Material Recycling of Mixed Commercial Waste in Austria

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1. Introduction

The separate collection of waste materials such as glass, tin, aluminum, paper, plastic packaging materials by the municipal sector in Austria has been practiced successfully for nearly 20 years. ARA AG (Altstoff Recycling Austria), in Austria the top dog in the packaging collection, recently announced an increase in the amount of collected packaging by 34 % since 1995. Last year, the ARA-system collects more than 835,000 tons of packaging waste [1], going directly to material recycling or combustion (energy recovery). In addition to the municipal sector, commerce and industry also produce large quantities of recyclables. An increasing number, but not all of these materials, are internally recycled. Wastes are often given to municipal but also private collectors. This is increasingly a great hidden resource for waste materials. This utilization potential to use is also associated with the implementation of EU Directive 2006/12/EC. The so called Waste Framework Directive of the European Union (EU) is implemented with 15th of February 2011 in the amendment of the Austrian federal waste management act (AWG-novelette 2010). The directive sets a strict priority ranking. Here, the material recycling after prevention and reuse is clearly ahead of other waste treatment processes (e.g. mono- and co-incineration). In practice, there are limits for material recycling. Besides the quantity the complexity of waste continuously increases too. Especially very heterogeneous (waste) mixtures are in many ways problematic. The spreading use of valuable fractions is often difficult (large grain size spectrum,
contamination, impurities etc.). This rapidly increases the technical effort to recover waste materials. Therefore pre-treatment and an appropriate material separation of commercial and industrial waste become an important role [2].

The following chapters are dealing with the potential of waste recyclable materials in mixed commercial waste fractions. Furthermore, state of the art splitting and sorting techniques are described.

2. Waste & secondary raw material market

In the Austrian Federal Waste Management Plan 2011 [3] a total amount of about 2.2 million tons of commercial and industrial refuse (waste materials from separate collection) is reported. This represents approximately 4 % of the total annual waste generation in Austria, which includes excavated soil too. Besides these separate collected waste materials the existing exploitable potential is many times higher. The appropriate sequence of process steps to separate waste materials from residues will lead to a reasonably pure output of mixed recyclables. This not only save primary resources but also reduce energy requirements in comparison to primary production. In addition to actual waste producers, collection and disposal companies profit from the sale of different waste material qualities on the secondary market. An update of the European secondary raw material market for waste paper and waste plastics gives an idea of achievable gains.

2.1. Waste Paper Market

The use of waste paper in the paper and cardboard industry reaches a recycling rate of about 50 % today. Paper is therefore one of the world's most recycled materials.

Figure 1: Price trend for mixed waste paper bales, quality 1.02

The classification of recovered paper is based on CEPI-specifications. Mixed wastes (recyclables) from the commercial and industrial sector are usually assigned to Class I – unsorted paper and cardboard mixed with a low impurity level. Due to the heterogeneous composition, the moisture content and the degree of contamination, higher grades are hard to achieve. After the market collapse during the economic crisis, paper revenues have recovered again to reach and sometimes also exceed the pre-crisis levels. The calculation of prices is basing on the Wiesbadener Index. This index reflects the price development for recovered paper, sold by wholesalers in Germany. In addition, the European Economic Review (EUWID) publishes monthly prices per ton of mixed waste paper (see Figure 1). The red area indicates the maximum revenue for a ton of recovered paper quality 1.02 (paper and cardboard mixed bales) with a minimum content of 40 % newspapers and magazines). The blue curve represents the same quality but describe the lower price level. Currently the revenue for quality 1.02 is between 85 and 90 €/t [6].

2.2. Waste Plastics Market

In 2009, according to the Association of European Plastics Manufactures, Europe produced about 55 million tons of plastics, which represents a decrease of 8.3 % compared to the year 2008. The industry demand for plastics in 2009 was about 45 million tons. 40 % of the generated plastic, i.e. around 18 million tons, are used for packaging material every year. Polyethylene (HDPE and LDPE), polypropylene (PP), polyvinyl chloride (PVC) and polyethylene terephthalate (PET) leading the group of the most widely used plastics for packaging. Nearly one-fifth of all plastics produced in the industry are used for other applications including the automotive sector and electrical engineering. For these applications, in 2009 approximately 24.3 million tons (50 %) of plastic waste were recycled. 5.5 million tons went to material recycling, 7.6 million tons went to energy recovery by thermal treatment [5]. Beside the material re-use, high-calorific polymer (waste) fractions go into substitute fuel production. Figure 2 shows the material and energy recovery rates of individual EU member states. As shown by the example of Switzerland, in 2010 the material recovery rate was almost hundred percent. Besides Switzerland, Germany, Denmark and Sweden, Austria has one of the highest recovery rates (material + energy) for waste plastics in Europe.

Accurate information on plastic waste quantities in Austria is difficult to obtain. The quantity of licensed packaging waste from private homes and businesses collected through the ARA-system, who is organizing and financing the collection and recycling of packaging waste throughout Austria, is well determined. On the other hand, the amount of plastic waste in some commercial, production-related waste streams is inaccurately recorded only. One reason might be the strong sector-specific fluctuation in waste qualities and also quantities. That means that the waste composition can only be estimated. Nevertheless, according to the Statistical Office of the European Commission [6] the amount of plastic waste in 2008 in Austria was around 640,521 tons. Approximately 22 M-% came from private households, about 54 M-% originated from the industrial and commercial sector. The rest was divided between the service and trade sector as well as waste and sewage disposal. The whole number of approximately 641,000 tons are composed of 40 M-% plastic packaging waste (251,569 tons). A portion of 36 M-% (87,717 tons) of this amount went in material recycling processes, 38 M-% (94,062 tons) are incinerated. The rest, 24 M-% (62,981 tons) were used for substitute fuel production (co-incineration in cement industry). As mentioned before, data was taken from various sources with more or less large uncertainties. This leads to blurring in the amount of plastic waste. Therefore it is still uncertain where a number of about 6,809 tons remain.
Figure 2: Recycling rates for waste plastics in Europe


Figure 3: Price trend for waste plastics – PE-production waste

Similar to the waste paper price development, the price level of used plastics on the secondary raw material market is very volatile. Considering the price development over the past 3 ½ years at the beginning of the economic crisis in November 2008, there was a dramatic price decline (see Figure 3) for PE production waste. At this time, the market activity came nearly to a standstill, and trading of waste plastic was temporarily suspended. This crash affected both used plastics and (recycled) plastic granules. Currently, the price situation has stabilized and the secondary market is likely to recover. Prices reach pre-crisis levels again.

3. Industrial & commercial waste – raw materials potentials

For detailed waste characterization and to identify the raw materials potentials of commercial waste the outputs of a commercial waste splitting plant located in Vienna, Austria were investigated. This was part of a major funded project together with a waste management company. Through the mechanical treatment process, especially by treatment steps like crushing, sieving, air classification and Fe-separation, two outputs are generated: a high-calorific (HC) and a middle-calorific (MC) fraction. Both fractions represent alternative fuels (RDF), which are used in cement plants and fluidized bed combustions. Apart from the different calorific value (HC ca. 18 MJ/kg DS, MC ca. 14 MJ/kg DS), there is another important difference in the grain size spectrum. The particle size is > 120 mm for the high calorific material and between 20 and 120 mm for the middle-calorific RDF. In order to take into account any seasonal variations occurring in the output of the splitting plant, the sorting analysis was repeated on a quarterly basis over the total period of one year. Figure 4 shows the consistently very heterogeneous material input (commercial waste) and both output fractions (HC and MC).

Figure 4: Input material splitting plant (top left and right), HC (bottom left) und MC (bottom right)
The average waste composition divided into HC and MC shows Table 1. For each of the four sorting analysis a total of 14 fractions were investigated.

Table 1: Average material composition

<table>
<thead>
<tr>
<th>Waste group</th>
<th>Ø HC kg</th>
<th>Ø HC M-%</th>
<th>Ø MC kg</th>
<th>Ø MC M-%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inert materials</td>
<td>0.2</td>
<td>&lt; 1</td>
<td>3.2</td>
<td>3</td>
</tr>
<tr>
<td>Metals</td>
<td>0.7</td>
<td>1</td>
<td>0.4</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Textiles</td>
<td>7.6</td>
<td>11</td>
<td>5.1</td>
<td>6</td>
</tr>
<tr>
<td>Beverage bottles (PET)</td>
<td>1.2</td>
<td>2</td>
<td>1.1</td>
<td>1</td>
</tr>
<tr>
<td>Paper/Cardboard</td>
<td>12.5</td>
<td>18</td>
<td>13.7</td>
<td>17</td>
</tr>
<tr>
<td>Wood</td>
<td>4.0</td>
<td>6</td>
<td>7.9</td>
<td>10</td>
</tr>
<tr>
<td>Organic</td>
<td>0</td>
<td>0</td>
<td>0.7</td>
<td>1</td>
</tr>
<tr>
<td>Hazardous Waste</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plastics 2D dark</td>
<td>2.0</td>
<td>3</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>Plastics 3D dark</td>
<td>3.1</td>
<td>4</td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>Plastics 2D bright</td>
<td>16.5</td>
<td>23</td>
<td>5.3</td>
<td>7</td>
</tr>
<tr>
<td>Plastics 3D bright</td>
<td>9.8</td>
<td>14</td>
<td>6.0</td>
<td>8</td>
</tr>
<tr>
<td>Sorting residue (fine fraction)</td>
<td>8.0</td>
<td>11</td>
<td>26.5</td>
<td>34</td>
</tr>
<tr>
<td>Composite materials</td>
<td>5.3</td>
<td>8</td>
<td>6.0</td>
<td>8</td>
</tr>
</tbody>
</table>


The high calorific fraction contains a high content of 2D and 3D bright plastics, a total of 37 M-%. Paper and cardboard are represented by about 18 M-%. In comparison to HC, MC contains significantly less plastics but consist of more than one third (34 M-%) of fine fraction. The fine fraction was not sortable due to the small particle sizes. The paper, cardboard and wood content amounts to 27 M-%.

4. Sorting technologies in the field of industrial waste sorting

The previous chapter shows that primarily in the area of paper and cardboard as well as plastics there is a certain potential to recover recyclables out of mixed commercial waste. Would it be able to separate a part of these valuable materials, proceeds would be obtained on the secondary raw material market. By application of appropriate (fully) automated sorting technologies, it seems to be possible to divert a part of the total waste stream in favor of recycling. That means that the material no longer go directly to energy recovery. There are at least two advantages for the waste management companies: on the one hand, the cost-intensive incineration of waste can be reduce, on the other hand gains can be achieved through the sale of waste materials. This would be a classic example of a win-win situation.

High-performance, sensor-based technologies are state of the art in modern waste business. These technologies are increasingly used in particular in the field of waste sorting. With few exceptions (pre-sorting of waste) error-prone human sorting forces were largely replaced by machines during the last years. Technology in the field of separating valuable materials out of waste ranging from electromagnetic sensors to high-resolution camera systems, operating in visible and infrared wavelength range, to the material-selective X-ray technology. The wide application of powerful hardware (materials handling, sensors, detectors
etc.) together with intelligent and efficient working software solutions in the background, the identification and classification as well as the spreading of materials is nowadays many times better and faster compared to earlier purely manual sorting techniques. Human sorting forces do only quality assurance procedures to achieve the required purities of over 98% and more. Figure 5 shows a comparison of sorting procedures between then and now. In the following a brief overview of state of the art of waste sorting technologies is given.

**4.1. Line Scan Cameras**

Line Scan Cameras are usually used for automatic sorting of small objects (e.g. broken glass). The principle is based on the detection of various object-characteristics such as color (e.g. colored and white glass), shape, size and surface structure. Current line scan cameras achieve a resolution of 0.3 mm per pixel and recognize objects with a minimum size of 2 mm [8]. The process scheme is relatively simple, yet very effective. Waste materials on a conveyor belt are illuminated by several bright bulbs to stand out from the conveyor belt background. Shining-through light bulbs optionally provide a better contrast and give way to detect transparent materials. Uniform illumination over the entire conveyor bandwidth is crucial. New systems use innovative LED lighting for better light intensities, which are infinitely variable. Material ejection is done by a targeted air pressure pulse [7].

**4.2. Electromagnetic Sensors**

Electromagnetic sensors are found in metal scrap sorting and electronic waste processing. The principle is based on the change in the electromagnetic field strength of an artificial magnetic field by electrically conductive materials in waste streams. Under the conveyor belt at a distance of a few centimeters coils built up a high frequency electromagnetic, upward directed field by applying voltage. When a conductive material (e.g. metal wire) passes this field, it comes to an induction of eddy currents. This subsequently results in a loss of field energy, which can be detected by sensitive electromagnetic sensors. The resolution of modern systems with variable thresholds can be increased by digital image processing techniques [7].

**4.3. Near-infrared (NIR)-sorting**

Near-infrared sorting systems operate in the infrared wavelength range between 800 and 2,500 nm. They are based on the principle of transmission and reflection of radiation. During irradiation, a variety of materials show very specific reflection properties, i.e. at certain
wavelengths, the resonant frequency of the irradiated molecules corresponds. The result is that the molecules begin to vibrate and send out light at a specific wavelength. This part of the non-absorbed wavelengths can be detected. By utilizing this effect, it is possible to clearly determine types of materials in real time. Similar to a material specific fingerprint, the spectra, which are represented by the reflected light, are unique for each type of material. In the first step, the detection of material flows consisting of different materials takes place. A NIR-detector unit which is placed above the acceleration belt conveyor scans the entire belt width. For the next step of separating out previously defined target objects, their properties such as material type, shape, structure etc. as well as their position on the conveyor belt are determined and stored in fractions of seconds. The removal of a target object can be positive or negative. During positive sorting (recyclable materials in the ejection fraction) objects are separated pneumatically. This is done by precision air jets to eject defined objects at the end of the conveyor belt. In contrast to this, negative sorting (recyclable materials remain in the flow) is an optional step for post-cleaning to reduce contaminants and also to increase the purity of the material flow. NIR sorting is among other application areas used in waste plastics sorting (yellow bag). Technical optimization accompanied with the extension to other waste fractions (e.g. commercial waste) is an ongoing process [2].

4.4. X-ray sorting

X-ray radiation has been used for many years in the medical and non-destructive material testing sectors. This short-wave electromagnetic radiation has the property to penetrate the material (e.g. waste). In contrast to the previously mentioned optical sorting methods (line scan camera and infrared spectroscopy), the performance of X-ray sensor is not negatively influenced by the degree of impurities. That means that inherent dirt particles don’t have a general influence on the material detection. The radiation is only influenced by the atomic composition and the density of the irradiated material (weakening effect can be measured). This weakening is picked up by imaging sensors and is evaluated by the classical methods of image processing. One potential field of application for X-ray sorters is the material-specific detection of dark and/or highly polluted (organic) materials (plastics, wood etc.), but also the detection of inorganic inert materials such as rocks, bricks etc. In the alternative fuel production, X-ray sensors are able to detect and to remove problematic chlorine sources such as dark PVC plastics as well as inorganic components (stones, ceramics etc.). The separation of special (heavy) waste from the municipal and industrial sector into a usable composting (or combustion) fraction and an inorganic deposit fraction is also possible [7].

5. Outlook

Rising greenhouse gas emissions, the careless handling of finite energy and raw material resources and the lavish use of limited landfill space require a rethinking, not only on the production and consumption sector, but also in terms of waste management. As mentioned in the introduction, the way of waste management towards resource management is clearly marked. The development has already begun. This is especially true for countries with a high environmental and technical standard. In terms of environmental legislation, Austria and Germany decidedly play a leading role within the European Union. The sustainable use of primary resources is more important than ever. The substitution of primary commodities and the enforcement of secondary raw materials have to be pushed even more in the future. This seems to be necessary in terms of energy-efficiency (comparing primary production and recycling). As shown, some of today’s waste fractions contain large amounts of recyclable materials (plastics, paper, metals etc.). It often requires appropriate and coordinated
pre-treatment processes to separate complex waste mixtures. The next step is to use modern sorting technologies to collect valuable materials out of waste streams. The comparison of costs and benefits should be more important than ever. Among other universities, Montanuniversität Leoben, namely the Institute for Sustainable Waste Management and Technology (IAE) is involved in several research projects on material recycling and has a long-term close cooperation with leading waste management companies.

6. Literature


