unfold the future

The Two Team Project

2050 cepi

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Contents

Our sector leads the way

The European pulp and paper industry supplies a quarter of the global market. It employs 225 000 people in 950 mills and 520 companies, and adds €16 billion per year to the European economy. The industry is part of the much larger forest-based sector, which has 200 000 companies, employs 1.9 million people and adds €75 billion to the EU economy. For the most part the sector uses raw materials from Europe.

In November 2011 CEPI launched the Forest Fibre Industry 2050 Roadmap. In it, we looked at how the sector might reduce its fossil-based CO_2 emissions by 80% while at the same time creating 50% more added value. One of the key conclusions was that breakthrough technologies would be needed by 2030 to achieve the targets.

Europe urgently needs growth and jobs. A vibrant industry is the way to achieve this. In 2012 CEPI set up the 'Two Team Project' to identify breakthrough technology concepts that would give the industry the required dynamic for a successful future in Europe. We know that the world changes fast and that the future is in our hands. We asked our two teams to take a giant leap forward.

This report describes the Two Team Project and its results – eight breakthrough technology concepts that the teams submitted for further discussion. The core of the work has been done by the team members, but not alone. National associations have made great effort to facilitate the process and give input. Companies all over Europe have brought ideas. Universities and research organisations have contributed as well. And a large number of enthusiastic individuals have submitted ideas via the dedicated website.

The report gives a flavour of what the breakthrough entails and is clearly for public use. The intellectual property of the outcome of the Two Team Project is owned by CEPI. After publication of this report, in line with the intellectual property and nondisclosure agreements, CEPI will grant licences to the team members and the wider CEPI membership for further use of these concepts.

Breaking through to 2050

With our 2050 Roadmap to a low-carbon bio-economy, we outlined how the forest fibre industry is uniquely placed to contribute to a resource-efficient world.

Consumer trends, industrial integration and the impact of policymakers were all discussed. But the fact remained; breakthrough technologies are required in order to be future fit.

This is why we launched the Two Team Project. To generate and develop new ideas together with an element of competition.

So join us as we unfold the future. Take a glimpse of how the pulp and paper industry will look in 2050...

Breakthrough technologies for the 2050 world

WINNER

Deep Eutectic Solvents

A ground-breaking discovery:
Deep Eutectic Solvents (DES), produced by plants, open the way to produce pulp at low temperatures and at atmospheric pressure. Using DES, any type of biomass could be dissolved into lignin, cellulose and hemicellulose with minimal energy, emissions and residues. They could also be used to
recover cellulose from waste and dissolve ink residues in recovered paper.

p16

FINALIST

Flash condensing with Steam

Waterless paper production?
Very nearly. Largely dry fibres would be blasted into a forming zone with agitated steam and condensed into a web using one-thousandth the volume of water used today.

p18

FINALIST

Supercritical CO_2

Neither gas nor liquid but somewhere in between, Supercritical CO_2 ($scCO_2$) is widely used in many applications, to dry vegetable, fruits and flowers, extract essential oils or spices. Suppliers for NIKE, Adidas and IKEA use it to dye textile.
Coffee and tea have been decaffeinated with scCO2 since the early 80s. We could use it to dry pulp and paper without the need for heat and steam, and why not dye paper or remove contaminants too, while we're at it?

p24

FINALIST

100% electricity

Shifting pulp and paper production to energy-efficient technologies using electricity rather than fossil fuel power
to generate heat will cut all CO_2 emissions as the power sector shifts to renewable energy. The sector would also provide
a buffer and storage capacity for the grid, storing energy as hydrogen or pulp.

p26

Steam

FINALIST

Using more energy to use less?
You read it right. Using the full power of pure steam for superheated steam drying would save energy as most heat could be recovered and recycled. Steam will then be used as fibre carrier for making and forming paper.

p20

DryPulp for cure-formed paper

FINALIST

Imagine a papermaking process that uses no water. This is it. Fibres are treated to protect them from shear, and then suspended in a viscous solution at up to 40% concentration. The solution is then pressed out and the thin sheet cured with a choice of additives to deliver the end-product required.

p22

Functional Surface

FINALIST

The key to unlocking greater added value from fewer resources depends on a shift to producing more lightweight products, and selling surface area and functionality rather than weight. Advances in sheet formation and new cocktails of raw materials will lead the way to the lightweight future.

p28

The Toolbox to replicate

FINALIST

What about the great ideas that never make it? Put together a combination of process, material and equipment innovations as a toolbox of stepping stones to 2050 and the pathway becomes clearer, boosting sector and investor confidence.

p30

Foreword

Some believe in miracles, but good results are more often the outcome of effort and hard work. Breakthroughs that revolutionise an industry do not happen overnight and cannot be realised within a year. Someone needs to kick off the process. After embracing the CEPI 2050 Roadmap and its vision, the European paper industry decided to take its future in its own hands, and identify the breakthrough concepts needed to deliver the Roadmap's targets. Some said open innovation at sector level could not be done. We believed they were wrong.

Like many others, our industry is in hardship. The deep economic crisis in Europe has led to closures and job losses. Europe's prospects lie in limited growth and a stable population. Our global competitors face very different circumstances. While we share the same technology basis and face similar changing consumer behaviour, constraints around the world are very different.

CEPI works to boost our sector's competitiveness. The Two Team Project is part of this effort. It will not bring an off-the-shelf solution to reduce energy costs today. Neither does it propose readymade technology abatement curves that policymakers can simply enforce. Instead, it looks to the future, aiming to forecast the best technologies for 2030. We need breakthroughs that change the way we operate, reduce costs, revolutionise technology, add value and lower our energy consumption and carbon emissions. This meant stepping beyond today's expectations and standards.

The result of the teams' work is a set of comprehensive concepts for the future. They constitute a combination of real solutions for the medium term, with a clear view on short-term steps, towards innovative solutions for a mature sector.

The concepts are a mixture of innovations from our own sector and those from other sectors adapted to the pulp and paper industry. There are many surprises.

While one team would have brought you a report, the two team format created competition, motivation, excitement and fun. The project delivered beyond expectations, with excellent results achieved thanks to teamwork. The involvement in each team of outsiders, suppliers and scientists together with paper industry insiders stimulated novel discussions and solutions. Even though the two teams were competing, the result is a win for the sector as a whole.

Although many ideas have surfaced since the shoe press introduction 20 years ago, they never took off, for all kinds of reasons. The Two Team Project went as far as any industry sector could go in organising an open innovation process and providing pre-competitive leads. It is up to the companies to take the next step and develop the concepts. This will need new forms of cooperation, and the support of European and national policy makers. The right conditions must be put in place to enable research, pilot, demonstration and investments.

The Two Team Project has been an interactive process, as much as a project. It has united the sector behind the idea that breakthroughs are necessary, and it has kicked off many discussions and new dynamics. We invite you to analyse the concepts and contribute to take them forward, in cooperation between policy makers and industry to revolutionise our sector, which is so important to the European economy. Together we can show that breakthroughs are feasible, and that Europe can lead. ■

Teresa Presas
CEPI Director General

Message from the Chairman

The CEPI 2050 Roadmap singled out three key directions for our sector – create value from our raw material, decarbonise and seize the opportunities available in the bio-economy. To meet the CEPI Roadmap's aspirations on both decarbonisation and value creation, the need for breakthrough technologies was clearly put on the sector's radar-screen.

Even in today's tough economic situation, especially in the graphic paper business; it is imperative to focus on innovation as a key tool to move forward.

In the last two years CEPI has made a large step from launching the CEPI 2050 Roadmap to rolling it out in practice. The Two Team Project has been a very stimulating and innovative way to do so.

As CEPI Chairman and Chairman of the jury of the Two Team Project I've been happily surprised with the results from this year long search for answers. The teams have really worked "out of the box" and have come with innovating, new concepts and technologies. Working together with suppliers, researchers and academics has paid off. We have opened the windows of our sector's meeting rooms and let in fresh air.

The Two Team Project is not the only place where this occurs. The companies in our sector have launched initiatives in many countries. The European public private partnership on bio-based industries is another key example of new ways of working together.

It is clear that a different policy framework is needed to allow industry to stay in Europe and provide the much needed jobs and growth. It is also clear industry needs new answers to the questions of the future and new ways of working. Based on a stable flow of constantly innovated pulp and paper products, we will generate the cash flow for new businesses, in the field of bio-energy, bio-based products and the like. We do have to make the most value out of every tree. This is what shareholders and stakeholders ask from us.

It has been a pleasure to lead this process in the industry. I trust you find equal pleasure in reading through the very innovating concepts in this report. They are the start of a next step in this process – pulp and paper companies and new partners getting together to see which of these concepts wins the race to become the solution of the future. ■

Jussi Pesonen
Jury Chairman of the Two Team Project
CEPI Chairman
CEO UPM-Kymmene

The CEPI 2050 Roadmap

In November 2011 CEPI launched the Forest Fibre Industry 2050 Roadmap for a low carbon economy. The Roadmap represents the vision for the sector in the next 35 years. It investigates how to achieve an 80% CO_2 emission reduction and at the same time create 50% more value.

The Roadmap looks ahead at ways in which the industry might transform in the context of the bio economy, outlining the technology needs, policy imperatives, and financial perspectives. 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. It does not prescribe; it attempts to start a debate. It will be reviewed to include the results of further discussions on the future of the sector, such as those that have arisen in the course of the Two Team Project.

The Roadmap concluded that breakthrough technologies would be needed to achieve the vision. At the time, we did not know whether such technologies would be possible or cost-effective. The first results from the Two Team Project indicate that fundamental breakthrough technologies that dramatically reduce greenhouse gas emissions by 2050 could indeed be possible. They will require considerable investment and research, but their potential to deliver cost savings is significant.

The sector warmly embraced the Roadmap. Over 6 000 copies were distributed and numerous industry events focused on its analysis, outcome, vision and roll-out. Far from remaining a Brussels-centred policy document, it has become the integral vision on the future of the sector. The economic crisis in Europe has made its aims even more compelling.

The future

The CEPI 2050 Roadmap starts from the assumption that consumers in the future will prefer sustainable bio-based goods to other materials. This is grounded in demographic evidence – the future consumer is known today; most EU citizens of 2050 have already been born, for example. The Roadmap was built around the same PRIMES scenarios that the European Commission used for its policymaking. The challenge set out in the CEPI Roadmap was therefore not only how to decarbonise and how to create more value, but how to do so in a stagnating EU market with a stable but ageing population facing moderate to low economic growth.

The future sector

According to the Roadmap, the 2050 forest fibre industry will be built around a holistic vision of product lifecycle. Fibres will be used and recycled in an optimal way, with the highest possible value added at each stage. When no more products can be made, residues will be turned into energy. The future forest and fibre industry will be seen to operate as a single ecosystem, optimising raw material and energy flows in a complex of wood-based and recycled fibre-based bio-refinery units and non-integrated mills. By 2050, new business models will have been set up through cooperation with other industrial sectors. A symbiosis of industrial activities will optimise raw material, energy and product flows in a cascade of uses.

Value creation

The core strategy defined in the Roadmap is to get the highest possible value from resources – wood, virgin and recycled wood fibres, and non-fibrous raw materials. Creating 50% more value in a mature market is a challenging proposition, but new product and markets are the answer. New bio-based products will add value, as will higher value-added successors of today's products. Although the relative share of EU exports in world markets will decline as other economies grow, our export role will remain strong. The forest fibre sector is already the largest bio-based industry sector in volume and value in the bio-economy. If it can hold this position, there is a solid future ahead.

Carbon reduction

The Roadmap technology assessment showed that with continued investment in current best available technologies a significant carbon emission reduction is possible, provided the right framework is in place. However, today's technologies, even within the combination of resource efficiency, energy efficiency and conversion efficiency measures, do not achieve 80%. The 80% CO_2 emission reduction pathway to 2050 thus depends on breakthrough technologies. This is two investment cycles or a maximum of two paper machines or boilers away.

Four times ten years

Breakthrough technologies are not the only answer found in the Roadmap. Cooperation, interaction, resource efficiency, new products, business models and markets all play a role. But breakthroughs and related research, innovation, piloting and demonstration remain central. To implement the Roadmap and deploy new technologies, the sector has 10 years to think (research), 10 years to test, 10 years to build and 10 years to run and optimise the new technologies. Breakthrough technologies therefore have to become available by 2030 if they are to be online for 2050.

Breakthroughs

In all stakeholder meetings where the Roadmap was presented, the audience was asked which was the last breakthrough technology that the sector implemented. Many people mentioned the bio-economy, and the production of biofuels and biochemicals. Two breakthrough technologies for papermaking were identified, the shoe press being the last. Although basic and applied research already takes place, no company on its own can currently bring breakthrough technologiies into reality today.

Building on that observation, the Two Team Project was born. ■

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 Two Team Project

The Two Team Project was an initiative by CEPI to identify the most promising breakthrough technologies to cut the carbon footprint of pulp and papermaking. It brought together two teams and set them to compete using a unique method of 'open innovation'.

The teams included researchers, scientists, manufacturers, suppliers and representatives from both the pulp and paper industry and other sectors. Stakeholders from around the world provided input via a dedicated website and social media campaign.

The project challenged the teams to be as creative and imaginative as possible while focusing on technologies and solutions for all - old and new, large and small mills, for northern and southern Europe, for tissue, packaging or graphic papers, and for virgin or recycled-based products. Each team decided where to focus, keeping in mind the broad sector scope.

CEPI paid particular attention to the geographical base of participants, to secure the broadest European approach. Two former CEOs, Veit Sorger (Mondi) and Frits Beurskens (Smurfit Kappa Group), served as mentors to the teams, giving guidance, inspiration and direction. In addition, each team was led by a captain, supported by a CEPI Director and driven by a CEPI 'team engine', a colleague dedicated to the team.

The teams were set up to compete on creativity, and not lose due to lack of information. At the start they worked together to establish a common knowledge base. They also used crowdsourcing: anybody could submit an idea(s) to the teams via the project's website twoteam.unfoldthefuture.eu. These ideas were considered during the generic concept development.

To achieve the best possible cooperation between team members, the final outcome was limited to 'generic pre-competitive concepts'. CEPI and all project partners set up a safe legal environment for team members and everyone who submitted an idea via the website. Partners signed a non-disclosure agreement and an assignment and licence of intellectual property rights.

The teams had seven opportunities to meet, and the meetings were an important part of the process. They were tailored to provide input from outside, gain knowledge from national experts and engage with the sector in several European countries. In December 2012, the kick-off meeting in Brussels (Belgium), held in the world-famous Atomium, allowed the participants to get to know each other and the project's ambition.

The next meeting was organised by the Austrian Paper Industry Association, Austropapier, in Lenzing (Austria). The teams learnt about hi-tech textile fibre with Lenzing AG before a day's brainstorming in separate rooms. In February 2013, Tata Steel opened its IJmuiden plant (Netherlands) to the teams, presenting the ULCOS (Ultra Low Carbon Steel) project. The teams also heard presentations from speakers organised by the Royal Netherlands Association for Paper and Board (Royal VNP).

In March 2013 the teams met experts from the Repsol laboratories in Madrid (Spain) and the Annual Meeting of the Spanish Association of Pulp and Paper Manufacturers, ASPAPEL. The next meeting was co-organised by the Finnish Forest Industries Federation (FFIF) and the Swedish Forest Industries Federation (SFIF) in Helsinki (Finland), where the teams visited the energy facilities of Fortum.

BASF hosted the last national meeting, organised by German Pulp and Paper Association VDP in Ludwigshafen (Germany) in June 2013, to present the chemical side of papermaking.

Over the summer, the teams each finalised four generic concepts for breakthrough technologies. They completed the reports at their final meeting, in September 2013. The jury process consisted of two rounds: a pre-jury and a final jury. The pre-jury advised the final jury, based on a scorecard that adressed carbon reduction, value adding potential, innovativeness and feasibility. The jury convened in Brussels on 17 October 2013 to select the winning concept.

Neither the teams nor the jury endorsed specific technologies or suppliers. The real test of the concepts now lies in the hands of the industry and the future – only then will we discover which options survive to make it to the market. ■

The CEPI TWO TEAM PROJECT

Team members
In the red corner...

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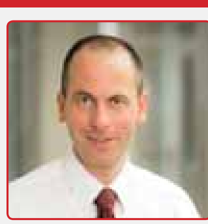

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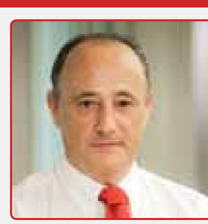

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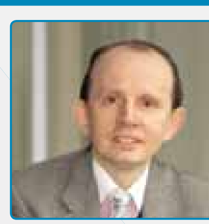

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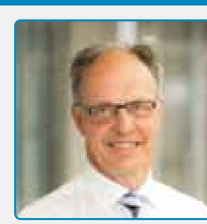


Sven Wird
Holmen

Introducing the concepts

The eight breakthrough concepts are each described in a two-page summary. Although presented in a similar manner, they differ widely in content and solutions.

As the Two Team Project was about pre-competitive sector cooperation, the concepts do not describe machinery, technologies or solutions. Each team submitted four concepts to the jury, without knowing what the other would propose. Some of the concepts overlap, but many are remarkably different. Taken as a set, the eight concepts are a testament to the strong promise of carbon-friendly innovation in the sector.

For each concept both CO_2 and energy savings have been estimated, based on a common energy profile of the pulp and paper sector. The savings in each concept are therefore comparable. Energy savings do not always clearly correlate with CO_2 savings as there is a large portion of carbon neutral bioenergy in the sector.

No single concept meets all the criteria, but a combination of several of the ideas could potentially deliver the reduction and value creation needed. This will need further discussion and development.

Sector innovation

The two teams considered the intermediate steps to 2030 and 2050. Several concepts thus set out 'innovation waves' on the path towards a breakthrough. This allows us to see three means of uptake:

- **Revolution**. Some concepts describe new technologies or machines for the sector. They might be developed by machine builders and purchased for a new or major rebuild of a mill.
- **Evolution**. Many concepts are suitable to be introduced in a stepwise approach in rebuilds. This offers the possibility to combine breakthroughs with existing technology, a major enabler.
- **Adaptation**. These are combinations of technologies that, while not a break-through in themselves, allow it to take place.

The Two Team Project considered both innovation and applicability, two criteria that might otherwise conflict: an out-of-the-box solution might be hard to grasp from today's perspective, while too strong a focus on applicability might mean a breakthrough would be assessed against business-as-usual only.

Both teams identified many good ideas. And by involving experts from outside the sector, via internet and within the teams, they sought to be more inventive than designing just another paper machine. What became clear in the course of the process, is that if our industry does not develop some of the concepts soon, other sectors will do so. There is an enormous amount of ongoing research on biomass within the bioeconomy in the chemical, fuel and food sectors. The forest fibre sector has the knowledge, logistics and assets to develop these ideas first, but it will have to act rapidly and, in doing so, embrace a new combination of standardisation and flexibility.

The largest breakthrough might be in our own minds

The teams' discussions gave rise to a vision on how the sector will need to adapt to benefit from the breakthrough concepts. But the adaptations entail not so much a series of technological breakthroughs as a breakthrough in mindset. The following ideas will need to be embraced at all levels of the sector if we are to progress towards the breakthroughs envisaged in the Two Team Project.

Sell functionality

Both teams agreed that the sector must start selling functionality instead of volume to realise added value potential. Today, for example, the industry sells volumes of products, while the customer asks for functionalities. Printers and publishers need paper products to act as a surface for conveying information. Retailers need packaging to protect a product and carry messaging on the outside. And the corrugated box and tissue sectors sell square metres or ply-thicknesses to customers, while buying in tonnes from the testliner or tissue roll producers. As long as we continue to think in tonnes of product, new technologies producing different products with the same functionality will not be introduced, even if they would bring more value. ***The teams therefore propose that the sector reflects on the way it conducts measurements and statistics – and report in square metres as well as tonnes***. This will be a huge driver for innovation, for less broke (production losses), for lightweighting, and for a focus on resource efficiency. A further step will be to report energy consumption in terms of functionality and added value to society.

Value engineering through standardisation

The teams felt that standardisation would be to everyone's benefit, and thus merits serious consideration within the sector. Only recently, for the first time ever, were two identical paper machines sold in a single order. Before this, no two paper machines had ever been produced alike. Some machines differ by just 1 or 2 centimetres. This needs to change. Tailor-made products may add value and boost customer relations. A value chain approach would make it clear to everyone along the chain that optimisation benefits all. The width of printing or converting machines determines, to a large extent, the width of paper machines, for example. Solutions might include introducing standard machine sizes, or modular machines with standardised components, or a larger number of installations using the same process equipment. This would depend on harmonised raw material supply systems and machine widths, all of which would lead to value engineering through standardisation. The historic reason for the size of a paper reel used to be the width of a truck or train - a form of standardisation in itself.

Be flexible to create value

Other sectors have very different ideas from ours on how best to process and develop biomass. They analyse the value of lignin, hemicellulose and cellulose and reach different outcomes. The pulp and paper industry has become expert in one method of extracting value from biomass but, according to insights gained in the Two Team Project, we risk ignoring other means of creating value. We can benefit from knowledge gained in other sectors, and lead the way to producing greater value from biomass than we have achieved to date. This requires us to be open-minded. We would also need to create 'turntables' in our production processes, to allow raw materials to be converted into a range of products via different technology pathways. We need to be flexible. Standardisation is no impediment to flexibility; the two can be combined to enable breakthrough concepts to materialise.

Small and regional is beautiful

The trend in industry technology has been towards larger, faster and wider. The latest factories are so large that they can operate only in South America or China, or else are so remote as to create enormous shipping distances for raw material and products. Some breakthrough concepts could manage to buck this trend, for example through a regional 'mini-mill' that is perfectly adapted to its surroundings and thus able to create more value. Breakthroughs will also lead to smaller installations, or combinations of smaller and larger operations. More flexible, less dependent operations are a clear option for the future. This could also mean that we operate quite differently in Europe than in other regions, but deliver the same functionality and create more value. ■

The teams therefore propose that the sector reflects on the way it conducts measurements and statistics **and report in square metres as well as tonnes**.

Deep Eutectic Solvents

A ground-breaking discovery: Deep Eutectic Solvents (DES), produced by plants, open the way to produce pulp at low temperatures and at atmospheric pressure. Using DES, any type of biomass could be dissolved into lignin, cellulose and hemicellulose with minimal energy, emissions and residues. They could also be used to recover cellulose from waste and dissolve ink residues in recovered paper.

How does it work?

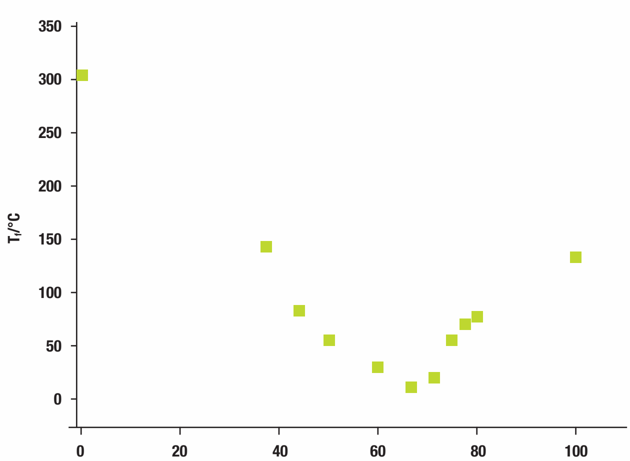
Deep Eutectic Solvents are an adaption of a natural phenomenon known from plant metabolism. Researchers found that plants can operate even under water stress[1] (i.e. during periods of drought or frost), using the organics in their cells to produce DES. Glucose-based natural DES can dissolve wood and selectively extract – as a function of the chemical characteristics and operating conditions – lignin, hemicellulose and most probably cellulose[2]. That is what makes them predestined to replace traditional pulping techniques. Research into DES has only just begun, and hundreds of new types of DES are yet to be discovered.

How would it work for our sector?

DES could have four key applications in the sector, based on the ability of the solvents to selectively dissolve specific components. The capacity to dissolve lignin allows Omnivorous Pulping.

DES that dissolve lignin could replace both chemical and mechanical pulping. DES pulping yields pure cellulose, lignin and hemicellulose at low cost. This has been demonstrated with wood and straw (where silica is removed by the DES). Tailor-made fibres can be obtained by adjusting the DES properties and process design.

DES are designer solvents: a mixture that melts at a lower temperature than any of its individual components.



Freezing temperatures of Chloline Chloride and Urea mixtures as a function of composition

The potential to dissolve cellulose can enable the recovery of cellulose from waste. Cellulose is soluble in DES. When developed further, this would enable the recovery of pure cellulose from papermaking residues (rejects, sludges, paper waste) in the form of clean dissolved pulp or as a basic building block for biochemicals, materials or fuels.[3]

In the future, DES could be used for recycled fibre processing. It should be possible to find DES capable of dissolving ink residues in recovered paper.

When the solubility of cellulose in specific DES is further improved, DES-based papermaking and sheet forming could become possible. The industry could use DES to eliminate water from papermaking entirely, prepare the stock and remove contaminants.

Contribution to CEPI 2050 Roadmap and carbon reduction

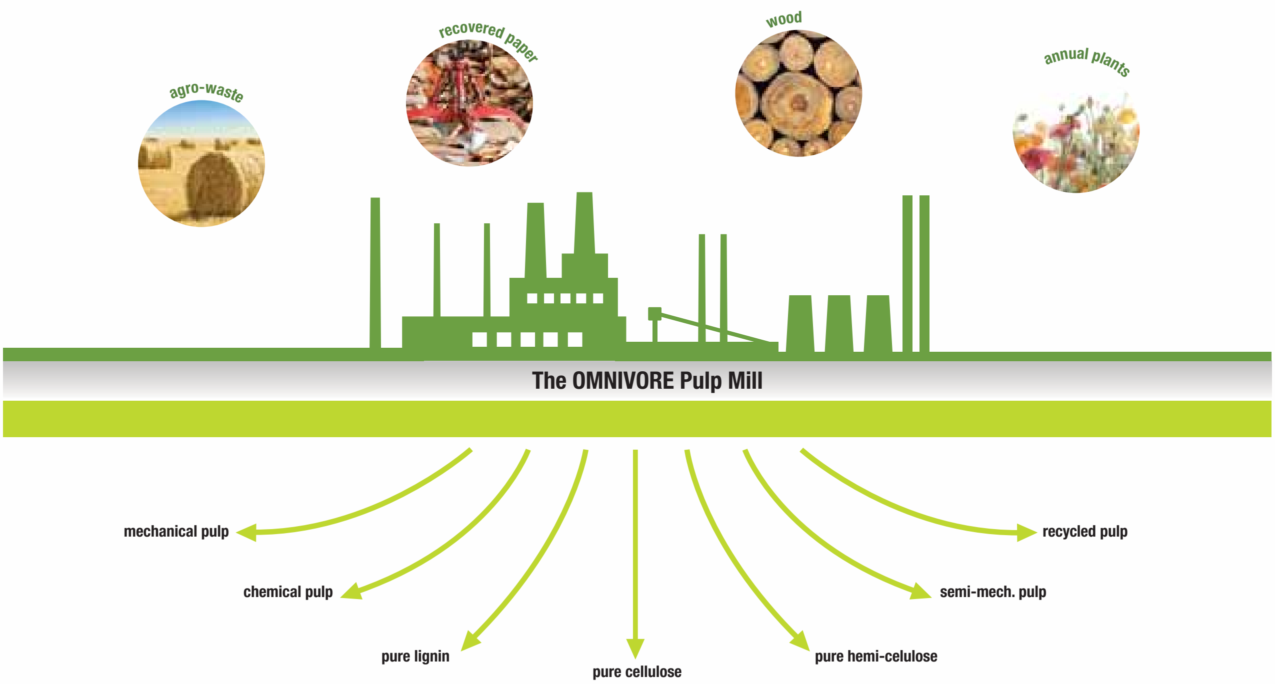
Energy consumption in a DES-based process is very different from today's pulping practices. If applied for pulping throughout the sector by 2050, it could reduce fossil CO_2 emissions by 20% compared to the 2011 baseline, and deliver 40% primary energy savings. The use of annual crops would bring additional savings in transport costs and emissions. The challenge of CO_2 savings in chemical pulping is the fact that it is already very much bioenergy based. The use of DES however makes even more sense when one takes a wider view. Pure lignin should not be used to produce heat or electricity but rather to replace aromatics in the chemical industry.[4] When these pulp and lignin/aromatics are produced in one system, the overall energy and CO_2 savings of the two systems combined are 90%.

Where is the added value?

Using DES to make pulp produces lignin in a pure (sulphur-free and unchanged) form. Income from sales of chemicals could cover most of the costs of cellulose production. We estimate a value increase of 200-300 euros per tonne of wood[5]. The new omnivorous pulp mill concept would allow tailor-made fibres to be produced, using a broader variety of raw materials, significantly less energy and fewer chemicals.

Today's recovery boiler and mechanical pulp plants could potentially no longer exist. A DES-based pulping process would have the technology needs of a recycled pulp process today. Investment costs could therefore be less than half those of a traditional chemical pulp mill. Using DES would further open the way for cost-effective pulp production units as small as 50 kilo-tonnes per annum, meeting the growing demand for more localised production units close to resources. These installations would serve local and regional markets, and reduce transport emissions and costs. Much lower capital and operational costs would ultimately turn the pulp market upside-down. This would also affect the recycled fibre market.

The omnivore pulp mill



How do we get there?

The DES pulping concept is completely new, yet proven and very promising at a lab-scale. It has not yet been tested in pilot, demo or industrial projects. More research is needed, also to validate associated processes, including the recovery of chemicals. However, it requires only readily available technologies for implementation.

We would expect DES pulping to be in a position to come to market at industrial scale in a maximum of 15 years, assuming industry embraces the concept and further research is able to attract support. Our sector will have to make a choice: leave the development to the chemical sector, or use the latest separation breakthrough to put ourselves at the heart of the bio economy. ■

Flash condensing with steam

Waterless paper production? Very nearly.
Largely dry fibres would be blasted into a forming zone with agitated steam and condensed into a web using one-thousandth the volume of water used today.

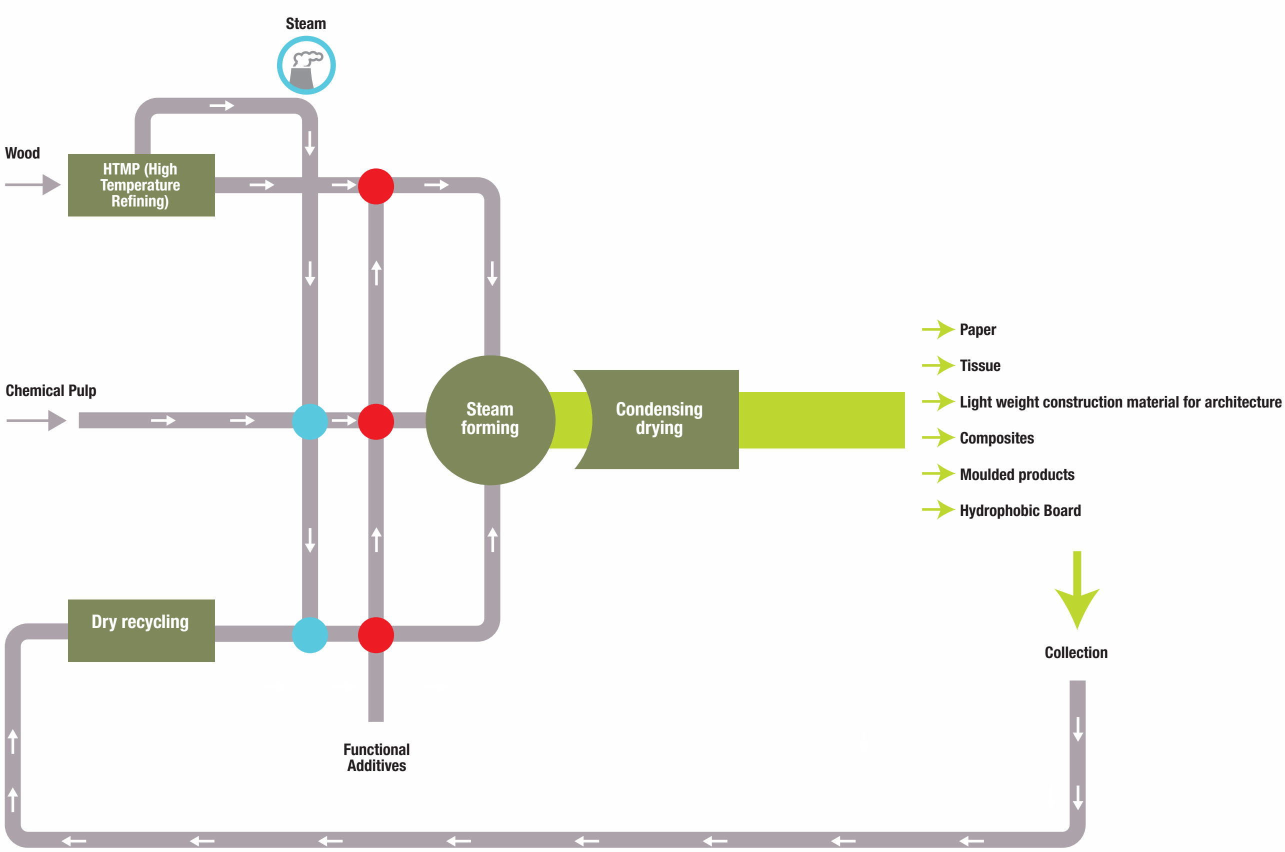
How does it work?

The breakthrough concept is the use of vapour combined with largely dry fibres to form paper and board. It works by introducing high-consistency fibres, fillers and chemicals into highly turbulent steam. The steam carries the fibres into the forming zone, where the combination of condensing and steam expansion creates the paper sheet and enables bonding. High gas velocities make the forming section very short. Very little extra heating is required for drying, as water content after the wire is less than 30%.

How would it work for the sector?

Steam forming could be used with all kind of fibres. It could most easily be applied to production using chemically-pulped virgin pulp fibres, but it could also be employed with recycled fibres obtained through dry recycling processes[6] and additional cleaning. It could even be applied to refine thermo-mechanically pulped 'gluing fibres', which are highly hydrophobic and are currently not used in conventional papermaking.

Process overview



In the ideal scenario, steam forming could enable massive water savings. Rather than using 100 litres of water to dilute 1 kilo of fibres, the fibres would be suspended in 100 litres of water vapour, generated from just 0.1 litre of water. This low volume of water could easily be adsorbed and dried out of the paper sheet. The combined press and drying has to be of a new type and would rely heavily on condensing and very little extra heating as very high entrance temperatures of the fibre web could be expected.

Contribution to CEPI 2050 Roadmap and carbon reduction

If applied throughout the sector by 2050, the concept would reduce fossil CO_2 emissions by about 50%, compared to the 2011 baseline, and some 20% savings of primary energy. Compared to today's consumption, the steam forming and dry condensed papermaking concept would cut current energy use for drying by at least 50%, due to the far lower volume of water needed for the drying section. In addition, since the pressing and drying method would be at or above boiling point and use condensing, it would need very little heating. The volume of fresh water required would be substantially reduced and there would be no need for an effluent treatment plant.

Where is the added value?

Besides the costs savings due to reduced water and energy needs, the technology would allow for smaller production units that cost much less per capacity, have a very low environmental impact and no effluent emissions.

In some cases, using steam for lignin-based bonding would enable the production of a new range of much stronger, lightweight products, offering enormous savings to packaging manufacturers. As well as high-strength packaging materials, other likely new products might include nonwovens, moulded products, composites and multi-layered products, and lightweight construction material for use in building. At high temperatures, the fibre used in paper formation would be sterilized when entering into the process.

How do we get there?

The steam forming technology should be applicable throughout the paper industry. For investors, it offers the promise of significantly lower investments due to smaller-scale, cost-efficient production units with greater energy and water efficiency, and the flexibility to use different fibres.

The fit with existing technology is expected to be good on the raw materials side as refiners may be refitted. New dry recycling lines could be attached to conventional papermaking lines. The production process in itself is completely new. Supporting operations like raw material and product handling and product converting could still be used with the new process.

In terms of timing, it would be at least 10 years before a commercial process is likely to be available. The fluidising of fibres in water vapour needs further research, as does the process to achieve inter-fibre bond formation during condensing/drying. Research into high temperature refining can draw on practice in other sectors. Further work is needed to develop the additional cleaning steps required in the dry recycling process. ■

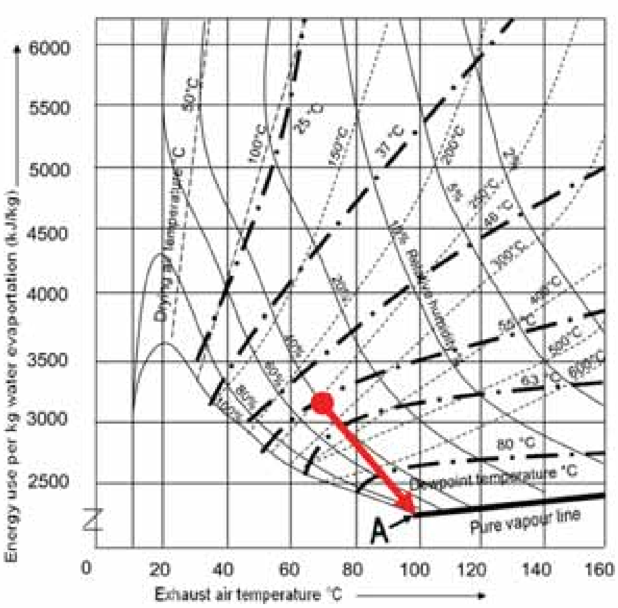
Steam

Using more energy to use less? You read it right. Using the full power of pure steam for superheated steam drying would save energy as most heat could be recovered and recycled. Steam will then be used as fibre carrier for making and forming paper.

How does it work?

Today, heated cylinders deliver the energy required to evaporate water from paper, and large quantities of air are used to remove the water vapour. With this air and vapour mixture, large amounts of energy (latent heat) leave the dryer section at low temperature. Temperature and humidity are increased towards "Pure vapour", where superheated steam replaces air as heat carrier. This allows full recovery of heat. Next, the use of steam is expanded into the papermaking process, with steam and heat-boosted forming, pressing, sizing and coating. And finally steam spray forming and steam foam forming are put in place[7]. Because of temperature, the new-concept paper machine should be operated by remote control, using robotics. The concept builds on expertise gained in the food sector and from a pilot plant in the panel board sector, but also on earlier work done in our industry.

The technology breakthrough of superheated steam is finding the pure vapour line



How would it work for our sector?

Implementation would be expected stepwise, following the readiness of the different technologies. Steam would progressively replace air and finally also water in the papermaking process. Starting at the drying section, the rest of the process would be transformed, rebuild by rebuild, as steam filled the whole paper machine. Three logical waves could be anticipated: superheated steam drying, with the total recovery of thermal energy in an air-free drying section; steam-boosted papermaking within an air-free paper machine; and steam-based papermaking, based on completely new forming technology, leading to more material efficient products.

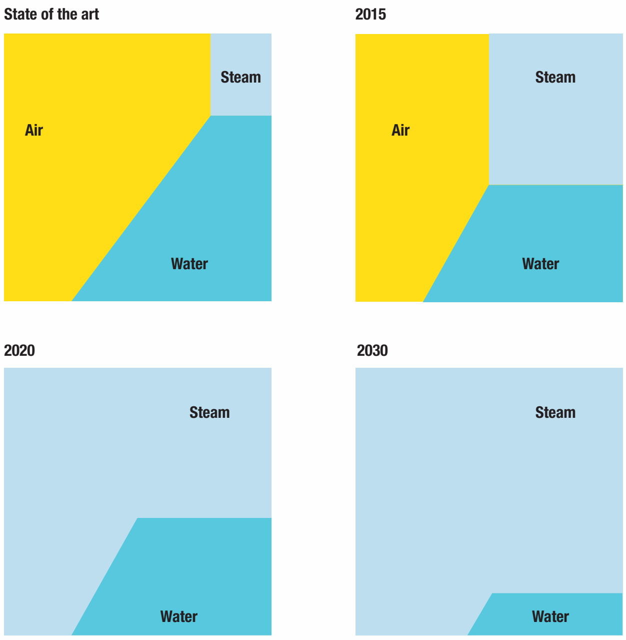
Contribution to CEPI 2050 Roadmap and carbon reduction

If the concept were fully applied, energy consumption would be reduced by some 25%. The large majority of these savings would come from the introduction of superheated steam drying. If applied throughout the sector by 2050, the concept could reduce fossil CO_2 emissions by half compared to the 2011 baseline. The core of fossil CO_2 emissions in the sector comes from the production of steam by gas-fired CHP in non-integrated and recycled fibre-based mills. This is why the concept shows large savings. The concept could be used in any drying section and in any mill.

Where is the added value?

Applying the full concept could lead to an overall cost reduction of at least 30% at mill level. Applying steam based forming technologies would further also create the means to reduce paper weight. Replacing forming water with steam would cut water handling and treatment costs. Meanwhile, the capital costs for machines would fall, as forming and drying sections would be much shorter, and machine output could increase thanks to higher speeds. Sheet stratification would also offer the possibility to use recycled fibres and/or coarse pulp fractions in middle layers in combination with virgin fibres, allowing for further savings in raw materials and energy.

The three steam waves



How do we get there?

The concept could be applied throughout the industry regardless of raw materials used or paper grades produced. It could be retrofitted to existing machines. Of course, there would be adjustments. It would change the need for combined heat and power, current chemicals might have to be replaced, and new skills and working practices would be required, e.g. robotics to handle the higher temperatures. Technology for the first step of superheated steam-drying might be developed by 2020, steam-boosted paper-making within a closed machine could be achieved by 2025 and the third step of “forming-waterless” steam spray and/or steam foam forming by 2030. At least two decades more would be needed for larger scale implementation.

The concept could first be applied in pilot paper machines to develop the closed paper machine technology. It could help drive technologies like robotics to change felts or wires, which could also be used by parts of the industry not yet converted and improve health, safety and environmental standards. ■

DryPulp for cureformed paper

Imagine a papermaking process that uses no water. This is it. Fibres are treated to protect them from shear, and then suspended in a viscous solution at up to 40% concentration. The solution is then pressed out and the thin sheet cured with a choice of additives to deliver the end-product required.

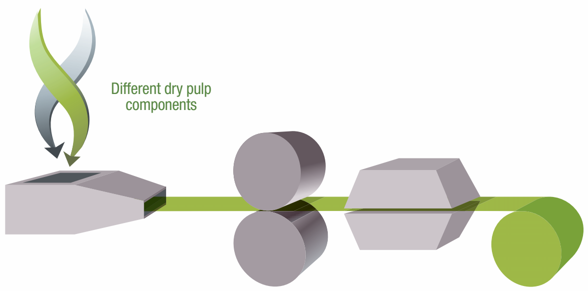
How does it work?

In papermaking today, cellulose fibres used to make paper have to be suspended in large volumes of water to prevent them forming clumps (flocs)[8]. The innovation introduces two technologies that enable the production of paper with no water.

First, the use of DryPulp: DryPulp consist of a shear-protected fibre in a highly viscous solution. Instead of today's water-intensive process in which cellulose fibres are suspended in water, DryPulp is a highly viscous solution, containing a high concentration of fibres. To prevent the fibres disintegrating in such a viscous solution, they are given a protective surface layer.

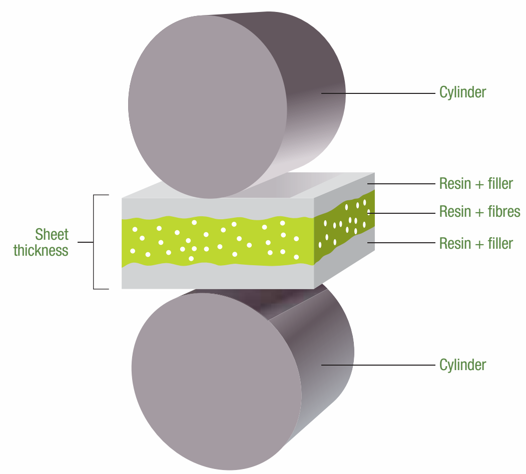
This is a technique borrowed from nature: a penguin accelerates to escape a predator underwater by releasing air collected while on the surface and trapped within its plumage. When the air is released it forms a thin layer around the penguin where viscosity is much lower than in the water, which reduces the friction forces. The concept has also been used in Russia to develop super-fast torpedoes. A gas bubble formed around the torpedo enables the torpedo to travel 10 times faster than competing technologies (supercavitation). In papermaking, bio-based substances could be used to modify the viscosity around fibres.

The process of DryPulp-CureForming



The principle of sheet forming of the paper and board. The components are mixed separately and brought to the film forming process, either as a single stream of as several streams that allow multi-layer sheet structures.

Multi-layered papermaking



One example of the multi-layered sheet structure that is formed with only resin and filler in the surface layer, making coating unnecessary, and fibres, micro-bubbles and resin in the middle layer creating the bulky base sheet.

The second technology is 'cure-forming', which allows the formation of a thin sheet. The high consistency DryPulp is pressed to remove the viscous solution. After pressing, the web contains up to 80% fibres. The sheet is then cured using processes adapted to the end-product required.

How would it work for our sector?

The combination of these two technologies would allow the sheet to be produced as a layered product, in response to demand for certain properties and with the means to add new functionalities. For example, a sheet could be composed of a bulky middle layer embedding air bubbles and sodium bicarbonate[9] and an outer layer with resin and fillers, making coating unnecessary.

Contribution to CEPI 2050 Roadmap and carbon reduction

Given that drying consumes about half the energy used in papermaking today, removing water from the process will contribute substantially to decarbonising the sector. It also cuts out coating, as this is done during the forming process. Moreover, the absence of water removes the energy costs of effluent treatment.

It is estimated that energy demand for the manufacture of all paper and packaging grades except sanitary and household will be much lower using this concept's technologies than in today's papermaking process. If the whole sector is considered, including pulp production as well as sanitary and household grades, this translates to a reduction in energy demand of about 25% and 55% CO_2 emissions reduction.

Where is the added value?

Being able to make multi-layered paper without water would offer the flexibility to make different and new products at lower cost. Initial tests of the technology looked only at three-layer paper, but more layers could potentially be added. It would also allow the forming of non-flat and three-dimensional shapes.

Lower energy demand would proportionally reduce energy costs for the entire manufacturing chain. The simplification and greater flexibility of the process would minimise losses and allow faster transition to new product grades. There would be no need to treat water effluents. Smaller production units would be possible, with the required capital investment up to 20 times less than today.

How do we get there?

This concept introduces a new production process for papermaking. The technologies are all based on existing knowledge but further research and development would be required to develop the optimal DryPulp compound, the process technology for mixing and pumping it, and the forming technology for shaping and curing it. ■

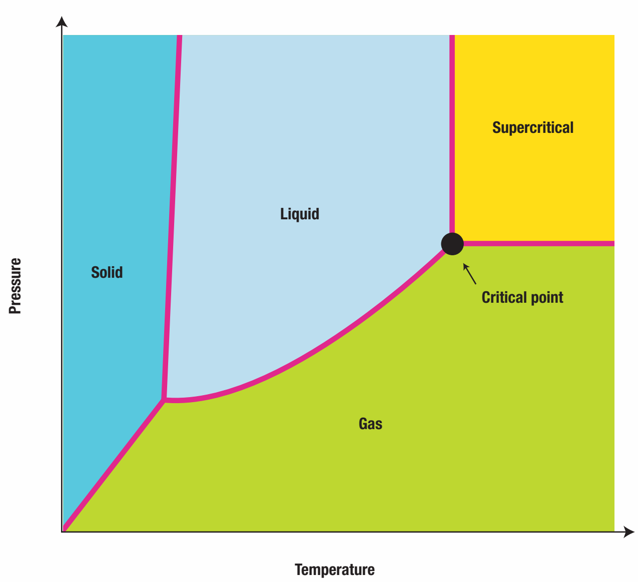
Supercritical CO_2

Neither gas nor liquid but somewhere in between, Supercritical CO_2 ($scCO_2$) is widely used in many applications, to dry vegetables, fruits and flowers, extract essential oils or spices. Suppliers for NIKE, Adidas and IKEA[10] use it to dye textiles. Coffee and tea have been decaffeinated with $scCO_2$ since the early 80s[11]. We could use it to dry pulp and paper without the need for heat and steam, and why not dye paper or remove contaminants too, while we're at it?

How does it work?

CO_2 in supercritical state takes on many of the properties of both gas and liquid. With small changes in temperature and pressure a large variation in solvent properties can be achieved. The liquid-like characteristics and the combination of pressure and temperature allow paper to be dried with $scCO_2$ in place of water before the $scCO_2$ is removed with a simple change of pressure. Second, the gas-like characteristics provide ideal conditions for extracting contaminants in the process. The proof of concept can be seen in other sectors. CO_2 is widely available. Little energy is required to take it to a supercritical state.

The different phases of CO_2



How would it work for our sector?

A first application for supercritical CO_2 lies in "extraction drying". The current drying section with steam-heated cylinders would to a large extent be replaced by two autoclaves. Lab tests showed wet paper with 50%-60% moisture content can be completely dried using this process, with minimal impact on paper quality and using much less energy than today's drying section[12]. $ScCO_2$ could first be tested in moulded fibre processes, in tissue and specialty mills and then in graphic paper and packaging machines.

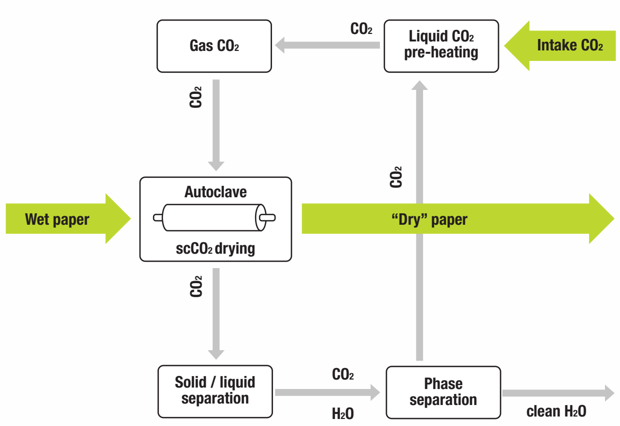
Supercritical CO_2 has great potential to remove contaminants such as waxes and stickies in the recycling process, improving runnability in papermaking. The use of $scCO_2$ in recycling processes can create fractionated fibre on demand, fit for purpose. Moreover, lab tests have shown that $scCO_2$ can remove mineral oils, a key issue today[13]. Waxes and stickies could be removed and the process would lead to certified 'clean' – and most important – dry recycled fluff pulp.

The key challenge of current Deinked Pulp Mills, the transport of wet deinked pulp, can be tackled this way. The process could also be used to remove adhesives, allowing papers containing these to be brought into the recycling process. Ultimately, the system could be used to produce products directly in $scCO_2$.

Contribution to CEPI 2050 Roadmap and carbon reduction

The technology offers savings exactly where the largest fossil CO_2 emissions take place today, in the drying of pulp and paper. It would take more electricity to run the autoclaves to dry paper than an optimised drying section uses today, but heat and steam would no longer be needed. If applied throughout the sector by 2050, the technology has the potential to reduce fossil CO_2 emissions by some 45% compared to the 2011 baseline, and result in around 20% primary energy savings within the current mill boundaries.

Drying with $scCO_2$



CO_2 can be obtained from industrial gas producers. When carbon capture technologies improve and create pure CO_2 streams from other sectors, some of the CO_2 could come from other production facilities at the same site. The CO_2 is not emitted; it is used in a closed system and constantly recycled. The pulp sector already has experience of using process CO_2 in the production of precipitated calcium carbonate. Now carbon capture and storage has the potential to become carbon capture and use.

Where is the added value?

Replacing the drying section could reduce energy costs by 10-20%, as well as allowing for lower infrastructure costs and boiler capacity. Treating recycled paper by separating the pulp into different fibre grades would enable purchasers to buy only the exact type of fibre for their needs. This would enable greater production from the available fibre in Europe. Furthermore, using $scCO_2$ to remove contaminants such as mineral oil, which has been proven at lab scale, could bring huge costs savings. The upcycling instead of recycling would increase material efficiency in the mill by at least 10%. If complete $scCO_2$-based systems were to be applied in the final stage, the result would be a water-free process.

How do we get there?

The concept could be applied to existing pulp and paper equipment and processes. The cleaning function of $scCO_2$ could be made part of current cleaning steps in recycling mills. For extraction drying, the forming section of the paper machine would remain the same. Paper machines would need to be retrofitted to replace the drying section with autoclaves. Pilot projects would be needed to establish the optimum combination of process conditions for drying paper. The realistic timing for design and implementation of extraction drying is about 15 years as the change of equipment would be disruptive and demonstration needed. ■

100% electricity

Shifting pulp and paper production to energy-efficient technologies using electricity rather than fossil fuel power to generate heat will cut all CO_2 emissions as the power sector shifts to renewable energy. The sector would also provide a buffer and storage capacity for the grid, storing energy as hydrogen or pulp.

How does it work?

The breakthrough consists in the optimal management of energy demand. It would decarbonise papermaking through the adoption of more efficient technologies that use electricity rather than fossil fuels to generate heat.

The sector could also provide a buffer and storage capacity for electricity, offering a means to store cheap surplus energy from the grid generated from intermittent renewable energy sources such as solar and wind power. It would do this by using electricity when it is cheap to produce and store Thermo-Mechanical Pulp (TMP) and hydrogen (H_2), using the latter to generate power during periods of high electricity prices or selling it to external users.

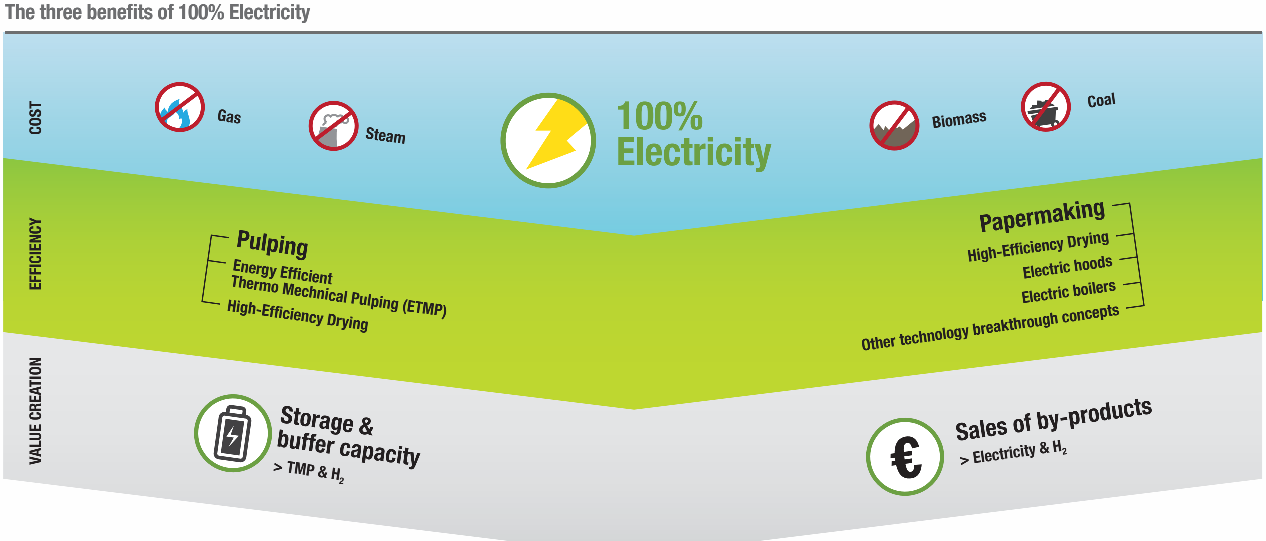
How would it work for our sector?

The concept allows for a step-wise implementation. The industry could first replace gas-fired boilers with electric boilers (almost 100% efficiency, compared to 70-90% efficiency for coal or gas-fired boilers).

In subsequent stages it could replace the drying section in the pulp process and later the drying section of the paper machines. Various technologies exist for high-efficiency drying which are available but not yet widely used. These include ultrasonic drying[14], impulse drying[15], Condebelt drying[16], microwave drying[17], infrared drying[18] and osmotic drying.

To perform the function of buffer and storage capacity, the paper industry would be able to take advantage of periods of cheap electricity by storing it as TMP or better, as H_2. When electricity is expensive, the stored H_2 would be used on site to drive a turbine and generate electricity[19]. This flexibility would help energy suppliers overcome the barrier of the intermittent supply of renewables.

The three benefits of 100% Electricity



Contribution to CEPI 2050 Roadmap and carbon reduction

With the current power sector, the concept will reduce CO_2 emissions by nearly 20%. If the EU meets its renewable energy target (nearly 100% CO_2-free electricity in 2050), the concept would result in fully decarbonised papermaking.

Where is the added value?

The cost of energy accounts for about 20% of total costs in the pulp and paper industry. This concept will reduce these costs by about 8%. The industry would employ flame-free power-to-heat technologies to apply heat directly to the fibre, making substantial energy savings. This would remove the losses due to steam boilers, combustion processes and air systems.

Ending the use of fossil fuels will also totally cut NOx and SOx emissions. The high safety requirements associated with combustion processes would be eliminated and machines and equipment could be significantly smaller. The sector could also add value by acting as an energy storage/ buffer. It could produce TMP and, even better, hydrogen, when electricity prices were low, and sell these by-products, e.g., to the chemical industry, or generate electricity on site when prices are high.

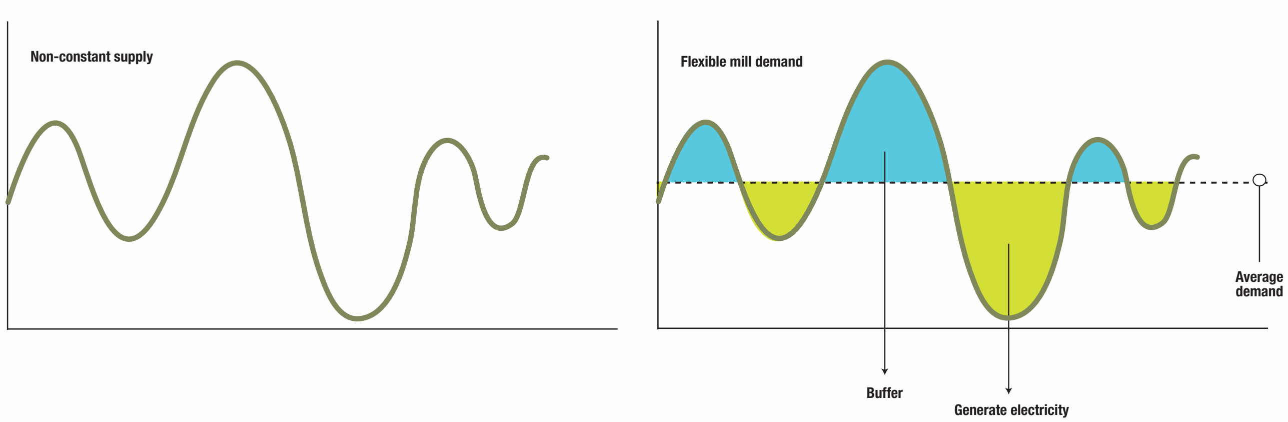
How do we get there?

The advantage of this concept is that it allows a transition period, which significantly reduces risk. The sector could adopt existing and new technologies in a stepwise manner, moving progressively to 100% electricity.

The concept fits with existing mill configurations and machines, and by applying new technologies would add value. It could reduce an installation's footprint and investments considerably: removing unnecessary Yankee or steam heated rolls and opening the way for shorter felts and wires, low weight lead rolls, less air ducting and smaller boilers. ■

Industry enables renwables by storing electricity and adjusting demand

Renewable energy



Functional surface

The CEPI TWO TEAM FINALIST

The key to unlocking greater added value from fewer resources depends on a shift to producing more lightweight products, and selling surface area and functionality rather than weight. Advances in sheet formation and new cocktails of raw materials will lead the way to the lightweight future.

How does it work?

The idea is to make breakthroughs in the material composition and the formation of paper, to offer greater functionality while reducing the weight of paper products. It is about developing technology that allows full control over the paper sheet structure, reducing the amount of material by 30% per square metre.

It would meet customer expectations by increasing the physical-mechanical characteristics of the paper (tensile, compression, printability, bending, bulk, etc.) and/or adding new features (electrical properties, optical characteristics, hygroscopic behaviour, etc.).

How would it work for our sector?

Achieving this concept would require breakthroughs in two sub-concepts. The first, Innovative sheet formation, requires modified headbox designs or new components distribution technologies. Secondly, modification of raw material composition, or using different cocktails of raw materials – fillers, starches, pigments etc. – to improve a product's performance or help develop new products with enhanced functionalities, for example building materials.

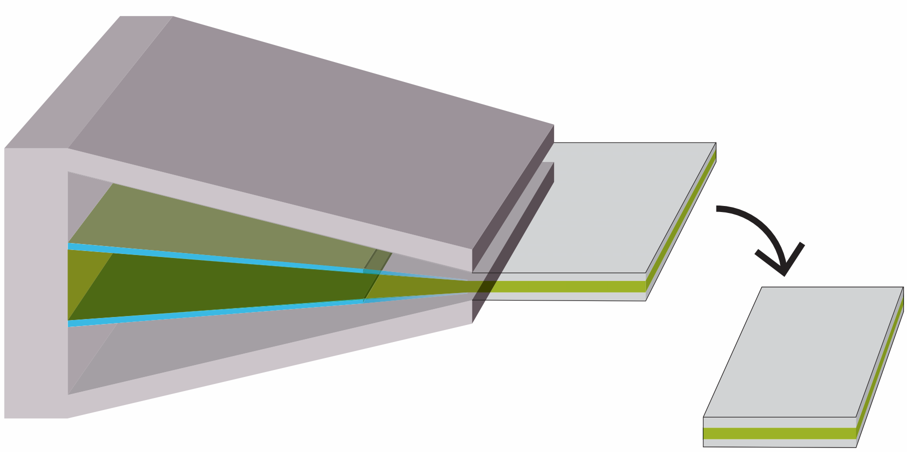
Alternative cost-effective raw materials could even replace a proportion of the pulp in papermaking, offering considerable energy savings.

Contribution to CEPI 2050 Roadmap and carbon reduction

Lighter-weight products would need less energy to dry the paper, reducing steam consumption as well as electricity for pumping and driving in the papermaking process. Lighter products would also indirectly reduce CO_2 emissions due to their reduced transport needs.

As an illustration of the concept feasibility, the past two decades have already seen a significant reduction in the weight of corrugated board products made in Europe. From 2009-11 alone, the average carbon footprint of producing 1 tonne of corrugated board fell by more than 4%.

An example of multilayered sheet forming is the Aqua-vanes process



Where is the added value?

Added value could be around 30% with lightweight paper and board. Firstly, making products with the same functionality using lower volumes of raw materials, water and energy could deliver cost reductions as well as the possibility to set higher prices. Secondly, enhancing the performance and features of paper products would add value, for example by making paper packaging that can withstand humid conditions, reducing the need for ink or providing better cracking resistance. Thirdly, reducing the volume of raw material inputs would bring down logistics costs at both ends of the value chain: before paper production and at the point of delivery to the customer.

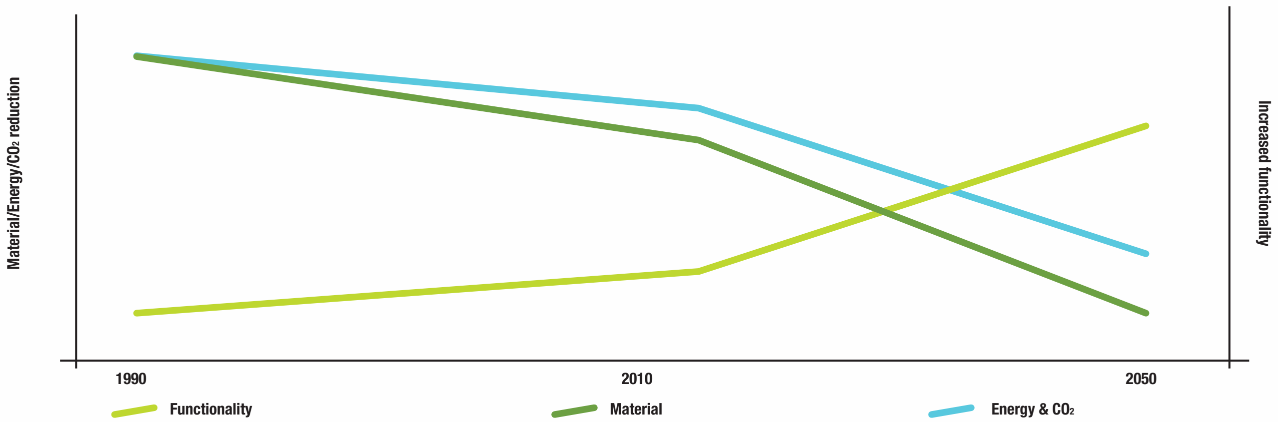
How do we get there?

Little investment would be required to lower the basis weight of paper through modifying the raw material composition. Further CO_2 reduction results could be achieved by investing in innovative sheet formation technologies (e.g. multilayer sheet formation) to further lower the paper weight and enhance functionalities.

Research is ongoing into new raw materials (microfibrillated cellulose (MFC), nanofibrillated cellulose (NFC), chemicals and polymers), into modifying existing materials or into innovative equipment to distribute the component mixes. It is likely that gains similar to those observed with corrugated material could be achieved with other paper grades, such as printing grades.

The success of this concept would depend on collaboration between equipment manufacturers and the scientific community, particularly in the field of chemistry, fibre structure and properties, and new materials. The concept should also ensure recyclability of the end-product. Innovation in this area could then also encourage a switch to paper instead of non-renewable materials. ■

Illustrating a need for a break in the curve towards grammage reduction in the sheet



The Toolbox to replicate

What about the great ideas that never make it? Put together a combination of process, material and equipment innovations as a toolbox of stepping stones to 2050 and the pathway becomes clearer, boosting sector and investor confidence.

How does it work?

In this concept there is no single breakthrough. There is a combination of breakthroughs and a direction in which to combine them. The toolbox shows an overview of the best, so far unused technologies within and outside the sector (stepping stones), and a vision of a future production system that could be realised by applying these technologies. The stepping stones are divided into time segments for 2025, 2035 and 2050. The direction of breakthrough for pulping is to go smaller – from tree to fibre, from fibre to chemical, from chemical to molecule. The direction for processing is to use the last technologies in layering, forming and 3, 4 and 5D[20] printing. Products become customised and allow a range of specific characteristics.

How would it work for our sector?

On one hand, the sector would progressively replace equipment with the most advanced technologies, once the pilot proof has been demonstrated. On the other, based on the latest material science and advanced manufacturing, biomass would be separated into all valuable streams, and used with the new manufacturing technologies to produce improved products. The technologies for this are already within sight. By 2025, the combination of new raw material processing and papermaking technologies will allow lightweight products, sandwich layers and limited customisation of products.

3D printing could play an important role between process and products. By 2035 the combination of stepping stones in the toolbox would result in even thinner layers, manipulation of layers and customisation down to parts of end products. By 2050 production sites would become custom-designed, able to make fully customised products using locally available raw materials.

The concept is intended to become an innovation system for the sector. If the sector agrees to fill the toolbox with new technologies and put in place a system for this and for piloting, new combinations will become available. The toolbox would ideally be updated every so many years.

Contribution to CEPI 2050 Roadmap and carbon reduction

One possible stepping stone combination – if applied throughout the sector – could reduce fossil CO_2 emissions in 2050 by 40% compared to the 2011 baseline. It would result in a 50% primary energy savings within the current mill boundaries. This is, however, only one possible combination of stepping stones; others should be investigated. Further emission reductions could be achieved by improving industrial ecology to boost heat integration within the mill and between a mill and its surrounding community. Locating production close to installations that generate waste heat at temperature levels sufficient to provide heat for drying, such as steel mills, cement plants or next generation nuclear power plants, would save energy while also freeing up biomass to be processed into higher value products.

Combination and Direction: Examples of stepping-stones to further develop

		Raw Material -Separate	Process	Product - Recombine	Wave
2025	Pulp 4.0	• Enzymatic treatment • Shear compression • Energy efficient thermo-mechanical pulping	• Stratification • Foam forming • Smarter automation • 3D-printing	• Light weight • Sandwich layers • Limited customisation at end (paper printability / packaging durability)	**Extreme makeover TRL 6-8**
2035	Sophisticated Biomass fractionation into lignin, cellulose and hemi-cellulose	• Ultrasonic assisted refining • Adsorption deinking • New pulping processes	• Extrusion • 4D-printing • Ultrasound dewatering	• Thinner layers • Manipulation of layers (print/ press/"glue" with biopolymers) • Customisation down to part of end products (e.g. treat part surface with sound to obtain patterned functionalities)	**Master Chef TRL 3-6**
2050	Biomass separation into molecules	• Molecular folding	• 5D-printing	• Recombination at will	**TRL 1-2**

Where is the added value?
Whatever the combination of stepping stones, savings would be derived from energy and material cost reduction. The envisaged 50% value increase in the Roadmap would be based on the large range of new products, markets and business models enabled. In short-term examples, the development of bio-barriers would bring new options for on-line production of packaging papers and boards. This would eliminate the need for a separate converting stage, simplifying the value chain, increasing the role of paper producers, and cutting CO_2 emissions. Foam-forming technology would introduce new opportunities for fibre-based products, enabling the production of very even and high porosity structures out of less valuable materials[21].

How do we get there?
Many of the technologies in the Toolbox are breakthrough technologies that need further development in research and pilot phases. As a whole, the concept drives forward the idea of an integrated vision of where the sector wants to go. It combines a mid-term range of solutions with a long-term vision for the sector. ■

What is needed next

The sector now has eight breakthrough concepts on the table. Some are good, some are better, one has won. None of the concepts will deliver solutions tomorrow. All require further research, pilot and demonstration projects. Where does CEPI go from there, what will the sector do and how can policymakers help realise the concepts' potential?

1. **Organise sector-wide discussion**
   As with our 2050 Roadmap, CEPI will organise a year of discussion within the sector about the eight concepts. They will be presented to the trade press and at internal and external stakeholder events. We will invite opinion from companies, CEPI members and suppliers, scientists and stakeholders. CEPI believes that we have some amazing ideas on the table, but we still welcome input from others.

2. **Grant licences**
   Apart from the team members, pre-jury and jury, no other CEPI member has yet seen the teams' results. CEPI is the formal owner of the project outcome and is entitled to license the concepts to its members. Licensing is necessary considering the project's non-disclosure and intellectual property rights conditions. CEPI members, but not others, will be able to access the material.

3. **Create opportunities**
   The next step will see individual companies or project consortia taking up the breakthrough concepts and ideas. CEPI's mandate ends with the Two Team Project, but we will continue to work for European funding opportunities, notably through the Horizon 2020 programme. CEPI is one of the co-founders and now associate members of the bio-based industries public private partnership (PPP) and has been active in setting up European Innovation Partnerships on water and raw materials. The Forest Based Sector Technology Platform (FTP), created to help the industry access EU funds, will also be instrumental. The two teams' concepts will have to be incorporated not only in the FTP strategic research agenda, but also in future calls for application opened at both national and European level.

4. **Update the CEPI Roadmap**
   In 2014 CEPI will update its 2050 Roadmap, based on lessons learned from the Two Team Report and in light of policy developments, other sector Roadmaps and the new EU economic and demographic outlook. As with the first Roadmap, this will be done with active stakeholder engagement.

5. **Report on progress**
   In the next version of the Roadmap, CEPI will report on progress regarding the eight breakthrough concepts - which have been successfully taken forward, which have not and why? What can and should be done? How can progress be speeded up?

6. **Implement lessons from the project**
   One key lesson from the project is the value of collaboration with the scientific and research community, and other sectors, suppliers and customers. All team members, including from other sectors, are entitled to see how their concepts take shape.

7. **Help create enabling policies and legislation**
   One of the main functions of CEPI remains our work with EU institutions to shape policies and legislation. CEPI will analyse the policy framework to identify what is required to enable the breakthrough concepts to be implemented, and how policymakers might help achieve this.

Breakthrough policies

Current EU policy does not sufficiently support the transformation of industry to meet climate targets. The 2030 climate change and energy policy package will have to be better and integrate industry policy with climate and energy policy. To adapt to industry needs, breakthrough innovation policy must be at the core of this package.

The CEPI 2050 Roadmap included a set of policy recommendations that for the large part have been taken on board and implemented by the current European Commission and European Parliament.

The establishment of the bio-based industries PPP was a great step towards creating the bio economy, but is not enough to bring the eight concepts to life. The shift in priority in Horizon 2020, the EU research budget, from research to innovation, pilot and deployment is very positive. But there is no dedicated funding available. To make breakthroughs happen, **we need different, innovative and breakthrough policy as well**.

In 2014 the European elections will establish a new EU Commission and Parliament. Our plea to this new generation of EU policymakers and member state governments is as follows:

1. **Be bold! Industrial breakthroughs need to lead a real industrial policy agenda**
   Develop a strong industrial policy for growth and jobs in Europe. This policy must reflect the need for a stronger economy in Europe, building on industrial competence and competitiveness, focusing on innovation, trade, reduced energy costs and fair competition with the rest of the world.

2. **Acknowledge the power of policy in innovation**
   For too long policymakers have left it to the market to deliver innovations to industry. Without policy intervention, however, there would be no Internet, no GPS and no microprossessors, to name just a few. The Apple iPhone is based on technologies developed by interventionist government innovation approaches. The current EU economy and market will not deliver the breakthroughs in the current climate.

3. **Create a breakthrough technology programme to support industrial sectors**
   Help implement the lessons of the industry Roadmaps developed to date. Support research, pilot and demonstration activities, taking inspiration, for example, from the US Incubator Program. Current flexible funding tools are only accessible to SMEs. This has to change.

4. **Use the EU ETS funds for the purpose for which they were intended**
   The European Emissions Trading Scheme (ETS) was designed to help industry sectors to decarbonise. But funding remains in the hands of member states; it does not reach industry. EU policy needs to address this. The ETS backloading debate came close to doing so, but the Parliament compromise failed. The EU will need to take a leading role on breakthrough technologies. Any post-2020 change to the EU ETS should include innovation funding as a fundamental principle.

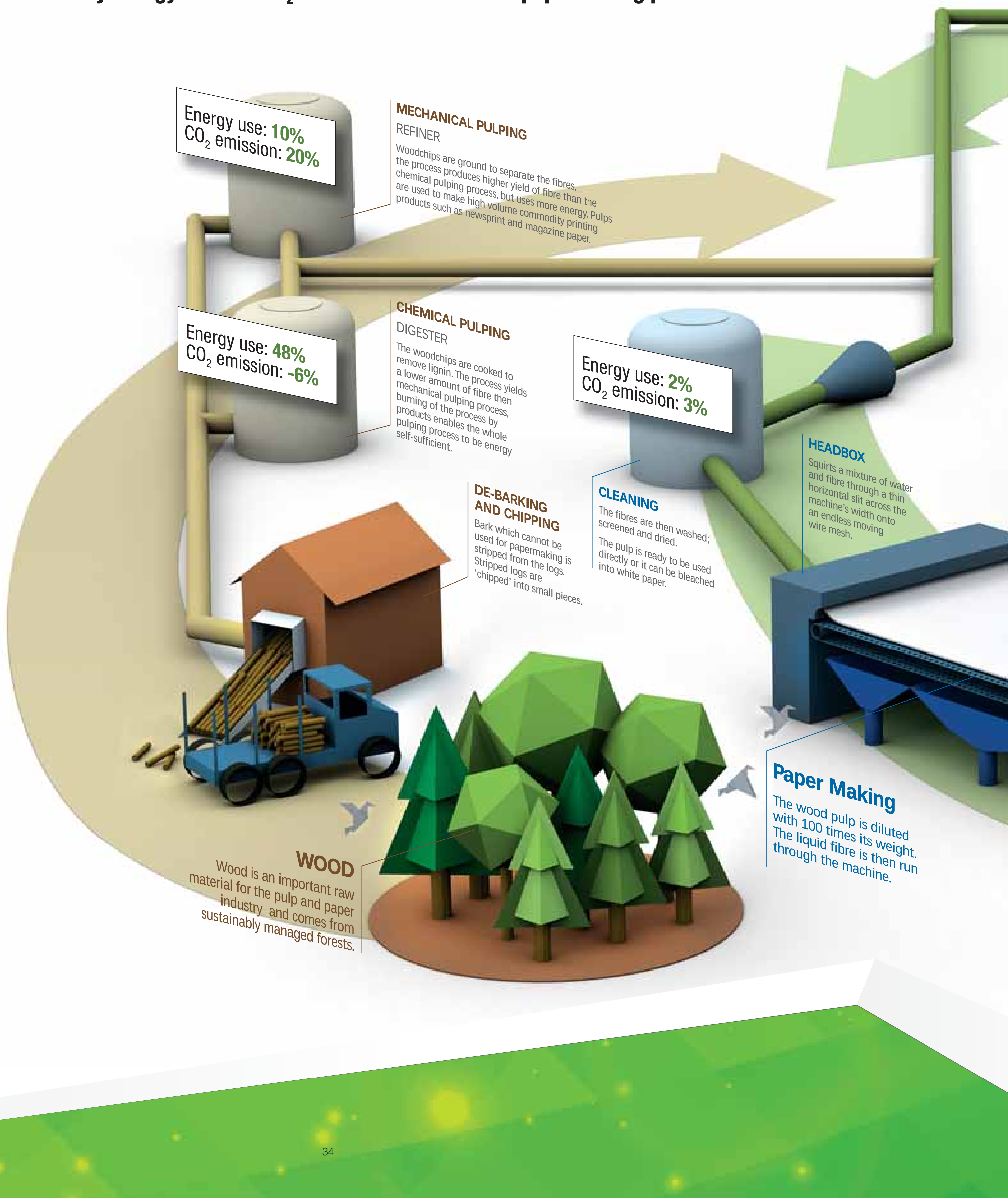
5. **Base policy on understanding how industry invests**
   The next steps in breakthrough technology development are all at risk from a lack of investment in industry and a lack of understanding about how industry investments work. The ultra-low carbon dioxide steelmaking (ULCOS) project shows that research and development can take place in Europe, but that there is still a huge gap before commercial application can take place in Europe instead of being exported to other parts of global companies. NER300 funding was a good step, but allocation of funding took so long that investment decisions had passed. This needs to change.

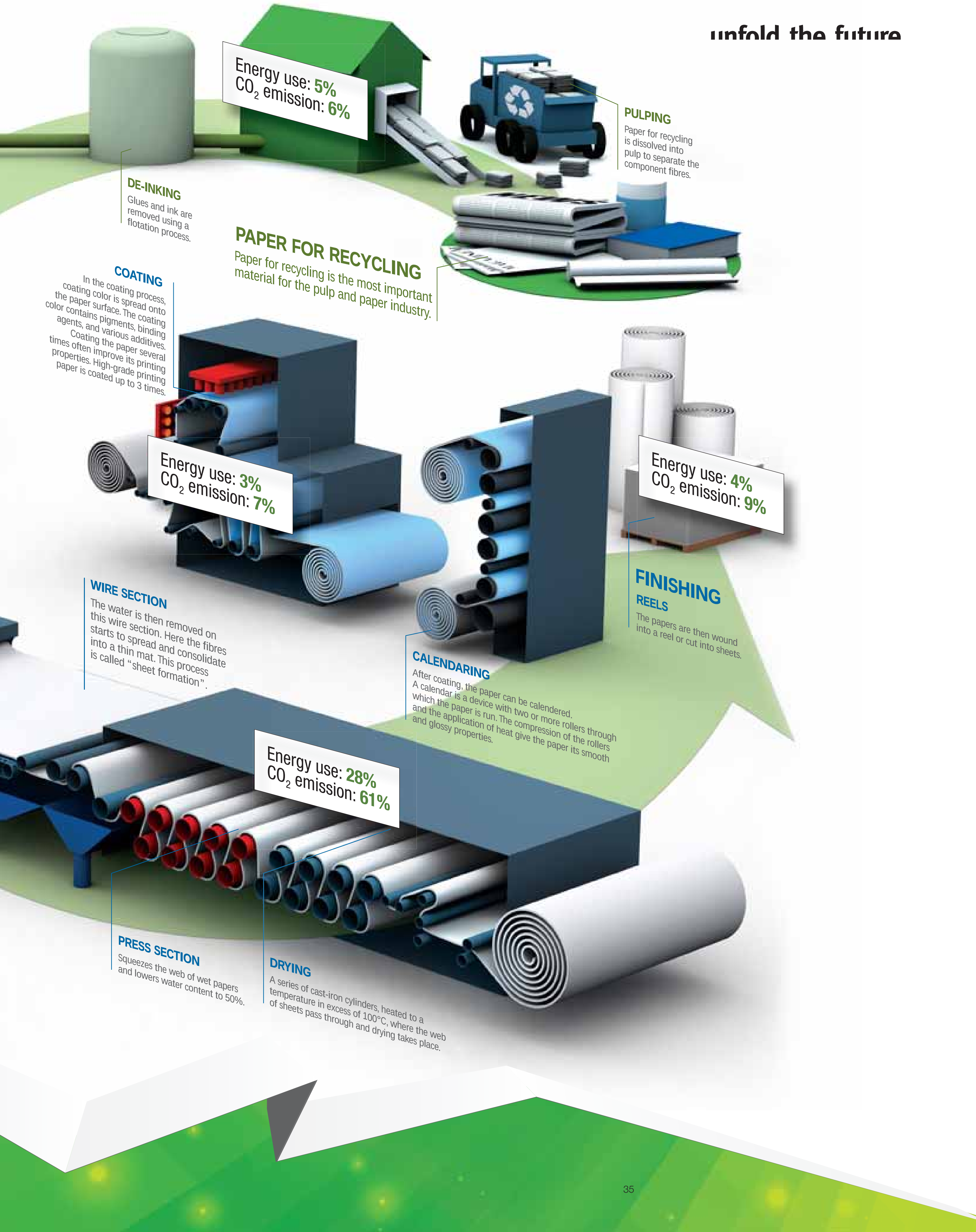
6. **Create innovation platforms, circles and programmes around industrial sectors in a more structured way**
   Help establish a more permanent and systematic exchange between sectors, suppliers and researchers, as the Two Team Project has shown. This is not a sector-specific technology platform, but a triple helix model of cooperation.

7. **Fund processes such as the Two Team Project**
   CEPI applied a workable and innovative approach that delivered fruitful results. This was based on the support and vision of the Board, members and companies and with limited funding. EU innovation policy should enable similar processes to take place, providing support to allow all sectors to undertake this sort of initiative.

Annex
How do we make paper today?

Primary energy use and CO_2 emission in the current papermaking process




Energy use: 5%
CO_2 emission: 6%
PULPING
Paper for recycling is dissolved into pulp to separate the component fibres.
DE-INKING
Glues and ink are removed using a flotation process.
PAPER FOR RECYCLING
Paper for recycling is the most important material for the pulp and paper industry.
COATING
In the coating process, coating color is spread onto the paper surface. The coating color contains pigments, binding agents, and various additives. Coating the paper several times often improve its printing properties. High-grade printing paper is coated up to 3 times.
Energy use: 3%
CO_2 emission: 7%
Energy use: 4%
CO_2 emission: 9%
FINISHING
REELS
The papers are then wound into a reel or cut into sheets.
WIRE SECTION
The water is then removed on this wire section. Here the fibres starts to spread and consolidate into a thin mat. This process is called “sheet formation”.
CALENDARING
After coating, the paper can be calendered. A calendar is a device with two or more rollers through which the paper is run. The compression of the rollers and the application of heat give the paper its smooth and glossy properties.
Energy use: 28%
CO_2 emission: 61%
PRESS SECTION
Squeezes the web of wet papers and lowers water content to 50%.
DRYING
A series of cast-iron cylinders, heated to a temperature in excess of 100°C, where the web of sheets pass through and drying takes place.

Glossary

Autoclave
A strong, heated container used for chemical reactions and other processes using high pressures and temperatures.

Biorefinery
Is a facility that integrates biomass conversion processes and equipment to produce a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power and/or heat). The biorefinery concept is analogous to today's petroleum refinery, which produce multiple fuels and products from petroleum.

Cellulose
Cellulose is a complex carbohydrate, $(C_6H_{10}O_5)_n$, that is composed of glucose units, forms the main constituent of the cell wall of wood and most plants, and is important in the manufacture of numerous products, such as paper, textiles, pharmaceuticals, and explosives. It is crystalline, strong, and resistant to hydrolysis.

Chemical pulping
In the chemical pulping process, the lignin bonding of the wood fibres are dissolved away by cooking the wood chips in suitable chemicals to obtain a woodpulp.

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.

Coating
A compound to impart certain qualities to the paper, including weight, surface gloss, smoothness or reduced ink absorbency. Kaolinite, calcium carbonate, bentonite or talc are used to coat paper for high quality printing used in packaging industry and in magazines.

Condebelt drying
In the Condebelt drying concept a wet web (sheet of paper) is carried between two steel bands, one hot band and one cold band, and subjected to high pressure (max. 10 bar) and temperature (max. 180°C).

DES
Refers to deep eutectic solvent. A deep eutectic solvent is a type of ionic liquid (a salt in the liquid state) with special properties composed of a mixture which forms a eutectic with a melting point much lower than either of the individual components. While ordinary liquids such as water and gasoline are predominantly made of electrically neutral molecules, ionic liquids are largely made of ions and short-lived ion pairs.

Fillers
Inorganic pigments like clay, calcium carbonate, titanium dioxide and other white pigments added to the paper machine furnish to improve brightness, opacity and printing smoothness.

Flocculation
In the field of chemistry, is a process wherein colloids come out of suspension in the form of floc or flak.

Foam forming
In foam forming large amounts of air are mixed into the fibre furnish which makes it possible to achieve unique product properties.

Hemicellulose
Any of several polysaccharides that are more complex than a sugar and less complex than cellulose, present along with cellulose in almost all plant cell walls.

HTMP
High-temperature-thermo-mechanical pulping is produced at temperatures close to the softening temperature of water saturated middle lamella lignin (170-180°C), the chips are defibrilated at or close to the middle lamella.

Hydrophobic
Hydrophobic is the physical property of a molecule that is repelled from a mass of water.

Impulse drying
Impulse drying involves pressing the paper between one very hot rotating roll (150-500°C) and a static concave press with a very short contact time. The pressure is about 10 times higher than that in press and CondeBelt drying.

Infrared drying
The electromagnetic energy that falls between ultraviolet and microwave energy in the spectrum. The heating effectiveness is governed by emitter temperature, emitter emissivity, paper emissivity and the emitter surface area.

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

Lignocellulose
Refers to plant dry matter (biomass), so called lignocellulosic biomass. It is composed of carbohydrate polymers (cellulose, hemicellulose), and an aromatic polymer (lignin).

Mechanical pulping
In the mechanical pulping process, the wood fibres are teased apart in a mechanical way to obtain a mass of individual fibres.

Mechanical vapour recompression
Vapour-compression evaporation is the evaporation method by which a blower, compressor or jet ejector is used to compress, and thus, increase the pressure of the vapour produced.

Micro/Nano-fibrillated cellulose (MFC/NFC, also termed CMF/CNF)
Refers to cellulose micro/nano-fibrils, which are natural components of the lignocellulosic fibre wall, released by enzymatic and/or chemical and mechanical treatment.

Microwave drying
The energetic conversion of the microwaves into heat takes place directly in the product. The resulting steam pressure ensures rapid and direct outlet of the water from the product.

Moulded products
Moulded products are by shaping pliable raw material using a rigid frame or model called a pattern.

Nonwovens
Is a fabric-like material made from long fibers, bonded together by chemical, mechanical, heat or solvent treatment. The term is used in the textile manufacturing industry to denote fabrics, such as felt, which are neither woven nor knitted.

Osmotic drying
Osmotic drying is an operation used for the partial removal of water. Paper and pulp is dried by having their moisture removed by osmosis rather than by heat drying.

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 traditionally used in the process or to make electricity.

Resin
Any of a large class of synthetic products that have some of the physical properties of natural resins but are different chemically.

Sheet stratification
Means processes to form a sheet in different layers either through a stratified or multi-jet headbox production a layered pulp jet, or by pressing together different layers formed separately, typically multi-ply board.

Sodium bicarbonate
Is the chemical compound with the formula $NaHCO_3$. Sodium bicarbonate is a white solid that is crystalline but often appears as a fine powder. Since it has long been known and is widely used, the salt has many related names such as baking soda.

Spray forming
Is based on spray technology where liquid or solid particles are sprayed onto surfaces and the material deposited thanks to the particle spray velocity given in the air/gas environment. Spray forming differing on that point from air-laid forming where particle deposition is achieved as the air-stream passes the forming wire.

Supercritical fluid
The defined state of compound, mixture or element above its critical pressure and critical temperature.

TMP
Thermo-mechanical pulping is a process that combines chemical and mechanical pulping.

TRL
Technology Readiness Level.

Ultrasonic drying
High frequency mechanical waves are coupled to a cellulose material that drives water out of the material into a collection system on continuous basis.

UV radiation
Is electromagnetic radiation with a wavelength shorter than that of visible light, but longer than X-rays. It is so-named because the spectrum consists of electromagnetic waves with frequencies higher than those that humans identify as the colour violet.

Viscosity
The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal notion of “thickness”. For example, honey has a higher viscosity than water.

White liquor
White liquor is a strongly alkaline solution mainly of sodium hydroxide and sodium sulfide. It is used in the first stage of the Kraft process in which lignin and hemicellulose are separated from cellulose fibre for the production of pulp. The white liquor breaks the bonds between lignin and cellulose. It is called white liquor due to its white opaque colour.

Yankee dryer
A large, gray cast iron cylinder used to dry tissue, towel, and wadding. The dryer is typically Coded pressure vessel and ranges in size from 2.5 to 5.5 min diameter and up to 7.5 m in width.

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