unfold the future

The Forest Fibre Industry

2050 Roadmap to a low-carbon bio-economy

Our sector is very interconnected.

It has a clear joint future and uses a common raw material. For this reason, we have taken a broad view of the industry, which we call the forest fibre industry, combining pulp and paper and wood-based (future) products. The forest-based wood products and pulp and paper sectors in Europe consist of 200,000 companies, employing 1.9 million people, and providing around 75 billion euro in added value to the EU economy. The sector is for the most part based on raw materials from Europe.

It is a global player. But the world is changing fast.

This roadmap has been developed by representatives of all parts of the pulp and paper and wood products sector. Both companies and national associations have been involved. The starting points are the 2050 society and the 2050 consumer and how the sector will have to change to meet their future demands. Faced with external constraints on carbon and resources, we unfold the path to 2050 for technology, raw materials and finance, and consider the framework conditions and policies that need be in place to allow for the transition.

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Executive Summary

In March 2011, the European Commission published a "Roadmap for moving to a competitive low-carbon economy in 2050", a discussion document to explore the future of climate change policy.

The document models pathways towards 2050 and the possible contribution of different sectors. It will be followed by an 'energy roadmap' towards the end of 2011 and will be combined with other roadmaps on, for example, the future of transport. In time, it will lead to a new "climate change and energy package".

The outcome will be crucial for Europe's pulp, paper and wood products industries, which operate at the crossroads of renewable energy policy, emission trading, industrial and raw material policies. Climate change policy, too, has a major influence on the future of these sectors. After all, climate change policy is, essentially, industrial policy.

This roadmap attempts to lay out the future of the forest fibre industry – the pulp, paper and board and wood products sectors combined – and its potential to meet future consumer demands, stay competitive and deliver a CO_2 emission reduction in line with the modelled overall industrial reduction of 80% by 2050, compared to 1990 levels. The roadmap explores the technical, financial and resource constraints that lie ahead, and the policy framework that will be needed to tackle them.

Our roadmap is an exploration into the future. The CO_2 reduction envisaged can only be achieved when the right policy framework is in place. The sector can play its part as long as it remains profitable and attractive to investments, keeps access to fibre and other raw materials and receives enough support to bring breakthrough technologies within reach.

This roadmap depends on global action

The roadmap is based on the European Commission's 'global action scenario with available technologies'. It depends on the conditions of that scenario being met, including the expected decarbonisation of electricity, carbon neutrality of biomass, availability of carbon capture and storage, and realisation of energy efficiency targets. As the Commission roadmap has shown, the cost of Europe going alone on emission reductions will be too high for industry and governments to bear.

The sector has the potential to succeed

The sector has the ambition to be at the heart of the 2050 bio-economy, an essential platform for a range of bio-based products and the recycling society. We expect the sector, in its broad definition, to continue to grow in line with EU GDP, by about 1.5% a year for the next 40 years. The future sector will be a cluster of more and more integrated activities and sectors. New business models, products and services will complement the future use of printing and writing papers and the growing need for packaging and hygiene solutions.

Carbon reduction can only be achieved with a technology push

The exploration shows that a reduction of 50 to 60 percent CO_2 by 2050 is possible given the right circumstances, based on investment patterns and available and emerging technologies. To achieve an 80% CO_2 reduction, however, it will need breakthrough technologies. These have to be developed and available by 2030.

Substitution adds a dimension

The forest fibre industry has a much broader carbon profile than simply one of direct and indirect emitter. Its products can substitute for carbon-intensive fossil fuel-based products, whether for construction, fuel, chemicals, packaging or other purposes. And it works within Europe's forests, which, when sustainably managed, store carbon.

The consumer will decide

Future sectors will provide future products to 2050 consumers. Their choices will determine the success of the bio-economy and the industrial sectors that provide solutions. This roadmap starts with the 2050 consumer. This individual holds the answer for policymakers and the sector alike.

2050 is both far away and around the corner

Although the 2050 future is far away and today's economy changes on an almost daily basis, the time to act is short. The 40 years ahead comprise only two investment cycles for a capital intensive industry; in other words, "2050 is two paper machines away". Policymakers and industry have few opportunities to make crucial choices

Start of a debate on the future policy framework

This roadmap is the start of a debate. It aims to contribute to the discussion on the future policies of the European Commission and member states. It is not an action plan. Uncertainties in modelling the economy are too great to simply translate a 2050 modelled future into an action plan. It is however a holistic exploration into the future of our sector.

This roadmap offers the basis for a discussion within and outside the sector, based on the following recommendations:

- **A new level of climate policies is needed**
  To achieve the reduction required while avoiding carbon leakage, policies need to be harmonised with global developments and industry investment cycles. The EU needs to complement the current carbon price and target-based policy approach with a multi-dimensional and industry specific climate change policy. The policy package should include a technology focus, be synchronised with industry investment cycles and global action, and include a raw material and product perspective.

- **The bio-economy requires an active system change**
  A successful transformation depends on a combination of technology push and product innovation. To succeed, the EU needs to see the bio-economy as the system-shift needed, rather than a mere decarbonisation policy. Policy needs to actively push the substitution of high-carbon materials with bio-based products.

- **There will be no change without sufficient biomass**
  The EU will need to invest in European forests and farming systems to produce this biomass. The reform of the Common Agricultural Policy needs to include biomass production. EU energy policy, meanwhile, needs a biomass supply policy, alongside coal, gas and oil supply policies.

- **Limited resources underline the need for added value**
  Policies will have to steer the EU economy to a system whereby the most value is produced – from the land available, from forest management, from trees, from the fibre and by sectors. The cascade of materials use, producing the most value added from a forest fibre, optimising recycling and reuse as a raw material before at a final stage materials are used for energy, needs to be a cornerstone of EU policy and support systems.

- **Recycling depends on virgin material**
  We expect resource efficiency policy to lead to new levels and dimensions of recycling in Europe. However, the recycling loop cannot function without input of quality virgin fibre. With future consumption patterns the input to the recycling loop is a concern that needs to be secured to allow the system to function.

- **The next step is a joint partnership guiding the sectors transition**
  Based on the roadmap we call for the establishment of a specific forest fibre industry transformation partnership. This industry led, joint EU, member state and industry initiative would guide the use of EU ETS auctioning revenues for the transformation of the sector, creating the joint technology push needed and overcoming barriers ahead, so that technology meets investments at the right time to deliver the low-carbon sector required.

- **Nothing is impossible, but there are no silver bullets**
  In 2050 terms, the roadmap starts with the assumption that nothing is impossible. It shows, however, that there are no ready-made or easy solutions. In order to meet the challenges of 2050, achieving targets and keeping a competitive economy, we have to move the discussions to the next level. Achieving the transition from today towards 2050 in a way that secures the sector's future is the largest challenge to overcome by policymakers and industry alike. ■

Paper-based batteries for mobile phones are already under development.

Foreword and Vision

In our 2050 vision, people around the world are proud of their contribution to overcome the challenges of a few decades earlier, when economies struggled to remain competitive and the world faced climate change, resource depletion and the loss of ecosystem services.

Consumers have chosen to live in a bio-society. They opted for "life" (bios), and the forest fiber industry fulfilled its promise. It seized the opportunity for which it had been preparing. Operating around a living resource, based on fibres and molecules derived from wood, the forest fibre industry has anticipated societal trends and consumer demand to develop new business models and technologies. The carbon footprint of human populations has been greatly reduced, the sector recognised as part of the solution to climate change.

One morning in 2050... people are getting up in a 20-storey wooden apartment building. Managing to drag themselves from beneath the warmth of their wood-fibre blanket, they shave or apply wood-based cosmetics, and are ready for breakfast. At the table, the family pour cereals from their paper box into a bio-composite bowl, milk from the beverage carton, coffee into the paper cup. Sophisticated paper tissue products allow for quick clean-up. They have time to pick up their own tailor-made newspaper, on subjects they are interested in, sent directly from the web to their bio-composite printer. The bus is coming. It is biofuel powered. The air is cleaner than that breathed by their parents. The passing cars are also made of bio-composites derived from wood and powered by hybrid or bio-diesel engines.

At work, the PCs and printers are made of the same bio-based composites as those at home. Mobile phones use paper-based batteries. Presentations are made on a fibre screen made of over 80% cellulose, and print-outs use high-quality paper.

At noon, the recycled paper lunch box is pulled out of the fridge, and heated in the microwave. The box indicates how hot the food is.

After work, a visit to the elderly parents allows time to check that the medicine box is correctly programmed with the times to take the wood-based medicines.

At home, after checking that the shopping ordered on-line has been delivered in good condition, packed in board boxes that bear freshness indicators, the day ends in front of a good movie shown on the bio-composite nano-fibre based entertainment set. Looking forward to the weekend in the forest. ■

Teresa Presas
CEPI Director General

Why the Roadmap?

The pulp and paper industry has developed this roadmap in cooperation with the wood products sector and other stakeholders to contribute to the discussion on how Europe can achieve a low-carbon economy by 2050.

The core strategy on the path to 2050 is to get the **highest possible value** from resources – wood, virgin and recycled wood fibres, and non-fibrous raw materials.

It is based on an European Commission-modelled scenario for action on climate change, and examines how our sector might meet emission reduction targets. At the same time, it launches a debate on our future.

Our business is about producing the maximum value from wood. Wood fibres are used to make products, recycled to produce more value, before being converted to energy at the end of their lifecycle. In the future, wood products will substitute carbon-intensive materials even more. Products will increasingly be based on all sorts of molecules in wood, also using other fibre sources.

Because the sector is so interlinked, has a clear joint future and uses a common raw material, we take a broad view of the industry, which we call the **forest fibre industry**, combining pulp and paper and wood-based (future) products.

The forest-based wood products and pulp and paper sectors in Europe consist of 200,000 companies, employing 1.9 million people, providing around 75 billion euro in added value to the EU economy. The sector is for the most part based on raw materials from Europe. It is a global player. But the world is changing fast.

We accept that modelling and scenarios cannot accurately predict the world of tomorrow. Nevertheless, we believe there is value in looking this far ahead. We need our own answers to questions about what technology, finance, raw materials and policy will be required in the future. 2050 seems far away, but in fact encompasses just two investment cycles for most of our industries. Decisions cannot wait long.

As competition for energy and resources grows worldwide, sectors and regions that flourish will be those that can extract the highest value from scarce raw materials, using the least energy.

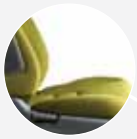
We aim to find the optimal balance between the use of raw materials - wood, residues, pulp and recycled wood and paper – the optimal recycling system and the lowest carbon solutions. As an industry at the core of the bio-economy, we believe we have a crucial role to play in the transformed industrial ecology of a decarbonised world.

Our sector is already progressing strongly in this direction. Many of our companies already produce large quantities of bio-energy and the first second-generation lignocellulosic biofuel projects have started. Many mills are now looking into ways to further integrate activities, drawing heat from other sectors, using waste to produce energy and using waste water treatment plants to produce biogas. Several companies are producing dissolved pulp to make viscose, able to replace land- and water-intensive cotton. One of the more specialised companies is the world's largest producer of industrial vanillin, a flavouring agent derived from wood.

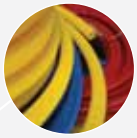
The roadmap is not a blueprint. It is an exploration of where developments might lead and an investigation into the policy framework and investments needed to get there. It does not prescribe; instead, it attempts to start a debate. It will be upgraded over time, to include the results of further discussions on the future of the sector. ■

Unfold the Potential of Forest Fibre

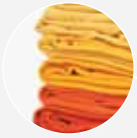
Transportation
Transportation packaging
Fuels • Oxygenates • Anti-freeze
Wiper fluids • Molded plastics
Car seats • Belts • Hoses
Bumpers • Corrosion inhibitors

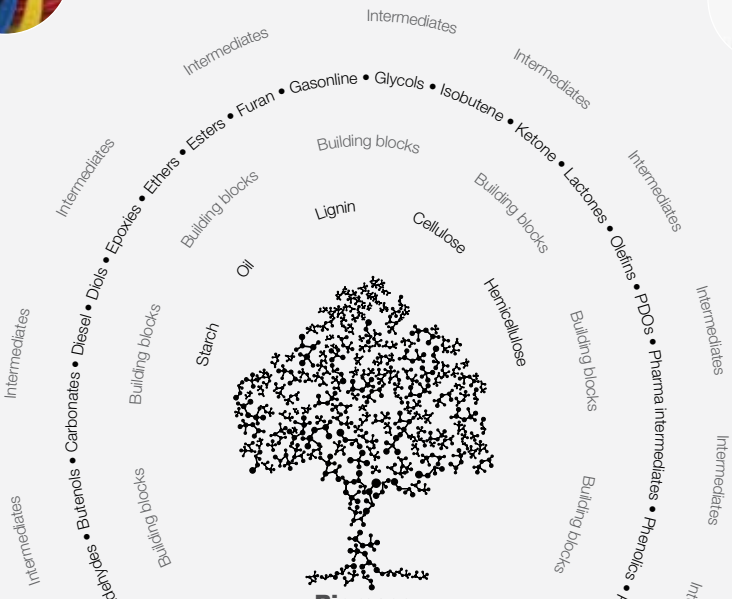


Industrial
Corrosion inhibitors • Dust control
Boiler water treatment • Gas purification
Emission abatement • Speciality lubricants
Hoses • Seals

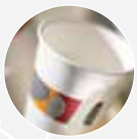


Textiles
Carpets • Fibres
Fabrics • Coatings
Foam cushions
Upholstery • Drapes
Lycra • Spandex





Safe Food Supply
Food packaging • Preservatives
Fertilizers • Pesticides
Beverage bottles • Appliances
Beverage can coatings • Vitamins



Communication
Paper products
Molded plastics
Computer casings
Optical fibre coatings
Liquid crystal displays
Pens • Pencils
Inks • Dyes

Environment
Water chemicals
Flocculants • Chelators
Cleaners & Detergents

Health & Hygiene
Tissue • Cosmetics
Detergents • Pharmaceuticals
Suntan lotion
Medical-dental products
Disinfectants • Asprin

Housing
Paints • Resins
Insulation • Cements
Coatings • Varnishes
Flame retardants
Adhesives • Carpeting

Recreation
Footgear • Protective equipment
Camera and film • Bicycle parts & tyres
Wet suits • Tapes/CDs/DVDs
Golf equipment • Camping gear • Boats

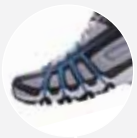


Diagram concept: Pöyry

The 2050 **Future**

The 2050 Mega-trends

Europe in the 2050 world

By 2050 the EU27 will have a relatively old and educated population compared to the rest of the world. It will peak at 516 million around 2035, declining to 512 million in 2050, up from 502 million today. The proportion of those aged 65 and over will double. The EU will still be rich, compared to other world regions, but its share of global GDP will be smaller. Competition for resources and land will grow, and "development" will rival if not eclipse the climate change issue. Electricity will meet most energy needs. With limited resources and a declining influence, Europe will need to adapt its economy and industry to the 2050 reality. To maintain influence and economic power, it will need to extract the highest possible value from limited resources.

The bio-economy

If we can develop a system based on biological resources, supplied and renewed by nature, the planet can sustain our society. The bio-economy could become the greatest single driver of the global economy. The forest fibre industry is together with agriculture in tonnage and added value the largest part of the bio-economy today. But other sectors are also getting active in this field, looking for a way out of fossil fuels. As demand for natural resources grows, the markets in which our sector will operate will be more crowded than we are used to today.

The forest fibre industry has the knowledge, logistics and systems in place to develop this economy. Together with the waste management sector, we have crucial expertise in paper recycling; we have core knowledge on forestry, fibre processing and wood chemistry; moving large volumes of biomass around is part of our daily operations; and our knowledge about wood construction could be applied much more widely than today.

Demands on our sector

Society will make further demands on our sector, besides good product performance and good value. Raw materials will have to come from traceable value chains that meet sustainability criteria. There will be more focus on sustainable consumption and recycling, to boost resource efficiency and reduce CO_2 emissions. The EU economy will need jobs, especially in rural areas. New, green jobs and technologies will demand new skills and education. ■

Cosmetics and pharmaceuticals based on forest fibre are already on the market.

2011

The forest-based wood and pulp and paper sector in Europe consists of

200,000 companies,

employing

1.9 million people,

and providing around

€75 billion

in added value to the EU economy.

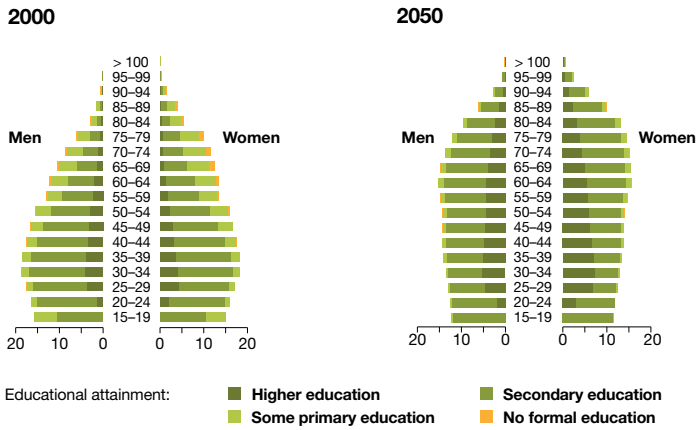
The 2050 Mega-trends

2050

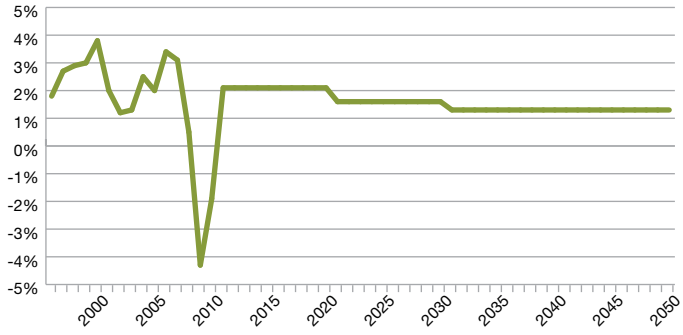
The Forest Fibre Industry has **a strong presence in a mature EU market with an ageing population.** The EU population will peak at **516 million around 2035**, and the **proportion of Europeans aged 65 and over will double from today's figure**. To succeed, the 2050 sector creates the highest possible value from its resources. **The Forest Fibre Industry is uniquely placed to provide for this, if we invest now**.

The ageing society[1]

Population by age, sex and educational attainment

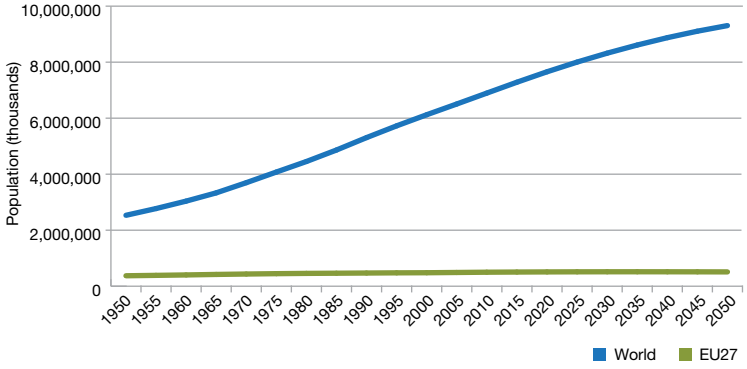


EU27 GDP growth[2]



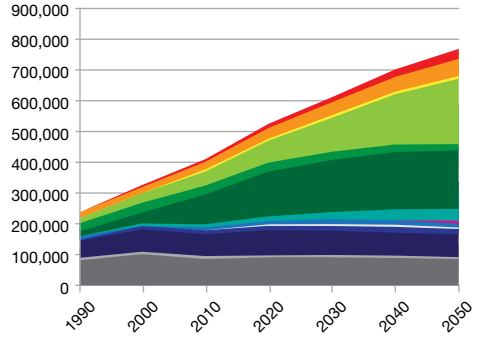
EU Population growth[3]

Within a global perspective

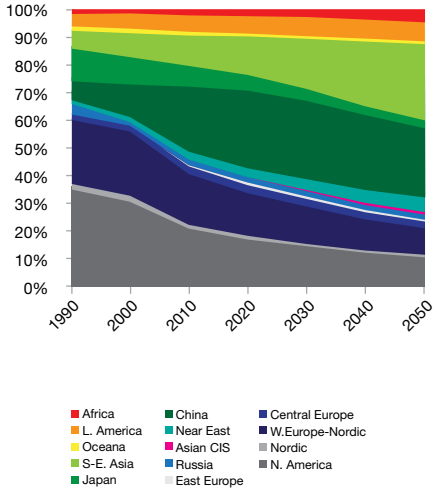


Long-term projection on paper and paperboard demand by region until 2050[4]

By 1000 tonnes



By % of of global paper and board demand



1 Source: European Environment Agency, 2010. The European environment - State and outlook 2010 (Megatrends publication/Samir et al., 2010).
2 Source: Eurostat and European Commission (2050 impact assessment POLES)
3 Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2010 Revision
4 Source: FAO Outlook Study on Sustainable Forest Industries: Opening Pathways to Low-Carbon Economy

The 2050 Citizen Consumer

Trends in consumer behaviour

Although we cannot predict behaviour, we know from trends and models the age, sex and education of future European consumers. We can also draw on cycles of change and key drivers to assess how attitudes, behaviours and values might evolve.

There are four major drivers for change of consumer behaviour: **economics** (population growth and resource constraints), technology (development and deployment of technologies), **social change** (societal values and style of governance) and **biosphere boundaries** (the planet's capacity to support its population and their lifestyles). Citizens' values will shift in response to these drivers and to changes in their environment. Over the longer term, behaviour will depend on the next wave of technological change and the future shape of institutions and governance models.

Consumption in 2050

With more people on the planet and increased per capita wealth, consumers will be aware of resource pressures and the need for efficiency. They will also expect better functionality from goods with a smaller carbon footprint. ICT will play an ever-increasing role, while nanotechnology, biotechnology and artificial intelligence will reshape society in ways we cannot imagine today.

There will be more emphasis on efficiency, in households, construction and industry. At the top end will be zero waste - 'cradle-to-cradle' - systems, in which all by-products are reused or returned cleanly to the soil. Elsewhere, there is likely to be extensive retrofitting of systems to reduce consumption. There will be a greater drive to reduce food waste. The emerging trend for urban food production and urban energy efficiency solutions will continue and will change our experience of cities.

The nature of social cycles suggests that the next cycle will be more driven around the wider needs of the community and less market-driven than at present. There appears to be a long values shift going on in wealthier markets from 'materialist' to 'postmaterialist' values, e.g. a desire for experience over material possession. The way that people judge success – and companies' performance – may change.

Bio-based products will come into their own. Able to produce the highest possible value added from initial raw materials, renewable and recyclable products will meet the demands and expectations of the 2050 consumer. If the sector is able to develop its knowledge of consumer demands, one day they might be lining up in front of stores to get the newest forest fibre-based gadget. ■

The 2050 Future

Forest Fibre Industries in the 2050 World

Products for the future
Although consumer demand and societal change will reshape our sector, the future can already be anticipated with some confidence. Fast forward to 2050...

European **forests** offer an attractive investment for ecosystem services and related products: forestry, biodiversity, wetlands and eco-tourism. Land not needed for food production or nature conservation has been planted as forest, enabled by a further move of people to cities. Forest management practices have created a balance between carbon storage in forests and wood products. The sector has been a key driver in further developing forests and forest management in Europe. New balances in land use are found between forestry and agriculture.

Wood-based **construction materials** are widely used, helping the built environment deliver an 80% CO_2 emission reduction by 2050, extending the carbon storage role of forests by providing a further storage period in products and at the same time replacing other (energy or carbon-intensive) construction materials. (Substituting cement or steel with a cubic meter of wood results in average CO_2 savings of 1.1 tonnes). New wood construction techniques allow for solutions not seen before. At the end of their service life, wood products are reused or recycled, before being used as a carbon neutral fuel.

Packaging has a much greater role in society. It is lighter, more efficient and more advanced. Demographic trends have prompted demand for smaller-sized goods for daily needs, while improved health and safety regulations worldwide have boosted the global demand for packaging. Advanced design and nanotechnology have helped develop strong, sealable and sterile containers for a wide variety of contents and even completely new products for the bio-economy. Smart packaging in systems combined with IT solutions has less waste, improved logistics and reduced transport.

Paper-based hygiene products serving basic human needs will become more and more available and used also in developing markets, while in mature markets they will remain essential for everyday life. Women will be important drivers of consumption, both in emerging and mature markets, and will work outside home to the same extent as men. This will increase the use of feminine care products as well as baby diapers. The ageing population will increase the need for incontinence care solutions that allow for an active life.

Graphic (printing and writing) paper products are produced in smaller quantities, but more varieties and grades are available. European companies enjoy a sizeable chunk of the global market, which is expected to grow. Lightweight paper for office applications allow the use of fewer resources, while supporting better print quality and machine performance. The virgin fibre input to the graphic paper products remains essential for the recycled fibre loop.

New, renewable products will be developed. Research has led to investment in new biorefinery processes, to produce biofuels, textiles, chemicals and new materials, including composites and pharmaceutical products.

Today the sector is the largest producer of bio-energy in Europe. As other sources of **bio-energy** grow, the relative share of the forest-based sector will decrease. It will continue, however, to produce bio-energy for its own and other industries needs, and provide logistics and platforms for others to produce bio-energy and biofuels.

Bio-composite materials will play an ever more important role in our lives.

The sector focused on the highest value added

The 2050 forest fibre industry is built around a holistic vision of product lifecycle. Fibres are used and recycled in an optimal way, with the highest possible value added at each stage. When no more products can be made, residues are turned into power and heat.

This applies in two ways – first getting the most value out of a single tree. Second, creating added value as an economic sector in EU's 2050 economy.

The European Commission Roadmap for a low-carbon economy by 2050 is informed for the pulp and paper industry by data from PRIMES. It assumes a value added growth of 1% average per year for the pulp and paper industry in its current definition. (This EU27 average disguises higher projected growth in new EU member states.) It does not, however, model the bio-based economy or break-through technology.

Vanillin, used as a flavoring agent in foods, beverages, and pharmaceuticals, occurs in tree bark and resin.

The European Commission model also expects an increase in black liquor energy output, estimated to increase 8% in the reference scenario and 19% in the decarbonisation scenario between 2010 and 2050. No data is available for the wood products sector as it falls under "other industry"; it is however expected to grow significantly and keep in line with EU GDP growth. Wood construction and renovation depend strongly on the future growth of the building sector in general.

EU GDP is modelled to grow in real terms about **1.5% per year**. We assume the overall forest fibre industry, covering current and new products, wood and paper, to follow this growth, meaning new products in the broader sector scope will make up the difference, aided by the export of these products to developing global markets.

Core strategy for the sector

An increase in value added will result from a more efficient use of raw materials, higher prices and turnover and/or new products. If we assume that price and turnover increases keep the same pace as cost increases, additional value should come from new products and more efficient use of raw materials. The core strategy on the path to 2050 is thus **to get the highest possible value from resources** – wood, virgin and recycled wood fibres, and non-fibrous raw materials. For the wood products sector this means, e.g., focusing on new building applications. For pulp, paper and board producers, it means further integrating activities, moving to new products and making use of residues. Where possible, mills will be part of an industrial system that optimises the use of raw material, energy and waste. A new industrial ecology will evolve.

A future sector based on three pillars

The future forest and fibre industry will operate as a single system, optimising raw material and energy flows in integrated complexes, as follows:

1 **Wood-based biorefinery complexes** will produce wood products, pulp, paper and board, bio-energy and biofuels, bio-composites and bio-chemicals. Most will be expanded chemical and mechanical pulp mills, although some will occupy greenfield sites. They will be situated mostly in rural areas, providing valuable green jobs in a world where most people live in cities.

2 **Recycled fibre-based biorefinery complexes**. Recycled fibre biorefinery based complexes also produce pulp, paper and board and biofuels. The sector will operate in consortia with other sectors - agriculture, waste, chemicals and energy - in industrial complexes. Their residues are used in high-value applications, be it fatty acids from waste water, moulded products or insulation materials.

3 **Non-integrated mills**. Non-integrated saw mills, wood product and paper mills will balance the system to allow for optimal use of the raw material in the different stages of the sector's development.

By 2050, new business models will have been set up through cooperation with other industrial sectors (energy, chemicals, refineries, steel, cement, etc.). A symbiosis of industrial activities will optimise raw material, energy and product flows. The forest fibre industry will have actively sought strategic alliances with other industries. ■

The Definition of Carbon Reduction

We take as this roadmap's basis for carbon emission reductions the European Commission Roadmap's global action scenario with efficient technologies and low fossil fuel prices, in line with the IEA blue low growth scenario and the Eurelectric Power Choices scenario.

We assume the forecast reduction will be shared equally across industry. With the steep reductions needed the EU ETS will later in the period have lost its cost-evening function. All have to reduce.

Starting point. The scenario's starting point is an 80% CO_2 reduction by 2050. For the **pulp and paper industry**, this translates into a reduction from roughly 60 Mt CO_2 in 1990 to 12 Mt CO_2 by 2050, covering 40 Mt direct emissions, 15 Mt indirect emissions from electricity purchased and 5 Mt transport emissions.

There are no emission statistics available on the **wood products sector**. Based on standard factors and production data we estimate total emissions for the **wood products sector** for 2010 to be 20 Mt; direct emissions to be 3-5 Mt, indirect electricity emissions to be 7-9 Mt and transport emissions 6-8 Mt. As there is no data on 1990 at all, it has not been possible to present the two emission profiles together yet.

The broad carbon profile. The approach above is simplified. The sector's carbon footprint consists of direct emissions, indirect emissions from electricity purchased from the grid, emissions from the transport of raw materials and products, emissions from raw material production and end-of-life emissions from our products. Furthermore, substitution effects of the increased use of bio-based products are not included in the calculations.

The more wood products are used, replacing cement or steel in construction, or to produce bio-energy, biofuels and bio-based packaging and products, the higher our contribution will be. The storage capacity of managed forests that supply fibre to our sector is another large asset, which needs to be taken into account when analysing the CO_2 impact of the forest fibre industry as a whole.

2050 energy prices. Total energy demand and the import/export balance of fuels are taken as a given in this roadmap. Electricity, carbon and fuel prices are key to answering the questions when certain investments become affordable, how profit margins will survive and how the sector can make it through the transition. In general, the EU will have to find a scenario where price increases match those of competing countries, keeping the EU investment climate attractive. Price levels will determine if and how the sector can make it through the transition, but do not change the starting point of the reduction. Furthermore, changes to the sector will not have a significant impact on the modelled energy data in the 2050 future. ■

The **Road** to 2050

The Pathway to 2050

The transformation of a sector

Industry transformation is a continuous process. For the forest fibre industry, it will occur at product, machine, mill, business and sector levels, all of which require ongoing research and investment. Companies that own several mills will need to decide where to invest for the future, taking into account comparative costs, investment conditions and payback times for that particular mill, technology and global region. In this context we expect further consolidation within the industry, but focused mainly on bulk grades. Small and medium-sized companies will remain, embedded in local markets, focused on specialised conventional and bio-based products. Access to finance and attractiveness for investments will be key. The sector has to break out of a cycle of low rates of return to get the investments needed to make transformation happen.

Managing innovation

The step beyond best available technologies (BAT) relies on the uptake of emerging technologies (ET) that are waiting for full-size pilot plants. For developments beyond 2030, we will depend on breakthrough technologies and techniques (BTT) that are yet to be explored, and that would not be focused on the EU market. Systems need to be put in place that support and enhance innovation for the EU. As growing markets adopt EU technologies, the EU will need to keep its technological edge. One option may be to cooperate with regions in a similar position, such as Canada, the US and Japan. Innovation requires the financial capacity to invest in R&D, piloting and deployment. To keep the momentum, however, developments have to start within the EU.

Value creation in a mature market

Forty years from now, the sector has the ambition to deliver the highest possible added value using only 20% of the fossil carbon it uses today, taking its position in the value growth of the EU economy. Doing so in a mature market is a challenging proposition, but new product markets can be the answer. An FAO outlook study predicted a stable to slightly declining demand in Western Europe and increasing demand in central and Eastern Europe, stabilising after 2040. There are however possibilities to meet our ambition. New bio-based products will add value, and so will higher value added successors of today's products. Although the relative share of EU exports on the world market will decline as other economies grow, our export role will remain strong. China and India and new developing countries will not have sufficient wood and recovered paper resources to meet domestic demand.

Both new and existing products are expected to boost growth in the sector, e.g. by:

1 The increased role of wood in construction sector, combined with the large need for renovation of existing buildings.
2 An increase in paper and wood recycling, reusing fibres to extract more value.
3 An increase in value from packaging. As packaging weight is reduced and smart packaging developed, the value added per tonne will increase.
4 An increase in volume and value from tissue/hygiene papers. The ageing society and higher hygiene standards will lead to a wider variety of hygiene papers (e.g. more sophisticated wipes and kitchen roll).
5 Specialisation in graphic grades. A move to higher value added products.
6 The wide potential of new bio-based products and business models. ■

The Road to 2050

Technologies for Transition

The technology challenge
The PRIMES modelling behind the European Commission roadmap shows that the final energy demand for the sector is expected to decrease by 20% between 2010 and 2050, while CO_2 emissions decline by roughly 80%. This means fuel mix change plays a large role. To achieve these emission reductions, improved and breakthrough technologies will need to be deployed, aimed at improving:

1 **Resource efficiency** and **energy efficiency**.
2 **Conversion efficiency** - processing of biomass into products using mechanical, thermochemical, biological/biochemical and extraction measures.
3 **Product efficiency**.
4 **New products** – for example nanocellulose, viscose (old and new), bio-based chemicals, pharmaceuticals and cosmetics.

As both current technology has to be replaced and new products and services developed, the question might arise as to what the best investment is – a new boiler or a new product design? We assume both are needed, knowing that both tracks might mix in the future. The assessment of which technologies are available is the basis for the technological transition towards 2050. In this chapter, we examine which technologies are available or should be developed to realise the potential in each of the platforms above.

Applying best available technologies
Replacing equipment could cut the sector's CO_2 emissions by 25%, compared to 2010. **Mills and machines** that have just been built will still be operating by 2050, or coming to the end of their life. Under-invested or older mills will have closed. Medium-age, sized or performance mills will have been changed, upgraded or rebuilt. Production scale will have increased, and consolidation continued. The basics of innovation will yield a year on year improvement of efficiency in operations. Optimisation of wood use in sawmilling can still bring large gains as well. All **power and heat boilers** operating today will have been replaced (boiler lifetimes are 35 to 40 years). However, the expected boiler efficiency improvement is limited. Appliances are either at today's BAT or will be by 2050. **Combined heat and power (CHP)** is seen as key technology for bio-energy and a key intermediate technology for natural gas use. At some stage, the production of fossil fuel-based CHP electricity on site will have higher carbon intensity than centralised power generation using a large share of renewables, nuclear or Carbon Capture and Storage (CCS). This would mean that to further decarbonise, CHP would be used in biomass/biogas applications only, in combination with CCS or new solutions have to be found for fossil fuel-based CHP. The potential of using biogas in sufficient volumes is not clear.

Recovery boilers may have been replaced (their lifetime is 30-35 years), although rebuilding and retrofitting to facilitate integrated biorefineries may be a preferred investment option, given the global competition. Development of black liquor gasification is a stepping stone.

For **specific production equipment**, we assume that the trend for more electricity-based installations using less heat will continue, and that this, along with the decreasing carbon intensity of electricity generation, will boost the CO_2 performance of mills, although for a number of mils the impact on the efficient use of bio-based CHP needs to be taken into consideration.

The contribution of emerging technologies
It is hard to estimate the potential of emerging technologies, but several merit closer investigation. In **paper production**, one priority is to reduce heat demand in the paper machine. Current emerging technologies focus on the machine's drying section, on layered sheet-forming, and on advanced fibrous fillers and highly selective fractionation processes. While all improve efficiency compared to today's processes, none offer the savings needed. In **pulp production**, emerging technologies focus on improving the efficiency of existing processes, notably in refining and grinding for mechanical pulp production and the pre-treatment of wood chips, to reduce electricity consumption.

For **new products and services**, technologies for the production of nanocellulose are being developed. The current challenge of the large amounts of energy needed to produced nanocellulose appears to be being overcome. Biocomposite materials, biofuels and biochemicals are produced on today's technology platforms, but will also need emerging technologies to increase their volume for the future.

Emerging **energy conversion technologies and fuel mix change** offer greater promise, especially as they can be applied in other sectors too. Lime production in pulp mills is already more efficient than in conventional installations. Further improvements would be to replace the natural gas or fuel oil with biomass-based fuels in lime kilns. This could deliver savings in Kraft pulp production in the order of 3-4 Mt of fossil-based CO_2.

Ongoing research into **biomass and waste/residue gasification** (expected application 2015-2025) could be of direct benefit to the pulp and paper sector.

The challenge is that no large gas turbine manufacturer is interested thus far. **Black liquor gasification in pulp mills** is a case of the emerging thermochemical path for producing syngas. It also provides other product options. A full-scale investment might come in 2015-2020. Other technologies are being developed to extract value from black liquor, for example lignin extraction. Lignin or other compounds from the pulping liquor can be used directly or modified to replace fossil based material in anything from chemicals to plastics. It could directly replace fossil fuels in the lime kiln or coal outside the mills.

In the wider bio-energy sector, biomass **torrefaction, carbonisation and pyrolysis** increase energy density and thus have wider potential application.

The challenge of the above technologies for our roadmap is that while they will improve resource efficiency, lead to new products and help integrated biorefineries to develop, fossil fuel-based CO_2 emissions at pulp and paper mill sites will not necessarily fall.

Developments in the production of **wood-based construction** products focus on new laser cutting technologies, material savings, wood drying concepts and the developments of glues, paints, coatings and further treatment for increasing the durability of wood material and surfaces.

Increased recycling and better sorting

Mills where production is based on recovered paper could reduce emissions if sorting technologies and the use of collected fibres were improved. Although there is still a potential to increase the use of recycled paper, freeing up more fibres for the sector, avoiding methane landfill emissions and improving resource efficiency, Europe is nearing capacity in this respect. Policy measures are necessary to avoid co-mingled collection and keep recovered fibre in Europe, to ensure that quality fibre will be available in the future.

Greater use of recovered paper and a lower input of virgin material will increase residues from recycled paper production, which can be used as a source of energy within mills, replacing fossil fuels. This is not to say that incineration of recovered fibre is desirable. Simply that with better sorting and larger volumes of recovered paper, there would be more left over either for conversion into new products (e.g. biofuels) or as fuel for the mills. In terms of technology, the existing fluidised bed boiler technology should be sufficient. In the recycled fibre biorefinery complex, mills will be able to recycle and mix more fibres than today, drawing on a broader assortment of fibres from collected materials.

Industrial ecology and the intermediate step

Our vision of integrated biorefinery complexes assumes the combination of industries on a single site. Further combinations with other sectors (waste management, steel, cement, refineries, and energy) could offer still larger potential. The challenge is that this requires measures akin to industrial planning or at least new-build mills. Heatmaps could help assess the potential for any such re-siting, but actual change of production sites lies beyond individual industries' capabilities.

An intermediate step in the development of this 'industrial ecology' is the further merger of pulp and paper mills (or any industry with heat demand) with the waste (management and incineration) sector. The CHP installations (an ideal solution, due to the year-round heat demand of paper mills) will supply municipalities and adjacent facilities with renewable energy and be operated by the mill itself or a (private or public) partner. Already, many mills use their own residues as an energy source. The next step is to use other waste flows and/or the heat from municipal waste incinerators. If these 'hubs' could also be attached to a CCS facility, they could be carbon-free.

Breakthrough technologies needed

The technologies and measures described thus far will help the sector decarbonise, but they will not take it to the 80% reduction target. For this, breakthrough technologies need to be developed and deployed over the next decade or two to reduce heat demand in papermaking, by reducing water use and improving drying processes. Breakthrough technologies will further create the jump in value creation needed. Paper drying accounts for up to 70% of fossil fuel energy consumption in the pulp and paper sector alone. In the broader sector, it represents the largest source of non-biological CO_2 emissions. It offers a great potential for energy saving. In practice, however, technological development in this area is slow, with little chance of a large-scale improvement in the coming two decades. Focus needs to be put here.

Breakthrough technologies would not only be needed for the carbon reduction aimed for in pulp and paper making. New technologies for new products are to be included as these are the key to higher value added solutions.

To CCS or not to CCS
The European Commission's emission reduction roadmap assumes the use of CCS, another breakthrough technology. This underlies our own assumptions for this roadmap, although in practice it seems that a delayed CCS scenario is more and more likely. The forest fibre industry is not in the first line of CCS application, as the focus is on larger emitters of fossil CO_2. One option for the pulp sector, according to the International Energy Agency, is Bio-Energy with Carbon Capture and Storage (BECCS), to commence by 2020-2025, with deployment starting by 2030. Flue gases of pulp and paper mills contain 13% to 14% CO_2 and are seen as potential application sites for BECCS. We do not include this option in our roadmap.

The incentives needed to drive BECCS, as described by the global CCS institute and IEA, include a valuation of negative CO_2 (biomass CO_2 stored underground): not only will this be applied to fuel production and co-firing before pulp mills, it will create a perverse incentive to burn wood. Alternatively, we argue for a focus on reducing heat demand to cut emissions. The money that would be needed to invest in BECCS could instead drive the development of breakthrough technologies in this area.

Non-technological options, new technology and new products
In forests, the development of improved species, new harvesting techniques, improved sustainable forestry practices, and the production of forest residues could bring more value to the chain and add room for new solutions. Within pulp and paper production, the increased use of fillers, coatings and other chemicals that indirectly reduce for example heat demand offers further energy savings potential and is a developing area.

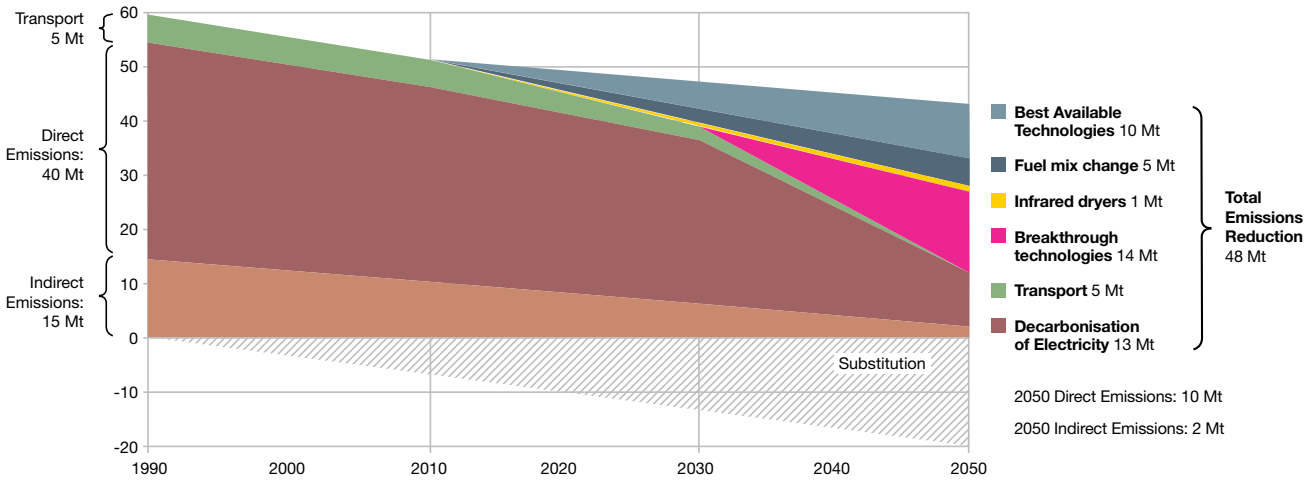
Fractionation technologies, meanwhile, offer the potential to modify the properties of fibre to develop new added-value products. These could improve compatibility with coatings, printing inks or polymers, for example, or increase water sorption capacity.

A key focus in paper production would be to reduce grammage, since efficiency is directly proportional to reduction in product weight (g/m^2). The challenge lies in how to fulfil quality requirements with fewer fibres.

In general, the growing demand for bio-energy and bio-based products can be regarded as an opportunity for the sector. The sectors efficient, extensive wood procurement infrastructure covering harvesting, transportation, wood handling facilities and energy systems give it the capacity to enter new markets.

Can technology bridge the gap?
Based on the technologies presented in this chapter and a sector definition without substitution, we see that half the modelled reduction of CO_2 emissions (from 60 Mt fossil-based CO_2 in 1990) can come from technological solutions we know today. This is shown in the graph below, which for lack of data does not include the wood products side of the sector.

Emissions Reduction Projection 1990 - 2050 (in million tonnes)



The exploration shows that a reduction of 50 to 60% of CO_2 emissions is possible given the right circumstances. To achieve a minus 80% reduction, however, the sector will need breakthrough technologies.

Using electricity
As the EU electricity mix is modelled to decarbonise strongly by 2050, the indirect emissions related to electricity for the sector will further come down, in an interplay between purchased and self-produced electricity with CHP. This applies to both pulp and paper and wood products.

Applying **best available technologies** in all mills (capital stock turnover, consolidation) could deliver an estimated 10 Mt (25%) reduction. Changing direct fired infrared dryers in paper machines to electricity-based would cut a further 1-2 Mt. Indirect emissions resulting from buying electricity from the grid will fall (assuming an equal demand) from 15 to 2 Mt by 2050.

Nanocellulose or Microcellulose is a material composed of nanosized cellulose fibrils and is usually made from wood (pulp fibres). The properties of microcellulose make it an interesting material for many applications i.e. as barriers in packaging, as an additive in paper coatings, in hygiene/ absorbent products and in a myriad of other applications. Source: Innventia.

Fuel mix change in lime kilns and in energy production (from gas, coal, oil and peat to biomass, pellets, biocoal, pyrolysis and biogas) could reduce emissions by 5-6 Mt. Biomass CHP in sawmills and panelboard production can make these self-sufficient and almost carbon neutral, reducing emissions by an estimated 1-2 Mt. Making recycled-based paper mills into integrated biorefineries would allow further fuel mix changes, although this would depend on larger quantities of recovered paper staying in Europe, more sophisticated sorting and lower paper qualities being used as fuel for paper production.

Emerging technologies. Current emerging technologies, especially in energy conversion, offer the means to substitute oil-based products with biomass-based products. In this roadmap we have not calculated the impact of substitution of carbon-intensive materials by bio-based materials as such.

The production of transport fuels
We expect the sector to increasingly produce biofuels for transport. The total transport emissions for the pulp and paper sector today amount to around 5 Mt of CO_2 annually. The transport emissions of the wood sector are estimated to be 6-8 Mt of CO_2. Total emissions are equivalent to 3-3.5 million tonnes of fossil diesel consumption. To neutralise the emissions from transport, a biofuel equivalent of approximately 4 million tonnes of second generation wood-based biodiesel would need to be produced, requiring some 30-40 million m^3 of wood as feedstock. We expect that more than the 20 full-scale plants needed for this could be in place in our sector by 2050, although the wood residue demand is large and has to be secured.

Substitution
The 2050 sector will produce wood fibre-based construction products replacing carbon-intensive cement and steel. The production of bio-based chemicals, packaging and materials will further replace oil-based products. Second generation lignocellulosic biofuels will replace fossil fuels. This substitution effect will be significant and an addition to the carbon reduction contribution of the sector. There are however no figures to date on the total potential of substitution by wood-based materials at the EU scale. Wood products activities are often grouped under "other" industry in modelling. More work needs to be done within the sector to unravel this potential.

Fuel and carbon price impacts
Energy and carbon price developments shown by the European Commission modelling will affect investments in the sector more than emissions. If the modelled global action scenario does not become reality, increased prices in Europe will result in business leaving Europe ('carbon leakage') and closures. The best potential for emissions reduction is capital stock turnover and fuel mix change, both of which will be possible as long as EU climate policy does not deter investors.

Linear reductions?
Further measures will still be needed to reduce emissions by 80%. Here, the focus should be on developing **breakthrough technologies** that significantly reduce the heat demand in chemical pulping and paper and board making. There are no known technologies for this today, and these would need to be in place by 2030 to allow for machine replacement and at least 10 years of optimisation. In this respect, the reduction pathway in the European Commission roadmap should be adjusted. Reductions will be gradual up to that point, after which they will rise significantly. This will occur around 2030-2040, if research is started now. Most of the emission reductions up to 2030 depend on emerging technologies coming to market. The low hanging fruit – e.g. fuel mix change – has taken place already, with biomass now representing more than 50% of the fuel used in the sector. ■

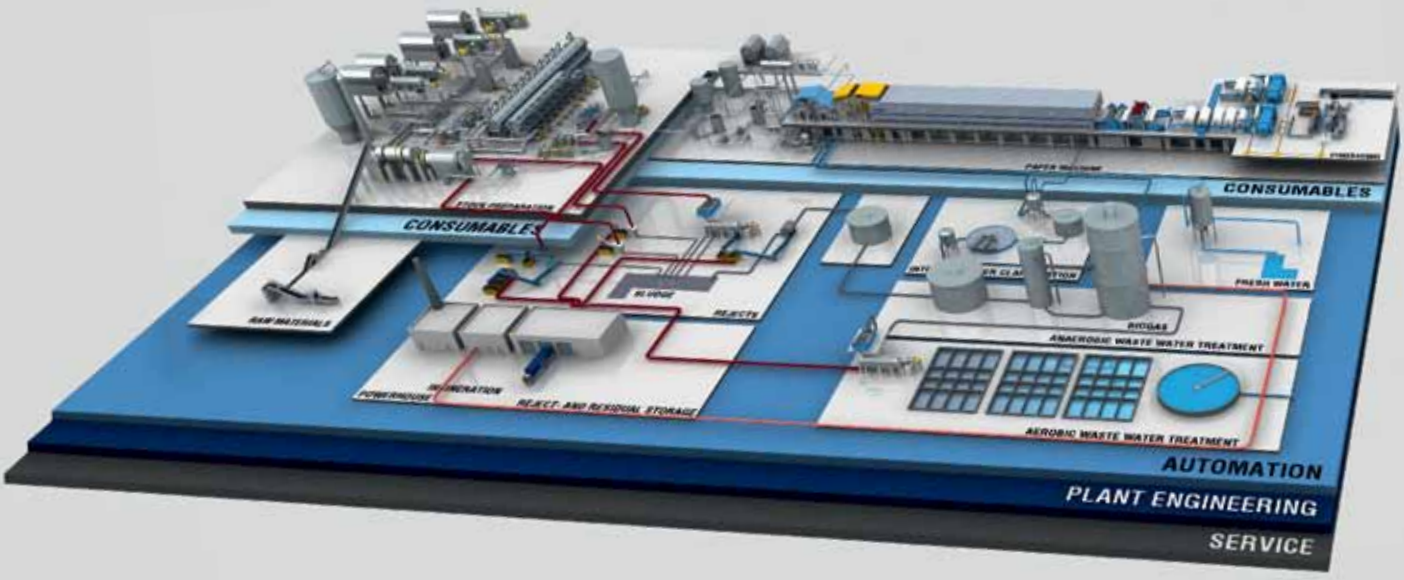
The industry of the future

The solution to ensure a competitive industrial base for Europe.

Our vision of integrated biorefinery complexes assumes the combination of processes on a single site. Further combinations with other sectors (waste management, steel, cement, refineries, and energy) could offer still larger potential.

An intermediate step in the development of this 'industrial ecology' is the further merger of pulp and paper mills (or any industry with heat demand) with the waste (management and incineration) sector.

The CHP installations (an ideal solution, due to the year-round heat demand of paper mills) will supply municipalities and adjacent facilities with renewable energy and be operated by the mill itself or a (private or public) partner. Already, many mills use their own residues as an energy source. The next step is to use other waste flows and/or the heat from municipal waste incinerators. If these 'hubs' could also be attached to a Carbon Capture and Storage (CCS) facility, they could be carbon-free.



Resources for Change

The raw material challenge
As the IPCC concluded in its fourth assessment report, the largest sustained mitigation benefit depends on a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest. The focus on the highest value from the raw material needs to be further extrapolated into a vision of the highest value from the land used. New balances in agriculture and forestry need to be found, providing food, fibre and feed in economically sound ways. The economic function of the forest is important. Adding the economic function to the forest improves forest management. So far, the forest sector is the only sector managing EU forests without the need for subsidy support.

By 2050, the forest fibre industry will create more value from its raw material base, but with greater competition for wood as other sectors increasingly turn to its use and as wood used for energy purposes increases.

By 2050 the forest fibre industry will create more value from its raw material base, but with greater competition for wood.

The models used are far less clear on the volume of products produced than on the value produced. We assume the overall output of the sector will grow, with underlying changes in wood, paper and pulp products growth. The per capita consumption of paper and board for example in especially Eastern Europe will grow, but will be balanced by stabilising consumption in Western Europe. Overall, wood consumption will increase, as will consumption of bio-based products.

We believe that there will only be enough raw materials for all purposes if Europe invests in its forests and efforts are made to bring more biomass to markets, the optimal recycling system is created, efficient use of biomass is mandatory and large volume biomass imports are possible. Without these ingredients, there will be fibre shortages and price volatility.

Self-sufficiency will be a crucial asset in 2050. The forest fibre industry, drawing as it does largely on EU raw materials, will have a central role to play in the bio-economy, where the focus will be on sustainable, renewable and recyclable raw materials, used in the most optimal way, and creating the highest possible added value. We believe both the virgin wood, pulp, paper and board products sector as well as the recycled fibre sector will have their share in the growth.

The wood raw material base
Future demand for wood in the forest fibre industry has been best modelled in the 2010 EUWOOD study for DG Energy. It assumes a 40% growth in volume demand by woodusing sectors by 2030, with strong demand in the building sector, to replace steel and cement. The PRIMES model, in contrast, forecasts the same growth but by 2050.

Demand for wood for material uses (for sawmills, veneer plywood, pulp and panel industries) is predicted to outstrip potential supply between 2015 and 2020. Demand for wood for energy will more than double by 2020, also exceeding supply potential (according to current utilisation intensity of ca. 680 M m^3). Wood recycling, e.g., the recycling of wood products, will be optimised as well, producing new fibrous raw materials from used wood.

Wood for energy
We expect that our sector will have to compete for resources with coal plants, which will be able to purchase energy wood for co-firing at increasingly competitive prices compared to buying coal and CO_2 emissions permits. The projected rise in CO_2 price – from 17 euro/t in 2010 to 190 euro/t in 2050 in the different European Commission scenarios – will drive coal replacement and give the coal sector greater buying power than our sector's capacity to raise prices with current products. Demand for "logs for energy wood" is projected in the European Commission roadmap to rise by about 35% from 2010 to 2050. Comparison of the European Commission modelling and the EUWOOD study shows that the biomass needed to meet the growing demand for bio-energy (49%) will partly be covered by logs and partly by residues.

The European Commission scenarios do not predict large imports of biomass or wood. We disagree. To the contrary, we expect imports to rise to meet the demands of large-scale electricity production including coal plants.

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Sources of wood supply

According to European Commission models, wood production is projected to rise from 500 Mm^3 in 2010 to 540 Mm^3 in 2050 in a low production increase scenario, or 750 Mm^3 in a high production scenario, which includes an increase in domestic production of forest biomass for energy. The EUWOOD study is partly in line with the European Commission high production scenario assessment, but differs in the analysis on supply and demand.

In the European Commission roadmap, agriculture is the prime source of biomass for energy. It projects much less growth in biomass from forestry than the EUWOOD study. A 2008 study by UNECE/FAO suggested than an additional 233 Mm^3 of roundwood equivalent could be supplied from various sources in the EU, if vigorous actions were taken by governments.

The role of plantations

Planted forests represent today around 7% of the world forest area and contribute 36% (1.2 billion m^3) of the annual requirements in roundwood. As global demand for biomass grows, interest will grow in species that offer the possibility of different end uses: for fibre production, for reassembly of larger solid wood items, for energy production and, for those rich in raw materials, perhaps for the chemical industry.

Hardwood species will prevail in southern Europe, while further north softwood alternatives will be favoured. Northern and central Portugal, northern Spain and a portion of France, Italy and even Greece will grow eucalyptus (whenever climatically possible). Poland and other Eastern European countries have a huge potential for short-rotation forestry on former farmland; they could use new hybrids of eucalyptus that are capable of withstanding frost. Across Europe, favourable conditions and the available area have the potential to add almost 3 million hectares of plantations (40% eucalyptus and 60% other species) in the next 30 to 40 years.

"...a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit." Conclusions of the 4th Assessment report of the Intergovernmental Panel on Climate Change.

How to Mobilise More Wood

- Sustainable forest management.
- Governments should stimulate a process of consolidation of forestland ownership to boost coordination and planning, and reforest areas previously used for agriculture.
- Improve infrastructure and logistics to support an adequate forest access network.
- Intensify wood harvest through management measures, use of higher-growth species, forestbreeding and plant material refinement.
- Boost education and training for forest owners and entrepreneurs, and inform the public about the benefits of using renewable raw materials.
- Facilitate financing sources and mechanisms to help forest owners fund harvest operations and improvement of logging technology and efficiency.
- Improve legal and fiscal framework to remove impediments to increased mobilisation and stimulate activity by forest owners.
- Address markets and marketing, organisation and transparency to promote wood supply.
- Improve recovery channels for post-consumer wood.

Genetic modification
Globally there is an increased focus on genetic modification of trees, with the aim of developing trees that use less water, are frost resistant, have a lower lignin content and respond better to diseases and pests. In Europe, however, GMO trees are not on the agenda at the moment, due to consumer preference and forest rotation periods. According to our assessment and simply because of the time required to grow trees, they are unlikely to play a role in the EU fibre supply by 2050, other than through imports.

The 2050 recycling society
Virgin fibre and recycling are complementary parts of the same system. One cannot do without the other. By 2050 we assume the recycled/virgin fibre balance for paper and board production in Europe will have changed from 50/50 to 60/40, but only if we are able to keep recovered paper in Europe and if enough quality virgin fibre is brought into the system.

Whereas the optimal recycling system would recover 80% of all paper and board consumed, we assume 75%, considering that the share of hygiene paper will increase while the share of high quality virgin fibres from printing and writing paper will decrease.

The three ways to improve recycled fibre quality are improved collection and sorting, ecodesign for recycling and more efficient treatment and refining of fibres. Brown and white paper can already be separated by sorting machinery; by 2050, machines will sort according to filler content, brightness and fibre length. The paper loop will also prevent products containing hazardous substances or substances that cannot be managed from entering into the recycling process.

This future vision faces two obstacles: more recycling will reduce the quality of recovered paper; and fibre will continue to 'leak' through exports. Already today paper mills are closed for lack of available recovered paper. China and India will continue to be the largest importers of recycled fibre in 2050, but their domestic collection systems will further improve. Demand for recovered paper from other countries, meanwhile, will increase. The fibre balance will therefore continue to be critical. Recycled fibre content will have been maximised, recovered paper quality will decline and paper makers will pay a premium for high virgin fibre content recovered paper. Starch and other chemicals will be used to improve strength properties. Unusable recycled fibres will be used to produce other bio-based products, biofuels or, ultimately, energy in mills.

The greater availability of recycled fibre (10-15% more than today) will free up wood resources for other uses (biofuels, biochemicals, bio-energy). It will not reduce the sector's overall demand for wood in the amounts sometimes expected.

Non-fibrous raw materials and other fibres
Towards 2050, non-fibrous raw materials will be increasingly used and recycled to reduce fossil CO_2 emissions. Already, it seems possible to reuse/recycle most pigments for reuse either in the paper mill itself or in other industries. Sludges from the de-inking process of waste paper are normally burned for energy production. The result is an ash which consists mainly of modifications of the original pigments, and is often used in the cement and brick industry. The combinations with other fibrous raw materials, from agricultural sources, can be instrumental in the further transformation. Although it is not likely that such fibre sources will be available in volumes, shapes and locations that enable full replacement of wood fibre, they could be combined in the sector's fibre base to provide low cost solutions.

Water
Water is the third crucial element in the forest fibre industry's processes. Water scarcity will co-determine the future potential of land to supply the 2050 world with bio-based products. Water within the industry is a crucial carrier of both fibre and energy. Already 90% of water used is returned to river systems. Keeping water systems sustainable, for both fibre production and manufacturing, will be a key factor in the future success of the sector. ■

The Road to 2050

Transformation, Innovation and Finance

Transformation: opportunity and challenge

Transforming the forest fibre industry towards 2050 offers an opportunity to become the central hub of the bio-based economy, integrating wood fibre, bio-based products and recycling concepts, waste and energy. There will be opportunities, too, to develop new markets, new products, new services and to operate in the decarbonised 2050 world. The many challenges will be technical, material and financial, but also psychological and political. Getting investments and access to raw material are two cornerstones of the industry's future.

Products and technologies

The industry's transformation will be driven by interlinked pathways of technology development, product development and consumer demand. Next to incremental efficiency improvements, innovation and new business concepts will be key to breaking the current cycle of financial performance. The system shift to a bio-based economy (a much broader framework than a low-carbon society alone) will open many opportunities; it will also take at least the next 40 years to achieve.

Companies will adapt firstly by changing their fuel mix, producing bio-energy and reusing residue flows. The European industry has already taken many steps in this direction and more are on the way. In a second phase, new product properties will be developed, part of a constant process of innovation within the industry. New functions will be added and, further along, new products and services introduced. A range of new companies and activities could grow out of today's industry entering new business models and markets.

Finally, companies will evolve. Those that produce wood, paper and board packaging will transform into companies selling smart packaging concepts and services. Producers of paper-based hygiene products and their value chain will become part of the healthcare sector, providing solutions for the ageing society. Graphic paper producers and their value chain will transform into an information industry in which paper and IT solutions are combined. Mills can develop into recycling, waste and energy hubs providing and supplying nearby cities.

Bio-based hub

The forest fibre industry can capitalise on its knowledge of (wood) fibre to become a springboard for diverse products and industries, multiplying the use and application of fibre-based insulation materials, nanocellulose, bio-composites, bio-chemicals and food additives, among others. By 2050, the forest fibre industry could resemble today's oil refineries, providing the building blocks for the chemicals of the future. This is the opportunity that needs to be grasped.

Innovation beyond technology

New technologies and a greater integration of activities will take the sector towards its low-carbon future. But the development of breakthrough technologies should not only focus on improving today's technology. The breakthrough might come from the combination of a new product with a new technology. Combining nanocellulose with packaging concepts could create new demands for paper and board products, for example, that completely change the machine concepts needed to produce these.

Transformation investments

With the recent low rates of return on investments, transforming the sector presents a major financial challenge. Our focus on the future forest fibre industry outlines the opportunities, products, concepts and likely future for tomorrow's consumer. Knowing that both the current technology has to be replaced and new products and services developed, the question might arise as to what the best investment is – a new boiler or a new product design? For now, we assume both are needed.

Replacing technology
We assume that total costs of **capital stock turnover** in the next 40 years will be around 260 billion euro. If this takes place gradually, that equates to 6 billion euro/year, compared to recent investment levels of 5.5 billion euro/year. In public literature, the only available source on the financial consequences of a 2050 decarbonisation pathway is the IEA Energy Technology Perspectives. It estimates costs for a decarbonisation scenario as 10% higher than business as usual. Additional investments in **emerging technologies** (i.e., on top of a change in best available technologies due to capital stock turnover) will be up to 10% extra for the global pulp and paper sector. This will be supported by machine producers, not the pulp and paper industry on its own. The additional costs lie in technologies for the gasification of biomass/black liquor, among other areas. We assume that the costs of emerging technologies in new energy conversion methodologies, allowing for new products to be developed, will be in the same order of magnitude, i.e., another 10% increase compared to capital stock turnover.

In our technology assessment, the CO_2 reduction pathway to 2050 depends on **breakthrough technologies**. Although it is difficult to cost such advances, we assume that they would enter the market at no more than 10% greater cost than existing or emerging technologies. We have not calculated the costs of CCS, as it is currently seen as a secondary option compared to breakthrough technology research in reducing heat demand.

Timing is everything
Even if margins of 10-30% additional investments seem low, these can only be made if there is a level playing field globally. They also depend crucially on timing. 2050 is two investment cycles, or a maximum of two paper machines or boilers, away. If we are able to develop technologies so that they are available when the next investment cycles are up, the costs are manageable. If machines need to be replaced outside normal investment cycles, costs will be exponentially higher.

Research
Based on the 2010 EU Industrial R&D Investment Scoreboard, the R&D investment per employee in the pulp and paper industry is around 1,540 euro, or 350 million euro in total. In addition, paper- and wood-related research organisations spend an estimated 230 million euro each year in joint projects with the industry. Machine development is conducted by machine suppliers, spending an estimated 2.5-5% on R&D, or roughly 150-200 million euro per year. If member states committed income from CO_2 auctioning to research into decarbonisation, initial budgets of 100 million euro per year could be obtained, increasing the R&D budget by 20%. In comparison, the Canadian government granted its forest fibre industry 1 billion Canadian dollars in 2010-2011 to transform. As well as R&D support, we would also argue for support for commercialisation as well as investment aids for new products and technologies.

Investing in new knowledge and market understanding
The transformation will not only require investment in technologies and new products – but also investment in people, knowledge and leadership. The sector has to improve value chain cooperation, knowledge of final customer demand, how to create partnerships and a multisector approach, and where investing time rather than cash will yield most dividends. Understanding future markets and consumers will be crucial.

Investing in (forest) biomass supply
The European Commission modelling envisages a huge contribution from the agricultural sector and forest sector in supplying the biomass needed for a low-carbon future. This will not materialise by itself. There are many market barriers to overcome. The last investment category therefore to consider is the investment in forest management, new forests, new techniques and technologies and most importantly, biomass mobilisation programmes and support. ■

In our technology assessment, the CO_2 reduction pathway to 2050 depends on

breakthrough technologies.

This is two investment cycles, or a maximum of two paper machines or boilers away. Breakthrough technologies have to become

available by 2030

to be on time for 2050.

The Enabling **Policies**

This roadmap explores the potential for developing a high-value, low-carbon forest fibre industry by 2050. Earlier chapters have outlined the role of companies, consumers, researchers, markets, technologies and investments in realising this goal.
Policymakers, too, will play a crucial role.

Both the European Commission's 2050 Roadmap and this CEPI Roadmap depend on policy support. **Transforming today's industrial complex – optimised over four centuries – in the next 40 years is a formidable task.** Based on the work in this roadmap project we have learned that:

Climate change policy is industrial policy. It needs to encourage industry to stay in Europe and create jobs for the future. To this end, it should focus on establishing a favourable investment climate that will help the sector raise finance to fund capital stock turnover and the research and development of breakthrough technologies.

A sector-specific policy package is essential, since the pathway (and investment cycles) for the forest fibre industry is not the same as for cement or steel, for example. For a later stage, there needs to be a process to facilitate the integration of sectoral (and national/regional) roadmaps, to enable learning and cross-fertilisation.

Climate change policy is closely linked to innovation policy. Climate policies must be backed up with an innovation and technology policy to help bring new products and emerging technologies to market, to conduct feasibility studies and to research breakthrough technologies and products. There needs to be a value chain perspective for new technologies to address challenges at an optimal stage.

The availability of raw materials is crucial for this roadmap and this industry. The EU needs to enhance the use of land to produce value and capture carbon. Economic and industrial systems must aim for optimising added value, with a cascading approach that includes as many recycling loops as possible. Policies must establish the right balance between raw materials and energy use of raw materials, in order to meet targets.

Action must be global. This roadmap is based on a global action scenario. Without worldwide mobilisation on climate targets, it will be impossible to meet the 2050 goal. Policies must be consistent with global developments, other policy areas and industry investment cycles. European Commission modelling assumptions such as CCS and energy efficiency targets must be met, all the more so given the plans for nuclear phase-outs.

Finally, **all sectors of the EU economy will have to take responsibility**. The potential to save carbon may vary across the various sectors, but there is no room for certain sectors to carry the burden of others. ■

A renewable and low-carbon solution that enables the bio-economy of the future. **Forest fibre.**

The forest fibre industry has the ambition to be at the heart of the bio-economy.

Our industry's expertise in forestry, recycling, wood chemistry and fibre processing provide a unique advantage for the future. However, meeting an 80% reduction in CO_2 emissions while ensuring sector competitiveness will only be possible through the right policy framework, combined with breakthrough technologies to be developed and available by 2030.

With 2050 only 2 investment cycles (or two paper machines) away, we urge policy makers to make the right decisions, and make them now.

A Call to Policy-Makers

This roadmap is the start of a discussion about policies that the sector will need in order to develop as modelled. We call on the European Commission and member states to include in the next climate change and energy package, or in national or regional 2050 roadmaps, the following measures:

1 **Sector-specific industrial policy packages.** These should be developed jointly by industry and policymakers and have an industry focus, while fitting the general debate on EU-wide climate targets and the function of the carbon price and emission trading system. The cap for industry has been set in the ETS directive, with the declining linear factor in place. Simply changing this cap or reduction factor will not take us forward. Within the framework flexibility is needed for industries. The development of breakthrough technologies will cause industry-specific backloading of emission reductions towards the end of the period. To avoid this, there needs to be a broader approach than carbon pricing alone.

2 **To fulfil the potential of the EU Emissions Trading System to become an innovation instrument that yields a double dividend rather than costs alone.** EU ETS auctioning revenues need to flow back to finance the transformation of the industries concerned, as established in the EU ETS directive. Starting in 2013, large funds will become available that can be used to transform sectors. There is now a window of opportunity to steer these funds in the right direction: the best insurance against carbon leakage is a competitive sector fit for the future.

3 **The EU, member states, industry and suppliers to jointly initiate a transformation partnership for the EU forest fibre industry.** The partnership would advise on how best to invest auctioning revenues for the sector's future, develop insight into the financial flows needed to take the sector through the transformation, and design an innovation system that brings forward the right solutions in due time for investments, preventing white elephants. The industry-driven forest fibre partnership could be an example for other sectors, addressing intellectual property and competitiveness challenges that might arise from EU-wide cooperation. The SET plan (Strategic Energy Technologies) or the SILC (Sustainable Industry Low Carbon Initiative) are important European Commission instruments that could support materialising the roadmap.

4 **Horizon 2020 should include sector-specific innovation support systems, including facilities to stimulate investment in large-scale pilot and demonstration plants.** Industry sectors need a dedicated facility to support transition to a low-carbon economy. EU ETS auctioning funds should be used for dedicated research, development and implementation of emerging and breakthrough technologies in the sectors concerned. SET-Plan industrial initiatives for the pulp and paper industry could be the basis of such a development, although the scope needs to be broadened from energy technology to industrial technology. **The SET plan should support cross-sector technology policy for energy conversion**. As well as bio-energy, the SET plan should support research into gasification of biomass and the future of CHP, to increase the efficiency of boilers EU-wide.

5 **The Resource Efficiency Roadmap and Raw Materials Initiative need to be followed by a dedicated recycled materials policy.** This could lead to further policy on an optimal recycling system, starting with a landfill ban for recyclable materials. Recyclability and traceability for all materials should be included in future ecodesign, ecolabel and green public procurement measures, while the EU LIFE programme and European Innovation Partnership (EIP) on raw materials should focus on improving recycling and sorting technologies.

6 **To broaden the climate change perspective to encompass a system shift towards a bio-based economy.** The 2050 goal requires a system shift in the EU economy. The upcoming Communication on the bio-based economy should be the start of further policy development, supporting the switch from oil- to bio-based products, substituting high-carbon with low-carbon materials. Forests must be an inherent part of it. The EU can thus create a first mover advantage on global markets.

7 **Policies that push substitution of carbon-intensive and fossil fuel-based products with bio-based products.** Governments need to drive the reduction in carbon intensity by supporting a greater uptake of bio-based materials, e.g., through green public procurement and incentives for using wood in construction. Current customer value is not yet sufficient to make this change. Removing subsidies for biomass for energy is an impediment to carbon reduction as well as to the use of biomass for value added products.

8 **The EU (Energy 2050 Roadmap) needs a biomass supply policy.** Renewable energy policies, action plans and impact assessments should consider where biomass will come from, within the framework of EU-wide sustainability criteria. **National renewable energy plans should include wood mobilisation policy.** The European Commission needs to assess technical and economic mobilisation potential, as well as how much wood is available in Europe. Policy should support increased afforestation, optimised management, mobilisation of residues and short rotation crops, as well as rectifying the vacuum in wood markets caused by feed-in tariffs. No support should be given to co-firing biomass in coalplants.

9 **The CAP reform needs to address production of biomass residues for energy.** The revision of the Common Agricultural Policy (CAP) pays little attention to non-food raw materials for products and energy. Both pillars could provide funding for biomass production from residues for energy purposes, and for sustainably increasing feedstock potential, including through afforestation and reforestation.

10 **EU forests needs an integrated and balanced forest policy aimed at providing raw material, energy biomass and carbon stocks.** There is no mandate in the treaty to develop an EU forest policy, and many member states are reluctant to allow this. An integrated policy approach is nevertheless needed, replacing the myriad of policies now impacting on the forest. Forest policy needs to find the right balance between retaining forests as carbon stocks and harvesting wood products. Closing forests to harvesting is counterproductive. As the IPCC concluded in its fourth assessment report, the largest sustained mitigation benefit depends on a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest.

11 **The 7th Environmental Action Programme can start the debate on industrial ecology or symbiosis.** Heat and resource maps would help member states assess where industries could best be grouped to optimise resource and energy flows. Structural or development funds could be used to support this future industrial ecology. ■

Glossary

BAT
Best Available Technology.

BECCS
Bio-energy with Carbon Capture and Storage is a greenhouse gas mitigation technology which produces negative carbon emissions by combining biomass use with geologic carbon capture and storage.

Biomass
Biomass means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.

Biorefinery
A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, heat, and value-added chemicals from biomass.

Black liquor
is the spent cooking liquor from the kraft process when digesting pulpwood into paper pulp removing lignin, hemicelluloses and other extractives from the wood to free the cellulose fibres.

BTT
Breakthrough Technology and Techniques.

CAP
EU Common Agricultural Policy.

Carbon leakage
occurs when industries close down, leading to an increase in CO_2 emissions in one country as a result of an emissions reduction by a second country with a strict climate policy.

CCS
Carbon Capture and Storage, alternatively referred to as carbon capture and sequestration, is a means of mitigating the contribution of fossil fuel emissions to global warming. The process is based on capturing carbon dioxide (CO_2) from large point sources, such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere. It can also be used to describe the scrubbing of CO_2 from ambient air as a geoengineering technique.

CEI-BOIS
European Confederation of Woodworking Industries.

CEPI
Confederation of European Paper Industries.

CHP
Combined Heat and Power or cogeneration is the simultaneous generation in one process of thermal and electrical and/or mechanical energy and where all of the products are put to use for an economically justifiable end.

CO_2
Carbon dioxide (chemical formula CO_2) is a naturally occurring chemical compound composed of two oxygen atoms covalently bonded to a single carbon atom.

Co-mingled collection
collecting of all waste in one collection stream to be sorted after collection, not by the user.

EIP
European Innovation Partnership.

ET
Emerging Technology.

ETS
Emission Trading System.

EU
European Union.

FAO
Food and Agricultural Organisation of the United Nations.

Flue gas
is the gas exiting to the atmosphere via a a pipe or channel for conveying exhaust gases from a fireplace, oven, furnace, boiler or steam generator. Quite often, the flue gas refers to the combustion exhaust gas produced at power plants

Fluidised Bed Boiler or Fluidised Bed Combustion (FBC)
is a combustion technology used in power plants. Fluidised beds suspend solid fuels on upward-blowing jets of air during the combustion process. The result is a turbulent mixing of gas and solids. The tumbling action, much like a bubbling fluid, provides more effective chemical reactions and heat transfer. FBC plants are more flexible than conventional plants in that they can be fired on biomass, among other fuels.

Fractionation
is a separation process in which a certain quantity of a mixture (solid, liquid, solute, suspension or isotope) is divided up in a number of smaller quantities (fractions) in which the composition changes according to a gradient.

GMO
A Genetically Modified Organism or Genetically Engineered Organism (GEO) is an organism whose genetic material has been altered using genetic engineering techniques.

ICT
Information and Communication Technology.

IEA
International Energy Agency.

IPCC
Intergovernmental Panel on Climate Change.

Lignin or lignen
is a complex chemical compound most commonly derived from wood, and an integral part of the secondary cell walls of plants.

Lignocellulosic biomass
Lignocellulosic biomass refers to plant biomass that is composed of cellulose, hemicellulose and lignin. The carbohydrate polymers (cellulose and hemicelluloses) are tightly bound to the lignin. Lignocellulosic biomass can be grouped into four main categories: agricultural residues, dedicated energy crops, wood residues and municipal paper waste.

Lime kilns
A kiln used to produce quicklime by the calcination of limestone (calcium carbonate). The kiln is a thermally insulated chamber, or oven, in which a controlled temperature regime is produced. Uses include the hardening, burning or drying of materials.

LULUCF
Land Use, Land-Use Change and Forestry is defined by the United Nations Climate Change Secretariat as "A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry activities."

Non-integrated mills
Paper mills can be fully integrated mills or non-integrated mills. Integrated mills consist of a pulp mill and a paper mill on the same site. Such mills receive logs or wood chips and produce paper. Non-integrated mills purchase wood pulp, usually in dry bales known as market pulp.

PRIMES
EU economy model from Athens University on which EU policy is based.

Pyrolysis
is the basis of several methods that are being developed for producing fuel from biomass, which may include either crops grown for the purpose or biological waste products from other industries.

R&D
Research and Development.

Recovery boiler
is the part of Kraft process of pulping where chemicals for white liquor are recovered and reformed from black liquor, which contains lignin from previously processed wood. The black liquor is burned, generating heat, which is usually used in the process or to make electricity.

Second generation biofuels
are derived from lignocellulosic crops. Plants are made from lignin, hemicellulose and cellulose; second generation technology uses one, two or all of these components. These biofuels can be manufactured from various types of biomass.

SET
EU Strategic Energy Technology Initiative.

SILC
Sustainable Industry Low Carbon Initiative.

Syngas
(from *synthetic gas* or *synthesis gas*) is the name given to a gas mixture that contains varying amounts of carbon monoxide and hydrogen. Examples of production methods include the gasification of biomass, and some types of waste-to-energy gasification facilities.

Torrefaction
is a thermo chemical treatment of biomass at 200 to 320 °C. It is carried out under atmospheric conditions and in the absence of oxygen. During the process, the water contained in the biomass as well as superfluous volatiles are removed, and the biopolymers (cellulose, hemicellulose and lignin) partly decompose giving off various types of volatiles. The final product is the remaining solid, dry, blackened material which is referred to as "torrefied biomass" or "bio-coal".

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United Nations Economic Commission for Europe.

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