvest. The authors use a model to simulate carbon fluxes, and they consider as the starting condition a boreal even-aged forest stand which is clearcut at year 0. After this, the aboveground biomass carbon is released to the atmosphere in one time step. This allows considering CO_2 emissions as a single pulse. The forest area is then immediately regenerated with the same tree species previously cut, and clearcut again after a period of 100 years. The authors consider that all the CO_2 emitted from combustion will be captured back by the vegetation within these 100 years. The study does not take into account changes in the carbon pools other than aboveground biomass (Cherubini et al. 2011).

In reality, trees growth rate affects the cumulative carbon sequestrations of the living forest biomass, and in situations which differ from the standard conditions described above this can make the CO_2 balance of the forest different from zero. Two situations can occur, either a lower growth rate compared to the standard situation due to decrease in soil fertility, or a lower growth rate compared to the standard situation after application of fertilizers (Cherubini et al. 2011). The year in which trees are harvested has also important repercussions on the CO_2 uptake capacity of the forest re-growth. Postponing the year of harvest with respect to the standard situation reported above causes a larger sequestration of carbon in standing biomass, while anticipating the harvest reduces the amount of carbon sequestered (Cherubini et al. 2011). The study reveals that the time of harvest is the most important determining factor in regulating the carbon balance of the forest. Forest bioenergy from boreal forests becomes a valid mitigation option only when long harvesting times are considered, for which climate cooling effects can actually be observed.

Aside from the scientific debate on the carbon fluxes in forests and on the role of forest-based bioenergy, part of the scientific community reflects over the fact that not only carbon related issues, but also biogeophysical factors such as reflectivity, evapotranspiration and surface roughness have influences on climate change mitigation functions of forests (Law and Harmon 2011). These factors can affect temperature more strongly than carbon sequestration. This is relevant for forest reforestation which is aimed at increasing forest cover (Jackson et al. 2008). Reforestation often darkens the land surface as compared to pasture, agricultural use and snow covered surfaces, leading to higher sunlight absorption which can locally warm up the land. Also, evapotranspiration from plants and soil is affected by these projects, since forests sustain the hydrologic cycle by evapotranspiration and consequently cooling climate through feedbacks with clouds and precipitation (Jackson et al. 2008; Bonan 2008). These issues complicate the role of forests in mitigating climate change.

When assessing trade-offs and synergies between the climate change mitigation function of forests and the extraction of energy wood it is important to also mention the effects of climate change on the same forests and their ability to provide wood for energy generation. Two main contrasting points are raised in literature with respect to this topic. On the one side, climate change can be beneficial to forest productivity in some areas of Europe, since the increasing temperatures might allow for the provision of higher amounts of biomass for energy production. On the other side, other parts of Europe might be subject to excessive drought as a result of global warming, which can result in a decrease of forest productivity and in a reduction of the amount of biomass available for bioenergy production (EEA 2007). The uncertainty related to the effects of climate change on European forests however dominates this study field, and forest adaptation strategies should take this into account when developing flexible management approaches which are able to respond to various climatic conditions (Millar et al. 2007).

3.2.3 Trade-offs and synergies between forest energy wood production and soil protection

Soil is a fundamental source of productivity and its structure also strongly influences hydrologic functions and water quality in forest ecosystems. Therefore, the considerations made in this section with respect to soil properties and their preservation have direct effects on the content of Section 3.2.4 which is dedicated to water protection in the forest environment and Section 3.2.6 dealing with forest productivity.

One of the main dangers posed by forestry operations to forest soils is soil compaction, which occurs as a consequence of operations which impact the soil for example through the use of heavy machinery. When a soil is compacted by the application of loads, vibration, or pressure, soil pore space is reduced. This situation prevents water and air from moving freely and rapidly through the soil, and results in unfavourable conditions for plant growth (Adams and Froehlich 1981). Soil compaction is particularly dangerous because it can take decades to recover (Oregon Department of Forestry 2008). Walmsley and Godbold (2010) report that soil compaction has far greater negative effects on tree health and root stability than other forest threats like soil acidification or air pollution. Soil compaction lowers forest productivity because it reduces tree and seedling growth. Moreover, it causes surface run-off because of the reduced water infiltration in the soil, which ultimately results in soil erosion. Soil erosion consists in the detachment of individual soil particles from the soil mass and their dislocation, for example, following heavy rainfall events which might occur shortly after harvesting activities (Walmsley and Godbold 2010). Individual particles are transported downslope and finally sediment is deposited on the slope or in nearby water catchments (Silde 1980). Soil erosion has a negative effect on soil productivity due to the loss of fertile surface soils, and it produces sediments which can impact the general water quality of the area (Adams and Froehlich 1981; Oregon Department of Forestry 2008). Soil compaction and erosion can be particularly strong on soft and wet soils, therefore particular precautions should be taken when carrying out forestry operations in these conditions.

The description above makes clear that trade-offs arise between the protection of forest soil from compaction and erosion, and the exploitation of the forest resource in general. The effects of forest soil compaction (and of its direct negative consequences on the status and productivity of forest soils) are exacerbated in some forestry practices that are especially carried out to extract wood for energy generation – such as collection of stem residues and litter, as well as whole-tree harvesting and stump extraction (Vasaitis et al. 2008; Walmsley and Godbold 2010; Laudon et al. 2011). Moreover, some of the features of intensive forest management approaches focussed on the production of energy wood, like the shorter rotation periods employed and the higher density of trees in the forests, require more frequent trafficking of machines on forest soil, and sometimes utilize heavier machinery compared to traditional forestry practices. This generates heavy trade-offs between energy wood production and protection of forest soil. If operations to extract wood for energy purposes are not carried out together with traditional harvesting activities, and management operations are carried out with the sole intention of extracting energy wood, the risks for forest soil compaction and erosion are even greater (Fernholz et al. 2009; Walmsley and Godbold 2010). Similar trade-offs can also be identified between the trend towards young uniformly managed forest stands and the role of forests in controlling avalanches and stabilizing slopes. Low young stands are indeed less efficient in buffering the effects of landslides and avalanches (Schulze et al. 2012).

There are particular concerns regarding the extraction of stumps and its effects on forest soil structure, especially considering a scenario in which this practice might be more intensively applied to satisfy the needs of the energy industry (Vasaitis et al. 2008; Walmsley and Godbold 2010). In this context, stump and root architectures have a substantial influence on the severity of soil disturbance in general, and the same is true for site characteristics like slope, soil type, soil moisture, wind exposure and planting density (Walmsley and Godbold 2010). For example, slopes force trees to concentrate root development upslope, while high planting density encourages trees to develop deeper root systems. Extracting stumps of trees with plate root systems will leave wide shallow holes and disrupt the superficial soil layers, while the same forest practice applied to trees with deep rooting systems will leave narrower but deeper holes disrupting deeper soil layers. Extraction of deep rooting trees is considered to be more dangerous for forest soils (Walmsley and Godbold 2010). Moreover, with respect to soil compaction, it has been demonstrated that extracting stumps on wet soils leads to a widespread disturbance of the soil surface, since wet sites are more sensitive to the impacts of heavy machinery (Walmsley and Godbold 2010). This description shows that important trade-offs exist between the intensification of forest exploitation by harvesting stumps and the protection of forest soils.

Another important aspect of soil protection is soil fertility, mainly analyzed in terms of soil carbon and nitrogen which are considered as the most important indicators of forest soil nutrients (Johnson and Curtis 2001; Oregon Department of Forestry 2008). Carbon is sequestered from the atmosphere by the plants and transferred to the soil through dead organic matter, which is decomposed by microorganisms generating substrate carbon that can be once again absorbed and utilized by plants. Microbial decomposition, through aerobic or anaerobic respiration, emits carbon to the atmosphere in the form of CO_2 or methane (Schlesinger and Andrews 2000; Potter et al. 2001; Nazaries et al. 2013). Indeed, soils contain about twice as much carbon as the atmosphere or as terrestrial vegetation (Johnson and Curtis 2001). Nitrogen is necessary for plant growth and it represents the primary limiting factor for NPP in many boreal and temperate forests (Laudon et al. 2011). During the last century forests have been subject to an increase in atmospheric nitrogen deposition, which has had a major impact on the ecological and biogeochemical dynamics of forest ecosystems. This has had positive consequences for nitrogen-limited forests, since the increase in nitrogen availability stimulates photosynthesis and increases the biomass of leaves and needles. Also, nitrogen additions can increase the carbon sequestration of forest ecosystems as such inputs can slow down the decomposition of soil organic matter (Laudon et al. 2011). In this sense, increases in the concentration of nitrogen, for example following fertilization, support the role of forests as carbon sinks. Carbon and nitrogen are intimately related in the soil dynamics. The carbon/nitrogen ratio of the organic material which arrives to the soil influences the rate of decomposition of organic matter. If the ratio is low, such as <5, then nitrogen may be released into the soil from the decomposing organic material. If the ratio is high, microorganisms will utilize soil nitrogen for further decomposition and soil nitrogen will be immobilized (Lukac and Godbold 2011).

Soil acidification is another aspect of soil protection that is linked to soil fertility. Coniferous tree species are known for their acidifying effect on soils. Soil acidification affects site productivity by reducing the amount of nutrients available for the trees and mobilizing aluminium in the soil. An excessive mobilization of aluminium in forest soils can disrupt essential tree functions such as cell division, root respiration and nitrogen metabolism. In the literature, acidification of forest soils, and the nutrient depletion effect are considered as a far greater threat to forest soil than the direct loss of organic matter (Walmsley and Godbold 2010). It is obvious that trade-offs exist between forest practices that cause soil acidification and soil fertility. Soil chemistry changes are registered for all types of harvesting, from conventional harvesting to whole-tree harvesting. However, stump extraction is the practice that results in the higher mobilization of aluminium in the soil (Walmsley and Godbold 2010). Also litter removal as a forest practice has detrimental effects on soil acidification and degradation, leading to losses of productivity (Walmsley and Godbold 2010). Since the retention of logging residues on-site is known to improve the acid-base status of the soil due to base cation input from forestry residues, whole-tree harvesting is described in literature as resulting in lower pH values in the soil if compared with stem-only harvesting (Wall and Hytönen 2011). In general, the potential for acidification is a function of the soil buffering capacity. Considerable effects of forestry operations can be expected on sensitive soils (Walmsley and Godbold 2010).

In general, the removal of biomass from forests can cause a depletion of the nutrient reservoir included in forest soil. Schulze et al. (2012) reflected on the historical phenomenon in which the more fertile lands are used for urbanization and agriculture, while the less fertile areas are used for forestry. The authors express the concern that an increased forest biomass extraction for energy purposes might impoverish even more the forest soil nutrient stock (Schulze et al.

2012), potentially generating trade-offs between energy wood production and soil fertility. The literature reports that different forestry operations have varying effects on soil nutrients. For example, harvesting and reforestation have little effects on carbon in the soil, and harvesting could even result in carbon gains due to the incorporation of slash into the mineral soil (Johnson and Curtis 2001; Oregon Department of Forestry 2008; Laudon et al. 2011). Fertilization results in an increase of carbon and nitrogen in the soils, but the possible negative effects on water quality need to be carefully considered (Johnson and Curtis 2001). More information on this topic can be found in Section 3.2.4. Also, nitrogen linkages which might follow fertilization in the form of nitrate ion (NO_3^-) may cause soil acidification, since when NO_3^- ions percolate through the soil into stream water, cations like Mg^+, Ca^{2+} and K^+ also move out of the soil. As more base cations are leached, there is a reduction in the capacity of forest soils to buffer pH changes (Laudon et al. 2011).

Site preparation techniques (such as scarification, mounding and soil harrowing) strongly affect forest soil nutrients. These operations, particularly carried out in forest plantations after clearcut, mostly encompass mixing mineral layers with humic soil layers, and they are performed using machinery. These techniques can improve seedling nutrient supplies and raise soil temperature, consequently improving the soil structure of the rooting area, but they might cause leaching of soil nutrients and decline in long-term productivity (Walmsley and Godbold 2010). In the literature, the effects of soil preparation techniques on soil nutrients are described as short-term and as varying with the intensity of the treatment (Walmsley and Godbold 2010). This picture shows that both synergies and trade-offs can be identified between site preparation techniques and soil fertility.

Particular concerns have been expressed with respect to the effects of forestry residue extraction for energy generation on soil fertility, and important trade-offs have been identified in this context. Residue removal in general is always associated with export of nutrients, and different considerations can be made depending on the portion of tree that is removed. The lowest nutrient concentration can be found in the wood, while the highest contents are located in the foliage (EEA 2007). The degree to which foliage and small branches are left in situ determines the impact of biomass extraction on forest soil nutrients (EEA 2007). The removal of stumps has been considered as detrimental for soil fertility, especially when dealing with stumps of small size that, if compared with mature stumps, consist of a high portion of bark and therefore include a high proportion of nutrients. Instead, the removal of mature and old stumps is unlikely to cause serious depletion of soil nutrients, due to the relatively low concentration of nutrients (Walmsley and Godbold 2010).

Also, the way in which stump extraction is carried out and the architecture of the root system taken into consideration affect the amount of nutrients that is removed. For example, if fine roots are left in situ, the effects of stump removal on soil nutrient depletion is limited since fine roots play an important role in the nutrition of the subsequent trees (Walmsley and Godbold 2010). Removing stumps of trees with shallow root systems removes also a higher amount of fine roots – when compared with deeper rooting tree species – and therefore increases the amount of nutrients depleted (Walmsley and Godbold 2010). In general, stump extraction should not be carried out on poor soils and on sandy soils because in these cases this operation is likely to affect nutrient reserves and mineralization rates. Moreover, stump extraction can cause changes in biological processes, such as in the nitrogen cycle, by potentially reducing the amount of new organic matter and associated ammonification/nitrification processes. This practice also causes changes in soil ecology processes, indirectly affecting soil nutrient content and availability (Walmsley and Godbold 2010). The same holds true for the effects of stump removal on forest floor depth. The lowering of soil nutrient stocks after stump removal has been linked to the reduction in forest soil depth due to elevated decomposition of surface organic matter, rather than to the direct removal of nutrients through stump extraction (Walmsley and Godbold 2010). Despite these considerations, it is possible to state that the effects of stump extraction on the chemical properties of soils are not as strong as the effects on the physical properties (Vasaitis et al. 2008).

Whole-tree harvesting is another practice that raises concerns with respect to negative effects on soil nutrients. Notably, whole-tree harvesting removes greater amounts of nutrients than stem-only harvesting because branches and leaves represent an important proportion of the nutrients bound in trees (Wall and Hytönen 2011). Several studies considered whole-tree harvesting without the option of leaving needles in situ, and concluded that this practice can cause slight decreases of nitrogen and carbon in the forest soil (Johnson and Curtis 2001; Laudon et al. 2011). Instead, Wall and Hytönen (2011) carried out a study which compares the effects on forest floor nutrient capital and subsequent productivity, caused by whole-tree harvesting with needles left on site and by stem-only harvesting. The two harvesting techniques were applied to Norway spruce stands. The authors carried out the study 30 years after the stands were clearcut. Wall and Hytönen (2011) conclude that no significant differences in effect can be detected between the two harvesting techniques on the amount of organic matter, amount of nutrients in the forest floor and concentration of foliar nutrients. This demonstrates that whole-tree harvesting with needles left in situ is a valuable option to maintain soil nutrient availability (Wall and Hytönen 2011).

3.2.4 Trade-offs and synergies between forest energy wood production and hydrological protection

Soil and water are two intimately connected elements of forest ecosystems. For example, groundwater and run-off transport dissolved nutrients and other solutes from terrestrial to aquatic ecosystems. Also, soil structure determines the movement of water through the soil layers (Laudon et al. 2011). In particular the abovementioned effects of forest management on soil, like soil disturbance and mineral soil exposure, can indirectly affect the hydrologic system in the forest soil and the quality of water in the forest ecosystem (Abbas et al. 2011).

Forest soil hydrology is affected by the ability of the soil to hold and transfer water. This ability is inhibited for example by soil compaction which represents an obstacle to water infiltration, with negative consequences of water erosion, sedimentation and spring run-off (Oregon Department of Forestry 2008). Different forestry practices have varying effects on forest soil hydrology. For example, clearfelling results in altered hydrology by decreasing evapotranspiration, increasing groundwater tables and causing greater run-off (Laudon et al. 2011). Changes in the hydrologic regime in forest ecosystems can have consequences for both terrestrial and aquatic ecosystems. An altered water flow can change biogeochemical processes such as decomposition and nutrient cycling, as well as the transport of dissolved and particulate materials (Laudon et al. 2011). Forest harvest can affect water catchments located nearby the forests increasing the level of suspended soils and reducing the quality of these waters (Abbas et al. 2011). This can possibly result in acidification of the water resource. Also nitrogen and other micronutrients could be released in water bodies following forest harvest or fertilization in forestry plantations, possibly causing water eutrophication (Walmsley and Godbold 2010). These phenomena can occur for example because of the reduced interception at the forest floor level caused by tree harvesting and litter removal, which results in more run-off in small streams and increased water yield (Abbas et al. 2011).

Forestry treatments specifically focussed at extracting biomass for energy like litter removal and stumps extraction have strong effects on water quality and hydrology, since they impact the soil regulating the water system (Abbas et al. 2011). Visible trade-offs are generated between energy wood extraction and protection of the forest water system. For example, logging residues and deadwood regulate water flows by capturing and storing water and reducing water run-off (EEA 2007). Nitrogen being the primary limiting nutrient for plants growth, it is likely that intensified forest exploitation approaches like the ones related to extraction of biomass for energy will rely on nitrogen-based fertilization (Laudon et al. 2011). The literature is divided with respect to the effects of forest fertilization on other forest ecosystem services, and possible trade-offs can arise when the application of an excessive amount of fertilizer causes saturation of forest ecosystems – because mineral nitrogen exceeds the demand of plants and microbes (Laudon et al. 2011). In this case, forests lose retentive capacity and leach nitrogen to groundwater and streams (Laudon et al. 2011). Nitrogen can act as a pollutant in surface waters, and an increase of nitrogen in water catchments is an unwanted consequence of forest fertilization (Laudon et al. 2011). Theoretically, also synergies can arise between the intensified extraction of wood from forests for energy generation (for example through whole-tree harvesting, stump extraction or collection of forest residues) and protection of water quality. Indeed, the forest practices mentioned above remove with the wood also part of the soil that would normally end up in water catchments nearby the harvesting site (Walmsley and Godbold 2010; Laudon et al. 2011). However, there are uncertainties with respect to the effects of stump extraction on the ability of nitrogen sinks in forest soils to function properly, since it has been found out that the recovery of forest residues and stumps "does not decrease the nitrogen exports to water courses, as a result of massive decline in microbial immobilization of nitrogen following the removal of all wood debris" (Walmsley and Godbold 2010 p. 26). Therefore it is possible to conclude that the complexity of nutrient cycling in forest ecosystems might generate trade-offs between wood extraction and water quality, which potentially offset existing synergies (Walmsley and Godbold 2010).

The establishment of trees plantations often managed through SRF approaches is one of the possibilities to increase the production of energy wood. The effect of trees plantations on the water system depend most of all on the type of land that the plantation is replacing. For example, forestry plantations have negative effects on soil and water when they substitute grasslands, permanent pastures, long-term set-aside lands and natural forests. In the case of the latter, often an increased effect on soil hydrology by SRF plantations is caused by the fact that the plantations are planted more intensively and managed to optimize growth, and in general quicker biomass accumulation is positively correlated with greater water use (LTS International 2006). Moreover, water quality may also be affected by the over application of herbicides in tree plantations (LTS International 2006). Instead, trees plantations have often lighter effects on soils and water systems than agricultural crops because of the lower soil compaction through machinery and because of the reduced amount of fertilizer needed – and consequent reduced percolation of nutrients to the soil water and run-off to water catchments (LTS International 2006; Dallemand et al. 2007). This description possibly leads to the consideration that substituting agricultural crops with SRF plantations can have positive effects on forest soil and water. Despite these claims, it has been demonstrated that tree plantations consume more water than agricultural crops (and especially of non-irrigated crops), since after the initial year of establishment they intercept more water and also evaporate it at a higher rate, in this way reducing the amount of water that reaches the soil. Moreover, their leaf area index enables higher potential water uptake from the site than agricultural crops (LTS International 2006).This paragraph shows how uncertainties exist with respect to the relations between the establishment of forest plantations and forest functions like the protection of water quality.

Another important factor which influences the effect of forestry plantations on the hydrology and water quality is the species chosen for the plantations. For example, evergreen species can potentially transpire actively for a longer period than deciduous species, and this has stronger effects on soil hydrology (LTS International 2006). The effects of plantations on soil hydrology depend on the site chosen for the plantation. Plantations situated near lakes or rivers will have strong impacts on soil hydrology. In sites where trees with deeper roots can access the groundwater, the overall water extraction of the plantation is very high (LTS International 2006). This information needs to be taken into account when considering the effects of plantations on the hydrological regimes of wetlands and groundwater recharge capacity (Dallemand et al. 2007)

3.2.5 Trade-offs and synergies between the production and use of forest energy wood and forest fire protection

Wildfires are an important natural element of the forest ecosystem (Costa et al. 2011), but can also be a threat to forests since they can destroy the forest habitat and the biodiversity it hosts, reduce the ability of forests to provide services, as well as convert forests to long-term sources of carbon emissions – due to the release of carbon during the fire and then over time as trees decay (Winford and Gaither Jr. 2012). Forest fires are a particularly serious problem in the Mediterranean region, due to phenomena like land abandonment and vegetation encroachment, and to the climatic conditions which in summer desiccate the vegetation and allow fire to spread (Agee and Skinner 2005). However, occasional hot and dry summers can also occur in other parts of Europe, meaning that vast territories are potentially at risk from forest fire (Agee and Skinner 2005; Rego et al. 2010).

Forest fires are more severe in cases in which the fire can spread from the forest floor to the tree crowns. This often occurs because of ladder fuels, parts of dead or living wood present on the forest ground which facilitate the spreading of the fire to the upper forest layer. Two main processes describe the progression of crown fire: 1) the initiation of the fire activity, i.e. the “torching”, which occurs when the surface flame length exceeds a critical threshold defined by moisture content in the crown and by the vertical distance to live crown, and 2) the active crown spread in which fire moves from crown to crown, influenced by the density of the overstory crowns and the rate of spread of the fire. In order to sustain active crown fire, the fire must consume a mass above a critical rate (Agee and Skinner 2005).

Nowadays, more than 95% of fires in Europe are caused by humans (voluntarily or involuntarily), for example through land management practices like the burning of agricultural and forestry residues, or land burning for pasture renovation. The literature explains that a “fire paradox” characterizes the forest fire context: “as we have become more efficient at suppressing wildfires, the wildfire problem has only become worse” (Agee and Skinner 2005 p. 83; Costa et al. 2011). The changes currently affecting socio-economic and environmental conditions which influence forest fires (for example, the aging of forest owners and practitioners and the decrease in active forest management, as well as vegetation encroachment, land abandonment and the warming of global temperatures) are recently leading towards higher fire risk as well as to a more aggressive spread of large wildfires (Rego et al. 2010; Costa et al. 2011). Also, modern management practices have altered natural fire cycles, for example, by accumulating large quantities of hazardous biomass which, constituting fuel for the fire, allows fires to spread rapidly (Costa et al. 2011). Moreover, the shift towards shorter rotation periods and an increased stand density (Law and Harmon 2011) may allow for high fire susceptibility (Winford and Gaither Jr. 2012). Finally, the increasing continuity of forested areas and abandoned farmlands in some areas of Europe allows for the development of long fire perimeters with difficult access (Costa et al. 2011). A widespread focus on fire suppression strategies has reduced low and medium intensity fire events which are relatively easy to suppress, and it has paradoxically intensified large wildfires which are often beyond the threshold of control (Costa et al. 2011). Wildfires in Europe are indeed increasing their frequency and intensity, with severe consequences for lives, properties and land-use systems and ecosystems (Rego et al. 2010; Costa et al. 2011).

Traditional forest management practices can be classified as beneficial or detrimental to the ignition and spread of forest fires. For example, thinning can reduce crown fire potential and mitigate crown fire severity, while a too intensive removal of standing trees in some situations can alter fire behaviour and facilitate wind speed through the forest increasing fire impact.

Considering three types of thinning – namely low, crown and selective thinning – it is possible to state that all three techniques reduce canopy bulk density, but only low thinning simultaneously increases canopy base height which – as demonstrated below – is an essential precondition for forest fire control (Agee and Skinner 2005). Also, leaving large quantities of forestry residues on the forest floor can increase the risk of fires, since the residues come to constitute fuel ladders which allow fire to spread from the forest floor to the crowns (Oregon Department of Forestry 2008). In general, forest practices aimed at addressing the fire problem should satisfy the following requirements (Agee and Skinner 2005; Law and Harmon 2011):

1) Surface fire behaviour should be controlled. This can be done by opening the understory so that mid-flame wind speed will increase and fine fuel moisture decline. This can be obtained for example by reducing surface fuel or by significant greening-up of grasses and low shrubs.
2) Torching potential should be reduced, for example by increasing canopy base height.
3) Potential active crown fire spread should be reduced, for example by reducing canopy bulk density.
4) Large trees should be preferably left in the forest, since they are the most fire-resistant trees in the stand because of their tall crown and thick bark.

Forest management practices which follow the above mentioned guidelines can generate both trade-offs and synergies with the production of wood for energy generation. Synergies could be generated when the biomass which potentially causes a risk of fire, like fuel ladder material and small diameter trees, is extracted from the forest and delivered to the energy wood industry. Trade-offs might arise when considering the need to keep larger trees in the forest. Even if at present stem harvesting is almost completely carried out to feed the sawnwood industry, this trend might change in the future in response to an increasing demand of energy wood, potentially conflicting with forest fire protection objectives.

Yablecki et al. (2011) refer to three main forest management approaches dealing with forest fires. The first approach is defined as reactive and it entails wildfire suppression with little or no pre-emptive control. This approach is often recognized as no longer suitable to forests and forest fires conditions, since ladder fuels left in the forest and high tree density which characterize modern forest management strategies allow fire development and expansion to a degree which goes beyond the capability of fire fighting. However, this approach is often still applied because it is the cheapest to apply – even though it leads to the greatest uncertainty in budgetary planning (Yablecki et al. 2011).

The second approach is the use of prescribed fire, which is a pre-emptive method encompassing the ignition of intentional fires to reduce the amount of forest fuels and to leave the woodland less susceptible to wildfire. Also, prescribed fires can be useful to increase canopy base height by scorching the lower crowns of the stand. Disadvantages of this approach include that it is not effective at reducing canopy bulk density because prescribed fires intense enough to obtain this result might exceed the desired threshold, and that initially fires consume substantial biomass but also create fuels by killing understory trees, and as result the amount of surface fuel biomass may return to pre-burn levels within a decade (Agee and Skinner 2005). Prescribed burns can be applied only in determined weather conditions and this practice is subject to smoke and air quality regulations, therefore representing a viable solution only in specific cases. Moreover, this technique does not have secondary benefits associated with the burning and in particular it generates potential trade-offs with the production of energy wood – since wood which could be potentially delivered to the energy industry (such as forestry residues) is instead burned in fires. The advantage of this practice is that prescribed burning is the cheapest of the two pre-emptive strategies(Yablecki et al. 2011).

The third approach is the harvesting of the underbrush, of low lying biomass and of dead and dying trees to reduce ladder fuels (Law and Harmon 2011), together with the removal of selected trees to reduce crown fire spreading (Yablecki et al. 2011). This approach often results not only in the reduction of the occurrence of fire, but also in the facilitation of fire management by fire fighters. When carried out mechanically, this practice is a more costly pre-emptive strategy than prescribed burning, but it potentially offers secondary benefits associated with the economic exploitation of the extracted biomass (Yablecki et al. 2011). Indeed synergies arise between the production of energy wood and the protection of forests from fires through biomass harvesting techniques. Yablecki et al. (2011) demonstrated that combining the management of forested areas for wildfire control and energy production using wood residues as a source can provide important benefits, especially if this combination develops in local contexts which utilize locally purchased biomass and local labour. However, in practice the extraction of biomass and its delivery to the energy industry sometimes do not take place because of wood mobilization or economic issues (UNECE/FAO 2007; EC 2010f; Röscha and Kaltschmitta 1999; Hogan et al. 2010; Ragwitz et al. 2006), and the collected biomass is piled and burned to be destroyed, with an approach that represents a blending of prescribed burning and mechanical harvest techniques. In these cases the synergies transform in potential trade-offs between the protection of forests from fires and the air quality and carbon emission issues. From a forest management and economic perspective, it is not useful to remove forest fuels without having a plan of how to destroy or commercialize them (Yablecki et al. 2011).

Despites economic considerations, it is important to address other issues when considering the trade-offs and synergies between the extraction of energy wood and forest fire protection. For example, the literature highlights the importance of carbon outcomes from forest management practices aimed at enhancing synergies between forest fire protection and bioenergy production, like the mechanical harvesting approach described above. The main questions are whether such fuel treatments actually increase forest carbon storage by reducing future forest fires emissions (Campbell et al. 2011), and whether the combination of these fuel treatments with bioenergy production can realistically reduce overall carbon emissions (Winford and Gaither Jr 2012). With respect to the first question, authors are divided between those who suggest that fuel reduction treatments are consistent with carbon sequestration in forest biomass (Hurteau et al. 2008; Stephens et al. 2009), and those who hold the inconsistency of the two (Hudiburg et al. 2011; Campbell et al. 2011). The first group of authors argues that short-term losses in forest biomass following fuel-reduction treatments are made up for by the reduction of future fire emissions. Within the second group, Campbell et al. (2011) hold that these claims are often based on specific and unrealistic assumptions about the efficacy of a fuel reduction treatment, wildfire emissions and burn probability. Campbell et al. evaluated how fuel treatments, wildfire and their interactions affect forest carbon stocks in conifer forests located in the western United States, and concluded that thinning trees and other forest fuel reduction practices are unlikely to be consistent with efforts of keeping carbon sequestered in terrestrial pools.

Indeed, Campbell et al. (2011) deem these forest fire practices as useful to restore historical functionality to fire-suppressed ecosystems, for example, by restoring native species composition, but not as being characterized by added benefits with regard to increasing forest carbon stocks. For example, since forest fuels reduction treatments are designed to reduce wildfire severity, rather than to preclude fire, comparing carbon losses under a high and a low severity fire scenario reveals that the biomass combusted in the high severity scenario is greater, but the difference between the two scenarios is smaller than that suggested by many authors (Campbell et al. 2011). Indeed, the water content of live wood is supposed to prohibit combustion beyond surface char also under the most extreme fire conditions. Moreover, the combustion of fine surface fuels like litter and fallen branches can be high also in low-severity fires (Campbell et al. 2011). Another point that Campbell et al. (2011) emphasize is that the carbon losses associated with some forest fire treatments like thinning followed by prescribed fire are respectively 30% and 50% of total aboveground carbon, while burning over fire-suppressed forests consume an average of 12-22% of this carbon. In this sense fuel treatments can be effective in reducing combustion in a subsequent wildfire, and the more intensive the treatment, the more future combustion is reduced. However, protecting one unit of carbon from wildfire combustion can come at the costs of removing more units of carbon during the treatments. This is because “reducing future wildfire emissions comes in large part by removing or combusting surface fuels ahead of time” (Campbell et al. 2011). Finally, the authors report that as fire frequency increases, the absolute and relative carbon combusted per individual fire decreases following a negative relation. This suggests that as fire frequency increases also the average carbon stock in the forest increases (Campbell et al. 2011). With respect to the desired stability in carbon fluxes in a forest, the carbon stock under frequent and low-severity fire regimes is more stable than in a situation of infrequent high severity fires (Campbell et al. 2011).

With respect to the combination of fuel treatments with bioenergy production and the effects of this combination on carbon emissions, Winford and Gaither Jr (2012) published a study which compares a scenario of fuel reduction treatment combined with bioenergy generation, against a situation in which biomass is left in the forest and carbon sequestration is pursued through a “no-action” approach. The study deals with a temperate and dry conifer forest in Sierra Nevada, California. The authors use a life-cycle model analysis and simulate forest growth over 50 years calculating emissions from harvest, transport and bioenergy combustion in a “fuel treatment + bioenergy generation” scenario, and relating these emissions to emissions from California's average electricity grid. This scenario is compared with emissions caused by forest fires in the "no-action" scenario. The fuel treatment encompasses a low thinning approach aimed at increasing height to live crowns, decreasing crown canopy, removing surface fuels and retaining large fire-resistant trees (Winford and Gaither Jr 2012). In the model simulation, wildfires are conceived as stochastic processes whose frequency varies in time and space. The authors define fire rotations as the number of years it takes a given area to burn, and the annual burn rate as the portion of the area of interest which burns in a given year. The authors do not choose a single fire rotation, but they opt for a range of rotations which allow understanding how changes in fire rotations affects carbon in the two scenarios (Winford and Gaither Jr 2012). The authors conclude that the fuel treatments sequester more carbon than the no action scenario only at the end of the 50 years period considered, and only if the fire rotation interval is 31 years or less. When the fire rotation interval drops below 31 years, the year in which the "fuel treatment + bioenergy generation" scenario holds more carbon than the "no-action" scenario drops below 50 years. When the fire rotation interval exceeds 31 years, the "no-action scenario" continues holding more carbon up to 50 years. This demonstrates the importance of fire rotations in the assessment of carbon fluxes in forests (Winford and Gaither Jr 2012). According to this study, over the 50-year period under analysis, wildfire under a 31-year fire rotation produce more emissions compared to the production, transportation and combustion of bioenergy from fuel treatment wood. Only when the fire rotation is increased to 200 years are emissions from wildfires lower than emissions from one other source considered in this study, i.e. combustion of woody biomass for bioenergy (Winford and Gaither Jr 2012). At 200-year fire rotation, the fuel treatments emit more than the "no-action" scenario because of the decrease in wildfire emissions linked to the increase in fire rotations. Continuing the model past 50 years could show a break-even fire rotation different than 31 years, since the fuel treatment scenario sequesters carbon faster than the no-action scenario, and at the same time the no-action scenario emits more carbon with fire rotations covering less than 200 years (Winford and Gaither Jr 2012). This study shows that when combining fuel treatments with bioenergy generation, the greatest reduction in carbon emissions derives from the reduced emissions from wildfires, rather than from the substitution of fossil fuels with bioenergy (Winford and Gaither Jr 2012).

3.2.6 Trade-offs and synergies between forest energy wood production and forest productivity and health

Forest productivity is defined as "the potential of a particular forest stand to produce aboveground wood volume" (Skovsgaard and Vanclay 2008 p. 14). Site productivity depends both on natural factors inherent to the site, like climate and water availability, and on management-related factors. According to Skovsgaard and Vanclay (2008, p. 14-15) "in managed forests, the inherent site potential is determined largely by soil characteristics and climatic factors. Management can affect the production potential through silvicultural options such as site preparation, choice of tree species, provenance, spacing, thinning and regeneration method. Additionally, environmental conditions in the surrounding forest (e.g.

wind-sheltering effect of neighbouring stands) and practical aspects of forest operations (e.g. damage to crop trees and soil compaction) may also influence the production potential". Forest productivity depends on many of the topics addressed in the previous sections, in particular those linked to soil and water protection (Sections 3.2.3 and 3.2.4, respectively).

Moreover, forest health is an important pre-condition for realizing the site productivity of a forest. Threats to forest health are represented for example by pest and insect attacks, invasive plant species, pollution drought, game browsing, wildfires and storms (Fernholz et al. 2009). Fungi and insects are the main biotic threats to forest health and they potentially affect wood availability with respect to quantity and quality (Vasaitis et al. 2008). With respect to management practices and their effects on site productivity, studies show that thinning dense coniferous forests can improve the vigour of the remaining trees, by reducing the competition for water and nutrients and by increasing light and soil temperature. Moreover, the increased vigour reduces the susceptibility to pest attacks and increases forest health in general (Oregon Department of Forestry 2008). This description shows that synergies exist between thinning practices in coniferous forests and forest productivity. However, removing a portion of standing trees can increase the susceptibility of the forest to windthrow and storms (Oregon Department of Forestry 2008) and potentially increase the risk of forest fires (see Section 3.2.5), demonstrating that also trade-offs can be identified between thinning and forest productivity.

Logging operations present potential trade-offs with forest health and forest productivity. Logging can result in damage to the remaining trees during transportation. The wounds can result in the spread of fungal diseases and parasites, potentially reducing the productivity of the site. Storing fresh logging residues and freshly cut stumps may attract some pests, such as pine weevils, further exacerbating the risks for forest health and the consequent reduction in forest productivity (Walmsley and Godbold 2010). Forest management practices aimed at reducing the susceptibility of forests to events like fires and storms present synergies with increased forest productivity. This is, for example, the case when extracting forestry residues to reduce the risks of forest fires, while at the same time reducing the risks of pathogen infection (Vasaitis et al. 2008; Walmsley and Godbold 2010). Moreover, collection of residues is also beneficial in areas characterized by high nitrogen depositions from the atmosphere (e.g. the strongly polluted areas of central Europe), where this practice can help establishing the right nutrient balance in the forest soil (Abbas et al. 2011). The literature also reports that soil preparation activities like scarification and stump harvesting have been used to reduce pest and pathogen outbreaks. For example, scarification has been used to reduce the effects of pine weevil attacks, since soil disturbance leads to the mixing of humus and mineral soil horizons, as well as to the reduction in the amount of shelters needed by pine weevils to infest and damage the wood (Walmsley and Godbold 2010). Moreover, stump extraction has been used as a control method for the spreading of fungi, since it reduces the area colonized by fungi, and also the amount of inoculum left in restock sites (Saarinen 2006).

Vasaitis et al. (2008) published a review study in which they suggest that stump removal from clear-felled forest areas in most cases results in several synergies between this forest practice and forest productivity and health. These synergies are related to both the improved growth conditions for newly established forest plantations and the sanitation of forest sites. Stump removal indeed results to be effective in the reduction of root rot in the next generation, improved seedling establishment and increased tree growth and stand productivity (Saarinen 2006; Vasaitis et al. 2008). With respect to the positive impact on forest regeneration, afforestation is proven to be more successful on sites where the stumps are removed than on sites where the stumps were left intact (Saarinen 2006). This is also partly due to the soil disturbance caused by stump removal which for example favours seedling survival, and to the reduced vegetative competition. These and other factors contribute to improved performance of planted trees during the early phases of establishment, and faster growth resulting in higher standing volume (Vasaitis et al. 2008). With respect to sanitation objectives, according to Vasaitis et al., leaving stumps in the ground can favour the spreading of pathogens, since stumps play a major role in the life cycles of the pathogens. Once the fungi attack the stumps, they can remain viable for decades, transferring the root rot to the following forest generations – via direct contact of roots or presence of spores in the soil (Vasaitis et al. 2008; Walmsley and Godbold 2010). Stump removal is instead a viable option to control root rot, and even if this practice does not result in the complete eradication of the fungi, it represents an effective preventive measure against the build-up of infections (Vasaitis et al. 2008). However, when considering the role of stump removal for sanitary purposes, it is essential to underline the important investment costs which go hand-in-hand with this technique, and the necessity to carefully plan and carry out the treatment in order to avoid soil disturbance (Vasaitis et al. 2008).

The authors above suggest that synergies exist between stump extraction for the production of bioenergy and forest productivity and health, since this practice can control root rot and at the same time generate an income if the stumps are used to generate energy (Vasaitis et al. 2008). However, it is important to mention that differences exist between the effects of stump extraction methods carried out to provide a source of energy, and methods applied to reduce susceptibility of a forest site to insects and fungi. For example, in the case of stump extraction for root rot control, sometimes the stumps are left upended near the extraction holes, and this allows the soil disturbance caused by the removal of the stumps to be minimized (Vasaitis et al. 2008). On the other hand, stump removal for sanitation purposes needs to extract a much bigger portion of the root system in order to be effective if compared to stump extraction for energy wood production (Walmsley and Godbold 2010) with important negative consequences on soil structure and biodiversity (see Sections 3.2.1 and 3.2.3 of this report). Moreover, stump extraction methods aimed at providing energy wood might not be sufficiently effective in reducing insects and fungi outbreaks (Walmsley and Godbold 2010). The disadvantages of stump extraction can sometimes outweigh the benefits on forest health. Most studies concern stump extraction as a technique to reduce forest pests and diseases (Vasaitis et al. 2008), and therefore uncertainties affect the relation of results obtained by these studies to the extraction of stumps for energy production.

Studies have demonstrated that tree plantations contribute to the spread of pathogens (Schulze et al. 2012), and therefore trade-offs can be identified between the establishment of these plantations and forest health, especially when the plantations are located nearby forests. The considerations reported here are particularly important for the energy wood context which might more and more strongly rely on plantations to satisfy the increasing demand of renewable energies (Brockerhoff et al. 2008). The literature reports that native trees species may carry a higher amount of pests and diseases than exotic species, but utilizing exotic species carries the risk of importing new pests and diseases (LTS International 2006). With respect to the productivity of forestry plantations, exotic tree species are often chosen for their fast growth and high amounts of wood produced during growth. However, in some cases exotic species might not be well adapted to local climate conditions and thus not suitable for wood production (LTS International 2006).

3.2.7 Conclusions on environmental trade-offs and synergies associated with energy wood: lessons learned and recommendations

Sections 3.2.1 to 3.2.6 demonstrate that the production and use of wood for energy generation will have certain environmental implications. Important trade-offs can be identified with environmental functions, especially with respect to biodiversity, soil and water protection functions of forests. With respect to the climate change mitigation function, the literature is divided between those who hold that substituting fossil fuels with forest wood energy will work to increase carbon sequestration and reduce carbon emissions, and those who state that using forest wood for energy will deplete carbon stocks and negatively affect forest carbon storage. These contrasting opinions arise because of different perceptions of the concept of “carbon neutrality” of wood as an energy source. The first group sees emissions from the energy use of wood as offset by the carbon sequestration activity of the forests where this wood comes from, while the second looks at the use of wood for energy as a carbon debt which will be repaid only over long periods of time.

Despite the trade-offs, there are also synergies associated with energy wood production. The climate change mitigation function is the one that presents the strongest synergies with the production of energy wood, because of the assumed reduction of GHG emissions consequent to the substitution of fossil fuels with wood. Also, practices aimed at producing energy wood present clear advantages for the protection of forests from the effects of wildfires, storms, diseases and excessive nitrogen deposition. Some elements of biodiversity and of the forest water system can also benefit from forestry operations aimed at providing wood for the energy industry. Finally, by improving forest health, forest practices like stump extraction which are recently becoming more widespread because of the high demand of energy wood can also benefit forest productivity.

Forest management practices aimed at producing energy wood should focus on offsetting trade-offs and strengthening synergies with environmental forest functions. With respect to managing trade-offs, the scientific papers and operational guidelines reviewed in this section of the report suggest particular precautions to take in order to reduce or avoid the negative environmental impacts of forest management practices for energy wood production. Here follows a compilation of the recommendations expressed by and the lessons learned from the literature examined.

With respect to biodiversity conservation, the literature points at the following guidelines for limiting the negative effects of energy wood production on this forest function (LTS International 2006; Oregon Department of Forestry 2008; Camprodon et al. 2008; Fernholz et al. 2009; Hartmann et al. 2010; Paillet et al. 2010; Sacchelli et al. 2012):

- Applying close-to-nature forest management approaches which impact forest ecosystems with different intensities can enhance forest biodiversity. For example, managing forests in order to keep a mosaic of different forest structures, creating open areas in the forests and opening dense canopies through thinning are practices which work in this direction. Also, maintaining a variety of thinning intensities can help creating habitat variability at the landscape scale.
- Avoiding the colonization of clearcut forest areas by invasive or exotic plant species helps maintain the natural composition of the forest and safeguard biodiversity.
- Addressing habitat fragmentation issues, for example by providing a continuity of forest habitats that supports species movement.
- When establishing forestry plantations, taking care to create a diverse environment by: creating edges of natural, non-linear shape; maintaining a balanced edge-area ratio in plantations to conserve forest habitats; preserving wetland patches and open patches within plantations; varying spacing between rows of planted trees; keeping a higher level of tree species diversity along streams and roads; creating a buffer zone between the plantations and eventual existing forests, to avoid the loss of forest edge habitats; maintaining stands of different ages to provide alternative habitats for animal species displaced by the felling of a stand. These practices allow the occurrence of a variety of stands with different exposure and soil moisture characteristics, assigning a greater nature conservation value to the plantation.
- Carefully choosing the time period in which to carry out specific forest treatments. For example, clearcutting carried out during the nesting season may result in high mortality of nestlings.
- Avoiding the substitution of natural or semi-natural forests with plantations since forest biodiversity levels are deemed to decrease in forest plantations.
- Keeping a part of the deadwood in the forest to favour the creation of specific habitats essential for forest biodiversity. This recommendation includes leaving in the forest some snags and large and older trees that formed cavities during partial or clearcuts as well as creating or maintaining coarse woody debris by leaving large wood sections during harvesting or by girdling standing trees.
- Keeping in the forest a part of the large diameter trees and of trees which form cavities to increase the availability of suitable habitats for forest animal species.
- Minimizing intensive site preparation techniques in order to maintain coarse woody debris and consequently supporting soil biodiversity.

- Avoiding extraction of energy wood from mountain forests and other fragile forest ecosystems, like sensitive native plant communities and forests which include rare tree species or endangered plants and animals.

With respect to the climate change mitigation function of forests, the literature is not very specific with respect to which forest management opportunities can be used to reduce trade-offs with the collection of energy wood. However, the following suggestions have been identified (Johnson and Curtis 2001; LTS International 2006; Millar et al. 2007; Walmsley and Godbold 2010; Cherubini et al. 2011):

- To cope with climate change, there is need of flexible forest management approaches which give the possibility to modify and change directions with changing climatic conditions. A priority setting approach can be useful, which takes risk into account and acknowledges the idea that no approach fits all situations.
- Favouring rapid growth and long-term site retention, for example by modifying silvicultural practices in a way to increase rotation length between thinnings or increasing stand age at harvest can help increasing the carbon storing capacity of forests.
- Maintaining healthy and vigorous trees and minimizing disturbances by fires and pathogens, for example by collecting forestry residues, to avoid carbon losses.
- Applying forest management practices which enhance the carbon sequestration in soils, like stem-only harvesting in coniferous forests.
- Avoiding forest management practices which produce excessive soil disturbance and consequent loss of soil carbon.
- Avoiding the conversion of forest lands that represent sensitive carbon stocks into other land uses, in order to buffer the risk of releasing carbon in the atmosphere.
- Producing and using wood in local contexts to reduce the impact of GHG emissions from transportation.

With respect to the protection of forest soils and their properties, the application of the following recommendations can help limit the trade-offs with energy wood production (Jacobson 2003; LTS International 2006; EEA 2007; Oregon Department of Forestry 2008; Vasaitis et al. 2008; Walmsley and Godbold 2010; Wall and Hytönen 2011; Abbas et al. 2011; Laudon et al. 2011):

- Determining forest biomass removal according to species and the site conditions. For example, the removal of woody biomass from the forest floor should be done only if considering the overall soil nutrient budget in a particular stand.
- Leaving foliage in situ to avoid an excessive loss of soil nutrients. In the case of coniferous species, extracting dry residues to allow needles to drop is a way to retain a good portion of the nutrients in the soil. For broadleaved species, harvesting in winter months when the leaves are dry is a solution to avoid the removal of the nutrients included in these parts of the trees.

- Avoiding harvest of forest residues from forest sites located on poor soils to avoid further impoverishment of these sites, or from organic soils which are very deep in order to avoid soil compaction.
- In soils with low buffering capacity, avoiding forest practices which result in lower pH values in the soil. This is, for example, the case for whole-tree harvesting which, compared to stem-only harvesting, reduces the role of forestry residues in stabilizing soil pH.
- Using wood ash to fertilize soils is a good option to restore the soil nutrients. This option should be particularly taken into account in delicate soils like peatlands.
- Carrying out forest energy wood collection in conjunction with the extraction of timber for the material industry helps avoiding excessive negative impacts on the forest soils.
- Carefully choosing the machines to use for forest works since lighter equipment does not cause as much soil compaction.
- Carefully planning forest activities. Using pre-existing skid trails and using existing routes to transport the wood outside the forest reduces the impact of forestry activities on soil structure.
- Avoiding reduction of rotation periods and avoiding increasing the density of trees in the forests, since these actions require more intensive and frequent disturbance of the forest soil.
- Carefully choosing the time period in which to carry out specific forest treatments. For example, opting for the winter season for the use of heavy machinery, when soils are frozen and therefore harder, reduces the risk of soil compaction and displacement. This is particularly important in wet soils and lowland sites. Another example is to avoid using heavy machinery on wet soils, especially on clay soils.
- In wet and soft soils, retaining forest residues to use as brash mats for heavy machinery to avoid soil compaction and erosion.
- Avoiding removal of stumps from wet and soft soils helps reducing excessive soil erosion and run-off.
- When removing stumps, these should be first shaken to leave as much soil as possible in the forest. Also, leaving fine roots in situ can help limiting the losses of soil nutrients.
- Avoiding harvest of wood if soil is damaged; for example, if there is evidence of erosion or compaction.
- Lifting biomass rather than skidding reduces damage to soil.

With regard to the hydrologic functions of forests, the literature points out at the following practices as able to reduce trade-offs with the provision of energy wood (LTS International 2006; Oregon Department of Forestry 2008; Laudon et al. 2011; Abbas et al. 2011):

- Holistic approaches are needed in forest management which consider water and soils as a unit and try to minimize the effects of intensive biomass extraction on these two elements of forest ecosystems. For example, practices which avoid soil

compaction also benefit the movement of the water in the forest soil and the overall hydrologic system.
- When carrying out forest management operations, taking care to minimize discharge of sediments and pollutants to water bodies. This is, for example, accomplished by avoiding removal of biomass from riparian zones and areas near small water bodies, and avoiding storage of forest residues in ditches- in order to reduce the effects of forestry residue removal on water quality. It is also important to avoid removal of stumps from ditches, streams and lakes in order to limit the release of soil particles to water.
- Avoiding fertilization when there is risk of nutrient leakage in the water system.
- Avoiding establishment of forestry plantations in areas with low water availability.

The collection of woody biomass for the production of bioenergy presents important synergies with the protection of forests from wildfires. The literature therefore suggests using forest management practices like the collection of forestry residues, harvesting of the underbrush and of low lying biomass as well as of dead and dying trees in areas subject to a high fire risk (Yablecki et al. 2011; Law and Harmon 2011). The collected wood assortments can be delivered to the energy industry. Also, practices like thinning aimed at reducing canopy bulk density and increasing canopy base height can strengthen the synergies between energy wood production and forest fire protection, when the wood cut during the operations is delivered to the energy industry (Agee and Skinner 2005; Rego et al. 2010; Costa et al. 2011)

Finally, with respect to forest productivity and health, the literature suggests the following recommendations to minimize trade-offs with energy wood production (Saarinen 2006; Vasaitis et al. 2008; Oregon Department of Forestry 2008; Walmsley and Godbold 2010; Abbas et al. 2011):

- Carefully carrying out harvesting operations by avoiding damage to trees which are left in the forest.
- Removing forest residues has potential positive effects on the reduction of insects and diseases outbreaks. In areas where these outbreaks are frequent or strong, the extraction of residues for energy wood use can benefit forest productivity and represent a source of income.
- Removing forest residues in areas characterized by high nitrogen deposition from the atmosphere can help establishing the right nutrient balance in the forest soil.
- Thinning dense forests can improve the vigour of the remaining trees, by reducing the competition for water and nutrients and by increasing light and soil temperature. Also, the increased vigour reduces the susceptibility to pest and pathogen attacks, and increases forest health in general.
- Avoiding storage of fresh logging residues and freshly cut stumps in the forest, since these can attract pathogens.
- Applying soil preparation activities like scarification and stump harvesting can help reducing insects and disease outbreaks in sites where these pathogens attacks strongly affect forest productivity.

3.3 Reflections on the trade-offs and synergies associated with the production and use of energy wood

Section 3.2 made clear that the production and use of energy wood has several implications, either having positive or negative effects on the social, economic and environmental issues affected by the energy wood context. The various social, economic and environmental implications of the production and use of energy wood are moreover intricately linked, mutually affecting each other in many ways. Forest management changes that might be needed to increase energy wood production (such as increasing the density of forest stands, the higher frequency of forestry operations, and the creation of new forest tracks for transporting wood outside forests) can at the same time negatively affect biodiversity conservation, soil protection and recreation (Schulze et al. 2012; Nabuurs et al. 2007; Rämö et al. 2009). Utilizing wood for energy generation can help mitigating climate change and it might benefit the rural economy by providing new sources of income for forest owners (Bohlin and Roos 2002), but it can create strong market competition for low value wood assortments which might negatively affect the economy of pulp and paper industries (Hetsch et al. 2008; Mantau et al. 2010). The scope of this report did not allow deepening the analysis of similar relations; further exploration of such issues in future research is needed.

The report presents an in-depth analysis of the environmental implications of forest energy wood production and use. Also within the environmental context, it is possible to identify intricate and mutual relations amongst the various aspects (Sections 3.2.1 to 3.2.6), and consequently amongst the various environmental trade-offs and synergies associated with energy wood production and use. Section 3 of this report made clear the interdependency of soil and water protection in the forest environment (Laudon et al. 2011), and on how these are amongst the main determinants of forest productivity (Saarinen et al. 2006; Skovsgaard et al. 2008). Soil compaction and erosion are amongst the main causes of loss of productivity, especially as they alter the hydrological system of the forest. Energy wood production will have to pay particular attention to these interrelations to avoid recurrent negative environmental impacts. Moreover, important interrelations can be identified between forest soil and water protection and biodiversity conservation in the forest environment (Paillet et al. 2010).

However, the intricate and mutual relations amongst the various environmental implications of energy wood do not only represent constraints to the production of energy biomass, but also synergies. Indeed, in some situations like areas at high forest fire risk or affected by high nitrogen depositions, the removal of assortments which are suitable for the energy wood industry represents a way to combine positive environmental effects on biodiversity and forest health with increased income for forest owners (Yablecki et al. 2011; Rego et al. 2010), and potentially increase the acceptability of biomass projects. Furthermore, creating small open patches in the forest by selective thinning over an area or with clearcuts can benefit forest biodiversity and forest health, and at the same time provide wood for energy purposes (Hartmann et al. 2010; Oregon Department of Forestry 2008).

The optimization of trade-offs and the enhancement of the synergies associated with energy wood production and use are characteristic of a type of forest management which is defined as “integrated” (Bauhus et al. 2013). Integrated forest management is “the management of the ensemble of all desirable forest resources at the stand scale” (Hartmann et al. 2010 p. 355). It was developed at the beginning of the 1990s in response to threats posed by productive forest management to biodiversity and other environmental factors important for forest ecosystems (Behan 1990). According to this approach, environmental protection, social functions and production should be pursued with every forestry operation, and in every portion of the forest, even though with different priorities according to portion of the forest matrix (Bauhus et al. 2013). This is accomplished by setting up management priority areas where some objectives are pursued more directly, while others have a secondary importance. Within this approach, environmental protection is part of the planning of forest activities, but “integrated forest management affects the whole forest matrix [...] and therefore environmental impacts will also affect the whole forest matrix” (Hartmann et al. 2010 p. 356). Integrated forest management approaches are dominant in Europe. For example, Bollmann and Braunisch (2013) reflect on the integration of biodiversity conservation in forest management and report that only 11% of European forests are managed through non-integrated approaches. Integrated forest management, however, could also consider other aspects than those related to biodiversity, and integrate also social forest functions like recreation (Bauhus et al. 2013).

Another approach which deals with achieving trade-offs between economic exploitation of the forest and other forest functions is the segregation of the respective objectives into different areas. In contrast to integrated forest management, this approach entails “forest zoning” and it aims at avoiding the impacts of forestry operation on the whole forest, by mapping zones to spatially separate environmental protection, social goals and production objectives (Hartmann et al. 2010). In this approach, a certain part of the landscape is allocated to ecological or social forest management objectives, while commodity production is maximized in the rest of the forest matrix (Bollmann and Braunisch 2013). This results in the separation of areas for wood production and biodiversity conservation functions, in addition to areas of less intensive, multiple-use forestry (Bauhus et al. 2013). This approach can be labelled as “segregative”. Relevant international literature on this forest management approach is lacking, as the difference between integrative and segregative forest management approaches has been mainly developed in the German forest science and management contexts (see the reference list in Bollmann and Braunisch 2013). In general, the distinction between segregative and integrative approaches is mostly a matter of scale and of legislation. With respect to nature conservation the establishment of strict national reserve or parks is considered a segregative practice, while small-scale approaches like the retention of habitat trees in the forest an integrative practice (Bollmann and Braunisch 2013). Purely segregative approaches are not very common in Europe. Rather, the combination of segregation and integration strategies is one of the preferred option in forest management, and also the one that proved to be successful, for example, in the conservation of biodiversity within economically exploited forests (Bollmann and Braunisch 2013). In an ideal context for biodiversity conservation integrative approaches could be distributed across the whole forest matrix, while segregative approaches could be used in areas of high conservation value because they mostly represent a small portion of the forest matrix (Bollmann and Braunisch 2013; Bauhus et al. 2013).

Considering the important trade-offs associated with energy wood production and the compromises that need to be made to simultaneously maintain different forest functions, it is possible that segregative forest management approaches will spread with the increase in energy wood production to satisfy growing demands. For example, Hartmann et al. (2010) holds that from an economic point of view the segregative approach is a more viable application for the sustainable pursuit of multiple management objectives in a forest. This is mostly because integrated forest management imposes constraints to all forms of commercial timber extraction by reducing the amount of wood that can be exploited also in areas where economic objectives are prioritized. Instead, the zoning approach allows extraction of more wood increasing the efficiency of specialized practices in specific zones, and at the same time allows patches of forests to grow older and, for example, support biodiversity and ecosystem functioning in these areas (Hartmann et al. 2010). Also, integrative forest management approaches have environmental consequences in all the forest matrix, while segregative approaches allow environmental implications to be restricted to the economically exploited forest zones (Hartmann et al. 2010). There is support for the idea that in order to optimize trade-offs associated with the production of (energy) wood, integrative approaches at forest stand level should be combined with segregative approaches at landscape level (Bollmann and Braunisch 2013; Bauhus et al. 2013).

4. Forest energy wood in the European Union: legislative and policy framework

Reviewed by Guillaume Ragonnaud

4.1 Introduction to the legislative and policy framework of forest energy wood

The production and use of forest energy wood are often described as "cross-cutting" issues which influence and are influenced by a wide range of environmental, societal and economic factors. In general terms wood is a natural resource and it is consequently influenced by recent developments in resource efficiency matters (ECN 2013). More specifically, wood is a forest product and as such it is affected by discussions in the forest management arena and related economic, social and environmental concerns. Wood is also an energy source which can be used instead of fossil fuel and to diversify the energy mix (EC 2009). In this sense it is influenced by debates in the energy and climate change fields. Wood is also a construction material (UNECE/FAO 2007) and forests are widely used locations for recreation (Bieling 2004; Nabuurs et al. 2007; Bollmann and Braunisch 2013). This short description shows the complexity and intricacy of the energy wood context, where wood is a highly contested resource object of conflicting interests (German National Academy of Sciences Leopoldina 2012).

Forests and the production of energy biomass from forests are, therefore, affected by the policies of numerous sectors. Next to the competing demands on wood, another cause of this intricate policy framework is that the Treaty on the Functioning the EU does not make reference to specific provisions for an EU forest policy, and as a result the EU has no common and legally binding legislations specifically made for the forest context (Winkel et al. 2009; Pülzl et al. 2013). However, the EU has a long tradition of contributing through non-legally binding policy efforts to influence MS decisions on forests. For simplification, these policy efforts are summarized in this report under the label "EU forest policy". Next to non-legally binding forest policy, this context is influenced by a whole set of legally binding policies dedicated to sectors other than specifically "forestry" but affecting the forest sector (Ragonnaud 2013). The picture resulting from the description above is a fragmented EU forest policy context and the partial subjugation of forest issues to other policy matters like agriculture and rural development, energy and climate change, industry, biodiversity conservation, resource efficiency, urbanization and construction. Moreover, compared to other renewable energy sources, wood is utilized in all three energy sectors of electricity, heating and transportation, which implies that it is impacted by an even broader range of policies and legislation. This situation calls for the need to clearly define the legislative and policy framework affecting the production and use of energy wood, in order to better locate forest energy biomass in recent policy debates taking place in the EU.

Table 15 includes a list and short description of EU legislation and instruments affecting the context of forest biomass for energy, with an explanation of how these affect the production and use of energy wood.

Table 15. List of the main EU legislations and instruments affecting the production and use of energy wood from forests. The first column lists the legislation or policy in question, including an internet link to the respective documentation. The second column indicates the impact on the energy wood context and the third column briefly describes policy objectives especially in light of the effects of the legislation or policy over the energy wood context. Adapted from: Pelkonen et al. 2014 p. 24; Lindstad et al. 2014.

Policy	Impact on energy wood	General objective and how the policy affects energy wood
Forest Strategy and Forest Action Plan (FAP) http://ec.europa.eu/agriculture/forest/strategy/index_en.htm and http://ec.europa.eu/agriculture/fore/action_plan/index_en.htm	Directly stimulating supply	These non-legally binding instruments aim at fostering forestry activity in the EU by elaborating a common approach to deal with increasing societal demands towards forests (EC 2006b). They address an increased supply of energy wood as one of the challenges for EU forests. Albeit not providing compulsory requirements or funds for forestry and energy wood, they foster competitiveness of the sector, protection of the forest environment, enhancement of the quality of life in forest areas, coordination amongst MS strategies and exchange of good practices (EC 2013b).
Common Agricultural Policy (CAP) (including Rural Development Policy (RDP) http://ec.europa.eu/agriculture/cap-post-2013/ and http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0487:0548:EN:PDF	Directly stimulating supply	The objective is to increase competitiveness of the European primary sector and promote rural development (EC 2013c). The RDP is the "main instrument at Community level for the implementation of the EU Forestry Strategy" (EC 2009c p. 16), since measures eligible for funds under the European Agricultural Fund for Rural Development (EAFRD) include forestry measures and forestry-related activities. The CAP, including RDP, provides financial support for forestry and forest-related activities like production of wood for energy, e.g. establishment of short rotation coppice plantations, production of energy wood as a side-product of harvesting activities, and investments in equipment for wood chipping. These policies determine the availability, types and costs of forest woody biomass to the energy sector .
Directive 2002/91/EC on energy performance of buildings http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0091	Indirectly stimulating demand	It promotes the use of renewable energies in buildings by fostering the use of CHP and district heating which are often based on wood. It regulates efficiency of boilers and other installations, indirectly promoting efficient use of wood as a resource.
Directive 2003/30/EC on the promotion of the use of biofuels and other renewable fuels for transport http://ec.europa.eu/energy/renewables/biofuels/biofuels_en.htm	Directly stimulating demand	It promotes an increased use of renewable energy sources for the transport sector, by requiring MSs to ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets, through the establishment of national indicative targets which contribute to the achievement of the overall EU 2010 biofuels target of 5.75% share of renewable energy in the transport sector. The 2010 target has been revised by Directive 2009/28/EC and upgraded to a new target of 10% for the year 2020 (see below).

Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community. Also known as EU-ETS http://europa.eu/legislation_summaries/energy/european_energy_policy/l28012_en.htm	Indirectly stimulating demand	The EU-ETS is the cornerstone of EU climate policy. It applies a market system to cost-effectively reduce greenhouse gas emissions. It applies a "cap and trade" system: it imposes a limit to the total emissions of industries, and it allows trading the assigned "emission allowances" which can be used to emit or can be sold on the market. By putting a price on greenhouse gas emissions and treating wood as a carbon-neutral energy source, its aim is to strengthen the economic competitiveness of woody biomass and other renewable energy sources and it finally incentivizes their use.
Directive 2003/96/EC on the taxation of energy products and electricity http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:283:0051:0070:EN:PDF	Indirectly stimulating demand	It aims at reducing market distortions in the EU generated by divergent taxation systems in the MSs. It promotes the use of renewable energies by allowing lower taxation for renewable energy products and by offering tax incentives for efficient energy generation like CHP.
Directive 2004/8/EC on the promotion of cogeneration of heat and electricity file:///C:/Users/frferran/Downloads/l_05220040221en00500060.pdf	Indirectly stimulating demand	It aims at increasing the use of respective high efficiency technologies. Member States are required to support and monitor the cogeneration of heat and electricity and demonstrate progress. It promotes CHP and other energy efficient technologies which are often fuelled with wood (e.g. district heating systems).
Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Also known as EU-RED http://www.buildup.eu/publications/31450	Directly stimulating demand	It promotes the use of energy from renewable sources. It requires the development of national Renewable Energy Action Plans and sets mandatory national targets for renewable energy to be reached by 2020 and thus stimulates increased use of wood as energy source.
EU Biodiversity Strategy http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm	Indirectly affecting supply	With this policy the EU aims at halting the loss of biodiversity and ecosystem services in its territories by 2020, and to protect, value and appropriately restore ecosystem services and their natural capital by the year 2050 (EC 2011e). This is done through the legally binding implementation of the Natura 2000 ecological network of protected areas (Directive 92/43/EC) and of the Green Infrastructure, a network of natural and semi-natural areas which is present in rural and urban settings and which provides ecological, economic and social benefits through natural solutions (EC 2013). Some of the actions required to achieve these targets are the implementation of a more sustainable forestry which takes better account of environmental issues related to wood extraction. These issues could represent a limitation for an increased extraction of energy wood.

EU Resource Efficiency Roadmap http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf	Indirectly affecting supply and demand	This non-legally binding instrument aims at developing a fully sustainable economic system in Europe by 2050 by increasing resource productivity and decoupling economic growth from resource use and its environmental impact (EC 2011h). Housing and mobility are two of the sectors responsible for most environmental impacts and actions in these areas are proposed to integrate the measures already imposed by EU energy, climate and biodiversity policies. Resources like wood are analyzed from a life-cycle and value-chain perspective to increase efficiency of both production and utilization. Maximizing the amount of wood that can be produced sustainably and reducing energy losses in energy wood use are amongst the actions which might influence the energy wood context.
EC Communication on Innovative and Sustainable Forest-based Industries in the EU http://ec.europa.eu/enterprise/sectors/wood-paper-printing/documents/communication/index_en.htm	Indirectly affecting demand and supply	The goal is to propose policy guidelines which ensure a coherent approach towards integrating climate change objectives into the industrial strategy of forest-based industries. The EC points at the need to reduce energy consumption by the addressed industries and increase energy use efficiency, but also at the opportunities offered to forest-based industries by the production of energy wood from forests.
EU Action Plan for Forest Law Enforcement, Governance and Trade (FLEGT) and EU-Timber Regulation http://ec.europa.eu/environment/forests/flegt.htm and http://ec.europa.eu/environment/forests/timber_regulation.htm	Indirectly affecting supply and demand	They set a licensing scheme for imports of timber in the EU which sets out legally binding measures for EU and MSs aimed at tackling illegal logging in the world's forests by ensuring that no illegal timber or timber products are sold in the EU (Council Regulation EC No 2173/2005; Regulation EU No 995/2010). They potentially reduce the amount of energy wood importable in the EU to the assortments which are ensured to come from legal and sustainable sources.

The variety and quantity of EU legislation and policies affecting the forest energy wood context shown in Table 15 illustrates the complexity and the intricacy of the forest biomass topic. Furthermore, some of the documents listed above are not legally binding for MSs (e.g. Forest Strategy), while the Regulations (e.g. Common Agricultural Policy – CAP Regulations) are directly applicable in all EU countries. The listed directives set out general rules to be transferred into national law by each country as they deem appropriate. These result in a very varied range of policies produced at national levels to deal with the increasing demand of energy wood from forests (Lindstad et al. 2014). In this mosaic of national responses, MSs apply EU Directives in a variety of ways and mix these with national objectives to fit domestic circumstances, which once again mirrors the complexity of this topic (Lindstad et al. 2014).

The typology of the current report and the timing of the study did not allow all policies that affect the energy wood context to be addressed. In making a selection which allowed a thorough inspection of EU policies to detect the elements relevant for the energy wood context, the author selected four policy fields which can be considered the most relevant for the energy wood context, and namely: forest policy, agricultural policy, energy policy and biodiversity policy. These four policy contexts are addressed in this order while special attention is given to the historical developments of these policies and their relevance to energy wood. In particular, forest policy and agricultural policy were selected as they directly address the production of forest energy wood and expressly mention it in their legislative and policy texts. Moreover, information on energy policy in the EU was included in particular in the EU-RED and the Biomass Action Plan which directly stimulate demand for energy wood. Finally, the report addresses EU biodiversity policy because of the importance of forests for biodiversity (Winkel et al. 2013).

4.2 The role of forest biomass for energy in the EU "forest policy"

The EU operates under the principles of conferred competences and subsidiarity. The principle of conferral asserts that competences not conferred upon the Union in the Treaty on EU (EU 2012) and the Treaty on the Functioning of the EU (EU 2012b) remain with the MSs. The principle of subsidiarity prescribes that EU governmental bodies should legislate only for those matters which cannot be dealt with at national level. In areas that do not fall within its exclusive competence, the EU acts only if the objectives cannot be sufficiently achieved by the MSs (Article 1, 4 and 5 of the EU Treaty). The EU Treaties did not provide for a common forest legislation for the MSs defined at EU level. According to the subsidiarity principle, forest legislation in the EU remains largely a competence of the MSs (Standing Forestry Committee ad hoc Working Group VII 2012). Reflecting on the linkages between forest policy and other policy issues which instead are regulated at EU level (see Figure 6), EU policy interest started since the 1990s to focus with more consistency on forest-related topics and on defining the role of forests in the context of the other interested policy issues. This allows it to be stated that although no EU forest legislation exists, there have been policy efforts made by the EU in the forest context, efforts which in this report are summarized under the umbrella label "EU forest policy".

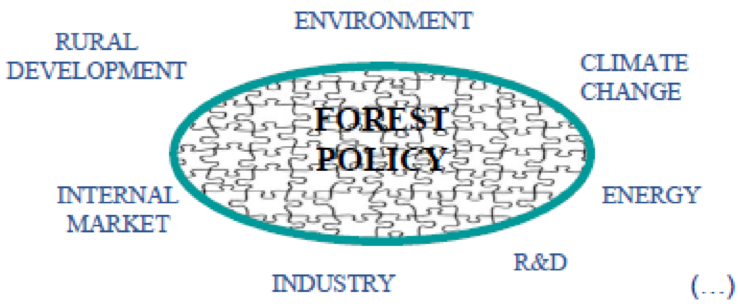

Figure 6. Diagram of the EU policy regulated issues which affect or are affected by forest policy. Source: Standing Forestry Committee ad hoc Working Group VII, 2012.

4.2.1 The EU Forestry Strategy of 1998

In 1998 the EC produced a communication dedicated to a non-legally binding Forestry Strategy for the EU (EC 1998). The Communication was followed by a Resolution of the Council on the same topic (Council Resolution of 15 December 1998). The 1998 EU Forestry Strategy identified common targets for the MSs in the management of European forests, to achieve through the implementation of National Forest Programmes (NFPs) prepared by the same MSs.

The 1998 Forestry Strategy described European forests as composed of diverse ecosystems covering 130 million ha of the EU territory (corresponding to 35% of the total EU territory), of which about 87 million ha are exploitable for wood and non-wood purposes (EC 1998). The EU is presented as the main importer of forest products in the world, and one of the main producers of pulp and paper products. EU forest-based industries include a wide variety of business typologies (e.g. sawmilling, wood panels, wooden packaging, paper and boards), but the sector is not very competitive also because of the copious number of small and medium enterprises (SMEs) and of the fragmented character of the forest resource in the EU (EC 1998).

The 1998 Forestry Strategy summarizes the key forest-related issues that require a strategic common action by MSs. Among these, rural development, environmental and landscape protection, sustainability of forest management, climate change and market competitiveness play a major role. For example, with respect to environmental issues, the strategy aims at implementing the environmental commitments taken by the EU at the United Nations Conference on Environment and Development (UNCED) of 1992, and at the Ministerial Conferences on the Protection of Forests in Europe of the years 1990 (Strasbourg), 1993 (Helsinki) and 1998 (Lisbon). Core environmental themes are: i) the protection of forests against atmospheric pollution, ii) the prevention of forest fires especially prominent in Mediterranean areas, iii) the conservation of forest biodiversity, and iv) the buffering of climate change which may lead to a change in forest species composition or contribute to an increase of extreme weather events (EC 1998).

With respect to socio-economic topics, the EC mentions the actions taken at community level under the Agenda 2000 program which benefit European forest ecosystems, such as the CAP measures aimed at promoting the afforestation of agricultural areas and resulting in the diversification of farming activities. These actions need to be incorporated in the EU strategy for a successful EU forest sector. Moreover, the EC supports the incorporation of market provisions made, for example by the World Trade Organization, on international trade. These provisions include (technical and environmental) standards for forest products, as well as the application of sustainable and multifunctional forest management practices.

The energy topic and the role of wood as a renewable source of biomass for energy do not play an important role in the EU Forestry Strategy of 1998. Despite in the late 1990s EU policy efforts already began to focus on renewable energy and on the importance of woody biomass in this context (see Box 5 in Section 4.4 of this report), the EC dedicated only a small paragraph of its communication to these topics (EC 1998). The EC mentions that wood can contribute to the diversification of the EU energy supply through SRF or forestry residues. However, according to the EC, the potential of EU forests should not be overestimated and the contribution of SRF should be weighed against environmental effects.

The mid-term evaluation of the EU Forestry Strategy (EC 2005b) showed that the concept of Sustainable Forest Management (SFM) played a major role in the implementation of the Strategy objectives. The focus over SFM was influenced by the recent developments in international policy, like the World Summit on Sustainable Development held in Johannesburg in 2002 and the 4th Ministerial Conference on the Protection of Forests in Europe held in Vienna in 2003. These policy events used sustainability as the main guiding principle for discussions on social and environmental issues and for the establishment of action plans. The assessment of the NFPs showed a very limited use of wood as energy source in EU MSs. Indeed, NFPs mostly focussed on economic viability of SFM, contribution of forests to rural development, forest biodiversity and climate change (EC 2005b). The role of wood as a bioenergy source is mentioned by MSs in the evaluation of the EU Forestry Strategy only in relation to the climate change topic (wood can contribute to offset fossil fuel emission), and no mention is made to the role of wood in fostering rural development and rural economy through the provision of renewable energy.

4.2.2 The 2006 EU Forest Action Plan

The lack of attention in the 1998 Forest Strategy towards the role of wood as a renewable energy source, amongst other pressing issues in the forestry context, generated the need to update the EU Strategy to include current emerging topics. Discussions arisen in 2005 at the Council Working Party on Forestry and at the Council's Special Committee on Agriculture made clear the need of developing an Action Plan to better coordinate MS actions with respect to these topics (Lazdinis 2008). The Forest Action Plan (FAP) was developed in 2006 after consultation with the main stakeholders involved in the forest sector (see for example Birdlife 2005; Union of European Foresters 2006). The plan was to cover the years 2007-2011 (EC 2006b).

The main objective of the FAP is the long-term multifunctionality and sustainability of forests in supporting societal needs and forest-related livelihoods. SFM is a key principle in the FAP. The main objective of the FAP can be achieved by four secondary objectives, displayed in the FAP with ideal time frames for accomplishing them (EC 2006b):

1) Improving competitiveness of the forest sector and enhancing sustainable use of forest products and services. This goal can be accomplished for example by assessing experiences on the valuation of NTFPs and forest functions and by promoting the energy use of woody biomass. Key action 4 of the FAP is

particularly relevant for the use of wood for bioenergy production (see Table 16). The FAP envisages the stimulation of markets for low-value timber and small-sized wood to be used as bioenergy sources. Another important action to be taken with respect to enhancing forest sector competitiveness is the cooperation among forest owners and the enhancement of forest employee education and training.

2) Improving and protecting the environment by enhancing biodiversity, carbon sequestration, health and resilience of forest ecosystems.
3) Contributing to life quality by preserving and improving social and cultural dimensions of forests. This can be accomplished, for example, by improving education and information on forests and exploring the potential of peri-urban forests.
4) Fostering coordination and communication among EU and national government bodies, and among different policy areas.
5) Disseminating best practices and improving visibility of the forestry sector.

Table 16. Key Action 4 of the 2006 EU FAP: "promoting the use of forest biomass for energy generation". Source: Pelli et al. 2009 p. 37

Key Action 4 Promote the use of forest biomass for energy generation			
Activity		Leading actor	Timeframe
4.1	Improve the mobilisation and efficient use of wood and wood residues, including low-value timber	SFC, COM	2007-2008
4.2	Developing cooperation methods and mechanisms between forest owners in energy markets	COM	2007
4.3	Support research and development of technologies for the production of heat, cooling, electricity and fuels from forest resources, and encourage the implementation of Strategic Research Agendas of the Forest-based Sector Technology Platform and the Biofuel Technology Platform	COM	2007-2011
4.4	Analyse how implementation of Key Action 4 is supported by rural development programmes in individual MS	COM, SFC	2011

The mid-term evaluation of the FAP carried out in 2009 showed that the activities within the plan have been carried out according to the established time frame, and the FAP has been therefore implemented efficiently (Pelli et al. 2009). The evaluation identified an improvement in the level of coordination across policy areas and more awareness of different situations related to forests and the forest sector. With respect to the secondary objective of increasing the competitiveness of the forest sector, MSs indicate that the EU FAP helped in drawing attention towards topics related, for example, with bioenergy and NTFPs. However, due to the short time frame of the evaluation which was carried out two years after the start of the FAP implementation, it was not possible for the evaluators to identify follow-up activities with respect to these topics. In general, the development of NFPs had an indirect effect on the fostering of the use of wood for bioenergy production, by contributing to the stimulation of policy dialogue on this topic (Pelli et al. 2009).

With respect to the other three secondary objectives of the FAP, the evaluation of 2009 showed that – despite the progress – the effectiveness of the FAP in enhancing environmental protection in forests could be improved, for example, by establishing an active forest monitoring system at EU level which is currently missing. The relatively short time frame of the evaluation did not allow conclusions to be drawn on the contribution of the FAP to quality of life in rural areas. Instead, the evaluation showed advances in the coordination and communication in the forest policy sector, for example, by reporting strong linkages between NFPs and the FAP. The improvement of the visibility of the forest sector could be boosted more in the future implementation phases of the FAP (Pelli et al. 2009).

Between 2011 and 2012 the ex-post evaluation of the FAP was carried out and structured around five evaluation points (EC 2012):

1. Has the FAP been effectively and efficiently implemented?
2. Has the FAP contributed to coherence and cross-sectoral cooperation in implementing the EU Forestry Strategy?
3. Has the FAP contributed to balancing economic, environmental and social forestry objectives?
4. Did the FAP represent an added value in the implementation of the EU Forestry Strategy? and
5. Are the objectives and key actions of the FAP still relevant?

The FAP ex-post evaluation stated that the FAP has been effectively and efficiently implemented following the work programme 2007-2011 (EC 2012). Even though no EU funds were specifically earmarked for the FAP, its implementation has been financed through the Rural Development Programs of the MSs and though other EU, national or regional funds according to the type of objective which was implemented. Naturally, objectives like environmental protection or coordination and communication have been better taken care of at the EU level, while others like socio-cultural aspects and forest owner cooperation have been taken care of at lower governmental levels. Despite its effective and efficient implementation, the uptake of the FAP at national and European level has been rather weak. This is also due to the fact that most of the activities carried out within the FAP concern the national and regional level of implementation, and they are seldom reported as contributing to the implementation of the FAP (EC 2012).

The FAP has helped information exchange between different Directorates of the EC and between MSs and the EC, and to raise awareness on forest-related issues in the EU (EC 2012). However, as the FAP is a voluntary policy instrument, the efforts put in fostering coherence and cross-sectoral cooperation mostly depend on the commitment of MSs and the EC, and the influence of the FAP on NFPs varies according to the MS considered. Most MSs declared that the FAP has to different extents influenced national policies especially in the context of rural development, bioenergy and public procurement, but room for improvement exists in this sense, especially with respect to political commitment and dedicated resources. Expectations of a strong, proactive and holistic integration of forest and other policies at EU level have not been met (EC 2012), and the FAP has rather been able to react to ongoing developments in other policy areas such as biomass and energy. A main impact the FAP has had was the support to forestry related research and to the elaboration of the new Rural Development Regulation published in 2014 (Regulation (EU) No 1305/2013 of the European Parliament and of the Council).

The FAP has strongly focussed on SFM, but its potential was hardly employed by MSs to develop an integrated approach to sustainability in practice, for example in actions like promotion of bioenergy and NTFPs or protection of biodiversity (EC 2012). As a result, the three dimensions of sustainability remained largely separated, and especially socio-cultural activities that were carried out in the national and regional context were not reported by MSs as measures taken to respond to the FAP. The potential of the FAP to represent an added value in the implementation of the EU Forestry Strategy was hard to assess, since it is not easy to recognize straightforward causal links between FAP and impacts on forestry in the EU (EC 2012). The forest context in the EU has moreover undergone important shifts in priorities (e.g. climate and energy targets, biodiversity and bioeconomy strategies) which were not foreseen when the FAP was drafted and which therefore were not sufficiently addressed through the FAP.

4.2.3 Preparing the future of the EU "forest policy"

The evaluation of the EU Forestry Strategy and the FAP made clear that a follow up was needed to achieve the goals of multifunctionality, sustainability and competitiveness of European forests. In order to address the need for stronger efforts at EU and national levels, discussions took place with respect to a new EU Forest Strategy and a new FAP which could accommodate newly emerging forest issues. Examples are the establishment of the 2020 renewable energy target and the consequent increased demand for woody biomass as a source of renewable energy (Standing Forestry Committee ad hoc Working Group VII 2012). The 1998 Forestry Strategy and the 2006 FAP were criticized for attributing vagueness to the concept of multifunctionality and for their lack of focus over potential trade-offs among different and competing uses of forests (FERN 2011). New policy measures should be directed toward forests as a whole rather than to forestry specifically. Policy goals should not be driven by the increased demand for energy wood, but this demand should be considered as one of the elements of multifunctionality. Energy wood demand should be attributed a fair level of importance compared to other aspects like nature conservation and social needs. An increased harvesting of timber from EU forests which would be needed to support the growing energy wood demand should consider the consequent decreased carbon storage capacity and the negative impact on biodiversity (FERN 2011).

Besides critical views such as those from FERN and other environmental non-governmental organizations (ENGOs), also EU governmental and consultative bodies recognized that the present forest-related policies failed to integrate current emerging forest-related issues in a coherent policy framework. In 2011 the Standing Forestry Committee (a body which is made up of representatives of MS forest administrations and chaired by the EC which acts as advisor and is consulted with respect to forestry-related policy measures) set up an ad hoc Working Group (WG) to discuss future developments of EU Forest policy; the WG was composed of representatives of MSs, of EC Directorates, and of stakeholders organizations (Standing Forestry Committee ad hoc Working Group VII 2012).

The WG of the Standing Forestry Committee discussed several options for a future EU forest policy framework, having to choose among legally binding and non-legally binding policy instruments, and among different degrees of soundness with current EU forest policy (EC 2011d). The WG opted for the development of a new EU Forestry Strategy which would be based on a revision of the current strategy, and would integrate this with the identification of areas in which the MSs would like to advance further. The WG concluded that the EU should have concentrated on developing a framework including i) a Forest Strategy and related FAP, ii) an initiative on Forest Information and Monitoring and iii) a communication on wood industry and value chain. The future Forest Strategy should have been non-legally binding and it should aim to enhance the long-term multifunctionality and sustainability of forestry, as well as to enhance innovation in the forest sector. According to the WG, it would be convenient to set a Forest Target to complement other EU targets: EU forests should have been demonstrably managed through the application of SFM as defined in the Forest Europe process by the year 2020 (Standing Forestry Committee ad hoc Working Group VII 2012). Forest Europe (formerly Ministerial Conference on the Protection of Forests in Europe) is the pan-European policy process for the sustainable management of European forests. It includes 46 signatory countries and the EU, and it develops common strategies on how to protect and sustainably manage forests. Moreover the WG agreed with the position of the non-governmental actors who requested a high level of inclusion and participation in the drafting of the new EU Forest Strategy (FERN 2011; CEPF 2012).

The role of wood for bioenergy generation is considered by the WG as a factor of environmental protection. In the context of tackling climate change, wood as bioenergy source can help reducing GHG emissions and reaching the EU 2020 climate change target. The use of wood for energy is also mentioned in relation to smart and sustainable growth. The production of environmentally sound and cost competitive bioenergy is represented as a challenge that, if won, can foster rural development in the EU. In order to win the challenge, policy affecting forests and woodlands should be assessed in a coherent manner. Moreover, attention should be placed on the enhancement of wood as a raw material and energy source, while taking into account other forest resources and functions and while minimizing the competition among different sectors. Finally, technology for wood-based energy products should be developed for implementing an efficient energy production and provision (Standing Forestry Committee ad hoc Working Group VII 2012).

4.2.4 The new EU Forest Strategy

Following the consultations addressed above, in September 2013 the European Commission published a Communication on *A new EU Forest Strategy: for forests and the forest-based sector* (EC 2013b). The title of the Communication already shows the changes occurring in the EU forest policy arena, making clear that the new EU strategy is not simply dedicated to forestry but to the whole ecosystem represented by forests, and to the sector which is managing and utilizing, but also protecting it. The Strategy takes an holistic approach by aiming to clarify the role of forests in satisfying the objectives of forest-exogenous policies indirectly affecting forests and forestry, and namely "the Resource Efficiency Roadmap, Rural Development Policy, Industrial Policy, the EU Climate and Energy Package with its 2020 targets, the Plant Health and Reproductive Materials Strategy and the Biodiversity and Bioeconomy Strategies" (EC 2013b p. 3). These policies contribute to the achievement of the EU 2020 targets and summarize important emerging issues which are becoming relevant in the management of European forests, such as growing threats which need to be mitigated and growing (competing) demands which need to be balanced. The result of the effect of these policies is a fragmented policy context strongly affected by market distortions related to fuel prices and fuel versus food land use competition. The Strategy aims at contributing to solving this complexity.

The Strategy presents the situation of EU forests in 2013, which is characterized by a rising growing stock, but also an expected increase in wood cuttings which might utilize the wood increments in the future (EC 2013b). Forests are presented as multifunctional ecosystems which provide habitats for species and benefits for human health, recreation and tourism. Forests are also providers of raw materials like wood for construction and for energy and NTFPs. The socio-economic importance of wood as an energy source is stressed in a specifically dedicated paragraph of the introductory section, and repeatedly mentioned in the text (EC 2013b). SFM is the main guiding principle which is evoked for the accommodation of competing economic expectations towards forests. This principle should ensure that competitiveness and job creation are enhanced while at the same time "ensuring protection and delivery of ecosystem services" (EC 2013b p. 4). Resource efficiency is another important criterion to follow in forest management and use of forest products, in order to avoid negative impacts on climate and environment, to have higher added values for forest products, and promote job creation.

The Strategy builds around eight "priorities" (EC 2013b):

1) Supporting rural and urban communities by promoting social welfare and sustainable jobs carried out by a trained workforce. Rural Development funds could be used by the MSs to accomplish social benefits from forests, but also to improve forest resilience and their environmental value.

2) Fostering the competitiveness and sustainability of the EU’s forest-based industries, bio-energy and the wider green economy by promoting both material and energy uses of wood and their climate benefits. In particular, forest energy wood accounts for 42% of the wood used in the EU, corresponding to about 5% of total EU energy consumption. Harmonized sustainability criteria might be needed to regulate the production of energy wood.
3) Fostering the role of forests in mitigating climate change and applying adaptive forest management options which can counteract the negative effects of climate change. Both material and energy uses of wood are mentioned as examples which can help the achievement of this goal.
4) Protecting forests and enhancing ecosystem services by protecting biodiversity, avoiding habitat fragmentation and the spreading of invasive species, managing water sustainably and limiting the effects of storms, pests and fires. The application of Sustainable Forest Management and the correct implementation of the Natura 2000 network can help achieving this target.
5) Improving the knowledge base on forest ecosystems and their changes.
6) Researching ways to produce new and innovative forestry and added value products.
7) Properly addressing cross-cutting forest policy issues by ensuring that the objectives of other EU policies affecting the forest sector are taken into account.
8) Coordinating MS action towards the achievement of EU commitments taken in the international arena and affecting the European forest context.

The structure of the Strategy is represented in Figure 7.

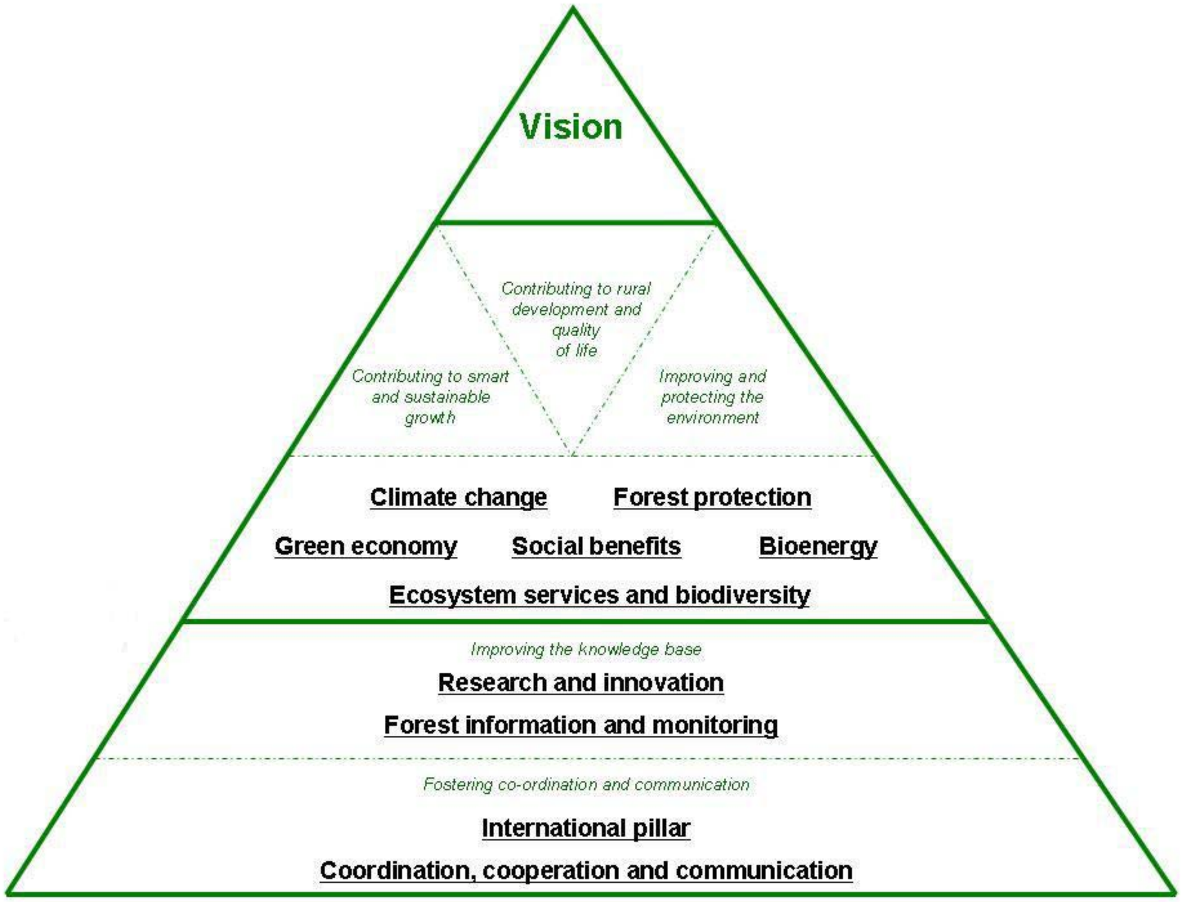

Figure 7. Diagram representing the structure of the new EU Forest Strategy. Source: Standing Forestry Committee ad hoc Working Group VII, 2012 p. 12

The implementation of the Strategy can rely on EU funds like (EC 2013b; 2013c):

- European Agricultural Fund for Rural Development (EAFRD), which contributes to the competitiveness of the agricultural and forest sectors and the sustainable management of natural resources (see also Section 4.3). It alone contributes to 90% of total EU funds allocated to the forest sector.
- LIFE+, fund dedicated to the European environment and aimed at financing biodiversity, resource efficiency, climate mitigation and adaptation projects.
- The EU's Regional Policy: the European Regional Development Fund (ERDF) and the European Social Fund (ESF), which aim at strengthening economic, social and territorial cohesion in the EU by correcting imbalances between European regions. In particular, the EFRD may finance, amongst other things, projects directly or indirectly linked to the forest sector like the promotion of biodiversity conservation in the forest environment and the N2000 implementation, or the use of biomass for energy and the support for small industries' innovation. The ERDF may also

finance transitional and interregional cooperation programs related to the forest sector like information sharing, biodiversity enhancement and favouring of bio-energy use in the principle of resource efficiency.

- Horizon 2020 secures global competitiveness for the EU by financing research and innovation, for example, by helping enterprises to develop technological solutions also in the field of renewable energy.
- Funds under the Intelligent Energy Europe Programme, which have until now supported the development of supply chains for woody biomass, and have provided inputs for the elaboration of strategies for the use of bio-resources.

4.2.5 The FLEGT and the EU Timber Regulation: controlling import of wood in the EU

Considering that about 10% of the wood used in the EU is imported from non-EU sources (Butler 2012), and that the imports of wood are expected to increase mirroring the increasing demand of wood for bioenergy (Ragwitz 2006), it is important to analyze the policy activity of the EU with respect to wood imports. This activity is likely to affect the use of wood for bioenergy production, insofar as the achievement of renewable energy targets through the use of energy wood is highly dependent and most likely not discernible from imports of wood from outside the EU (Ragwitz 2006).

The EU’s policy against illegal logging and associated trade dates back to 2003, when the European Commission adopted the Forest Law Enforcement Governance and Trade (FLEGT) Action Plan (EC 2003b), which was then endorsed by the Council in November 2003. The Action Plan consists of a Regulation from the Council establishing a FLEGT licensing scheme for imports of timber into the EU (Council Regulation EC No 2173/2005). The licensing scheme sets out measures for EU and MSs aimed at tackling illegal logging in the world’s forests. This objective is supposed to contribute to the goal of managing world’s forests in a sustainable and durable way. According to the FLEGT regulation, only timber products produced or traded in a non-EU country in a legal way may enter the EU market. These products have to be provided with a licence demonstrating the legality of their origin and trade. This licensing scheme is achieved through the establishment of voluntary partnership agreements (VPAs) between the EU and timber-producing countries or regional organizations. Timber-producing countries can join the VPA with the EU, or exit this agreement according to their preference and with a due notice (Council Regulation EC No 2173/2005).

Currently, only timber products included in Annex II and III of Council Regulation EC No 2173/2005 can undergo the FLEGT licensing system. These products include i) wood rough, stripped or squared; ii) railway or tramway sleepers; iii) wood sawn or chipped lengthwise, sliced or peeled; iv) sheets for veneering, for plywood or for other laminated wood, and v) plywood, veneered panels and laminated wood. Since Council Regulation EC No 2173/2005 provides for the possibility of amending Annex II, new types of wood products which could more strongly affect the production of bioenergy might be added to the list in the future, increasing the effects of the FLEGT over the bioenergy topic.

In order to strengthen the FLEGT Action Plan the EU produced the so-called EU Timber Regulation that requires wood operators who put timber and timber products on the EU market to show "due diligence" and respect "traceability requirements". This regulation came into force in March 2013. In practice, operators have to display information on the various steps of the supply chain of wood products imported in the EU (Regulation EU No 995/2010). This regulation is expected to address sustainability and nature conservation issues linked to illegal logging of wood, as well as the depression of wood market prices caused by illegal wood in the EU market (Butler 2012).

4.3 The role of forest biomass for energy in EU agricultural policy

Agricultural policy has a long history in the EU (EC 2012c). The Common Agricultural Policy (CAP) was created in 1962 and it then evolved through a set of updates and reforms which resulted in the current framework established by the last CAP review carried out in 2013. Figure 8 summarizes the developments of the CAP since its origin to the so-called Health Check in 2008, which highlighted the need to "modernize, simplify and streamline the CAP" with the goal of reducing restrictions for farmers and helping them responding to emerging challenges and market demands (EC 2008).

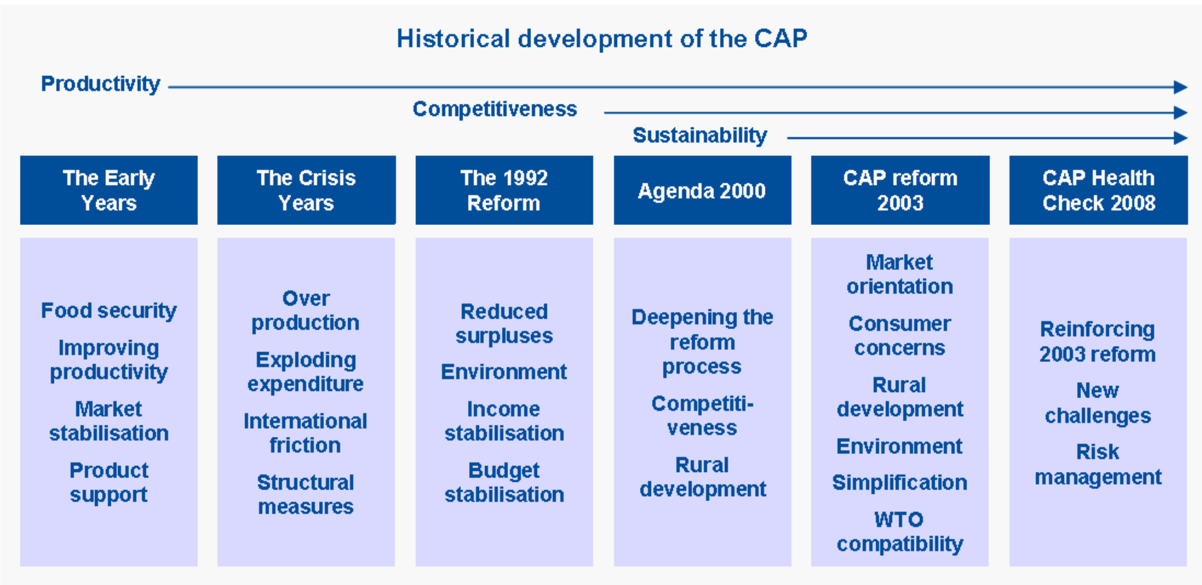

Figure 8.Historical development of the CAP. Source: EC 2014.

Forestry-related actions in the CAP have historically been located in its second pillar, i.e. the Rural Development Policy (RDP) which aims to help meeting the challenges faced by EU rural areas and to contribute to their sustainable development. Box 4 reports the titles of the four axes on which the RDP was built before the last review in 2013.

Box 4. The four axes of EU Rural Development Policy before 2013. Source: EC, 2009c.

The four axes of EU Rural Development Policy before 2013

- Axis 1: Improving the competitiveness of the agricultural and forestry sectors
- Axis 2: Improving the environment and the countryside
- Axis 3: Improving the quality of life in rural areas and diversification of the rural economy
- Axis 4: Leader (policy instrument to enhance local rural governance and structures)

This policy requires MSs to set up National Rural Development Programs (NRDPs) with which they apply for EU funds that are used to co-finance agriculture and forest-related matters (European Network for Rural Development 2010). The fund dedicated to rural development is the EAFRD, which has also been the main fund financing forestry interventions under the EU Forestry Strategy and FAP in the period 2007-2013 (EC 2009c). In particular, 14 measures relevant for forestry were included in the 2003 CAP reform and by the following 2008 CAP Health Check in Axis 1 (dedicated to the improvement of the competitiveness of the agricultural sector) and Axis 2 (dedicated to the improvement of the environment in rural areas) of the RDP. Eight of these measures strictly addressed forestry matters and can be defined as “forestry-specific measures”, while the remaining could also be employed to support agricultural measures and can therefore be defined as “other forestry measures”. With respect to budgets, it was intended that the eight forestry-specific measures would attract €12 billion, and over half of this amount would come from the EARFD. From these €12 billion, the specific measure “Improvement of the economic value of forests” under Axis 1 would alone receive €2 billion. Other forestry measures would instead attract €10 billion, and about 6% of this would come from the EAFRD (EC 2009c). Moreover, forestry-related activities could be financed through some of the actions under Axis 3 of the RDP, aimed at the diversification of rural economy such as “adding value to agricultural and forestry products” and “support to infrastructure related to the development and adaptation of agriculture and forestry”. The Axis 3 “forestry related actions” would attract €1–2 billion (EC 2009c).

The production of wood for the energy industry was strongly included in the RDP especially after the 2008 CAP Health Check, together with general concerns for the increasing demand for bioenergies. In particular, the modification of the Rural Development Regulation following the Health Check (Council Regulation (EC) No 74/2009) highlighted the need to address new types of operations which are essential for achieving new challenges in agriculture and forestry, including the mitigation of climate change through the substitution of fossil fuel energy sources with renewable and low-carbon sources. In this context, new actions which can be financed under EAFRD include, for example, the modernization of holdings, the reliance on perennial energy crops like SRC plantations and the enhancement of the fossil fuel substitution effect. However, despite the growing role of forestry in the context of the RDP and the fact that the EAFRD has a much broader land scope than just agriculture and comes to include forested areas which constitute 43% of EU total areas, agriculture and farming are the sectors which historically benefited the most from the EAFRD budgets (Allen et al. 2012). This should change with the implementation of the newly modified Rural Development Regulation and the flexible approach it entails.

The latest CAP reform took place at the end of 2013. The new CAP regulations (Regulation (EU) No 1305/2013; Regulation (EU) No 1306/2013; Regulation (EU) No 1307/2013; Regulation (EU) No 1308/2013) entered into force on 1st January 2014. The 2013 CAP reform is the result of a three years process of reflection and discussion. The EC organized a public debate early in 2010 (EC 2010c), and a final conference in July 2010 (EC 2010d). Moreover, the Council of the EU and the Parliament, as the two EU co-legislators on the CAP, negotiated the CAP reform. This was the first time in history that the European Parliament and the Council have acted as co-legislators (EC, 2013d), due to the entry into force of the Lisbon Treaty in 2009. The reform was also influenced by discussions on the overall EU funding system ("Multiannual Financial Framework") for the period 2014-2020, which was discussed in parallel. The reform aims at taking into account the unique and in some instances unexpected new challenges with which the EU agricultural sector is confronted, and to develop a better targeted, more equitable and greener policy. Also, the 2013 reform continues along the path established by previous reforms moving from product to producer support (EC 2013d).

The outcome of the consultations, discussions and negotiations is a strong common policy still structured around two main pillars as its predecessor policy. Pillar 1 includes legally binding measures such as instruments related to the functioning of agricultural markets and of the food supply chain, and related to direct payments for farmers which are bound to statutory management requirements and good environmental practices. Pillar 2 includes voluntary measures referring to the Rural Development Regulation which aims at the competitiveness of agriculture and diversification of economy also through the provision of specific environmental goods (EC 2011f). The general concept for rural development is that MSs or regional governments are responsible for designing their own multi-annual programmes and to choose, depending on their characteristics, the measures available in the EU Regulation on

Rural Development that meet their needs. Table 17 reports figures on the budget assigned to the two pillars for the funding period 2014-2020.

Table 17. Budgets for the two CAP pillars for the period 2014-2020. (billion €). Source: EC, 2013d.

	2014-2020 Ceiling (Current Prices)
Pillar 1	312,74
Pillar 2	95,58
Total CAP	408,31

The approach of the new CAP also allows for the agricultural sector to contribute to the EU 2020 targets, for example, through smart, sustainable and inclusive growth of the agricultural sector. These goals are pursued by strengthening the linkages between the two pillars of the CAP, and accomplishing a "greening" process in order to achieve a territorially and an environmentally balanced agricultural sector (EC 2010d). The main goals of the new CAP are (EC 2013d):

- Viable food production, achieved through enhancing food security, quality, value and diversity which will allow the EU competing in the international agricultural market and contributing to satisfy a worldwide increasing demand for food. Competitiveness and innovation are essential elements of this approach
- Sustainable management of natural resources and climate action, achieved for example through environmental protection and contribution to climate change mitigation by improving energy efficiency, fostering production of biomass as renewable energy source and carbon sequestration.
- Balanced territorial development, achieved through support to local employment and enhancement of territorial benefits to keep rural areas vital and dynamic.

Both CAP pillars include measures which contribute to the achievement of all the three goals reported above. In particular, higher level and safety of food production should be achieved together with the preservation of the natural resources agriculture depends upon (EC 2013d). The new CAP aims at being efficient, targeted and coherent, and it applies a more holistic approach to the financing of agricultural activities, strengthening common objectives and interactions amongst pillars. Also from a financial point of view, the two pillars are intimately linked. For example, MSs may transfer up to 15% of their national envelope from Direct Payments falling under Pillar 1 to the Rural Development envelope of Pillar 2. In the same way, MSs are free to transfer up to 15% or 25% from the Rural Development envelope to actions falling under Pillar 1 (Art. 7 of Regulation (EU) No 1307/2013 of the European Parliament and of the Council). This flexibility is however framed by regulatory and budgetary limits to ensure that common objectives are met. Moreover, MSs have to make sure that the transfer of funds from Pillar 2 to Pillar 1 does not inhibit a strong RDP in their territories (EC 2013d). Table 18 shows the actions targeted under both pillars.

PILLAR I	TARGETED ACTION	PILLAR II*
Green payment	ENVIRONMENT	Agri-environment-climate Organic, Natura 2000
Top-up payment	YOUNG FARMER	Business development grants Higher investment aid
Top-up payment	AREAS WITH NATURAL CONSTRAINTS	Area payments
Alternative simplified scheme	SMALL FARMER	Business development grants
Improved legal framework	PRODUCER COOPERATION	Aid for setting up producer groups Cooperation and short supply chain

Table 18. Actions targeted under both CAP pillars. Source: EC, 2013d.

The main changes affecting the 2013 CAP concern the acknowledgment of fact that farmers should be rewarded for services they deliver to the public which are not valued on the market, such as landscapes, farm biodiversity conservation and climate stability (EC 2013d; EC 2013c; 2011g; Allen et al. 2012). With respect to RDP, modifications have been applied especially concerning its architecture, and less with respect to the content. The co-financing principle behind the EAFRD remains the same; however, the fund is not anymore structured around three axes but around six priorities. The fund concurs to the achievement of the EU 2020 targets through the request for MSs of setting a clear link to performance in the NRDPs, by means of establishing targets for the six EAFRD priorities: i) fostering knowledge transfer and innovation, also through the European Innovation Partnership for Agricultural Productivity and Sustainability, ii) enhancing competitiveness of farming activities and sustainability of forestry activities, iii) promoting food chain organization and risk management, iv) restoring, preserving and enhancing ecosystems related to farms and forests, v) promoting resource efficiency and transition to low carbon economy in the agriculture, forestry and food sectors, and vi) promoting social inclusion, poverty reduction and economic development in rural areas. The main content changes which this policy underwent regard the insertion of the climate goals to already existing environmental concerns, and the development of a specific measure for organic farming. A specific percentage of the national Rural Development envelope needs to be reserved for voluntary measures which are beneficial for the environment, like actions aimed at mitigating climate change and adapting to its occurrence, as well as the implementation of the N2000 network in agricultural and forested areas. The new Rural Development Regulation refers to 30 different measures which can be financed through the EAFRD, 21 of which are particularly relevant for the achievement of the environmental priorities of the policy.

Also within the new CAP energy wood is referred to in the RDP. In particular, the flexibility characterizing the new CAP is supposed to offer farmers and foresters new opportunities to combine agriculture and forestry for the delivery of environmentally sound and sustainable goods and services, as well as to highlight the role of forestry measures in supporting the shift towards a low carbon and climate resilient economy (Allen et al. 2012). For example, the EAFRD can be used to finance measures such as “Investments in new forestry technologies and in processing and marketing of forest products”, “Agri-environment- climate” and “Forest-environmental and climate services and forest conservation” (Regulation (EU) No 1305/2013). These measures are directly linkable to the establishment of energy wood plantations or the fostering of energy wood production in already existing forested areas, and they target energy wood as an innovative forest product or as a product which potentially benefits climate change mitigation. Also other measures can be used to finance energy wood projects, such as “Afforestation and creation of woodland”, “Establishment of agro-forestry systems”, “Investments in physical assets” (Regulation (EU) No 1305/2013) and the various capacity building and training measures. This description makes clear that the energy wood topic is present in the new CAP and RDP, but the voluntary character of the RDPs reveals that the actual implementation of energy wood projects in the forest sector through the EAFRD is left to MSs, and has to compete with other agricultural, environmental and market initiatives also potentially financeable through the EAFRD and potentially conflicting with energy wood production. Only the future evaluations of the CAP implementation will provide a realistic overview on the extent to which forest energy wood production and use have been fostered by the new EU regulations.

4.4 The role of forest biomass for energy in EU renewable energy policy

The important role played by energy issues in societal debates during the last decades has affected the EU legislative and policy activity, which since the mid-1990s started to concentrate on the energy theme. The attention paid to the energy topic is shown by the wide array of regulations, directives, communications, resolutions, and other types of policy documents and legislations related to this topic and published by the EC or other EU institutions and bodies. Most of these documents are included in the reference list of this report. Box 5 below represents a synthesis of the main EC policy documents addressed to the MSs or to other EU institutions like the European Parliament and EU bodies such as the European Economic and Social Committee. The policy strategies and legal requirements contained in these official documents support the bioenergy debate, with wood being one of the central renewable sources of energy the EU is relying on to reach the 2020 renewable energy target.

Box 5. An overview of important EC documents affecting the energy wood context.

1996 - Energy for the future: renewable sources of energy. Green Paper for a Community Strategy (http://aei.pitt.edu/1280/1/renewalbe_energy_gp_COM_96_576.pdf)

2001 - Green Paper. Towards a European strategy for the security of energy supply (http://ec.europa.eu/energy/green-paper-energy-supply/doc/green_paper_energy_supply_en.

2004 - The share of renewable energy in the EU (http://ec.europa.eu/energy/res/legislation/country_profiles/2004_0547_sec_country_profile pdf)

2005 - Biomass action plan (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0628:FIN:EN:PDF)

2006 - Green Paper. A European strategy for Sustainable, Competitive and Secure Energy (http://europa.eu/documents/comm/green_papers/pdf/com2006_105_en.pdf)
- Action Plan for Energy Efficiency: Realising the Potential. (http://ec.europa.eu/energy/action_plan_energy_efficiency/doc/com_2006_0545_en.pdf)
- Renewable Energy Road Map. Renewable energies in the 21st century: building a more sustainable future (http://ec.europa.eu/energy/energy_policy/doc/03_renewable_energy_roadmap_en.pdf)
- An EU Strategy for Biofuels (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0034:FIN:EN:PDF)

2010 - Energy 2020. A strategy for competitive, sustainable and secure energy (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:En:PDF)
- The EU climate and energy package (http://ec.europa.eu/clima/policies/package/docs/climate_package_en.pdf)

2011 - Energy Roadmap 2050 (http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf)

2012 - Renewable Energy: a major player in the European energy market (http://ec.europa.eu/energy/renewables/doc/communication/2012/comm_en.pdf)

The titles of the listed documents in Box 5 show that security of energy supply, competitiveness of the European energy market and renewable energy sources are the issues which have received more attention from the EC. All these issues strongly affect the forest energy wood context and in their turn are influenced by this context. Wood is indeed the renewable energy source most appreciated for its security of supply and which needs to be made competitive on the market (Ragwitz et al. 2006; EC 2009). Further the documents show that the focus of interest has shifted from energy supply security to the market competitiveness. For example, the EC communication of 2010 *Energy 2020. A strategy for competitive, sustainable and secure energy* has a similar title to that of the Green Paper of 2006 *A European strategy for Sustainable, Competitive and Secure Energy*. However the combination of words is changed giving emphasis to competitiveness. This shift reflects global policy trends moving from the embracement of the sustainable development discourse to the emphasis on market driven and neoliberal approaches towards problem solving (Ferranti 2011).

Next to the EC communications, the EU energy context is characterized by a number of directives dedicated to the energy topic and aimed at reforming the European legislative framework with respect to energy production, efficiency and use (see Box 6 for the main directives).

Box 6. Main EU Directives regulating energy production, efficiency and use.

- Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market.
- Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.
- Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport
- Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity
- Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC
- Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC
- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
- Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

Within the directives, the EU-RED (Directive 2009/28/EC) is particularly relevant for the context of energy woody, albeit treating forest energy wood amongst other renewable energy sources. The EU-RED and its implications for the energy wood context are described in Section 4.4.1. Section 4.4.2 addresses the EU Biomass Action Plan, which directly assesses the use of (woody) biomass as a source of bioenergy.

4.4.1 The Renewable Energy Directive 2009/28/EC

The EU-RED aims at promoting security of energy supply, technological development and employment opportunities related to the increased use of renewable energy sources in the European context. The EU-RED also aims at reducing EU energy import dependency and at increasing energy efficiency, saving and diversification. Moreover, the EU-RED asserts the need to simplify administrative procedures and improve transparency in the energy field. With respect to the renewable energy market, the EU-RED envisages a sustainability driven market in which, for example, woody biomass produced with sustainable management strategies can be sold at higher prices compared to those that are not. Energy prices should reflect costs of production and consumption, such as environmental, societal and healthcare costs. Sustainability is not only envisaged in wood production, but also in the context of biomass imports: MSs have to ensure that the woody biomass they purchase from outside the EU respects environmental and social requirements agreed upon at Communitarian and international levels. For example, imports of woody biomass have to take into account groundwater and surface water quality, as well as land competition of wood production with food demand. Effects on food production have to be considered especially with respect to the conversion of arable lands in areas available for SRF aimed at producing energy wood.

The EU-RED expresses environmental concerns especially with respect to the exploitation of woody biomass. It excludes lands with high biodiversity values from the production of renewable energy. Forests where there has been little or no intensive human intervention, and areas designated for nature protection purposes or constituting habitats for endangered species should not be exploited for energy production. Further, the EU-RED excludes areas with a high carbon stock, insofar as the extraction of biomass from these areas could result in the release of carbon into the atmosphere. These areas are represented by wetlands, peatlands, and continuously forested areas. Environmental concerns are especially strong with respect to the conversion of lands into areas dedicated to SRF. This conversion has to consider issues related to carbon balance and pollution. The conversion can take place when SRF represents an improvement in the carbon storage situation or reduces the input of pollutants with respect to previous circumstances. It should be avoided when SRF worsens the environmental condition of the area, for example, by releasing more carbon or by requiring higher water and fertilizer inputs. This description makes it clear that the EU-RED encompasses environmental concerns which are most of all climate change related when addressing the production of renewable energy in the EU. The reduction of GHG emissions and the compliance with the Kyoto Protocol are cited in the first paragraph of the EU-RED as an umbrella objective which the EU aims to contribute to, based on an increase of renewable energy share. It also highlights the linkages between energy and climate change policies in the EU (EC 2010b).

The EU-RED establishes a 20% mandatory target for the overall share of energy from renewable sources to be achieved by 2020. The year 2020 is also chosen as a milestone for the EU climate change policy, which imposes the target of reducing GHG emissions by 20% by 2020 with respect to the 1990 level (Directive 2009/29/EC). The combination of the two targets has been defined as the EU “climate and energy package” (EC 2010b). To achieve the

2020 renewable energy target, the EU-RED has imposed legally binding objectives on EU MSs, individually designed taking into account the different starting points and potentials of each MS. The main aim of the mandatory target is to provide certainty for investors and encourage technological development. The EU-RED has also imposed a 10% target for energy from renewable sources in transport to be reached by 2020. This last target is set at the same level for all MSs in order to ensure consistency in transport fuel specification. To organize their efforts in achieving the 2020 renewable energy target, MSs are required by the EU-RED to draft national Renewable Energy Action Plans starting from 2005, the year for which the latest reliable data for all the MSs are available. These action plans have to consider that biomass has different uses, and that it is therefore necessary to mobilize new biomass resources to avoid competition among sectors. Especially with respect to woody biomass, which is often produced and used in local contexts, regional and local authorities should be involved in the realization of the Renewable Energy Action Plans.

The EU-RED highlights the importance of SMEs in the provision of renewable energy. These enterprises need to be supported by state support schemes which can also operate across political borders among MSs as well as European borders. The attention toward SMEs is particularly relevant for the European forestry sector, which is mainly composed of small and medium private forest owners (FAO 2009). Decentralization of renewable energy production and its benefits (i.e. use of local sources, increased local security of supply and shorter transport distances) are underlined in the EU-RED. However, next to a focus on local processes related to renewable energy production and consumption, the EU-RED also addresses international issues. Cooperation among MSs and with countries outside the EU for the trading of renewable energy and related technologies is envisaged in the EU-RED. Trading procedures and authorizations should be made simpler, rules and subsides should be harmonized and certification and licensing schemes should be made more transparent, in order to avoid obstacles to the trading of renewable energy. On the one hand the EU aims to reduce dependency on non-communitarian energy sources, while on the other hand it recognizes the likely unceasing dependency on non-EU regions especially in the short term until the year 2020. As this dependency will constitute an unavoidable fact in current energy production and use patterns, the EU-RED aims at addressing it by imposing sustainability requirements onto the imports of renewable energy.

A proposal for the modification of the EU-RED has been published by the EC in 2012 (EC 2012d). In the new framework that was presented by the EC (approval by the MSs needed by autumn 2014) a new renewable energy target for the year 2030 has been introduced, which requires the increase of the share of renewable energy to 27% of the EU’s energy consumption.

4.4.2 The Biomass Action Plan

In order to assess the specificities of biomass utilization as a renewable source of energy, the EC published a Communication in 2005 focussing on an action plan for this specific resource (EC 2005). The Biomass Action Plan (BAP) aims to create market incentives and reduce market barriers to the use of the three types of biomass: wood, wastes (also including wood residues from industrial processes), and agricultural crops. Moreover, the BAP addresses the role of biomass in the three energy sectors of heating, electricity and transport. It requires MSs to develop national BAPs which describe these sectors at the national level (EC 2005). In the 2005 Communication the EC underlines the advantages of biomass as compared to other conventional energy sources. The pros shared by biomass and other renewable energy sources are displayed in Table 1 (see Section 1). In addition low costs, low dependence on short-term weather changes and provision of alternative sources of income for rural actors are to be listed (EC 2005).

In particular, the heating sector benefits the most from the advantages offered by wood and industrial wood wastes. Indeed, technology for the use of these biomass types in residential and industrial heating is simple and cheap. For example, the use of standardized pellets makes processes environmentally safe and easy to handle. The EC presents the district heating option through CHP plants as a feasible alternative to reduce disadvantages and increase benefits of using wood and wood wastes in the heating sector. Disadvantages as identified by the BAP relate to the environmental implications of using wood and wood wastes in the heating sector (burning biomass emits pollutants), and to non-technical barriers such as market confidence and stakeholder attitudes (EC 2005). About 35% of the annual European wood growth is not used because the market demand for small size timber suitable for energy production is very low (EC 2005). Most of the unutilized wood lies in small private holdings and it is difficult to mobilize. Moreover, studies and forecasts on the use of wood and wood wastes in the heating sector suffer from the lack of data completeness on the amount of woody biomass used by private households and on the degree of efficiency of the related heating process. Finally, wood as a resource needs planting, growing and harvesting activities. This increases the costs of producing energy from wood (EC 2005).

With respect to the transport sector, second generation biofuels that can be produced from various biomass sources including wood and wood wastes are highlighted as a viable option for using cellulose material in the production of liquid fuels. Second generation biofuels have a better quality than conventional diesel, they have the advantage of securing a higher market share for biofuels by allowing a wider variety of raw material as source, and potentially reduce GHG emissions by limiting the inputs necessary to the cultivation of the prime cellulosic material (if compared to traditional agriculture and first generation biofuels). Because of the complexity of energy extraction from cellulosic material, second generation biofuels will have a higher costs than regular diesel and first generation biofuels. The EC underlines that these costs will have to be borne by consumers (EC 2005).

4.5 The role of forest biomass for energy in EU biodiversity policy

As for the other policy contexts addressed in Sections 4.2 to 4.4 of this report, the year 2020 represents an important milestone for EU biodiversity policy, and it corresponds to the establishment of targets that need to be achieved by coordinated action amongst MSs. Indeed, after not having achieved the 2010 biodiversity target established by the EU at the 2001 Gothenburg Summit with the purpose of halting biodiversity loss in the EU territory by the year 2010, the EU set an even more ambitious target as part of the so-called “2020 EU biodiversity strategy” (EC 2011e). This target reads “halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss” (EC 2011e p.2). As for climate and energy (Directive 2003/87/EC of the European Parliament and of the Council; European Commission 2011c) the year 2020 becomes a milestone in the European context also for biodiversity, showing the attempt to integrate different policy goals in one single effort towards the improvement of Europe’s environmental features and economic situation. The EU vision is extended to the year 2050, when EU biodiversity and the services it provides will have to be protected, valued and appropriately restored, both for their intrinsic value and for the contribution to human wellbeing and economy (EC 2011e). The focus on the 2020 and 2050 milestones places EU biodiversity policy in line with energy and climate change policies, and attempts an efforts toward policy integration and coherence at EU level. The description below illustrates how biodiversity policy in the EU takes into account the energy wood topic during its historical developments, and in particular it examines how biodiversity conservation and energy wood production relate in the management of the forest environment.

4.5.1 The 2020 Biodiversity Strategy

The EU 2020 Biodiversity Strategy recognizes the high economic value of biodiversity and its loss as an incommensurable cost for European society, higher than the costs that arise for conserving it (EC 2011e). The economic value of biodiversity is currently not recognized by official markets and its pricing is not reflected in society accounts. Consequently, biodiversity often falls victim to competing claims over natural resources and fails in being prioritized when deciding about the land use of a certain area (EC 2011e). However, the private sector is increasingly aware of the economic risks encompassed in the loss of biodiversity, and is gradually inserting biodiversity conservation within its corporate strategies (EC 2011e). This phenomenon is also demonstrated by the establishment of the EU Business and Biodiversity Platform, which addresses six different economic sectors (agriculture, extractive industries, finance, food supply, forestry, and tourism) and facilitates the exchange of experiences and best practices related to biodiversity conservation (EC 2012).

The EU 2020 Biodiversity Strategy encompasses six main targets, divided in a set of actions that are useful to achieve these targets. In particular, Targets 1 and 2 aim to protect and restore biodiversity and associated ecosystem services, especially though the implementation and management of the ecological network of protected areas Natura 2000 (see Section 4.5.3). They include goals for the year 2020 which read: "To halt the deterioration in the status of all species and habitats covered by EU nature legislation and achieve a significant and measurable improvement in their status so that, by 2020, compared to current assessments: (i) 100% more habitat assessments and 50% more species assessments under the Habitats Directive (HD) show an improved conservation status; and (ii) 50% more species assessments under the Birds Directive (BD) show a secure or improved status" and "By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems" (EC 2011e p. 5). Targets 3 and 4 aim to reduce pressure on EU biodiversity from agriculture, forestry and fisheries activities. Target 5 aims to prevent the introduction and establishment of Invasive Aliens Species, and Target 6 aims to step up EU contribution to global biodiversity (EC 2011e). Target 3 is especially relevant for the energy wood context because it specifically addresses agriculture and forestry activities and their effects on biodiversity. Point 3b directly addresses the specific role of forests in enhancing EU biodiversity. According to this target, it will be necessary that "by 2020, Forest Management Plans or equivalent instruments, in line with Sustainable Forest Management, are in place for all forests that are publicly owned and for forest holdings above a certain size (to be defined by the Member States or regions and communicated in their NRDPs) that receive funding under the EAFRD. This with the aim to bring about a measurable improvement in the conservation status of species and habitats that depend on, or are affected by, forestry and in the provision of related ecosystem services as compared to the EU 2010 Baseline" (EC 2011e p. 12-13).

The actions needed to implement Target 3b encompass the encouragement of forest holders to protect and enhance forest biodiversity and the integration of biodiversity measures in forest management plans. These measures include keeping deadwood in the forest, preserving wilderness areas, combating forest fires and ensuring the sustainability of afforestation (Winkel et al. 2010). Some of the other actions under Target 3 highlight the need to integrate biodiversity policy with other EU policies dealing with forest and agriculture related matters, especially through the funds made available by the EU for agriculture, forestry and RDP. This policy integration is needed in order to establish policy coherence at EU level and to foster practical integration of biodiversity conservation goals in the management and economic exploitation of rural areas. CAP tools aim at contributing to such policy coherence, for instance through the application of cross-compliance to direct payments received by farmers; the scope of cross compliance may be adjusted to include other requirements during CAP reforms. For example, the inclusion or exclusion of Directive 2000/60/EC (also known as the Water Framework Directive - WFD) in the cross compliance system has been a controversial issue in the 2013 CAP reform; in the end, it was not included in the system (Regulation (EU) No 1305/2013 of the European Parliament and of the Council). Moreover, well targeted EAFRD funds could contribute to better policy integration, by including quantified biodiversity targets into rural development strategies and programmes.

There are ongoing discussions in policy and science over the potential conflicts between biodiversity conservation and energy wood production; these indicate the likely limitations that conserving deadwood, mature forests and specific habitats in the forest environment could impose on increased production of forest energy wood. However, the EC communication (EC 2011e) does not directly address the energy wood topic. The same is true for the resolution of the European Parliament on the 2020 Biodiversity Strategy (European Parliament 2012), which does not directly address the effects of the likely increase in energy wood extraction which might follow the rising demands for renewable energies on European biodiversity. The Parliament resolution however acknowledges the potential conflicts between energy biomass utilization and biodiversity, by introducing the need to "introduce further safeguards regarding the sources, efficiency and quantity of biomass used for energy" (European Parliament 2012 p. 19) especially with respect to the negative implications of biomass production for biodiversity**.** In its resolution the Parliament emphasizes the potential role of the upcoming 2013 reform of the CAP in allowing the integration of biodiversity criteria into forestry practices, and it underlines the business opportunities derivable from the economic valuation of biodiversity and its services in the forest sector. The resolution also highlights the need to assess the negative impacts of economic activities on biodiversity, and it calls on regional authorities to balance the economic pressure over natural resources with environmental criteria also through instruments like the environmental impact assessment, sustainability impact assessment and strategic environmental assessment. With respect to the sustainability of economic activities, the European Parliament calls on MSs to "foster the coexistence of environmental protection, sustainable economic growth and social development as equal, non-contradictory principles" (European Parliament 2012). Although the resolution dedicates a whole section to forestry and its role in maintaining biodiversity, no reference is made to the specific case of energy wood production and most of the statements are generally addressed to traditional timber extraction activities. It is true that nowadays energy wood extraction is carried out mostly as a side product of traditional timber extraction (Kärkkäinen et al. 2014), and therefore the general statements produced for timber production can be valid also for energy wood provision. However, it is likely that in the future energy wood extraction might take a stand of its own in determining the direction of forest management in Europe (Kärkkäinen et al. 2014), and this may pose more dangers to biodiversity conservation than traditional forest management activities, especially with respect to shortening of rotation periods, changes in species composition, and utilization of deadwood (see Section 3.2.1 of this report).

4.5.2 A focus on the Green Infrastructure

Target 2 of the EU 2020 Biodiversity Strategy directly addressed the establishment of a Green Infrastructure (GI), defined as a strategically planned network of natural and semi-natural areas which is present in rural and urban settings and which provides ecological, economic and social benefits through natural solutions. It incorporates natural terrestrial and marine areas as well as their physical features (EC 2013). The GI is thought to support the conservation of ecosystems and the services they provide, therefore enhancing the contribution of nature to satisfy social needs like air pollution reduction and protection from extreme atmospheric events. The principle behind the building up of a GI is that constructing a network of natural and semi-natural elements helps to stop relying simply on “grey infrastructures” (human-engineered solutions often using concrete and steel) which are often expensive to build and sometimes less effective than solutions offered by the GI. For example, incorporating biodiversity rich parks, green spaces and fresh air corridors in the planning of a urban area can help to reduce the so-called “urban heat island effect” and limit the need for air conditioning in cities. Ecological restorations of floodplain forests can help filtering water, maintaining the water table and preventing erosion with less one-off and maintenance costs than building a dam or a floodplain reservoir (EC 2013).

In its communication on the GI the EC describes the benefits which humans can expect to gain from an effective implementation of the GI. In the EC’s description, the GI has an especially important role in preserving, conserving and enhancing the EU’s natural capital which includes “food, materials, clean water and air, climate regulation, flood prevention, pollination and recreation” (EC 2013 p. 2). Moreover, the GI can be very helpful for the achievement of a suitable climate change adaptation, for the maintenance of biodiversity and of ecosystem services (EC 2013). From this picture it emerges that bioenergy does not play a vital role in the description of the advantages derived from the establishment of the GI, while it is just one of the aspects mentioned in relation to the GI. Also, the energy topic is only shortly hinted at in a text box where the relation between GI and climate change is discussed together with the role of forests in this context. Moreover, the EC states that the GI will also be essential for the reduction of the carbon footprint of transport and energy solutions, however without explaining what role the GI will play (EC 2013). In this perspective, the GI is included in this study because, even if currently not very relevant, it is likely to be an important factor for the realization of bioenergy projects in the future.

According to the EC, the GI can also contribute to the effective implementation of other policies whose objectives are related to natural resource and regional contexts, and which are partly reachable thanks to natural solutions (EC 2013). These include for example policies in the fields of regional cohesion, climate change, disaster risk management, health and consumer policies. As examples of these policies, the EC mentions amongst others the Cohesion Fund, the European Regional Development Fund, the CAP (including RDP), the European Maritime and Fisheries Fund, as well as the Energy Performance of Buildings Directive (EC 2012). As it is possible to note the EU (renewable) energy policy is not considered to be one of the policies which can be synergistically implemented through the GI.

The only linkage between the GI and the EU's energy strategy is the role played by the Directive on Energy Performance of Buildings. With respect to wood, the communication from the EC on the GI stresses especially the need of innovative materials and design features to lower GHG emissions from the building sector, and it does not mention the provision of biomass for energy generation.

4.5.3 The Natura 2000 network

The backbone of the EU Biodiversity Strategy mentioned in Target 1 and repeatedly addressed in the EC Communication on the strategy (EC 2011e) is the Natura 2000 network (N2000), an ecological network of protected areas established in the European territory to assure the long-term survival of the most threatened habitats and species affected by degradation, fragmentation, isolation and extinction. The strategy undertaken by the EU is the creation of a network of sites protected on the basis of the presence of species and habitat types important for European biodiversity (EC 2009b). The realization of N2000 is regulated by two European Directives, the Birds Directive (BD) 79/409/EEC (Council Directive 79/409/EEC) and the Habitats Directive (HD) (Council Directive 92/43/EEC). The two directives not only list the procedure for identifying, selecting and designating N2000 sites, but they also include in their annexes the lists of species and habitat types that have to be protected on the European territory.

With respect to the legal procedure of establishing N2000, each MS has to select the most important sites for the mentioned habitats and species. The selection occurs with different procedures for the two EU directives and results in two types of protected areas: the Special Areas of Conservation (SACs) designated under the HD, and the Special Protection Areas (SPAs) designated under the BD. For the HD, the MSs submit a list of proposed Sites of Community Importance (pSCIs) to the EC, which evaluates the list and eventually modifies it in discussion with the MSs. The sites are finalized in a list of Sites of Community Importance (SCIs), which the MSs have to designate and manage as SACs. For the BD, the process of inclusion of sites in N2000 is simpler: the MSs select SPAs which automatically become N2000 sites and have to be managed as such (EC 2002). For the time being, most EU MSs have terminated the selection and designation of the N2000 protected sites and are implementing their management (EC 2014b).

As mentioned above, N2000 does not only protect endangered species but also the habitats of these species, as well as habitat types selected on the basis of their general importance for European biodiversity. In this sense, N2000 represents an innovative strategy toward nature conservation which overcomes traditional top-down, nation-state centered conservation systems focussed on sole species' protection, and based on vast isolated protected areas (Alphandéry and Fortier 2001; Ferranti 2011). From the attention toward both species and habitat types derive the two types of conservation measures encompassed within the N2000 strategy. The so-called "species protection measures" require MSs to protect the N2000 species wherever these species occur, also outside the boundaries of N2000 sites. Under the so-called “site protection measures”, MSs are required to designate a N2000 site whenever a protected habitat or a habitat of protected species is found on the European territory (Jackson 2011).

The conservation of both endangered species and habitat types is complemented by other innovations introduced by N2000 in EU nature conservation. The most noteworthy innovation is represented by the attempt of N2000 to integrate ecological, economic and societal criteria in the conservation of European biodiversity (EC 2002). This represents a turning point in the nature conservation strategies of many EU MSs, which used to only draw upon ecological criteria (Primack and Carotenuto 2003). According to the HD, biodiversity conservation must take into account “economic, social, cultural and regional requirements” (Council Directive 92/43/EEC). Humans are recognized as integral parts of nature rather than as external factors (EC 2009b). N2000 aims at moving the concept of nature conservation away from strictly protected natural reserves where human activities are systematically banned. Indeed, many of the habitat types and species protected by N2000 recur in semi-natural territories such as farmlands, forests and grasslands which are managed in traditional and sustainable ways (EC 2005c).

Traditional land management activities, and low impact activities such as some forms of recreation and tourism, are allowed and sometimes encouraged in N2000 sites to avoid the abandonment of territories and maintain the associated habitats and species (EC 2009b). As a consequence of the occurrence of protected habitats and species in territories which host these activities, the N2000 network includes different types of territories, from naturalized to more anthropogenic areas (EC 2005c). No human activities are systematically excluded from N2000 areas, provided that these activities do not negatively affect protected habitat and species (EC 2005c). This statement shows the relevance of socio-economic issues in the implementation of N2000. However, these socio-economic issues are assessed in scientific-ecological terms within the framework established by N2000. For example, for the management of N2000 sites, the criterion is the “conservation status” of habitat types and species for which a site has been designated (Mehtälä and Vuorisalo 2007). This status is measured and monitored in ecological terms like the size of the area of a population, or the persistence of long-term structures within a habitat (Council Directive 92/43/EEC).

According to the precautionary principle (EC 2002), activities to be carried out within and around N2000 sites must be assessed in advance to verify if these negatively affect the status of protected habitats and species. However, next to this technical-scientific procedure called “assessment of implications of an activity on a site”, the restrictions imposed by N2000 to human activities provide for some dispensations. Activities which are assessed to negatively affect the status of habitats and species can be carried out where there are imperative reasons of overriding public interest concerning, for example, human health or public safety (Diaz 2001). This description makes clear the interlacing of ecological and socio-economic elements. The integration of ecological criteria with a socio-economic approach in a new conservation strategy, where nature conservation aims at not representing an obstacle but rather an opportunity for human activities (EC 2005c), is an intriguing characteristic of the N2000 strategy. In the perspective of "conservation but flexibility" (EC,2002. p.3), this integration represents an attempt of the EU to apply the Sustainable Development principle (EC 2009b). The implementation of a balance between ecology, economy and society in a single strategy called N2000 has turned out be to be a difficult task and has not always been accomplished at the European level (Alphandery and Fortier 2001; Verschuuren 2004; Palerm 2006). For example, the HD has often been criticized for putting too much emphasis on scientific aspects, especially in the selection procedure for sites (Paavola 2004; Julien et al. 2000).

4.5.4 Natura 2000 and forests

Another innovative characteristic of N2000 is the ambitious size of the network, which nowadays comprises more than 25 000 sites and covers about 17% of the EU territory (Winkel et al. 2009). N2000 has been described as the largest ecological network in the world (EC 2003). The relevance of forests within N2000 is exemplified by the fact that the network encompasses about 380 000 km^2 of forests, corresponding to 46-50% of the N2000 surface. This in turn represents 22-23% of the total EU27 forest resource (N2K Group 2012). The HD includes 59 forest habitat types and 389 key forest species, of which 151 are plants. The BD lists 91 birds as protected key forest species, which represent about half of the total number of birds protected by the Directive (N2K Group 2012). Forests are one important component of European nature, with forestry activities having had a lower ecological footprint than other land uses such as agriculture. Many habitats and species occurring in European forests can be exclusively found in our continent. Despite their ecological importance, European forests have been degraded in the past, and many forest-related species have been brought to the verge of extinction (EC, 2003).

In 2003 the EC published an interpretation guide dedicated to the establishment of N2000 in forested areas, and to the "challenges and opportunities" this establishment entails (EC 2003). The document was developed after a broad stakeholder consultation and its main focus is to debunk false beliefs about the role of N2000 in the forest environment - for example, the idea that N2000 aims at establishing a strict system of protected areas where economic activities are excluded. In particular, the document "makes it very clear that Natura 2000 is not opposed to economic activity in the forestry sector" (EC 2003 p. 5), since it recognizes that European forests are the result of a long lasting interaction between humans and nature and can be defined as "semi-natural" areas (EC 2003 p. 269). Such a recognition assumes that "stakeholders can reach a compromise between the objectives of nature conservation and of economic production" (EC 2003 p. 7). In general, the management of N2000 sites prioritizes nature conservation goals, but economic activities can be carried out as long as they do not threaten the favourable conservation status of protected habitats and species. However, the same EC interpretation guideline recognizes that integration of human activities and nature conservation is not possible in forest areas which are strongly damaged and whose habitats and species are in high danger of deterioration or extinction (EC 2003).

The interpretation guide produced by the EC reports non-mandatory guidelines for the management of N2000 sites in forested areas, mainly based on the interpretation of SFM produced by the Forest Europe process (FOREST EUROPE, UNECE/FAO 2011). The management guidelines also rely on the "multifunctionality" principle, widely adopted in the EU Forestry Strategy of 1998 to summarize the benefits provided by forests to European society. These benefits include ecological, economic, protective and social functions, which in the history of N2000 have been differently addressed by the various EU MSs. In particular, MSs characterized by extensive forestry systems mostly designated large N2000 sites where the various forest functions are integrated in the land use of the area, while MSs characterized by intensive land use mostly designated small N2000 sites where nature conservation functions are segregated from economic and sometimes also social functions in areas set aside for biodiversity protection (EC 2003).

The EC interpretation guide underlines that the HD does not provide specific indications on the management of N2000 forested areas, such as restrictions on harvesting levels, dimensions of clearings, timing of interventions etc (EC 2003). However, Article 6 of the HD makes clear that activities carried out within and around the protected sites need to undergo the assessment of implications of such activities. In practice, if forestry activities do not disturb habitat and species leading to a decline in conservation status, they can continue without changes. If forestry practices lead to a deterioration of the conservation status of habitats and species then they need to be adapted. Moreover, interventions that lead to a temporary disturbance like group cuttings or thinning are legitimate, provided that they allow recovering of the initial situation (EC 2003).

The EC interpretation guide reports operational-level guidelines for the application of SFM in N2000 forested areas, following the Criteria and Indicators set for SFM elaborated by the Forest Europe process (FOREST EUROPE, UNECE/FAO 2011). The guidelines include actions aimed at maintaining the health and vitality of forest ecosystems, conserving and enhancing biodiversity and safeguarding protective functions of forests related to soil and water conditions (EC 2003). Moreover, the guidelines include actions aimed at maintaining the productive functions of forests, as well as other socio-economic functions and conditions. These last elements are particularly relevant for the wood energy context, since they recommend that "harvesting levels for wood products should not exceed a rate that can be sustained in the long term, and optimum use should be made of the harvested forest products, with due regard to nutrient offtake" (EC 2003 p. 30). Moreover, the guidelines underline that the management of N2000 has to take into account the role of forestry in rural development and the new opportunity for employment offered by this sector (EC 2003).

Besides the management practices reported here that are relevant for the energy wood context, the 2003 interpretation manual does not specifically address the extraction of wood for energy purposes from N2000 sites. However, it reports some recommendations that can affect forest energy wood, insofar as aimed at fostering nature conservation goals that influence objectives of (energy) wood production. These recommendations potentially reduce the quantity of wood that can be extracted and conflict with the need to ensure a continuous provision of energy wood to satisfy the constant demand of bioenergy. Examples are (EC 2003):

- Conserving mature and dead or decaying trees that host birds and other animal species. In N2000 sites these should be left in the forest and not extracted for economic purposes.
- Conserving trees with cavities that are used as nesting sites for small birds and mammals.
- Adapting the timing of forestry and logging operations to avoid interference with the reproductive seasons of specific animal species.
- When replanting a forest after final felling, avoid planting at a density at which all available space is filled. This allows creation of a more diverse range of forest habitats including for example grassy patches, bogs and mires.

The EC is currently in the process of elaborating a new updated guidance document on N2000 and forests that will address key issues related to European forests and their conservation: it will help assessing potential conflicts as well as identifying synergies between forest management and nature conservation in N2000 areas (Standing Forestry Committee 2012). The new guidance document will be drawn up on the basis of a consultation process carried out with relevant stakeholders including representatives of the forest sector, NGOs, MSs and the relevant EC services. The goal of the document will be one of enhancing mutual understanding and cooperation among the different interests toward forests, by promoting biodiversity conservation in N2000 forested areas while addressing the economic and social functions of forests. The new guidance document will include non-mandatory recommendations for forest practices within N2000 (Standing Forestry Committee 2012).

To set up the consultation, the N2K Group prepared on behalf of the EC a Scoping Document on Forests and Natura 2000 (N2K Group 2012) that was submitted to key stakeholders for comments and feedback. The document addresses the relevant issues that will be included in the new guidance manual on N2000 and forests. Despite the proclaimed goal to tackle current key issues affecting the management of the network in forested areas, the document does not include reflections on the provision of wood for energy generation. Instead, amongst other things, the scoping document identifies main pressures and threats on EU forests, mentioning unsustainable forestry activities, climate change, habitat fragmentation and forest fires as main elements (N2K Group 2012).

With respect to forest practices within N2000, the scoping document underlines that forest management will mostly depend on the targets for which the forest area is included in the ecological network. For example, some forests are protected because they comprise habitat types listed in the HD, or areas that host habitats for species listed in the BD or HD (N2K Group 2012). For these areas, management objectives have to prioritize the restoration or maintenance of a favourable conservation status of protected habitats and species, and in the case of particularly vulnerable ecological elements the concept of "non-intervention management" should be applied. However, N2000 also incorporates forest areas for reasons of ecological coherence. These areas are likely to be able to maintain current forest management practices as they are. In general, forest measures which bring mutual benefits for forestry and nature conservation should be maintained and encouraged (N2K Group 2012).

4.6 Reflections on the legislative and policy framework of forest energy wood

The general analysis of policies produced at EU level and the detailed study of EU forest, agricultural, energy and biodiversity policies carried out in Section 4 confirms the intricacy of the policy framework affecting the energy wood sector. Many different EU policies are influencing the extraction and use of energy wood from forests, with objectives pursued by these policies appearing, in some cases, to be in conflict (e.g. biodiversity conservation and resource efficiency goals). In other cases EU policies have a synergistic influence on energy wood developments (e.g. climate change mitigation and rural development goals). This brings about what can be defined as a "coherency challenge", which the EU is faced with when defining policy goals related to the production and use of energy wood (Ragonnaud 2014).

Forest biomass for energy is variously treated in the four policy areas which underwent in-depth analysis in Section 4. In particular, the production of biomass for energy plays a role in the CAP- where it is one of the main elements building up the RDP. It is also a strong component of the rationale behind the Biomass Action Plan and the EU-RED. What the author defines as "EU forest policy" has only recently focussed on the importance of energy wood. Although energy wood, and the processes put it place to mobilize it, are not amongst the more frequently referenced topics in this policy area, they are becoming increasingly important and are referred to fairly consistently in its provisions. As mentioned, "EU forest policy" compared to the other three policy sectors (agriculture, energy, biodiversity) addressed here is not legally binding and the documents building up the policy often refer to the regulations underpinning the CAP (in particular RDP) as the main tools to implement and finance actions in the forest context. Lastly, EU biodiversity policy is the area that more weakly recognizes and treats the role of energy wood, which is only addressed briefly and not discussed amongst the issues that deserve special attention for the pursuing of the policy's sectoral objectives. Room for improvement exists for the actual integration of biodiversity conservation and energy wood related goals, and the upcoming EU guidelines for the management of N2000 forest sites may fill this gap (CEPF 2014).

Furthermore, the historical analysis of the four policy areas showed insights in the developments underwent by forest energy wood related policy goals and their acknowledgments in specifically-forest-exogenous policies. The CAP and EU forest policies, energy wood from forests have played an increasing role over the years. The 2003 CAP reform included the production of energy wood in its legislative texts and in the list of possible measures to finance this production under the EAFRD, but the dedicated EU funds were weakly utilized by the MSs for this purpose. The new, more flexible CAP rules for rural development that emerged from the latest reform could lead some MSs to use the funding possibilities, more than in the past, also for energy wood production. This is fostered by framing energy wood as a climate and rural development friendly resource. In the same way, while the 1998 Forestry Strategy did not mention energy wood amongst the challenges faced by European forests, the 2013 Forest Strategy includes bioenergy amongst the pillars of the strategy's structure (see Figure 7 in Section 4.2.4). The historical analysis of EU energy policy showed that the role of energy wood has been increasing with the growth of the "renewable energies" discourse, especially because of the security of supply advantages presented by wood for the EU when compared with other renewable energy sources, and also to the emergence of climate change as a crucial issue for the EU's future. Moreover, concerning biodiversity policy it is possible to detect a slight growth of the role of energy wood in the policy documents (the importance of the topic was not mentioned in the earlier legislation and policy documents, while it was briefly referred to and acknowledged in the EU 2020 Biodiversity Strategy), even if this growth is commensurate to the very limited role that energy wood currently plays in this policy.

5. The integration of forest energy wood and biodiversity policy goals in EU policies

Reviewed by Raoul Beunen

5.1 Introduction to the integration of forest energy wood and biodiversity policy goals

Section 3.2 showed that important environmental concerns can be raised with an increasing the provision of forest energy wood in Europe to satisfy the growing demand of bioenergy. Biodiversity is one of the environmental aspects which are expected to be amongst the most affected by the addressed increase of energy wood provision from forests. This is due to the fact that forests are essential hotspots for European biodiversity, being one of the ecosystems where biodiversity is best conserved despite the rather constant human activities going on in European forests (Paillet et al. 2010; Winkel et al. 2009). It is expected that biodiversity would be considerably affected by changes in forest management approaches towards intensification of energy wood extraction. Those could include shortening of rotation periods, changes in tree species composition, removal of forestry residues, deadwood and stumps. In this sense, biodiversity conservation can represent a constraint for energy wood production and impose limits to the increase in energy wood provision from European forests (Nabuurs et al. 2007; Asikainen et al. 2008; EEA 2007). This leads to some trade-offs between energy wood extraction and forest biodiversity conservation which need to be managed at policy level.

It is true that the integration of biodiversity conservation and energy wood provision to forest management will need to take place mainly at the local policy level. However, it is important that European policies also put in place such an integration. This among other things is due to the fact that EU policies have varying effects at national and local levels (Lindstad et al. 2014; de Koning 2014), and without a strong framework for such integration, socio-economic interests might steer local policy making at the disadvantage of environmental interests (Ferranti 2011). A great majority of the policies addressed in this report, as well as the related EC communications and other policy documents, refer to the need to integrate and coordinate in particular environmental goals with other socio-economic goals (just to cite a few examples: EC 2006b; EC 2011h; EC 2011e; EC 2013d). However, it needs to be verified to what extent such a policy integration goal is actually accomplished in European policy. This is the focus of Section 5, which firstly analyzes the level of integration between forest energy wood related policy goals and biodiversity conservation concerns in the EU policies affecting the energy wood context, and secondly the eventual policy conflicts which arise amongst competing policy objectives. It takes into account the policies which were addressed in Section 4 of this report, namely EU forest, agricultural, energy and biodiversity polices. Detecting the extent of coherence and the eventually unaddressed conflicts between energy wood and biodiversity related goals allows underlining the contexts in which policy coherence at EU level could be improved to better coordinate the pursuit of conflicting goals in forest management.

5.2 Energy wood production and biodiversity conservation: integration in EU forest policy

The description of the EU policy approach to biodiversity conservation presented in Section 4.5 makes clear that the EU Biodiversity Strategy is a very ambitious project which allows for a certain degree of flexibility for the MSs to implement biodiversity conservation goals through tailor-made national solutions. This flexibility allows national and sub-national governments to integrate biodiversity conservation goals into socio-economic activities. For example, through the implementation of N2000 and the GI. However, the flexibility characterizing EU policy in general and biodiversity policy in particular (EC 2002) brings about important ambiguities with respect to what it actually means to implement the integration of biodiversity related concerns in the context of increased bioenergy demands (Winkel et al. 2013). Some of the ambiguities regard the fact that the communications and scoping documents elaborated at EU level on biodiversity conservation do not meaningfully address the growing concerns on this increasing demand. The HD and the related interpretative documents elaborated by the EU (EC 200; 2001b; 2002; 2003; 2009b), as well as the documents building up the GI policy (EC 2013), do not explicitly refer to the forest energy wood topic.

While this is understandable in the case of the HD which, as framework legislation, does not address any other forms of land use in detail, it has been observed that currently published guidance documents like the one explicitly dedicated to N2000 and forests do not address such a challenging issue. This is particularly surprising considering that forests areas are the most frequent land use in N2000 (Winkel et al. 2009). Indeed, the EC document on *Natura 2000 and forests* reports only general recommendations for the safeguard of biodiversity to take into account in every forest management operation, such as leaving enough deadwood and trees with cavities and not using practices that can damage nests during the breeding season (EC 2003). They do not reflect on the specificities of forest energy wood production. Also the Scoping Document on Forests and Natura 2000 (N2K Group 2012) does not directly address the role of energy wood production in the management of these areas. This raises worries about the future EU approach towards the challenges posed to biodiversity conservation by forthcoming forest management trends, and the way in which the conflicts will be dealt with once they will become reality.

The situation is slightly different, but not much more promising, when looking at the integration of nature and biodiversity conservation concerns into EU energy policy documents affecting the production and use of forest biomass for energy. If considering policies produced by the EU in the late 1990s and 2000s, one notices that some directives, EC documents and communications do not specifically refer to biodiversity and its need for protection (Directive 2001/77/EC; Directive 2002/91/EC; Directive 2003/30/EC; Council Directive 2003/96/EC; Directive 2004/8/EC; EC 2006; EC 2004; EC 2006) while others mention these items at least once (EC 1997; EC 2001; EC 2005; EC 2006d; EC 2009). All these legislative and policy documents refer in general terms to the need to take environmental considerations into account, mainly due to the fact that Article 11 of the

Lisbon Treaty asks for environmental protection requirements to be integrated into the definition and implementation of EU policies and actions (ClientEarth 2010). Starting from the publication of the EU-RED and from the development of the EU 2020 targets, an increase in references to biodiversity and nature conservation issues is visible through explicit quotations of biodiversity related topics (Directive 2009/28/EC), or through referring of EU international commitments in environmental themes, of EU environmental legislation, and of the need to mitigate environmental impacts of energy projects (EC 2010; EC 2011c; EC 2012b; Directive 2012/27/EU). While environmental and biodiversity related concerns are at least formally acknowledged in EU energy policy documents, these documents do not address how provision of biodiversity conservation and forest energy wood can be integrated (neither with respect to integration in national legislation or with regard to implementation).

The production and use of forest energy wood as well as the protection of the forest environment and its biodiversity are also influenced by other policies produced at the EU level such as the Forestry Strategy, the FAP, the CAP and the RDP. Although these policies are not directly targeted to energy wood, or forest biodiversity, these themes are represented to varying degrees. The 1998 Forestry Strategy (EC 1998) did not give a substantial space to the forest energy wood topic, which is only mentioned in relation to the diversification of the energy mix through SRF and the collection of forestry residues, and to the climatic benefits of substituting fossil fuels (EC 2005b). Environmental aspects, and biodiversity conservation in particular, are addressed more broadly in the Strategy, both in relation to the application of the SFM principle, and in relation to the possible environmental drawbacks of SRF and residues collection (EC 1998). The mutual effects of producing energy wood and protecting biodiversity are not substantially treated in the Strategy and therefore the understanding of how these two themes are interlocked in this policy is not straightforward.

The 2006 FAP developed to coordinate MS actions in the implementation of the Forestry Strategy and to include emerging topics in the practical application of the Strategy dedicates a broader space to forest energy wood. The main aim there is the achievement of multifunctionality and sustainability of forests in supporting societal needs and forest-related livelihoods though the application of the SFM principle. Energy wood contributes to the achievement of the first objective of the FAP, namely improving the competitiveness of the forest sector and enhancing the sustainable use of forest products and services, for example, by stimulating energy markets for low-value timber and small-sized wood. Within this objective, Key Action 4 is dedicated to the use of forest biomass for energy generation, and it addresses wood mobilization, cooperation amongst forest owners, energy market, support of energy wood technology, and research and linkages with the RDP. Biodiversity conservation is broadly treated in the 2006 FAP, and it contributes to the second FAP objective dedicated to environmental protection in the forest environment. It is not mentioned how these two aspects should be balanced in practical management, and which conflicts may develop while enhancing forest multifunctionality.

The FAP however includes a fourth objective dealing with coordination amongst different policy areas. This makes clear that this document acknowledges possible policy conflicts between different forest management objectives, together with the need to minimize these conflicts by producing integrated policies at the EU level (EC 2006b). According to the FAP, forest policy is the responsibility of MSs. As many policy issues relevant for the forest environment are regulated at EU level, coordination in this context amongst EC Directorates, between EC and MSs, and amongst MSs is essential. This can be accomplished by: 1) strengthening the role of the Standing Forestry Committee, through enhancing cooperation with advisory bodies like the Advisory Group on Forestry and Cork and the Advisory Committee on Community Policy; 2) strengthening the coordination between policy areas in forest-related matters by requesting each EC Directorate to establish a "coordinator for forest-related policies" which can inform the Standing Forestry Committee on initiatives and actions in other policy areas relevant for forests, and by strengthening the role of the Inter-Service Group on Forestry; and 3) improving information exchange and communication between policy makers and the public (EC 2006b). Despite the expressed intensions in coordinating forest relevant policy areas and the acknowledgment of potential conflicts, the likely trade-offs among policy areas are not clearly identified or described. This may result in the envisaged policy integration remaining a formal expectation rather than a realizable ambition.

The mid-term evaluation of the FAP (Pelli et al. 2009) highlighted that the plan stimulated the use of energy wood together with a higher level of coordination amongst policy relevant areas, by contributing to the visibility of the forest sector and to dialogue on bioenergy. Room for improvement was detected with respect to forest environmental protection (Pelli et al. 2009). The ex-post evaluation of the FAP (EC 2012) allowed the effects of the Plan to be identified with more precision. Despite evaluating the FAP as efficiently and effectively implemented, the document highlighted that its uptake at both EU and MSs level has not been considerable. A limited amount of activities have been reported as directly responding to the FAP guidelines, while most of the forestry activities were seen as responding to other policies, for example, the CAP. A possible reason may be that it is difficult to recognize the causal links between FAP and impacts on forestry. This may be due to the broad variety of other EU policies affecting the forest sector (EC 2012). Moreover, the FAP is voluntary while other forestry-relevant policies are often legally binding. Therefore policies from other fields may show stronger impacts on the forest sector as they ask MSs to implement compulsory requirements which cannot be circumvented. Finally, the FAP does not provide for a specifically dedicated EU fund, and it is obvious to imagine that MSs would address more attention to the policies whose implementation is instead co-funded at EU level.

FAP objectives such as environmental protection and policy coordination have had a broader effect at EU level. They contributed to information exchange between EC Directorates and raised awareness on forest-related issues (including energy wood) in other policy sectors. Other objectives like cooperation amongst forest owners, which is essential for the mobilization of energy wood in a condition of fragmented forest ownership (UNECE/FAO 2007.), had a broader effect at MSs and local levels, but were seldom reported as responding to the requirements of the FAP. The voluntary character of the FAP and the missing availability of earmarked EU funds supporting its implementation can be regarded as a reason for low uptake of action. MS compliance with and allocation of funds to the FAP implementation depends on national policy objectives and institutional organization (EC 2012).

Bioenergy alongside rural development is one of the fields mentioned by MSs as being influenced by the publication of the FAP. However expectations for a proactive and holistic integration of the FAP with other EU level policies have not been sufficiently met, since the forest policy sector has only been able to react to and not to strongly influence important developments in other policy sectors like that of energy (EC 2012). Moreover, the sustainable integration of economic, environmental and social aspects envisaged by the FAP did not take materialize. A possible reason for the lacking integration of forest policy objectives and policy objectives of other sectors is that the forest context in the EU has undergone important shifts in priorities (see e.g. the 2020 energy and biodiversity targets), which were not included in the FAP formulation (EC 2012).

The new EU Forest Strategy makes important steps forward in the formal policy integration of biodiversity conservation and energy wood related goals. The implementation of the N2000 network and of its biodiversity conservation goals, as well as the fostered use of forest biomass for energy, take a more prominent role in the new Forest Strategy (EC 2013b; 2013c). Latest developments in biodiversity reporting and monitoring and in discussions related to environmental impacts of forest energy wood use are hinted at as major policy processes. In particular, energy wood production and biodiversity conservation are dealt with together in the document, and are listed amongst the eight priorities of the new Forest Strategy (EC 2013b). The new Forest Strategy stresses amongst its priorities the need to properly address cross-cutting forest policy issues which refer, for example, to the coordination between forest policy goals and to biodiversity and energy wood policy goals. The EU Climate and Energy Package and the EU Biodiversity Strategy are mentioned amongst the exogenous policies affecting the forest sector, while the RDP is referred to as one means to achieve nature and biodiversity related objectives while fostering economic activities in the forest (EC 2013b).

Despite the high importance attributed by the 2013 EU Forest Strategy to biodiversity conservation, the document repeatedly refers to the CAP and its upcoming review for the practical actualization and for the financing of biodiversity conservation in the forest environment. The CAP, and especially the RDP with its EARFD, has historically been the main regulating and funding instruments for forestry in the EU (EC 2012), and so the repeated reference to the CAP is not surprising. Section 3.2 shows that already the 2003 CAP reform represented a milestone in the integration of nature conservation goals into forestry objectives, by underlining the significant role of wooded land in delivering environmental benefits (Allen et al. 2012). This development continued in the 2008 CAP Health Check which aimed at strengthening the environmental implications of the 2003 CAP reform. As an example, before 2013, the second axis of the RDP was specifically dedicated to the improvement of the environment in rural areas with significant funds assigned to this objective within the EAFRD. However, despite forested and wooded areas covering about the same proportion as agriculture, agricultural land management and farm businesses remained the main focus of EAFRD expenditure and dominated the CAP reform debate (Allen et al. 2012; EC 2012). Further, the 2008 CAP Health Check represented a significant step for the inclusion of the forest energy wood topic in EU agricultural policy, and therefore a development towards the integration of biodiversity and energy goals.

The lack of use of EAFRD forestry related funds is amongst the factors which led to the reform of EU agricultural policy (EC 2013d). Other elements are the necessity to take better into account environmental issues, and to better include emerging challenges such as climate change mitigation and the contribution to a green economy. These challenges can be supported by an increased production of energy wood from forests; this will enhance the substitution of fossil fuels and foster the role of forests in providing nature friendly solutions for economic growth. The 2013 CAP reform follows the footprint of the 2008 Health Check by envisaging the greening of EU agricultural policy. It renders more flexible the funding of actions including N2000 implementation in rural areas and the production of woody biomass (EC 2013d). These objectives are pursued through an approach which is defined as "holistic" and "coherent", underlining the attempt to integrate diverse and sometimes conflicting policy goals. For example, by sustainably managing natural resources and by rewarding farmers and foresters for the provision of services which are not valued on the market such as biodiversity conservation and climate stability, the rural environment can substantially contribute to the EU 2020 targets (EC 2013d). In particular, of the 30 measures included in the RDP, 21 can be considered as environmentally friendly and classified in key measures, supporting measures, and cross cutting measures. Four types of funds dedicated to the conservation of the environment have been identified: 1) incentive payments for land operations, 2) direct investments in agriculture, forestry or environmental infrastructures, 3) adding value to environmentally sustainable production, and 4) capacity building. Especially forestry related measures are defined as positive for the environment, including nature and biodiversity conservation but also the reduction of GHG emissions through the substitution of fossil fuels with energy wood production (Allen et al. 2012).

As often in EU policies, integration of partially competing objectives is also pursued through an integrated financing mechanism. For example, 30% of the budget granted to the first pillar of the CAP dedicated to Direct Payments for farmers and to market management mechanisms will be allocated to the so-called "greening payments". Therefore, it will finance those rural stakeholders who engage in environmentally friendly activities, such as the institution of ecological focus areas which become a precondition for the request of funds under Pillar 1. This is an important step forward in the envisaged greening process of the CAP, as the first pillar of the new CAP is based on legally binding regulations. Also, organic farming has been included in the list of measures which can be financed under Pillar 1, with obvious benefits for farm biodiversity. Moreover, the 2013 CAP is rooted on the principle of flexibility with respect to funding, since MSs are allowed to transfer funds between the first and the second pillars (EC 2011f), and therefore between legally binding and voluntary requirements. Despite limits imposed on the quantity of funds that can be transferred between the two pillars, the financing flexibility leaves MSs the leeway to chose how to allocate significant amount of funds, with the risk that the voluntary measures under the RDP (including many of the forestry related measures relevant for biodiversity conservation and energy wood production) will remain once again underfunded in the future.

Always with respect to funding integration, Allen et al. (2012) explicitly mention that the EAFRD should be used to achieve policy targets set by other policies like Biodiversity Strategy, the Birds Directive and the Habitats Directive. Allen et al. recognize that multiple environmental priorities exist in the rural environment, and enumerate these without a clear hierarchy, but rather generating a list of factors which should be pursued with same ranking of importance. With respect to other environmental issues like climate change mitigation and water protection, biodiversity occupies a broader space in the list, but this does not allow inferring that a higher priority is assigned to the biodiversity conservation topic. The CAP regulations and the documents defining the integration of environmental objectives (such as Allen et al. 2012) set up the potential of EU agricultural policy to achieve environmental goals. However, it is essential to state that the actual delivery of environmental (and of socio-economic) services depends on the interpretation of the CAP measures by the MSs, and this becomes even more important when different CAP measures are combined to achieve European requirements or national priorities.

5.3 Conflicts between biodiversity and forest energy wood-related goals

The low uptake of bioenergy topics within EU biodiversity policy, and the limited inclusion of biodiversity conservation in energy legislations and policies call for an analysis of the limited policy coherence at EU level. Although several EC documents on both energy and forest biodiversity address the need for policy integration (EC 2006; EC 2011e; EC 2013), this goal cannot be completely fulfilled in practice. Neither biodiversity nor energy wood related documents suggest how objectives which are in principle conflicting, for example, the conservation of species and habitats within N2000 and an increased energy wood production envisaged in the EU Biomass Action Plan, should be made compatible in the national and local implementation of these policies. The potential policy conflicts between forest energy wood production and biodiversity conservation have been identified also by Winkel et al. (2009) in their analysis of major challenges for European forests, especially as a result of socio-economic trends such as the changing societal demands and expectations toward forests (Nabuurs et al. 2007). With respect to these trends, competition can be identified between, on the one side societal claims towards biodiversity conservation and integrated forest management approaches which take environmental considerations into account in every forestry operation, and on the other side the increasing demands for both timber as a material and wood for energy (Winkel et al. 2009; Bollmann and Braunisch 2013). These tensions can be summarized in an ongoing process affecting European forests, and namely by changes in forest management which are embracing two contrasting development patterns (Winkel et al. 2009). The first pattern represents the multifunctionality of management objectives which are aimed at applying a balance between environmental, social and economic goals. The second is directed toward the “economization” and “monofunctionalization” as a result of globalization and of increasing demands of wood as a product (Winkel et al. 2009).

According to the EC (2011e), the inclusion of biodiversity objectives in other policy sectors should occur through monitoring and reporting, for example through the EU biodiversity baseline and indicators which could be taken into account in the implementation of natural resources utilization related policies like EU-RED and CAP. However, such an integration method echoes currently applied and “business as usual” policy coherence strategies which proved in Section 5.2 to be rather unsuccessful at EU policy level. In the practice, the limited success of currently applied integration efforts are shown by the increasing conflicts between biodiversity conservation and provision of forest biomass highlighted as one of the main limiting factors to an increased production of forest energy wood (Verkerk et al. 2011b; Schulze et al. 2012; Pedroli et al. 2013). One main point in this context is that when declaring the importance of forest ecosystem services in rural areas, no prioritization of objectives is made in EU policies, and the choice of how to balance different pressing issues regarding resources utilization is left to the national and sub-national policy implementation. The literature reflects on the fact that final decision making in topics addressed by EU policies is carried out at local or national levels where the same act of taking decisions implies that not all policy objectives can be equally achieved and compromises must be made amongst competing goals. Beunen et al. (2009) suggested that there is still a lot to do to achieve policy integration at EU level.

Despite considerations on the practical achievement of integration between contrasting objectives, Winkel et al. (2009 p. 12) report “potential contradicting policy objectives with similar importance for forests without set priorities” as one of the major current problems regarding the protection of the forest environment in Europe. This statement may apply also to the sustainable exploitation of energy wood from forests. If prioritization of forest-related policy objectives would be carried out at EU level, it would be easier for the national and local policy levels to implement EU policies affecting the production of forest energy wood without infringing European requirements and incurring sanctions from the EU (for example, for not having contributed enough to the achievement of the 2020 energy or biodiversity targets). The main issue underpinning the problem of missing priorities is the lack of a common, comprehensive and legally binding forest policy in the EU which is mainly due to the exclusion of forest products from the EU primary laws on established Common policies (Winkel et al. 2009). The lack of mandatory requirements for MSs leads to diverse levels of national enforcement of EU forest-related policies like biodiversity and energy wood policies, and fosters the setting of different priorities in EU countries. It may also lead to an overall mosaic of varying degrees of coherence between nature protection and energy wood production policies, with some MSs allowing policy and practical conflicts between biodiversity and energy wood goals to arise much more than others. This situation is exacerbated by the existence of a wide variety of EU policies with objectives extrinsic to the forest topic but nevertheless affecting the EU approach to forests and forestry (e.g. the Common Agricultural Policy, the Water Framework Directive, the Resource Efficiency Policy, and the Climate Change Policy). While national diversity in EU policy implementation is a consequence of the subsidiarity principle and it does not necessarily have negative connotations, there is a risk that due to recent economic trends dominating EU and national approaches to land use (Ferranti et al. 2013), biodiversity conservation goals in some countries may be given a lower priority than energy wood production goals. This would result in a lower level of forest protection in some EU MSs than in other MSs, potentially undermining the goal of biodiversity conservation.

The lack of prioritization is visible both within single EU policies affecting the protection and exploitation of forests, and amongst different EU policies. With respect to the first case, the 2006 FAP simultaneously pursues the improvement of long-term competitiveness of forests and the protection of biodiversity and other environmental forest functions. According to Winkel et al. (2009) forest competitiveness and forest protection are partially conflicting objectives, insofar as protecting forests implies restrictions for economic activities carried out in forests. For this reason, these two objectives should either "be prioritized or [...] regulated" (Winkel et al. 2009 p. 50). In this sense, the FAP generates potential endogenous policy conflicts between forest conservation and economic forest objectives. Moreover, the FAP does not establish a hierarchy of importance in the pursued objectives. The balancing of conservation and energy goals is left to the MSs, which may apply different approaches to satisfy the FAP recommendations while reflecting national priorities. In the same way, they have allocated financial resources derived from EU funds in response to their domestic needs (EC 2012).

If considering the increasing demand of wood as an energy source, the link between environmental and economic elements might in the future be unbalanced toward economic-driven goals. The effects on forest management standards and the implementation of forest management practices in conflict with SFM could be regarded as a threat to environmental forest functions (Winkel et al. 2009). Similar considerations can be applied to the new Forest Strategy (EC 2013b) which mentions as key objectives the strengthening of SFM and the improvement of competitiveness and job creation in rural areas, together with forest protection and the maintenance of ecosystem services provision. These objectives are simultaneously pursued without a clear prioritization. A prioritization could be deduced from the fact that production functions of forests are given a slightly stronger emphasis than conservation. For example, biodiversity conservation is only mentioned in the context of the Natura 2000 network and RDP implementation (two exogenous policies), while the production of energy wood is mentioned with respect to the development of rural areas, job creation, resource efficiency, climate change mitigation and energy targets. However, the documents produced by the EC on the new Forest Strategy (EC 2013b; 2013c) continuously refer to the need of balancing socio-economic objectives with environmental ones, mainly through the application of SFM.

When fostering of energy wood production is mentioned in the new Forest Strategy or related policy documents, the protection and conservation of forests is often formally balanced through a reference to the SFM principle. This principle itself however is subject to different interpretations (Schraml and von Detten 2010) and is centre of discussions on whether the balancing of the social, economic and environmental objectives it envisages is actually applicable in practice (Winkel et al. 2011). In a few cases a reference is made to the need to address policy trade-offs between competing goals like energy wood production and biodiversity conservation (for example EC 2013c p. 60), but the way in which this balance should be applied is not specified. Moreover, with respect to the new Forest Strategy, the need to strengthen biodiversity conservation is not linked to the expected increased exploitation of forests following a growing demand for wood. This shows that within the new Forest Strategy endogenous conflicts of energy wood production and conservation goals (e.g. EC 2013c p. 26) are not fully taken into account, despite the emphasis it puts on the coherence and coordination amongst competing forest functions and related policy goals (EC 2013c). Finally, the implementation of the new Forest Strategy as a voluntary instrument will rely on funding instruments like EAFRD, Life+, cohesion and structural funds and Horizon 2020. These funds are developed for financing also actions other than the implementation of the Strategy, and therefore their allocation at MS level depends on the MS commitment towards forest policy and prioritization of policy objectives (EC 2013b).

Experience shows that forest-related measures received low priority in funds allocation (CEPF 2014b). Under-spending characterizes the implementation of forestry measures under the EAFRD especially with respect to Natura 2000 implementation in forested areas which resulted to be less than 14% of the expected expenditures (EC 2013c p. 45). At the end of 2011, the financial implementation of forestry measures received 34% of expected expenditures. This also takes into account MS attempts to allocate EAFRD funds in order not to lose them (2013 was the last year for using the available financial resources). MSs reported that the main reasons for not allocating enough EU funds to forest activities are the difficult interpretation of funds requirements, the high administrative burden linked to the funds request and allocation and the overall low contribution of EU funds (EC 2013c).

Internal conflicts similar to those described for the FAP, the 1998 Forestry Strategy and the new 2013 Forest Strategy can be identified within the CAP, which is influencing the implementation of measures in the forest sector through the EAFRD. The 2003 CAP and its 2008 Health Check foster the maintenance of agricultural and forest productivity and the enhancement of the competitiveness of these sectors, while supporting afforestation, restoration and conservation of forests and woodlands (Winkel et al. 2009). Again, MSs have the freedom to decide the priority assigned to these different goals, and in a period of strong economic pressure this may result in a lack of forest conservation measures. With respect to the new CAP, several aspects generate internal conflicts between economically driven activities like the extraction of energy wood and other forest functions which are not valued on the market like biodiversity conservation. Pillar 1 aims at encouraging farmers and foresters to respond to global demands for wood resources and base their production on market signals, while Pillar 2 aims at implementing SFM through nature conservation and climate change mitigation, actions for which it is essential to preserve biodiversity and its functions without allowing market trends to influence decision making at a too broad extent. It could be said that the production of forest energy wood is framed in EU policies as a way to integrate climate change mitigation and ensure a contribution of forests to increasing raw material demands. This framing risks underestimation of the negative implications of the carbon neutrality assumption of wood (Section 3.2.2 of this report), because it does not considers possible negative feedbacks of using energy wood on climate change. As with other recently published EU policies, also the 2013 CAP is affected by the lack of prioritization. The Rural Development Regulation indeed is not anymore based on three axes, but is built on "six priorities" (EC 2013d, see Section 3.2.2). The same term "priorities" is once again used in the RDP without an internal hierarchy of importance amongst the mentioned priorities. This results in the apparent contemporary pursuit of two competing objectives like enhancing "competitiveness" and "restoring, preserving and enhancing ecosystems".

Besides endogenous policy conflicts between biodiversity conservation and forest energy wood production, it is also possible to identify conflicts amongst different EU policies which are partly due to the lack of prioritization amongst these polices. EU directives and other legally binding legislations need to be implemented at national and local levels, with the same ranking of importance, even when their objectives in theory are competing and often incompatible in practice. The reasoning is different when considering policy objectives which are legally binding (e.g. N2000 and the 2020 targets) versus non-legally binding policy goals (included in e.g. the 1998 Forestry Strategy, the new Forest Strategy, FAP and RDP). Experience shows that the voluntary policies receive lower attention and less allocation of funds than the legally binding policies. This automatically generates a prioritization amongst policies which is not set at EU level but develops during the national and local implementation of EU policies.

A list of examples is presented where there are clear policy conflicts between different EU policies concerning the protection of biodiversity and the production of forest energy wood:

- Given the coverage of the N2000 network in the EU, complemented by semi-natural areas where biodiversity is safeguarded, conflicts might arise between EU biodiversity policy and renewable energy projects (Jackson 2011). Jackson (2011) highlights the "strictness" of EU biodiversity policy which derives from the ambitions of the EU in environmental themes and it manifests itself in the adoption by the EU of more demanding targets compared to other partners of the Convention on Biological Diversity of 1992, as well as during the tenth meeting of the Conference of the Parties in 2010 (Jackson 2011). Also the technocratic imprint of nature conservation under N2000, which protects sites for the presence of important habitats and species judges the level of protection of these sites through their ecologically determined conservation status (Ferranti et al. 2013). The extension of the ecological network are important manifestations of the same "strictness", allowing the EU to be defined as a testing ground for the implementation of ambitious environmental policy goals. It also embeds potential conflicts with social and economic policy goals (Jackson 2011). According to Jackson (2011) this strictness might set the ground for a dispute between economic development and biodiversity conservation policy goals (for example inducing national authorities to deny permission for environmentally invasive actions such as the construction of dams or wind power stations). The same can be considered for strategies aimed at intensifying energy wood extraction following a thorough implementation of EU energy and biomass related policies, and the implementation of the HD - especially if taking into account the percentage of forest area in N2000.

- N2000 site protection measures represent the main source of possible conflicts between biodiversity conservation policy and economic projects (Jackson 2011). These measures require MSs to identify, designate and protect sites where the habitat types of Annex 1 of the HD and the habitats of the species included in Annex 2, and species and habitats listed in the Birds Directive occur. When a N2000 site is designated, an appropriate assessment of activities planned and/or carried out in or nearby its borders needs to be implemented in order to verify whether there may be negative effects to the protected habitats, according to Article 6(3) of the HD. In order to avoid misleading interpretations of the meaning of this article, the European Court of Justice legislated that the assessment needs to be carried out not only in case in which significant effects can be demonstrated, but even when significant negative effects on the protected site cannot be ruled out. This restrictive interpretation of Article 6(3) sets a high threshold for plans and actions in or nearby N2000 area borders (Jackson 2011). This may hold for ambitious plans for energy wood extraction. If the actions fail the test of an appropriate assessment they will not take place, unless the following three conditions for derogations identified in Article 6(4) of the HD apply. They are:

    1) a demonstrated absence of alternative solutions;
    2) a demonstrated reason of overriding public interest;
    3) the MS at stake demonstrates to take all compensatory measures necessary to ensure the minimum impact on the protected natural elements.

- The derogation option allows for resolution of conflicts, but does not improve the situation for renewable energy projects which are unlikely to be underpinned by reasons of overriding public interest.
- Conflicts can arise between biodiversity conservation policy objectives and the EU climate and energy package. Winkel et al. (2009) specifically mention the energy wood context and the expanding use of woody biomass for the production of second generation biofuels which follows the establishment of the 10% target for renewable energies in the transport sector established by the Biofuels Directive (Directive 2003/30/EC of the European Parliament and of the Council). This target may compete with conservation goals of N2000 forest sites which constitute more than 20% of EU forests (Winkel et al. 2009). With the rising economic value of wood, environmental functions of forests may in future "decrease in relative terms" (Winkel et al. 2009 p. 51).
- Possible conflicts might arise between the implementation of the GI and industrial and societal interests in Europe which aim at further intensifying wood production for the provision of wood for biomass. From a land use perspective this could imply managing forests which are not currently managed (action which might be hard to

perform considering existing technical limitations) or expanding forest areas. At the same time societal and political interests ask for a full functionality of forest landscapes, as parts of GIs which provide ecosystem services and which guarantee ecological integrity and recreation possibilities. Most of the environmental objectives currently pursued in forests require large areas (Andersson et al. 2013). Potentially, wood production and environmental interests towards forests can turn into a synergy for current forest management, insofar as an active management has proved to be positive also for the role of forests as connecting and protective landscapes. However, a study from Andersson et al. (2013) showed that the equal focus on production and environment elaborated in EU policies is likely to generate land use conflicts on the ground between increased production of forest energy wood and the development of GIs, mainly because of a lack of prioritization of the objectives. It presented that in the investigated area, forested zones which gave a stronger contribution to the GI are those which are less available for intensification of forest management. The areas at higher conflict risks are the ones not hosting cultural landscapes or old deciduous forests, and therefore not attracting strong recreational or nature conservation interests. This might lead then to a segregation of forest management objectives in different zones of a forest (Andersson et al. 2013). In particular, this may emphasize the need to identify sites where forest management should not aim at the production of wood biomass due to environmental and/or social reasons. The above would entail engaging in a precautionary path which relies on the scientific evidence of the negative effects of biomass extraction in sensitive sites (Hesselink 2010). This path would also have to take precautions in the exploitation of areas which are currently suitable for biomass extraction, but because of physical characteristics might not be able to stand intensified removals in the future (Hesselink 2010).

5.4 Conclusions on the integration of forest energy wood and biodiversity conservation policy goals

Sections 5.1 to 5.4 made clear that the envisaged integration and coherence amongst EU policies dealing with diverse and competing objectives for biodiversity conservation and forest energy wood production is not fully achieved. Mostly this is due to the lack of prioritization amongst EU policies and amongst objectives pursued within single policies. In order to explore possibilities for increasing coherence among requirements of EU policies for national implementation, it is useful to detect the conflicting elements between the respective policies. This can be useful in light of possible revisions of the policies at stake which could provide the chance to bring forward a discussion on such conflicting elements and to improve policy incoherence (Winkel et al. 2013). Highlighting the synergies which exist between competing policy goals can be useful for increasing policy coherence, insofar as these synergies can represent a starting point for a stronger integration of conflicting policy objectives. For example, the main principle of biodiversity conservation within N2000 is the consideration of human activities in natural and semi-natural sites when implementing nature protection objectives. N2000 does not explicitly forbid forest management in protected forested sites, and wood can be harvested. If the targets set for particular N2000 areas are not negatively affected by forestry operations, wood production including for energy is allowed (Bieling 2004). Following these principles, wood extraction could even be encouraged, provided that it contributes to maintenance of habitats of endangered species. The economic dimension of natural resource exploitation is very much relevant in the discussions taking place around the implementation of GI (EC 2013), as well as the management and financing of N2000 (Gantioler et al. 2010; 2010b; Eftec 2012; Winkel et al. 2013). Strengthening the socio-economic benefits of N2000 and highlighting the possibilities to extract higher quantities of wood from forests without negatively impacting species and their habitats can benefit the integration of biodiversity conservation and energy wood production.

Stronger efforts should be made at EU level to achieve the envisaged integration between biodiversity conservation and wood production objectives. This is relevant especially considering that ineffective integration of EU policy goals in wood production and biodiversity conservation might have substantial effects on national and sub-national forest policy and management. There is a danger that the current economic crisis and the neoliberal turn in policy making (Ferranti 2011), combined with a lack of prioritization between economic and environmental goals, might hinder forest biodiversity conservation in national and local contexts. Increasing policy coherence at EU level through an holistic debate on the relations between different EU policies (Jackson 2011) can allow a more fair balancing of diverse expectations towards forests at national and local levels. According to Jackson (2011), if EU biodiversity policy was to be strictly enforced, the EU might trigger a need for renegotiation of the HD, which would reduce its conservation strictness and make it more consonant with energy policy. This might then lead to a weakening of nature conservation in the EU and to a potential loss of credibility of the EU in the international environmental arena. According to Jackson, a renegotiation of the HD would not be desirable, but rather the establishment of a hierarchy between different EU policy goals could be needed, in order to reduce potential conflicts in the future (Jackson 2011).

Based on the above discussion, it is suggested that it would be helpful to produce interpretation manuals which are able to explain how the integration of competing policy and management objectives could take place in concrete terms, and simplify the abstractness of the currently employed policy jargon. Other envisaged solutions regard the creation of policy tools which are specifically dedicated to the integration of already existing and diverging EU legislation and policies. An example of the tools to overcome policy and practical conflicts between EU energy targets and biodiversity conservation goals are binding EU sustainability criteria for biomass (Pedroli et al. 2013). This perspective coincides with those of ENGOs which see legally binding criteria as the only option to balance nature conservation and economic interests in forests (Birdlife, Greenpeace, EEB, Client Earth and Fern 2012). The development of such criteria is currently under discussion at the EC. Until this moment, the EC has provided MSs with a document including recommendations on the development of such criteria in a national context (EC 2010e). The document underlines the aim of these sustainability criteria, which is the coherence of the EU energy targets with the climate change mitigation through the reduction of GHG emissions, and of the same targets with biodiversity conservation (Pedroli et al. 2013).

6. General conclusions

This report has addressed one of the major challenges that European forests are currently faced with, namely the trend towards an increasing production of woody biomass to satisfy the growing demand for renewable energies. This topic is high on EU, national and local policy agendas. It is also of considerable interest to stakeholders representing not only forest and energy sectors, but also sectors affected by the production and use of energy wood including nature conservation, tourism, consumers and industry. The results of the study can be seen as background information for policy makers at European, national and local levels, insofar as they shed light on the implications of engaging in an energy pathway which strongly relies on forest energy wood as energy source. This pathway is currently envisaged by many of the EU policies reviewed in this report. The pathway is bound to increasingly affect policy making also at lower governmental levels, including a whole range of practical and societal aspects relating to forest management, markets, stakeholder preferences, technological development, rural development and employment. The compiled information may be useful for researchers and experts focussing on various environmental, social or economic aspects of forest energy wood. It can further be utilized by organizations and institutions operating in the European context and representing the sectors interested in the production and use of forest energy wood.

The report has provided insights into specific aspects of the forest energy wood context: the assessment of the European forest energy wood potential; the trade-offs and synergies associated with forest energy wood; the legislative policy framework affecting forest energy wood; and the integration of energy wood and biodiversity conservation goals in EU policy. The analysis of these aspects sheds light on the complexity and intricacy of the energy wood context, which becomes also visible in the various international scientific studies on EU energy wood potential characterized by uncertainties affecting calculated estimates. The development of factors like effects of CO_2 emission, land conversion, forest management and technological developments in energy efficiency is undetermined. These factors make it challenging to determine future forest energy wood supply and demand.

Despites uncertainties, studies on forest energy wood potential are highly relevant as they provide quantitative references for the amount of wood that could be destined for energy use. Such limitations can be nature conservation or the quality of the water-soil system in the forest. They can lead to a reduction of areas available for energy wood production or pose restrictions to wood availability. Further, levels of mechanization and social acceptance may affect an increased mobilization of wood. This highlights the complexity of the forest energy wood context, an energy source whose utilization comes with several implications and is affected by a variety of environmental, social and economic factors. The uncertainties associated with estimation of the theoretical forest energy wood potential (maximum amount of terrestrial biomass theoretically available for energy production within bio-physical limits) along with the limitations related to achieving this potential mean that future energy wood potential studies need to focus on the calculation and estimation of the sustainable implementation potential (Rettenmaier et al. 2010). This corresponds to the fraction of the biomass potential which can be produced and mobilized by taking into account an as broad as possible a range of environmental, social and economic factors (Rettenmaier et al. 2010). This will allow for more reliable estimates of energy wood potential, and these estimates reflect the various implications of forest energy wood production and use.

In order to take the three pillars of sustainability (environment, economy and society) into account, it is important that studies of energy wood potential consider a resource-based approach rather than a demand-based approach. This is because concentrating on the amount of wood that can be produced allows environmental and social limitations to be better taken into account; these are likely be the strongest factors reducing energy wood availability (Hesselink 2010; Nabuurs et al. 2007; Vogt et al. 2005). Consequently, a resource-based approach can generate estimates which more realistically reflect the actual possibilities of forests, and the willingness of stakeholders to more meaningfully contribute towards renewable energy paths. A demand-driven approach risks overestimating the potential of wood, because wood demand is based on market related factors which are some of the most mutable variables affecting the energy wood context. Instead, a resource-based approach might precautionary underestimate energy wood production, with a broader wood availability than forecasted. This is not a desirable option from an economic point of view, because it would entail re-organizing eventual policy processes based on the underestimated energy wood potential. However this is a reversible solution, which carries less risk than the overestimation of energy wood potential following the application of a demand-based approach. This may lead to the need to import wood to sustain the policy paths undertaken basing on the overestimated energy wood potential. The necessity to import forest energy wood would undermine the power of wood to be an energy source characterized by security of domestic supply and sustainable value chains, and therefore the meaningfulness of contributing through wood to the achievement of the EU 2020 targets (Schulze et al. 2012).

The complexity of the forest energy wood topic and the various limitations to the production and use is confirmed by the information presented in Section 3. It shows that there are both positive and negative implications associated with forest energy wood, and that these touch all three pillars of sustainability. The economic, social and environmental trade-offs and synergies associated with forest energy wood influence each other and result in an inter-linked mosaic of cause–effect relations that are challenging to assess. For example, producing energy wood can have positive effects on rural economy and employment, but can have negative effects on forest nature conservation. Using forest energy wood as an energy source can benefit the mitigation of climate change while creating strong market competition and reducing the wood available for specific industry sectors. This complexity underlines the need for further studies dedicated to understanding the implications and interactions of the various policies.

The most important conclusion coming from the variety and complexity of relations between forest energy wood and social, economic and environmental aspects is that a broad range of trade-offs and synergies should be taken into account. They should be identified by weighting the positive or negative implications of increasing energy wood use against factors like forest nature conservation, tourism and recreation, employment, climate change. Practical actions aimed at obtaining energy wood from forests should consequently balance trade-offs and emphasize synergies and foster development of these synergies. Especially environmental trade-offs associated with forest energy wood production and use should be taken into account, as those determine the sustainability of wood production in the long run. Not taking these environmental trade-offs into account might result in much higher costs to bare in order to restore negatively affected elements and functions, and in worst cases in the impossibility to continue the economic exploitation of the forest.

The consideration of especially environmental but also social and economic implications of wood production is central to the concept of integrated forest management (Bauhus et al, 2013; Bollmann and Braunish 2013). This concept consists in the pursuit of social, productive and environmental functions on the whole forest area, even if there are different priorities for specific areas within the total area (Bauhus et al, 2013). This management approach is currently the most common in EU forests (Bollmann and Braunish 2013). This report recognizes that an economic turn, in which economic aspects become determinants of socio-political developments also with respect to environmental themes, is affecting EU environmental governance (Ferranti 2011). Reflecting this, important changes are occurring in the forest sector such as the increasing demand for energy wood, the likely intensification of forestry activities, and the changes in forest aesthetics. Despite a great body of literature supporting the idea that integrative management approaches are more suitable for addressing the very many conflicts and trade-offs associated with energy wood production, some authors argue that a viable option would be to segregate energy wood production from other forest uses like nature conservation and tourism. This would allow environmental damage to be confined to specific forest areas with high resilience and maximize production in areas with few environmental limitations (Hartmann et al. 2010). Bollmann and Braunish (2013) present an approach involving the establishment of strict forest reserves in vulnerable forest areas, and allowing wood extraction in the rest of the forest matrix while applying environmental considerations like the retention of habitat trees.

Finally, the complexity of the energy wood topic is illustrated by the policy analyses in Sections 4 and 5. These sections present a picture in which forest energy wood related policy goals are at a cross-roads amongst several EU policy areas including forest, agriculture, rural development, industry, construction and building, climate change, biodiversity and resource efficiency. In this intricate policy framework, sectoral policies influence the production and use of energy wood through their specific sectoral goals, which may conflict with or complement energy wood related matters. For example, biodiversity and resource efficiency policies may impose limitations on the production and use of energy wood, while climate change and rural development policies may foster production and use of energy wood. This intricate policy context calls for coordination and coherence which are currently pursued by the EU in the attempt to integrate competing policy goals (EC 2011d; EC 2011e; Winkel et al. 2010). Despite efforts to improve coordination and coherence of policies at EU level, important policy conflicts can still be identified. For example, between biodiversity conservation and energy wood related policy goals. It is uncertain how these policy conflicts will affect national and local implementation of EU policies and practical accommodation of conflicting practical goals.

The current report did not allow a comprehensive understanding of the underlying specificities of the reasons behind the lacking coordination and coherence between biodiversity and energy wood policy goals. However a lack of prioritization of policy objectives (Jackson 2011) within and amongst EU policies was identified as a possible reason. This topic needs to be addressed in order to move towards policy coherence in the forest energy wood context. Competing goals such as nature conservation, climate change and resource efficiency on the one side, and rural development and market virtuosity on the other side, are pursued in EU policies simultaneously and with the same importance (EC, 1998; 2005; 2011d; Regulation (EU) No 1305/2013; Regulation (EU) No 1306/2013). This results in the fact that EU MSs are left with the leeway to prioritize national goals in the face of current environmental, social and economic challenges. Considering the turn towards the dominance of economic factors in EU governance (Ferranti 2011) and the ongoing economic crisis, it is suggested that at national and local levels economic policy goals may be prioritized over environmental policy goals. In the forest energy wood context, this will affect forest nature and biodiversity conservation, with negative effects on forest productivity and health and ultimately on the economic function of forests.

It also emerged that there has been a rather limited consideration of the energy wood topic in EU legislative texts and policy instruments affecting forests and forestry. The historical analysis of EU forest, agricultural, renewable energy and biodiversity policies indicated an increase in the reference to forest energy wood in these policies, especially in recent years. In particular, energy wood production and use play a rather consistent role within agricultural and renewable energy policies (EC 2005; Regulation (EU) No 1305/2013; Regulation (EU) No 1306/2013; Directive 2009/28/EC). The same is true for "forest policy" (EC 2013b; 2013c), even if the frequency with which energy wood is mentioned is lower in "forest policy" than in agricultural and energy ones. Despite the progress, there is space for improvements in the integration of energy wood concerns with respect to all three policy areas. Biodiversity conservation is the policy field which more weakly addresses the role of forest energy wood, and important efforts are needed in this context in order to avoid conflicts in EU policy implementation.

The low uptake of forest energy wood related matters in EU biodiversity policy is particularly surprising considering the important conflicts and consequent trade-offs identified between energy wood production and biodiversity conservation. The low integration identified in this report contrasts with the constant effort by the EU to integrate biodiversity conservation in economic and social activities (Beunen et al. 2009; EC, 2006b; 2012; European Parliament 2012; Council Directive 92/43/EEC). Considering the limited inclusion of energy wood related matters in biodiversity policy at EU level, it is understandable that policy conflicts between energy wood production and biodiversity conservation still persist. They are likely to negatively affect the integration of biodiversity protection and forest management for energy wood production at lower governmental levels. Even though conflicts such as the ones affecting energy wood and biodiversity will continue to prevail, conclusions can be drawn on the need to improve the acknowledgment of these conflicts in EU policies. Such efforts will lead to improvements in dealing with practical trade-offs at national and local levels.

Based on the above, several recommendations are proposed to support dealing with the complexity of the forest energy wood topic and managing corresponding challenges:

1) Studies on forest energy wood potential in the EU should focus on the sustainable implementation potential rather than on technical or economic wood potentials in order to meaningfully reflect the main practical limitations to forest energy wood production and use. Studies should moreover adopt precautionary approaches when accounting for uncertainties and prefer a resource-based approach to the estimation of forest energy wood potential, to avoid negative consequences of overestimating such a potential.
2) Likewise, policy decisions on forest energy wood related matters should rather be based on estimates calculated using a resource-based approach. This can help to avoid a possible overestimation of the demands for energy wood, and consequent needs for importing wood from countries outside the EU.
3) Scientific research should ensure focus on the mutual relations between various synergies and trade-offs associated with forest energy wood production and use, in order to better understand the underlying relations amongst competing and synergistic forest functions.
4) Practical actions and projects dealing with the production and use of forest energy wood should take into account a broad range of trade-offs and synergies associated with forest energy wood, weigh pros and cons of producing and using energy wood against the effects on other forest functions, and aim at emphasizing synergies and fostering and balancing trade-offs.
5) Forest management approaches embedding different forest functions and ecosystem services are well suited to address conflicts and consequent trade-offs associated with forest energy wood production. Their pursuit in the European context should be supported in the context of increasing demand for energy wood and possible intensification of forestry activities.
6) More attention should be given to improving policy coherence and coordination in the forest energy wood context at the EU level. This could be addressed by a) prioritizing competing policy objectives at EU level, and b) better including forest energy wood related matters in policies which are relevant for the energy wood context. Emphasis should be given to biodiversity policy.
7) Scientific studies are needed on the effects of conflicts and trade-offs between forest energy wood production and biodiversity conservation at EU level, and on approaches and experiences of their application at national and local level – including the practical accommodation of conflicting forest management goals.
8) Despite ongoing emphasis on stimulating the economy in EU (environmental) governance, national and local governments need to ensure that environmental issues are not forgotten. Over-emphasis on economic goals can negatively affect forest health and productivity, eventually leading to decline of the quantity and quality of wood that can be extracted from the forest.

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Annex 1. Acronyms and abbreviations used in the report

[BAP] Biomass Action Plan
[BD] Birds Directive
[CAP] Common Agricultural Policy
[CO2] carbon dioxide
[CHP] Combined Heat and Power
[EAFRD] European Agricultural Fund for Rural Development
[EC] European Commission
[EEA] European Environmental Agency
[EFICENT] European Forest Institute Central European Regional Office
[EFISCEN] European Forest information SCENario Model
[EFSOS] European Forest Sector Outlook Study
[ENGO] environmental non-governmental organizations
[EU] European Union
[EU-ETS] European Union Emission Trading Scheme
[EU-RED] European Union Renewable Energy Directive
[FAP] Forest Action Plan
[FLEGT] EU Action Plan for Forest Law Enforcement, Governance and Trade
[GHG] Greenhouse gases
[GI] Green Infrastructure
[HD] Habitats Directive
[MS] Member States of the European Union
[N2000]Natura 2000 network
[NER] New Entrants Reserve
[NFP] National Forest Programme
[NGOs] non-governmental organizations
[NO3-] nitrate ion
[NPP] net primary production
[NRDP] National Rural Development Program
[NTFP] non-timber forest product
[OECD] Organisation for Economic Co-operation and Development
[RDP] Rural Development Policy
[RED] European Union Renewable Energy Directive (Directive 2009/28/EC)
[SFM] Sustainable Forest Management
[SME] small and medium enterprise
[SRC] short rotation coppice
[SRF] short rotation forestry
[VPA] voluntary partnership agreement
[WFD] Water Framework Directive
[WG] Working Group

Annex 2. Alphabetical list of the reviewers of the current report with information on their expertise

Name of the reviewer	Description of main expertise
Alexander Held	Forest and fire manager and researcher at the European Forest Institute Central European Regional Office. He is one of the leaders of the FRISK-GO project (http://www.efi.int/portal/2894) aimed at creating a forest risk facility in Europe. He has a long experience with forest fire both in the contexts of forest protection and of land management and nature conservation.
Stefano Carnicellli	Professor of Pedology at the Earth Sciences Department of Firenze University. Long-term member of the Forest Soils Expert Panel in the frame of the Forests Program of the International Convention on Trans-Boundary Pollution (ICP-Forests).
Tobias Cremer	Professor for Forest Utilization and Timber Markets at the University for Sustainable Development of Eberswalde. Having worked for a large energy company after his PhD, he has considerable practical and research experience in the bioenergy sector. His special expertise and focus of teaching and research are on bioenergy potentials, short rotation coppice and the sustainability of biomass supply chains.
Raoul Beunen	Assistant Professor in Environmental Governance at the Open University of the Netherlands and at Wageningen University. His research deals with the implementation of EU biodiversity policy and the conflicts between nature conservation and economic activities.
Benjamin Engler	Scientific Assistant at the University of Freiburg, Chair of Forest Utilization. After studying forest sciences, he specialized in the area of biomass supply for bioenergy and biomass conversion. He is currently involved in research projects dealing with these topics and coordinating and contributing to studies within the master programs Renewable Energy Management (REM) and Forest Sciences (FS).
Till Pistorius	Senior scientific consultant at UNIQUE forestry and land use GmbH, an advisory and forest management company for the land sector. Prior to this position he was assistant professor at the chair of Forest and Environmental Policy (University of Freiburg). The focus of his work is on international policies for the land sector and environmental governance, in particular on climate and biodiversity policies.
Guillaume Ragonnaud	Administrator in the European Parliament. He is currently working in the Directorate-General for Internal Policies of the EU, in the Policy Department B Unit. He is a member of the team dealing with agri-food issues (including the EU CAP) and forestry.