Maximum value from paper for recycling

Towards a multi-product paper mill

Project report

Report by:
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Foreword

Waste is not just a problem which needs regulation to ensure least harmful disposal. It is also a resource. Recognition of this was one of the most important changes in the EU waste law set in the Thematic Strategy on waste in 2006 and the revised Waste Directive 2008/98/EC. This change was strongly advocated by many, paper industry in particular, as we felt that the best practices in industry were not at all supported by the out-dated legal framework. Paper recycling is the most natural thing to do, but only some years back it was not a priority for the policy. Now the Commission is setting EU onto the path of transforming our economy: the Roadmap to resource efficient Europe¹ was published in September.

\[
\begin{align*}
\text{Europe has the world's highest net imports of resources per person,} \\
\text{and its open economy relies heavily on imported raw materials and energy.} \\
\text{Secure access to resources has become an increasingly strategic economic issue,} \\
\text{while possible negative social and environmental impacts on third countries} \\
\text{constitute an additional concern.} \\
\end{align*}
\]

\[
\begin{align*}
\text{Improving the reuse of raw materials through greater 'industrial symbiosis'} \\
\text{(where the waste of some firms is used as a resource for others) across the EU} \\
\text{could save €1.4bn a year and generate €1.6bn in sales} \\
\text{- EU Roadmap to Resource Efficiency (2011)} \\
\end{align*}
\]

Where CEPI was a pioneer in recycling – implementing a recycling society in Europe decades before the term even was coined – it now is taking the challenge of using even more carefully the materials we have in our hands: even the reject from paper recycling can still include valuable resources.

With the continuously increasing recycling rate the fibre yield from recycling is bound to decline, producing continuously more reject. As prices of paper for recycling and cost of reject management are ever increasing, the move to seeing the value of reject is also economically important. Like we have done before regarding fibres, paper for recycling should be seen as a source of many valuable components that can be used for the production of additional high value products alongside with paper.

The compilation of techniques – in total 21 – for the most common by-streams in paper recycling is just a start: we wanted to show what is already possible and commercially available. There are more examples of extracting value from recycling rejects, and new techniques are being developed. This search for added value is also one of the guiding principles in the CEPI Roadmap 2050 for the European forest fibre industry².

In order to achieve economies of scale necessary to be economically feasible, and ensuring sufficient material streams, paper mills may need to join up in clusters, even with other sectors, in industrial symbiosis. Such ideas will be further developed when unfolding the CEPI 2050 Roadmap in the upcoming years. The work has already started!

Brussels, November 2011

Teresa Presas
Director General, CEPI

² The forest fibre industry “Unfold the future”: 2050 Roadmap to a low carbon bio-economy, CEPI 2011.
Executive summary

Obtaining maximum value per unit of paper for recycling is an important aspect of paper production. This importance will in the future be even greater, as demand for biomass increases because of demand from sectors that were traditionally not based on wood such as the energy and chemical sector, resulting in higher biomass prices. Obtaining maximum (economic) value per unit of paper for recycling may become a determining factor for paper production to be profitable.

During paper recycling various solid by-streams are formed which contain unwanted materials or useful materials that are accidentally removed from the production line. These streams are currently considered by many as rejects that need to be disposed at least possible costs.

In order to stay competitive and become an increasingly sustainable industrial sector the paper industry needs to radically change its production process and mind-set concerning by-streams. Paper recycling by-streams should in the future no longer be considered as (costly) streams that, next to valuable fibres, contain disturbing contaminants for paper making that need to be removed as waste or inactivated. Instead, paper for recycling should be regarded as a source of many valuable components that can be used for the production of other high value products in addition to paper.

This study focuses on identifying useful applications for the occurring solid by-streams (see For own use the paper mills can use energy conversion options, separate the fibres from the foil fraction (in coarse rejects), use sludges as feedstock for production of lower paper grades, recycle minerals from sludge ashes.

The use of the application technologies can often either be performed externally (central) or on-site. In both cases the technological installation can be owned by either the paper mill or a third party. In order to achieve economies of scale necessary to be economically feasible, paper mills and/or third parties can form clusters.

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3 This report uses the term “paper for recycling” instead of the earlier term “recovered paper”.
4 On that note, this report only refers to by-streams from paper production as opposed to waste-streams, in order to emphasize the potential value of these streams.
Table 1, overleaf. Recovery of the valuable components of these streams can result in the potential production of new marketable bio-products (bio-energy, bio-materials, etc.).

The technologies listed in Table 1 are discussed in this report and each is explained in further detail in fact sheets in Annex I to this report.

The amount of technologies that focus on creating value from paper production rejects is growing, indicating the general acknowledgment of the value of current waste streams. This trend will continue as the climate saving ambitions and environmental legislation continues to pressure use of fossil fuel and waste of primary material. Therefore, new fact sheets will be added to the Annex II as the users or suppliers of those technologies inform CEPI about it.

The types of application technologies vary greatly, from use as feedstock in production, converted into energy or energy carriers, to use in their current state. The technologies vary from conventional (composting, incineration) methods to highly innovative (fermentation, separation) technologies.

For own use the paper mills can use energy conversion options, separate the fibres from the foil fraction (in coarse rejects), use sludges as feedstock for production of lower paper grades, recycle minerals from sludge ashes.

The use of the application technologies can often either be performed externally (central) or on-site. In both cases the technological installation can be owned by either the paper mill or a third party. In order to achieve economies of scale necessary to be economically feasible, paper mills and/or third parties can form clusters.
<table>
<thead>
<tr>
<th><strong>Table 1: Applications for by-streams</strong></th>
<th><strong>Applies to:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deinking</td>
</tr>
<tr>
<td><strong>Use of by-streams as such</strong></td>
<td>On-site or external</td>
</tr>
<tr>
<td>Land management options (land spreading, land restoration)</td>
<td>n/a</td>
</tr>
<tr>
<td>Absorbent, animal bedding</td>
<td>n/a</td>
</tr>
<tr>
<td>Anti-dust</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Conversion to product</strong></td>
<td></td>
</tr>
<tr>
<td>Land management options (composting)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Feedstock for other paper grades</td>
<td>External</td>
</tr>
<tr>
<td>Pyrolysis (chemicals)</td>
<td>On-site</td>
</tr>
<tr>
<td>Feedstock for softboard production</td>
<td>External</td>
</tr>
<tr>
<td>Feedstock for hybrid MDF</td>
<td>External</td>
</tr>
<tr>
<td>Feedstock for cement bonded sludge board production</td>
<td>External</td>
</tr>
<tr>
<td>Feedstock for tiles</td>
<td>External</td>
</tr>
<tr>
<td>For use in cement/asphalt/etc. production</td>
<td>External</td>
</tr>
<tr>
<td>Fibre/plastic recovery</td>
<td>Both</td>
</tr>
<tr>
<td>Synthetic Calcium Carbonate</td>
<td>Both</td>
</tr>
<tr>
<td>Hydrolysis to fermentation feedstock (higher added value chemicals)</td>
<td>Both</td>
</tr>
<tr>
<td>CDEM</td>
<td>Both</td>
</tr>
<tr>
<td><strong>Conversion to energy</strong></td>
<td></td>
</tr>
<tr>
<td>Gasification</td>
<td>Both</td>
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<tr>
<td>Supercritical gasification</td>
<td>Unknown</td>
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<tr>
<td>Combustion</td>
<td>Both</td>
</tr>
<tr>
<td><strong>Conversion to energy carrier</strong></td>
<td></td>
</tr>
<tr>
<td>Direct digestion</td>
<td>Both</td>
</tr>
<tr>
<td>Pyrolysis (oil)</td>
<td>On-site</td>
</tr>
<tr>
<td>Torrefaction</td>
<td>External*</td>
</tr>
<tr>
<td>Hydrolysis to fermentation feedstock (bio-ethanol, bio-methane)</td>
<td>Both</td>
</tr>
<tr>
<td>Secondary fuel</td>
<td>Both</td>
</tr>
</tbody>
</table>

*On-site potential is unknown*
The future

Underlying report only summarizes application options for solid reject. Identifying the value of other paper mills waste streams (liquid, gaseous, heat), would further increase the economical value to be gained from recycled paper. Heat losses can be captured, unwanted but valuable components from the water circuit could be isolated, etc. By-streams are full of components that may be unwanted in the paper production process but quite often are of high value for other industries.

The ambition of ‘valorisation of waste streams’ even limits the view on possible innovations that can lead to a higher value out of the paper recycling raw material. Instead, the ambition ‘Increasing the economic value of recycled paper’ leads to new routes of isolating other high added value components from the pulp, components that currently end up in the paper with no benefit to its quality specifications.

Legislation

The renewed European Waste Directive provides a useful framework for organising the paper industry in the way described above; for the first time the materials in waste are not seen only as a waste management problem, but also as a valuable resource. Furthermore, the Directive now provides the essential clarity between what is waste and what can be considered a by-product. Commission has provided guidance\(^5\) on distinguishing between waste and by-products: this guidance includes a helpful decision tree that can be used by paper-mills for any by-stream they have. REACH regulation, however, will have to be taken into consideration, too.

\(^5\) Interpretative Communication on waste and by-products (COM(2007) 59 final)
4. Feedstock for other paper grades 42
5. Pyrolysis oil 44
6. Feedstock for softboard 47
7. Hybrid MDF 49
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1. Introduction

1.1. Background

To maximize the efficient use of wood material and limit its impact on biomass availability, the paper industry prolongs the life of its wood resources by reusing old paper as feedstock in its production process. As recycling of old paper has steadily increased over the last decades in Europe, today paper for recycling forms an important raw material for most of the European paper industry. During paper production using paper for recycling various solid by-streams are formed which contain unwanted materials or useful materials that are accidentally removed from the production line. These solid by-streams are disposed of by third parties for a gate-fee or disposed of on-site by e.g. incineration.

Obtaining maximum value per unit of paper for recycling is an important aspect of paper production. This importance will in the future be even greater, as demand for biomass increases because of demand from (traditionally not-wood based) sectors such as the energy and chemical sector, resulting in higher biomass prices. Obtaining maximum (economic) value per unit of paper for recycling may become a determining factor for paper production to be profitable.

This study focuses on solid by-streams from pulp and water treatment to increase value of paper for recycling.

Solid by-streams in the papermaking process can vary greatly and can be classified into different groups (see Figure 1). All by-streams contain potentially valuable elements, especially with the development of new isolation and conversion technologies.

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6 Although these streams are often referred to as waste streams, this report denotes them as by-streams in this report to emphasize the potential value that they contain.
**Maximum value of solid by-streams**

It is expected that the current value obtained from using paper for recycling is only a fraction of the full potential value of paper for recycling. Solid by-streams from pulping and water treatment occur in high volumes and material losses of these streams are significant. The value from paper for recycling can be strongly increased, when the potential value of the by-streams is utilised. This value is currently lost as the by-streams are treated as waste streams.

In order to stay economically competitive and become a more sustainable industrial sector the paper and board industry needs to radically change its production process and mind-set concerning by-streams. Paper recycling by-streams should in the future no longer be considered as (costly) streams that, next to valuable fibres, contain disturbing contaminants for paper making that need to be removed as waste or inactivated. Instead, paper for recycling should be regarded as a source of many valuable components that can be used for the production of additional high value products in addition to paper (see Figure 2).

![Figure 2: Schematic overview of current and potential future recycled paper production](image)

Research on the composition of by-streams from pulping and water treatment of recycled paper production has shown that there is significant potential value in these streams, as they contain useful elements that can potentially be used for production of high value products, paper production (fibres) or energy conversion.

Best-practice paper producers are currently applying part of their rejects from solid by-streams for useful applications such as onsite energy conversion or as re-use as feedstock for paper production. However, even these best practices are still far from gaining maximum value of sources of paper for recycling. The identification of interesting new by-products from a paper mill requires the awareness of the potential value of the by-streams and its individual components.

This report provides a broad overview of options to create additional value from solid by-streams that are available or currently under development.
**Legislation**
To create added value from solid by-streams non-technological factors that hinder the usage of the by-streams contents such as restrictive legislation also need to be taken into account. Legislation concerning waste, and in particular its implementation in national and local permitting, is often not designed to take the usage of by-streams in consideration. Because of this, current legislation often hinders the usage of by-streams as production facilities e.g. require permits in order to process the material as waste. In such cases utilization of by-streams from paper recycling is both difficult and delaying (e.g. because of long permit procedures) or simply not possible, to a great loss to resource efficiency.

### 1.2. Objective

The objective of this report is:

**To provide an overview of possible applications, both industrially applied technologies as technologies that are in development, which can increase the economic and environmental value of paper production by-streams.**

This report focuses on:

- The major solid by-streams produced in the paper industry
- Identifying and categorizing recovery options and identifying to which paper production solid by-stream they apply
- Creating fact sheets for each technology in which general economical, legislative and technological information are presented for each option
- Legislation relevant to application of solid by-streams

**Report layout**

This report will continue in chapter 2 with a description of the used research approach. In Chapter 3 an overview of the solid by-streams that are produced in the paper industry is presented along with figures on the volumes and compositions of these by-streams in Europe. A short summary and categorized overview of the application technologies that were found during this study is presented in chapter 4. Chapter 5 provides the conclusion. Finally, chapter 6 contains a discussion of the future of paper production by-streams. Fact sheets containing more detailed information on each application technology are provided in the Annex I. More fact sheets on additional technologies are progressively added to Annex II.
2. Approach

2.1. Tasks

This report shows the results of three tasks:

Task 1: Create an overview of by-streams of paper recycling production in Europe
In this task information from both desk study and data from CEPI was used to determine the type of solid by-streams created during paper recycling production in Europe. For each by-stream the volumes per country were determined as well as the composition of the by-stream.

Task 2: Create an overview of application technologies for solid by-streams
In this task a desk study was performed in combination with available knowledge from the CEPI and KCPK network to create a list of application options that can be used for paper production solid by-streams. Information for each application technology was obtained by desk study and/or contact with the industrial firm or knowledge institute that utilizes/researches the application option.

Task 3: Creating fact sheets for each application technology
For each application technology it was determined to which type of solid by-stream the technology applies as well as general information regarding the process, legislations, environmental implications and finances. The information was inserted into fact sheets.

2.2. Economic and environmental aspects

The production of new products from the by-streams has both an economic value as a sustainability value.

By-streams need to be managed within paper mills. The costs for land filling and waste disposal are high. By using application technologies land filling costs are reduced. Potentially the application technology can even create a net profit. The economic value is the result of the avoided management costs and the market value of the additional product.

The sustainability value comes from the avoided usage of other resources for feedstock, avoided use of fossil resources for energy production and (if relevant) less energy requirement for the production of the by-product in comparison to energy intensity of the product which is substituted (e.g. energy use for production of cement by providing a cement substitute).
## 2.3. Limitations to the scope

- Due to the large diversity in waste management options (and associated costs) and the (often) unavailability of information on exact costs and benefits of the technologies, the exact economic added value cannot be determined.

- Due to complexity of determining the added sustainable value of using by-streams, the added sustainable value is not quantified. This prevents comparison of the sustainable value between the presented application technologies and incorrect conclusions.

- Considering the impact on the environment, this study focuses on the impact of the technology on energy use. Although there are many different types of indicators to determine the influence on sustainability, information on most of these indicators would require more extensive research.

- The list of application technologies is inherently not exhaustive as development of technologies takes place world-wide and in an increasingly fast pace. The inventory of technologies in this report provides a good representation of the total range of available technologies, and indicates the wide acknowledgement of the potential of solid by-streams to be converted to higher value added applications.
3. Solid by-streams

3.1. Introduction

In paper making solid by-streams are produced during various production steps such as: pulping, high density cleaning, prescreening (flotation), forward cleaning (fine screening, reverse cleaning), and whitewater clarification.

The solid by-streams can be divided into

- Primary sludge
- Secondary sludge
- Deinking sludge
- Coarse rejects
- Screen rejects

*Primary and secondary sludge* are generated from the residue water treatment unit from respectively a mechanical-chemical or a biological method. Secondary sludge is therefore also called biological sludge. Both contain organic matter, for primary sludge mainly cellulose, and minerals. Often they are then mixed together resulting in a “mixed sludge”. Secondary sludge from anaerobic waste water treatment quite often has value as start-up sludge.

*Deinking sludge* is generated during recycling of paper (except for packaging production). Separation between ink and fibres is driven by “flotation” process, where foam is collected on the surface of flotation cells. The generated deinking sludge contains minerals, ink and cellulose fibres (that are too small to be withheld by filters).

*Coarse rejects* are produced during early filtration steps in which large non-fibre materials such as plastics are removed. These rejects also still contain cellulose fibres.

*Screen rejects* are produced during filtration steps with screens with very small slots to remove pulp possibly containing stickies that might disturb the production process and quality of end product. Screen rejects have a high content of cellulose fibre.
### 3.2. Volumes of solid by-streams in Europe

Table 2 provides an overview of the volumes of solid by-streams produced in (recycled) paper production in Europe. The screen rejects volumes are not included because there is insufficient country specific data for these by-streams. Also, the composition and volume of these streams are dependent upon the collected paper for recycling material. The quality of recyclate varies per country and can also vary over time.

**Table 2: Overview of by-stream volumes of paper production in Europe (2008 figures).**

*Source: Information provided by CEPI (Environment data) and COST e-48*

<table>
<thead>
<tr>
<th>Country</th>
<th>Deinking sludge (kton&lt;sub&gt;dry&lt;/sub&gt;)</th>
<th>Effluent sludge (kton&lt;sub&gt;dry&lt;/sub&gt;)</th>
<th>Other sludge (kton&lt;sub&gt;dry&lt;/sub&gt;)</th>
<th>Coarse rejects (kton&lt;sub&gt;dry&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>0</td>
<td>656</td>
<td>0</td>
<td>64</td>
</tr>
<tr>
<td>Belgium</td>
<td>116</td>
<td>67</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>4</td>
<td>44</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Finland</td>
<td>134</td>
<td>466</td>
<td>72</td>
<td>67</td>
</tr>
<tr>
<td>France</td>
<td>402</td>
<td>473</td>
<td>5</td>
<td>185</td>
</tr>
<tr>
<td>Germany</td>
<td>1.457</td>
<td>729</td>
<td>0</td>
<td>325</td>
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<tr>
<td>Hungary</td>
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<td></td>
<td></td>
<td>10</td>
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<tr>
<td>Italy</td>
<td>83</td>
<td>138</td>
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<td>138</td>
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<td>Netherlands</td>
<td>51</td>
<td>24</td>
<td>66</td>
<td>74</td>
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<tr>
<td>Norway</td>
<td>41</td>
<td>55</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>33</td>
<td>61</td>
<td>72</td>
<td></td>
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<tr>
<td>Portugal</td>
<td></td>
<td></td>
<td></td>
<td>18</td>
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<tr>
<td>Slovak Republic</td>
<td>40</td>
<td>27</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>198</td>
<td>133</td>
<td>124</td>
<td>127</td>
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<tr>
<td>Sweden</td>
<td>190</td>
<td>230</td>
<td>110</td>
<td>40</td>
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<tr>
<td>Switzerland</td>
<td>67</td>
<td>26</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>556</td>
<td>90</td>
<td>4</td>
<td>119</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.372</strong></td>
<td><strong>3.219</strong></td>
<td><strong>507</strong></td>
<td><strong>1.243</strong></td>
</tr>
</tbody>
</table>

7 This is also true for coarse rejects.

8 Note that for the countries that did not provide CEPI with 2008 data, the volumes of the last year for which they provided this data was used.
Table 3 provides an overview of the current use for disposal of the solid by-streams in Europe.

**Table 3: Disposal methods for by-streams in 2008 (information from CEPI)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Total by-streams (kton)</th>
<th>Landfill (kton)</th>
<th>Incineration (kton)</th>
<th>used on land (kton)</th>
<th>Reuse in industrial processes (kton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>656</td>
<td>0</td>
<td>495</td>
<td>0</td>
<td>161</td>
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<tr>
<td>Belgium</td>
<td>183</td>
<td>0</td>
<td>132</td>
<td>51</td>
<td>0</td>
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<td>Czech Republic</td>
<td>54</td>
<td>7</td>
<td>3</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td>Finland</td>
<td>671</td>
<td>43</td>
<td>415</td>
<td>36</td>
<td>177</td>
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<tr>
<td>France</td>
<td>880</td>
<td>25</td>
<td>235</td>
<td>400</td>
<td>220</td>
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<tr>
<td>Germany</td>
<td>2,186</td>
<td>0</td>
<td>1,171</td>
<td>182</td>
<td>833</td>
</tr>
<tr>
<td>Hungary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy*</td>
<td>359</td>
<td>78</td>
<td>103</td>
<td>101</td>
<td>77</td>
</tr>
<tr>
<td>Netherlands</td>
<td>141</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>134</td>
</tr>
<tr>
<td>Norway</td>
<td>99</td>
<td>13</td>
<td>72</td>
<td>7</td>
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<td>19</td>
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<td>Portugal</td>
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</tr>
<tr>
<td>Romania</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Slovak Republic</td>
<td>109</td>
<td>11</td>
<td>9</td>
<td>33</td>
<td>56</td>
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<tr>
<td>Spain*</td>
<td>455</td>
<td>75</td>
<td>10</td>
<td>186</td>
<td>184</td>
</tr>
<tr>
<td>Sweden</td>
<td>460</td>
<td>4</td>
<td>306</td>
<td>120</td>
<td>30</td>
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<tr>
<td>Switzerland*</td>
<td>93</td>
<td>39</td>
<td>18</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>650</td>
<td>8</td>
<td>286</td>
<td>288</td>
<td>68</td>
</tr>
<tr>
<td>Total</td>
<td>7,469</td>
<td>305</td>
<td>3,281</td>
<td>1,523</td>
<td>2,053</td>
</tr>
<tr>
<td>% Of total</td>
<td>100%</td>
<td>4%</td>
<td>46%</td>
<td>21%</td>
<td>29%</td>
</tr>
</tbody>
</table>

*Italy: figures include coarse rejects
Spain: split estimated by CEPI
Switzerland: 2006 figures

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9 This information is not available on reject type level.
10 Note that for the countries that did not provide CEPI with 2008 data, the volumes of the last year for which they provided this data was used.
3.3. Compositions and energy content of solid by-streams

This paragraph provides overviews of the composition (Table 4), overview of the energy content (Table 5) and composition of the dry matter content (Table 6) of different solid by-streams. Information regarding the composition of by-streams is not available on national level for all European countries. Several sources (CEPI, KCPK, Ecofys) are used to define the average composition for each by-stream. The composition of the by-streams is depicted in the table below. Note that these figures can vary per individual mill as they depend highly on the input material as well as the specific end product characteristics.

Table 4: Composition of sludges and rejects

<table>
<thead>
<tr>
<th>By-stream</th>
<th>Dry solid (%)</th>
<th>Organic matter (%)</th>
<th>Mineral matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary sludge</td>
<td>50</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Secondary (biological) sludge</td>
<td>40-50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Deinking sludge</td>
<td>56</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Coarse rejects</td>
<td>55</td>
<td>92</td>
<td>8</td>
</tr>
<tr>
<td>Screen rejects</td>
<td>55</td>
<td>90</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 5: Energy contents of sludges and rejects

<table>
<thead>
<tr>
<th>By-stream</th>
<th>Energy content (MJ/tonwet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary sludge</td>
<td>2690</td>
</tr>
<tr>
<td>Secondary (biological) sludge</td>
<td>4000-5000</td>
</tr>
<tr>
<td>Deinking sludge</td>
<td>3000</td>
</tr>
<tr>
<td>Coarse rejects</td>
<td>12,000</td>
</tr>
<tr>
<td>Screen rejects</td>
<td>8,000</td>
</tr>
</tbody>
</table>

Table 6: Composition of dry matter content of solid by-streams

<table>
<thead>
<tr>
<th>By-stream</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary sludge</td>
<td>Fibres, fillers, coating clay, calcium carbonate</td>
</tr>
<tr>
<td>Secondary (biological) sludge</td>
<td>Calcium carbonate, cupper, micro organisms, fibres, proteins.</td>
</tr>
<tr>
<td>Deinking sludge</td>
<td>Cellulose fibres, calcium carbonate, kaolin, ink</td>
</tr>
<tr>
<td>Coarse rejects</td>
<td>Recyclable fibres, wet strength fibres, plastics, wood, metal, others</td>
</tr>
<tr>
<td>Screen rejects</td>
<td>Cellulose, plastics, hair, stickies</td>
</tr>
</tbody>
</table>

11 The composition can vary per paper mill. The figures in this table are an average based on different reports
12 Of dry content
13 Of dry content
4. Inventory of application technologies

4.1. Introduction

Until recently, landfilling has been a major route for sludge disposal. However, both the increase in sludge quality and the legislative framework are militating for other management options. Landfilling is currently no longer applied/allowed in most countries (see Table 3).

The disposal tax is the major driver for finding alternative solutions. The application technologies described in this chapter form alternatives with (potentially) higher economic and sustainable value. Table 7 provides an overview of the application technologies that were identified during this study.

The application technologies are categorized as:

- Use of by-streams as such
- Conversion to product
- Conversion to energy
- Conversion to energy carrier

Use of by-streams as such
The by-stream is the end product in its current state. No additional processes are required.

Conversion to product
The by-stream requires processing in order to acquire the end product(s). Depending on the technology a residual is left-over.

Conversion to energy
An energy conversion technology is used in order to convert the energy content of the by-stream into heat or electricity (or both). Depending on the technology a residual is left-over.

Conversion to energy carrier
The by-stream is converted into an energy carrier. This product can be used by the mill or by third parties as fuel. Depending on the technology a residual is left-over after the processing and/or the combustion of the product.
Table 7: Application technologies for solid by-streams

<table>
<thead>
<tr>
<th>Use of by-streams as such</th>
<th>Applies to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On-site or external</td>
</tr>
<tr>
<td>1a Land management options (land spreading, land restoration)</td>
<td>n/a</td>
</tr>
<tr>
<td>2 Absorbent, animal bedding</td>
<td>n/a</td>
</tr>
<tr>
<td>3 Anti-dust</td>
<td>n/a</td>
</tr>
</tbody>
</table>

**Conversion to product**

<table>
<thead>
<tr>
<th></th>
<th>Applies to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On-site or external</td>
</tr>
<tr>
<td>1b Land management options (composting)</td>
<td>Unknown</td>
</tr>
<tr>
<td>4 Feedstock for other paper grades</td>
<td>External</td>
</tr>
<tr>
<td>5a Pyrolysis (chemicals)</td>
<td>On-site</td>
</tr>
<tr>
<td>6 Feedstock for softboard production</td>
<td>External</td>
</tr>
<tr>
<td>7 Feedstock for hybrid MDF</td>
<td>External</td>
</tr>
<tr>
<td>8 Feedstock for cement bonded sludge board production</td>
<td>External</td>
</tr>
<tr>
<td>9 Feedstock for tiles</td>
<td>External</td>
</tr>
<tr>
<td>10 For use in cement/asphalt/etc. production</td>
<td>External</td>
</tr>
<tr>
<td>11 Fibre/plastic recovery</td>
<td>Both</td>
</tr>
<tr>
<td>12 Synthetic Calcium Carbonate</td>
<td>Both</td>
</tr>
<tr>
<td>14a Hydrolysis to fermentation feedstock (higher added value chemicals)</td>
<td>Both</td>
</tr>
<tr>
<td>15 CDEM</td>
<td>Both</td>
</tr>
</tbody>
</table>

**Conversion to energy**

<table>
<thead>
<tr>
<th></th>
<th>Applies to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On-site or external</td>
</tr>
<tr>
<td>16 Gasification</td>
<td>Both</td>
</tr>
<tr>
<td>17 Supercritical gasification</td>
<td>Unknown</td>
</tr>
<tr>
<td>18 Combustion</td>
<td>Both</td>
</tr>
</tbody>
</table>

**Conversion to energy carrier**

<table>
<thead>
<tr>
<th></th>
<th>Applies to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On-site or external</td>
</tr>
<tr>
<td>19 Direct digestion</td>
<td>Both</td>
</tr>
<tr>
<td>5a Pyrolysis (oil)</td>
<td>On-site</td>
</tr>
<tr>
<td>20 Torrefaction</td>
<td>External</td>
</tr>
<tr>
<td>14a Hydrolysis to fermentation feedstock (bio-ethanol, bio-methane)</td>
<td>Both</td>
</tr>
<tr>
<td>21 Secondary fuel</td>
<td>Both</td>
</tr>
</tbody>
</table>

*On-site potential is unknown

Note that some of the technologies can be both integrated in the processes of the paper mill or be used externally by a third party.
4.2. Description of the technologies

A short description of each technology is provided in this paragraph (in same order as Table 7). More detailed info is provided in the fact sheets (see Annex I).

1. Land management options

Land restoration
Land restoration covers the use of dried sludge as a product applied on derelict land, damaged industrial sites topsoil, during road constructions, topping of landfills, mine filling, etc. When aiming to increase soil quantity on the site, two techniques are observed: it can be either directly applied or mixed with the soil present on the site before application.

Land spreading
Land spreading is highly practiced in some countries (e.g. the UK) and recently recognised once again\(^\text{15}\) for its organic and mineral qualities. Valuable compounds present in sludge are reinserted into the soil, by transporting it, often in a cake form, from the mill to the fields, then either spread on the land as a thin layer or ploughed into the surface between crops (CEPI unpublished).

Composting
Factors inhibiting the land spreading of many paper mill wastes are their elevated carbon to nitrogen (C/N) ratios and relatively high Biochemical Oxygen Demands (BOD). Supplementary fertiliser additions are essential to prevent nitrogen immobilization and to provide sufficient nitrogen for crops. Composting pre-treatments will reduce C/N ratios. Composting will also reduce mass, volume and moisture contents benefiting handling, transportation and storage requirements. Overall, the process will produce a stable material, of low odour, with modest levels of nutrients (Tucker 2005).

These land management options are industrially applied but not all are allowed in all countries due to e.g. certain contaminants in the sludges. The technology can be used for deinking and waste water treatment sludges.

2. Absorbent, animal bedding

Waste water treatment reject can be transformed into animal bedding for barns. The material is similar to (previous industrially applied) kitty litter from by-streams. The main difference in these products is that the quality demands are lower for animal bedding and that no additives are needed to increase the absorption capacity of the end product.

This technology is industrially applied. The technology can be used for waste water treatment sludge.

3. Anti-dust agent

Waste water treatment sludge can be used as anti-dust agent by e.g. coal fired power plants.

This technology is industrially applied. The technology can be used for waste water treatment sludge.

4. Feedstock for other paper grades
Deinking sludge and effluent sludge can be used for production of certain board products. This reduces feedstock costs, as deinking sludge can replace feedstock 1 to 1 (dry matter)\(^{16}\). The ratio of feedstock to deinking sludge that can be used depends on the type of end board product. Screen rejects can also be applied in small concentrations for production of solid board. The long fibres make screen rejects a promising reject stream.

This technology is industrially applied. The technology can be used for deinking sludge, waste water treatment sludge and screen rejects.

5. Pyrolysis
Bio-oil obtained through pyrolysis can be used as a substitute for fossil fuels to generate heat, power and/or chemicals. Short-term applications are boilers and furnaces (including power stations), whereas turbines and diesel engines may become available on the somewhat longer term. Upgrading of the bio-oil to a transportation fuel is technically feasible, but needs further development. Transportation fuels such as methanol and Fischer-Tropsch fuels can be derived from the bio-oil through synthesis gas processes. Furthermore, there is a wide range of chemicals that can be extracted or derived from the bio-oil.

The technology has not been industrially applied. Several commercial scale plants will be built in the near future. The technology can be used for coarse rejects and (perhaps) also for sludges and screen rejects (this requires further investigation considering the wetness, organic content and ash content of these by-streams).

6. Feedstock for softboard production
Softboard is a wood fibre based product that is often used as thermal/accoustic insulation, ceiling tiles and as in-fill product for timber frame construction. The wood fibres can be obtained from timber such as Eucalyptus (Gunnersens data sheet 2007), or from waste materials.

According to Goroyias et al. (2004) softboard produced from paper by-streams containing around 80% sludge and 10% other fibres is possible. The other fibres can be either MDF fibre or virgin wood fibre. MDF fibre is preferred to achieve further cost savings.

This technology has been proven on lab scale but has not been industrially applied. The technology can be used for deinking sludge, waste water treatment sludge and screen rejects.

7. Feedstock for hybrid medium-density fibreboard (MDF)
The relative high fibre content of dry sludge (45-50%) induced the idea of producing hybrid MDF. A content of 45% sludge in hybrid MDF proved feasible.

\(^{16}\) Confirmed by a mill that requested to remain anonymous.
The hybrid MDF can be used in several applications in dry conditions where high internal bond strength is not required. (Goroyias et al. 2004)

This technology has been proven on lab scale but has not been industrially applied. The technology can be used for deinking and waste water treatment sludge

8. Feedstock for cement bonded sludge board production
Up to 30% of sludge can replace the virgin wood fibre currently used in cement bonded particle board (it is assumed for now that the virgin wood fibre is similar to that used in softboard). Key advantages are strength, fire resistance and dimensional stability. Interest in this product has been expressed with applications suggested for exterior cladding, outdoor paving systems and suggestion for niche applications as fire surrounds (Goroyias et al. 2004)

This technology has been proven on lab scale but has not been industrially applied. The technology can be used for deinking and waste water treatment sludge

9. Feedstock for tiles
Using paper production sludges for production of floor tiles leads to a product which is warmer than ceramic tiles (but less suited for moist areas).

The production of tiles from 80-85% sludge based on dry weight has been tested. It is unclear if the product fulfilled the required standards (EN316). Also the tile required significant amounts of MID resin (20%) to achieve the strength and hard wearing characteristics.

This technology has been proven on lab scale but has not been industrially applied. The technology can be used for deinking and waste water treatment sludge

10. For use in cement/asphalt/etc. production
The cement industry is an energy intensive sector with significant CO₂ emissions. The paper industry can cooperate with the cement industry by providing substitute raw material¹⁷ as filler material or for incineration as fuel. Also other sectors such as e.g. the asphalt industry can be suited partners for use of solid by-streams from paper making.

Ashes from e.g. incineration of coarse rejects or sludges is already used in the cement and asphalt industry for production (see e.g. CDEM).

This technology can be used for paper sludges (filler material) or coarse rejects (RDF).

11. Fibre/plastics recovery
There are different initiatives that focus on separating the foil and fibre fraction from coarse rejects. A paper mill in the Netherlands has developed its own technology, PhD Bartek Stawicki build and researched a lab scale coarse reject treater (Stawicki 2008) and the VAR (company focused on recycling in the Netherlands) has (together with a partner) developed a technology that can separate the fibre and plastic fraction of coarse

¹⁷ The status of this technology is unknown. Although many sources mention the potential of using paper sludges as substitute of fuel or input material for cement production, no confirmation of actual use of paper sludges as such for cement production.
rejects from the paper industry. The separated fibres can be reused in board production process thereby saving transportation costs and feedstock costs. In this report the VAR’s technology will be used as example.

The VAR technology has not been industrially applied (first commercial installation is currently (2010) being build). The technology can be used for coarse rejects.

12. Synthetic Calcium Carbonate
The company CalciTech has developed a process for the production of synthetic calcium carbonate (SCC), an advanced form of precipitated calcium carbonate (PCC) (www.calcitech.com). The new process is able to separate paper sludge ash into an ultra pure calcium carbonate and a form of metakaolin.

According to CalciTech the SCC recycled mineral has a positive influence on the gloss, brightness, opacity and printability of the coated paper end product. This is due to its narrow particle size distribution compared to PCC or GCC and its high brightness.

This technology is under development; on small scale, samples have been produced. The technology applies to ashes from the paper industry (residues from incineration of deinking and effluent sludges).

13. Bio-BTX
The Bio-BTX technology converts rejects into industrial grade benzene, toluene and xylene (BTX).

The expected benefit using the Bio-BTX technology in comparison to e.g. incineration of the rejects is that more value added is created. BTX are the highest valued platform chemicals in the petro-chemical industries. The product can be used directly in existing chemical plants. This allows the production of green products with relatively small investments.

This technology is under development. The concept is proven by small experiments. A pilot plant is yet to be built. The type of rejects to which the technology applies is confidential.

14. Hydrolysis to fermentation feedstock
Many companies and institutes currently perform R&D on the development of economic processes for hydrolysis of ligno-cellulosic materials to individual sugars, intended to be used as (2nd generation) feedstock for fermentation processes towards bio-ethanol or higher added value bio-chemicals. Examples include enzyme aided hydrolysis (Novozymes18) and acid hydrolysis (Bio-Rights). In this report Bio-Rights will be used as example.

The Bio-Rights technology is under development. The technology can be used for any by-stream that contains cellulose.

18 See internet article http://www.ethanolproducer.com/article.jsp?article_id=6373
15. CDEM
Deinking sludge is suited for the production of mineral products. In The Netherlands Dutch mills initiated an installation (CDEM Holland BV) which converts deinking sludges into a mineral product with cement like properties (SenterNovem CDEM 2009).

The mineral product, called TOP-crete, can be used in the construction of roads/foundations, concrete, or as feedstock for the production of sand-lime bricks (SenterNovem CDEM 2009).

The technology can also be installed on-site.

This technology is industrially applied. The technology can be used for deinking and waste water treatment sludges.

16. Gasification
World-wide there are already many gasification installations active. Rejects (refuse derived fuel and municipal solid waste) are also gasified.

Motivations for use of gasification of rejects for industry are avoiding negative impact of high Natural gas prices, reluctance to use combustion (waste incinerator status), less residue after energy conversion than with combustion, using partly biomass and the fact that syn-gas from gasification can be used in existing CHP installation.

This technology has not been industrially applied. The technology can be used for coarse rejects.

17. Supercritical gasification
The supercritical gasification technology is well suited for wet biomass streams. Currently a global estimation by the developers at the University of Twente is that streams containing at least 3% of organic material will prove energy neutral. Higher content of organic material will lead to an increasing positive netto output of energy. There is a threshold of maximum 50% solid material because of the viscosity.

This technology is under development. The technology is expected to apply to sludges and coarse rejects.

18. Combustion for electricity production or steam production
Rejects can be used for the production of steam or electricity by combustion. Low moisture content and high calorific value are of importance here in the selection of useful by- streams.

According to Dehue et al. (2006) coarse reject as well as screen rejects are by- stream that are well suited for energy recovery due to its high calorific value. Deinking sludge and effluent sludges have less potential but can still be incinerated for their energetic value.

In Parenco the Netherlands a bio-boiler is used to incinerate all paper by- streams (deinking sludge, primary sludge, secondary sludge and plastics). This boiler is used in this report as an example.
This technology is industrially applied. The technology can be used for deinking sludge, waste water treatment sludges and coarse rejects.

19. Direct digestion

Digesting is used by farmers and municipal sewage water plants as a relatively simple technique for a long time. The last decade biogas becomes a strong alternative for fossil fuel. The technology is developing rapidly and more and more attention is put into the pre-treatment processes. The produced biogas is cleaned and transferred into green natural gas. This can be inserted into the existing high-pressure gas distribution system.

According to a report by Bioclear (Bioclear 2007) there is currently no industrial running application of digestion of solid by-streams\textsuperscript{19} in the paper industry\textsuperscript{20}. The technology can be used for screen rejects, deinking rejects and secondary sludge.

The digestion technology is being further developed towards production of higher added value chemicals (instead of biogas)

20. Torrefaction

Torrefaction can convert streams containing organic matter into a brittle product with high energy density. This product can be used in coal based power plants for co-incineration or as a substitute for wood pellets.

There are no commercially operative torrefaction plants at this moment.

In the Netherlands EQnomics has a daughter company “Foxcoal”. Driven by the fact that \(\frac{3}{4}\) of the use of coal is used for electricity production, in which \(\frac{3}{4}\) of that coal consists of “ketel” coals, and the expected increase in prices for waste management\textsuperscript{21}, Foxcoal has researched the potential to convert by-streams from a.o. the paper industry into a secondary fuel (SRF) that can match the demands of large power plants. The characteristics of the SRF have to match those of powder coal.

This technology has been proven on small scale, and is currently in the phase of upscaling. The technology can be used for coarse rejects and potentially sludges, although the latter option is unsure.

21. Secondary fuel\textsuperscript{22}

Coarse rejects have a high calorific value and are therefore suitable as RDF. Qlyte (a spin-off of the company DSM) focuses on expanding the commercialization of the subcoal technology. This technology converts coarse rejects from paper production into high value fuel material (fluff, pellets or powder form). A working installation is running at the Smurfit Kappa Roermond (Netherlands) site since around 8 years. The main buyers of the subcoal are lime producing companies and cement producing companies. A

\textsuperscript{19} In the paper industry digestion is used for treatment of waste water.
\textsuperscript{20} There has been some activity in Spain concerning the use of digestion.
\textsuperscript{21} In Germany, the Netherlands and Sweden there are currently too many waste incineration plants. The large demand for material from these plants lowers the prices of waste management of waste streams.
\textsuperscript{22} Note that there are different ways of production of RDF in Europe. KCPK and CEPI are aware of this, but due to the limited time frame these other options have not been included in this report.
potential future market lies in the electricity producing sector, as a powder form of the subcoal could replace powder coal currently used by some electricity producers\textsuperscript{23}

This technology is industrially applied. The technology can be used for coarse rejects.

### 4.3. Summary of technology characteristics

A short description of the economic and sustainability aspects of each application technology is provided in Table 8. Fact sheets of the technologies are provided in Annex I.

\textsuperscript{23} This has been tested and is applicable. One current barrier is that the great demand of an average electricity producer for co-incineration of the subcoal cannot be met due to lack of production capacity. In the future this may be resolved as a central subcoal producing facility can gain input of several paper producers their reject streams.
Table 8: Added value of application options
(IA=Industrially applied, LP=Lab-scale proven, UD=Under development/research phase, PS=Pilot scale proven, UP=Up-scaling phase)

<table>
<thead>
<tr>
<th>Use of by-streams as such</th>
<th>Status</th>
<th>Economic aspects</th>
<th>Sustainability aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land management options (land spreading, land restoration)</td>
<td>IA</td>
<td>Potentially lower gate fee</td>
<td>Arguably has favourable effect on land due to organic and mineral components of sludges</td>
</tr>
<tr>
<td>Absorbent, animal bedding</td>
<td>IA</td>
<td>Gate fee avoided and profits are made from selling of animal bedding. Investment costs for installation needed for drying and granulation of the by-stream.</td>
<td>Animal bedding replaces normally used straw and saw dust, which can potentially be used for energy production</td>
</tr>
<tr>
<td>Anti-dust</td>
<td>IA</td>
<td>Potentially lower gate fee</td>
<td>Depends on what is currently used instead of sludges for anti-dust</td>
</tr>
<tr>
<td>Conversion to product</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land management options (composting)</td>
<td>IA</td>
<td>Potentially lower gate fee</td>
<td>Arguably has favourable effect on land due to organic and mineral components of sludges</td>
</tr>
<tr>
<td>Feedstock for other paper grades</td>
<td>IA</td>
<td>Reduced need paper for recycling. Investment in pulper line suited for processing of sludge material needed. Delivery fee or costs from the receiving mill unknown.</td>
<td>Reduced need for paper for recycling. Increase in electricity demand (15 kWh/ton wet sludge)</td>
</tr>
<tr>
<td>Pyrolysis (chemicals)</td>
<td>UP</td>
<td>Avoid gate fee and free feedstock. Negative side of by-streams is low quality of the feedstock (more water, more ash content and lower yield per ton). Investment costs for installation.</td>
<td>Pyrolysis oil is CO₂ neutral, because residues are used. Only the transportation costs of the oil should be taken into account which is approx. 5% of the total energy content.</td>
</tr>
<tr>
<td>Feedstock for softboard production</td>
<td>LP</td>
<td>Insufficient information</td>
<td>Reduces demand for virgin wood fibre</td>
</tr>
<tr>
<td>Feedstock for hybrid MDF</td>
<td>LP</td>
<td>Insufficient information</td>
<td>Reduces demand for virgin wood fibre</td>
</tr>
<tr>
<td>Feedstock for cement bonded sludge board production</td>
<td>LP</td>
<td>Insufficient information</td>
<td>Reduces demand for virgin wood fibre</td>
</tr>
<tr>
<td></td>
<td>Feedstock for tiles</td>
<td>For use in cement/asphalt/etc. production</td>
<td>Fibre/plastic recovery</td>
</tr>
<tr>
<td>---</td>
<td>---------------------</td>
<td>------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>9</td>
<td>LP</td>
<td>Insufficient information</td>
<td>PS*</td>
</tr>
<tr>
<td>10</td>
<td>Insufficient information</td>
<td>Potentially lower gate fee</td>
<td>Estimated cost of installation around €600.000. Economic feasibility depends on current disposal costs, feedstock costs, disposal costs foil fraction, avoided transportation costs.</td>
</tr>
<tr>
<td>11</td>
<td>Insufficient information</td>
<td>When used as filler the material is reused thereby saving primary material.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Insufficient information</td>
<td>Bio-BTX</td>
<td>The demand for fossil-based chemicals is reduced. Current production of these chemicals is highly energy-intensive (fossil BTX is made by naphta cracking).</td>
</tr>
<tr>
<td>13</td>
<td>Insufficient information</td>
<td>Hydrolysis to fermentation feedstock (higher added value chemicals)</td>
<td></td>
</tr>
<tr>
<td>14a</td>
<td>Fibre/plastic recovery</td>
<td>Synthetic Calcium Carbonate</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Insufficient information</td>
<td>Insufficient information</td>
<td>Paper mills pay a fee to CDEM in case of external installation. Example costs CDEM installation: initial investment 20 million euro, payback time around 5 years.</td>
</tr>
<tr>
<td>15</td>
<td>Insufficient information</td>
<td>Insufficient information</td>
<td>Paper mills pay a fee to CDEM in case of external installation. Example costs CDEM installation: initial investment 20 million euro, payback time around 5 years.</td>
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<td>16</td>
<td>Insufficient information</td>
<td>Insufficient information</td>
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</tr>
<tr>
<td>17</td>
<td>Insufficient information</td>
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<td>Paper mills pay a fee to CDEM in case of external installation. Example costs CDEM installation: initial investment 20 million euro, payback time around 5 years.</td>
</tr>
<tr>
<td>18</td>
<td>Insufficient information</td>
<td>Insufficient information</td>
<td>Paper mills pay a fee to CDEM in case of external installation. Example costs CDEM installation: initial investment 20 million euro, payback time around 5 years.</td>
</tr>
<tr>
<td>Conversion to energy carrier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>19</td>
<td>Direct digestion</td>
<td>IA**</td>
<td>Feasibility strongly depends on alternative disposal costs, cost of handling of digestate, economies of scale etc.</td>
</tr>
<tr>
<td>5b</td>
<td>Pyrolysis (oil)</td>
<td>UP</td>
<td>Avoid gate fee and free feedstock. Negative side of by-streams is low quality of the feedstock (more water, more ash content and lower yield per tonne). Investment costs for installation.</td>
</tr>
<tr>
<td>20</td>
<td>Torrefaction</td>
<td>PS</td>
<td>Gate fee to be paid in case of external conversion.</td>
</tr>
<tr>
<td>14b</td>
<td>Hydrolysis to fermentation feedstock (bio-ethanol, bio-methane)</td>
<td>UD</td>
<td>Insufficient information</td>
</tr>
<tr>
<td>21</td>
<td>Secondary fuel</td>
<td>IA</td>
<td>Investment costs/licence cost when buying the turn key technology, avoiding disposal costs and profiting from selling subcoal. In case of solely conversion rejects to subcoal without ownership of installation, a gate fee has to be paid.</td>
</tr>
</tbody>
</table>

Demand for natural gas is reduced. Benefit to environment also depends on the use of the digestate.

Pyrolysis oil is CO₂ neutral, because residues are used. Only the transportation costs of the oil should be taken into account which is approx. 5 % of the total energy content.

Avoiding use of coal in coal fired power plants.

Depending on the business plan, the product substitutes range is: Ethanol, Buthanol, Methane, heat, electricity.

*Pilot scale proven, first commercial application being build
**But not to paper production by-streams
5. Conclusions

During paper recycling various solid by-streams are formed which contain unwanted materials or useful materials that are accidentally removed from the production line. These streams are currently considered by many as rejects that need to be disposed at least costs possible, while other potential application possibilities may be present which can generate more value from the reject streams.

Proof of value from by-streams
The growing amount of technologies that focus on creating value from paper production rejects indicates the general acknowledgement of the value from paper production by-streams. This trend will continue as the environmental legislation continues to pressure use of fossil fuel and waste of primary material. This situation provides the paper industry with pressure from high energy prices and feedstock prices on the one hand but also with the increase of the potential value per unit of paper for recycling on the other hand due to increasing demand for rejects or product from rejects by third-parties. The value from the by-streams therefore is of great importance to the economic feasibility of the paper production process.

Applications for by-streams
The types of application technologies for paper production by-streams vary greatly. The by-streams can be used as feedstock in production, converted into energy or energy carriers, or used in their current state. The technologies used to achieve these application forms also vary from conventional (composting, incineration) methods to highly innovative (fermentation to produce bio-chemicals) technologies.

For own use the paper mills can use energy conversion options, separate the fibres from the foil fraction (in coarse rejects), use sludges as feedstock for production of lower paper grades, and recycle minerals from sludge ashes.

On-site or central
The use of the application technologies can often either be performed externally (central) or on-site. In both cases the technological installation can be owned by either the paper mill or a third party.

Cluster forming
In order to achieve economies of scale necessary to be economically feasible, paper mills and/or third parties can form clusters. This can ensure meeting the material input needed for large scale installations.
6. The future

Not only solid by-streams can be used to generate high value products. Paper making has many other by-streams.

Currently by-streams in the paper industry can generally be classified into:

- Solid others
- Solid by-streams removed from pulp and waste water treatment operations
- Liquid by-streams (e.g. waste water)
- Gaseous by-streams (e.g. exhaust from CHP, drying section of paper machine)
- Furthermore, potential new by-streams may arise from changes in production processes

The opportunities for improving the production processes are nearly endless as for each by-stream applications can be found. Heat losses can be captured and used for low temperature processes or through innovation even used for high temperature processes. By extracting and isolating unwanted components from the water circuit enables both the production of additional high value by-products as well as the closing of the water circuit, thereby terminating the need for fresh water. “By-streams” are full of components that may be unwanted in the paper production process but are of high value for other industries; isolation of these components creates additional high-value by-products.

Figure 3: Maximum value in a multi-product mill
The ambition of ‘valorisation of waste streams’ limits the view on possible innovations that can lead to a higher value out of the recovered paper raw material. Instead, the ambition to ‘Increasing the economical value of paper recycling’ should be used.

This ambition also leads to more options:
- Isolation of valuable components out of pulp and process water
- Changing the primary papermaking process in such a way that it creates by-streams with higher value.

Other options that make more value from a recycled paper mill:
- Reuse rest-heat from gaseous by-streams
- Close the water loop (reuse water)
- CO$_2$-capture of CHP exhaust
- Consider the potential market value of (sometimes detrimental) substances in the (recycled) pulp: starch, stickies, fatty acids, ink components, coating components, etc.
- Consider removing more (fine) fibres from your process to be sold with value as fermentation feedstock and improve your own process efficiency.
7. References

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Annex I: Fact sheets

In this annex the fact sheets of each technology is provided. An explanation of the content of the fact sheets is provided below.

<table>
<thead>
<tr>
<th>Title:</th>
<th>Name of the technology (current application status).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reject type:</td>
<td>Type of solid by-streams to which the technology applies.</td>
</tr>
<tr>
<td>Background:</td>
<td>General description of the purpose of the technology.</td>
</tr>
<tr>
<td>Process:</td>
<td>Description of the processes of the technology.</td>
</tr>
<tr>
<td>Finance:</td>
<td>Description of the benefits and costs of the technology.</td>
</tr>
<tr>
<td>Environment:</td>
<td>Description of impact of the technology on the environment (with focus on saved energy).</td>
</tr>
<tr>
<td>Experience of legislation:</td>
<td>Users/Suppliers views on needed permits and other regulatory matters concerning the technology (may be changed with the implementation of new Waste Directive).</td>
</tr>
<tr>
<td>Contact:</td>
<td>Contact information of parties that utilize/develop/commercialize the technology.</td>
</tr>
</tbody>
</table>
1. **Land management options**

**Title:** Land management options (Industrially applied)

**Reject type:** Sludges

**Background:**

*Land restoration*

Land restoration covers the use of dried sludge as a product applied on derelict land, damaged industrial sites topsoil, or during road constructions, topping of landfills, mine filling, etc. When aiming to increase soil quantity on the site, two techniques are observed: it can be either directly applied or mixed with the soil present on the site before application.

*Land spreading*

Highly practiced in some countries (e.g. the UK) and recently recognised once again for its organic and mineral qualities. Valuable compounds present in sludge are reinserted into the soil, by transporting it, often in a cake form, from the mill to the fields, then either spread on the land as a thin layer or ploughed into the surface between crops (CEPI unpublished).

Main practical difficulties of landspreading recovery for paper sludges consist of available land and transportation costs (CEPI unpublished).

*Composting*

Paper mill sludges have been composted successfully in the past, though both nitrogen and structural amendments are generally needed for the process (Tucker 2005). Composting of sludges can be an attractive alternative to e.g. land spreading when legislation for use of untreated sludges becomes more stringent.

**Process:**

*Land restoration*

The quantity of sludge usually applied can engage high amounts, as in some cases a thickness of cover can understand several centimeters over hectares of area. This solution can be expected to increase in future, as pulp and paper sludges offer sufficient quality levels, while other options are becoming more legally restricted. (CEPI unpublished)

*Land spreading*

Application, when permitted, is recognised as a soil fertilizer (cellulose and organic content) or as a soil improver (mineral matter content). Land spreading is regulated on the national or local level. Moreover, limed sludge is identified as an efficient mineral

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amendment which can mainly be used to correct the pH of acid soils. The carbonate, highly contained in paper sludge, is well known as a good long-term soil amendment\textsuperscript{25}, compared to other treatments. The usability of the sludge for land spreading is highly dependent on the local conditions and the soil needs (CEPI unpublished).

**Composting**

Factors inhibiting the land spreading of many paper mill wastes are their elevated carbon to nitrogen (C/N) ratios and relatively high Biochemical Oxygen Demands (BOD). Supplementary fertiliser additions are essential to prevent nitrogen immobilization and to ensure sufficient nitrogen for crops. Composting pre-treatments will reduce C/N ratios. Composting will also reduce mass, volume and moisture contents benefiting handling, transportation and storage requirements. Overall, the process will produce a stable material, of low odour, with modest levels of nutrients (Tucker 2005).

**Finance:**
Gate fee is to be paid to party that accepts by-stream.

**Environment:**
Other benefits from land application, particularly accurate when considering threats on the European soil, includes improvement of soil microbiological activity, better water holding capacity, tilt and workability, etc. Soil improvement is particularly evident on sandy soils and in very dry seasons\textsuperscript{26}. In practice, spreading is mostly accomplished on agricultural land, although forests and particularly plantation can also be an appropriate field\textsuperscript{27}. All in all, this “natural cycle” of biological products used on land improve soil quality as well as reduces erosion risk (CEPI unpublished). There are no problems with using paper sludges for landspreading concerning heavy metal or organic pollutant content. Potential problems from landspreading come from the high C/N ratio that can cause immobilization of soil nitrogen and thus deprive crops from it. Nevertheless, low nitrogen content avoids nitrate leakage to the ground water\textsuperscript{28} on the other hand, which are often very pollutant (CEPI unpublished). Scientific research and best practices give clear indication on how to avoid N immobilization risks. Indeed, losses in yield due to paper sludge can be minimized in the first year by adding fertilizer N. More practically is application of 30 to 50 kg of fertilizing N/hectare per 100 t/ha of sludge. Results indicate that in the second year after application there was very little or no N immobilization at all. Application should also take into account local conditions, such as weather, snow cover, soil needs, crops cultivated, etc. If adapted to conditions and applied early enough before agricultural cultivation, even without additional N, the N immobilization will not occur (CEPI unpublished).

\textsuperscript{25} Following acid rainfalls, several years ago, German authorities where driven to apply a carbonate amendment in forests. Instead of using chemicals, this contribution could be done by natural by-products such as paper mill sludges.
\textsuperscript{27} INRA, “La forêt, une alternative pour recycler les boues de station d’épuration”, Bordeaux, 2004.
\textsuperscript{28} Guillet F., “Land application of pulp and paper industry sludge”, Investigacion y Tecnica del Papel, nº 148, p. 84.
**Experience of legislation:**
Legislation on land spreading varies but in most EU countries this application option is banned (WRAP 2006).

**Contact:**
No firms were directly contacted for this fact sheet.
2. Absorbent, animal bedding

**Title:** Absorbent, animal bedding (Industrially applied).

**Reject type:** Waste water treatment sludge. (Deinking sludge is likely to be unsuited due to heavy metal content and partly mixing with plastics. But should the levels of contamination be low enough than deinking sludge could potentially be used for animal bedding production.)

**Background:**
The waste water treatment reject is transformed into animal bedding for cowsheds. The material is similar to cat litter (also industrially applied). The main difference is that the quality demands are lower and that the absorption capacity is less important.

**Process:**
First pressing for dewatering of the material takes place. Then the product is granulated and dried. In the dryer the reject is almost completely dried (removing 60% moisture). Waste energy is used for this process because using gas or other primary energy sources is too expensive. Instead, waste heat from the combined heat and power (CHP) plant can be used. The flue gasses from the CHP are cooled by a closed water loop. The water loop warms up the inlet air temperature for the sludge dryer up to 110 °C. Depending on the outside air temperature more or less energy is needed. The average energy use is about 23 GJ per ton of dried product.

**Finance:**
The price for the material can help to make the process financially feasible. Aside from avoiding disposal costs added value is generated from the sales of the animal bedding product.

**Environment:**
Normally cowsheds use natural products such as saw dust and straw (which could also be used for e.g. sustainable energy production). Because the material out of the waste water plant contains rest fibres and chalk (calcium carbonate) it has an added value due to absorption and manure.

**Experience of legislation:**
Unknown.

**Contact:**
The paper mill which has provided the information for this fact sheet does not wish to have its name and contact data mentioned.
3. **Anti-dust agent**

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Anti-dust agent (Industrially applied).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Waste water treatment sludges.</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>As example we take Crown van Gelder (paper mill in the Netherlands). The waste water treatment sludge of Crown van Gelder is currently processed by a company that sells the sludge (e.g. to coal based power plants) as anti dust material.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>The sludge at Crown van Gelder is further diluted to make the spreading easier. No other processes are required.</td>
</tr>
<tr>
<td><strong>Finance:</strong></td>
<td>The fee to the trader is lower than the fee to incineration plants for waste disposal in the case of Crown van Gelder.</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td>The sludge from paper mills is likely to replace sludges from other industries (e.g. the starch industry).</td>
</tr>
<tr>
<td><strong>Experience of legislation:</strong></td>
<td>Registration of the sludges is necessary. A specific waste stream code is assigned to the sludges of Crown van Gelder. For the waste disposing actor obtaining the required permits is necessary.</td>
</tr>
</tbody>
</table>
| **Contact:** | Herman J.A. Jansen  
Head TPO/Project Manager  
Crown van Gelder N.V.  
Tel: +31 (0) 251-262207  
Mobile: +31 (0) 6-53933642  
Mail: h.jansen@cvg.nl |
### 4. Feedstock for other paper grades

<table>
<thead>
<tr>
<th><strong>Title:</strong> Feedstock for other paper grades.</th>
</tr>
</thead>
</table>

| **Reject type:** | Anaerobe sludge, aerobe sludge, deinking sludge, screen rejects. |
|------------------------------------------------|

| **Background:** | Deinking sludge and effluent sludge can be used for production of certain board products. This reduces feedstock costs, as the sludge potentially replaces feedstock 1 to 1 (dry matter). The ration of feedstock to sludge that can be used depends on the type of board product. There have been reports on paper products containing 10% of sludge. It has been reported that screening rejects can also be applied in small concentrations for production of solid board. The long fibres make screening rejects a promising reject stream. The high ash content however can result in problems with dewatering. Other problems include age of the material and biological activity (odour). |
|------------------------------------------------|

| **Process:** | The sludges are inserted into the pulper using a separate line. So far there have been no reports on noticeable negative effects on the paper production process. There is also still ongoing research on the influence on the characteristics of the end product. |
|------------------------------------------------|

| **Finance:** | Paper for recycling costs are saved as well as the total fee for land filling of the used by-stream as no leftover residues are created. Added costs through the influence of the use of sludge as feedstock on productions processes such as variations in energy consumption for drying have not been determined yet. |
|------------------------------------------------|

| **Environment:** | Investments are needed in a pulper line suited for the processing of sludge material. Added energy use for reuse of deinking sludge is estimated to be around 15 kWh/ton deinkings lb. As previously mentioned, the exact influence on the production energy is unknown. |
|------------------------------------------------|

| **Experience of legislation:** | Depending on the specific national legislation regarding waste treatment, a mill using waste streams from other mills may gain the status of waste disposer. A permit needs to be acquired for this. The application process for such a permit may have effect on the economical feasibility. However, as the used sludge stream is a mono-stream used under well defined conditions the legal aspects of using sludges should (in theory) not prove a large barrier (Tauw 2008). |
|------------------------------------------------|
Contact:
The paper mill which has provided the information for this fact sheet does not wish to have its name and contact data mentioned.
# 5. Pyrolysis oil

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Pyrolysis-oil (upscale phase).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Any type of biomass can be used for pyrolysis, however it makes sense not to use wet biomass types (more than 60 % moisture) and because of sustainability issues there should be a focus on residues and not to use anything from the food chain.</td>
</tr>
</tbody>
</table>

**Background:**

Pyrolysis transforms difficult-to-handle biomass of different nature into a clean and uniform liquid, called pyrolysis oil.

**Pyrolysis-oil application**

Bio-oil can be used as a substitute for fossil fuels to generate heat, power and/or chemicals. Short-term applications are boilers and furnaces (including power stations), whereas turbines and diesel engines may become available on the somewhat longer term. Upgrading of the bio-oil to a transportation fuel is technically feasible and has been demonstrated on laboratory scale, but needs further development. Transportation fuels such as methanol and Fischer-Tropsch fuels can be derived from the bio-oil through synthesis gas processes. Furthermore, there is a wide range of chemicals that can be extracted or derived from the bio-oil.

The key advantage of liquids from biomass is that its production can be de-coupled from any application. Pyrolysis oil can be a fuel as such or a feedstock for further processing. Application possibilities include gasification and further processing, combustion, diesel engine, chemical upgrading (hyrotreated oil), physical upgrading (removing tar), and isolation of chemicals ([www.btgworld.com](http://www.btgworld.com) and [www.btg-btl.com](http://www.btg-btl.com)).

**Fast pyrolysis application**

Fast pyrolysis is a process in which organic materials are rapidly heated to 450 - 600 °C in absence of air. Under these conditions, organic vapours, permanent gases and charcoal are produced. The vapours are condensed to pyrolysis oil. Typically, 50-75 wt.% of the feedstock is converted into pyrolysis oil.

Pyrolysis oil can be used for the production of renewable/sustainable energy and chemicals. Its energy density is four to five times higher than the original solid material, which offers important logistic advantages.

It is the intention to bring the pyrolysis technology to the biomass. As the character of the biomass is relatively small it is not foreseen that plants will be centralized. It makes sense to have the pyrolysis plants decentral and the upgrading of the oil will be central in a large plant.

The technology has not been industrially applied although there are some larger commercial scale plants in the world. The business case has to be proved for energy and bio-refinery applications. Several commercial scale plants will be built in the near future. One 5 ton per hour plant will be built by BTG-BTL on the AkzoNobel premises in Hengelo and Xynergo (daughter of Norske Skog) will build a 8 tons per hour plant in Norway.
### Process:

*Pyrolysis oil*
See background, for more detailed information contact BTG (see contact information bottom of fact sheet).

*Fast pyrolysis*
BTG's fast pyrolysis technology is based on intensive mixing of biomass particles and hot sand particles in a modified rotating cone reactor. A wide variety of different feedstock can be processed in the pyrolysis process. Before entering the reactor, the particles must be reduced to a size below 6 mm, and its moisture content to below 10 wt.%. Normally, sufficient excess heat is available from the pyrolysis plant to dry the biomass from 40-50 wt% moisture to below 10 wt%.

In the process up to 75 wt.% pyrolysis oil and only 25 wt.% char and gas are produced as primary products. Since no "inert" carrier gas is used the pyrolysis products are undiluted. This undiluted and hence small vapor flow results in downstream equipment of minimum size. In a condenser the vapor is rapidly cooled yielding the oil product and some permanent gases. In only a few seconds the biomass is transformed into pyrolysis oil.

Charcoal and sand are recycled to a combustor, where charcoal is burned to reheat the sand. The permanent gases can be utilized in a gas engine to generate electricity or simply flared off. In principal, no external utilities are required.

### Finance:
Due to the small number and limited scale of existing pyrolysis oil production units, the economics of a commercial scale unit can only be estimated. Costs of bio-oil production depend i.a. on feedstock (pre-treatment) costs, plant scale, type of technology etc. The use of solid by-streams has the advantage avoiding disposal costs and free feedstock. The negative side of using the by-streams is lower quality of the feedstock (more water, more ash content and lower yield per ton). The exact financial outcome will require more research.

### Environment:
Pyrolysis oil is CO₂ neutral, because residues are used. Only the transportation costs of the oil should be taken into account which is approx. 5 % of the total energy content.

### Experience of legislation:
REACH is important. Every producer in Europe, producing more than 1000 tons per year has to apply for REACH.

### Contact:
Gerhard Muggen
Managing Director BTG Bioliquids BV
Pyrolysis oil, the sustainable alternative!
PO Box 835, 7500 AV
Josink Esweg 34, 7545 PN
### 6. Feedstock for softboard

**Title:** Softboard (Labscale proven).

**Reject type:** Deinking sludge, primary sludge and screen rejects.

**Background:**
Softboard is a wood fibre based product that is often used as thermal/accoustic insulation, ceiling tiles and as in-fill product for timber frame construction. The wood fibres can be obtained from timber such as Eucalyptus (Gunnersens data sheet 2007), or from waste materials. According to Goroyias et al. (2004) softboard produced from paper waste streams containing around 80% sludge and 10% other fibres is possible. The other fibres can be either MDF fibre or virgin wood fibre. MDF fibre is preferred to achieve further cost savings. It is assumed that both primary and deinking sludge can be used for this application option due to their confirmed high amount of organic (fibres) content.

**Process:**
![Process flow diagram for softboard (Goroyias et al. 2004)](image)

**Finance:**
Using sludge can replace virgin wood fibre. Virgin fibre costs are about £50-70/ton. The actual price per ton of by-stream cannot be estimated as it depends on the market.

**Environment:**
The energy savings by using the rejects are around 0.10 GJ/ton<sub>wet</sub> and 10 kWh/ton<sub>wet</sub>.

**Experience of legislation:**
Impact of using the rejects on health codes, waste handling permits, or REACH requires further investigation.

**Contact:**
Rob Elias
Commercial manager

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30 Assumption is that the fibres from the reject save the energy needed for the processing of wood chips normally used as feedstock.
## 7. Hybrid MDF

**Title:** Feedstock for hybrid MDF (Labscale proven).

**Reject type:** Sludges (deinking and waste water treatment).

**Background:**
The relative high fibre content of dry sludge (45-50%) induced the idea of producing hybrid MDF. A content of 45% sludge in hybrid MDF proved feasible. The hybrid MDF can be used in several applications in dry conditions where high internal bond strength is not required. (Goroyias et al. 2004).

**Process:**
![Process flow diagram for hybrid MDF (Goroyias et al. 2004)](image)

Finance:
The sludge can replace virgin wood used in normal MDF production. Virgin fibre costs are about £50-70/ton. The actual price per ton of by-stream cannot be estimated as it depends on the market.

Environment:
The energy savings by using the rejects are around 0.10 GJ/ton\textsubscript{wet} and 10 kWh/ton\textsubscript{wet}\textsuperscript{31}

Experience of legislation:
Impact of using the rejects on health codes, waste handling permits, or REACH requires further investigation.

**Contact:**
Rob Elias
Commercial manager
Centre University of Wales
Tel: +44 (0)1248 388599

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\textsuperscript{31} Assumption is that the fibres from the reject save the energy needed for the processing of wood chips normally used as feedstock.
Email: r.m.elias@bangor.ac.uk
### 8. Cement bonded sludge board

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Cement bonded sludge board production (Labscale proven).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Sludges (deinking and primary).</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>Up to 30% of sludge can replace the virgin wood fibre currently used in cement bonded particle board. (It is assumed for now that the virgin wood fibre is similar to that used in softboard). Key advantages are strength, fire resistance and dimensional stability. Interest in this product has been expressed with applications suggested for exterior cladding, outdoor paving systems and suggestion for niche applications as fire surrounds (Goroyias et al. 2004).</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td><img src="process_flow_diagram.png" alt="Process flow diagram for cement bonded sludge board (Goroyias et al. 2004)" /></td>
</tr>
<tr>
<td><strong>Finance:</strong></td>
<td>The sludge can replace virgin wood used in normal cement bonded sludge board production. Virgin fibre costs are about £50-70/ton. The actual price per ton of by-stream cannot be estimated as it depends on the market.</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td>The energy savings by using the rejects are around 0.10 GJ/ton(<em>{\text{wet}}) and 10 kWh/ton(</em>{\text{wet}})^32</td>
</tr>
<tr>
<td><strong>Experience of legislation:</strong></td>
<td>Impact of using the rejects on health codes, waste handling permits, or REACH requires further investigation.</td>
</tr>
</tbody>
</table>

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^32 Assumption is that the fibres from the reject save the energy needed for the processing of wood chips normally used as feedstock.
Contact:
Rob Elias
Commercial manager
Centre University of Wales
Tel: +44 (0)1248 388599
Email: r.m.elias@bangor.ac.uk
## 9. Tiles

**Title:** Feedstock for tiles (Labscale proven).

**Reject type:** Primary and deinking sludge.

**Background:**
The production of tiles from 80-85% sludge based on dry weight has been tested. It is unclear if the product fulfilled the required standards for fibreboards (EN316). Also the tile required significant amounts of MID resin (20%) to achieve the strength and hard wearing characteristics. This makes the overall product quite expensive (Goroyias et al. 2004).

**Process:**

![Process flow diagram for tiles (Goroyias et al. 2004)](image)

**Finance:**
The added value cannot be estimated as it depends upon the market.

**Environment:**
The energy savings are thus far unknown due to lack of information on the energy intensity of the sludges to tiles process.

**Experience of legislation:**
Impact of using the rejects on health codes, waste handling permits, or REACH requires further investigation.

**Contact:**
Rob Elias
Commercial manager
Centre University of Wales
Tel: +44 (0)1248 388599
Email: r.m.elias@bangor.ac.uk
<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Use of paper sludges in cement/asphalt/etc. production (Exact application status unknown).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Paper sludge.</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>The cement industry is an energy intensive sector with significant CO₂ emissions. The paper industry can cooperate with the cement industry by providing substitute raw material. Also for production of asphalt or other material with flexible feedstock solid by-streams can be used. Paper sludges can potentially be used for Portland cement production. The cement industry is willing to consider by-products as alternative fuels and/or ingredients that contribute to the recipe of the cement clinker. Main drivers are environmental policies and the desire to reduce primary fuel and material use (Dunster 2007). Paper production sludges can be used as raw material for the production of cement blocks. In cement block production the introduction of 2.5-5% of sludge has no significant negative impact on properties of the final product. Ashes from e.g. incineration of coarse rejects or sludges are already used in the cement industry and the asphalt industry for production.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>No detailed description available.</td>
</tr>
<tr>
<td><strong>Finance:</strong></td>
<td>Gate fee is paid (Dunster 2007).</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td>In comparison to current practices (incineration and land filling) the material is reused thereby saving primary material.</td>
</tr>
<tr>
<td><strong>Experience of legislation:</strong></td>
<td>The sludge is classified as waste.</td>
</tr>
<tr>
<td><strong>Contact:</strong></td>
<td>No firms were directly contacted for this fact sheet.</td>
</tr>
</tbody>
</table>
# 11. **Fibre/plastics recovery**

<table>
<thead>
<tr>
<th>Title:</th>
<th>Fibre/plastics recovery (First commercial installation under construction).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reject type:</td>
<td>Coarse rejects.</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>In this fact sheet the VAR technology is used as example.</td>
</tr>
<tr>
<td></td>
<td>The VAR has together with a partner developed a technology that can separate the fibre and plastic fraction of coarse rejects from the paper industry. The separated fibres can be reused in board production process thereby saving transportation costs and feedstock costs. The plastic fraction can be incinerated with energy recovery, although increased plastic recycling systems in many countries have increased the development of higher added value applications for recycled plastics. Success of the technology depends on the application possibilities of the recovered fibre and the willingness of the paper companies to use these fibres. This technology has not been commercialised yet, but a first commercial application is currently being built. The technology has had extensive testing on several machines at VAR using the rejects of different paper mills. The machine has also been tested for other streams(^{33}) that could potentially provide feedstock for the paper industry.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>The technology can be applied to reject streams as they are currently (after mechanical pressing) being disposed of to MSW or other processors of rejects. A detailed description of the process cannot be provided due to confidentiality reasons. The basics of the technology however involve the separation of a reject stream into a fibre and foil fraction in which the focus lies on avoiding damage to the fibres. The foil fraction and any unwanted contaminants are removed together. The process is executed under dry conditions. According to the calculations made by VAR roughly 95% of the fibres can be isolated from the reject stream. Some fibres are lost as a separate fraction and some will be lost in the foil fraction. The exact amount of fibres does not form a condition to the separation process (i.e. either 25% or 70% makes no difference to the process itself). What is important is the moisture content of the reject stream (the percentage of moisture content has a negative correlation with the efficiency of the separation process) and the presence of any large contaminants such as rubber or metals. Considering the moisture content, when mechanically dewatered the moisture content of the rejects is sufficiently low for the process.</td>
</tr>
<tr>
<td><strong>Finance:</strong></td>
<td></td>
</tr>
</tbody>
</table>

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\(^{33}\) Identity of the industries of these alternative streams is not mentioned due to confidentiality reasons.
Multiple business models are possible. In case of a paper mill with high amounts of rejects it can be possible to station the separation module onsite. In case of relatively low amounts of rejects per paper mill a centralised installation can be constructed which uses reject streams from multiple mills.

Whether the paper mill becomes the owner of the installation and pays a licence fee to VAR or VAR is the owner of the installation themselves will have to be judged per paper mill.

The estimated costs of the installation will be around €600,000,. However the investment costs are highly dependent on the exact situation and the specific requirements of the paper mill. Economical feasibility depends on:

- Current disposal costs
- Purchase costs of current feedstock
- Disposal costs of foil fraction
- Avoided transportation costs.

Environment:
The process requires around 23 kWh per tonne of reject material.

Experience of legislation:
The impact from REACH regulation on the application of the VAR technology is at the moment uncertain. For now VAR assumes that as paper recycling mills acquire their waste streams under a certain European waste code, the recovered fibres from VAR could also be acquired by paper mills under a (to be determined) European waste code.

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www.var.nl
12. Synthetic calcium carbonate

Title: Synthetic calcium carbonate (Up-scaling phase).

Reject type: Deinking sludge or waste water treatment sludge ash.

Background:
The company CalciTech has developed a process for the production of synthetic calcium carbonate (SCC), an advanced form of precipitated calcium carbonate (PCC) (www.calcitech.com). The new process is able to separate paper sludge ash into an ultra pure calcium carbonate and a form of metakaolin.

According to CalciTech the SCC recycled mineral has a positive influence on the gloss, brightness, opacity and printability of the coated paper end product. This is due to its narrow particle size distribution compared to PCC or GCC and its high brightness.

A small scale plant located in Eastern Germany currently produces samples for customers interested in testing the SCC in their products (www.calcitech.com).

Process:
The sludge is first incinerated. The calcium oxide is then separated from the ashes using the CalciTech separation step. Then the calcium oxide is (using CO₂) converted into SCC using the CalciTech conversion step. CalciTech estimate that about 30-40 kt of SCC will be obtained out of 500kt of paper for recycling.

Finance:
A full scale plant with a capacity of 40,000 tonnes of SCC per annum has been designed and could be built on a 2,000 m² area. An on-site plant would avoid freight and handling costs. The CalciTech process eliminates the disposal costs of the sludge or ash.

Environment:
The process converts a waste product into two valuable product streams: SCC and metakaolin. 44 tonnes of CO₂ is sequestered for 100 tonnes of SCC produced. The satellite concept eliminates the transport of raw materials and finished products.

Experience of legislation:
REACH: SCC has been registered as a SIEF application for calcium carbonate
Enables mills to meet EU Directives on:
- Waste 2008/98/EC
- Integrated Pollution Prevention and Control IPPC 96/61/EC
- Landfill 1999/31/EC.

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Mobile : + 41 79 376 60 97
Email : michael.watts@calcitech.com
**13. Bio-BTX**

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Bio-BTX (Under development).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Confidential information.</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>The technology converts rejects into industrial grade benzene, toluene and xylene (BTX). The expected benefit using the Bio-BTX technology in comparison to e.g. incineration of the rejects is that more value added is created. BTX are the highest valued platform chemicals in the petro-chemical industries. The product can be used directly in existing chemical plants. This allows the production of green products with relatively small investments. The exact business case (central plant, on-site installation) is confidential information. The technology is not yet commercially available. The concept is proven by small scale experiments. A pilot plant has yet to be built.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>The technology is based on a thermo-chemical conversion. Other information regarding this technology is mostly confidential.</td>
</tr>
<tr>
<td><strong>Finance:</strong></td>
<td>This information is confidential.</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td>The demand for fossil-based chemicals is reduced. As production of these chemicals is highly energy-intensive (fossil BTX is made by naphta cracking) it is expected that the Bio-BTX will save significant energy.</td>
</tr>
<tr>
<td><strong>Experience of legislation:</strong></td>
<td>This information is confidential.</td>
</tr>
<tr>
<td><strong>Contact:</strong></td>
<td>KNN advies Werfstraat 9712VN Groningen <a href="mailto:info@knnadvies.nl">info@knnadvies.nl</a> +31 50 317 5558</td>
</tr>
</tbody>
</table>
14. Hydrolysis to fermentation feedstock

**Title:** Hydrolysis to fermentation feedstock (Research phase).

**Reject type:** Any reject type containing cellulose.

**Background:**
In this fact sheet Bio-Rights will be used as example.
The company Bio-Rights is building (start in 2009) in a test installation in Hardenberg (the Netherlands) that will produce methane. The key technology is called the Gravity Pressure Vessel (GPV). The technology allows the production of bio-methane from different cellulose containing waste streams (e.g. wood and saw dust waste, household wastes, food processing industry waste, manure, grass etc.). The greatest innovation of the GPV is that the traditional batch process of weak acid hydrolysis is converted into a continuous process. According to Bio Rights the process output and the process flow can be increased and decreased without problems. They also state that the system is very robust and due to its closed-off setup does not emit any gasses.

**Process:**
The Gravity Pressure Vessel is a tube with a closed-off outside pipe and an open inside pipe. These are inserted into a 700 meter deep well with an iron wall and a concrete foundation. The shaft is completely closed off and under vacuum (thermos flask). For the production, the cellulose fraction of the waste streams is isolated and grinded to (maximum) 40 millimeter size. The particles are mixed with water in tanks that are heated to 80 °C. The cellulose mixture is then pumped (about 10% dry matter content) to greater depths where the reactor chamber is located. Here the conversion of cellulose and hemi-cellulose into sugars takes place under high pressure in a weak acid environment. The whole stream of aldehydes, alcohols and sugars can after ample separation be transferred to an anaerobe digester to produce methane or bio-chemicals.

**Finance:**
No information.

**Environment:**
Depending on the business plan, the product substitution range is: Ethanol, Butanol, Methane, heat, electricity.
The hydrolysis and utilization in a fermentation or digesting plant is a simple reaction step and fully predictable. The GPV is a unique reactor concept that gives high energy

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34 The GPV is developed and patented by an American company called GeneSyst Int. Inc. In the US there are three projects under development using GPV. Bio-Rights has obtained from Genesyst Europe BV the license rights for the Benelux.
transfer values, because of the vacuum insulated thermo bottle concept. Energy and mass balance available depend on specific raw material intake.

**Experience of legislation:**
For the building of the installation environmental and building permits are required. At the moment an environmental permit (waste processing a.o.) is already in place for the production of Ethanol and Methane. An addition to this for just Methane to come to an electric output of 8MW is applied for together with an addition to produce just Methane. A building permit (first part, GPV, intake and MBR reactors) is in place.

**Contact:**
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7772 TB Hardenberg
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Email: genesysteu@yahoo.com
15. **CDEM**

**Title:** CDEM (Industrially applied).

**Reject type:** Paper sludges (deinking and waste water treatment).

**Background:**
Deinking sludge is suited for production mineral products. In this fact sheet the CDEM plant is used as example.
The CDEM plant was originally invested in by Dutch mills in anticipation to more restricting legislation and higher costs regarding disposal of their sludges. Separation of the fibres from the inorganic material for recycling was considered unfeasible due to the difficulty of separation and that the inorganic end product had low value due to the mix of calcium compounds and meta-kaolin (individually the inorganic materials are much more valuable).

**Application**
The mineral product, called TOP-crete, can be used in the construction of roads/foundations, concrete, or as feedstock for the production of sand-lime bricks (SenterNovem CDEM 2009).

**Europe**
Although there has been some interest for expansion, CDEM is thus far the only installation in Europe producing high quality cement substitution products from paper sludges. The technology can also be installed on-site.

**Process:**
In the CDEM-process the remaining water of the sludge is evaporated and the organic fraction incinerated (SenterNovem CDEM 2009). Conversion takes place in an exothermic reaction at around 800 °C. The input materials of in-organics, organics and water are turned into Meta-kaolinite, calcium carbonate, calcium-oxide and vapour. The surplus energy during the process can be used to meet heating or electricity demand of other facilities/houses ([www.cdem.nl](http://www.cdem.nl)). The primary output is a stable, non-toxic cementitious mineral that can be sold as admixture to Portland cement or as a mercury sorbent in a coal-fired power stations ([www.cdem.nl](http://www.cdem.nl)).

CDEM processes around 185,000 ton (2009) of deinking sludge (wet) per year ([www.cdem.nl](http://www.cdem.nl)) with a capacity of around 25 ton/h (Voogt 2010). Only paper process sludges are eligible to be used as input in CDEM (deinking sludge, fibre sludge and waste water treatment sludges).

Differences with the method of combustion of deinking sludge and selling the residue as cement substitute is the quality. The process of low temperature (800°C) incineration of
the paper sludges only (no other materials are processed) is specifically designed to avoid any chemical mineral reactions, therefore no fly ash is created. Focus of CDEM is on the end-product (Topcrete) while the focus of combustion is on energy production.

Finance:
After initial investments the paper mills withdrew their participation as stakeholder of the CDEM plant. The CDEM plant is therefore independent. For the disposal of their sludges the mills pay CDEM a fee (competitive market price). CDEM also processes waste sludges of other paper mills. Aside from disposal fees, CDEM acquires income from selling TOP-crete to the cement industry and from selling (green) electricity to the grid. The payback time of the plant is difficult to assess but is estimated to be around 5 years with an initial investment of around 20 million euros (Voogt 2010). A minimal scale size of around 100.000 ton sludge processing per year is required according to Voogt (2010) for the plant to be economically feasible.

Environment:
The incineration (fluidized bed) of the sludges produces heat that is used to produce steam. The steam is converted into electricity using a steam turbine. As the energy production is bio-based in can be considered CO2 neutral. The electricity output is netto35 roughly 110 kWh/ton sludge_wet (Voogt 2010). CDEM produces 28.000 MWh of electricity per year (www.cdem.nl). The TOP-crete also substitutes cement, which is a highly energy intensive product emitting about 0.8 ton CO2 per ton of cement (www.cdem.nl). Note however that the partial calcination of the calcium carbonate in the deinking sludge also releases CO2 emission. Therefore, the netto avoided CO2 emissions is less. This study only focuses on the avoided energy consumption, which for an average Portland cement production is considered to be 4 GJ/ton heat and 100 kWh/ton electricity.

Experience of legislation:
The input side of the CDEM concept involves legislation for waste incineration. However, due to the process inherent ability of capturing all harmful emissions within the end-product, this provides no problem. As all emissions are far beneath the legal conditions, no expensive material is required for cleaning of the flue gases. The output side involves REACH legislation. This is however only valid for the CDEM concern as they provide the new product, and does not concern paper makers that provide the input sludges. Also, for CDEM REACH provides relative little problems, as the process takes place at low temperatures which therefore ensure that no chemical formations take place. In other words, merely the volume ratio’s change but the components in the end-product are already known under REACH.

Contact:
MinPlus CDEM
Nico Voogt

35 Electricity output after subtraction of initial needed energy for other processes.
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Mobile: +31 6 53 905 445
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6802 EB Arnhem-NL
Email: voogt@cdem.nl
16. **Gasification**

**Title:** Gasification36 (Industrially applied but not to paper production by-streams).

**Reject type:** Coarse rejects.

**Background:**
Crown Van Gelder (the Netherlands) has investigated gasification technology. Main motivations for this were the high Natural gas prices (at that time), reluctance to use combustion (waste incinerator status), less residue after energy conversion than with combustion, partly biomass and the fact that syn-gas from gasification can be used in existing CHP installation.

An advantage of gasification is the high energy density of the gas. Gasification takes place using low oxygen environment. This produces syn gas. One of the main issues of gasification at certain temperatures is the forming of tar during gasification. The gasification technology chosen by Crown Van Gelder has not shown problems with tar due to the higher process temperatures (about 1600°C).

CVG researched the gasification of plastic/paper waste streams, because of their high calorific values (about 18 MJ/kg). Use of sludges after drying for gasification has been researched by Crown Van Gelder. This option did not appear to be economically feasible. It is expected that larger gasification installations will be able to handle wet sludges for co-gasification, but this requires additional calculations.

The gasification process produces syngas which would also be used to replace an estimated 25% of the Natural gas use of CVG.

World-wide there are already many gasification installations active. Gasification of rejects (refuse derived fuel and municipal solid waste) are also gasified. Mixing with other streams is possible but in the Netherlands there is insufficient capacity.

**Process:**
Gasification uses a fluidized bed in low-oxygen conditions and high temperatures to convert organic material into gasses. Depending on the process conditions either syn-gas or product-gas is produced. Syngas is used for further conversion such as Fischer-Tropsch reactions. Product-gas is used for combustion.

The gasification technology researched by Crown Van Gelder will produce syn-gas which is combusted in the existing CHP and a new boiler. The new boiler produces steam which will be used to meet the heat demand of the drying section or be fully condensed in a steam turbine to generate electricity.

A disadvantage is that the biomass stream in general cannot have a higher moisture content than 15%. Although some suppliers claim that their installation can handle up to 50% moisture content, there is relatively little experience with these installations (Dehue 2006). The technology chosen by Crown Van Gelder however can handle 25% moisture content (proven).

About 6% of the material is leftover after conversion as inert granulate residue which can be used in road building works.

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36 This fact sheet was composed based on conversations with Ecofys and Crown Van Gelder
### Finance:
Large installation costs about 200-250 mln euro. The payback time depends strongly on the gas prices and the gate fee for Refuse Derived Fuel (RDF).

### Environment:
Some emissions that are emitted when using regular incineration is avoided due to the fact that clean syn-gas is produced. Recovered energy reduces the need for natural gas. Granulate residue replaces current needed material for road building.

### Experience of legislation:
Depending on the input of the gasification installation either national laws concerning emission conditions for combustion installations need to be followed or national laws concerning conditions for waste incineration plants. The gasification process has to comply with emission regulation for incineration. For example for the building of a gasification installation in the Netherlands a building permit and environmental permit is needed. The strictness of environmental legislation increases when building large installations.

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Mobile: +31 (0) 6-53933642  
Mail: h.jansen@cvg.nl
### 17. Supercritical gasification

<table>
<thead>
<tr>
<th>Title:</th>
<th>Supercritical gasification (research phase).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Sludges, coarse rejects.</td>
</tr>
</tbody>
</table>
| **Background:** | The supercritical gasification technology is well suited for wet biomass streams. Currently a global estimation by the developers at the University of Twente is that streams containing at least 3% of organic material will prove energy neutral. Higher content of organic material will lead to an increasing positive net output of energy. There is a threshold of maximum of 50% solid material because of the viscosity. Advantages are:  
- The technology is suitable for efficient processing of biomass with high moisture content  
- Utilization of different kinds of biomass as an energy source  
- Depending on feed composition, complete gasification can be achieved with in a short reaction time.  
- The formation of tar and char depends on feed, -conditions, reactor design and catalysts.  
- Product gas is available at high pressure in a single step process, thereby avoiding the cost of expensive gas compression  
- High energy conversion efficiency is achieved by avoiding the process of drying step  
- Selectivity towards methane, hydrogen, or syngas can be steered with temperature, pressure and using proper catalysts (www.utwente.nl)  
The technology is still under development. A full-time running micro-scale installation (2.5 liter/hr) has proven successful. Feeding solid biomass or slurries requires a larger scale installation, which is not yet available. Batch tests to investigate gasification conditions and efficiency are possible. Process development work will be required to make the process continuous. |
<p>| <strong>Process:</strong> | The process takes place at supercritical conditions, at temperatures above 374 °C and pressures above 22.3 MPa. Under these conditions water behaves like an adjustable solvent and biomass gets rapidly decomposed by hydrolysis. Because the cleavage products of biomass dissolve in the supercritical water, tar and coke formation is minimized. The technology produces energy rich gases such as hydrogen, synthesis gas or syn-gas (a mixture of CO and H2) and methane from the wet biomasa. An important element is the heat recovery of the energy of the outgoing stream. It is estimated that around 90% of the heat can be recovered by heat transfer between the outgoing and ingoing stream. |</p>
<table>
<thead>
<tr>
<th><strong>Finance:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>No information.</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
</tr>
<tr>
<td>No information.</td>
</tr>
<tr>
<td><strong>Experience of legislation:</strong></td>
</tr>
<tr>
<td>No information.</td>
</tr>
<tr>
<td><strong>Contact:</strong></td>
</tr>
<tr>
<td>DR. IR. D.W.F. BRILMAN</td>
</tr>
<tr>
<td>University of Twente</td>
</tr>
<tr>
<td>TNW/TCCB Meander 222</td>
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<tr>
<td>PO Box 217</td>
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<td>7500 AE Enschede</td>
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<tr>
<td>Telephone: +31-53-489 2141</td>
</tr>
<tr>
<td>Mob: +31-53-489 6969</td>
</tr>
<tr>
<td>Fax: +31-53-489 4738</td>
</tr>
<tr>
<td>e-mail: <a href="mailto:wim.brilman@utwente.nl">wim.brilman@utwente.nl</a></td>
</tr>
</tbody>
</table>
## 18. Combustion

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Combustion (Industrially applied).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Coarse rejects, deinking sludge, waste water treatment sludge, screen rejects.</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>According to Dehue et al. (2006) coarse reject (rejects from the screening phase of paper recycling process) is a waste stream that is well suited for energy recovery due to its high calorific value. In the Netherlands these waste stream are available in significant quantities. Deinking sludge and effluent sludges have less potential but can still be incinerated for their energetic value. In this fact sheet the combustion of coarse rejects at Parenco (paper mill in the Netherlands) is used as an example.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>In Parenco the Netherlands a bio-boiler is used to incinerate all paper waste streams (deinking sludge, primary sludge, secondary sludge and rejects). After removing ferro metals from the paper recycling rejects they are crushed and mixed with other components (such as wood and sludge) and stored. The sludges (deinking, waste water treatment sludge) are first mixed and pressed to obtain 50-60% dry matter and then fed to the boiler. The boiler can handle up to 390 tonnes per day of dried solid fuel. The installation can handle 30 ton/hour (approximately 240,000 ton annually). The boiler produces max. 48 MW thermal and max. 15MWe electricity by using a backpressure steam turbine. The low pressure steam (3 bars) is consumed internally in the process. After incineration ashes are leftover (about 30% of original volume). These can be landfilled or used for production of cement, asphalt or ground improvement.</td>
</tr>
<tr>
<td><strong>Finance:</strong></td>
<td>According to Dehue et al. (2006) it is economically favorable to incinerate coarse rejects for the production of low-pressure steam instead of electricity. Important is to note the chloride content of coarse rejects streams, this percentage can vary between paper mills. High chloride content can potentially lead to corrosion problems at especially high-temperature steam production. Electricity production requires such high-temperature conditions (Dehue et al. 2006). This in combination with significantly higher investment costs for a electricity producing facility in comparison to a low pressure steam producing facility make the usage of coarse rejects for steam production favorable. The investment in the incineration installation by Parenco was, when it was built (2003-2004), around 35-40 million euro. The payback time varies from 3-10 years depending on 1) the type of waste streams used, 2) any forms of subsidies, 3) savings on energy/disposal costs. In the case of Parenco the annual savings from reject incineration are around 800,000 euro (16,000 rejects per year).</td>
</tr>
</tbody>
</table>
The ashes are given to the cement industry. Currently this still requires a disposal fee, but Parenco has indicated that this may change from costs to profit in the future.

**Environment:**
The exact impact of the energy generation is difficult to determine as a large amount of the input comes from wood, sludges and rejects.

**Experience of legislation:**
New REACH legislation will affect Parenco procedures as mineral products are included.

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Website: www.norskeskog.com
## 19. Direct digestion

**Title:** Direct digestion (Industrially applied, but not to paper production rest streams\(^{37}\)).

**Reject type:** Screening rejects, deinking sludge, secondary sludge and (possibly) primary sludge.

**Background:**
Digesting is used by farmers and municipal sewage water plants as a relatively simple technique for a long time. The last decade biogas becomes a strong alternative for fossil fuel. The technology is developing rapidly and more and more attention is put into the pre-treatment processes. The produced biogas is cleaned and transferred into green natural gas. This can be inserted into the existing high-pressure gas distribution system. In Groningen (Holland) the Dutch government is supporting the start of the “Groningen Biogas Centre”, a knowledge centre where taller digesting units (10 to 150 m\(^3\)) are used to execute tests.

The project is set-up and coordinated by PROCES-Groningen. This company has performed research for the last 10 years in the field of digesting and biogas. They are leading in the area of pre-treatment of organic biomass as a preparation step before digesting biomass into biogas.

The main results of PROCES are a strong increase of the efficiency in biogas production and an increase of the capacity of the digesters. Both effects count positively in the financial calculations of digesters. ([www.proces.nl](http://www.proces.nl))

Some components of paper production rest streams such as calcium compounds can interfere with the digestion process, making them less suited. ([www.bioclear.nl](http://www.bioclear.nl))

**Process:**
The biomass is inserted into a digestion tank. In the tank micro-organisms convert the digestible fraction into biogas. The biogas consists of methane, CO\(_2\) and low concentrations of other gases (e.g. water vapour). 3-5% of the organic material is used for the growth of the bacteria. After the digesting process a watery stream containing dry matter called the digestate is leftover. ([Bioclear 2007](http://www.bioclear.nl))

The scheme below shows all the steps in the digesting-biogas process. The colour varies from green (well known) to red (practically no knowledge available). The English version will be put on the PROCES website soon.

Former digesting units only consisted of the number-3 block: the digester. They used to operate on waste and incidental feed flows. Modern digesters consist of 12 blocks and are fed with specific feed flows on a large scale. Digesting is becoming an industrial process.

---

\(^{37}\) Some streams that are digested sometimes contain paper. The largest stream of this type is the organic wet fraction of households. Also in some countries by-streams from the paper industry are co-digested with other streams. ([Bioclear 2007](http://www.bioclear.nl))

\(^{38}\) There has been some activity in Spain concerning the use of digestion. This has not been further investigated due to lack of time.
The waste flows from paper industry look very promising as feed flow for digesting units. The flows are substantial, are constant and consist of high concentrations of organics. These are important parameters for economically building and operating a digesting unit. The final and exact lay-out of a digesting unit for paper-waste has to be determined through lab-scale tests. The amount of gas production from the stream depends upon its components. Pure cellulose is very good for digestion with a yield of about 800 m3/ton d.m.. However the expected yields for secondary sludge is around 150 m3/ton d.m., and for screening rejects and deinking rejects around 200 and 400 m3/ton d.m. Reason for this is content of non-digestible impurities and components that are less well digestible (e.g. lignin). (Bioclear 2007) It is suggested that the digestate of the process might be suitable for use for paper production. (Bioclear 2007).

Finance:  
Currently the payback time of digestion of paper production by-streams is very long, even under favourable conditions such as high gas prices. To be economically feasible the disposal costs of the streams have to be high, biogas production yield needs to be improved and digestate needs to be applicable to preferably paper production (Bioclear 2007). Economic digesting can only be done when the yield of biogas in increased. The results of increasing yields are shown on the PROCES-lab. On chicken manure the yield went up from 18% to 55%; almost tripled. Economics of digesting systems are strongly depending on the cost of handling digestate.

Environment:
The produced bio-gas reduces the need for external (fossil) gas. Advantage to the environment will also depend upon the possibility to re-use the digestate. The process itself is hardly effecting environment.

**Experience of legislation:**
Building and environmental permits are required. Using bacteria as biogas producing organisms introduces the possibility of producing odour on a digesting plant. Attention should be given to this item.

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## Torrefaction

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Torrefaction (Pilot scale proven).</th>
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<tbody>
<tr>
<td><strong>Reject type:</strong></td>
<td>Coarse rejects (potential for sludges unclear yet).</td>
</tr>
<tr>
<td><strong>Background:</strong></td>
<td>In this fact sheet fox coal is used as an example. 75% of total world production of coal is used for power production. Since power is mainly made using steam coal, this is the design product for FoxCoal. Global power demand will double within 25 years and coal will stay to be the mayor fuel for it since it is the most abundantly available fossil fuel. FoxCoal has researched the potential to convert mixed waste streams from a.o. the paper industry into a fuel that equals the specifications of steam coal so it can be co-fired.</td>
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</table>
| **Process:** | The FoxCoal process involves the torrefaction of the waste stream after removal of the metal fraction (which is sold) at temperatures between 200-400°C. The heat is generated by using the gasses that form during the torrefaction process creating an autotherm process. Using this process results in:  
- Higher energy density (28 - 32 GJ/ton $\rightarrow$ 1,3 * Gross Calorific Value on dry basis)  
- Hydrophobic material  
- Black  
- No forming of tar gasses (major problem in gasification installations)  
Advantages to combustion on own site is:  
- No residues (so less waste management costs)  
- No requirements for investing in expensive flue gas cleaning equipment (this way the equipment of the power plant is used)  
- Chloride is partly captured by lime in paper and can be removed in a later stage by washing.  
Only streams that have a minimum of 50% fibres with the plastics are interesting, as otherwise it would be better to simply recycle the plastic. |
| **Finance:** | This depends completely on the market. What are the power plants willing to give etc. |
| **Environment:** | Conversion of coarse rejects (wet) using the FoxCoal technology delivers a powder coal replacing product with a value of 11.2 GJ per ton coarse rejects (wet). |
**Experience of legislation:**
The role of REACH is unclear yet. Uncertain whether the SRF is seen as waste or as a product under REACH.

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## 21. Secondary fuel

**Title:** Secondary fuel (Industrially applied).

**Reject type:** Coarse rejects.

### Background:
In this fact sheet Qlyte is used as an example.
Qlyte is a spin-off from the company Dutch chemical and biotechnology company Royal DSM N.V. Qlyte focuses on expanding the commercialization of the Subcoal® technology. This technology converts coarse rejects from paper and cardboard production into a high quality fuel (fluff, pellets or powder form). A working installation has been running at the Smurfit Kappa Roermond site for around 8 years. The main buyers of the Subcoal® fuels are lime- and cement producing companies. A potential future market lies in the electricity producing sector, as the powder form of the Subcoal® can replace powder coal currently used by some electricity producers.39

### Process:
The coarse rejects consist of roughly 50% water, and a mix of plastic, paper and other materials (e.g. metals, sand, rope fibre, wood shreds. The rejects are directly removed from the pulper and go into the process. Then after mechanical pressing the unwanted materials (metals, sand, pvc, water etc.) are removed by in subsequent steps. Then through thermal dewatering up to 10% water content a secondary fuel is obtained. Finally the product is pelletized.

Typically this fuel has around 22-23 GJ/ton energy value (although this can vary depending on the composition of the coarse rejects). About 15% of this end energy value is needed for the total conversion process of reject to pellet.

The composition of the coarse reject material may vary from 20%-80 % to 80%-20% ratio of plastic to cellulose (i.e. biomass).

Advantages of converting the coarse rejects to Subcoal® are:
- The higher efficiency of energy use per ton of coarse rejects
- Low ash content (making it ideal for use amongst other lime production)
- Low chlorine content
- Stable composition of end product
- Converting a waste stream into a valuable product for further use in proven applications

A Subcoal® producing installation is in operations at Smurfit Kappa Roermond for almost 8 years. The installation has low operation costs as virtually no personal is needed to run it. The installation produces approximately 16.000 ton Subcoal® per year from 35.000 ton of coarse rejects.

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39 This has been tested and is applicable. One current barrier is that the great demand of an average electricity producer for co-incineration of the Subcoal® cannot be met due to lack of production capacity. In the future this may be resolved as a central Subcoal® producing facility can gain input of several paper producers their reject streams.
A new installation is currently being built in Delfzijl, The Netherlands, which will use the reject streams of multiple paper mills. Estimated production is around 45,000 ton of Subcoal® from 80,000 ton coarse rejects per year. End-users of the Subcoal® will be lime- and cement factories in, among others, United Kingdom, Scandinavia and Germany. Projects for new Subcoal® installations in other European countries are also in progress.

**Finance:**
Qlyte offers two business cases. Either they supply the technology and installation as a total package (including marketing of the Subcoal® fuels) in which the paper mill becomes the owner of the installation and therefore gains profits from selling the pellets, resulting in a reduction of costs compared to the landfill or incineration of their coarse rejects. In the second option, Qlyte becomes the owner of the installation in which case Qlyte operates the plants and commercializes the Subcoal® fuels. Qlyte works with Siemens Paper and Pulp Technologies to deliver the process technology on a turn key basis.

If the paper mill chooses to own the installation, they will pay a license fee to Qlyte. If Qlyte owns the installation paper mills typically pay a fee to Qlyte per ton for processing of the coarse rejects. This fee will be lower than the fee for incineration or land filling.

Financial advantages are the avoidance of disposal costs and the sales income of the Subcoal® fuel. Benefits from avoiding disposal costs depend on the type of disposal and are also country specific (e.g. difference in land filling fees). Benefits from sales income depend upon regional prices for Subcoal® fuels.

The total investment for the Rofire® plant is around €6.580.000 (ManageEnergy, SenterNovem, 2000). The payback period is about 4 years when including the reduction in waste disposal costs (ManageEnergy, SenterNovem, 2000).

**Environment:**
Conversion of coarse rejects using the Subcoal® technology produces netto 12.8 GJ per ton coarse reject (wet)\(^{40}\).

**Experience of legislation:**
At the moment Subcoal® still falls under the waste directive. Because of this the necessary permits\(^{41}\) and protocols are required for moving of the Subcoal® to its end users. Should the status eventually change from waste to product status, such administrative procedures will no longer be necessary. However, this will mean that Subcoal® production will likely fall under REACH regulation. This in turn will also result in administrative work as well as obligation to proofing safety of Subcoal® according to REACH regulation. It is unknown how this status will change in the near future. Future developments in legislation concerning reduction of landfilling and waste incineration are expected to further increase in Europe and therefore further strengthening the commercial attractiveness of Subcoal® production.

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\(^{40}\) Environmentally, research has shown that creating subcoal® saves more energy than direct incineration (CE 2000 Schoen, et al, 2000.).

\(^{41}\) According to Qlyte obtaining of the environmental permit for their plant in The Netherland took around 8 months, which is a normal period of time for such permit trajectories. This is mainly because as they do not incinerate the waste themselves they do not have to obey the more stringent waste incineration legislations.
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Annex II:
New Fact Sheets (to be added progressively as submitted to CEPI).

In case you would like to submit a new Fact Sheet, please use the template below, filling all appropriate fields, and send it to Sophy Ashmead (s.ashmead@cepi.org) at CEPI.

In this annex the fact sheets of each technology is provided. An explanation of the content of the fact sheets is provided below. Fields marked with * are obligatory.

<table>
<thead>
<tr>
<th><strong>Title:</strong> Name of the technology (current application status)</th>
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<tbody>
<tr>
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<tr>
<td><strong>Reject type:</strong> Type of solid by-streams to which the technology applies</td>
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<tr>
<td><strong>Background:</strong> General description of the purpose of the technology</td>
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<tr>
<td><strong>Process:</strong> Description of the processes of the technology</td>
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<tr>
<td>Finance: Description of the benefits and costs of the technology</td>
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<tr>
<td>Environment: Description of impact of the technology on the environment (with focus on saved energy)</td>
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<tr>
<td><strong>Experience of legislation:</strong> Users/Suppliers views on needed permits and other regulatory matters concerning the technology (may be changed with the implementation of new Waste Directive)</td>
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<tr>
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<tr>
<td><strong>Contact:</strong> Contact information of parties that utilize/develop/commercialize the technology (OBLIGATORY)</td>
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