POLICY BRIEFING

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The challenge: decarbonising whilst being recycling pioneer

SUMMARY FOR POLICY MAKERS

Delivering a circular economy, needs a successful European recycling industry. In September 2017 the European Commission published its "New Industrial Policy Strategy". One of the key levers to create jobs, boost Europe's competitiveness, foster investment and innovation in clean and digital technologies, whilst "building on Europe's leadership in a low-carbon and circular economy".

The European paper industry fully supports this approach. The industry has already reduced carbon emissions by 26% since 2005, (now accounting for less than 1% of EU GHG emissions), reduced energy consumption by 11%, while increased the share of renewable energies to almost 60% of final energy. The industry delivered a 72.5% paper recycling rate, (making the EU the best performing region in the world) whilst at the same time developing innovative bio-based products.

Investments in energy efficiency will further strengthen the links between low carbon practices and the circular economy. Moreover, the European paper industry is already working on developing breakthrough technologies to reduce carbon emissions and energy use even more.

That being said, paper production requires energy; carbon emissions in the paper industry come almost entirely from combustion of energy sources. Generalising, countries with large forestry resources tend to have paper-based industries based on virgin fibres, while counties with smaller forestry resources tend to have paper-based industries based on recycling fibres. Of course, the whole system comes together to deliver sustainable, renewable based products as part of the growing bio-based economy.

This split has major implications for energy use. Mills using virgin fibre are integrated into a local forest economy and (additional to energy rich process by-products) have access to low grade forest residues. Generally, these mills have heavily invested in green energy and are largely self-supplying and often provide energy to users outside the mill.

By contract mills using recycled fibres don't have direct access to wood based green energy, with natural gas being the main source of energy – for larger mills often used in high efficiency Combined Heat and Power plant, for smaller mills often used in heat boilers with electricity drawn from the grid.

This is illustrated in the table below (2016 figures). Most of the production of recycled paper in Europe happens in countries with a high share of natural gas in the paper industry's energy mix. For these countries paper for recycling is by far the main source of domestic raw material used for paper making.

	Share of Natural Gas in fuel used for paper making in each country	Share of Paper for Recycling in domestic raw material input for paper making[1]	Share of Paper for Recycling utilisation in Europe	Cumulative share of Paper for Recycling utilisation in Europe
Italy	100%	93%	11%	11%
Netherlands	92%	96%	5%	16%
Spain	70%	79%	11%	27%
United Kingdom	68%	93%	7%	33%
Germany	56%	89%	37%	70%
France	38%	83%	12%	81%
Austria	33%	64%	5%	86%
Belgium	28%	81%	3%	89%
Portugal	24%	22%	1%	90%
Norway	18%	26%	1%	90%
Czech Republic	14%	34%	0%	91%
Slovakia	13%	15%	0%	91%
Finland	7%	7%	1%	92%
Poland	4%	69%	5%	97%
Sweden	1%	12%	3%	100%

It follows that the industry is not suited to a simplistic energy use plan that covers all mills – especially if the physical recycling of paper collected in Europe is to be delivered in Europe as part of a circular economy.

While those parts of the industry based on virgin fibre have access to bio-based energy sources, this is not the case for recycling mills currently using natural gas. While recycling mills continue to focus on energy efficiency, alternative energy strategies (proposed as alternatives to gas) either simply don't work at present or are not economic if mills are to be financially viable.

The rest of this report explores the main alternatives to gas and suggests ways that gas use could be reduced in the sector. However, the key point is to highlight to policy makers that any policy assumption that presumes no use of gas in the sector is mistaken if a European paper recycling industry is to be retained. Gas use can be reduced with appropriate support, but (certainly without breakthrough technologies) cannot be reduced to zero.

[1] *"Domestic raw material input" defined as the sum of raw material inputs available at national level. In includes Pulp produced and used domestically in integrated woodpulp production, pulp produced and delivered domestically, and paper for recycling. It excludes imports and exports of pulp.*

Introduction

Understanding differences in domestic raw material used for papermaking is fundamental to understand the diversity in the paper industry between different countries.

The pulp needed for producing paper can come from wood or from paper for recycling. When making pulp from wood, paper mills also produce different side-streams like bark, lignin, or other biomass components. This biomass is turned into renewable heat and electricity and provides most of the energy needs of the plant.

However, when it comes to recycling paper, these by-products are not available. A limited amount of solid by-stream from waste and from fibres improper for paper production can be directly converted to energy or turned into biogas, but the most competitive energy source is often natural gas.

The use of natural gas is not a necessary precondition for paper recycling. However, due to a combination of several factors (cost-efficiency, lack of viable alternatives, local conditions, national energy policies…) natural gas has become the predominant energy source.

Natural gas is often used in high-efficient combined heat and power installations (CHP). Electricity from CHP accounts for about half of the electricity needed. The rest is purchased from the grid.

Recent data suggests that despite efficiency improvements, marginal carbon reductions in mills using gas-fired CHP continue to diminish. Therefore, one of the key challenges for our industry is to determine how to decarbonise the paper recycling.

Timing is critical. Without a clear perspective, recycling of paper might soon become a financially unsustainable practice in Europe. And this could equally apply to other industries that recycle.

This policy briefing explores the most relevant options to reduce carbon emissions in recycling of paper: (1) Breakthroughs in energy and carbon efficiency; (2) On-site renewable energy sources; (3) Decarbonised natural gas; (4) Fuel switch – electricity; (5) Fuel switch – biomass; (6) Carbon Capture and Storage.

Some of them can be realised within the paper sector. Others rely on the decarbonisation of the energy sector. To date, none of the options identified seems to deliver, on its own, a satisfactory answer that is both technologically and financially viable to meet the 2050 challenges. However, combining different options can potentially lead to progressively move towards ambitious carbon emission reductions. Solutions will inevitably be site-specific, as they will depend on local, regional and national circumstances.

The paper industry is exposed to international competition. This requires solutions to be cost-competitive from an international perspective. It is therefore of utmost important to develop strategies, from European to national and local level, to systematically addressing the identified bottlenecks. Specifically:

- Innovation
    - Support research, development and deployment of new solutions
    - De-risking financing programmes, to mitigate the first-mover disadvantage
    - Make the identified areas eligible for sustainable financing programmes
- On-site renewable energy sources (RES)
    - Research, Development and Deployment (RD&D) of cost-competitive collection and use of biogas and of renewable heat solutions to be integrated in paper mills
    - Promote dialogue between RES-Heat producers, industry and public authorities, in order to understand and address barriers (knowledge gap, financing, public acceptance…)
    - Promote energy recovery technologies, in compliance with the Waste Framework Directive

- Energy supply
    - Ensure timely availability of clean and affordable energy supply. This requires the availability of both clean energy carriers and related infrastructures
    - Develop local and regional plans and partnerships to develop biogas production
    - Allow industry to compete in the electricity market, on equal footing, in providing flexibility solutions

Option 1: Breakthroughs in energy and carbon efficiency

Without breakthroughs in energy efficiency, it will be extremely difficult and prohibitively costly to decarbonise the energy sector. The paper industry is the fourth largest industrial energy consumer in Europe and energy efficiency gains in our sector can deliver substantial societal benefits. Moreover, our circular and bio-based products are progressively penetrating different markets, thus contributing in lowering carbon emissions in other sectors.

Several areas for innovation have been explored to assess their potential to deliver promising decarbonisation effects. Annex I provides an overview of main technology options with the potentials to deliver significant emission reductions in the paper recycling.

The technology readiness levels (TRL) of these solutions vary. Some are still at their infancy (TRL levels 1-3), but others are making substantial progresses and are very close to commercialisation (TRL levels 8-10).

Financing programmes would be needed, such as the Innovation Fund foreseen under the EU ETS, new financing programmes in the new multiannual financial framework, and sustainable financing programmes.

Option 2: On-site renewable energy sources

The use of on-site renewable energies can reduce the need to import energy sources, such as natural gas or electricity. Several solutions could be envisaged:

1. <u>Bioenergy from solid by-streams</u>

    Energy recovery from solid by-streams (sludge and rejects) accounts for about 1% of energy fuels used in the paper industry. It can take the form of conversion to energy carriers (such as gasification, pyrolysis, anaerobic digestion and secondary fuels production) or direct conversion to energy (incineration).

    Moreover, several paper mills are already producing biogas from anaerobic waste water treatments. In some cases, biogas accounts for 5% of a paper mill energy consumption. And, potentially, this figure could go up to 10%.

    In most of the cases technology is mature and could be more widespread across the sector. More than 50% of solid by-streams are composed by organic matter and, when used for energy purposes, it counts towards meeting the renewable energy target. In some cases, this has contributed in reducing carbon emissions in paper mills by a remarkable 30%.

    An increased use of organic matter in end-users products, as implementation of the bioeconomy strategy, can contribute in reducing carbon emissions while increasing the share of renewable energies.

    However, energy recovery often faces strong local opposition, and a number of mills use such materials for different processes such as soil improvement or animal bedding. Additionally, research continues to commercialise other ideas that could be alternatives to simple energy recovery.

2. Heat Pumps

   Heat pumps are an interesting technology to reduce external energy input and can be potentially deployed in paper mills. Developments are still needed for temperature above 180 °C, but some preliminary studies suggest that heat pump could supply steam up to 160 °C (with a efficiency of around 2.4), starting from ground water of 10 °C or higher temperature waters where the heat is currently economically unrecoverable.

   Pilot projects already proved successful and demo plans in paper mills are ongoing. Research and development efforts are still needed to reduce capital expenses and increase the output temperatures. However the huge issue, is that this technology effectively increases the use of electricity which is often not an economic option.

3. Geothermal

   Ultra-deep geothermal energy could also potentially deliver the necessary heat for paper making. Projects could also be developed in partnership with local municipalities or industries. The technology is currently being tested in other sectors, although it currently looks still very expensive. Moreover, drilling underground for several kilometres would require quite specific geological conditions and societal acceptance.

4. Solar & Wind

   Deploying photovoltaic panels, solar heating or small wind turbines is theoretically possible, depending on the size and the geographic conditions of the paper mill. Examples of roof-top photovoltaic are already present in some paper mills, while a large scale solar heating is currently being installed in a first-of-a-kind project. However, considering the high volumes of energy currently needed for paper making, energy produced by on-site solar and wind is unlikely to supply more than 5% of the energy demand in a given paper mill.

Option 3: Decarbonised natural gas

The paper industry currently consumes about 11 bcm of natural gas. A simple solution would be replacing natural gas with “decarbonised” natural gas, to be delivered at the point of consumption via existing infrastructures.

The gas industry has identified three options:

1. Hydrogen from carbon capture and sequestration: carbon would be separated from hydrogen at the extraction point, with carbon being re-injected into the gas field.
2. Hydrogen from power-to-gas: electricity would be used to generate hydrogen and/or synthetic gas.
3. Biogas: biomethane would be produced by recycling waste from various sources.

In all these cases, the final product would be injected in the existing natural gas grid and/or part of local distribution networks.

The paper industry could potentially be a good enabler of these solutions, as it could use biogas, hydrogen, or a combination of the two, in combustion plants. Burners of natural gas boilers would have to be replaced by burners using hydrogen. Such a switch is expected to require relatively limited investments and, most importantly, would not require changes in the paper machineries.

This being said, there several considerations to be made:

- In none of the studies commissioned by the gas industry, natural gas would be 100% carbon free and/or neutral by 2050.

- The transition from natural gas to hydrogen requires careful planning in adjusting infrastructures and combustion equipment in end-users. To date, there is no plan for a European hydrogen network, though some regional initiatives are under consideration
- If volumes remain small, hydrogen would be used in products delivering higher added value (e.g. fuel cells) rather than as a combustion fuel.
- Although biogas production is projected to increase, by 2050 the biogas share in natural gas consumption is still relatively low (below 30%). It might ultimately make more sense to use it locally, potentially reaching 100% share of local demand, rather than having a minor share in the upstream gas distribution.

Option 4: Fuel switch - electricity

Paper-making requires low-temperature steam (<180°C). From a technical point of view, steam can be generated using electricity, thus replacing natural gas. Electrical boilers are a well-established technology and could be the first step towards the deployment of new electro-technologies and solutions.

A growing number of paper mills are already engaged in demand-side flexibility programmes, driven by price signals. The activities undertaken by these paper mills can be quite differentiated, be it adjustment of production volumes, energy consumption, or energy supply. Regardless of the path chose, these solutions allow paper mills to provide a service to the grid, without jeopardising paper production. In other words: creating added value in Europe.

This being said, use of electricity for demand-side programmes and full electrification are two different concepts. In the first case, industry provides a service to the network by ensuring grid stability and reducing network stress from peaks in electricity demand and supply. In the second case, it becomes a liability to the electricity sector, as it brings additional baseload demand to the electricity transmission networks.

To put things into perspective, the sector currently consumes about 390 TJ of natural gas, equivalent to about 108 TWh of final energy. And the sector is currently a net buyer of about 45 TWh of electricity. Replacing natural gas with electricity would increase the industry's baseload demand by a factor of almost 2.5.

Matching this additional demand would require investments in both reinforcing transmission lines and in increasing electricity generation. Delivering additional 153 TWh of final electricity demand would in fact require an increase in electricity generation in the range of 330-375 TWh, due to energy conversion and network losses.[2]

Such an increase in baseload demand would have to be matched by an increase in decarbonised electricity generation and by a programme to reinforce high voltage transmission lines. This aspect should be seen in the wider picture, where electrification could be an option to decarbonise several other sectors.

Last but not least, a 100% switch to electricity would require replacing current assets, thus making the exercise particularly CAPEX intensive. This should be seen in conjunction with electricity prices being already 2 to 7 times higher than natural gas. And an increase in electricity generation and infrastructures to accommodate the additional demand from electrification would have an impact on the cost of using electricity.

In many Member States the cost of grid supplied electricity is prohibitively expensive and mills could not fully electrify and be financially viable.

In conclusion, while an increased role of electricity in paper mills is to be expected, a full electrification of paper mills doesn't seem to be economically viable in the foreseeable future.

[2] Assuming a primary energy factor of 2.0 to 2.3, as currently under discussion in the review of the Energy Efficiency Directive, and a 7% average transmission losses.

Option 5: Fuel switch - biomass

The paper industry has a long tradition in sustainably sourcing and using biomass. From an energy perspective, biomass already accounts for almost 60% of fuel used in the paper industry. There is no technical reason impeding further biomass use.

This being said, further use of biomass is quite limited. This is due to a combination of factors, the most relevant being:

- Limited to no access to biomass feedstock
- Lack of public acceptance by local communities
- Lack of storage facilities
- Logistics constraints

In conclusion, the possibility to switch to biomass, although technically possible, is expected to play only a marginal role in further decarbonising the recycling of paper.

Option 6: Carbon Capture and Storage (CCS)

Carbon emissions from the combustion of natural gas could be captured and then stored. However, general issues on CCS apply to the paper industry as well: storage location, infrastructures, public acceptance, economics…

Moreover, emissions from gas-fired paper mills are relatively low – no more than 400 $ktCO_2$/year – and often originated in different combustion facilities. This makes CCS particularly expensive, as the ratio of volumes over costs of CO_2 captured would be very low.

CCS deployment would also have to be assessed from an overall energy balance perspective, as carbon capturing generates efficiency penalties that might offset efficiency gains from cogeneration.

In conclusion, CCS doesn't seem to be a primary solution for the paper industry. It should be first developed in view of reducing emissions in other industrial sectors. Should that be the case and other industrial sites being located in the proximities of paper mills, one could ultimately imagine the possibility to cluster with those sites and join existing infrastructures to transport the captured CO_2.

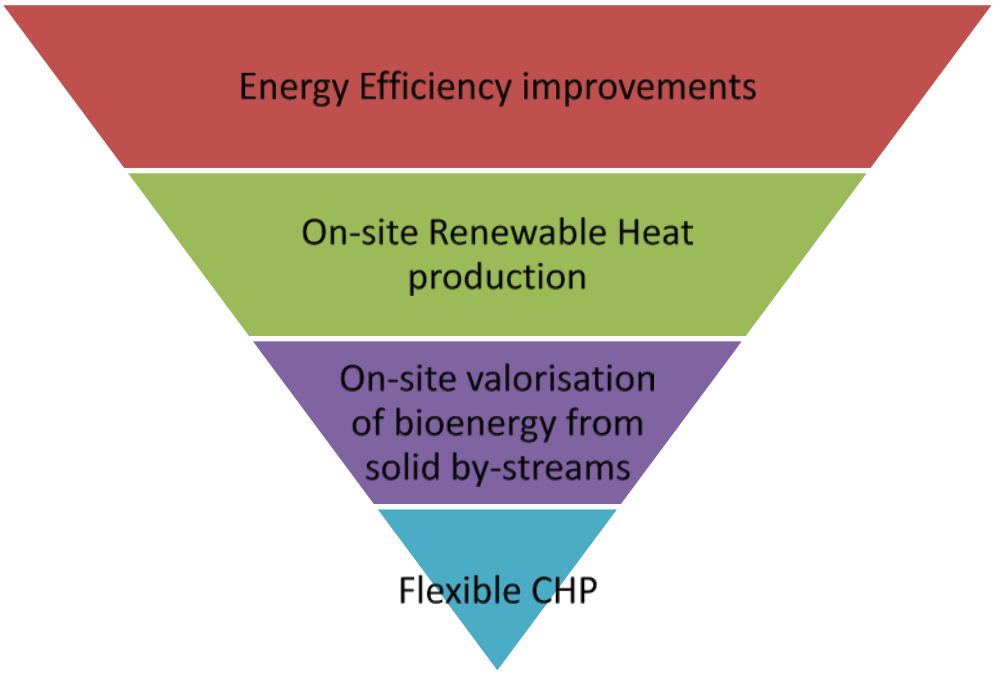
Moving forward: combining no regrets options

The options assessed present a mix of potentials and challenges. Several of the options assessed are subordinated to exogenous factors (decarbonisation of the energy sector, availability of energy infrastructures, availability of natural resources…). Others require the successful and timely commercialisation of innovative solutions.

The following table identify, in a simplified snapshot, the most relevant hindering factors to the deployment of identified options:

OBSTACLES / OPTIONS	High CAPEX	High OPEX	Local / Geographical condition	Social / Political resistance	Additional infrastructures
On-site RES					
- Bioenergy from solid streams				X	
- Heat Pumps	X				
- Geothermal	X		X	X	
- Solar & Wind	X		X	X	
Decarbonised natural gas		X			X
Switch to full electrification	X	X			X
Switch to solid biomass	X		X	X	X
CCS	X	X	X	X	X

This being said, reducing primary energy in heating production is a 'no regrets' goal, as it would lower the dependency from future infrastructure developments. This can be reached by combining several non-mutually exclusive options, such as:



Specifically:

1. Energy and carbon efficiency improvements will reduce the overall energy demand.

2. On-site renewable heat production, through the integration of innovative technologies such as heat pumps or solar thermal, would reduce the demand for natural gas, thus delivering important co-benefits in terms of reducing carbon emissions, reducing primary energy consumption, and increasing the share of renewable energy sources.

3. On-site valorisation of bioenergy from solid by-streams will also contribute in reducing the demand for natural gas, thus delivering the benefits previously mentioned. Moreover, when seen in combination with the previous points, the relative role of bioenergy will be much more predominant, though alternative uses for such by-products may limit this opportunity.

4. More flexible CHP units and operational changes will enable to use electricity, when this is cheaper than natural gas. By switching the energy source, this solution would enable paper mills to provide a service to the electricity sector without affecting paper production. In other words: it enables the creation of added value in Europe. Moreover, it allows storing bioenergy produced on-site for a later use, thus further reducing the need for natural gas.

Annex I – Most relevant R&D areas potentially delivering emission reductions in recycling (non-exhaustive list)

TRL: Technology Readiness Level

Technology	Type	Description	TRL (current)
Flash Condensing with Steam	**Energy Efficiency**	Blasting mostly dry, high-consistency fibres with agitated steam into a forming zone where the combination of condensing and steam expansion enables bonding	TRL 1-3
Use of Steam in the Paper Drying Process	**Energy Efficiency**	Full power of steam enables total recovery of thermal energy, to be used in subsequent processes. In papermaking, steam and heat-boosted forming and pressing take place within an air-free paper machine.	TRL 1 - 3
Supercritical CO_2	**Energy Efficiency**	Liquid-like characteristics of scCO2 allow for substitution of steam-heated cylinders with scCO2 in the "extraction drying" process. With gas-like characteristics scCO2 has uses removing contaminants, adhesives and mineral oils in the recycling process.	TRL 1-3
Valorisation of pulp/paper making waste streams	**Materials Efficiency**	This includes valorisation of waste, waste water and sludge; reduced dewatering and drying needs; improving dewatering retention; light weighting …	TRL levels: 7-8. Timeframe: from 2025 onwards
Fuel switching (electrification and biomass gasification)	**Electrification and Biomass**	This includes full integration of power production and drying processes, gasification of biomass, full electrification of the paper-making process…	TRL levels: 3-10. In some cases technologies are already commercially available. In others, e.g. electrification, a full re-design of paper mills is required. b. Timeframe: depends on long-term energy commodity prices evolutions. In any case, new electro-technologies will not be deployed before2030
CO_2 valorisation	**CCU**	This includes CO_2 valorisation in the paper industry value-chain, synergies with other sectors …	TRL levels: N/A. Timeframe: from 2040 onwards