Impacts of forest bioenergy and policies on the forest sector markets in Europe – what do we know?

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EXECUTIVE SUMMARY

The main political objectives of EU's renewable strategy are decreased use of fossil energy sources, reduced CO_2 emissions and increased energy self sufficiency. Wood based bioenergy plays an important role in this strategy. The potential increase in wood demand for bioenergy production is of high interest for the EU forestry and forest industries due to its impacts on wood prices, profitability of forestry and forest industries, rural employment, recreation and forest ecology. In recent years, several studies have addressed the development of the wood demand for bioenergy, policies affecting it, and the above-mentioned impacts. To facilitate the use of the results by policy makers and other forest and energy sector stakeholders, a synthesis of the studies is in place. What are the policy relevant messages that come out of the studies, and what are the primary issues we lack science based information on? This report seeks addressing these questions, reviewing five recent studies that analyse renewable energy sources (RES) policy implications to forest industry and forest biomass markets with the focus on economic analyses of these implications. The objectives of the report are to summarize major results from these studies, discuss their main policy implications, and identify issues where further research seems most important. The five studies are briefly described in Table E1.

Table E1. Overview of the reviewed studies.

Study and publication forum	Purpose	Region and products analysed	Method(s)
Mantau et al. (2010) **The European Commission, DG Energy, Studies**	Project scenarios for the total demand and supply of forest biomass from EU27 (international trade not considered) up to 2030. Particular interest is the EU RES policies impact to forest biomass based bioenergy demand and supply	EU27, country level. No trade included. Industrial and non-industrial roundwood, forest residues, all main forest industry products, bioenergy, cascading use	- Econometric demand equations - EFISCEN forest resource model - Expert analysis - Wood Resource Balance accounting framework
Moiseyev et al. (2011) ***Journal of Forest Economics*, peer reviewed journal**	Analyses effects of EU's RES policy on the wood fibre markets and the forest industry production in Europe under two IPCC scenarios for global development and considering different assumptions regarding fibre supply from forest plantations in developing countries and the availability of wood for energy in the EU region	Global coverage, with Europe divided at country level (32 regions) and the rest of the world in 26 regions, with trade included between each of the regions. Forest residues, chips, 6 roundwood assortments, 24 forest industry products. Wood energy production decided exogenously	EFI-GTM (global partial equilibrium simulation model)
Lauri et al. (2012) ***Forest Policy and Economics*, peer reviewed journal**	Analyses the effects of the price for CO_2 emissions from fossil fuels on the use of wood in Europe, with emphasize on the economic potential to substitute wood for coal and peat in heat and power production	European coverage (32 countries and “Rest of The World”), including trade between the regions. Includes 6 roundwood categories, other woody biomass, 20 forest industry products and heat and power production from wood, peat and coal.	EU FASOM (European forest and agriculture sector partial equilibrium simulation model)
Moiseyev et al. (2013) ***Journal of Forest Economics*, peer reviewed journal**	Analyse the effects of coal, gas and carbon emission prices on the use of wood for energy and wood-based products in the EU region up to year 2030. The study also provides a sensitivity analysis of the impacts of possible decreases in future paper demand and of subsidies for wood-fired and wood & coal co-fired power.	Global coverage, with Europe devided at country level (32 regions) and the rest of the world in 26 regions, with trade included between each of the regions. Includes 6 types of wood assortments, 24 types of forest industry products and 12 types of energy productions	EFI-GTM (global partial equilibrium simulation model) – revised version expanded on renewable energy
Kangas et al. (2011) ***Energy Economics*, peer reviewed journal**	Impacts of different RES policies on forest biomass based biofuel production in the pulp and paper biorefinery producing 2nd generation biofuels	Finland. Pulp and paper, 2nd generation transportation biofuel	FinFEP (partial equilibrium simulation model for Finland)

Increased use of energy wood is not a threat to the EU forest industry

The review indicates that the future utilization of forest biomass from EU may not be as large as is often thought. Also, the results indicate that forest biomass utilization for bioenergy purposes will not be very extensive, even at high carbon price levels in some cases. It also seems that the forest industry will continue to keep its important role as a producer and user of wood based energy. This is despite the possible decline in consumption and production of some end products, like graphic papers, that is likely to decrease the production of pulp, which is also an important generator of bioenergy. Large share of the woody biomass going to energy production will also in the future consists of the side products of the forest industry, like bark, sawdust and black liquor. Also, the supply of logging residues and stumps for bioenergy is strongly connected to the industrial wood harvests. The studies suggest that if the carbon price is assumed to be the only instrument spurring the use of woody biomass for energy, it needs to rise to quite a high level before the competition between forest industries and the energy sector over the forest biomass starts to affect the forest industry production in a large scale.

The widely cited EUwood study's medium scenario suggests that the EU forest biomass supply (from forests and cascading use) would increase by 11% from 2010 to 2030. However, assuming the EU 20-20-20 target and the continuation of forest industry production in EU along the past decades trend, the study estimates that the demand for forest biomass would increase by 73%. As a result, there would be a shortage or a gap of 316 million cubic meters of forest biomass in 2030, which would amount to 22% of the total EU forest biomass demand.

The above gap has aroused concerns that scarcity of wood could lead to fierce competition over woody biomass between the buyers in the future, and also to significant loss of forest biodiversity due to increasing forest biomass utilization. However, studies taking into account recent structural changes in forest products markets, international trade, and the market (price) adjustments according to economic theory project that the demand for forest biomass could be significantly lower in the EU. In fact, there are three main factors not included by the EUwood study which in our opinion imply that the study is most likely significantly overestimating the future demand for forest biomass harvested in the EU (some of these factors are also included in the economic studies we have reviewed):

1. The structural changes in global and EU forest products markets are likely to result in a lower demand and production of forest products in the EU. Accordingly, also the forest biomass demand for industrial purposes is likely to be lower.
2. The EUwood study does not take into consideration the impacts of international trade in forest biomass. These imports exist already today, and are likely to increase in the future, given that the markets and policies in EU provide needs and incentives for this.
3. Forest biomass markets, bioenergy production and the forest industry production react to market incentives, such as the prices of raw material and end products. These market adjustments may be significant and they clear the "gaps" between supply and demand for forest biomass. For example, the potential increases in forest biomass prices decrease its demand.

There is a clear need to make an assessment of the future EU forest biomass demand which also takes into account these three factors.

Uncertainty over future policies makes the business environment challenging for the investors

The projections of future energy wood demand vary quite significantly between the studies. This indicates the high uncertainty that prevails over the future development of the use of energy wood. Perhaps the most important source for uncertainty is political. How will the carbon price develop in the future due to local or global climate policies and what type of taxes and subsidies will be implemented for wood bioenergy and alternative competing energy forms? Will future policy treat woody biomass used for energy production as carbon neutral or not? Do the possible sustainable biomass criteria effect woody biomass utilization for energy? Clearly, answers to these questions will be important for the future development, but there is high uncertainty regarding which policies will be implemented and what their more precise content will be. The reviewed studies show that it is not only the level of carbon price that affects the future use of wood for bioenergy, but also how the carbon price develops over time. Due to high investment costs required for new heat and power and biorefining capacity, expectations on the directions of future climate and RES policies are decisive for the investments in such technologies. Early signals for high future carbon prices reduce the lock-in to the more carbon intensive technologies of energy production.

Under the uncertainty of the future carbon prices, additional RES policies help to promote new investments, but can also cause new problems. Subsidies directed to one sector may harm the other sectors and they can also increase the costs of mitigating climate change. For example, it has been found that subsides given for biodiesel production tend to increase the forest biomass price, which in turn may decrease the production of wood-based heat and power in the region. In some cases, they could also decrease pulp production. Subsidising the co-firing of wood with coal in heat and power production leads to lower displacement of coal in the whole energy system, and it can also lead to some displacement of gas, which emits less CO_2 than coal. Thus, although coal with wood co-firing may be a "low-cost" option in the short term, a policy supporting this type of energy production may in fact result in situations where the long-term CO_2 policy target is even more difficult to reach. Moreover, even relatively modest subsidies to production of energy from wood may imply significant increases in the use of industrial wood for energy, and also lead to increased imports from outside EU, causing potential carbon leakages and concerns regarding the sustainability of these supplies. Consequently, such subsidies may not be cost-efficient from the point of view of reducing CO_2emissions. In summary, it is vital that the policy makers are aware of the many impacts of the various policies and have clear priorities guiding them to accept trade-offs between sometimes conflicting policy goals.

Need for a synthesis study taking into account also the environmental sustainability

The issue of environmental sustainability is likely to bring additional challenges to policy makers. For instance, if the RES target is triggering woody biomass imports for bioenergy purposes to the EU, it is clear that these imports should meet the same sustainability standards as forest biomass from EU has. The EU has recently implemented means to inspect the legality of wood placed in the EU market, but this does not guarantee all dimensions of sustainability of the imported wood. Another important sustainability issue is related to carbon (and climate) neutrality of forest biomass as fuel. It is currently a hot topic both in the policy and science arena. It is also a very complicated issue, where simple solutions and widely applicable generalizations will not be easily found. The production of energy from forest biomass can be based on many different raw material sources and different technologies, and results in various types of end products (heat, power, transportation fuels, or a combination of these). Also, the reactions of forest owners to RES policies may change their forest management practices, which in turn may have significant carbon sequestration implications. As a result, the energy efficiencies and climate (carbon) impacts of RES policies and wood based bioenergy productions may vary greatly. Clearly, there is a strong need for further studies that synthesise the best scientific knowledge available about the carbon neutrality issue and point out the importance and implications to policy making of considering consistently the interlinkages between bioenergy and climate policies.

In summary, the policy makers are in a very difficult position. The operating environment for RES and climate polices is complex, and there are still many uncertainties related to the scientific information that could support such polices, as this review has demonstrated. The review indicates that there is unlikely to be any simple policy or technology solutions which are suitable for a wide range of situations or problems related to RES targets or mitigating climate change.

There is also a need to update the assessment and outlook of EU forest biomass markets by taking into account the factors outlined above. This is important not only for getting a better picture of the supply and demand balance in the EU forest biomass markets, but also for analysing many of the indirect impacts that the above mentioned factors may cause. These studies should be complemented with foresight analyses that address the possible structural changes and new products that may be difficult to model, and for which we do not yet have data.

1. INTRODUCTION

The European Union (EU) policy on increasing the use of renewable energy sources (RES) aims at reducing greenhouse gas emissions, diversifying energy supply, and reducing dependence on volatile fossil fuel markets. The new directive (EU 2009) on renewable energy sets ambitious targets for all Member States. The EU should reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy in the transport sector. The directive also requires national action plans for the development of renewable energy sources, and it establishes sustainability criteria for biofuels. It is left to the member countries to decide upon what type of policies they will implement in order to reach the targets. Consequently, we observe in EU a large number of different bioenergy policies in the various countries. Wood based bioenergy[1] plays a central role in the 20-20-20 target.

The forest industry is unique when it comes to climate and renewable energy policies. It produces both energy and energy intensive products like pulp and paper, and it is therefore closely linked to the energy sector. The forest industry can use the same input, namely wood, both for energy and industrial production. Thus, climate and energy policies have multiple impacts on the sector, but the impacts of the policies are not always evident, as this study will show.

The potential increase in wood demand for bioenergy production is of high interest for the EU forestry and forest industries (hereafter referred to as *the forest sector*). First, it opens possibilities for new investments, production and employment, such as in forest biorefineries and energy companies producing heat and power. By *forest biorefineries* we mean forest industry plants that produce new bioenergy and/or biochemicals products, possibly along traditional forest products. Such investments can also be located in rural areas, thus helping the economic viability of areas with few alternative business opportunities. Moreover, bioenergy production generates new demand for wood, and is therefore beneficial to forestry. On the other hand, increasing use of forest biomass for energy can weaken the profitability of the existing forest industries, as it may lead to increase in wood prices and thus in the

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[1] If nothing else is stated, we use the three terms "*wood based bioenergy*", "*wood energy*" and "*forest biomass energy*" interchangeably throughout the report to mean all types of wood fibre-based raw material: forest residues, branches and tops, stumps, pulpwood, sawlogs, chips, sawdust, pellets, recycled wood, etc.

production costs of the wood-using industries. Moreover, increasing forest biomass harvests for bioenergy may cause negative ecological impacts, such as loss of forest biodiversity. Changes in wood demand can also have important implications to the international trade in biomass. Countries like Germany and UK have ambitious renewable energy targets, and if they implement policies that give strong support for using forest biomass for energy, their forest biomass imports may increase from e.g., Canada, Finland, Sweden, the Baltic countries and Russia.

The above impacts may vary significantly according to particular circumstances, such as specific country conditions, technologies used for production, and the implementation of the RES and climate policies. It is therefore of high interest to assess the future development of the wood use for energy and the potential impacts of this development on the EU forest sector. In recent years, several studies focusing on different aspects within this rather large and complex issue have been published. It is, however, difficult to capture all relevant aspects in detail in one study. The devil tends to be in the details, not least because, for example, the RES policy impacts depend very much on the particular policy instrument used, and the impacts may vary between the different sectors, such as combined heat and power (CHP) energy producers, forest industry, forest industry-integrated biorefineries and forest owners. Thus, the users of research results – policy makers and forest and energy sector stakeholders – may have difficulties in capturing the overall implications of what science has published about the issue. There seems to be a need for a policy relevant synthesis of existing studies. The essential question is, what are the policy relevant messages that come out of the recent studies, and what are the primary issues we lack science-based information about?

It is this need the current paper seeks to meet. The literature on RES policy implications to the forest sector is already very large, and research on it can be found under many different approaches, disciplines and journals. Here, we have chosen to focus on the literature that analyses the RES implications to forest industry and forest biomass markets, and mainly on economic analyses of potential implications. We review five recent studies, which represent "the state of the art" of the literature, or are extensively cited and have been influential also for practical policy planning (Mantau et al. 2010). The studies vary regarding specific research questions addressed, methodological assumptions, geographical scope and data used, as well as results generated. The main objectives of this report are to (i) synthesise the results and insights rising from these studies, (ii) identify major similarities and differences in the results between the studies and explore the reasons for why they differ, (iii) discuss main policy implications arising from the studies, and (iv) identify the needs for further research.

The following five studies were considered[2]:

Study 1: Mantau, U., Saal, U., Prins, K., Steierer, F., Lindner, M., Verkerk, H., Eggers, J., Leek, N., Oldenburg, J., Asikainen, A. and Anttila, P. 2010. EUwood – Real potential for changes in growth and use of EU forests. Final report. Hamburg/Germany, June 2010. 160 p.

Study 2: Moiseyev, A., Solberg, B., Kallio, A.M.I. and Lindner, M. 2011. An economic analysis of the potential contribution of forest biomass to the EU RES target and its implications for the EU forest industries. Journal of Forest Economics 17:197–213.

Study 3: Lauri, P., Kallio, A.M.I. and Schneider, U.A. 2012. Price of CO_2 emissions and use of wood in Europe. Forest Policy and Economics 15:123–131.

Study 4: Moiseyev, A., Solberg, B., Kallio, A.M.I. 2013. Wood biomass use for energy in Europe underdifferent assumptions of coal, gas and CO_2 emission prices and market conditions. Journal of Forest Economics. http://dx.doi.org/10.1016/j.jfe.2013.10.001

Study 5: Kangas, H-L., Lintunen, J., Pohjola, J., Hetemäki, L. and Uusivuori J. 2011. Investments into forest biorefineries under different price and policy structures. Energy Economics 33:1165–1176.

The five studies are briefly described in Table 1.1.

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[2] The studies 1 and 5 have been reviewed mainly by Hetemäki, study 3 mainly by Kallio, and studies 2 and 4 mainly by Kallio, Moiseyev and Solberg. Sjølie reviewed and spell-checked the report.

Table 1.1. Overview of the reviewed studies.

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Moiseyev et al. (2011) ***Journal of Forest Economics,* peer reviewed journal**	Analyses effects of EU's RES policy on the wood fibre markets and the forest industry production in Europe under two IPCC scenarios for global development and considering different assumptions regarding fibre supply from forest plantations in developing countries and the availability of wood for energy in the EU region	Global coverage, with Europe devided at country level (32 regions) and the rest of the world in 26 regions, with trade included between each of the regions. Forest residues, chips, 6 roundwood assortments, 24 forest industry products. Wood energy production decided exogenously	EFI-GTM (global partial equilibrium simulation model)
Lauri et al. (2012) ***Forest Policy and Economics,* peer reviewed journal**	Analyses the effects of the price for CO_2 emissions from fossil fuels on the use of wood in Europe, with emphasize on the economic potential to substitute wood for coal and peat in heat and power production	European coverage (32 countries and “Rest of The World”), including trade between the regions. Includes 6 roundwood categories, other woody biomass, 20 forest industry products and heat and power production from wood, peat and coal.	EU FASOM (European forest and agriculture sector partial equilibrium simulation model)
Moiseyev et al. (2013) ***Journal of Forest Economics,* peer reviewed journal**	Analyse the effects of coal, gas and carbon emission prices on the use of wood for energy and wood-based products in the EU region up to year 2030. The study also provides a sensitivity analysis of the impacts of possible decreases in future paper demand and of subsidies for wood-fired and wood & coal co-fired power.	Global coverage, with Europe devided at country level (32 regions) and the rest of the world in 26 regions, with trade included between each of the regions. Includes 6 types of wood assortments, 24 types of forest industry products and 12 types of energy productions	EFI-GTM (global partial equilibrium simulation model) – revised version expanded on renewable energy
Kangas et al. (2011) ***Energy Economics,* peer reviewed journal**	Impacts of different RES policies on forest biomass based biofuel production in the pulp and paper biorefinery producing 2nd generation biofuels	Finland. Pulp and paper, 2nd generation transportation biofuel	FinFEP (partial equilibrium simulation model for Finland)

The report is structured like this: First, we give a brief account of each study, focusing on objectives, methodology and results. Then follows a discussion of main similarities and differences between the studies, and assessment of research needs. Finally, conclusions and policy implications are presented.

2. OVERVIEW OF FIVE RECENT STUDIES

2.1 Study 1: Wood resource availability and potentials in Europe – Mantau et al. (2010)

2.1.1. Background and objectives

The EU Directive on the use of energy from renewable sources (EU 2009) is a big driver for forest-based energy demand in the period until 2020 and beyond. For each member state, legally binding targets of the share of the overall energy consumption and use in transportation deriving from renewable sources by 2020 are set. The general view is that there will be a significant increase in the demand for forest biomass in EU. In this context, the question of whether it is enough forest biomass within the EU to meet the growing demand and at the same time fulfilling necessary sustainability requirements has also been raised. One of the most cited and authoritative analysis on this topic is the study known as the "EUwood study" (Mantau et al. 2010), which analyses and projects the wood demand and supply for the EU27 up to 2030 focusing on the impacts of the EU RES policy on the forest biomass balance. This study also forms an important background for the UNECE-FAO European forest sector outlook study's (UN 2011) analyses of the future development of the forest industry and forest bioenergy markets.

In this chapter we review the EUWood study, hereafter referred to as S1. In addition, with already some possibility for hindsight (the study's analysis was carried out 3-4 years ago), and by taking account of some aspects not addressed by the study, we discuss the robustness of its projections. Our intention is to bring forward some new insights and identify potential needs for additional assessments in the discussion of what is the likely long-run wood balance in the EU.

2.1.2 Methodology

The EUwood study (Mantau et al. 2010) is actually a synthesis of many different studies or modules, which together form and provide the outlook for demand and supply of forest biomass for the EU up to 2030. The main modules of the study are the following: First, there is a *Wood Resource Balance (WRB)* computing framework, which basically describes all the demand sources for forest biomass and the corresponding supply sources, and then assesses what the likely demand and supply balance will be in the future. The WRB utilizes data and results (projections) from other modules of the study. First, it uses projection results for the demand of forest products in EU based on estimated econometric demand equations using historical data (1961–2007), and scenarios (mainly for GDP) development to project forest products consumption up to 2030. The future potential wood demand for new forest products that are still on development stage are estimated based on expert analysis.[3] The same type of analysis was carried out for the demand for forest biomass in the energy sector. The fact that there are very poor time series data, or no data at all, for energy wood markets (not to speak about the new upcoming forest products) for many European countries, makes it very difficult to use quantitative modelling and estimation for this sector.

Secondly, the supply side of the WRB is based on the large-scale *European Forest Information Scenario model (EFISCEN)* that is used to estimate the theoretical availability of biomass *from forests* available for wood supply in the 27 European Union countries. Starting with the theoretical potential, possible supply scenarios are derived using various assumptions and expert analyses. These are developed independently from the demand side. The study consists in addition of various expert analyses not based on formal quantitative models that provide estimates for *biomass supply from other sources than forests* (e.g. short rotation coppice, recovered wood, residues from forest industries, etc.). The final part of the EUwood study is a chapter discussing the policy implications and actions needed, given the results of the WRB and the needs to fulfil the EU RES policy targets.

The EUwood studies, and its separate methodology report, are extensive reports with much detail and various models, assumptions, different scenarios and results, and it is beyond the scope of this chapter to include all of them. We have limited this review to the major results along with a discussion of the most important factors behind these results.

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[3] The EUwood study states (p. 40) that the wood demand for new forest products “could be 20 million m^3 in 2030 or 100 million m^3 in 2030. So far only a few quantitative estimates are known, like the ones for wood plastics components, but real empirical data is lacking.”

2.1.3. Results

The basic question the EUwood study sets out to analyse is the following: What would be the effects of the European RES Directive on the EU wood balance, assuming that the growth of the forest industry continues? The study looks at this question under alternative scenarios. On the supply side, the potential supply from forests is estimated for three forest biomass mobilisation scenarios (high, medium, low). On the demand side, two scenarios of the gross national product (GDP) are applied, which correspond to the IPCC scenarios A1 (annual GDP growth consistently above 2.0% in the period 2010-2030) and B2 (annual GDP growth gradually declining from over 2% to 1% towards 2030, and even under 1% in some years).

Wood demand

If the energy demand develops approximately according to the RES policy targets, and assuming that biomass accounts for 40% of the total renewable energy, then the demand for energy wood will grow by 65% from 2010 to 2020. This would imply that the annual wood biomass consumption for energy generation grows from 346 million m^3 in 2010 to 573 million m^3 in 2020 and 752 million m^3 in 2030. Thus, the EU energy wood demand would more than double within the next two decades. On the other hand, the wood consumption of the forest industry (labelled "material use" in the EUwood study) is in this scenario projected to rise by 35% by 2030, corresponding to an annual growth rate of 1.8%. This would amount to an increase from 458 million m^3 in 2010 to 620 million m^3 in 2030. The energy demand would exceed the material demand at some point between 2015 and 2020 and the part of the wood for material use will drop from 56% to 44%, with the share for energy use increasing correspondingly.

For these development paths to take place, the sawmill industry is particularly important. First, the sawmill industry is the biggest users of industrial roundwood, consuming currently about 40% of the industrial roundwood harvest. Secondly, more than one third of the stemwood consumed by the sawmilling industry is transferred to by-products (chips, sawdust, etc.) which are used by the pulp, panel, and energy industry. Thirdly, because of the higher prices for sawlogs relative to pulpwood, the sawmill industry is very important for the mobilisation of private forest owner's wood supply, including the small-sized stemwood for pulp, paper and energy purposes and forest residues. The demand for sawlogs also mobilises small-sized wood as it is a complement product in the harvest of sawlogs (large wood);

thinnings are also done mainly to produce high value logs in the long run. Thus, the sawmill industry is the key industry for wood-energy mobilisation.

In the wood-based energy sector, the single most important production or what the International Energy Agency (IEA) and EUwood study calls the “main activity producers” is the heat and power production for markets (i.e. excluding production for internal use). This definition excludes for example forest industry internal heat and electricity production. The results of the EUwood study indicate that wood energy generation by these *main activity producers* is expected to see the biggest increase in absolute and relative terms. The consumption of about 83 million m^3 wood in 2010 is expected to almost triple to 242 million m^3 in 2020, and increase further to 377 million m^3 by 2030. The main activity producers are expected to replace private households as the biggest single wood energy consumers around 2020. In 2030 the main activity producer sector is expected to be by far the biggest woody biomass based energy producer in the EU.

The above results are sensitive to the efficiency of the future bioenergy production. For example, if the assumed energy efficiency gain by 2020 was zero, instead of the assumed 20%, the demand for wood for energy in EU27 would increase an additional volume of 205 million m^3 in 2020 and 297 million m^3 by 2030. For comparison, the total roundwood harvest of Finland, France, Germany, Portugal, Spain and Sweden was 259 million m^3 in 2011. In summary, energy efficiency plays a significant role in the wood demand development.

Wood Supply

The EFISCEN model estimates that the theoretical biomass supply potential from European forests in 2010 was 1.28 billion m^3 per year including bark. About 52% of this potential is in stems, while logging residues and stumps represent 26% and 21%, respectively. This theoretical potential was based on the average volume of wood that could be harvested over a 50 year period, taking into account increment, the age-structure, present stocking levels and harvesting losses. The potential is expected to stay almost at the same level up to 2030, when it is projected to be 1.25 billion m^3 per year.

The theoretical forest biomass potentials estimated by EFISCEN are higher than what can actually be supplied from the forest due to various environmental, social, technical, and economic constraints. In order to estimate the actual potential supply, three different wood mobilisation scenarios were used: *high, medium and low mobilisation scenario.* The realistic biomass potential from forests under the medium mobilisation scenario is estimated at 747 million m^3 per year in 2010, and could range from 625 to 898 million m^3 per year in 2030, depending on the scenario.

These supply scenarios should be seen as the maximum amount of wood that can be supplied under given conditions as described in the mobilisation scenarios. Whether the wood will be harvested depends on the markets and demand for wood for material and energy use. In case the potential supply exceeds the demand for wood, part of the potential may be available later and some more biomass could thus be harvested in future periods. Altogether, these results indicate that in a situation with high demand, more wood could be made available by taking appropriate measures to mobilise biomass from forests.

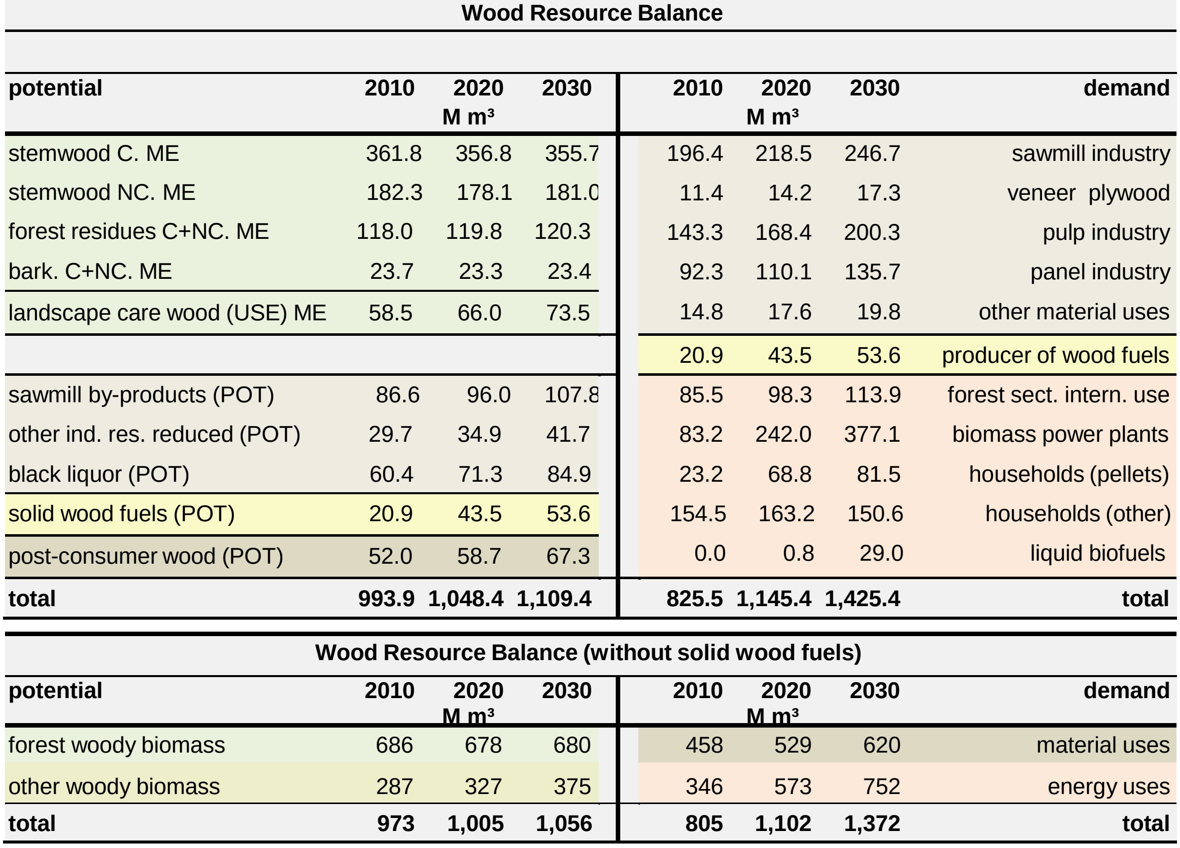
In summary, the EUwood study estimates *the realistic* wood biomass supply potential from European forests as 747 million m^3 per year (over bark) in 2010, which represents 58% of the theoretical potential. However, the study's projections of future resource use suggest that the biomass potential range is high – from 625 to 898 million m^3 per year (over bark) in 2030 – depending on the wood mobilisation efforts in policy making, society and practice.

Results for Wood Balance

The EUwood study estimates that in 2010 the EU27 total supply of all woody resources was about one billion cubic meters, of which almost 70% came from forest and 30% from woody biomass outside the forest (Mantau et al. 2010, p. 19). On the demand side of the balance, the total wood consumption was about 800 million m^3, of which 57% was used for material purposes and 43% for energy. In the medium mobilisation scenario, potential demand will overtake potential supply between 2015 and 2020 (Figure 2.1.1). The growth of potential woody biomass supply is highly linked to a prosperous development of wood products industry. The most significant change in forest biomass markets is the higher demand for energy wood to achieve the RES targets.

Table 2.1.1 displays the results for the medium forest biomass mobilization supply scenario and the IPCC A1 economic growth demand scenario. The development of the main sub-sectors provides insight about the character of the resource as well as the calculation method. Forest resources represent a potential supply of woody biomass that is relatively stable over time in the medium mobilisation scenario. However, the forest biomass potential differs between the mobilisation scenarios, as shown below. The supply of other woody biomass, such as chips, increases over time because most of these potentials are based on industrial residues, which increase as the production of the main product increases (scenario A1). For this reason, the growth of other woody biomass in the medium mobilisation scenario is about the same as the development of the material sector.

Table 2.1.1. Wood Resource Balance results for Europe (EU 27). Source: Mantau et al. (2010). Note: The scenario A1 assumes annual growth rates of the gross national product (GDP) between 2.0% and 2.5% for Europe in 2010–2030. M = million. ME (Medium) refers to medium mobilisation scenario. POT (Potential) refers to "real" availability under given constraints.



Wood Resource Balance

potential	2010	2020 M m³	2030	2010	2020 M m³	2030	demand
stemwood C. ME	361.8	356.8	355.7	196.4	218.5	246.7	sawmill industry
stemwood NC. ME	182.3	178.1	181.0	11.4	14.2	17.3	veneer plywood
forest residues C+NC. ME	118.0	119.8	120.3	143.3	168.4	200.3	pulp industry
bark. C+NC. ME	23.7	23.3	23.4	92.3	110.1	135.7	panel industry
landscape care wood (USE) ME	58.5	66.0	73.5	14.8	17.6	19.8	other material uses
				20.9	43.5	53.6	producer of wood fuels
sawmill by-products (POT)	86.6	96.0	107.8	85.5	98.3	113.9	forest sect. intern. use
other ind. res. reduced (POT)	29.7	34.9	41.7	83.2	242.0	377.1	biomass power plants
black liquor (POT)	60.4	71.3	84.9	23.2	68.8	81.5	households (pellets)
solid wood fuels (POT)	20.9	43.5	53.6	154.5	163.2	150.6	households (other)
post-consumer wood (POT)	52.0	58.7	67.3	0.0	0.8	29.0	liquid biofuels
total	**993.9**	**1,048.4**	**1,109.4**	**825.5**	**1,145.4**	**1,425.4**	**total**

Wood Resource Balance (without solid wood fuels)

potential	2010	2020 M m³	2030	2010	2020 M m³	2030	demand
forest woody biomass	686	678	680	458	529	620	material uses
other woody biomass	287	327	375	346	573	752	energy uses
total	**973**	**1,005**	**1,056**	**805**	**1,102**	**1,372**	**total**

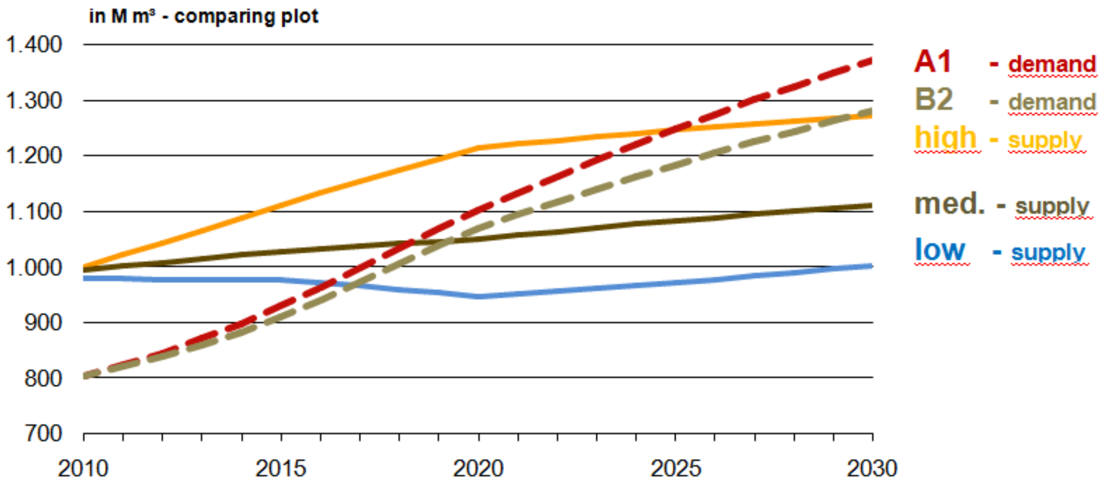


Figure 2.1.1. Development of woody biomass potential demand and potential supply. Source: Mantau et al. (2010).

The total demand for woody biomass (without solid wood fuels) is estimated to increase from the 2010 level by 567 M (million) m³ to nearly 1,400 M m³ in 2030 (A1 scenario), and about 100 M m³ less in the B2 scenario. The illustration makes clear that the demand scenarios do not differ significantly, even though the average growth in A1 (2% – 2.5%) is significantly stronger than the growth in scenario B2 (0.7% – 2%). This is mainly due to the fact that the consumption of energy wood does not depend significantly on the GDP, but is mainly determined by the energy policy.

The EUwood study concludes: “The combined results suggest that the potential supply from forests and other sources of wood in Europe exceeds the potential demand until 2015 or 2025, depending on the mobilisation scenario. This means that without additional measures, forests and other sources of wood in Europe cannot maintain their large share as a renewable energy source without leaving a shortage for the forest-based industries” (Mantau et al. 2010, p.33).

The analyses show that there is a large potential supply of wood from forests and other sources. However, it has not been possible to assess in the Wood Resource Balance whether this potential could become *economically available*, and therefore actually be supplied to markets. The EUwood study is not based on market models, and thus does not address this issue. There are market models that do include such considerations, but they are often limited to the forest-based industries. Still, the EUwood study showed that a large share of the potential supply lies outside forests, which are not considered by existing market models. Furthermore, even the supply costs of certain biomass types from forests (e.g. stump extraction) are typically not fully addressed by existing market models, due to limited data availability.

The main conclusion of the EUwood analysis is that the expected demand is likely to exceed the potential supply before 2020 in the *medium mobilisation scenario.* Even if all measures for increased wood mobilisation are implemented, wood demand can probably not be fulfilled from domestic sources in 2020. This applies to EU27 as a whole although the situation differs according to region and country. In the *high mobilisation scenario***,** it is difficult, but not impossible in 2020 to supply enough wood to fulfill the needs of the industry and to meet the targets for renewable energy on a sustainable basis; but for 2030, even high mobilisation would not be enough to meet the demand. Furthermore, to achieve the high mobilisation would require long term commitment and investment, a comprehensive approach, numerous specific policy measures, and favourable framework conditions in areas not directly controlled by the forest sector policy makers.

2.1.4. Discussion and assessment

The EUwood study clearly points out many reservations and uncertainties related to the projections. For example, on the demand side, the woody biomass consumption of new forest products that come to markets before 2030 is highly uncertain. Also, the wood biomass utilization for energy purposes is highly sensitive to a range of factors, including the energy efficiency development and policies implemented to support bioenergy development. On the supply side, there are uncertainties related e.g. to the EFISCEN model and its assumptions. For example, the model is based on the assumption that all European forests are managed as even-aged forests. However, at the European level, about 17% of the forests are considered uneven-aged. Furthermore, the impacts of growth changes and large-scale disturbances due to environmental and/or climate change on the estimated potentials from forests, were not included.

The basic idea that there would be a major *gap* between wood demand and supply is incorrect. Economists would argue that the markets are always in balance, at least in the longer run. Potential gaps between demand and supply would be cleared through price adjustments and trade in the markets. Thus, a potential “physical” gap in EU27 wood supply could be balanced by imports from outside the EU27 region. For example, EU has been a net importer of roundwood in the past decades; the quantity being varying from 10 to 30 million m^3. Given, e.g., the enormous potential from Russian forests, this supply could be much higher in the future.

However, these shortcomings do not imply that the EUwood study is not useful. On the contrary, it is very helpful in pointing out potential scarcities in wood markets as well as trends and levels of wood utilization to which the demand and supply factors are moving the markets in the long-run. In essence, it had to be done in order to assist further analyses and policy planning.

Yet, there are some major developments, uncertainties and assumptions which have not been addressed by the EUwood study or most other studies that can have potentially significant impacts to the future wood balance in EU27. One such a shortcoming is the fact that the EUwood study did not acknowledge the structural change in the global and EU27 pulp and paper markets, which has been evident since the beginning of 21st century.

Pulp and Paper Market Projections

As earlier indicated, the EUwood study projects a forest products (or material use) growth of 35% from 2010 to 2030, or an average growth rate of 1.8% per annum. That means that the past historical trends are assumed more or less to continue the next two decades. However, given the structural changes in the EU paper and paperboard consumption and production, such a development seems rather unlikely.

Figure 2.1.2 below shows the EU forest products consumption from 1990 to 2012. The forest products *production* trend (not shown) is about the same as the consumption. The Figure shows that graphics paper consumption started first to stagnate in 2000, and then to decline from 2006 onwards. The other paper and paperboards consumption has a similar pattern, but not as significant drop. Sawnwood consumption growth rate has slowed down after 2000, but started to decline in absolute terms only after 2007, i.e. one year before the economic slump. The important question is to what extent the production pattern changes in the 21st century have been a result of structural factors and of cyclical factors related to the financial crises.

If we compare the pattern of the paper consumption to the GDP pattern in Figure 2.1.2, we see a clear change from 2000 onwards, indicating that the paper consumption does not anymore grow as clearly along with the GDP. In fact, for graphics paper the relationship has turned negative. This is also indicated by the simple correlation coefficient between GDP and graphics paper consumption, which was +0.96 for the period 1990–1999, and -0.53 for the period 2000–2012. Thus it seems apparent that part of the paper consumption change is due to structural factors (see also Hurmekoski and Hetemäki 2013; Hetemäki et al. 2013). This is indeed a historically significant change, since over 100 years the graphics paper consumption (production) has been increasing in Western Europe, whereas in this century it does not seem to do so anymore.

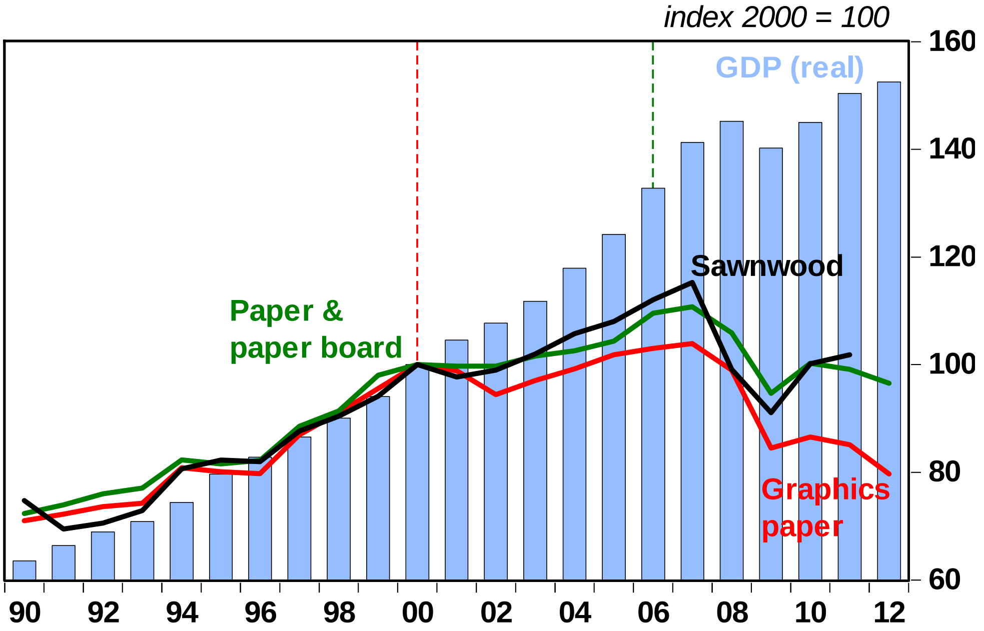


Figure 2.1.2. EU GDP (real) and forest products consumption index over the period 1990-2012 (2000 = 100). (Forest products data from FAO; GDP data from IMF, Gross domestic product based on purchasing-power-parity (PPP) valuation of country GDP).

Let us assume that EU paper and paperboard consumption would develop on average as it has done in the past 10 years (2003-2012 trend). This period consists of six years before the economic slump, and five years after, as the EU GDP bar in Figure 2.1.2 also indicates. The five slump years are of course lower than average growth periods. However, the structural change in the EU paper consumption seems to be accelerating (due to e.g. digital media impacts), and we may expect this impact to increase over time. Thus, maybe on average the 2003–2012 trend in Figure 2.1.2 is not that bad estimate for future pattern, despite the five slump years. Using this trend in future projections implies that graphics paper consumption would decline from its historical maximum level of 92 million tonnes in 2007 to 69 million tonnes in 2030. Thus, it would decline by almost 23 million tonnes or by 25%, instead of increasing by 35% as projected by the EUwood study.

A similar trend projection for the EU paper and paperboard *production* would imply that paper production in EU would decline from its historical maximum level of 101 million tonnes in 2007 to 81 million tonnes in 2030. Thus, the total paper production would decline by 21 million tonnes or by 21%. In addition to the declining paper consumption, the EU producers are facing increasing competition from the Asian producers (and South American in pulp). This is indicated e.g. by Figure 2.1.3, which shows the markets shares of paper and paperboard production in Asia (excluding Japan), EU, and North America.

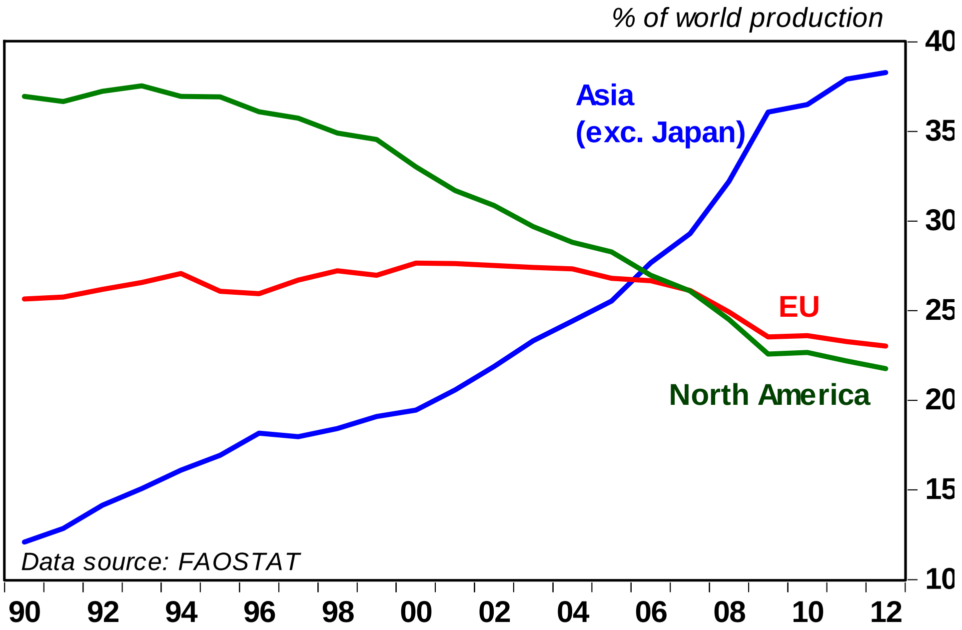


Figure 2.1.3. Market Shares of World Total Paper & Paperboard Production in 1990–2012.

Using the 2003–2012 trend to project EU wood based pulp consumption, and calculating the associated pulpwood consumption required by using a simple multiplier (see the footnote 4 for technical explanation), we get the projections shown in Figure 2.1.4. According to these results, wood pulp consumption in the EU would decline from 47.5 million tons in 2007 to 30.3 million tons in 2030[4]. Correspondingly (using the multiplier), the demand for pulpwood

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[4] In 2011, about 75% of the EU total pulp consumption was chemical pulp (wood utilization multiplier for coniferous pulp is 5.5 m^3/ton, for hardwood pulp it is 4.2 m^3/ton), and 25% was mechanical pulp (wood utilization multiplier for mechanical pulp is 2.8 m^3/ton). Assuming multiplier 5 for chemical pulp (most of this pulp is based on coniferous pulpwood), and 2.8 for mechanical pulp, the average multiplier is 0.75*5 + 0.25*2.8 = 4.45. However, typically, about 33% of the total wood pulp consumed in EU is imported from outside EU, so we here simply assume that the impact to EU pulpwood demand would similarly be 33% lower.

would decline from 142 million m^3 to 90 million m^3. In contrast, the EUwood study projects this to increase to 200 million m^3. That is, if the markets would behave in the coming 17 years as they have on average in the past 10 years, the pulpwood consumption would be *110 million m^3 lower* in 2030 compared to what the EUwood study projects.

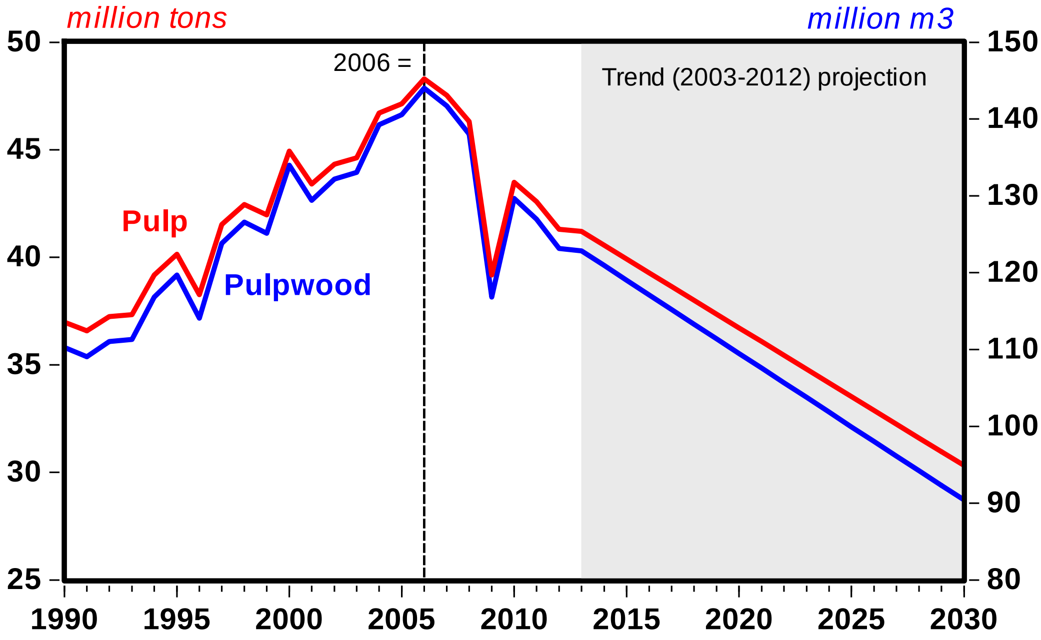

Figure 2.1.4. EU Woodpulp and Pulpwood Consumption in 1990-2012 and Trend Projection to 2030. P = preliminary data for 2012; TP = trend projection based on the last 10 years, i.e., 2003–2012 trend; EUwood = Mantau et al. (2010) projection. *Mantau et al. 2010 do not report these figures as such. However, the study reports the wood demand increase by sawnwood, pulp sector, and for the material uses from 2010 to 2030; these increases in demand are 25.6%, 39.7% and 35.3%, respectively. We have made a simple assumption in this Figure, that this demand is reflected in an equal percentage increase in end product demand from 2010 to 2030.

The lower paper consumption and production would have many impacts for the EU wood balance. First, the demand for paper, pulp and pulpwood will be significantly lower than what EUwood study projects. By reducing the demand for pulpwood, it tends to lower the price of pulpwood (ceteris paribus), and therefore, lowering the costs to bioenergy producers. However, by reducing the pulpwood demand, it also reduces the forest residues generation, and tall oil production in pulp mills, both of which could be used for bioenergy production. Pulp mills are significant producers of bioenergy in EU, and if their production declines, so will also their bioenergy production. For example, in the EUwood study, energy generation from pulp process (black liquor) is expected in scenario A1 to increase from 60 million m^3 solid wood equivalents in 2010 to 66 million m^3 in 2020 and 85 million m^3 in 2030 (67 and 72 million m³ in scenario B2). The net impacts of these factors can be either positive or negative for bioenergy production.

It should be noted that in the future, the pulp production does not necessarily decline exactly in line with the decline in fine (woodfree) paper production.[5] First, the EU countries can export more softwood pulp (probably not hardwood pulp, due to competition from South America and Asia). Secondly, some of the old "paper pulp" plants can be transformed to produce dissolving pulp for textile industries, as is already taking place e.g. in some plants in Finland and Sweden. Moreover, some pulp plants may start to produce only energy, such as gas (e.g. Joutseno pulp mill in Finland is planning to start to do this for the city of Helsinki). However, despite these possibilities, it is very likely that these factors will not be of important magnitude for many reasons, and there will be significant decline in pulp production in EU along with graphics paper consumption.

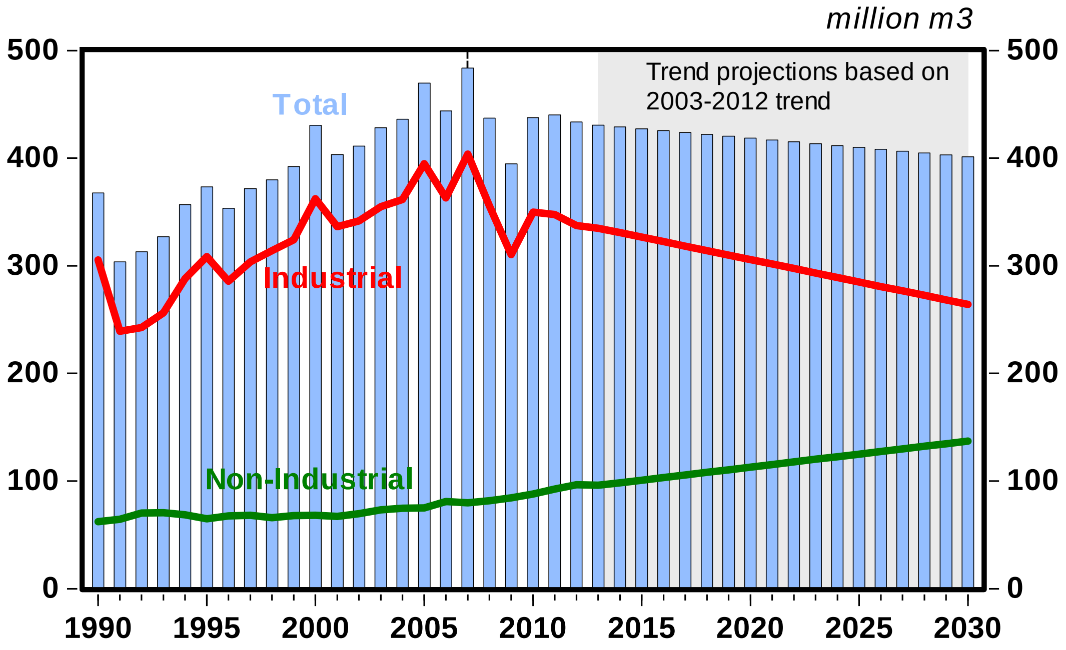

Figure 2.1.5. EU Roundwood Consumption and Trend Projections for 2013–2030.

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[5] The mechanical pulp production is likely to decline in line with the mechanical paper production decline.

Wood Products and Roundwood Consumption Projections

The big question mark is also the development of the wood products sector in EU. As the Figure 2.1.5 shows, the growth of sawnwood consumption (and production) has slowed down the past decade and actually decreased in absolute terms since 2007. Most likely, the absolute decrease is due to cyclical factors. Indeed, many global drivers point to potentially brighter future for the wood products sector. For example, wood products have a large potential to benefit from a general trend to more sustainable construction, as energy regulations and environmental consciousness may favour wood as construction material with low carbon footprint, and as a carbon storage. Still, the increasing competition from e.g. Russian and emerging economies' wood products manufacturing makes the outlook uncertain.

This uncertainty related to the production of EU wood products is also of particular significance for the EU bioenergy target (Eriksson et al. 2012). First, the wood products industry is a major generator of rawmaterial for bioenergy as a side product (chips, sawdust, bark). Secondly, sawlogs are the most valuable wood category, and generate most of the income for forest owners. Consequently, the sawlog market is of central significance in mobilising wood supply, and therefore, also raw material for bioenergy purposes. As a result, the level of EU wood products production has important implications for the EU bioenergy production.

In summary, if the EU forest products production (and consumption) trends of the past decade were to continue up to 2030, the demand for industrial roundwood would decline, instead of increase, as projected by the EUwood study (see Figure 2.1.1). The simple trend projections are of course unlikely to be realized as such, and their implications should be interpreted with caution. Still, the main message they transmit is the fact that the EUwood study scenarios for industrial roundwood consumption may be significantly too high due to the structural changes taking place in the forest products markets. There is clearly a need to analyse this possibility in more detail.

2.2 Study 2: An economic analysis of the potential contribution of forest biomass to the EU RES target and its implications for the EU forest industries – Moiseyev et al. (2011)

2.2.1 Objectives

This study (Moiseyev et al. 2011, hereafter referred to as S2) analyses how the EU's RES policy might affect the wood fibre markets and the forest industry production in Europe, considering in particular the competition for wood between bioenergy producers and forest industries. These effects are explored under two IPCC scenarios for global development – the A1 and B2 – which represent two different future paths (Table 2.2.1). The paper also provides a sensitivity analysis in order to gain insight into the impacts of different assumptions regarding fibre supply from forest plantations in developing countries and the availability of wood for energy in the EU region.

2.2.2 Methodology

The analysis applies the EFI-GTM, a regionalized partial equilibrium model of the global forest sector with a special emphasis on Europe. This model simulates the behaviour of profit-maximizing producers and utility-maximizing consumers in the global markets for wood and forest products. The competitive market equilibrium where demand equals supply in each region for each product is found by using a mathematical programming formulation. A detailed description of the model is presented in Kallio et al. (2004).

To estimate the maximum sustainable potential harvest defined as the maximum annual harvest level that can be sustained over a period of 100 years for each EU country, the forest resource model EFISCEN (Schelhaas et al. 2007) was used (Table 2.2.1). The EFISCEN model simulates the development of forest resources from regional to the European level. It uses data from National Forest Inventories to construct the initial age class distribution and growth function for each combination of, tree species, site class and owner class that can be distinguished in a country. For this study, the maximum sustainable harvest levels were determined for broadleaves and conifers separately. In addition to updating the timber supply parameters, they were used in the EFI-GTM to constrain the harvest level for the EU countries to be less or equal to the maximum sustainable potential harvest. The maximum levels per country are shown in Table 2.2.2

For the non-European countries, the roundwood supply curves were shifted over time according to the additional potential supply provided by the FAO Global Plantations Outlook (Brown 2000) as displayed in Table 2.2.2.

The economics of the wood biomass supply for energy was studied with the same methodology as in EEA (2006; 2007). It was assumed that the wood biomass for energy may originate from harvesting residues, forest industry residues and roundwood, of which the latter two are potential supply sources also to the forest industries. The potential supply of harvesting residues depends upon the roundwood harvest. The costs for harvesting residues reflect the varying marginal extraction costs for residues in the different countries caused by differences in forest types and harvest technology.

In addition to the supply of harvesting residues, the EFI-GTM was used to estimate the complementary harvesting (i.e. the increase in roundwood harvest caused by the increase in price of energy wood) and what is labelled competitive use of wood for energy (i.e. the amount of wood redirected to energy production instead of being used for forest industry products).

The wood demand in the energy sector was not explicitly modelled, but it was assumed that the energy sector buys wood biomass at mill gate prices which vary depending on the chosen implementations of the EU RES policies. The price range considered was from 25 €/m^3 to 120 €/m^3, and the model projections were done for each of these exogenous energy prices with intervals of 5–10 €/m^3. A typical buyer of energy wood could be a combined heat and power (CHP) or a local heating plant.

Table 2.2.1. Assumed maximum sustainable harvest levels above and under bark for time periods from 2010 to 2030 for EU countries based on EFISCEN. Fuelwood numbers are average over 2006–2008.

Country	Roundwood over bark, thousands m^3					Fuelwood, thousands m^3
	2010	2015	2020	2025	2030	
Austria	27,609	27,907	28,179	27,512	26,841	4,842
BelgiumLux	5,303	5,298	5,314	5,238	5,084	721
Bulgaria	6,390	6,476	6,535	6,651	6,663	2,701
Czech	18,463	18,388	18,308	18,141	16,958	1,665
Denmark	2,143	2,039	2,017	2,243	2,251	1,125
Estonia	11,301	11,295	11,196	10,915	10,616	1,057
Finland	68,711	71,121	73,282	70,398	71,920	5,393
France	75,078	77,142	76,743	79,688	77,551	30,448
Germany	88,231	89,313	91,849	90,762	87,464	8,517
Hungary	8,745	8,963	9,057	9,103	9,034	2,895
Ireland	2,711	2,757	3,386	3,384	4,002	33
Italy	61,281	59,458	56,863	53,869	51,488	6,179
Latvia	14,440	14,575	13,042	13,868	16,696	868
Lithuania	8,840	8,424	8,308	8,941	8,695	1,200
Netherlands	1,344	1,355	1,294	1,302	1,395	290
Poland	39,972	40,011	39,495	38,737	38,227	3,632
Portugal	6,026	6,234	6,035	5,762	6,830	600
Romania	27,437	27,558	27,461	27,285	27,235	4,145
Slovakia	9,272	9,327	9,070	9,011	9,008	426
Slovenia	6,852	6,770	6,666	6,376	5,933	900
Spain	21,012	21,530	22,218	21,896	22,283	2,052
Sweden	92,715	96,719	96,651	100,365	102,517	5,900
United Kingdom	14,928	13,482	14,219	16,050	15,865	445
EU total	**618,805**	**626,141**	**627,188**	**627,498**	**624,556**	**86,034**

Table 2.2.2. Potential industrial roundwood supply from plantations and A1, B2 potential supply assumptions (2030).

	Potential industrial roundwood harvest, thousand m3						Actual 2005 industrial wood harvest (5 years average)	B2 Potential Supply, 2030 Thousand m3	A1 Potential Supply 2030 Thousand m3
Region	**2000**	**2010**	**2020**	**2050**	**Additional increase over 2005-2030**	**2005 potential harvest**			
SouthAfrica	16,552	15,876	19,936	22,505	4,578	16,214	19,366	23,944	23,944
Other Africa	6,607	9,189	12,462	23,901	8,377	7,898	50,784	50,784	59,161
AFRICA	23,159	25,066	32,399	46,407	12,956	24,113	70,151	74,729	83,106
Japan	28,178	34,909	37,329	38,385	6,138	31,544	16,242	22,380	22,380
S.Korea	2,901	5,856	10,528	11,062	6,328	4,379	2,278	8,605	8,605
Asia Developed	31,079	40,765	47,857	49,447	12,465	35,922	18,520	30,985	30,985
China	54,444	156,904	248,960	453,855	211,584	105,674	93,919	93,919	305,504
India	4,125	12,074	29,456	57,463	30,692	8,100	22,243	22,243	52,935
Indonesia	6,024	13,497	22,222	54,765	23,309	9,761	35,324	35,324	58,633
Turkey	1,656	4,543	8,568	12,938	6,925	3,100	11,817	11,817	18,742
Malaysia	474	1,198	2,363	5,189	2,469	836	23,852	23,852	26,321
Thailand	121	559	1,845	5,075	2,582	340	8,700	8,700	11,282
Other developing Asia	5,282	10,823	18,345	48,078	20,204	8,053	22,683	22,683	42,887
Asia Developing	72,126	199,598	331,759	637,363	297,765	135,862	218,538	218,538	516,303
ASIA	103,204	240,364	379,617	686,812	310,231	171,784	237,058	249,523	547,288
NewZealand	26,070	28,806	43,931	65,937	23,828	27,438	19,842	43,670	43,670
Australia	14,297	15,532	16,938	25,448	4,860	14,915	26,439	31,299	31,299
OCEANIA	40,668	44,778	61,551	92,704	29,212	42,723	50,545	74,970	74,970
UnitedStates	130,584	148,284	227,936	341,351	126,307	139,434	407,621	533,928	533,928
Chile	17,497	27,724	45,480	70,938	31,356	22,611	31,586	31,586	62,941
Brazil	17,274	26,885	40,664	63,011	26,034	22,080	117,048	117,048	143,081
Argentina	4,938	7,613	10,726	17,018	6,548	6,276	9,528	9,528	16,075
Other LA	4,902	9,937	17,850	34,602	16,015	7,420	15,722	15,722	31,737
LA&C.AMERICA	44,611	72,159	114,720	185,569	79,951	58,385	173,883	173,883	253,835
Total	342,226	530,651	816,223	1,352,843	558,658	436,439	939,258	1,107,033	1,493,126

No RES energy target outside Europe was assumed. Impacts of varying the wood energy prices were explored by two contrasting scenarios of global development represented by the IPCC A1 and B2 scenarios. The A1 storyline exhibits a globalizing world with rapid economic growth as shown in Table 2.1.3 and low environmental awareness. It represents a consumer oriented world with diluted national governance and highly developed global trading systems. International best practice technologies spread quickly and global standards emerge for many products and services. The underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. In the B2 storyline, economic growth is slower (Table 2.2.3), but environmental awareness higher than in A1. There is also a greater focus on regional products and solutions. In this scenario, it was assumed in the EFI-GTM analyses that Russia has increased its roundwood export tariffs to 50 €/m^3 in 2009. No concrete policy instruments were attached to the ideological difference in the IPCC storylines, but it was assumed ad hoc that land use evolves differently in the two scenarios due to environmental concerns related to deforestation and loss of biodiversity. In the modelling, implicitly, all these factors are included in the assumptions of economic growth shown in Table 2.2.3.

Table 2.2.3. Assumed annual GDP growth for aggregated global regions for each IPCC scenario.

Region	**Average annual GDP growth in percent 2010-2030 for each IPCC scenario**	
	A1	**B2**
Africa	6.3	5.0
Japan & South Korea	3.0	1.9
China & India	8.2	6.0
South-East Asia	7.1	5.0
Mid-East Asia	6.3	3.8
ASIA Developing	7.5	5.4
Oceania Developed	1.7	0.8
Latin America	7.0	4.4
North America developed	2.3	1.3
Western Europe	2.0	1.1
Eastern EU countries	6.4	3.9
Russia, Ukraine & Belarus	6.4	4.4
World total	**4.3**	**2.7**

2.2.3 Main results

Development of the wood fibre supply to the energy sector under alternative prices

Most (over 90%) of the wood biomass used for energy comes from forest residues when energy wood price is below 50 €/m^3. Only after that, competition for wood fibre with the forest industries gradually starts. If the energy sector were capable of paying 70–80 €/m^3 for the forest chips in competing uses, roundwood removals redirected from the forest industries to the energy sector in B2 in 2020 would be 25–40 million m^3 per year, constituting 20%–25% of the energy wood biomass feedstock in that reference future. In 2030, EFI-GTM projects the competition over roundwood with the forest industries to be tighter, and the energy wood price would need to be about 90 €/m^3 to supply 40 million m^3 per year. In the reference future A1, a similar development happens, but with higher prices, because the demand for forest industry products is higher due to assumed higher economic growth. Increasing the energy wood prices assumed to be payable by the power plants increases the absolute amount of wood biomass used for energy and tightens the wood market.

The imports to the EU-25 of wood biomass increase strongly with the energy wood price. If this price is 60, 80 and 100 €/m^3 in 2020 under B2 scenario, the wood biomass imports to EU increases by 5.6, 40.5, and 89 million m^3, respectively, from 2010. Nevertheless, the import share in the total energy wood usage remains below 10% in 2020, unless the energy price exceeds 80 €/m^3.

According to the model runs, complementary (increased) roundwood fellings do not play a very important role in the energy wood supply during 2020–2030, compared to the other sources of biomass feedstock. When more energy wood is bought from the roundwood market, the rising timber prices increase the marginal production costs of the forest industry and typically crowd out some of its production from the market. This does not happen if the forest industry is operating at the level where its marginal revenues are above the marginal costs. Such a case may prevail, if the industry is capacity constrained, but not yet making sufficient profit to invest in new capacity. Thus, some redirection of roundwood from the pulp, paper and particle board industries to the energy sector typically takes place before any complementary fellings occur. In the model projections, the supply of wood chips from complementary felling of roundwood depends strongly on price. In the short term (around 2010–2015), complementary fellings could be an important source of wood for bioenergy, as the utilization of harvest potentials is still not very high. However, in the longer term, harvests increase and wood resources become a limiting factor for additional biomass potentials. In 2020 and especially in 2030, significantly less biomass became accessible from complementary felling, mainly because the reference demand for industrial roundwood was projected to approach the assumed EU maximum sustainable harvest levels in the EU countries. This was especially the case in the A1 scenario, where practically no wood was coming from complementary felling in 2030 even with a forest chips price of 100 €/m^3. Hence, the model results indicate that complementary fellings are not likely to be an important sources for energy biomass, unless the forest resource potentials increase more than currently projected as a consequence of e.g. climate change, fertilization, or intensified forest management, or unless the demand for forest industry products develops more weakly than assumed in the study.

Effects on the forest industries

Higher biomass prices impact the forest industry branches differently. In the model analyses, wood chip prices do not rise to the level where sawlogs are directed to energy wood; higher prices for wood chips stimulate sawnwood production slightly (about 1–2% increased production compared to the reference scenario). Sawmilling generates a lot of wood residues which are sold either to the energy sector or to the producers of pulp and wood based panels. However, with the very high price of 120 €/m^3 for wood chips, sawnwood production is also reduced, by around 5% relative to the reference scenario in 2020, and even more in 2030. Assuming 100 €/m^3 for energy chips, competition for wood fibre with bioenergy reduces the EU wood based panel production by 25% in 2020 relative to the B2 reference. The highest impact of increased price for biomass is projected to be on the EU pulp and paper industry. Especially the pulp industry suffers from high bioenergy prices, since the production of chemical pulp (especially softwood pulp) requires high input of wood fibre. With a mill gate price for wood chips for energy at 70 €/m^3, the model projects that by 2020 the chemical pulp production in EU decreases by around 5% relative to the reference. If the price for wood chips was increased even higher to 100 €/m^3, the model projections suggest that the reduction of chemical pulp production could be up to 25% in 2020 relative to the B2 reference (i.e. 80% of the production in 2010). The production of paper in the EU at that wood chip price is reduced less, by 4–5% relative to the reference (i.e. 111% of the production in 2010).

The higher price for wood fibre due to competition with bioenergy increases the production costs for pulp sharply, thereby strongly reducing the competitiveness of the EU pulp industry in the global market. The EU is today a net pulp importer, and the lowered competitiveness would lead to further substantial increases in European pulp imports. Since pulp and paper are produced globally and widely traded, the possibilities of transmitting the higher production costs to the end product prices are limited, unless developments regarding energy sector similar to those in Europe would occur also in other world markets.

Sensitivity analysis

In the long term and with higher prices paid for energy wood, increased wood imports may become a second or third large source for biomass (after forest residues and competition with forest industries for wood fiber). The relative importance of the different sources of wood biomass for energy may vary over time depending on factors like wood biomass prices, growth of the EU and global economies, wood supply development in the EU and in the main global regions outside of EU, and also development of trade tariffs.

It was found that the amount of annual wood biomass supply for energy varied in the A1 and B2 scenarios from 23 Mtoe (111 mill m^3) to over 60 Mtoe (290 mill m^3), depending on the assumptions. The B2 reference scenario with 44 Mtoe (213 mill m^3) of wood fuels is in the middle of the range. Naturally, less restrictive global wood supply (as in A1 reference) combined with B2 GDP growth and other assumptions, increases this result to 55 Mtoe (265 mill m^3). Higher Russian wood supply (along with EEA B2 assumptions) increases the B2 result to over 60 Mtoe (290 mill m^3), which is even slightly higher than the EEA result (EEA 2007).

2.2.4 Discussion and conclusions

In the study, it was found that the highest prices likely to be paid by the energy sector for energy wood would be 70 €/m^3 and 80 €/m^3 in 2020 and 2030, respectively. A value of 100 €/m^3 for energy wood was regarded as an extreme scenario, not very likely to be realized under current trends and expectations.

If the energy sector were capable of paying an extreme high price of 100 €/m^3 for wood, it would obtain the highest amount of wood biomass in the scenario with relatively low economic growth combined with unrestricted wood supply globally. Then the maximum potential supply of wood for energy would be around 60 Mtoe by 2030, or 290 mill m^3.

With 80 €/m^3 as energy wood price level the maximum potential supply of wood for energy would slightly exceed 20 Mtoe (97 mill m^3) in 2030, most of which would come from logging residues, with only 2–4 Mtoe (10–20 mill m^3) coming from competitive use of wood. According to the model projections, the annual energy wood supply from competitive use of wood is not likely to exceed 1 Mtoe (4.8 mill m^3) if the energy wood price level does not exceed 70 €/$m^{3.}$

The projections also show that in the long run it is possible that the supply of wood biomass for energy may be largely limited to logging residues, because of increasing demand for forest industry products. In the short–to medium future (2010–2025), domestic or imported roundwood and forest industry residues could play a more important role, but later on, these volumes are not likely to be sustained unless wood energy prices rise to a very high level due to CO_2 taxes or subsidies, or unless there is a global decline in the demand for forest industry products.

Assuming the energy wood price staying below 100 €/m^3, the wood coming from the forests and from the forest industries can at most provide only around 17% (60 Mtoe or 290 mill m^3) of the EU RES target in 2020. In addition to that, come wood-based fuels like black liquor from pulp industry, household waste wood and demolition wood, but these products were not considered in the model used in S2. The share could rise to some 23% (80 Mtoe or 386 mill m^3) of the EU RES target if these products are included. It should be noted that in the EEA study (EEA 2006) logging residues were estimated at a rather conservative level with various environmental constraints, corresponding to a medium mobilisation scenario of the more recent EUwood study (S1). Under a high mobilisation scenario in S1, an additional 140 million m^3 logging residues could be utilized in the EU in 2030. Furthermore, S1 estimated fuelwood consumption by private households for heating in the EU to be around 150 million m^3 in 2030, partly coming from forests, partly from wood supply sources outside of forests. Considering a high mobilisation scenario for logging residues and an additional fuelwood consumption (equalling 140 + 150 = 290 million m^3 = 60 Mtoe) and the highest estimate of 80 Mtoe mentioned above, the total annual use of wood for energy could then be about 140

Mtoe (660 mill m^3), corresponding to a woody biomass share of some 40% of the EU RES target. In our opinion, a realisation of this scenario would call for very high wood prices.

Under the more conservative scenario for logging residues and energy wood prices of 70–80 €/m^3, S2 indicates that the total wood supply for energy would be limited to 20 Mtoe (96 mill m^3) or 6% of the EU RES target, and inclusion of black liquor, wood waste and fuelwood would potentially increase this figure to 70 Mtoe (330 mill m^3) or 20% of the EU RES target. Consequently, the majority of the EU RES target would also here need to be met by other sources of biomass (agriculture, bio waste) and other RES sources (hydro, solar and wind power).

The rising energy prices would have a negative impact on the forest industries. S2 shows that while the amount of wood directed from the forest industry to the energy sector would at most be around 20 Mtoe (96 mill m^3) in the terms of energy, given an energy wood price of 100 €/m^3, this would cover only around 6–7% of the European Union's RES target for 2020, and an even lower share for 2030. But for some forest industry sectors like production of pulp and panels, it would mean an important output reduction, around 20% compared with the present (2010) capacities.

Similar results were obtained by Raunikar et al. (2010), who examined the impacts of the biofuel demand implied by the IPCC scenarios A1B and A2 on the global forest sector development. For that, they used the forest sector model GFPM, which has structural similarities to the EFI-GTM. The main difference between the models is in the level of regional and products details, and how technology and trade is treated. While S2 sets out from exogenously assumed prices for the wood biomass demanded by the energy producers (i.e. their willingness to pay), to which the markets reacted through quantities supplied, consumed and traded, Raunikar et al. start from the exogenously determined quantities of fuelwood demand, to which the wood prices and the forest industry production adjust. Other important differences between the approaches is that Raunikar et al. consider globally increasing fuelwood demand, and they do not include logging residues as a source for wood supply. Under the A1B scenario, they project price of fuelwood (wood used for bioenergy in a general sense) and industrial roundwood to be around 100 US$/m^3, with fuelwood production in Europe around 500 million m^3 (about 100 Mtoe) by 2030. Adjusted to the EU, this figure would be close to the EFI-GTM projection under the B2 scenario, with wood energy prices between 100 and 120 €/m^3. According to Raunikar et al. the European pulp industry is projected to decrease by roughly 25–30% compared to the present (2010) capacities.

2.3. Study 3: Price of CO2 emission and use of wood in Europe – Lauri et al. (2012)

2.3.1 Objectives and methodology

Study 3 (Lauri et al. (2012) – hereafter referred to as S3) examines the effects of the price for CO_2 emissions from fossil fuels on the use of wood in Europe. Specifically, the economic potential to substitute wood for coal and peat in heat and power production is assessed. Also, the impacts of increased energy wood usage on the forest industry and roundwood prices are projected.

The study is conducted using a revised version of the European Forest and Agriculture Sector Optimisation Model (Schneider et al. 2008). The main revisions are that the agriculture, forestry, and other land uses are kept exogenous, the timber supply is approximated by price-elastic roundwood supply functions, a larger set of forest industry production technologies is included, and heat and power production options are added in order to project the competition for wood with the forest industry. Another central feature is the capacity dynamics, which makes investments in new capacities of heat and power plants and the forest industry endogenous.

The model simulates the operation of the competitive economy by maximizing a social welfare function which is the sum over regions and commodities of consumers' and producers' surpluses less interregional transportation costs, subject to market clearance and constraints regarding e.g. production capacities and harvest possibilities. The welfare function discounts the annual surpluses over infinite time period, which is an important difference to some other forest sector models like EFI-GTM (Kallio et al. 2004) used in S2 and S4 and GFPM (Buongiorno et al. 2003). This means that energy and forest industry are assumed to have perfect foresight so that they perceive the consequences of their actions (investments and production choices) on all of their future costs and revenues, and that they can fully anticipate how for instance carbon prices change in the future. In recursive-dynamic models as EFI-GTM and GFPM, agents are assumed to make their decisions having only knowledge of the current policies and current costs, income and price levels. However, there are ways to model degrees of foresight between no information and perfect information (Sjølie et al. 2011).

Three carbon price scenarios for the EU countries are considered, as shown in Table 2.3.1. Zero carbon prices are applied to Russia, Belarus and Ukraine. This means that large quantities of wood remain available for exports from these countries to the EU.

The carbon prices affect the fuel costs in heat and power production and thereby the energy prices. Higher carbon prices mean higher fuel costs for coal and peat fired heat and power plants, which makes wood more attractive as a fuel choice. In the model, heat and power plants are forced to supply fixed amounts of heat and power to the national markets using wood or coal/peat as a fuel. The amount required equals the coal, peat and wood based heat and power production in the countries in 2010.

It is assumed that the national electricity prices converge towards a common European price of 70 €/MWh by 2030 at a price of carbon of 20 €/tCO_2. The heat prices are calculated assuming that coal is the marginal fuel in heat production with energy efficiency of 90%. The prices for energy are assumed closely tied to the carbon prices as carbon prices have complete pass-through to heat and power prices in the model. Because the production of heat and power for energy are fixed to satisfy a certain pre-specified demand level, these assumptions on energy prices affect only the production costs of the forest industries in the scenarios.

The economic growth is assumed to be 2% p.a. for all European countries during 2010–2040.

Table 2.3.1. Assumed development of the prices of carbon, heat and power in the scenarios. The prices change linearly between periods.

Scenario	Commodity	2020	2030	2040
	Carbon	20 €/tCO_2	20 €/tCO_2	20 €/tCO_2
Low	Electricity	60–80 €/MWh	70 €/MWh	70 €/MWh
	Heat	4.7–7.1 €/GJ	4.7–7.1 €/GJ	4.7–7.1 €/GJ
	Carbon	30 €/tCO_2	40 €/tCO_2	50 €/tCO_2
Middle	Electricity	68–88 €/MWh	87 €/MWh	95 €/MWh
	Heat	5.8–8.2 €/GJ	6.8–9.2 €/GJ	7.8–10.2 €/GJ
	Carbon	50 €/tCO_2	80 €/tCO_2	110 €/tCO_2
High	Electricity	85–105 €/MWh	120 €/MWh	145 €/MWh
	Heat	7.8–10.2 €/GJ	11.0–13.4 €/GJ	14.1–16.5 €/GJ

2.3.2 Main results

The use of roundwood and sawmill chips and sawdust in heat and power plants was projected to be 11, 25 and 75 mill. m^3 in the Low, Middle and High scenario, respectively, in 2020. In 2040, these figures have changed respectively to 4, 48 and 206 mill. m^3. Figure 2.3.1 shows this development by biomass category in the High scenario. The average price of softwood pulp logs under bark decreases over time from some 52–54 €/m^3 in 2015 to about 50 €/m^3 in scenario Low in 2040, while it is increasing to 59 €/m^3 in scenario Middle and to 89 €/m^3 in scenario High in 2040 (Figure 2.3.2). The raise is caused by the assumed increasing carbon prices inducing higher demand for energy wood.

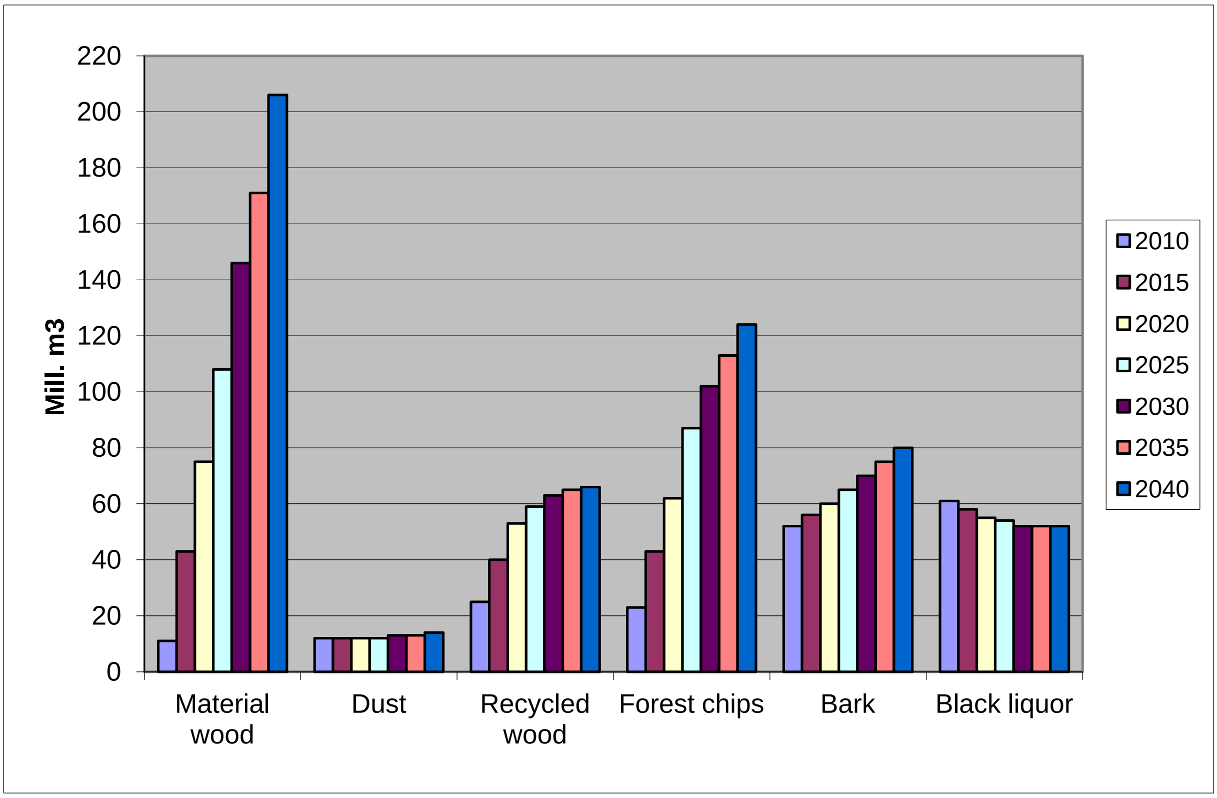

Figure 2.3.1. Use of wood in heat and power plants in the EU27 region in the High scenario.

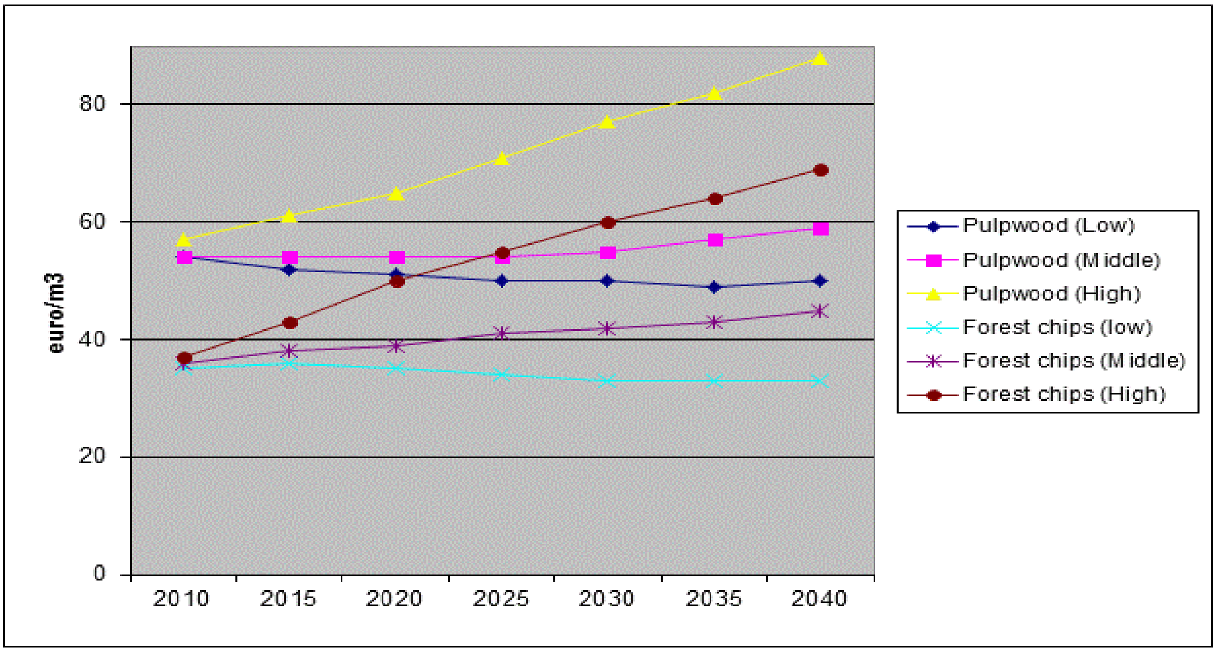

Figure 2.3.2. Mill prices of softwood pulpwood (under bark) and forest chips in scenarios Low, Middle and High scenarios.

In this study, mainly in scenario High, there is a strong competition for wood between heat and power plants and the traditional forest industries. (It should be noted though that in this study, wood is only assumed to compete with coal and peat in the heat and power sector and that the quantity of heat and power produced with solid fuels is kept constant.) Yet, when we compare the production of the forest industries in the High scenario in 2040 to that in 2010, only pulp production is declining (7% from 2010 to 2040). The board production is projected to grow by 17% and the sawmilling industry by 25% by 2040. Paper and paperboard production increases by modest 9% from 2010 to 2040. The projected harvest of roundwood in the EU increases from roughly 370 mill m^3 in 2010 to 416, 440 and 510 mill m^3 by 2040 in scenarios Low, Middle and High, respectively. In Study 2 (Moiseyev et al. 2011), the harvest in EU27, Norway and Switzerland increases to 530 mill m^3 in 2030 in both A1 and B2 under energy wood price assumption of 100 €/m^3. In S3, the High scenario comes closest to that price level, but both the EU harvests and wood prices are lower in S3 than in S2 in 2030. That is well in line with the settings of the two studies. S2 looks at the *availability* of wood for uses outside traditional forest industries for given prices, whereas in S3, the use of wood for energy is constrained at the price level where wood is competitive with coal.

Imports of roundwood and forest chips to the EU increase modestly in the Low and Middle scenarios to 28 mill m^3 and 36 mill m^3 in 2040, respectively. Almost all the increase takes place in roundwood trade. In the High scenario, the imports to EU27 are 100 mill m^3 above the Low scenario. This increase is divided about equally on quantities of pulpwood and forest chips. Thus, about 100 mill m^3 (one third or more) of the increase in the consumption of forest chips and roundwood in heat and power production is directly or indirectly provided by imports. This underlines the significance of the assumptions made regarding imports, and is rather similar to what is obtained in S2, where the import under A1 and B2 are respectively 57 and 39 mill m^3 at a pulpwood price of 90 €/m^3. Lauri et al. (2013) and Solberg et al. (2010) suggest that the policy developments in Russia regarding climate, energy, trade and investment risk could change the EU wood use considerably.

2.3.3 Discussion and conclusions

The results of S3 suggest that there will be no scarcity of roundwood in Europe in the next 10 to 15 years, although production of heat and power from pulpwood and sawmilling residues is economically feasible at least in some EU countries already with the carbon price of 20 €/t-

CO_2. With a carbon price of 30€/tCO_2, forest chips and material wood are increasingly competitive with coal, but that does not influence pulp and paper production much. With carbon prices higher than that, this study projects pulp and paper production to react more strongly to the increased energy wood prices than what S2 (Moiseyev et al. 2011) suggests. One reason for this is that in study S3, pursuing consistency with the carbon price, the heat and power prices are increased correspondingly, which raises the costs of the forest industries.

Like S2, S3 finds that the contribution of wood for reaching the EU RES target is likely to remain rather low. It is notable that an important part of the use of wood energy remains to be directly or indirectly tied to the forest industry production also in the future.

This study (S3) projects the demand for wood to increase less than S1 (the EUwood) does. The studies share the point of departure of the 2010 wood use in the EU27: the material use of 460 mill m^3 and the energy use of 350 mill m^3. The future development, however, differs. In this study, the projected figures for the use of wood in EU27 in 2030 are lower than in S1: material use 480–520 mill m^3 (EUwood 530–620 mill m^3) and energy use 390–600 mill m^3 (EUwood 750 mill m^3). The demand scenarios are one important reason for the difference. In the EUwood study, the final products demands follow historical trends, while in this study, forest industry production is endogenous and competitive effects of Russia and rest of the world diminishes the production growth in Europe. In S1 (EUwood), the future demand of energy wood follows the EU renewable energy targets, whereas in this study it depends on the future carbon price and its impact on the incentive to substitute wood for coal. The supply and prices of energy wood are also affected by the competing demand of wood in the forest industry.

When looking at the high end projections of S3 for the use of energy wood, which are lower than those in S1 (EUwood), it must be kept in mind that while there are some arguments to regard them as conservative (see the next section), they rely on several strong assumptions. First, they call for carbon price to increase rapidly, reaching 50€/tCO_2 in 2020 and 80€/tCO_2 in 2030 before hitting 110 €/tCO_2 in 2040. Furthermore, it is essential that those deciding upon investments in heat and power plants have strong faith for such tightening climate policies to take place. Second, energy produced from solid fuels should not loose market shares to other energy sources even at the higher fuel prices obtained in the High scenario of S3. At the same time, biomass from agriculture should play only a marginal role in the energy palette. Third, the exports of wood from Russia to the EU should rather increase than diminish. Finally, S3 did not assume any improvement in the energy conversion efficiencies of the heat and power plants. With improving efficiency, less biomass would be needed to produce the same amount of heat and power in the future.

That said, there are also some reasons to consider the projections made in S3 for the use of wood as fuel to be conservative, at least when it comes to the Low scenario with a moderate carbon price. To see more rapid changes in their energy systems, several countries in Europe have set their own renewable policies additional to the EU ETS, some of which favour the use of wood also in other applications than those where wood replaces coal or peat as studied in S3. The obligations given in the EU RES directive has been one driver for this development. Liquid biofuels are among these alternative applications, which S3 did not consider. There is currently no commercially operative liquid biofuel production units utilizing woody biomass, but it might be in the future. S1 expects the wood use for liquid biofuels to be 29 million m^3 or less in EU27 in 2030. Moreover, more woody biomass might be shifted from the forest industry to energy production than projected in the scenarios of S3 if the demand for forest industry products turns out to be weaker than assumed. The demand and output of printing and writing papers in the EU may decline in the coming decades due to further break-through in the information technology. Also, the markets for other forest industry products might mature, which would mean lower growth in their demand than assumed in S3. That would mean lower prices for biomass suitable for energy production due to less tight market demand.

The large variations in the projected developments for the use of wood across the scenarios in this study and also in other studies indicate that high uncertainty prevails over the future development in the demand and supply for wood in energy production. The uncertainty of climate policy poses a special challenge for investors. The investment costs in heat and power capacity are high, and thus the expectations on future climate policy are decisive. Comparison of the scenarios in this study reveals that early signals for high future carbon price lead to higher penetration of wood-based heat and power production.

2.4 Study 4: Analysing the impacts on the European forest sector of increased use of wood for energy with endogenous wood energy demand – Moiseyev et al. (2013)

2.4.1 Background and objectives

In this study (Moiseyev et al. (2013) – referred to as S4), the effects of coal, gas and carbon emission prices on the use of wood for energy and wood-based products in the EU region are analysed up to year 2030. The study focuses on the large-scale heat and power sector in the EU and examines the potential demand for wood fuel by the coal and wood fired heat and power sector when also natural gas supply are considered, and how this demand depends upon different developments of the fossil fuel prices and CO_2 taxes. A sensitivity analysis of the influence of possible decreases in future paper demand is also provided. The analysis uses a revised version of the partial equilibrium model for the global forest sector applied in S2, the EFI-GTM model (Kallio et al. 2004), and includes rather detailed the international trade of wood biomass and forest products to/from various regions outside the EU.

2.4.2 Methodology

Model type and future energy price assumptions

The study approach is somewhat similar to the one applied in S3 (i.e. Lauri et al. 2012), but the energy sector representation is expanded to cover endogenously the gas power sector, and to include exogenously the wind and solar PV power productions based on projections of their expected future capacity expansions by ECF (2010a; 2010b).

The main revision made in this study of the EFI-GTM global model is that coal, gas and wood-based production of heat and power are added to the modelled commodities, which previously consisted of the forest and forest industry products only. In total, the model includes four types of thermal power electricity generating plants (by type of fuel used – lignite, coal, gas and wood), four types of heat plants and four types of combined heat and power (CHP) plants, as described more in detail below.

The relative development of the future prices of carbon, coal and natural gas are emphasized in the analyses. Regarding the CO_2 price development, five levels from 10 to 100 €/tCO_2 are considered until year 2030:

1. Present carbon emission price level of 10 €/tCO_2 remaining constant until 2030.
2. Low scenario: 30 €/tCO_2 in 2020 rising linearly to 40 €/tCO_2 in 2030.
3. Middle scenario: 40 €/tCO_2 in 2020 rising linearly to 60 €/tCO_2 in 2030.
4. High scenario: 40 €/tCO_2 in 2020 rising linearly to 80 €/tCO_2 in 2030.
5. Very high scenario: 40 €/tCO_2 in 2020 rising to 100 €/tCO_2 in 2030.

The gas price variation relative to coal is a key factor in the analysis, and two future alternatives are assumed for each CO_2 price scenario:

1. High coal and gas prices: European coal prices increase linearly to 85 €/t of coal in 2020 from the present level of 70 €/t, and natural gas prices increase to 11 €/mmBTU in 2020 from the current price of 8.5 €/mmBTU. These coal and gas price developments are similar to the assumptions in ECF (2010).
2. Low coal and gas prices: European coal price increase only modestly to 75 €/t in 2020, while natural gas price decrease moderately from the present level to 7.7 €/mmBTU by 2020. These developments could be justified by e.g. expected future export of North American shale gas.

Consequently, altogether 10 alternatives are analysed: Present - Low - Middle - High - Very high CO_2 prices combined with High coal & gas prices, and the same five CO_2 price scenarios combined with Low coal and gas prices.

It is assumed that Russia, Belarus and Ukraine within Europe and other regions outside of Europe are not going to take part in EU ETS system. This assumption has an important impact on the price of wood in Europe and on the competitiveness of the European forest sector relative to other regions.

For all 10 alternative scenarios the study uses the GDP growth assumptions of the IPCC B2 reference scenario and other assumptions regarding forest products demand and wood supply as described in S2 (Moiseyev et al. 2011). Logging residues availability is defined as a share of industrial wood harvest based on the “Promoting wood energy” scenario assumptions in EFSOS II report (UN 2011). Logging residues costs (delivered to the energy mill) are based on EEA (2007).

Energy sector assumptions

S4 focuses on how wood biomass will compete with coal and natural gas in the future. The development of the supply of solar and wind power are accounted for by using the EC Energy Roadmap 2050 (EC 2011), which projects the electricity production to increase from some 3400 TWh in 2010 to 4100 TWh in 2030 in the Roadmap's reference scenario. Still, the supply of thermal energy is projected there to be rather stable over 2010–2030 period, while in the decarbonisation scenarios, it is projected to decline from 1900–2000 TWh in 2010–2015 to 1250–1400 TWh in 2030, mainly due to a sharp increase in wind and solar power generation. Based on that, this study assumes that the quantity corresponding to the current electricity production by thermal power, about 1900 TWh, must be supplied by competing gas, coal and biomass fired power plants or, up to some extent (about 800 TWh) by solar PV and wind power in the future. The rest of the power supply is assumed to come from hydro or nuclear power plants and also from wind and solar power. However, that part of the power supply is kept exogenous to the analysis. The overall thermal heat production is assumed stable at its current level, but the supply is subject to competition between coal, heat and biomass fired plants. Demand for thermal electricity and heat is assumed to be inelastic.

The capacities of the current coal, gas and biomass fired power, heat and CHP mills in the European countries (except CIS region) are based on Platts World Electric Power Plants Database. The current capacity and potential increases of the regional wind power and solar PV capacity are modelled in accordance to the projections by ECF (2010a), adjusting the figures for 2050 in “Higher RES” scenario (ECF 2010b) to the year 2030. Country level demand for heat from CHP and district heating and electricity demand at country level (proxied by the gross electricity generation) is based on EC (2010).

Table 2.4.1 shows assumed electricity and heat generation efficiencies for eight types of thermal power and CHP plants, based on the Global Emission Model for Integrated Systems database (GEMIS 2012). Required fuel input corresponds to the electricity efficiency and is based on GEMIS data as well. Average estimate for low heat value (LHV) of hard coal and lignite is taken from Schuster and Penterson (2002). LHV of wood is based on FPL (2004), and is assumed to be 13.76 MMBtu per tonne of air-dried wood (20% moisture content) and 12.04 MMBtu per tonne of semidried wood (30% moisture content). For logging residues, the latter figure is assumed. Average weight of wood is assumed at 0.6 tonne/m^3 (air dry wood).

Consequently, air-dried wood has LHV of 13.76*0.6=8.26 MMBtu/m^3 (8.7 GJ/m^3) and semidried wood LHV has 12.04*0.6=7.22 MMBtu (7.6 GJ/m^3). The LHV of wood pellets is assumed to be 13.6 MMBtu per tonne (FPL 2004). Required fuel input for coal and wood is calculated on the basis of required heat input and LHV of corresponding fuel, which is expressed in tonnes for hard coal and lignite and both in tonnes and cubic meters for wood. For coal with wood pellets, co-firing 20% of energy input is assumed to be coming from pellets. Natural gas is measured in MMBtu and price for gas is also expressed in value per MMBtu. Table 2.4.1 also provides the assumed CO_2 emission factors for all thermal power and CHP plants except wood fired plants, which are assumed to be CO_2 neutral. For heat (district heating) plants an efficiency of 0.85–0.9 is assumed. For wind and solar PV power, heat and electricity efficiencies are not relevant in the study.

Table 2.4.1. Electricity and heat efficiency for power and CHP plants.

	Heat efficiency	**Electricity efficiency**	**Fuel input (MMBtu /MWh)**	**Fuel LHV (MMBtu/ ton)**	**Fuel input (ton /MWh)**	**Wood fuel input (m3/ MWh)**	**CO_2 emissions**
Power plant, coal		0.40	9.5	25	0.38		0.9
Power, coal with pellets co-firing		0.40	7.6	25	0.30		0.7
pellets input for co-firing			1.9	13.6	0.14		
Power plant, lignite		0.40	9.5	10	0.95		1.0
Power, lignite with pellets co-firing		0.40	7.6	10	0.76		0.8
pellets input co-firing			1.9	13.6	0.14		
Power plant, gas		0.58	6.5				0.4
Power plant, wood		0.33	11.5	12	0.96	1.60	
CHP, coal	0.55	0.33	11.5	25	0.46		1.0
CHP, lignite	0.55	0.33	11.5	10	1.15		1.1
CHP, gas	0.45	0.45	8.44				0.5

Investment and production costs for thermal power, wind and solar PV (Table 2.4.2) are based on estimates from ECF (2010b). The same operational and maintenance (O&M) costs were assumed for both CHP and electricity-only mills. Consequently, their total costs differ only due to differences in electricity and heat efficiencies and required fuel input in terms of volume and value (based on assumed fuel price). Table 2.4.2 also shows the cost for elements other than fuel. For comparing and modelling costs of new electricity generation technologies the study uses the commonly applied LCOE method (Levelized Cost of Electricity), and specifically the simplified LCOE method as applied in Tarjanne and Kivistö (2008). Column F (Table 2.4.2) shows total annualised electricity generation cost without fuel cost. For wind and solar PV power fuel is not required, consequently these costs estimates are final. For the solar PV power this estimates are given from ECF (2010b) as averaged between 2020 and 2030.

Table 2.4.2 Assumed electricity generation costs. Production and investment costs are from ECF (2010b).

Cost of electricity generation														
Electricity generation techno-logy	Capital cost, €/KW	Fixed O&M cost, €/KW	Variable O&M cost, €/MWh	Capacity load factor	Total annualised cost without fuel, €/MWh	Annualised capital costs, € / MWh	Non-fuel O&M Cost, €/MWh	Fuel, €/ MWh	Total costs, €/MWh	CO_2 emission factor	CO_2 40 €/ ton	CO_2 60 €/ ton	CO_2 80 €/ ton	CO_2 100 €/ ton
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Coal conventional	1400	20	1	0.86	16.8	13.2	3.7	26	42.8	0.9	79	97	115	133
Coal co-firing (pellets)	1400	20	1	0.86	16.8	13.2	3.7	42	59	0.7	88	102	116	130
Gas conventional	700	15	1	0.6	13.3	9.4	3.9	50	63.3	0.4	79	87	95	103
Wind Onshore	1400	35	0	0.3	51.1	37.8	13.3	0	51	0	51	51	51	51
Wind Offshore	2560	40	0	0.37	68.4	56.0	12.3	0	68.4	0	68	68	68	68
Solar PV	1550	15	0	0.12	118.9	104.6	14.3	0	118.9	0	119	119	119	119
Wood	2700	13	9	0.8	38.2	27.3	10.9	58	96.2	0	96	96	96	96

The fuel costs assumed in the study are compared in column I of Table 2.4.2.The costs are based on the Low coal and gas price scenario's fuel prices assumptions and required fuel input from Table 2.4.1. For biomass power and CHP generating technologies, the fuel cost is going to be a key factor. To complement this cost comparison, different CO_2 prices in the range of 40 to 100 €/tCO_2 are assumed and resulting electricity costs are shown in columns L-O. It is seen in column J, with no price on CO_2 emissions, that coal power is the cheapest, wind onshore is second and gas is the third cheapest, and wood-fired power is substantially more expensive. Only the coal fired power sector is able to produce electricity below the present market price (45-50 €/MWh), which reflects the current situation in the EU. However, if we deduct annualised capital costs from total electricity costs, then existing coal power mills (without investment related debts) can make a substantial profit margin above 15 €/MWh, while gas-fired plants cannot even make break-even, again reflecting the current situation in Europe. 40 €/tCO_2 is needed to make market conditions equal for coal and gas (see column L, Table 2.4.2). Wood based electricity cost may become equal to coal with 60 €/tCO_2 assumption and with 80 €/tCO_2 wood will be on equal foot with gas-fired power. This unfavourable situation for wood energy changes with a carbon tax of 100 €/tCO_2; also wind power will benefit a lot with such extremely high CO_2 prices.

The cost data in Table 2.4.2 for various CO_2 prices, give a simplified indication of the likely future development of the electricity production. However, CHP mills can sell the heat, which let them offset electricity costs, and one needs to examine different coal and gas prices developments to analyse the interactions between the electricity and heat markets.

2.4.3 Main results

Shares of the electricity production in the EU region

Allocation of the annual electricity production in 2030 under alternative scenarios is shown in Table 2.4.3. Under the Low Coal & Gas prices scenario with 40 €/tCO_2, the competition takes place mainly between coal and gas – with gas taking a major share in electricity production. Wood-fired CHP takes a modest share of 5%. Under the 60 €/tCO_2 scenario, the share of coal powered plants shrinks to supply just a tiny bit more than wood-fired power plants, and wood-fired power expands marginally from 5% to 5.5%. Under the 80 €/tCO_2 scenario, coal power is practically driven out of markets due to high carbon emission prices. Under the Low Coal & Gas prices scenario most of the competition takes place between coal and gas, with a slowly increasing competition from wind and solar PV production, while the wood-fired power sector is stuck below 6% share.

Under the High Coal & Gas prices scenario with 60 €/tCO_2, coal is still a major supplier of electricity (44%) and dropping to 15% only in the 80 €/tCO_2 scenario, while wood-fired power provides around 6.2% of the total electricity. Higher coal and gas prices coupled with a carbon price of 100 €/tCO_2 results in a price of electricity exceeding 120 €/MWh in 2030, which allows more solar PV power to enter the electricity market. Both coal and gas power shares go down with gas power still keeping a high 40% share, while coal has only an 8% share. A high electricity price also favours wood-fired electricity to a limited extent, whose share increases up to 6.8%. Hardly any co-firing of wood with coal takes place.

Table 2.4.3. Annual electricity production in the EU region (plus Norway & Switzerland) by energy source in 2030 (GWh/year).

CO_2 price in 2030 (€/ton)	**Gas**	**Coal**	**Coal & wood co-firing**	**Wood**	**Wind & Solar**
	- - - - - - - - -- - - - - **Low Coal & Gas prices** -- - - - - - - - - - - - -				
10	757,822	1,075,950	0	63,149	17,151
40	1,097,300	354,436	0	99,809	361,903
60	1,224,777	144,417	0	109,892	434,000
80	1,359,182	8,008	952	110,623	434,000
100	1,340,555	7,956	753	111,908	451,257
	- - - - - - - - - - - - - **High Coal & Gas prices** - - - - - - - - - - - - -				
10	368,408	1,165,403	0	73,084	306,624
40	408,625	968,743	0	101,540	434,000
60	530,558	829,573	0	117,745	434,480
80	962,031	280,023	0	119,255	550,611
100	762,547	153,627	755	128,845	866,602

Table 2.4.4 shows the data regarding electricity and heat production in 2030 in more detail, by different type of wood-fired energy mills under the High Coal & Gas prices assumption and different levels of CO_2 prices. The CHP mill produces both electricity and heat in the most efficient way. Dedicated heat mills are profitable with the current low CO_2 prices, but they contribute only 6.5% of the total heat supplied by wood-fired mills. Dedicated wood-fired power mills may supply up to one-third of the total electricity supplied by wood-fired plants; however, with rising CO_2 prices this share goes down to less than 1%. With the high CO_2 prices, CHP wood-fired mills will produce the most of the electricity and heat. Despite a low share (<7%) of wood-fired electricity, wood-based heat is projected to go up to 31% of the total heat provided by the medium- to large-scale energy sector. Use of woody biomass to energy is projected to increase from 151 million m^3 to 256 million m^3 with increasing CO_2

prices. While most of these volumes will come from the lowest costs logging residues, a significant 32 million m^3 may come from industrial wood sources with the high CO_2 prices of 100 €/tCO_2.

The main result is that wood-fired electricity is able to gain only a marginal market share due to limited availability of low-cost wood from logging residues. Industrial wood starts to be used increasingly only with higher coal and gas prices and with very high carbon emission prices of 100 €/tCO_2. With carbon emission prices well above 100 €/tCO_2, more wood biomass will become available for energy. While looking at the current situation, such carbon prices seem very high, but such prices might occur if the low carbon Europe roadmap becomes a reality (EC 2011b; 2011c).

Table 2.4.4. Annual electricity and heat production in the EU region (with Norway & Switzerland) by wood-fired plants in 2030 under High Coal & Gas prices scenario.

CO_2 price in 2030 (€/t)	**- - - - - CHP - - - -**		**Power only**	**Heat only**	**- -Total wood-fired - -**		**Wood, million m^3**	
	Electricity, GWh	Heat, MMBtu	Electricity, GWh	Heat, MMBtu	Electricity, GWh	Heat, MMBtu	Wood biomass use total	Industrial wood use
10	72,405	506,832	680	35,471	73,085	542,303	151	0
40	86,186	603,303	15,354		101,540	603,303	200	4
60	87,848	614,933	29,897		117,744	614,933	229	8
80	108,821	761,747	10,434		119,255	761,747	236	14
100	128,184	897,289	661		128,845	897,289	256	32

This rather marginal use of industrial wood for energy can be higher under different forest sector market developments and policy tools used to stimulate faster introductions of renewable energy sources. The main instrument for stimulating acceleration of renewable energies in the EU has been feed-in tariffs. In addition, investment subsidies and extra bonuses and renewable obligation certificates are used to stimulate use of renewable raw materials in electricity production, as discussed in the next section.

Impact of subsidies for wood based electricity on the use of wood for energy

Subsidy (compensation) for wood-fired electricity produced at power and CHP mills is introduced by specifying an additional compensation for the production costs at the level of

30 €/MWh of electricity. This is marginally higher than the lowest level of "NawaRo" bonus in Germany for power production using solid renewable biomass (BMELV 2009).

In addition, 30 €/MWh is assumed as a compensation for the coal with wood and wood pellets co-firing, which is nearly 50% lower compared to the present renewable obligation certificate in the UK of about 55 €/MWh. High-level subsidies are also used for coal co-firing in the Netherlands and Denmark. We assume a more modest level of coal co-firing subsidy at the EU level from 2020. This level of compensation will barely cover annualised capital costs for a new wood-fired power/CHP mill (Table 2.4.2). However, for the existing coal powered mills this level of compensation will cover higher wood fuel costs and provide an extra bonus. These subsidies will increase the relative competitiveness of wood-fired power mills and especially for co-fired coal and wood energy production.

Table 2.4.5 shows the results for the electricity generation in 2030 for the High Coal & Gas prices scenario under two different CO_2 price levels with and without subsidies. With the assumed 30 €/MWh subsidy and a carbon price of 40 €/tCO_2, the most striking result is that coal co-firing saves the coal powered sector to a large extent, while the impact on the increased use of wood for wood-fired mills will be rather modest. It seems that the subsidy can boost the use of wood for energy much more than by increasing carbon price. This may explain why at present in some countries substantial quantities of industrial wood is used for power production besides forest residues, even with rather low carbon prices. In addition, there are other possible reasons for using industrial wood (mainly pulpwood and residues from sawmills) for power production, like falling pulpwood prices caused by the long economic recession or declining paper demand, as discussed later.

Table 2.4.5. Annual electricity production (GWh) in the EU plus Norway and Switzerland in 2030, for High Coal and Gas prices with and without subsidies.

Fuel type	Without subsidy	Subsidy 30 euro/MWh	Without subsidy	Subsidy 30 euro/MWh
CO_2 price (€/tonne)	- - - - - - - 40	- - - - - - - - -	- - - - - - - - -	100 - - - - - -
Coal	968,743	28,006	153,627	0
Coal co-firing	0	970,452	755	694,974
Gas	408,625	361,896	762,547	288,040
Wood (Logging residues)	99,404	118,249	112,000	116,475
Wood (Industrial wood)	2,136	429	16,845	5,674
Wind & Solar	434,000	434,000	866,602	806,653

Subsidies will increase the use of wood for energy in 2030, mainly industrial wood, while the use of logging residues increases only marginally since the supply of logging residues is limited by harvest levels. An extra source of industrial wood comes to the energy sector by diverting wood from the wood-based sector, which is hurt by increasing wood prices and especially electricity prices under higher carbon price levels. Additional wood is also increasingly imported from other regions with increasing carbon prices and subsidies. Industrial wood price development and wood imports are analysed in the following section.

It is important to note that subsidies for wood-fired and especially coal with wood co-fired mills substantially increase the use of wood and especially industrial wood for energy. Consequently, wood displaces both coal and gas from the electricity markets. However, with the low carbon prices (40 €/tCO_2) wood will displace mostly gas-fired power mills because carbon prices are too low to drive coal out of the market, and gas power is much more vulnerable under the assumption of higher gas prices. Perhaps this could explain why major European power sector companies are planning to downsize their gas-fired mills contrary to the general strategy by the European Commission to increase the use of gas and reduce use of coal in the medium term (until 2030). It will require much higher carbon prices to get coal and gas on a more equal footing. Increased carbon prices and subsidies for wood seem to influence rather strongly the distribution between coal and gas. However, even with a high 100 €/tCO_2 price and subsidy, mostly gas-fired electricity is projected to be displaced by increasing use of industrial wood, which is not beneficial regarding reducing the high CO_2 emission from power production using coal. In addition, the model results show that the main sources of the growing use of industrial wood for energy are imports from the regions outside of the EU, which thus creates considerable carbon leakages.

The impact of reduced graphic paper consumption and lowering global economic growth on the use of wood for energy

The present economic situation in the EU with its debts problems and generally low GDP growth (varying between EU member countries between negative to low GDP growth) combined with the overall global economic slowdown may have a long lasting effect on the medium-term economic growth. To consider this possible alternative general economic condition, the IPCC A2 reference scenario with its GDP of about 75% of the B2 reference scenario GDP in 2030 was used. In addition, over the last 10–15 years, there has been a decline in graphic paper consumption in the USA (Ince and Nepal 2012). This trend is also likely to occur in Western Europe, mainly as a result of competition with electronic media. We wanted to test how sensitive such a decline could be for increasing the potential supply of industrial wood for energy. Our assumption regarding future graphic paper consumption in 2030 is that in North America and the EU, it will be about 50% of the consumption level in 2010, and that in other regions consumption will not grow from the present level. The other paper and paper board demand is assumed to grow in the same proportion to the GDP growth as in the main scenarios, but the GDP growth according to A2 reference scenario will be slower. Overall, the paper demand in 2030 will be about 200 million tonnes less under the A2 reference GDP growth and reduced graphic paper consumption, than under the B2 GDP growth and paper growth in line with the past growing trend. As a result, less demand for wood pulp and lower future pulpwood prices increase the use of industrial wood for energy.

Table 2.4.6 shows projected electricity generation in 2030 for the High Coal & Gas price scenario under different CO_2 price levels with A2 reference GDP growth without subsidy for wood-fired electricity and coal with wood co-firing, and with a subsidy of 30 €/MWh. These results shows that without subsidies, the amount of industrial wood used for electricity is moderate (14 million m^3) with CO_2 price of 40 €/tCO_2, but it increases up to 88 million m^3 in 2030 with CO_2 price of 100 €/tCO_2, which is 2.5 times more than with the same CO_2 price but with higher paper demand (see Table 2.4.5). The subsidy for wood firing and co-firing increases the amount of industrial wood used for electricity up to 315 million m^3 with a CO_2 price of 40 €/tCO_2 and 280 million m^3 with a CO_2 price of 100 €/tCO_2 in 2030. Most of this wood will be used in coal with wood and pellets co-fired power mills, while use of industrial wood by wood-fired mills will be somewhat lower compared to the no-subsidy case.

Table 2.4.6. Annual electricity production (GWh) in the EU plus Norway and Switzerland in 2030, for High Coal and Gas prices with and without subsidies for wood-fired electricity under A2 reference GDP growth and declining graphic paper consumption.

Fuel type	Without subsidy	Subsidy 30 euro/MWh	Without subsidy	Subsidy 30 euro/MWh
CO_2 price (€/tonne)	- - - - - - - 40	- - - - - - - - -	- - - - - - - - -	100 - - - - - -
Coal	970,821	28,023	99,871	0
Coal co-firing	0	1,053,109	42,748	767,700
Gas	404,840	280,516	749,277	262,118
Wood (Logging residues)	95,497	115,473	109,707	115,473
Wood (Industrial wood)	7,749	1,695	41,694	28,036
Wind & Solar	434,000	434,000	868,303	738,488

Under the conditions when economic growth and paper demand is weakening, use of industrial wood for energy may substantially increase, but this will require high carbon prices. However, the subsidy for wood-fired and coal with wood co-firing power will be a major force in driving the increase of the industrial wood use for energy; a weakening demand for forest products will give an additional boost to this process.

Changes in the use of wood between forest industries and energy production

Table 2.4.7 shows the projected increase of wood use for energy and corresponding sources from the reduction of wood used for wood pulp, sawnwood, wood-based panels, imports and additional harvests under scenarios studied in the previous sections. The High Coal & Gas price case was used in these scenarios, because practically no industrial wood is used for energy under the Low Coal & Gas price case, and the use of logging residues for energy has no impact on the forest sector in Europe. Higher coal prices, and especially high gas prices, combined with a very high CO_2 price of 100 €/t results in 30.2 million m^3 of wood used for energy production. This causes a reduction of 6.8 million m^3 wood used for wood pulp, and a reduction of 4 million m^3 used for wood-based panels. The total 11.5 million m^3 reduction in 2030 compared to the Low scenario is only 2%. The additional 10.3 million m^3 of industrial wood for energy comes from increased imports to the EU, which in 2030 increases from 36.6 million m^3 in the Low price scenario to 46.3 million m^3 in the High price scenario. The remaining 8.5 million m^3 of industrial wood come from additional harvesting (compared to the Low carbon price scenario). With a subsidy level of 30 €/MWh the total amount of industrial wood used for energy is eight times more than the amount without subsidy. In the latter case reduction of wood for wood based products is almost four times more than without subsidy, additional harvests are three times higher, and imports are 17 times higher compared to the no-subsidy case. Subsidy for firing wood will mainly hit the pulp and panel industries; however, sawnwood will also get some reduction.

Table 2.4.7. Projected use of industrial wood for energy by source under High coal and gas price in 2030. Million m^3.

Subsidy for wood energy	Pulp	Sawn-wood	Panels	Total from wood products	Trade	Harvest	Total
	Industrial wood for energy by source under B2 economic growth						
No subsidy	7	1	4	11	10	8	30
Subsidy 30 euro/MWh	23	4	15	42	173	25	241
	Industrial wood for energy by source under A2 economic growth and declining graphic paper demand						
No subsidy	18	1	8	26	35	23	84
Subsidy 30 euro/MWh	30	3	18	51	186	38	275

The same trends are observed under the alternative scenario with reduced graphic paper demand and lower GDP growth, but the total levels of industrial wood used for energy is somewhat higher and additional harvest is substantially higher. The model results show that without subsidies, imports of wood to the EU region mainly come from Russia. With the subsidy North America becomes the biggest exporter of wood for energy, which will mainly be traded in the form of wood pellets. Russia and Latin America will be the second and third largest exporters of wood pellets and wood chips for energy.

Figure 2.4.1 shows the projected development of the industrial wood harvest in the EU region with the different CO_2 price levels without subsidies and with a 30 €/MWh subsidy (assumed for the 100 €/tCO_2 case). The chart on the left shows harvest development under the main scenario (paper demand continues with the past growth). It can be clearly seen that the harvest level is mainly affected by subsidies for the wood-fired and coal with wood co-fired power, and that increasing CO_2 price has a minor effect on increasing industrial wood harvest. Nevertheless, under the alternative scenario with the weakening paper demand (Figure 2.4.1, right chart), the high CO_2 price of 80-100€/tCO_2 has a substantial effect on the increased harvest in 2030, and the subsidy for the wood-based power has an even stronger effect in the long term, but especially in the short term.

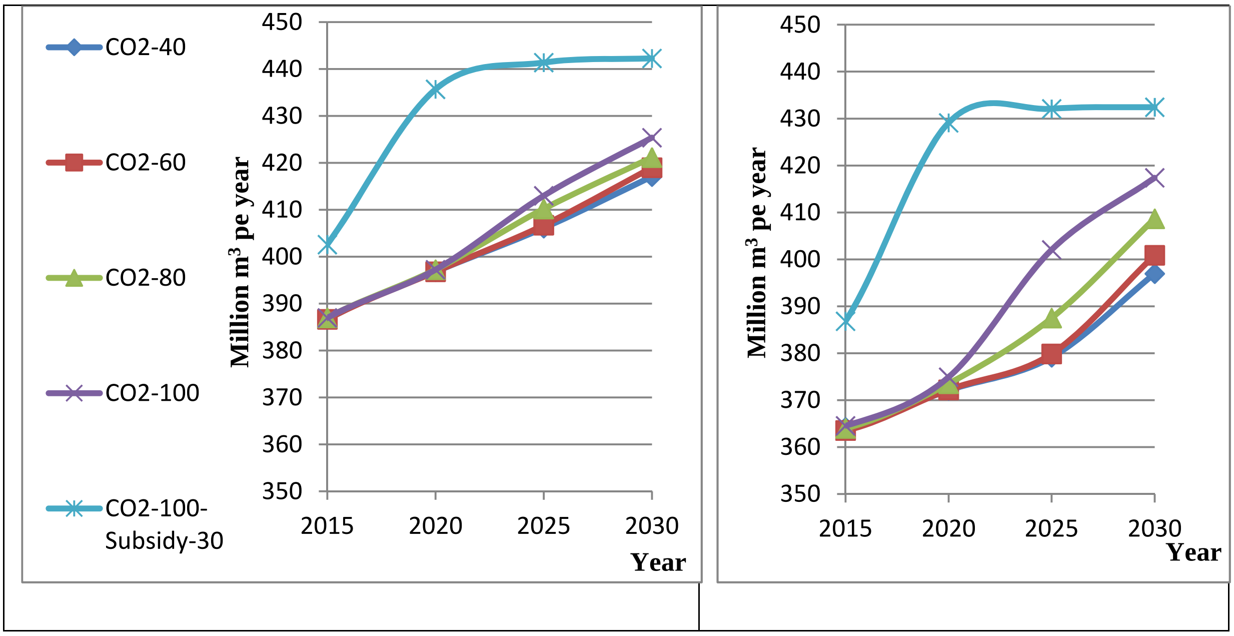

Figure 2.4.1. Projected industrial roundwood harvest development in the EU plus Norway and Switzerland under the High coal & gas prices over the period 2015-2030 for various CO_2 prices and with subsidy level of 30 €/MWh (Left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline). Million m^3 per year.

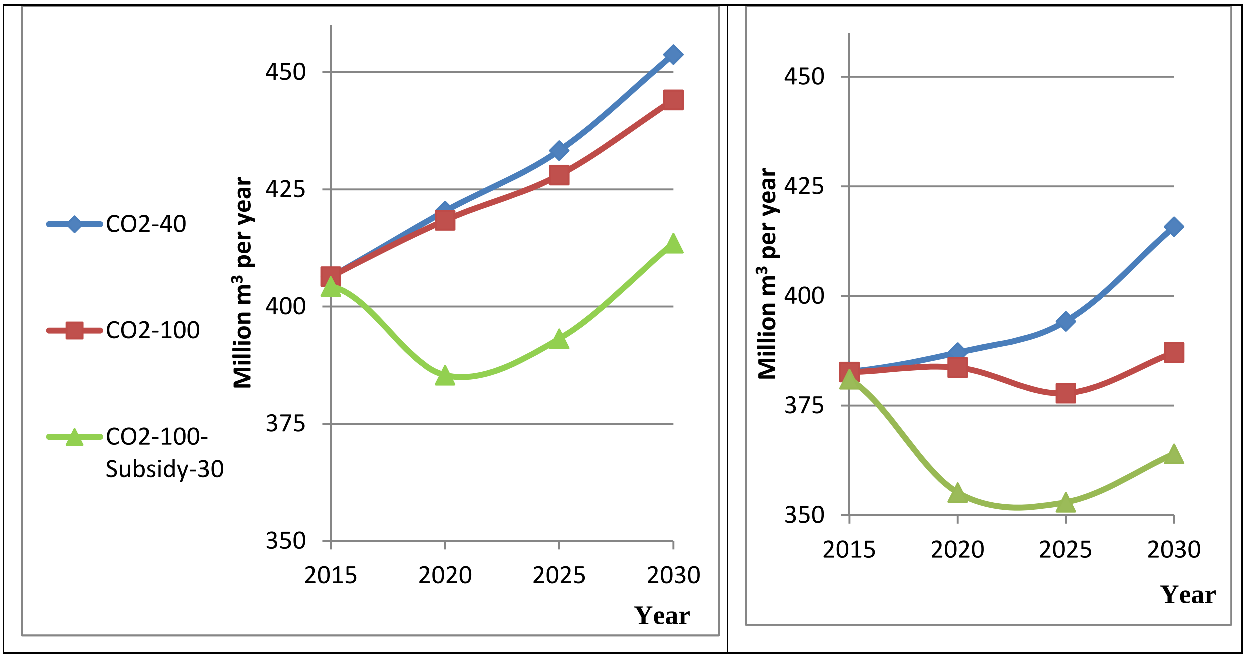

Figure 2.4.2. EU region (with Norway and Switzerland) projected industrial wood use for forest products development under the high coal & gas prices over the period 2015-2030 for various CO_2 prices and with subsidy level of 30 €/MWh (Left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline). Million m^3 per year.

Figure 2.4.2 shows the development of industrial wood used for wood-based products (totals) under different alternative scenarios. Higher carbon prices have a modest impact on the amount of wood used by EU forest products industries, however this becomes much more substantial with a very high carbon price and weakening forest products demand. A subsidy of 30 €/MWh for wood firing and co-firing with coal will cause the most dramatic reduction of wood used for forest products.

Figure 2.4.3 shows the projected pulpwood price development in the EU region. The chart on the left shows harvest development under the main scenario. Increasing CO_2 price up to 100 €/tCO_2 affect the pulpwood price only marginally, while a subsidy for energy has a much more dramatic effect. The same trend is also seen in the chart on the right for the alternative paper demand scenario, except that increasing carbon price has a more substantial effect in the long run.

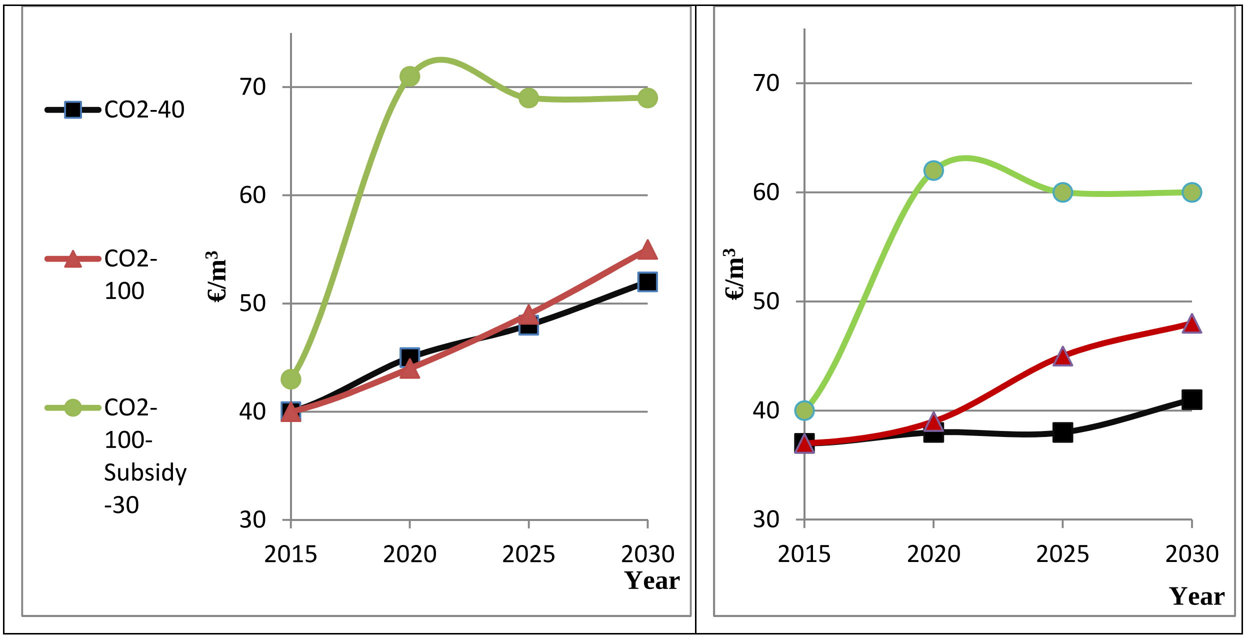

Figure 2.4.3. Projected pulpwood price development in the EU plus Norway and Switzerland under the High coal & gas prices over the period 2015–2030 for various CO_2 prices and with subsidy level of 30 €/MWh (Left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline) €/m^3.

Overall, under the main scenario with the paper demand growing in line with the long-term past trend, increasing carbon emission prices up to the very high 100 €/tCO_2 level combined with the high coal and gas prices have a relatively marginal impact (about 2% reduction in 2030) on the wood-based industry production and a marginal impact on EU harvest (2% increase in 2030). A subsidy of 30 €/MWh to the wood-based energy sector will have a much more pronounced impact on the European wood-based industry: there is a 10–12.5% reduction in 2030 relative to the low carbon price scenario without subsidy, depending on the paper demand development, a 6–9% increase in harvest level in 2030, about a 30–60% increase in the pulpwood prices, and EU wood imports will grow by 6–9 times (see Figure 2.4.4). Additional wood imports are projected mostly from North America, Russia and Latin America mainly in the form of wood pellets and wood chips.

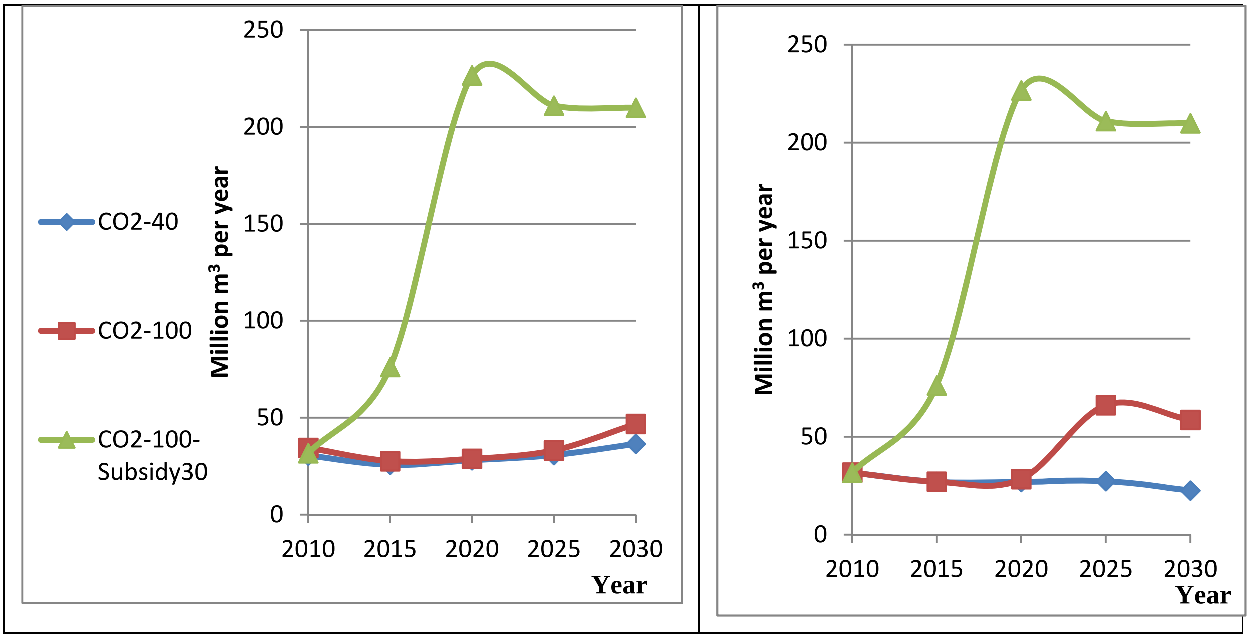

Figure 2.4.4. EU region (with Norway and Switzerland) projected industrial wood imports development under the high coal & gas prices over the period 2015-2030 for various CO_2 prices and with subsidy level of 30 €/MWh (Left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline). Million m^3 per year.

2.4.4. Discussion and conclusion

In this study, the production of wood based electricity and heat is studied under different levels of coal, gas and carbon emission prices, as well as under present and lower demand for pulp and graphic paper. With low coal and gas prices, coal is practically displaced out of the market with a CO_2 price of 80 €/tCO_2. Yet, wood based electricity is then limited to the use of low costs logging residues, and its share is below 2.7% of the total 4100 TWh EU electricity production in 2030 (EC 2011c). With higher coal and especially gas prices coal is projected to be displaced from the market completely only with carbon price well above 100 €/tCO_2. Up to 80 €/tCO_2, production of wood-based electricity does not increase much. It takes a carbon price of up to 100 €/tCO_2, before wood-based electricity production reaches 3.1% of the total market in 2030. Then some 32 million m^3 of industrial wood in addition to 224 million m^3 of logging residues will be used to produce electricity and heat.

An EC report (2011b) estimates that the use of forest biomass for energy will increase by a modest 27% (11 Mtoe – about 40 million m^3 of wood) during 2005–2030. The report is based on the EU PRIMES energy model linked to the GLOBIOM model, which models supply of agriculture and forest biomass. The report projects that the agricultural biomass supply for energy will increase by 85 Mtoe, waste biomass supply will increase by 38 Mtoe over 2005–2030, and that the share of wood biomass from the total biomass use will drop to 25% from the current 50%. The report points at rather high uncertainty related to the agricultural and forestry biomass supply. In the EFI-GTM study, only wood based electricity and heat production is included within the thermal power sector. Inclusion of agricultural and waste biomass supply would decrease the share of wood based power, the magnitude of that impact depending on the relative competitiveness of wood versus agricultural biomass and waste. The ECF report (2010b) projects biomass-waste share to be 10% in 2030 (410 TWh), while the S4 estimate for 80 €/tCO_2 and High coal & gas price scenario (similar assumption as in the ECF report) suggests a share of 2.9% for wood biomass only (119 TWh). This means there is a 29% share for electricity from woody biomass in the total electricity production from biomass (410 TWh). This is somewhat higher than the EC (2011b) estimates, but considering the high uncertainty, the EFI-GTM study estimate of wood based power share is in the same order of magnitude as the EC report (2011b).

Using EU ETS as a main market instrument, only limited amounts of industrial wood are used for energy even assuming a CO_2 price of 100 € per tonne, and forestry biomass for energy supply is mostly coming from logging residues. Under these circumstances, the average price of pulpwood in Europe reaches 55 €/m^3. This is in line with the results in EEA (2007) and Moiseyev et al. (2011), who found supply of wood biomass for energy to be limited to logging residues below 50 €/m^3, and at 60 €/m^3 still being marginal. With the price above 70 €/m^3, energy wood supply was substantially increasing. However, even with the CO_2 price of 100 €/t, the S4 results show that the energy sector will not accept prices much higher than 55 €/m^3 for wood, because then the other options for producing energy, such as gas-fired energy, solar and wind power become more competitive. Also the supply of agricultural biomass including energy crops and short rotation crops can be increasingly supplied for energy at a lower price point. This implies that the share of wood in the total biomass for energy supply may decline in the future.

However, a firm conclusion that use of industrial wood will always be limited to a marginal supply cannot be made, because the wood use is supported by other policy instruments in addition to the EU ETS in the several EU countries, like feed-in tariffs, various kinds of premium bonuses, and subsidies for using wood for electricity and heat. S4 did not analyse feed-in tariffs, but premium bonuses commonly used in some of the EU countries were considered. Even a relatively low subsidy or bonus of 30 €/MWh of electricity (3 eurocents/ kWh) lead in the presence of a relatively low or modest carbon price to substantial increase in the use of industrial wood for energy. The latter increase can be dramatically magnified if the use of pulpwood is simultaneously declining in the forest industry due to lower economic growth and weakening paper demand in Europe and to some extent globally. These energy wood subsidies can increase the supply of wood for electricity and heat more than increasing carbon emission prices. However, they are not cost-efficient from the point of view of reduction of the carbon emissions in the whole energy sector. Depending on prices on coal, gas and CO_2, increased use of wood for energy with subsidies can lead to lower displacement of coal and higher displacement of gas, which emit less CO_2 than coal. S4 results indicate that it would be more efficient to increase CO_2 prices than to use subsidies for wood based energy.

Subsidy for wood based energy is a topic which requires additional analyses. S4 did not examine different options like specific subsidies for using logging residues or wood biomass from short rotation wood plantations (which at present gives a premium bonus for using renewable biomass fuels in electricity and heat production in Germany). However, the inclusion of electricity and heat production within the EFI-GTM model allows for examining different market and policy instruments such as carbon trading systems and using subsidies for energy generation. This opens new interesting applications of the forest sector model which should be pursued in future studies.

2.5 Study 5: Investments into forest biorefineries under different price and policy structures – Kangas et al. (2011)

2.5.1 Background and objectives

Regarding energy, the studies S1, S2, S3 and S4 address the impact of RES and climate policies to wood utilization and forest and energy industries in Europe with particular emphasize on the *heat and power production sector*. The focus in this study (Kangas et al. (2011) – referred to as S5) is a different one, namely the impacts of RES policies on wood based *biofuel production for the transportation sector*. Given this, the study complements the perspectives gained from the previous papers. Although the empirical application is based on only one country (Finland), the policy implications and insights generated are supposed to have general relevance also to other countries having extensive forest resources and large pulp and paper industries.

The production of liquid biofuels from biomass in second generation *biorefineries* is a key issue in the renewable energy debate. A widely used definition for a biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass (Cleveland and Morris 2006). From an economic and market perspective, it is essentially a multiple input–multiple output production unit that uses renewable biomass in an efficient way. In a *forest biorefinery*, biomass can be used for pulp, paper and energy production (electricity, heat, biofuels) as well as for chemicals (turpentine, acids, etc.). The wood-based biomass can be black liquor, pulpwood, chips, bark, sawdust or forest residues.

Currently, there are no pulp and paper plants in Europe that produce second generation biofuels at commercial scale. However, some plants are being built, and others are in the investment planning stage. Thus, in the near future, we will most likely see pulp and paper mills transformed into biorefineries, producing liquid biofuels together with their traditional pulp, paper, electricity and heat production.

There has been discussion on many alternative policy designs to induce investments into second generation biofuel production, and one can expect that the cost-effectiveness and indirect impacts of these policies vary. The EU has mandated an overall requirement of 10%

share for non-fossil energy of the overall petrol and diesel consumption by 2020 (European Commission 2008). Moreover, separate member states of the EU have explicit liquid biofuel production or consumption targets. For example, Finland has set a 12% (7 TWh) consumption target for 2020, and the objective is to reach the target to a large extent by liquid biofuel production in pulp and paper integrated forest biorefineries (Ministry of Employment and Economy 2010).

However, there are also some concerns related to promoting liquid biofuel production. For example, using agricultural land for biofuel production may decrease food production and increase food prices globally. This concern was also a major reason behind the EU updating of its biofuel policy in 2012, when the European Commission published a proposal to limit global land conversion for biofuel production. As a result, the use of food based biofuels to meet the 10% renewable energy target of the Renewable Energy Directive will be limited to 5%. This is to stimulate the development of alternative second generation biofuels from non-food feedstock, forest biomass or waste, which do not directly interfere with global food production.

Another concern is that the use of woody biomass for biofuel production may have the same type of negative side impacts to the profitability to forest industries as discussed in S2, S3 and S4: Increasing demand for forest biomass tends to increase the price of wood, and therefore, may reduce the profitability of forest industries using the same raw material. However, a significant difference in the biofuel case, is that the pulp and paper industry most likely will be also the producer of biofuels, and the potential impacts are therefore less clear. Due to the synergies between pulp and paper and biofuel production, the overall impacts may not be negative for the pulp and paper industry, despite increasing wood consumption and prices.

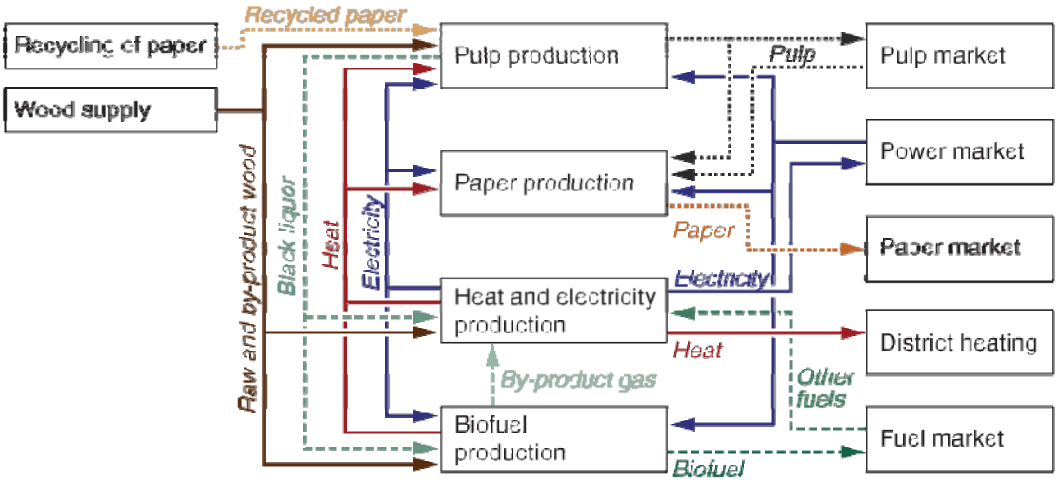

Figure 2.5.1. An example of the wood and energy flows in a forest biorefinery Source: Kangas et al. (2013).

Most of the previous research on forest biorefineries has been technology focused**.** This study – S5 (Kangas et al. 2011), is to our knowledge the first one to link the pulp and paper markets with the investment possibilities for different forest biorefinery technologies, and to analyse the impacts of RES policies to biofuel production and wood biomass utilization. Because of the large number of different options available for forest biorefineries, it is important to analyse how different policy instruments and raw-material and energy price levels influence the choice of forest biorefinery investments. For example, at what energy price and subsidy levels are forest biorefineries profitable? What types of raw-material, technology and end-product mixes are most profitable? What are the impacts to wood consumption and prices?

The study (S5) addresses these questions by analysing the levels of fuel price and policy instruments (subsidies) that are needed to reach the targets Finland has set for biofuel production (7 TWh in 2020). The setting is based on actual plant level data from the pulp and paper industry and the energy market in Finland in 2008, whereas the data for biofuels production were taken from engineering literature (for details, see Kangas et al. 2011).

Three different policy instruments are studied:

1) *Production output subsidy:* A price premium is given on top of the biofuel price for all the biofuel units produced (by wood or black liquor).
2) *Production input subsidy (for forest residues):* Subsidy is received for each wood fibre unit of forest residues used in biofuel production (i.e. only forest residues are subsidised - not any other type of forest biomass).
3) *Investment subsidy:* A share of the investment costs is paid by the government (for both wood and black liquor).

The study analyses the impacts of these policy instruments on the total policy costs, addressing the following questions: First, which policy instrument generates the overall policy target (7 TWh biofuel production) at minimum cost to the government (taxpayers)? Secondly, what are the policy instruments' impacts on the quantities of wood biomass going into biofuel production, and on the pulpwood prices?

2.5.2 Methodology

Similarly to S2, S3 and S4 the methodology of Kangas et al. (2011) is based on partial equilibrium simulation modelling. The numerical optimization is based on microeconomic theory and the practical technical conditions of the producers studied. The model is formulated as mixed complementarity problem (MCP), which is a way of generating models for mixtures of equations and inequalities. Mixed Complementary Problem, first introduced to GAMS by Rutherford (1995), is basically a method that can be used to solve linear and non-linear equations and complementarity problems. The main advantage of an MCP formulation lies in its flexibility and speed solving complex economic models. It also allows for policy analyses where the policy instrument value is endogenous and has been used for a variety of engineering and economic problems (for technical details see Kangas at al. 2011). This model, i.e. the Finnish Forest and Energy Policy Model (FinFEP), or its variations, has been used in several other studies (Kangas et al. 2009; Lintunen et al. 2010; Mäkelä et al. 2011).

The model incorporates economic theory (markets) with rather detailed technical and realistic description of the production processes. Different Leontief production functions for pulp, paper, biofuel and CHP production are determined and used exogenously in the model. Biofuel production can be based on two different technologies: wood or black liquor gasification. Producers are assumed to maximize profits at plant level. The model computes equilibrium levels of: (i) pulp, paper, biofuel and heat *supply*; and (ii) wood and pulp *demand*. Wood transport costs are assumed to increases as a square root of wood use. This reflects that the longer the distance the producer needs to transport the wood raw material, the higher the total costs will be. Also, it is assumed that the marginal biorefinery investment cost decrease as the size of an investment increases. No international trade is included.

The policy simulations are based on the following policy setting. First, it is assumed that the government sets a biofuel production target of 3, 6 or 9 TWh per year, which would amount to about 5%, 10% or 15% of the total transport fuel consumption in Finland. Given these targets, the paper analysed the levels of biofuel price and of the three policy instruments that are needed to reach these targets. The required subsidy levels are calculated endogenously for biofuel prices ranging from €20/MWh to €50/MWh. In comparison, the average crude oil price in 2008 was about €38/MWh (or 91$/barrel). As a reference case, also the results with no biofuel policy targets or subsidies, i.e. no policy case, were presented.

2.5.3 Results

Figure 2.5.2 shows that the biofuel production capacity investments are close to being profitable in Finland, but support is needed to induce the investments. One clear result is that in order to reach the policy targets for biofuel production with minimum costs to the government (taxpayers), the *production subsidy* (a price premium) should be used. The reasons behind this result are that with the production subsidy, the producer can freely choose its mix of inputs since none of the inputs is in a privileged position. In the case of the input subsidy, only forest residue is subsidised, and being the only input which allows for profitable large-scale production of biofuel, this subsidy is distorting the optimal mix of inputs. Extensive use of only one input leads to high transportation costs, inducing high marginal production costs.

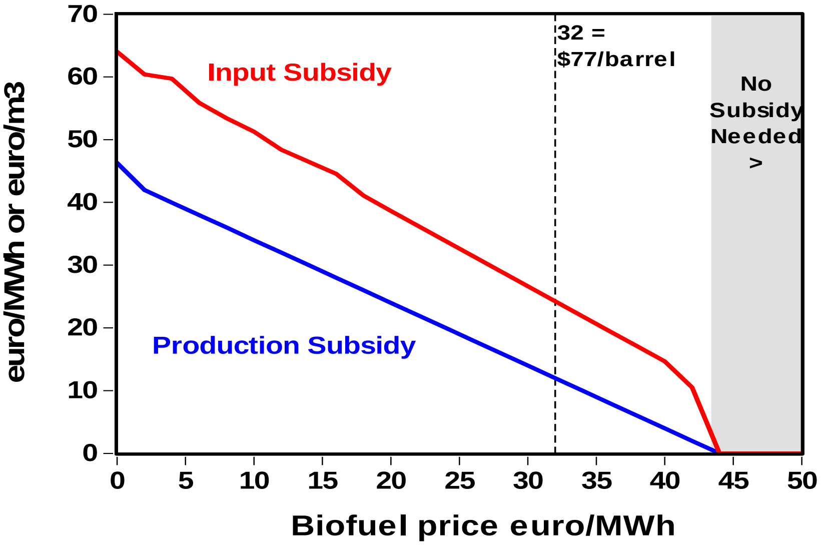

Figure 2.5.2. Subsidies needed to achieve 6 TWh (≈10%) output of biofuels at different biofuel market price levels.

However, a drawback with the production subsidy is that since the investment costs for biofuel production are notable, and there is uncertainty about the biofuel price, the producers might not be willing to invest in biorefineries. This problem could be avoided if a fixed price for biofuels were guaranteed for the producers. In this case, the production subsidy would change with the biofuel price. The production subsidy would be equal to the difference between the fixed price and the market price, and would be similar to the feed-in premiums in renewable electricity production. According to the model results, the fixed price should be between €43 and 45 €/MWh, depending on the biofuel production target.

The analysis shows that typical investment subsidy levels, which amount to a 30–40% share of the total investment costs, can only induce investments if the biofuel price is already at a fairly high level (above €40/MWh). This is due to the high variable (running) production costs of biofuel. According to the model results, the direct *investment subsidy* is usually the most costly subsidy for the government. The rational for this is the following: For the investment subsidy, the production of biofuel has low profitability when the biofuel prices are under €40/MWh. Thus, the level of the investment subsidy needs to be high. The high rate of subsidising gives incentives for not utilizing the economies of scale observed by the firms, and therefore, the firms invest in relatively small units with high unit costs of investment, resulting in inefficiently small biofuel production units and high subsidy costs. Consequently, the investment subsidy may not be the optimal policy for promoting biofuel production from the policy makers' perspective. However, the policy-makers may appreciate the single payment nature of the investment subsidy. Moreover, from the company perspective, the investment subsidy may be a desirable policy, since it decreases the risk of the investment by lowering the investment costs.

With the *input subsidy,* the number of pulp and paper mills investing in biofuel production was slightly higher (usually by one plant unit) than with the production subsidy, because the input subsidy encourages the use of wood residues rather than a mix of raw materials. Using only one wood fibre type, in turn, favours smaller plants because of higher transportation costs. The model results also indicate that, the higher the government *investment subsidy* share is, the smaller the biofuel production unit tends to be. Therefore, high investment subsidy shares (over 40%) distort the economies of scale resulting in inefficient small-scale biorefineries, and thus increase the direct costs of the policy to the government.

The use of wood fibre types varied for the different policy instruments. Under the input subsidy, the use of wood for liquid biofuel production consisted only of forest residues, whereas under the production and investment subsidies, the use of wood fibre was more diverse and even small amounts of pulpwood were used in the production. However, the policies had only small impacts on the total wood consumption of the pulp and paper industry in the short run, because the use of wood for biofuel production amounted to only a small part of total wood consumption in the industry. The total wood use in the pulp and paper sector increased around 1%, 3% and 6% compared to the reference case with no biofuel production for the targets of 3, 6 and 9 TWh respectively.

The production and investment subsidies increase the price of pulpwood by about 2-4% compared to the input subsidy. This would reflect negatively on the profitability of the pulp and paper industry and, therefore, it would, ceteris paribus, be in the interest of the industry to favour the input subsidy over the other subsidies.

On the other hand, the biofuel production subsidies cause a decrease in the wood use in CHP and heat production because the competition for the wood resources increases, and alternative fuels (coal, peat, oil) for energy production exist. This leads to higher CO_2 emissions in the CHP and heat production, since emission neutral wood is partly replaced by fossil fuels. The increase in CO_2 emissions is about 10% for all subsidies and targets. Thus, the climate benefits from greater liquid biofuel production are partly offset by higher emissions in other energy production.

2.5.4 Discussion and conclusions

The model results show how important it is that the goals of the policies are made clear when choosing policy instruments, as the optimal policy depends on the policy objective. Table 2.5.1 illustrates this, ranking the policy instruments for two different policy objectives: The first objectives (column 1) is to minimize the costs of implementing the policy; and the second (column 2) consists of maximizing the forest residue utilization and, therefore, minimize the impacts on pulpwood prices. It was found that the *investment subsidy* and the *input subsidy for forest residues use* are more costly policy instruments for the government than the *production subsidy*. However, if the policy goal is also to increase the use of forest residues or secure the profitability of the pulp production, the input subsidy could be the optimal policy. On the other hand, if the goal is purely to minimize direct policy costs, the production subsidy would be the optimal choice.

Table 2.5.1 Policy Targets and Ranking of the Policy Instruments.

Minimize Policy Costs	Maximize Forest Residues Use + Minimize Impacts to Pulpwood Price
1. Production subsidy	1. Input subsidy
2. Input subsidy	2. Investment subsidy
3. Investment subsidy	3. Production subsidy

One of the shortcomings of this paper is that the impact of *climate policies* on biofuel production was not analysed, because the main user of liquid fuels, i.e., the transportation sector, was not included in the model. Therefore, the possible increases in carbon prices and their direct impacts on transportation fuel prices could not be analysed. Tighter climate policy in the transportation sector would most likely imply higher CO_2 emission prices, and therefore higher fuel prices (both fossil and biofuel), which in turn would lower the subsidy prices that are required to make forest biorefinery investments profitable. On the other hand, tighter climate policy would also lead to decreased pulp and paper production and thus the sector's biofuel production opportunities would be weakened.

Indeed, including the transportation sector in the model would be an interesting extension of the current study. Additionally, since only the biofuel production in the pulp and paper industry was examined, the increase in wood use, for example, in the pellet production is not addressed. If also the other targets for increasing wood use for energy production had been included simultaneously with biofuel production targets, there would most probably be increased scarcity of forest resources. This would imply higher wood prices and thus higher biofuel production costs, and therefore also higher subsidy levels would probably be required. Therefore, extending the study to analyse simultaneously various wood energy production targets would be important.

In summary, the study emphasise that one has to be careful when using the results for policy advice. Obviously, the results of policy simulation models are as good as the model and data. The models can never give a perfect representation of reality. Still, the policy simulation models are helpful analytical tools for assessing policies. Particularly, they are helpful in revealing complex linkages, feed-back effects and trade-offs between different policy instruments and economic sectors, which might be difficult to identify otherwise. They also help to quantify the possible policy impacts. Even if the absolute magnitudes of these quantity impacts should be regarded cautiously, they provide consistent information about the relative magnitude of the impacts between different policy instruments.

3. SYNTHESIS AND DISCUSSION

The five studies reviewed here show how many-sided and complex the RES policy framework and its implications to forest and energy sectors are. There are many interlinkages and feedback effects between different industry sectors. Just to take one example, a pulp mill can produce pulp for paper products, dissolving pulp for textile industry, gas for district heating, or biodiesel for transportation. Given a specific RES policy, such as feed-in-tariff or investment subsidy, the incentives and impacts created for these products typically differ, and may also lead to new trade-offs between them. If we consider simultaneously also the potential impacts of the policies to the *wood products* and *energy industries*, which both may be acting in the same forest biomass raw material markets as the pulp mills, the possible outcomes get even more complicated. In short, besides their direct objectives and impacts, the RES policies tend to have important indirect economic impacts. The latter are often difficult to see at first hand, and they can lead to unwanted side impacts.

Due to the above mentioned complexities, the implications of the study results and the main reasons behind them, are not obvious. The purpose of this study was to review these studies and interpret the results in a way that can be utilized for policy support purposes.

Differences and similarities in methodology and scope

The five studies examined have one aspect in common: They all investigate potentials for wood-based bioenergy and the impacts of RES policies on forest biomass markets. Four of the studies focus primarily on the EU level, and the heat and power bioenergy production. However, Kangas et al. (2011) differs from these in that it focuses only on one country (Finland), and on *biofuels* for the transportation sector. In many respects, the studies complement each other, and make it possible to draw a more complete picture than before of the potential impacts of RES policies for EU forest biomass demand and supply, and of market implications. Here, we seek to provide a synthesis of the studies, and point out main similarities and differences between them.

The EUwood study's (S1) objectives and approach are rather different from the other reviewed studies. It seeks to give an overall macro picture of what happens to forest biomass demand in the EU, if forest industry development continues along the present long run trend, and EU and national governments impose the 20-20-20 targets and RES polices. It does not consider the economic impacts of these policies and does not account for market mechanisms which make demand meet supply through price adjustments. Also, for simplicity, it assumes EU to be “a closed world”, and does not take into account the potential impacts of the international trade to EU forest biomass markets. In contrast, the other four studies are much more focused on market and economic impacts and incentives created by different types of RES and climate policies at a more detailed level. Moreover, three of the studies (S2, S3 and S4) also take into consideration the impacts of international trade.

The studies differ regarding which products are included, and regarding geographical coverage. S5 includes only Finland, does not incorporate sawmilling as provider of chips, and looks primarily on the production of biofuel in interactions with pulp and paper and CHP production. It is a first attempt to analyse the RES policies within this type of a setting, i.e. a forest biorefinery that produces second generation biofuel. This type of plants does not yet exists in markets, but will be a fact already in 2014 (see Footnote 5.).

S2 includes chips, pellets and CHP as wood based bioenergy productions, whereas S3 and S4 include in addition the competition between coal and wood in CHP productions. S4 includes also natural gas in this competition and takes into consideration the production of solar and wind energy. S2, S3 and S4 are the only ones which account for possibilities for imports from Russia and other world regions outside the EU.

On the other hand, S5 is the only one dealing specifically with the impacts of choice of bioenergy policies, i.e., how the impacts differ between the polices, and what would be the costs of the policies to government/taxpayers. The latter is naturally an important aspect, especially in the current economic situation in EU where governments seek to cut budgets. S4 has a sub-case where impacts of subsidies to wood harvest versus bioenergy production are compared. S4 is also the only one considering a decline in printing paper demand. This allows e.g. to assess how this decline will impact forest biomass supply and prices, which in turn, have important implications to forest bioenergy potentials.

S2, S4 and S5 apply recursive optimisation in the meaning that all investments decisions in a given year are based on the costs and prices in that year – i.e. imperfect foresight is assumed. S3 applies dynamic optimization and thus assumes perfect foresight. This is done for the investments in forest industries and energy production (not forestry, which is exogenous). This makes it possible to study how expectations of different future developments may influence the investments to forest products and bioenergy production and the use of resources in these.

With these differences in mind, it is interesting to see to what extent the results are similar and support each other, or whether the results point to different conclusions.

What can we say about the long-term forest biomass demand in EU?

Of the five studies, the scope of S1 is by far the most extensive and comprehensive one. It is a landmark study which has been extensively referred to in other research publications, policy planning and stakeholder reports. In particular, much attention has been given to the EUwood study (S1) projection showing that there would be a very large increase in forest biomass demand in EU up to 2030. This projection has, in turn, raised concerns that EU may not have enough forest biomass to support the RES policy target, or that it can only be reached at the cost of compromising sustainability, such as a decrease in biodiversity. However, one of the major conclusions rising from this review, is that the other four studies, as well as the critical review of S1, points to the possibility that the EUwood study projection for forest biomass demand may significantly overestimate what actually could be expected. Our review presents several factors that are likely to limit this demand and probably cause a significantly lower consumption of forest biomass originating in the EU countries in 2030, than projected by S1 Thus, it is of high interest to look in more detail into these differences and the implications for the EU forest biomass demand.

S1 is a synthesis of many different studies, model projections, assumptions and expert analysis, which together form and provide projections for potential demand and supply of forest biomass for EU in 2020 and 2030. The study is a very important and helpful wood balance projection. It provides a framework for all woody biomass and the possibility to calculate many key numbers for a better understanding of woody biomass and wood consumption within the complex structure of EU wood flows.

The main results from S1 are the following. The medium scenario projects a 73% increase of forest biomass demand in EU27 from 2010 to 2030. As such, the demand is projected to be 28% higher than the supply of wood biomass in EU in 2030. The largest demand increase for woody biomass comes from heat and power producers. It is assumed that by 2030, woody biomass would come 59% from forests and 41% from other wood biomass (like building constructions through cascading use).

S1 also points to the significance of energy efficiency of the wood biomass energy production technology. According to the study, each 1% increase in wood energy efficiency reduces total wood demand in the EU 27 by 7.5 million m^3. Thus, a 20% increase in efficiency would imply a decrease of 150 million m^3 in wood biomass demand. This would already account for almost half of the excess demand projected for 2030.

According to the medium scenario, EU27 wood biomass resources as a whole would not suffice to reach the targets for renewable energy. “This means that without additional measures, forests and other sources of wood in EU cannot maintain their large share as a renewable energy source without leaving a shortage for the forest-based industries” (S1, p. 33)

S1 provides basically a “gap projection”. That is, it is an accounting balance-sheet approach, in which the end result can be an over-supply (credit) or excess demand (deficit) of woody biomass. In the markets, there is no such credit or deficit, but the demand and supply would balance through prices and trade. In that sense, the study generates an outcome that markets (or economic analyses) would not generate. Thus, it would be important to consider also the market adjustments through changing prices and trade flows. Moreover, S1 assumes implicitly that "mobilisation" will produce the demanded quantities of wood, leaving unanswered questions like: Why would forest owners supply significantly more roundwood than they do today without getting higher stumpage prices? Theoretically, it is possible that e.g. subsidies to forest owners could increase significantly the forest biomass supply, but subsidies would need to be accepted politically in countries which today have severe budget problems, and they may also be found distorting the international wood markets. In some cases, subsidies may even violate the EU directives, and cannot be implemented.

Also, when using S1 results to draw implications for the actual future development, it is important to acknowledge the fact that the study does not include any impacts of international trade. Increased imports of bioenergy feedstock to EU (e.g. from Canada, USA, Russia) is already a fact. Similarly, for the material usage, such as paper products, increasing hardwood pulp imports from South America and Asia are likely. Thus, it is likely that not all the new demand for forest biomass would be supplied within the EU region, but also imported from outside the region.

The other drawback is that S1 is based on the premises that forest industry development in EU up to 2030 would follow very much the same patterns as in the 20th century. However, as shown in the review of S1 in this paper, there has been a significant structural break in these markets, and both the consumption and production of communication papers and pulp are likely to decline, not increase in EU.

For example, if one assumed that the future would, on average, continue on its course as in the past 10 years (2003–2012), and a linear trend projection is made, the EU paper production would decline to about 82 million tonnes and pulp production to 30 million tonnes by 2030. As result, the pulpwood demand would also be about 110 million m^3 lower than projected by the study S1.

In summary, there are a number of reasons that give concerns that the projection of the use of woody biomass from EU harvests in 2030 in S1's medium scenario is significantly overstated. The main reason for this is that S1 does not consider the need for market clearance (price impacts), the impact of international trade, and the structural changes taking place in global and European forest products markets.

What are the impacts on markets and prices?

The studies S2-S5 complement the picture provided by S1 in particular by taking into considerations the markets and prices. The pulpwood prices are of highest interest, as it is through these prices that the direct competition between the traditional forest industries and wood-based energy is likely to be the strongest. The studies S2-S5 look at the pulpwood price development based on different settings or assumptions, due to which also the results differ (see Table 2.5.1). The main reasons for the differences in price impacts is the fact that incorporating more substitution possibilities for wood-based bioenergy (like S3 including coal and S4 incorporating both coal and gas) and allowing for international trade, moderate rather strongly the pulpwood price increases.

In S4, in the scenario which assumes decreasing demand for pulpwood because of lower demand for graphic papers, we see a significant decrease of the pulpwood prices and a corresponding increase of the quantities of wood going to bioenergy.

S5 in particular, but also S4, show that the choice of policy instruments is very important regarding how much wood-fibre the energy sector will use. Even a relatively low subsidy to the bioenergy production leads to substantial increase in the use of industrial wood for energy. Interestingly, S4 also shows that the subsidies to forest bioenergy production cause a much larger increase in the consumption of forest biomass for bioenergy purposes, than even rather large increases in the CO_2 prices.

Of the five studies, only S1 considers alternative forest management options, using three reductions from the theoretical maximum potential (high, medium and low - see Chapter 2.2.1), but this is done independently of the wood demand development over time. Thus, no dynamic optimisation to simulate optimal forest management adaptations is made in any of the five studies. In reality, the wood markets adjust over time to new information obtained and new expectations, and the model analyses, in particular S2–S5, may therefore underestimate the quantities supplied and overestimate the corresponding wood prices on this aspect.

Future research needs

To assess the potential impacts of RES policies to forest biomass, forest products, and bioenergy markets, it appears in our opinion necessary that also partial equilibrium modelling is applied. The strength of this type of models is that they can reveal many of the cross-sectoral impacts, feedback effects and trade-offs which would be difficult to quantify consistently without such models. Indeed, without this type of analysing tools, there is a high risk that major RES policy implications are not taken into account, and as a result misinformed or even misleading conclusions may be taken. Also, including rather detailed sub-models of forestry and forest industries seems necessary. Interesting research extensions of the studies reviewed in this report would be to enlarge the model framework to include i.a.:

- Other wood-based energy carriers like torrified wood, pellets and liquid biofuels
- Parts of the energy sector most relevant for bioenergy
- Parts of the transportation sector most relevant for bioenergy
- International trade between EU regions as well as between EU and other world regions.

- Consistent links to general equilibrium (GE) modelling (GE models cannot be as detailed as partial equilibrium models, but provide consistency with other sectors of the economy).

- Possibilities to account for changing market conditions and long-term structural changes. In the likely case that not all important structural changes are possible to incorporate into the partial equilibrium models, there is a need also to supplement the analysis with other approaches, as e.g. suggested by Hurmekoski & Hetemäki (2013).

It is of high interest to see how expectations may influence the investments in forest industries and in the alternative options to use wood for energy. This would demand more use of dynamic optimization modelling, e.g. as in S3 and Sjølie et al. (2011).

Another research challenge is the simultaneous analysis of different renewable energy targets and polices, such as emission trading and various subsidies and mandatory targets. One special aspect here is to be able to take into account the potential coherences or conflicts between RES policies and climate policies. In order to do this, the policy simulation models need still further developments, like to better combine the various forest industry and bioenergy sectors to the simultaneous impacts of these policies.

Finally, the results are as good as the model and the data used. It is important to get as accurate data as possible on the production costs and investments for various bioenergy options. For some interesting bioenergy productions (e.g. torrifaction, or pulp and paper mill integrated biofuel production), an additional challenge is the lack of empirical data because no commercial scale plants yet exist. Data has then to be taken from the engineering literature, and this implies special caution.

4. CONCLUSIONS AND POLICY IMPLICATIONS

Conclusions

This report has reviewed and summarized five recent studies on the implications of the EU or national RES policies to the forest and bioenergy sectors in Europe. The purpose has been to synthesize recent scientific results and their implications to policy. Also, we have pointed out needs for further knowledge.

It is not straightforward to compare the results between the studies, partly because different methodologies, regional scope and background assumptions (including basic assumptions on variables like economic growth, energy production efficiencies, trade, wood sources included, etc.), and partly due to terminologies used. However, some conclusions seem rather robust.
The studies which account for competition of wood energy with other energy forms and account for international trade, project the most modest increases in pulpwood prices, and thus the highest increases in the quantities of wood going to bioenergy in the EU. Assuming decreased demand for pulpwood because of lowered demand for graphic paper, results in lower pulpwood prices, and increased quantities of wood processed to bioenergy.

The review indicates rather clearly that the choice of policy instruments to promote bioenergy influences much the energy sector's use of wood-fibre. It is also shown that subsidies directed to one bioenergy sector (for example biodiesel production) may harm other wood-using sectors like heat and power productions, as well as the pulp production , and thereby increase the abatement costs of climate change.

High uncertainty prevails over the future development of the use of energy wood. The level of carbon price and its future path, which depends heavily upon future agreements and polices, will have a large impact on the development of future use of wood for bioenergy. Due to high investment costs required for increased bioenergy production capacities, expectations on the directions of future climate policies are decisive for how much the energy sector will invest in the use of wood for bioenergy. Early signals for higher future carbon prices lead to higher investments. Nevertheless, all studies – except perhaps S1 - indicate that the contribution of wood harvested in EU is bound to be modest in achieving the EU RES target. Furthermore, the carbon prices or subsidies to woody fuels need to rise to quite a high level before the competition between the energy sector and the forest industries over forest biomass starts to affect the production levels of the forest industry.

The studies S2-S4 and our review of the EUwood study (S1) indicate that in the next 10-20 years the EU demand for forest biomass from the EU region may be significantly lower than suggested by S1's medium scenario. The S1 results have been influential and widely referred to, and have in part helped to form a view that there will be a shortage of woody biomass in this region. Although, based on the approach used in S1, it makes sense to project a shortage or gap between supply and demand of forest biomass in EU, in reality in a market economy such a gap is unlikely. This review points to several issues that are likely to lead to lower demand for forest biomass harvested within the EU than projected by S1. The arguments behind this can be summarized specially in the following three factors:

> F1: The structural changes in global and EU forest products markets are likely to result in a significantly lower demand of forest biomass for industrial purposes than projected by S1.
>
> F2: Due to international trade, EU already imports considerable quantities of forest biomass, both for forest industry and bioenergy purposes. These imports are likely to increase in the future, given that the markets and policies in EU provide needs and incentives for this.
>
> F3: Forest biomass markets, bioenergy production and the traditional forest industry production react to market signals, such as the prices of raw material and end products. The studies S2-S5 show that these market adjustments may be significant, and that they clear also the potential gaps between supply and demand for forest biomass. For example, the potential price increases of forest biomass decrease its demand.

Policy implications

One clear implication rising from this review is that there is a need to update the assessment and outlook of EU forest biomass markets by taking into account the three factors outlined above. This is not only important for getting a better picture of the potential supply and demand balance in EU forest biomass markets, but also for analysing many of the indirect impacts that the three factors may cause. Just to take one example to illustrate the latter point: The factor F1 above is, among other things, likely to cause significantly lower productions of graphics paper in EU than previously widely expected, and also projected by S1. This will in turn reduce the pulp production and the demand for pulpwood. However, the lower pulp production will also have implications to the EU 20-20-20 target, since pulp mills are major producers of bioenergy – i.e., the targets will be harder to reach. On the other hand, lower pulpwood demand tends to decrease the price of pulpwood, which again may induce higher demand of pulpwood for bioenergy purposes. What becomes the *net impact* of this to the EU 20-20-20 target, and the EU forest biomass balance, would need further analyses.

Considering factor F3 listed above, it seems likely that the shortage of forest biomass for bioenergy purposes in the EU will be smaller than projected by S1. Therefore, also the pressures for new bioenergy capacity not finding raw-material, or negative trade-offs to forest biodiversity in EU, may not be as large as indicated by S1. However, many challenges stay, and even new ones arise. For example, the factor F2 is likely to raise new concerns for policy makers. If the RES target is triggering woody biomass imports for bioenergy purposes to EU, it is clear that these imports should meet the same sustainability standards as forest biomass from EU has (Muys et al. 2013). Through what type of polices would that be guaranteed?

This review also illustrates how complex and many-sided the impacts of RES polices to forest and bioenergy sectors can be. For example, it is very easy and tempting to consider only the direct RES policy impacts. However, as the studies S2-S5 show, the devil is often in the details. The RES polices may also have many indirect distorting impacts, such as causing inefficient bioenergy production. For example, this was the implication in S5, which indicated that investment subsidies to new biorefineries may result in too small production units, thus giving reduced scale efficiencies and suboptimal plant sizes.

Moreover, S5 demonstrated that different RES polices used for the same purpose tend to have different impacts, and cause trade-offs between policy targets. For example, a RES policy that is optimal on basis of minimizing the costs of the policy to taxpayers, may be the worst policy if the objective is to minimize the side impacts to forest industry (see Table 2.5.1). Therefore, the policy maker should have clear priorities, and be aware of and willing to accept trade-offs.

This study and the studies we have reviewed do not explicitly address the issue of sustainability and climate (carbon) neutrality of forest biomass bioenergy production. At the time of writing this, it is a hot topic both in the policy and science arena (see, e.g. Bracmort 2013 for a review). It is also a very complicated issue, and it is not likely that simple and widely applicable generalizations can be found on this issue (Muys et al. 2013). Forest biomass production can be based on many different raw material sources, different technologies to produce bioenergy, and it may produce different end products (heat, power, transportation biofuels or a combination of these). Also, the reactions of forest owners to RES policies may change their forest management practices, which in turn may have significant carbon sequestration implications (Sedjo 2011). As a result, the energy efficiencies and climate (carbon) impacts of RES policies and wood based bioenergy production may vary greatly. Clearly, there is a strong need for further studies that syntheses the best scientific knowledge we have about the issue of forest biomass carbon neutrality, and points out the importance and implications to policies.

There is also a clear need for further research to assess the outlook for EU forest biomass markets, and the impacts of RES and climate policies to bioenergy and forest product markets. This research should preferably include even more detailed forest sector modelling than applied in the studies reviewed, incorporating forestry dynamics, the complete forest industries, different types of technologies for producing wood-based bioenergy (including pellets, torrified wood, liquid and gaseous biofuels), international trade, and various types of policy instruments. These studies should preferably be complemented with foresight analyses that address also possible structural changes and new products for which we do not yet have data (Hurmekoski and Hetemäki 2013).

In summary, the policy makers are in a very difficult position. The operating environment for RES and climate polices is very complex, and there are still many uncertainties related to the scientific information that could support such polices, as this review also has demonstrated. Yet, it is likely that the policy makers do not have much time to wait until more solid scientific evidence becomes available, as they need to act now even with incomplete information. In such a case, and based on the already available studies, it would be advisable to consider the possibility that the EU demand for woody biomass harvested within the EU region, may be significantly lower than has generally been thought.

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