The pulp and paper overview paper

Sector analysis for the Climate Strategies Project on Inclusion of Consumption in Carbon Pricing

Overview paper

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About the Project

A project led jointly by Climate Strategies and DIW Berlin has been exploring whether inclusion of domestic sales of selected energy intensive commodities (e.g. steel) in domestic emission trading schemes is an effective and feasible approach towards restoring the carbon price signal in these sectors, without damaging competitiveness. It has been delivered by a multidisciplinary, international team of researchers from a number of institutions, representing various fields (EU law and institutions, climate policy and economics, energy market and infrastructure policy and economics).

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About Climate Strategies

Climate Strategies is an international organisation that convenes networks of leading academic experts around specific climate change policy challenges. From this it offers rigorous, independent research to governments and the full range of stakeholders, in Europe and beyond. We provide a bridge between research and international policy challenges. Our aim is to help government decision makers manage the complexities both of assessing the options, and of securing stakeholder and public consensus around them. Our reports and publications have a record of major impact with policy-makers and business.

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Executive Summary

Pulp and Paper sector dynamics driven by demand development

The European pulp and paper sector has undergone significant consolidation since the turn of the century. While in the lead up to the European economic crisis in 2009, production of pulp and paper was rising on the back of larger more efficient mills, since 2007 production has declined and remained below the pre-crisis level. Further, paper and paperboard consumption has not recovered from the pre-crisis levels, but rather has continued to decline, partly due to digitalization.

Economic development in Asia has triggered growing demand and thus a shift of global demand. While Europe is a net importer of pulp, the net export of paper has, however, steadily grown over the last decade. With declining demand volumes, the sector anticipates and some companies actively explore opportunities in higher value papers, such as coated fine papers for magazines and advertisement, which are, however, also under pressure from digitalization. Further prospects for the pulp and paper sector are expected from the bioeconomy; for example food-packaging and pulp-based fabric.

Opportunities for pulp and paper production from climate policy

Climate policy could trigger more mitigation opportunities for the sector than might be otherwise anticipated. Globally, the pulp and paper industry is the fourth largest industrial energy consumer. Energy costs make up, on average, 16% of total production cost. Reported carbon emissions of the sector are low because over half of the energy used (55%) comes from biomass and most of the rest from natural gas (38%). This explains why, despite the pulp and paper sector is a very energy intensive, reported carbon intensity is low.

With new production processes, a share of the biomass used for heat in the pulp and paper sector could be freed up for use in other sectors, thus reducing carbon emissions there. Given the overall shortage of biomass, any biomass saved in the sector could be used in other sectors, if there is market demand, for example meeting peak power demands, providing raw material for bio-plastics and securing low-carbon energy for transport.

Technological options to realize these mitigation opportunities can be structured in three groups: (1) improving the carbon efficiency of the current machinery stock; (2) production process changes; and (3) new low-carbon machinery. However, to date most of the efforts have focussed on increasing energy efficiency and increased use of biomass residuals for heat and power generation. This may be partially linked to the commodity type nature of the product and the focus on short-term cost minimization by producers. But such efforts will not be sufficient to reach the long-term decarbonisation of the pulp and paper industry.

Areas that need further attention and issues that may be important

An important issue to ensure material efficiency and to avoid market distortions is that the scheme also includes materials that are in close competition to paper products. This concerns for instance plastic and glass as packaging materials, but also electronic products that compete with paper products such as newsprint and graphic paper. Further investigations regarding which products to include are needed.

The focus of the sector on increased use of biomass for heat and power production reflects the nature of the sector, which receives renewable support granted for power produced from bio-energy burned in combined heat and power installations and is rewarded by the EU ETS that considers bio-energy to be carbon neutral. Thus, while energy prices and competitive pressure create incentives for efficiency use of biomass, the EU ETS does not create any such incentives and renewable support even reduces incentive for more efficient use of bio-energy in paper production and efficient paper use.

The energy and climate package for 2030 is now under construction – therefore the next few years will determine climate energy policy in the post-2020 era in the EU. Many options are on the table for EU ETS design with respect to the treatment of biomass and further development of forestry policy. Furthermore the discussions on resource efficiency and circular economy raise the question of whether it will remain economically viable to use biomass for base-load heat provision, rather than as input for bio-materials, fuels for mobile applications, or as storable energy that meets peak heat or power demands.

This raises the question how the policy framework could evolve to strengthen incentives for innovation and use of new material types and production processes. This will likely involve both push and pull policy elements. The discussions on sector road maps – like the CEPI Two Team Project – have initiated a debate on innovative new materials and processes. It needs to be considered whether public support can contribute to an accelerated further development of set of these technology options.

Private leadership and co-funding can help identify credible technology options as well as rapid development and commercialization. This will require a credible business case for larger scale roll out – thus directly raising questions as to how EU ETS and renewable support policies need to be adapted in order to create a level playing field for different commercialized technologies options.

Investors will consider in parallel a set of interlinked policy dimensions including allowance allocation, power price compensation, renewable support provisions and carbon neutrality definitions. They need to therefore be jointly discussed when evaluating policy options, including, for example, the Inclusion of Consumption (IoC) of paper into EU ETS so as to correct for disincentives that result from the use of free allowance allocation for leakage protection purposes.

1. Introduction

The European pulp and paper sector has undergone significant consolidation since the turn of the century. While in the lead up to the European crisis, production was rising on the back of larger more efficient mills, since 2007 production has declined and remained below the pre-crisis level. Paper and paperboard consumption has also not recovered from the pre-crisis levels, but rather has continued to decline such that in 2013, consumption was 17% lower than in 2006. At the same time, European producers are facing increased competition from Asia, which is sometimes driven not only by market fundamentals, but also output and employment targets. These factors are not related to climate change, but make the sector sensitive to climate policy and its impact on competitiveness.

Although energy intensive, the pulp and paper industry has low carbon intensity as biomass, which is considered carbon neutral, dominates the fuel mix. However, if the sector is to achieve its long term decarbonisation goals, increased adoption of Best Available Technologies and energy efficiency measures is required in addition to continued fuel switching and break-through technologies. Hence, any post-2020 reform must provide a clear and long-term perspective, built upon three policy elements. First, an effective carbon price emerging from the European Union Emissions Trading System that is relevant both for producers, to facilitate switching to lower-carbon production, and also for intermediate and final consumers in order to create a viable long-term business case for large-scale investments in lower carbon processes, materials, and efficient use. Second, public funding for innovation and demonstration of breakthrough technologies. Third, institutional adjustments and additional regulatory instruments to facilitate implementation of sector roadmaps.

In this paper we assess the opportunities and challenges for the European pulp and paper sector. We provide a detailed perspective on the sector in terms of production and consumption patterns, international trade, and energy intensity. We then assess the opportunities, drivers, and barriers for greenhouse gas reduction within the sector. Finally Inclusion of Consumption is discussed as a viable option for EU ETS reform with a specific focus on the design opportunities and challenges for the European pulp and paper sector.

2. The current situation of the European pulp and paper sector

Paper products are frequently used in a variety of every day applications, from paper for writing to paperboard as packaging material. In this section we give a brief introduction to the European pulp and paper industry, focusing on different production processes as well as recent trends in production and consumption, trade patterns, energy and carbon intensities.

2.1. Paper products and the production processes

The main inputs for paper and paperboard are different forms of pulp, which in turn are made from wood or other raw materials containing cellulose fibres. In Europe, wood is the main raw material, although in a few cases cellulose material, such as straw, hemp, grass or cotton, is used (BREF, 2013).

Pulp and paper mills can either be integrated or separated. An integrated mill produces pulp on site, while in a non-integrated pulp mill market pulp is dried and pressed before being transported to the paper mill. Since pulp is a product by itself, pulp and paper are treated separately throughout this report.

The pulp for papermaking can be produced from virgin fibre or from re-pulping of recycled paper. To produce virgin pulp, wood logs are first debarked and chipped. Then water and heat are added and by mechanical or chemical means the wood is separated into individual fibres.

Mechanical pulping is primarily used in integrated pulp and paper mills. In this process fibres are separated through the use of mechanical energy. With a raw material conversion efficiency[1] of 45%, mechanical pulping is considered both a simple and efficient process, but with the disadvantage that wood fibres are often damaged (Healy & Schumacher, 2011). Therefore, mechanical pulping is mainly used for weaker paper such as newspaper, printing paper, towelling, tissue, or paperboard. Sometimes chemical pulp is mixed for additional strength. Electricity is the main energy input for mechanical pulping (Worrell, 2007). Mechanical pulp production yields substantial amounts of heat as side product, which can be used for district heating.

Chemical pulp is used both in integrated and non-integrated pulp and paper mills. Through chemical pulping, non-cellulose wood components are removed leaving the cellulose fibres intact (Bajpai, 2012). Hence, chemical pulp is better suited for high quality paper (Healy & Schumacher, 2011). There are mainly two different processes for chemical pulping: Kraft (sulphate) and Sulphite. Black liquor is an energy rich by-product of chemical pulping, which is burned in recovery boilers to produce combined heat and power.

Paper can also be made from **Recycled pulp**, where scrap paper is recovered, shredded, heated, cleaned and de-inked. The resulting product is recycled pulp that can be processed into paper products.

Pulp is made into paper in the paper making process, which roughly can be divided in the following steps (See Figure 1):

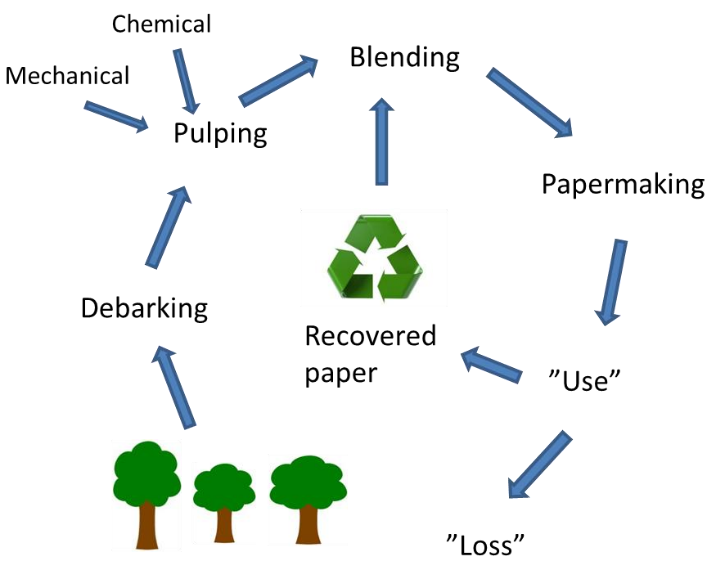
1. Stock preparation. Raw stock is converted into finished stock for the paper machine. This includes blending of different pulps, dilution and addition of chemicals.
2. Paper machine. In the paper machine, water is removed and the papers' properties are developed.

[1] Conversion efficiency refers to how many units of virgin biomass are required to produce a unit of pulp.

3. Finishing and coating. The paper is coated, depending on the desired end product.

Paper products can be split into two broad categories: paper and paperboard. Paper products are either coated with a compound or polymer to deliver a certain quality (weight, gloss, etc.) or are uncoated such as copy (graphic) paper, newsprint, or tissue/sanitation products. Paperboard is similarly treated or processed to deliver specific qualities and is used in case materials, as cartons for consumer products or packaging. Often, a combination of different kinds of pulps is used in the process and a certain product may be produced through different processes.

Figure 1. Paper and Paperboard Production Process



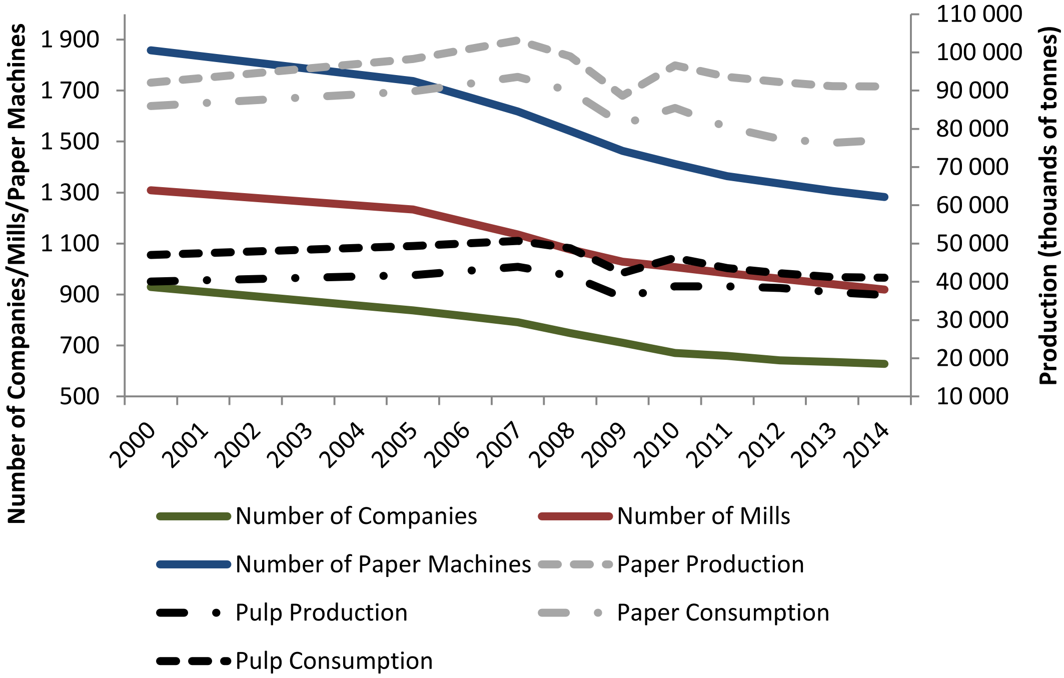
Source: Authors' illustration

2.2. Production and consumption in EU member states

Figure 2 illustrates the evolution of the pulp and paper industry in Europe[2] from 2000 to 2014. Since the turn of the century, there was an upward trend in the production of pulp and paper. For example, pulp and paper consumption grew 14% and production grew 11% between 2000 and 2007 (see Figure 2). Production fell starting with the advent of the financial crisis in 2007. Despite a slight recovery between 2009 and 2010, production remains 13% below the pre-crisis level. This decrease in consumption has been sustained relatively equally over all paper grades.

[2] Data is based on the Confederation of European Paper Industries (CEPI) Statistics. CEPI members include Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom.

Figure 2. Industry evolution, 2000-2014.



Source: CEPI key statistics, 2014.

There has been a steady decrease in the number of companies and the number of paper mills in the European Union since 2000. Technological innovation has reduced labour intensity, which has resulted in reduced employment and increased industry consolidation. Compared to 2000, the number of companies has decreased by 31%, the number of pulp mills has been reduced by 32%, and the number of paper and paperboard mills has decreased by 30% (see Table 1). This decrease was slightly more noticeable during the financial crisis, while a more stable trend has existed since 2012. According to (CEPI, 2011), consolidation will continue with small and medium enterprises supplying local markets.

Table 1. Sector Progress 2000-2014.

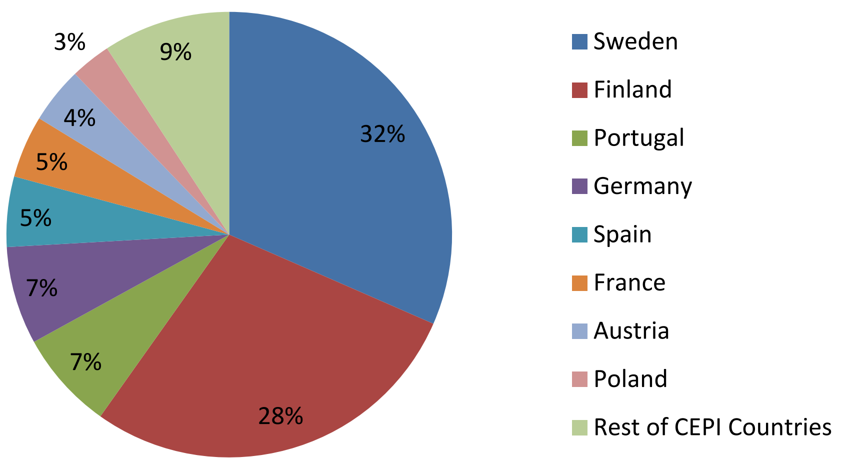
Industry Structure	2000	2013	2014	% Change 2014/2013	% Change 2014/2000
Number of Companies	929	636	628	-1.3%	-32.4%
Number of Mills	1,309	941	920	-2.2%	-29.7%
Pulp	233	164	159	-3.0%	-31.8%
Paper and Board	1,076	777	761	-2.1%	-29.3%
Number of Paper Machines	1,858	1,307	1,283	-1.8%	-30.9%
Employment (Jobs)	279,987	183,690	181,111	-1.4%	-35.3%
Turnover (Million Euros)	79,388	74,987	74,500	-0.6%	-6.2%
Investments (Million Euros)	5,637	3,431	3,500	2.0%	-37.9%
Added Value (Million Euros)	24,413	16,500	16,000	-3.0%	-34.5%
Pulp Production (Million tonnes)	40.0	37.3	36.5	-2.0%	-8.8%
Paper Production (Million tonnes)	92.0	91.1	91.0	-0.1%	-1.1%

Source: CEPI Key Statistics, 2014.

Pulp

In 2014, total European pulp production was 36.5 million tonnes, of which Sweden and Finland contributed the largest shares: 32% and 28%, respectively (Figure 3). Germany and Portugal are also large producers, each contributing 7% of the total European pulp produced. The remaining 26% is spread across 14 countries.

Figure 3. Pulp Production by Country, 2014.



Source: CEPI Key Statistics, 2014.

About a third of the pulp produced in Europe today is market pulp with the rest produced in integrated mills. Within Europe, 72% of total pulp is made from chemical pulping (see Table 2).

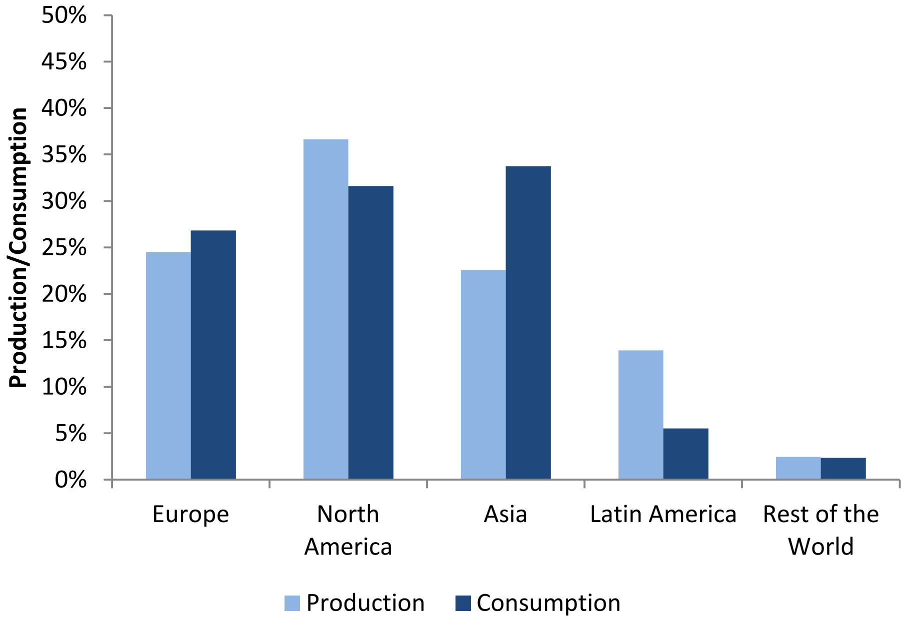
Table 2. Total pulp production in Europe by production process, 2014.

Pulp production process	Total Production (Mt)	Share (%)
Chemical pulp	26.264	71.9
Mechanical pulp	10.109	27.7
Other pulp	0.172	0.5
Total	36.545	100

Source: CEPI Key Statistics, 2014.

Globally the production of pulp is led by North America, which accounts for over one-third of the pulp production and generates an excess supply of 5%. Europe and Asia follow, each with close to one fourth of global pulp production (see Figure 4). The overall production of pulp in 2014 equalled 178.5 million tonnes, with total consumption equalling 179.6 million tonnes.

Figure 4. Pulp Production and Consumption by Region (worldwide), 2014.



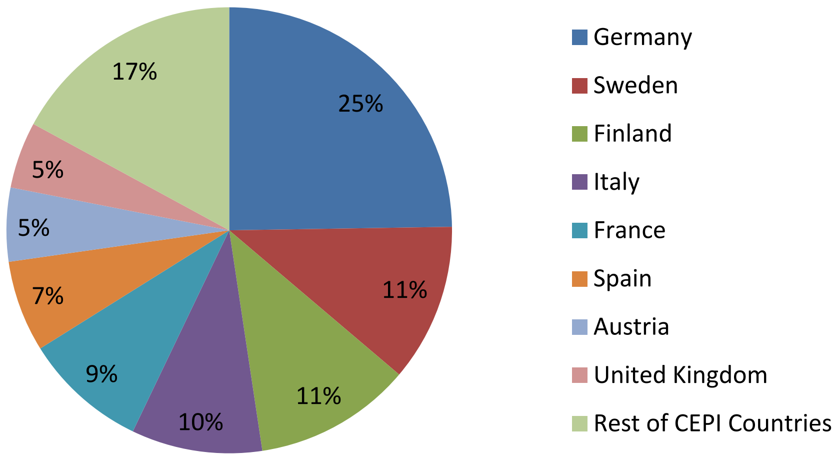
Source: CEPI Key Statistics 2014.

Based on a survey by the Food and Agriculture Organization (FAO, 2015), stable trends for pulp production are expected over the next five years. Specifically, global capacity is expected to increase 5.9%, while European capacity is expected to increase only 1.6%. Global capacity growth is driven largely by Brazil and Russia, which expect a 48% and 18% expansion, respectively. Despite lower European capacity growth as a whole, large capacity growth is expected in France and Spain of 14% and 8%, respectively.

Paper

Total European paper and board production was 91.1 million tonnes in 2014. In that year Germany was the leading country for paper production with 25% of the production, while Sweden and Finland each provided 11% (Figure 5). These three countries combined accounted for almost half of the European paper production. Figure 5 also shows other important producers: Italy (10%), France (9%) and Spain (7%).

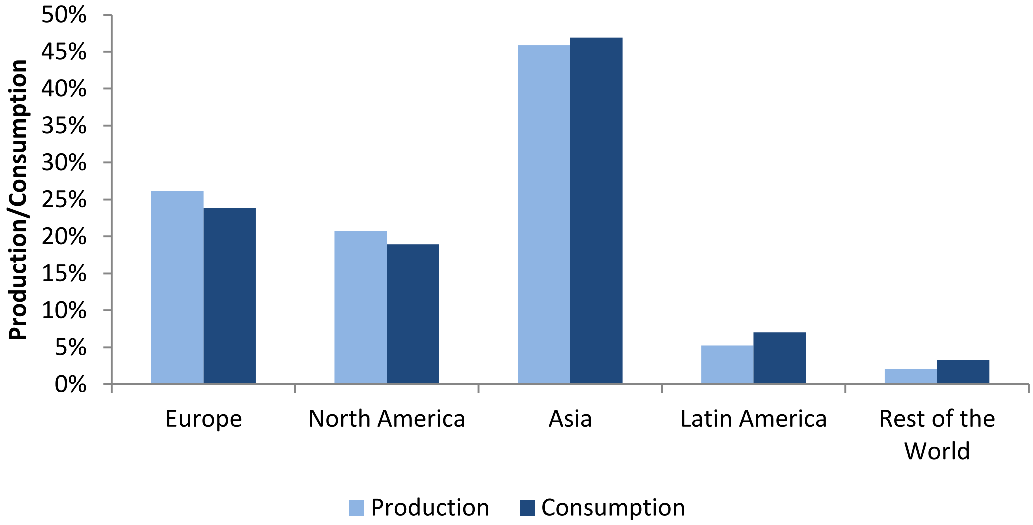
Figure 5. Paper and Board Production, CEPI Countries, 2014.



Source: CEPI Key Statistics, 2014.

Globally, the production of paper and board in 2014 was 406 million tonnes, with 407.6 million tonnes consumed. Asia is the leader in both production and consumption with about 45% in both categories (see Figure 6). European production represents 26%. In contrast to the pulp sector, in Europe paper and paperboard production is slightly higher than its consumption. In term of future capacity, future trends in the paper and board industry show a stable production over the next five years (FAO, 2015).

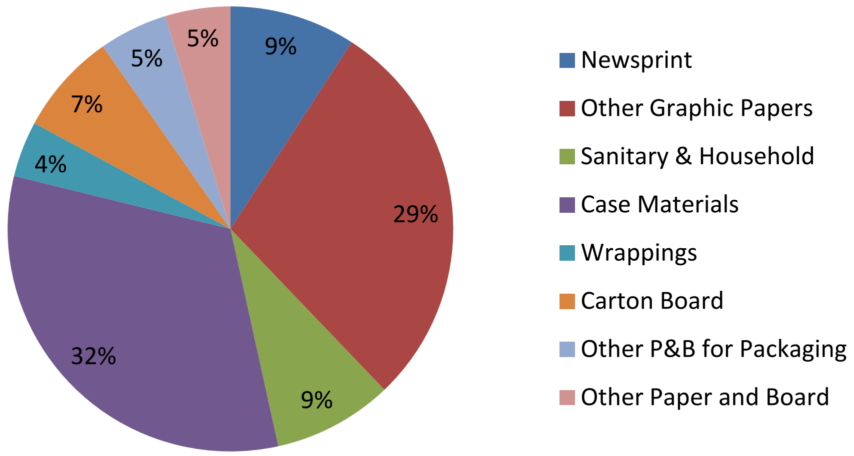
Figure 6. Paper & Paperboard Production and Consumption by Region (worldwide), 2014.



Source: CEPI Key Statistics, 2014.

Figure 7 describes the shares of different paper grades in European paper. Packaging paper represents almost half of all paper products consumed. Graphic papers and newsprint consume 29% and 9%, respectively. Sanitary and household paper products represent only 9% of consumption. However, this paper grade is expected to increase due to changes in consumption patterns associated with the ageing population. Conversely, newsprint and other graphic papers are expected to decline in more developed digitalized economies. However, this decline could be offset by increased demand for graphic papers by emerging economies (Hetemäki, et al., 2014).

Figure 7. CEPI countries paper consumption in tonnes, by paper grade, 2014.



Source: CEPI Key Statistics, 2014.

2.3. International trade

There is significant international trading with pulp and paper products. In short, Europe mainly imports low quality products, such as market pulp and newsprints, while exporting high quality products such as coated paper. Key trends in international trade are discussed below.

Pulp

Europe imports considerably more pulp than it exports. Trade of pulp between Europe and the rest of the world is mainly focused in exports to Asia and imports from Latin America and North America (Figure 8). Comparison between years shows that Europe has shifted away from imports from North America toward Latin America. Furthermore, exports of pulp to Asia have increased since 2000. Finally, total net pulp imports have decreased by around 2 million tonnes since 2000 to a total value of 4.7 million in 2014.

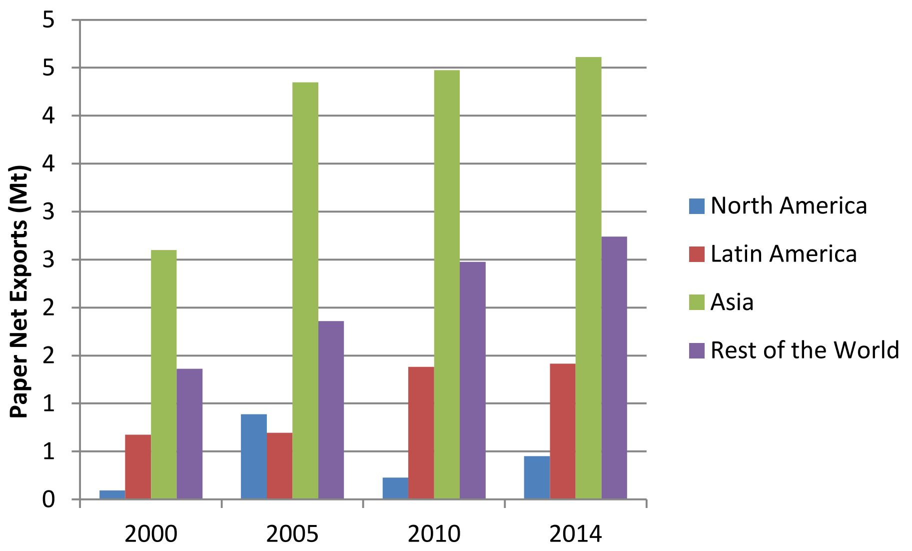
Figure 8. EU Pulp Net Imports by region, 2000-2014.

Source: CEPI Key Statistics, 2014.
Note: CEPI Countries only. Trade flows between European countries not represented here.

Paper

In contrast to pulp, Europe exports around 9 million tonnes more paper than it imports. Net exports have grown steadily over the last decade, with net exports in 2014 almost double that of 2000. Growth has been enjoyed in the Asian, Latin American and Rest of the World markets (Figure 9). While net exports are relatively low for North America, this is not to suggest that there is little trade between the regions. In fact, trade flows between North America and Europe totalled almost 3.5 million tonnes in 2013, with European exports offsetting imports from North America by around half a million tonnes.

Figure 9. EU Paper and Paperboard Net Exports by Region, 2000-2014.



Source: CEPI Key Statistics, 2014.
Note: CEPI Countries only. Trade flows between European countries not represented here.

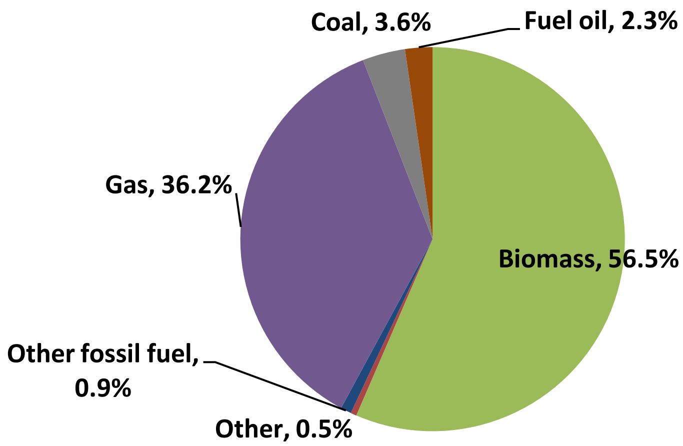
2.4. Energy intensity

Globally, the pulp and paper industry is the fourth largest industrial energy consumer (IEA, 2008) after iron and steel, chemicals, and non-metallic minerals. Production of pulp and paper requires energy input in the form of heat and electricity. On average, energy costs make up 16% of production costs (CEPI, 2014), but can be as high as 30% at specific sites. Therefore, rising energy costs are a concern for the industry.

Based on overall totals of energy and production data, specific primary energy use in the European pulp and paper industry was 13.3 GJ per tonne market pulp and paper and paperboard. This includes 1.8 GJ per tonne of specific net bought electricity. In 2013, the industry produced 51% of the electricity it consumed (CEPI, 2014). Most of the electricity produced (96%) originates from Combined Heat and Power (CHP) generation. It has, however, been estimated that only 40% of CHP potential is installed (JRC, 2011).

At the European level more than half of the energy used by the industry originates from biomass, with most of the rest coming from natural gas (see Figure 10). The pulp and paper sector is one of the largest producers of bioenergy, generating 20% of bioenergy used in Europe (CEPI, 2012). That said, energy sources vary for different countries, depending on, above all, availability of biomass (see Table 3). Sweden, Portugal and Finland have the highest share of biomass in the fuel mix while Italy, the Netherlands and the UK have the lowest.

Figure 10. Fuels consumption in 2013



Source: CEPI Key Statistics, 2014.

Table 3. Average fuel mix in selected EU countries for the period 2005-2007

	Coal	Gas	Fuel oil	Other fossil	Biomass	Waste
Austria	7%	45%	2%	0%	46%	0%
Belgium	7%	33%	11%	1%	48%	0%
Czech Republic	16%	19%	5%	0%	59%	0%
Finland	0%	14%	4%	6%	73%	2%
France	5%	40%	5%	0%	51%	0%
Germany	13%	62%	2%	NA	21%	2%
Italy	0%	95%	5%	0%	0%	0%
Netherlands	0%	97%	0%	0%	2%	0%
Poland	25%	3%	4%	0%	69%	0%
Portugal	0%	15%	10%	1%	74%	0%
Slovakia	18%	23%	0%	0%	59%	0%
Spain	1%	62%	5%	0%	32%	0%
Sweden	0%	1%	9%	1%	89%	0%
UK	6%	88%	1%	0%	5%	0%

Source: Ecofys, 2009.

Energy use in pulp production

Energy use in the pulping production process depends on the particular pulping process, properties of the raw material and the quality demands of the end product (Ecofys, 2009).

There are several types of processes that can be used for **mechanical pulping** (see Table 4). Only a fraction of the mechanical energy supplied to the process is used for pulping. Therefore heat is recovered in the form of hot water and steam. This heat can be used for other purposes in the processes e.g. drying in the paper machine or generating hot steam for use in the paper machine (for integrated mills) or in district heating. According to Ecofys (2009), the Thermo-mechanical pulp (TMP) process can be a net energy exporting process.

Table 4. Energy consumption and recovery of energy in mechanical pulping.

Mechanical pulping technology	Energy consumption (kWh/t) for oven dry pulp[1]	Recoverable energy (hot water) %	Recoverable energy (steam) %[2]
Groundwood pulp	1100-2300	20-30	20
Thermo-mechanical pulp (TMP)	1800-3600	20	40-80
Chemi-thermo-mechanical pulp	1000-4300	20	40-45

Source: 1Ecofys, 2009; 2BREF, 2013

The specific energy consumption in **chemical pulping** varies depending on the process used. Both Kraft pulping and Sulphite pulping are energy-intensive, but the Sulphite process demands greater fuel input (see Table 5). In both the Kraft process and the Sulphite pulping process, energy can be recovered. Modern non-integrated Kraft pulp mills are energy-self-sufficient, primarily because of energy recovery when burning the by-products such as bark and black liquor as a fuel (BREF, 2013). For Kraft pulping, lime kiln is an integral part of the process, which can result in emissions from the use of fossil fuel, but also process emissions. Sulphite pulp mills are around 90% self-sufficient, mainly because of energy recovery from burning incoming wood and the use of auxiliary boiler fuel (BREF, 2013).

Table 5. Best-practice specific heat consumption for the production of virgin pulp.

Chemical pulping technology	Heat consumption[1] (kWh/adt)[2]	Electricity consumption (kWh/t)[3]
The Kraft (sulphate) process	2777-3888	600-800
Bleached Sulphite pulp	4444-5000	550-750

[1]Converted from GJ/Adt to kWh/adt

[2]Source: Ecofys, 2009

[3]Source: BREF, 2013

To give an example of energy distribution in pulp mills, for bleached Kraft pulp making, the major heat consumption steps are the cooking process (15%), evaporation (30%) and pulp drying (20%) (Ecofys, 2009). Pulp drying is, however, avoided in an integrated mill.

Recycled paper is often used as input in integrated pulp and paper mills. Recovered fibres account for more than 50% of the total raw materials for European paper manufacturing (CEPI, 2014). For pulping of recycled paper, cleaning of contamination is needed and sometime deinking, depending on the end product. Processing of recycled fibre requires energy use, with the average heat demand at about 0.3 GJ/adt (Ecofys, 2009).

Energy use in paper production

Energy intensity varies between different technologies and paper products. Energy use in the papermaking process is concentrated in the paper machine. The energy use depends, among other things, on the specific grade of paper to be produced and the fibre quality (Ecofys, 2009). Tissue products and coated fine paper have the highest final energy intensity (see Table 6).

Table 6. Final energy intensity for different paper products (excluding electricity use)

Raw material	Product	Process	Fuel use for steam (kWh/Adt)[1]
Recovered paper		Recovered paper processing	83
pulp	Uncoated fine paper	Paper machine	1800-2500
	Coated fine paper	Paper machine	1944-3055
	Tissue mill	Paper machine	1527-2083
	Newsprint	Paper machine	1416
	Board	Paper machine	1861
	Containerboard	Paper machine	1638

[1]Converted from GJ/Adt

Source: Ecofys, 2009

An example of energy use in the different processes in papermaking is provided in Table 7. The table illustrates average specific energy consumption, focusing on the papermaking process only, for different products with virgin pulp and recovered pulp as input in the Netherlands. Pre-drying is the most energy intensive process representing on average 49% of all energy use.

Table 7 Average specific energy consumption per process for four different paper grades in the Netherlands

	Deinking (GJ/adt)	Dispersion (GJ/adt)	Other stock prep (GJ/adt)	Wire and press (GJ/adt)	Pre-drying (GJ/adt)	Coating/ sizing/ laminating (GJ/adt)	After drying (GJ/adt)	Other processes paper machine (GJ/adt)	Total (GJ/adt)
Board	0	0	1.0	1.5	4.5	0	0.3	0.3	7.5
Graphical	0	0	2.8	1.5	4.7	0.2	2.6	0.7	12.5
Tissue	0.8	1.5	3.3	1.9	6.9	0	0.0	0.3	14.7
Other	0.6	0.4	1.1	1.5	4.9	0.1	0.5	0.4	9.4

Source: Laurijssen et al, 2013

Energy use in integrated production

Integration of pulp and paper mills results in energy savings due to reduced need for drying the pulp and opportunities for better heat integration (Worrell, 2007). Table 8 illustrates energy intensity values for different products in an integrated pulp and paper mill.

Table 8. World Best Practice Final Energy Intensity Values for Integrated Pulp and Paper Mills (values are per air dried metric tonnes)

Raw material	Product	Process	Fuel use for steam (KWh/adt)[1]	Electricity (kWh/adt)
Wood	Bleached Uncoated Fine	Kraft	3889	1200
	Kraftliner and bag paper	Kraft	3889	1000
	Bleached Coated Fine	Sulphite	4722	1500
	Bleached Uncoated Fine	Sulphite	5000	1200
	Newsprint	Thermo-mechanical process	-361	2200
	Magazine paper	TMP	-83	2100
	Board	TMP	972	2300
Recovered paper	Board (no deinking)		2222	900
	Newsprint		1111	1000
	Tissue (deinked)		1944	1200

Source: Worell, 2007

3. Low-carbon technologies: options and incentives

3.1. Technical options for mitigation

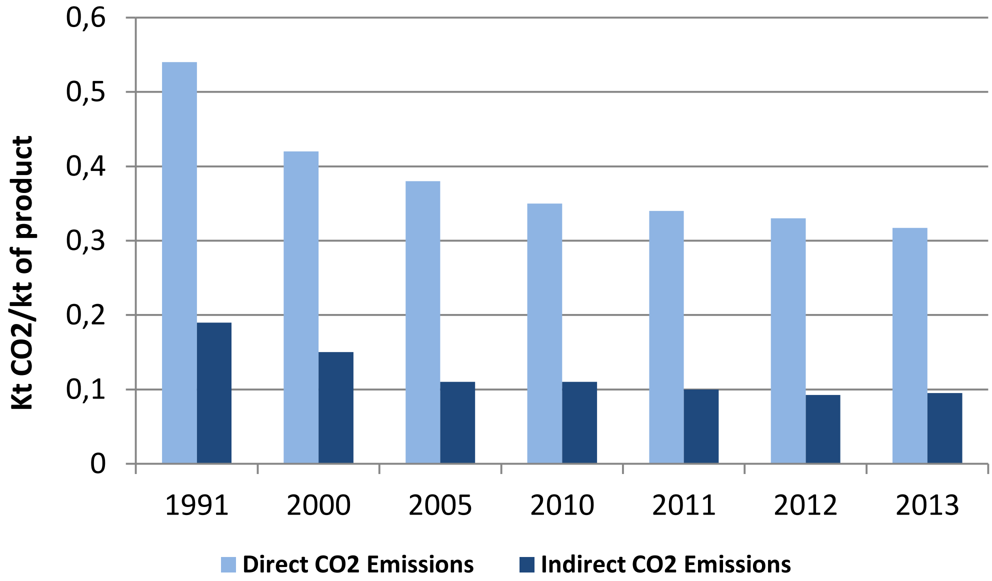
Emissions of greenhouse gases in the pulp and paper industry come mostly from the combustion of on-site fuels and non-energy related emission sources (for example, by-product CO_2 emissions from the lime kiln chemical reactions and CH_4 emissions from wastewater treatment). In addition, emissions of GHG associated with the off-site generation of steam and electricity contribute to the indirect emissions of the pulp and paper sector.

Although the industry is energy intensive, carbon intensity is relatively low compared to other sectors, since biomass dominates the fuel mix. In 2013, the sector was responsible for around 43 million tonnes of CO_2, of which 33.2 million were direct emissions and 9.8 million were indirect (through power use, see Figure 11). When production levels are taken into account, this translates to a direct emissions intensity of 0.32 (kt CO_2/kt product)[3] and an indirect emissions intensity of 0.1 (kt CO_2/kt product).

[3] CO_2 Emissions are the fossil emissions produced by the pulp and paper mills and connected energy plants.

Despite increasing production, the sector has achieved a 20% reduction in CO_2 emission intensity since 2000 (Figure 11). The sections that follow discuss how adoption of more efficient technologies, fuel-mix change and increased recycling has assisted the sector to decarbonise. We then turn to address breakthrough technologies that could assist the sector achieve more ambitious mitigation targets.

Figure 11. Emissions from pulp and paper Production, 1991 - 2013.



Source: CEPI Key Statistics, 2014.

3.1.1. Enhancing energy efficiency in conventional production processes

Opportunities for mitigation

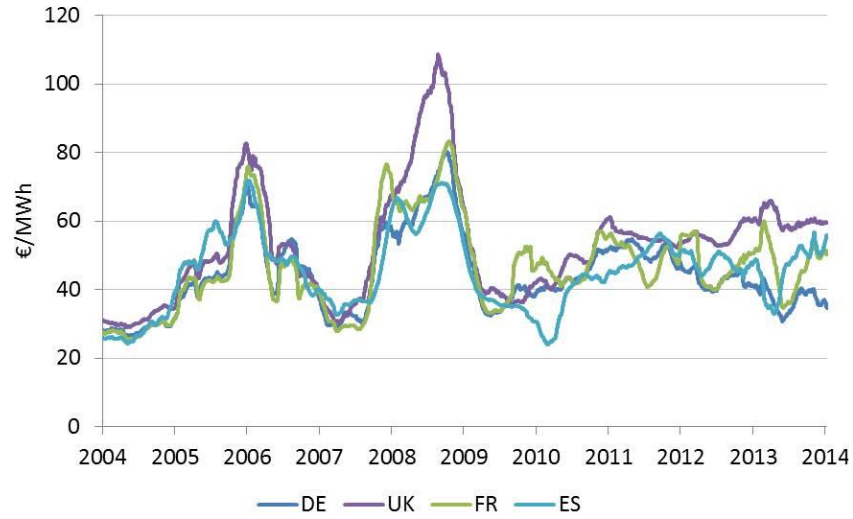
Within the pulp and paper sector, implementing Best Available Technologies (BATs) offers emission reduction opportunities. The opportunities can be divided to (1) improving the carbon efficiency of the current machinery stock; (2) production process changes; and (3) new and more efficient machinery. In particular, the carbon efficiency of the current machinery stock can be improved by improving the energy efficiency. Many of these BATs have low to medium investment costs with relatively short payback periods. As an example, it is estimated that upgrades to burners and burner controls could reduce emissions in the United Kingdom pulp and paper sector by 2.4% and have a modest payback period of around a year and a half (WSP, 2015). The production process changes include, for example, shifts to less energy intensive pulping. The mitigation options that require a replacement of the machinery stock, for example boilers that can also use renewable electricity[4] or improved paper machines

[4] Boilers that are powered from electricity.

can be expected to come to markets over the coming decades. According to CEPI (2011), the full adoption of BAT should be complete by 2050 and will result in a 25% emissions reduction compared to 2010. A summary of BAT and the expected emission reductions is found in table 9 below.

Improved processes control can also enhance the performance of existing equipment by optimising the energy use to production ratio. According to (WSP, 2015) improved process control could reduce variability in energy consumption over the operating time of a paper mill while at the same time increasing production.

Figure 12. European power prices 2004 to 2014.



Source: EEX Spot, APX Power UK Spot Base Load Index, EPEX SPOT, OMEL-Elec. Spain Baseload

Table 9. Available technologies for pulp and paper production processes.

Process	Mitigation options	Reduction potential
Boilers	Burner replacement, Boiler process control, Reduction of excess air, Blow down steam recovery	12.5% Emissions
Chemical Recovery Furnaces	Black liquor solids concentration, Quaternary air injection, Improved composite tubes for recovery furnaces	30% Energy 20% Fuel[5]
Turbines	Boiler/steam turbine CHP, Combined cycle CHP, Steam injected gas turbines	14% Electricity
Natural-Gas Fired Dryers and Thermal Oxidizers	Selection of technologies requiring less fuel consumption, Proper design and attention to monitoring and maintenance	
Kraft and Soda Lime Kilns	Piping of stack gas to adjacent PCC plant, Lime kiln oxygen enrichment	7-12% Fuel
Makeup Chemicals	Practices to ensure good chemical recovery rates in the pulping and chemical recovery processes	40% Energy
Flue Gas Desulfurization Systems	Use of sorbents other than carbonates, Use of lower-emitting FGD systems	
Wastewater Treatment	Use of mechanical clarifiers or aerobic biological treatment systems (instead of anaerobic treatment systems), Minimization of potential for formation of anaerobic zones in wastewater treatment systems	
On-site Landfills	Dewatering and burning of wastewater treatment plant residuals in on-site boiler, Capture and control of landfill gas by burning it in onsite combustion device (e.g., boilers) for energy recovery and solid waste management	

Sources: (CEPI, 2011) & (Ernest Orlando Lawrence Berkeley National Laboratory, 2009)

Key Drivers

As European paper manufactures face an increasingly competitive environment, they will seek to reduce production costs, including energy costs. As detailed in Figure 12, electricity prices have been volatile since the turn of the century and are on an upward trend. Given the energy intensity of the sector, European paper manufactures are exposed to both electricity price increases and price hikes. In response to these competitive challenges, fuel mix change, shifting away from fossil fuel based electricity (discussed below), reducing energy consumption and optimising energy use across the production process has occured.

Ericsson et al. (2011) assess the impact of increasing electricity prices on the Swedish pulp and paper sector. According to the authors, increased electricity prices triggered the industry to develop new energy strategies and may explain the increased

[5] Industrial Efficiency Technology Database: http://ietd.iipnetwork.org/content/pulp-and-paper

investments in onsite electricity, in combination with other factors such as the green certificate system. For example, the industry's onsite electricity production increased from 851 MWh in 2000 to 1060 MWh in 2007 (Ericsson, et al., 2011). In addition, the industry supplied a greater share of heat delivery to municipal district heating.

The pulp and paper sector is also covered under the EU ETS. At the current prices below 10 € /tonne CO_2 it is difficult to assess to what extent carbon prices affect investments in BAT. For example Rogge et al. (2011) state that the EU ETS has had a very limited impact on the innovation activities of German pulp and paper sector.

Although the EU ETS has not to date had a significant effect on carbon mitigation measures, it has played a role in mitigation in the sector. For example a study by Gulbrandsen & Stenqvist (2013) highlights that even though EU ETS has not triggered innovation for low carbon solutions, it has reinforced commitments to improve energy efficiency and reduce carbon dioxide emissions. Moreover, activities for monitoring and accounting for CO_2-prices have become more significant. In that way, the EU ETS can have a signal value. With the introduction of the Market Stability Reserve, the EU has shown that it is committed to reducing carbon emissions and that carbon pricing is here to stay (European Union, 2014).

National policies have also driven adoption of more efficient production technologies as well as the increased public focus on climate mitigation. Sweden offers an informative example. Increased energy efficiency and increased use of locally produced bioenergy, such as bark, are the main reasons for the dramatic decrease of carbon emissions in the Swedish pulp and paper industry. However, it is unclear if this development has been driven by energy efficiency policies. The Swedish Program for Improving Energy Efficiency (PFE) was a voluntary agreement for electricity intensive industries.[6] Participating industries received a tax reduction on electricity in exchange for improvements in electricity efficiency. For the pulp and paper industry the program resulted in energy audits that led to process innovations and strengthened environmental management system (Scoradato, et al., 2013). Scorado et al. (2013) note that the PFE resulted in significant investments from the industry, according to the Swedish Energy Agency. Investments of €36 million took place during the first phase, 2004-2009. The effect from the program is, however, debated and it is unclear whether the investments would have taken place even without participation in the program. Swedish industry representatives explain that these investments probably would have happened anyway but took place earlier because of the PFE.

In a comprehensive study of the United Kingdom paper industry, three barriers to the adoption of BAT were identified (WSP, 2015). First, uncertainty regarding the impact of new technologies on machine operability, with known technologies being favoured in new investment choices. This is linked to the integrate nature of the paper machine where many parts must operate in sync, making incremental adjustments with new technologies difficult. Second, a lack of awareness and limited access to information regarding new technologies and their performance. Third, a lack of skilled labour

[6] The program was introduced in 2005, but repealed in 2012.

necessary to operate new machines and processes also acts as a barrier to adoption of BAT.

3.1.2. Fuel Mix Change

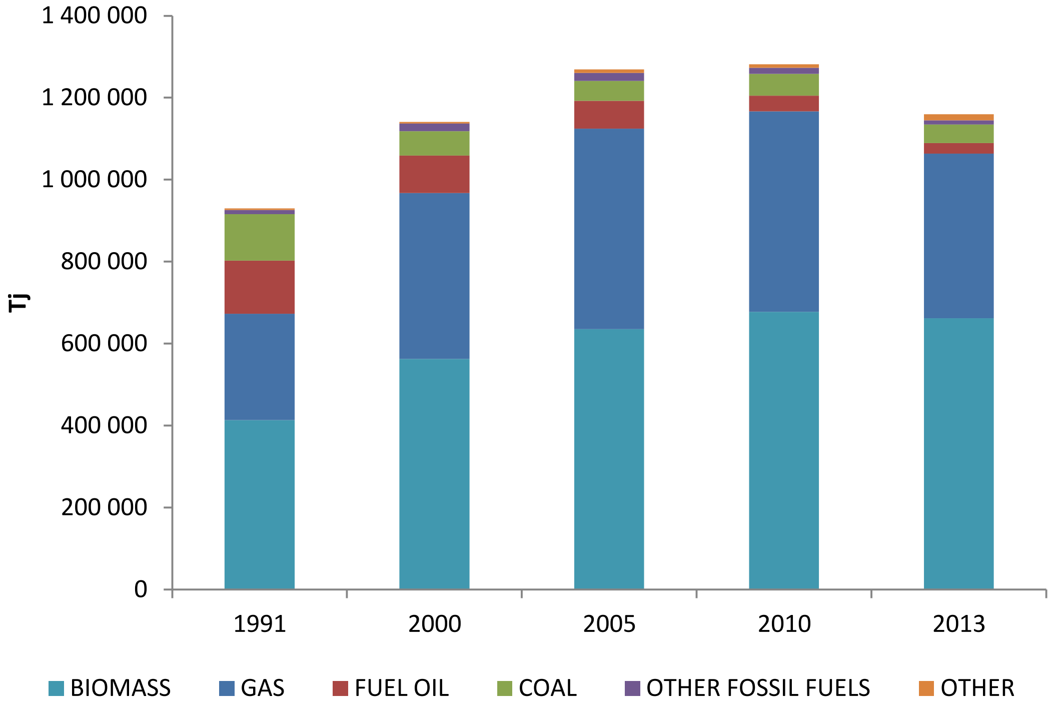
Opportunities for mitigation

Since 2000 the industry has changed the composition of its fuel mix, increasing the use of biomass and decreasing reliance on fuel oil and, to a small degree, coal (Figure 13). This shift in fuel mix has contributed to the decrease in carbon intensity within the sector.

There exists opportunities to further increase the use of bioenergy within the European pulp and paper sector. For example, switching from fossil fuels to bioenergy in lime kilns is estimated to reduce European emissions by 5-6Mt CO_2 by 2050. Biomass CHP in sawmills and panel-board production can render these facilities energy self-sufficient and almost carbon neutral, reducing emissions by an estimated 1-2 Mt CO_2 (by 2050) (CEPI, 2011). However, the pulp and paper industry is currently competing with the European energy sector and potentially in the future also with other sectors like transport for the same bio-energy resources.

In addition, emerging technologies will facilitate bio-refineries to be integrated with pulp and paper production. Within a bio-refinery, the residual wood, virgin biomass or by-products of the processes can be used to produce energy products such as electricity or transportation fuels, and other bio-based products such as biochemical. For example, black liquor gasification in pulp mills is a process of creating clean syngas from the biomass contained within black liquor (a by-product from pulp production). The syngas can then be used in boilers and in combined cycle processes to generate on-site electricity, steam or in the production of transportation fuels (Kramer, et al., 2009). Other technologies could also extract value from black liquor, for example lignin extraction. Further integration of bio-refineries with pulp and paper mills should increase the conversion efficiency of raw materials.

Figure 13. European pulp and paper fuel mix, 2000 to 2013.



Source: CEPI Key Statistics, 2014.

Key Drivers

Sweden has a higher share of biomass in the pulp and paper fuel mix than any other EU country (89%). A study by Thollander & Ottoson (2008), shows that the Swedish green certificate system has been key to increasing the share of biomass in Sweden. The green certificate system was introduced in 2003 with the objective of increasing the production of renewable electricity. Electricity producers receive one green certificate for each MWh produced from renewable sources. New installations receive certificates for 15 years. The certificates are then traded on an open market. Purchasers are Swedish or Norwegian parties with quota obligations (e.g. electricity distributors). In a study by Ericsson et al. (2011), the green certificate system was described as crucial for investments in electricity production from biomass in the pulp and paper industry. Companies have benefited from this program since they are excluded from the obligation to surrender certificates for power acquired on wholesale markets and can generate certificates with their own power production that they can sell to third parties. The system has, however, been criticized for not driving technical development, which was one of the purposes with the system (Bergek & Jacbosson, 2010). In addition, other EU member states have implemented renewable energy support mechanisms that cover bio-energy for power generation.

Most European member states have implemented support mechanisms for the power production in combined heat and power installations. CHP installations either receive some form of feed-in tariff or premium payments for the electricity they produce or investment subsidies (Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Finland, Germany, Greece, Ireland), excise duty exemption, energy tax exemption (Belgium, Finland, Germany, UK), preferential treatment for grid access (Estonia, Slovakia, Bulgaria), or fuel subsidy (gas used as input fuel for CHP in Bulgaria, wood chips in Finland)(COGEN 2007a).

The full decarbonisation potential of biomass for the pulp and paper sector is unclear. While potential exists for increased fuel switching and better use of waste streams, the availability and cost of feedstock is uncertain. Indeed power generation for the grid or in other industrial sectors as well use in other sectors including domestic heating and transport will compete for the same, limited resources. Bioenergy policy will need to be developed with careful consideration of the economy wide trade-offs in the allocation of biomass feed stocks.

3.1.3. Increased recycling

Opportunities for mitigation

As pulp production from recycled fibres is less carbon and energy intensive than pulp production from virgin wood, increasing the use of recovered paper in paper production reduces emissions. Specifically, substituting virgin wood for recycled fibres reduces emissions by about 37% (Table 10). As such, increased use of recycled paper over the last two decades has been another driver in the sectors decarbonisation. Specifically, European recycling rates have increased from around 40% in 1991 to over 70% in 2013. In terms of paper grades, newsprint and case materials had a recycling rate of over 90% in 2013.[7]

Table 10. Savings from use of recycled fibres

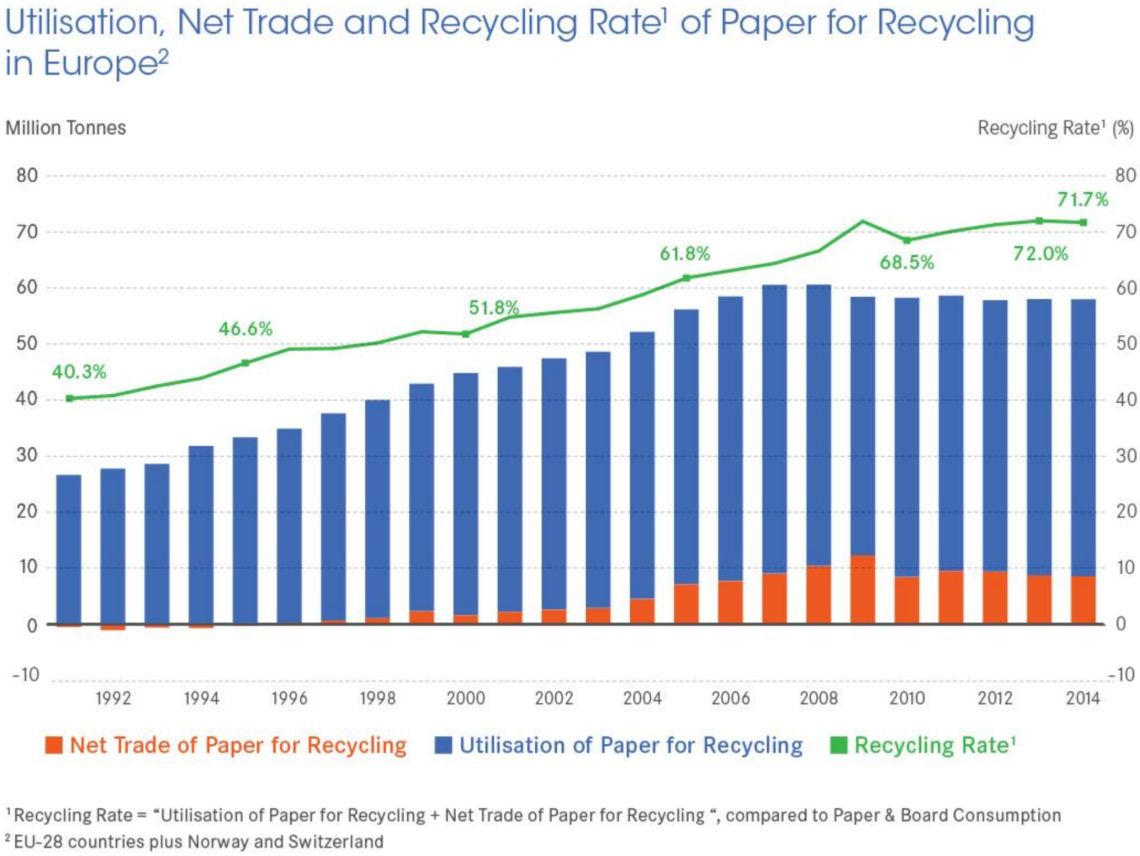
	1 Tonne Virgin Fibre	1 Tonne Recycled Fibre	Savings
Energy	33 million BTU	22 million BTU	33%
GHG – CO_2	5,601 pounds	3,533 pounds	37%
Wastewater	22,853 gallons	11,635 gallons	49%
Solid waste	1,922 pounds	1,171 pounds	39%

Source: Conserve tree, 2013

The utilisation rate measures the volume of recycled fibre used in the paper manufacturing. Germany has by far the highest utilisation rate of 35%. Spain and France have the second highest rates at around 10%. The utilisation rate is dictated by the quality of the recovered paper linked to the collection and sorting processes, the grade of paper collected and de-inking technologies (see Figure 14). In terms of paper grades, packaging papers have the highest utilisation rate of 66%. On the other hand, sanitary and household paper uses the least recycled fibres with an utilisation rate of only 6%.

[7] Paper for recycling also contains unusable materials - non-paper components as well as paper and board detrimental to new paper production. The share of unusable materials depends on the processes and techniques used for collection and sorting. Furthermore, recycled paper may also have competing uses such as thermal utilisation or incineration to generate heat.

Figure 14. Utilization, net trade and recycling rates in Europe, 1991-2014.



Source: CEPI, 2014b

Since 2001, Europe has exported an increasing share of paper for recycling. Exports are not consistent across countries with the UK, France and Italy exporting the largest share. A number of countries, including Germany, Austria and Spain, are net importers of recovered paper. In 2013, European exports of paper for recycling were around 10 million tonnes, with 95% flowing to Asia. This reflects the fact that recovered paper collection has been increasing faster than utilisation. However, not all trade is driven by market fundamentals, but also reflects the large capacity of empty ships returning to Asia after importing goods to Europe. Maintaining these fibres in Europe would increase the stock of recycled fibres available for low emission pulp production.

Key Drivers

The increase in the use of recycled paper can be attributed to cost savings in paper production as well as a broad range of dedicated recycling policies. Recovered paper represents a valuable input into the paper making processes. Indeed the price of recovered newspapers increased from around €90 per tonne in 2006 to over €120 per tonne in 2011 (UNECE/FAO, 2012), increasing the incentive for waste collection facilities to recover and sell the material.

Public policy and social suasion has also been important. The European Commission proposes an 75% recycling goal for European countries by 2025 (European Commission, 2015a). As not all paper is collectable or suitable for recycling, this reflects the upper bound of what is possible for the sector. The revision to the European Standards for paper and paperboard recycling has contributed to increased recycling rates. The shortcomings found in the previous standard included zero tolerance levels for non-paper components and unusable material, missing detailed grade descriptions, and a need for adaptation to market realities (new grades, out-dated grades).

Demand driven policies, such as the “Blue Angel” eco-label in Germany, have been successful in providing environmentally conscience consumers options to consume recycled paper. Separate collection targets for municipal waste as well as landfill and incineration restrictions for recovered paper have also contributed to increased recycling rates.

In addition increased recycling has been facilitated through technological advances in pulp production. Specifically, a new process to re-pulp wet-strength paper, the implementation of scorecards on de-inkability, and removability of adhesive applications has increased the number of times fibres can be reused (ERPC, 2013).

The changing structure of the paper market could create barriers to further increasing recycling rates. Digitalization reduces the use of newspapers and other highly recyclable papers, such as telephone catalogues and directories. Accordingly, newspaper grades that are easily recovered and reused are declining in the share of overall paper product consumption. Conversely, packaging papers are increasing their share from 40.8% in 1992 to 47.5% in 2013 (CEPI, 2014), but are less suitable for reuse due to contaminations.

3.1.4. Breakthrough technologies

Technologies used today will be insufficient to achieve the level of emissions reductions that is envisaged by the European Commission. New technologies are required. The Two Team project was an initiative by CEPI that, following the 2050 CEPI roadmap, gave two research teams the challenge of developing breakthrough technologies in paper and paperboard production (CEPI, 2013). The breakthrough technologies emerging from the project are summarised in the points that follow.

Deep Eutectic Solvents (DES) Pulping: DES are produced naturally by plants and can break down wood and selectively extract cellulose fibres required in the paper making process. Therefore it offers a new concept for pulping that does not rely on high heat and energy inputs. With further research, as cellulose is soluble in DES, they could also be used to recover cellulose from waste and dissolve ink residues in recovered paper. It is estimated that DES pulping could reduce emissions by 20% compared to 2011.

Flash condensing with Steam: Large dry fibres are blasted into a forming zone with agitated steam and condensed into a web using one/thousandth of the volume of water used today. High gas velocities make the paper forming section very short, with little extra heating required for drying, as water content after the process is greatly reduced. The process is most readily applicable to virgin fibres produced with chemical pulping, but can also be applied to recovered and mechanically pulped fibres. Emissions savings come from the greatly reduced water volumes used in the forming process and hence the reduced drying requirements. If applied across the sector, the process could reduce emissions by up to 50% compared to 2011 levels.

Dry-pulp for cure-formed paper: this innovation introduces two technologies that allow for the production of paper without the use of water. First, a new dry pulp technology, where fibres are treated to protect them from shear, and then suspended in a viscous solution at up to 40% concentration. The solution is then pressed out and the thin sheet cured with a choice of additives to deliver the end-product required. The process removes the use of water and therefore eliminates emissions associated with drying and effluent treatment (around 55% total emissions).

Supercritical CO_2: can be foremost used to dry paper with vast reductions in energy requirements. Second, it can be used to remove containments from recycled paper and therefore increase utilisation rates. Emissions savings are estimated at 45% compared to 2011 levels, because of reduced steam and heat use in the drying process.

100% Electricity: Using electricity rather than fossil fuel power to generate heat will cut all CO_2 emissions as the power sector shifts to renewable energy. The sector would also provide a buffer and storage capacity for the grid, storing energy as hydrogen or pulp. The concept can be introduced incrementally, by first replacing gas-fired boilers with electric boilers. As technologies develop, heat and steam dryers can be replaced with electrified dryers. Electricity can be used to develop Thermo Mechanical Pulp (TMP) and Hydrogen. At times of peak electricity demand, the Hydrogen can be used to drive turbines and generate electricity for the grid. With the current power mix, 100% electrification would reduce emissions by 20%. The greater the share of renewables in the grid is, the larger the potential for decarbonisation of this breakthrough technology.

Functional Surface: the idea is to reduce the weight of paper without impacting its quality or structure. Advances in sheet formation and new cocktails of raw materials will lead the way to the lightweight papers. Lighter weight paper is then easier and less energy intensive to dry.

Steam: rather than allowing heat and energy to escape as hot air, temperature and humidity are increased to form pure vapour. At this point, the vapour can be collected, thus heat and energy are not lost from the system. The steam is then used in the paper making process. With full implementation, emissions could be reduced by half compared to 2011.

Key Drivers

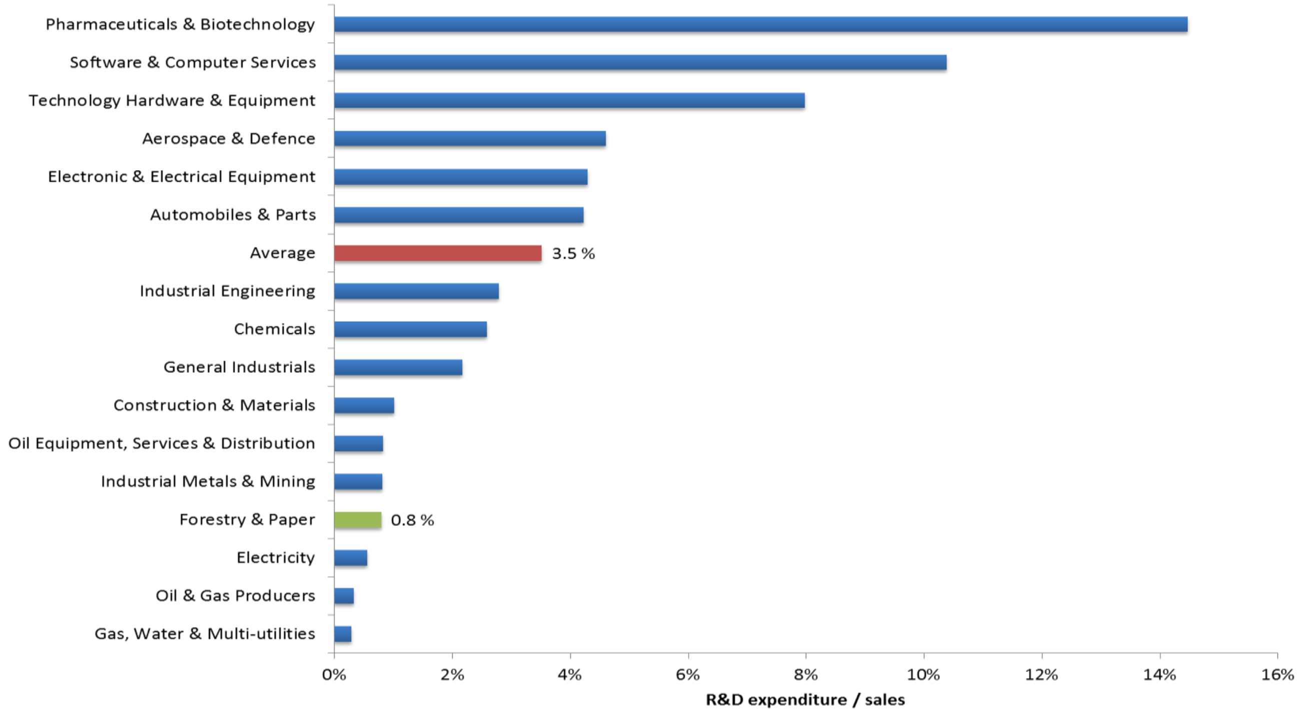
The NER 300 program[8] uses the revenues from the sale of European Union Allowances (EUAs) to new entrants as a means to fund innovation in Carbon Capture and Sequestration (CCS) and low carbon processes, providing an opportunity for funding innovation in new low-carbon technologies and processes. However, the opportunities that were provided from the NER 300 fund were considered too risky by many central office managers, since support for a demonstration project would have had to have been returned in the event that the technology failed. Indeed stakeholder interviews[9] revealed innovation in such new processes were considered to be outside their "core business."

In addition, under the 7th Framework Programme within the "Forest-based Sector EU Research" €3.7 billion euros were allocated for the Bio Economy through a Public-Private Partnership (European Commission, 2014). Other sources of funding include the COST (Cooperation in Science and Technology), which had forests, their products and their services on their research agenda[10].

Private spending on R&D, particularly on technologies that are close to commercialisation and have a clear link to consumers, will also be important. However, spending on research and development compared to sales has been considerably lower in the forestry and paper sector compared to the average across all sectors, representing just 0.8% in 2013 (see Figure 15). Anecdotal evidence points to three barriers that may be reducing the level of investment in the sector. Firstly, papermaking requires a complex set of technologies that must be compatible with one another. As such, it is difficult to innovate only a single part of the production process. Secondly, market concentration in the technology supply market may have reduced incentives for innovation. Indeed, it appears that over the last ten years, the focus has been on increasing the scale of machines to meet the growing Asian and Latin American markets, rather than on enhancing carbon or energy efficiency. Finally, it is not clear to what extent pulp and paper companies have the skills or capacity to undertake research.

[8] The NER300 program was established by the revised Emissions Trading Directive 2009/29/EC. According to article 10(a) 8, proceeds from the sale from up to 300 million allowances should be used to finance commercial demonstration projects in the area of CCS and renewable energies. European Commission (2015b): NER 300 program.
[9] Interviews were conducted at the Workshop "Inclusion of Consumption for Carbon Pricing– Relevance and feasibility for the pulp and paper sector" held by DIW Berlin and IVL in Brussels on June 8,2015.
[10] See website of the COST project: www.cost.eu

Figure 15. Expenditure on research and development as a proportion of sales, 2013.



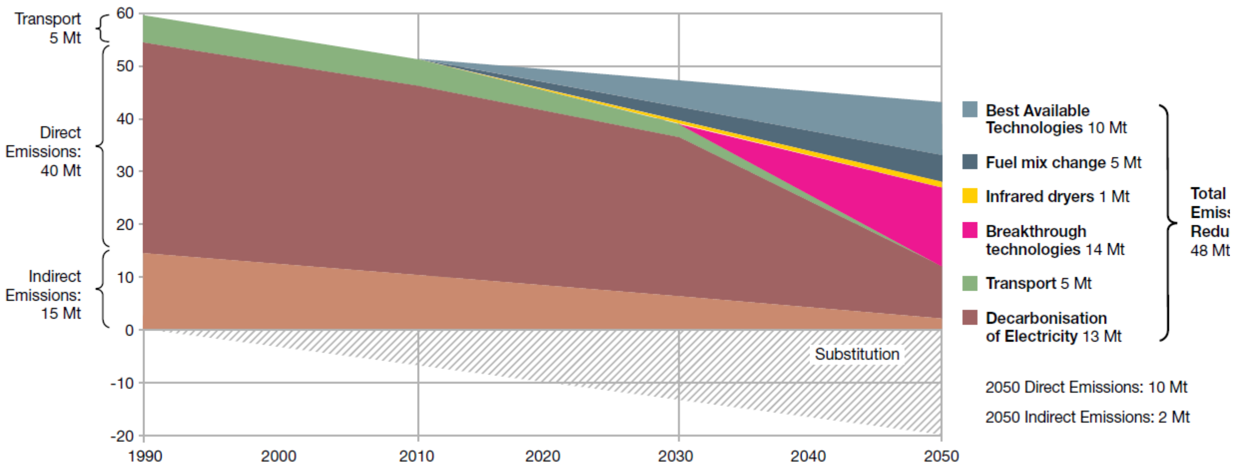
Source: R&D Scoreboard, 2014.

Furthermore, the decreasing demand for paper products and the overcapacity seen in several plants and subsectors (FAO, 2015), diminishes revenue streams and future profits. This increases the uncertainty for the future of the industry, reducing investments that might increase efficiency and decrease costs. Additionally, long-term contracts between paper manufacturers and their most important costumers make the sector unattractive to new entrants who might encourage competition and/or use newer technology for production.

3.2. Policies, incentives and other drivers and barriers for mitigation

The pulp and paper sector will need to be highly energy efficient and innovative in a future that is shaped by ambitious climate and energy policy goals. Figure 16 below outlines one path to decarbonisation, as developed by CEPI in their 2050 roadmap. To achieve 80% emission reductions by 2050, the sector needs to reduce emissions by 48Mt compared to 1990 levels. Continued adoption of best available technologies is expected to contribute 10 Mt to this effort with continued fuel mix change reducing emissions by a further 5Mt. Significant decarbonisation of the European power market is expected between now and 2050, such that technologies allowing for heat generation from electricity rather than conventional fuels will also play a leading role. However, known technologies are insufficient. At least 10Mt must come from breakthrough technologies.

Figure 16. Emission reduction potential, 1990-2050, in million tonnes.



Source: CEPI, 2015

Achieving the emission reductions outlined above will require a positive perspective toward carbon and energy improvements so as to attract investment, skilled labour, increase efficiency, and remain among the technology leaders. While there are significant opportunities, there are also serious challenges and risks. Therefore, both effective policy and forward looking and innovative companies are required to translate the set roadmaps into tangible investments and innovation.

Both the views derived from conventional economics and experience with the sector to date confirms that carbon pricing will be fundamental in driving a pulp and paper sector transition. Importantly, the price signal will need to be felt by not just the producers, in order to improve the efficiency of production, but also consumers, in order to create a business case for low carbon paper products, breakthrough technologies and bio-based products in other sectors. An effective carbon price for intermediate and final consumers is necessary to provide a credible basis for the large-scale use of innovative materials and production processes.

As well as carbon pricing, coordination may be required in some member states to ensure that collected paper can be most effectively utilised. Best practice in terms of collection, sorting and re-pulping should be seen as a priority in waste collection tendering contracts.

Finally, innovation and strategic investment may be required. While the pulp and paper sector are not reliant on CCS and CCSU for decarbonisation, unlike the materials sectors (for example, steel and cement), break-through technologies are still in infancy. Where markets are fragmented, timescales are long, risks are large, and public technology has a high spill over, there may be a case for public funding to complement private investments. If demonstrations of breakthrough technologies require significant risks, public-private risk sharing arrangements may also be required.

3.3. Benchmarks for free allocation of allowances

Free allocation in the EU ETS is based on benchmarks for carbon emissions per tonne of production in different sectors. In this section we describe the current benchmarks in the EU ETS system for the third trading period as well as benchmarks in other trading schemes in the pulp and paper sector.

Benchmarks in the EU ETS

The production process for different types of paper is very diverse. For example, virgin pulp is used for carton board and sanitary and household products, but it is not possible to split this into mechanical or chemical pulping. Moreover, it is difficult to associate emissions for individual products in mills that produce several products. Therefore constructing benchmarks based on the 10% most efficient installations in EU was complicated in the pulp and paper industry. Consequently, Ecofys (2009) recommended basing emission benchmarks in the pulp and paper sector on the most energy efficient processes, in combination with assumptions on energy conversion efficiency and reference fuels.

When benchmarks were developed for pulp making in the EU, energy intensity from BAT was converted to carbon intensity. Ecofys (2009) advised that there is no need for free allocation for pulp making for heat consumption since biomass dominates as fuel source in countries where most pulp is produced. The exception is the lime kiln in Kraft pulping, which is associated with some process emissions. A separate benchmark for Kraft pulp was therefore proposed (see Table 11 for proposed benchmark values for virgin pulp).

Table 11. Emissions factor and proposed benchmarks values for virgin pulp products

	Emission factor t CO_2/adt	Benchmark Emissions factor (proposed but not final) t CO_2/adt
Bleached Kraft pulp		0.048
- Bleached kraft pulp excluding lime kiln	0	0
- Lime kiln		0.048
Bleached Sulphite pulp	0	0
TMP and other mechanical pulp		0

Source: Ecofys, 2009

Carbon intensities vary for different paper products and depend on the energy source. When benchmarks were developed for paper products, Ecofys proposed to assume gas as the default fuel. Table 12 illustrates emissions factors for different products, based on the proposed benchmarks for paper products by Ecofys (2009), given their different energy intensities.

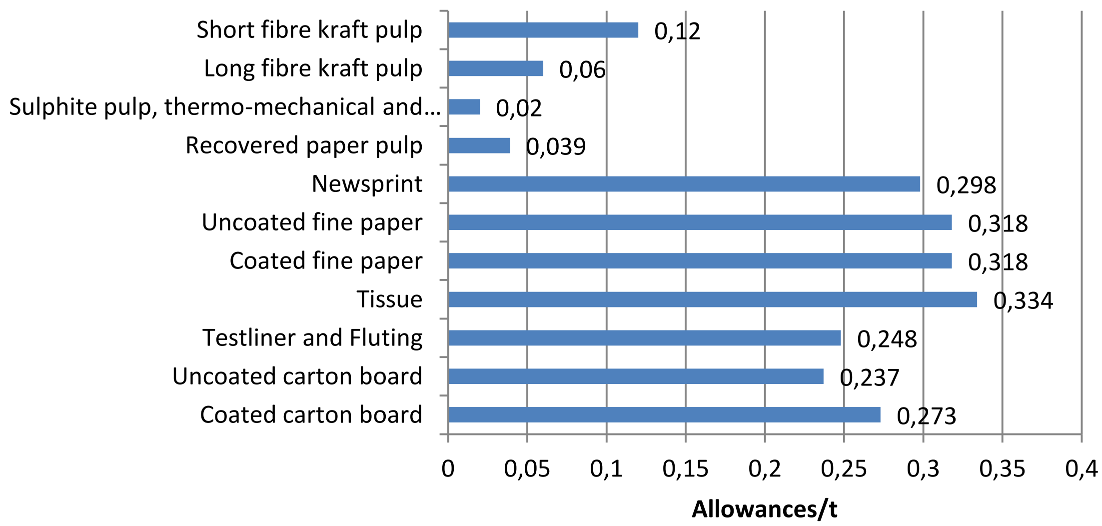
Table 12. Proposed benchmark for different paper products

Product	Benchmark Emissions factor (proposed but not final) t CO_2/adt
Newsprint	0.318
Uncoated fine paper	0.405
Coated fine paper	0.463
Tissue	0.343
Containerboard	0.368
Carton board	0.418
Other papers	No benchmark

Source: Ecofys, 2009

The EU Commission subsequently consulted with stakeholder on the initial proposal and adjusted benchmarks. The resulting benchmarks used in the pulp and paper industry in the EU are presented in Figure 17. These benchmarks differ somewhat from the emissions factors and proposed benchmarks in Table 11 and Table 12. Benchmarks are based on non-integrated mills, which can be considered favourable for integrated pulp and paper mills that use biomass rather than gas to meet heat demand, meaning that pulp input are not included in the paper benchmarks. The reason for choosing non-integrated mills as reference was that otherwise the allocation for non-integrated paper mills was considered too low and difficulties were incurred in splitting up the process between pulp and paper in an integrated mill (Ecofys, 2009).

Figure 17. CO_2 Carbon intensity benchmarks in EU.



Source: European Commission, 2011.

The EU benchmarks for pulp and paper raise a number of questions. First, what fuel input is used as default fuel? While in other sectors this has been gas, in pulp production it was biomass. It could also be that biomass should be treated in an alternative way, given that this biomass could be used elsewhere in the economy and replace fossil fuel. From this perspective, there might be other more cost effective fields of application for biomass. In this discussion one must, however, take into account that a significant part of the used biomass/bioenergy is inherent to the process and cannot be replaced by other fuels and that there must be joint research with other sectors, i.e. buyers of the bioenergy products, for those investments to take place.

Global outlook

Similar to the EU, the Californian cap-and-trade program allocates allowances to leakage exposed sectors based on product benchmarks. The benchmarks were set at 90% of average emissions intensities (CARB, 2011)[11]. No pulp is produced in California and accordingly the benchmarks only concerns paper products. There are paper benchmarks for four different paper processes, which are compared with the EU benchmarks. Compared to the EU, the product benchmarks are approximately twice as high. One explanation for this could be that EU benchmarks are based on best available technology while the Californian benchmarks represent 90% of average emissions per product.

Table 13. Benchmarks in the Californian Cap-and-Trade Program for paper production

Sector	Activity	Californian Benchmark (Allowances / metric tonne)	Comparison EU Benchmark (Allowances / metric tonne)
Paper (except newsprint)	Through-Air-Dried (TAD) Tissue Manufacturing	1.43	Not available
Paperboard mills	Recycled Boxboard Manufacturing	0.550	0.273
Paperboard mills	Recycled Linerboard (Testliner) Manufacturing	0.516	0.248
Paperboard mills	Recycled Medium (Fluting) Manufacturing	0.434	0.248

Source: CARB, 2011.

The proposed Carbon Pricing Mechanism in Australia, which was repealed in 2014, also had benchmarks for allocation to carbon leakage exposed sectors. The benchmarks were based on average performance within the sector. Compared to the EU benchmarks, the Australian benchmarks also included indirect emissions from

[11] In some sectors, this approach resulted in more stringent levels than current emissions for any existing facility in California. In these cases benchmarks were based on the “best-in-class” value in California.

grid electricity usage.[12] A standalone benchmark for newsprint was developed since it was identified that most newsprint is produced in integrated mills. Regarding other paper products (packaging, carton board, printing and tissue), separate benchmarks were developed for non-integrated mills but with an additional common baseline for wet pulp manufacturing applied to integrated mills. The benchmark for wet pulp does not distinguish between different types of pulp and is applied to all pulp and paper activities.[13] In addition, one benchmark was developed for non-integrated pulp making.

Table 14 illustrates direct emissions for different pulp and paper products in Australia, serving as basis for allocation of free allowances. The listed paper categories are not directly comparable to EU products, but the benchmarks in Australia seem distinctly higher than in the EU. Possible explanations could be that the Australian benchmarks include indirect emissions, which the EU ones do not, and that the Australian benchmarks are based on average performance, compared to BAT in EU.

Table 14. Basis for allocation for pulp and paper in Australia

Sector	Description	Direct + Indirect emissions (CO_2/tonne)
Newsprint	Per air dried tonne of newsprint	0.496
Packaging and industrial paper	Per tonne of saleable rolls of uncoated packaging and industrial paper.	0.338
Carton board	Per tonne of saleable rolls of carton board	0.886
Printing and writing paper	Per tonne of saleable rolls of coated and uncoated printing and writing paper	0.617
Tissues	Per tonne of saleable rolls of uncoated tissue paper	0.646
Dry pulp	Per tonne of saleable rolls of dry pulp	0.873
Wet pulp	Air dried equivalent pulp from either or both of woodchips and sawdust	0.130

Source: Australian government, 2012.

4. Potential applicability of Inclusion of Consumption to the pulp and paper sector

Europe is about to embark on a debate regarding structural reform options for the post-2020 European Union Emissions Trading System (EU ETS). A key aspect of this debate will be the treatment of emission intensive trade exposed industries that are at risk of leakage. In the EU ETS, leakage protection is provided through partial free allocation of allowances to carbon and trade intensive industries. Today, while there are differences across sectors, international competition limits the possibility for carbon intensive sectors in EU ETS to pass carbon costs on to consumers (Ecorys,

[12] A national grid emissions factor was applied, fixed to 1 tonne CO_2e/MWh but subject to adjustments for very large existing electricity supply contracts (Ecofys, 2014).
[13] The reason for this was the government's principle of taking into account intermediate products when defining the activities.

2013), which constrains the ability of EU ETS to incentivize mitigation options down the value chain. Moreover it could jeopardize the ability of the EU ETS to drive a long term decarbonisation of the European Economy. A third concern is that free allocation is to be phased out, which may lead to increased risk for carbon leakage.

Hence it is worthwhile to explore new approaches to restore incentives for investment in mitigation and innovation in the value chain, where these incentives are largely muted from the use of free allowance allocation as leakage protection mechanism. One such approach is the Inclusion of Consumption (IoC) for carbon intensive materials in the EU ETS. The production of carbon intensive commodities would remain covered by the EU ETS but an additional consumption charge is levied.

The aim of this section is to identify the key design choices, opportunities and challenges of applying Inclusion of Consumption to the European pulp and paper industry. Specifically, the chapter discusses:

- How the Inclusion of Consumption to the European pulp and paper sector can be implemented,
- The choice of benchmarks and the metric upon which to base the consumption charge,
- Treatment of indirect emissions.

4.1. The Inclusion of Consumption approach

Under the Inclusion of Consumption, the production of carbon intensive commodities, like steel, cement and paper, would still be ensured with partial free allocation of allowances. To preserve incentives for energy and carbon efficiency improvements in primary production, the use of BAT benchmarks determines the volume of the free allocation (Ecofys, 2009).

As an additional measure in the Inclusion of Consumption approach, a consumption charge is levied for carbon intensive commodities. The charge is the same for domestic and imported commodities, so it balances the competitiveness of EU production and imports. Again, the carbon price of production signals the costs of externalities beyond primary production and can support innovation.

The inclusion of consumption of carbon intensive materials post-2020 will:

i) Allow for carbon leakage protection to be continued by (benchmark based) free allocation;
ii) Avoid distortions to competitiveness of EU production by same consumption charges for domestic and imported products; and
iii) Restore the carbon price signal that is muted, resulting in substitution away from carbon intensive commodities and providing an incentive for e.g. lighter paper innovations.[14]

[14] For further details on the Inclusion of Consumption approach see Neuhoff et al. (2015).

The charge is levied per tonne of material consumed. In order to arrive at the amount of the charge, the weight is multiplied by a benchmark emissions value (carbon emissions per tonne of the commodity) and the carbon price, according to the following formula:

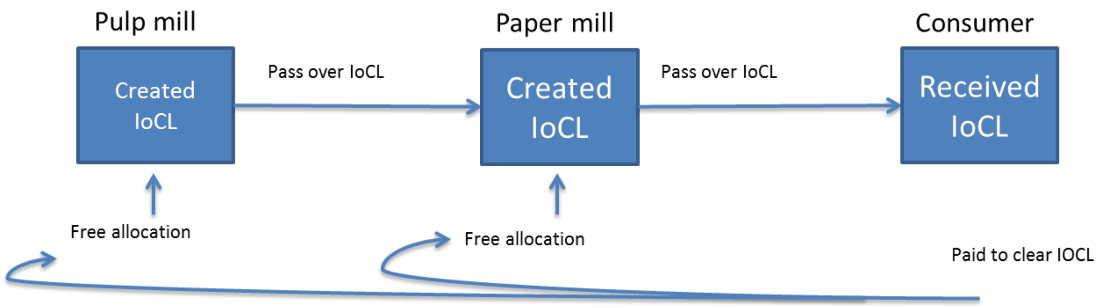
$$\begin{aligned} Consumption\ fee \\ &= paper\ consumption\ [ton\ paper] \\ &\times benchmark\ [tonne\ CO_2/ton\ paper] \\ &\times current\ carbon\ price\ [EURO/ton\ CO_2] \end{aligned}$$

The consumption charge is levied for all consumption of carbon intensive materials at the same benchmark rate – irrespective of the origin or production process of the material. Thus discrimination across different installations and distortions of production decisions are avoided, and the mechanism is not considered to be a trade related measure.

Conceptually, Inclusion of Consumption can be modelled after consumption levies that are well established, such as excise charges on fuels, alcohol and tobacco. Simple and effective schemes functioning in Europe (and globally) based on computerized systems, can be replicated.

Under IoC, the production of carbon intensive materials generates a liability per tonne of material, e.g. pulp or paper, produced or imported. The producer or importer then passes the liability on with the sale of their product; see Figure 18 for a schematic picture. The payment of the charge is suspended through the intermediate good chain and only comes due at the time the good is released for consumption. As long as no release for consumption has taken place, the charge is not due. For a detailed overview of the approach see Neuhoff et al. (2015) and for its implementation see Acworth et al. (2014).

Figure 18. Schematic picture of Inclusion of consumption in non-integrated pulp and paper mills (IoCL=Inclusion of Consumption Liability)



4.2. Benchmarks for Inclusion of Consumption

There are several issues that need to be investigated when it comes to designing benchmarks in the Inclusion of Consumption approach. Below we discuss different possible metrics for deciding benchmarks, treatment of indirect emissions and recycling.

The production process for different types of paper is diverse and benchmarks currently used in the EU ETS for free allocation are based on assumptions of the most energy efficient processes, in combination with energy conversion factors for reference fuels. An important issue for the Inclusion of Consumption approach for pulp and paper is deciding on the metrics for the consumption fee. The most straightforward approach would be to replicate the current EU framework for benchmarks for determining the consumption fee.

Another option would be to produce a set of internationally harmonized benchmarks considering the ones used by EU, California, Australia and other countries. Other changes in the EU climate and energy policy for the post-2020 era, e.g. the renewal of the RES directive, will also impact the benchmarking question.

Biomass Carbon Accounting

The pulp and paper production processes require heat and electricity; biomass is a common energy source. Part of this energy could be replaced and produced by e.g. other renewable energy sources. This could free up biomass - such as branches or tall oil - that could be used elsewhere in the economy, for instance for producing transport fuels or bioplastics.

It would require a change of mind set and possibly incentives to enable such developments. Currently the use of biomass in co-generation is incentivized with renewable energy and CHP support mechanisms. They are structured to correct for increases in biomass prices linked to alternative use options. As the incentives are provided in proportion to electricity production and, therefore, also heat use, this does however create disincentives for more efficient use of produced by CHP plants in pulp and paper production.

Currently, pulp and paper entities are required to acquire and surrender allowances only for those emissions released by the combustion of fossil fuels, such as coal, oil and gas, thus they receive correspondingly small levels of free allocation. Emissions released via the combustion of biomass are assumed neutral and, therefore, do not create a carbon liability or implicit credit. Instead one may consider associating replaceable biomass with a benchmark based on fossil gas. This would be analogous to the EU benchmark for district heating, which is based on gas, even though in some countries the most common fuel for district heating is bioenergy. A gas based benchmark on replaceable biomass would provide pulp producers' free allocation and would improve incentives for more efficient and high-value use of the bioenergy carriers whether within pulp or paper or other sectors. A gas based benchmark would also somewhat reduce incentives for bioenergy in CHP production.

This is not to be confused with the debate on carbon neutrality of bioenergy, but addresses the issue that part of the biomass used in pulp and paper production could be provided by other energy sources. Hence, there is a shadow carbon cost of using this replaceable biomass for heat and electricity purposes. It should be noted that a significant share of the biomass that is used is inherent to the process and cannot be replaced by other fuels. The process related biomass, such as black liquor, can only be used locally. This non-replaceable share of biomass has no carbon liability under the EU ETS and IoC framework (see Figure 18).

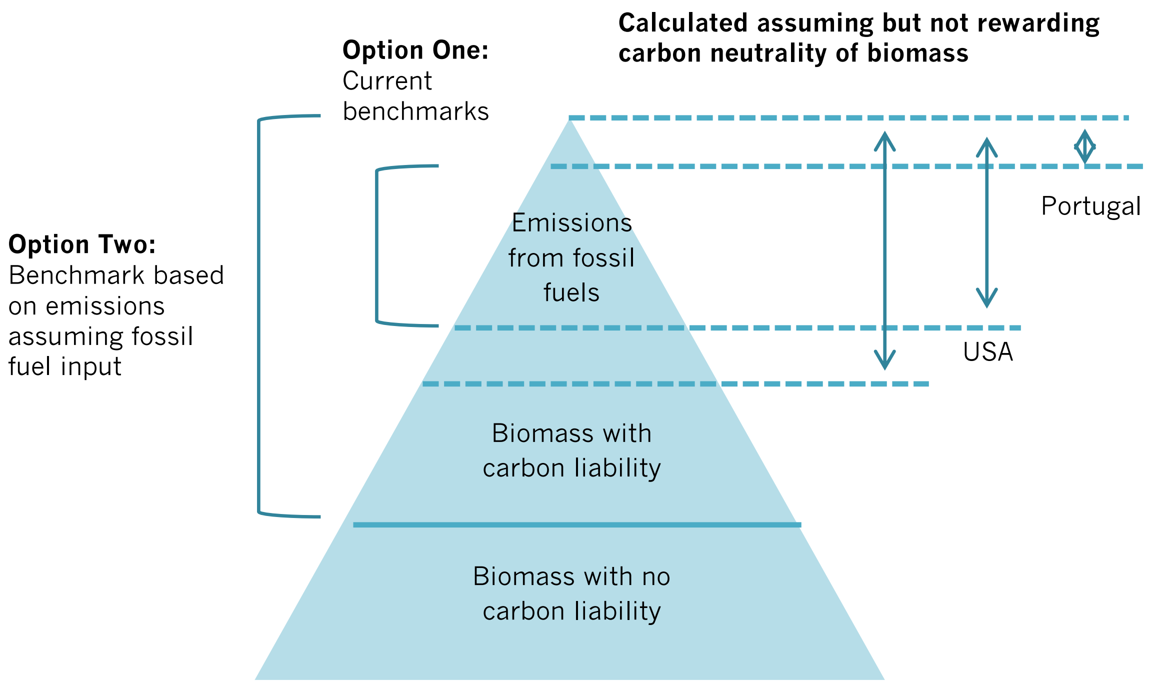
Implementing a fossil benchmark on replaceable bioenergy would have a set of implications:

- The support level for CHP and RE could be reduced. This would increase incentives for efficient use of heat from co-generation based on bio-mass.
- Free allocation would increase to the sector (in the EU ETS), which would allow for the sales of surplus allowances.
- Incentives for more efficient and high-value use of the bioenergy carriers would increase.
- As a result, the sector would become more concerned about the cross-sector reduction factorThis enhances incentives for efficiency improvements and other mitigation options and free up bio-energy for new “bioeconomy” production processes.

Inclusion of Consumption could:

- Both drive efficiency upstream in the pulp and paper production processes but also create a stable business case for breakthrough technologies as final consumers pay a charge corresponding to the upstream carbon price incentive.
- Furthermore, Inclusion of Consumption in EU ETS reflects the externality costs in final product prices, and thus contributes to a business case for innovative products, for example lighter paper

Figure 19. Treatment of biomass in carbon accounting for the paper and pulp sector



Inclusion of indirect emissions from electricity use in the consumption fee and compensation to paper producers

Although the discussion of compensation for indirect costs is broader than the scope of this project, it is worth investigating whether Inclusion of Consumption could offer new prospects when it comes to incentives for electricity intensity measures and compensation for indirect costs. Power price compensation is an important issue for the pulp and paper sector. During interviews with Swedish pulp and paper mills, indirect costs from electricity consumption were described as the main issue regarding carbon leakage (IVL, 2015).

The current framework for compensation for indirect costs in the EU ETS by the European Commission states which sectors and sub-sectors are eligible for compensation[15]. Manufacture of paper and paperboard, as well as mechanical pulp, are included on the list. The decision to compensate sectors depends, however, on the respective Member States. As of today, only a handful number of member states in the EU grant state aid to compensate for electricity intensive sectors.[16]

In the Australian Carbon Pricing Mechanism, indirect emissions were proposed to be included in the product benchmarks and a similar approach could be an option in the EU to protect against carbon leakage from indirect emissions.

If compensation is granted for power price increases linked to indirect emissions, then in the Inclusion of Consumption approach correspondingly the consumption charge could be increased, thus ensuring that the carbon price is reflected in production and consumption decisions throughout the value chain.

4.3. Discussion

Materials play a key role in the transition to a low carbon economy. From a material efficiency perspective Inclusion of Consumption could strengthened the link between the producer and the consumer. Inclusion of Consumption could incentivise mitigation as the carbon price signal is preserved along the value chain. As such, the scheme makes low carbon products more competitive and incentivizes the substitution away from carbon intensive alternatives. Specifically, this could incentivize consumers to choose more material efficient packaging and paper products, such as lighter packaging and paper products as well as digitally based alternatives.

A consumption charge could also support the free allowance allocation to production at a fossil fuel based benchmark as the same charge is subsequently levied at the consumption end. This in turn could then allow for reduction of CHP and RE support provided and improve thereby incentives for efficient use of heat produced from CHP.

[15] In order to be eligible, a sector or sub-sector must have a trade intensity higher than 10% and the sum of indirect additional costs induced by the EU ETS would lead to an increase in production amounting to at least 5% of gross value added (European Commission, 2012).
[16] The countries are Belgium, Germany, Greece, Netherlands, Spain and United Kingdom.

An important issue to ensure material efficiency and to avoid market distortions is that the scheme also includes materials that are in close competition to paper products. This concerns for instance plastic and glass as packaging materials, but also electronic products that compete with paper products such as newsprint and graphic paper. Further investigations regarding which products to include are needed.

Perhaps most important with the proposed scheme is that it could provide long term certainty regarding allocation of free allowances and therefore prevent carbon leakage from EU. Long term certainty on leakage protection could also stimulate new innovations, funding of break-through technology in Europe and prevent investment leakage.

A number of issues must, however, be clarified before Inclusion of Consumption can be materialized in the EU. For the pulp and paper industry especially metrics for determining the consumption fee must be further investigated as well as treatment of indirect emissions from electricity consumption and recycled material. Regarding benchmarks, the most straightforward option would be to replicate the current framework for benchmarks to determine the consumption fee. One may also consider applying a gas based benchmark on the share of biomass that is replaceable (such as branches). This could create incentives to free up biomass that could be used elsewhere in the economy, for instance for producing transport fuels or bioplastics. Treatment of recycling and indirect costs within the scheme are issues that concern not only the pulp and paper industry, but needs to harmonized for all the sectors that would be covered by the proposed scheme.

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