# Processing of Heterogeneous Waste Streams by NIR Sorting

## – Reflections on the Material-Specific Recovery based on selected M(B)T-Waste Streams –

Arne Michael Ragossnig, Manuel Sommer, Simone Maria Pieber and Martina Meirhofer

## 1. Introduction

### 1.1. Background

The material recycling as well as the energetic utilization of waste are preferred options in waste management in Europe and Austria in particular. Recovery options are not only to be found based on the current legal framework [4] but are also preferable options compared to pure disposal due to economic reasons. In general, optimized material specific waste routing not only allows for maximizing recovery but also minimizing the over-all costs for the management of a specific waste stream.

Especially in case of heterogeneous waste streams which cannot be reused or material recycled *Waste-to-Energy* (WtE) is one particularly interesting option. Waste material used as energy resource, e.g. in industrial co-incineration as *Solid Recovery Fuel* (SRF) in order to replace fossil fuels, needs to be processed to meet certain quality criteria (e.g. in terms of fuel properties as well as the chlorine and heavy metal content). Being the reason for this to avoid negative influences on the co-incineration process as well as the product quality in the case of the cement industry and to secure that environmental standards are not being compromised [10]. During the last years in Europe the biogenic carbon content of the waste streams to be co-incinerated has gained in importance as a determining criterion for the energetic recovery of waste due to legal obligations and resulting economic considerations (EU's $CO_2$ emission trading scheme) [5].

The required processing demands – material-specific splitting of heterogeneous waste – in order to allow for an optimized routing of resulting waste streams can potentially be met by the use of sensor-based sorting technologies, which are already state-of-the-art for the treatment of separately collected recyclables which are rather homogeneous in their composition. According to Faist & Ragossnig [6] as well as Titech [11] practical results show that the implementation of NIR (*Near-infrared*) sensor-based sorting is capable of splitting also heterogeneous wastes by material-specific characteristics and allows for generating waste streams that can be recovered.

## 1.2. Motivation

Technical experiments have been conducted in order to evaluate the applicability of NIR-sensor-based sorting on output waste streams from (case 1) an existing mechanical (splitting) facility as well as (case 2) a mechanical biological waste treatment plant.

In case (1) the investigations concerning the technical feasibility encompassed the objectives to decrease the chlorine/pollutant content and to generate one output-stream with elevated biogenic carbon content as well as one with increased fossil carbon content [9]. Based on the quality achieved the former of these output streams could be routed to material recovery in the pulp & paper industry or be used as SRF in co-incineration (for example as calciner fuel in the cement industry). The latter output stream could be further processed to a high quality kiln burner fuel for the cement industry.

In case (2) the aim was to separate high calorific components (e.g. plastics, wood, textiles) from inert materials (e.g. glass, stones) [7]. The motivation here was to allow for subsequent landfilling of the inert material (i.e. heavy fraction (HF)) and to energetically recover high calorific components (i.e. light fraction (LF)) as opposed to a thermal treatment of the complete mass stream as it is the case at the moment.

## 2. Sensor-based sorting

Basically, the process of sensor-based sorting consists of the same principal sub-processes as manual sorting, but there are some significant advantages, which speak in favour of automated sorting units. While manual sorting is restricted to a relatively coarse grain size, with sensor-based sorting systems also small particles, depending on the material, can be sorted. Additionally higher throughputs and better qualities can be achieved.

For sensor-based sorting it is essentially to create a monolayer of waste particles on the conveyor belt which is feeding the sorting device. While passing through the sensor-based sorting device objects get detected by a sensor. In case of sensor-based NIR-sorting the identification criterion are material specific NIR spectra. After detection the information is sent to a computer for processing. If the specific NIR spectrum is similar to the NIR spectrum of the material that is targeted to be ejected, the system issues a command and pressurized air coming from ejection valves ejects the detected object.

Figure 1 displays the functional principle of sensor-based sorting. The input stream is separated into a Passing fraction and a Reject fraction based on the material specific properties of the individual particles.

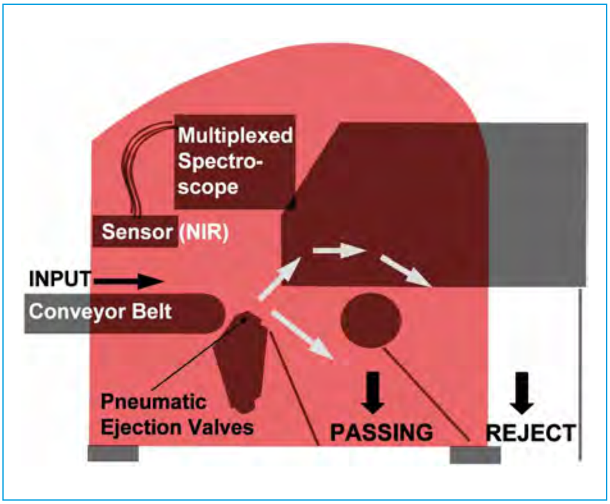


Figure 1:

Functional principle of sensor-based sorting

Source: BT-Wolfgang Binder: Information and material provided by the BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria). 2010, mod.

# 3. Technical feasibility

## 3.1. High calorific (HC) and middle calorific (MC) waste stream from a mechanical treatment (splitting) facility (case 1)

Following two waste streams (highlighted in red in figure 2) were selected for the investigations with regard to further processing by sensor-based NIR sorting:

- High calorific fraction (HC), particle size >120 mm, lower heating value (LHV) > 20 $MJ/kg_{dry}$, used for SRF-production,
- Medium calorific fraction (MC), particle size 20 – 120 mm, LHV < 20 $MJ/kg_{dry}$, currently used directly as SRF in the so-called *HOTDISC* process (calciner fuel in the cement industry).

Figure 2 displays the over-all plant concept of the mechanical treatment plant and the fractionation of the respective output streams. This plant treats approximately 60,000 t/a of commercial and pretreated waste.

The HC waste stream mainly contains fossil materials (bright and dark plastics, about 40 to 80 wt %) and a smaller part of biogenic components (undefined organics, wood, paper and cardboard, about 20 wt %). The MC waste stream consists of high portions of biogenic materials (undefined organics, wood, paper and cardboard, about 30 wt %) as well as fossil materials (bright and dark plastics, about 20 wt %). Due to the small particle

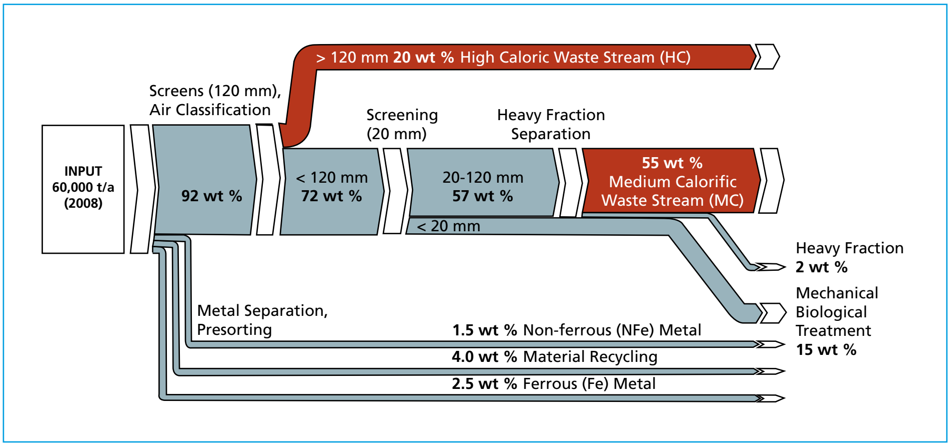


Figure 2: Sankey flow chart of the waste streams of the addressed mechanical treatment plant (Case 1)

size about up to 50 wt % of the MC waste stream was classified as *fine fraction* and not distinctly characterized with regard to its material composition during the manual sorting campaigns. Detailed information concerning the material composition as well as results in terms of purity and yield of the processed waste streams can be found in literature [8].

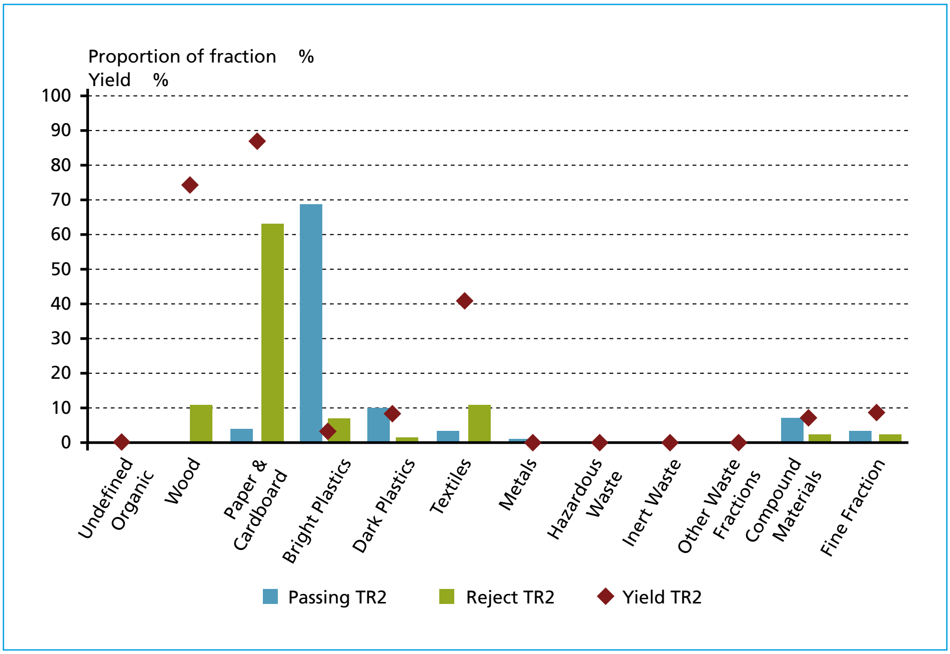


Figure 3: Fraction specific yield (Reject) as well as material composition of resulting output waste streams (Passing, Reject) from sensor-based NIR-sorting of the HC-waste stream (Case 1)

The processing of the HC and the MC waste stream by sensor-based NIR-sorting should allow for optimized material specific routing of the resulting output waste streams in order to increase the application potential in a variety of (co-) incineration options in industry and to also possibly open new options for material recovery. This was realized by separating polyvinyl chloride (PVC) from the waste stream in a first step. The trials showed that the separation of around 4 – 5 wt % of the total mass allowed for the separation of > 30 – 40 % of the chlorine-freight. Simultaneously cadmium and lead (used as PVC-stabilizers) were removed up to an extent of > 60 % [9].

Additionally, a waste stream with increased biogenic carbon content was separated in a second processing step as the share of biogenic $CO_2$-emissions is crucial for co-incineration facilities which are subject to the EU $CO_2$ emission trading scheme [5]. The processing trials have shown that the percentage of biogenic carbon could be increased 3 to 4-fold [9] such that up to 77 % of the resulting $CO_2$-emissions from the co-incineration of this SRF would be of biogenic origin. Figure 3 and figure 4 exemplarily (test-run 2 (TR2)) display the composition of the resulting output waste streams (Passing = fossil carbon enriched waste stream, Reject = biogenic carbon enriched waste stream) of this second processing step for the HC (figure 3) as well as the MC (figure 4) waste stream under investigation.

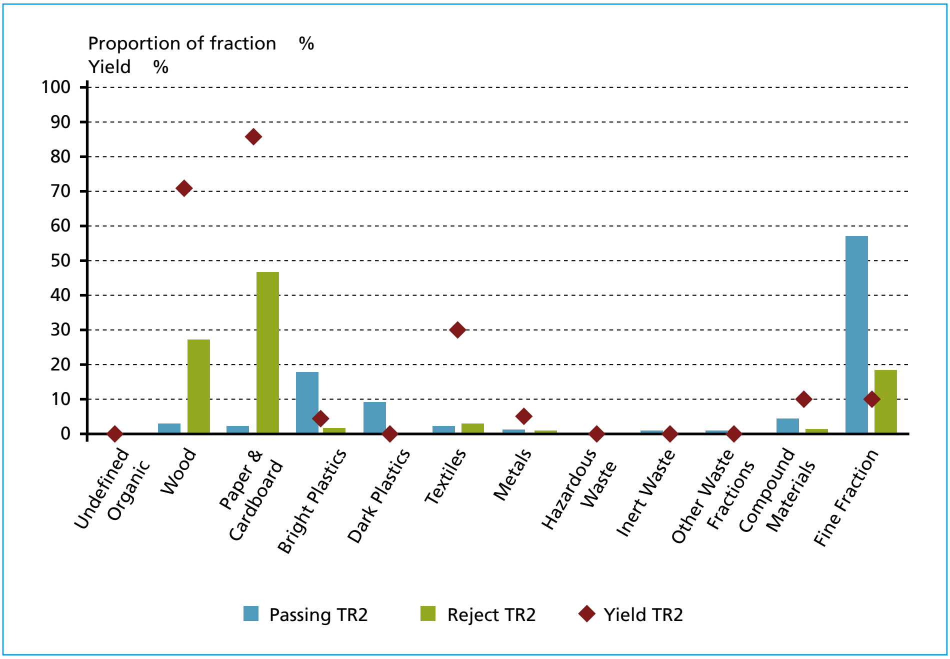


Figure 4: Fraction specific yield (Reject) as well as material composition of resulting output waste streams (Passing, Reject) from sensor-based NIR-sorting of the MC-waste stream (Case 1)

In addition to the material composition of the resulting output waste streams figure 3 and figure 4 display the yield of the individual fractions into the Reject. Based on the objective of this processing step (i.e. maximizing the biogenic carbon content in the Reject) wood, paper & cardboard, textiles of biogenic origin as well as biogenic components in the fine fraction and undefined organics should be ejected to the Reject-fraction. Most of the paper

& cardboard (> 85 %) and wood (> 70 %) was ejected correctly and could therefore be found in the Reject. With regard to the fine fraction and undefined organics the separation was not very specific respectively not possible at all. The reason for this was the small particle size of the fine fraction on the one hand and the lack of specific NIR-identification spectra for the undefined organic fraction on the other hand. Only very small quantities of plastics have wrongly been ejected to the Reject.

## 3.2. Heavy fraction (HF) from a mechanical biological waste treatment plant (case 2)

In case (2) the technical application for NIR sensor-based sorting was evaluated for the processing of a heavy fraction (HF) from a mechanical biological waste treatment plant (particle size 20 – 80 mm) that includes – besides approximately 40 wt % of inert material – more than 50 wt % of high calorific components. Therefore this waste stream cannot be dumped on Austrian landfill sites according to regulatory requirement in place [1].

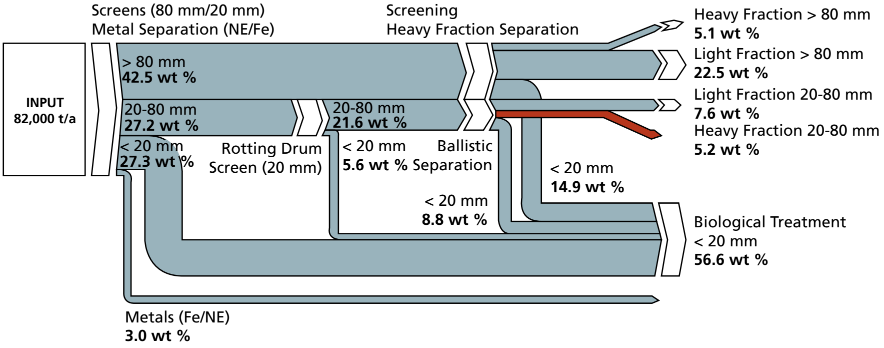


Figure 5: Sankey flow chart of the waste streams of the addressed mechanical biological waste treatment plant (Case 2)

Figure 5 displays the over-all plant concept of the mechanical stage of the mechanical biological waste treatment plant and the fractionation of the respective output streams (HF highlighted in red). This plant treats approximately 82,000 t/a of household and household like commercial waste.

The objective here was to separate materials with a comparably high calorific value (=> light fraction (LF)) from non-combustible components (i.e. inert materials, => heavy fraction (HF)) in order to meet the Austrian requirements for waste to be landfilled [1] (e.g. higher heating value < 6.6 $MJ/kg_{dry}$). Detailed information on the technical feasibility based on the processing experiments concerning this waste stream is to be found in Meirhofer et al. [7]. Figure 6 exemplarily (test-run 2 (TR2)) displays the composition of the resulting output waste streams (Passing = heavy fraction (HF), Reject = light fraction (LF)) of this processing step for the waste stream under investigation.

In this application the material selectivity of the separation step was lower than in case (1) nevertheless the Passing (=heavy fraction) of this separation step met the requirements for landfilling as defined in the Austrian landfill directive [1]. The higher heating value achieved for that output waste stream was 4.6 $MJ/kg_{dry}$. The fractionation was 48 wt % HF (to be landfilled) and 52 wt % LF (to be energetically utilized).

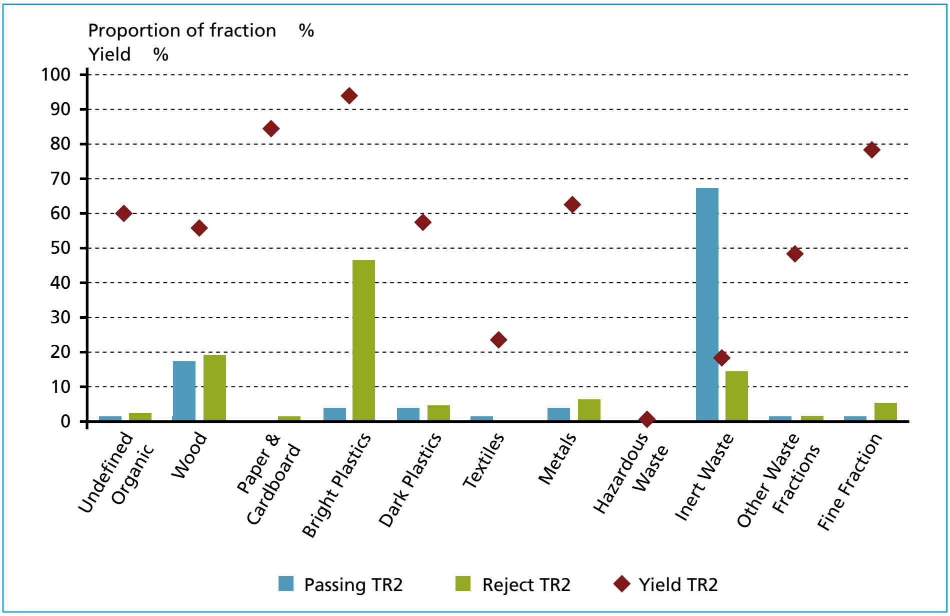


Figure 6: Fraction specific yield (Reject) as well as material composition of resulting output waste streams (Passing, Reject) from sensor-based NIR-sorting of the HF-waste stream (Case 2)

In both cases the motivation of evaluating the NIR sensor-based sorting technology is to investigate its capability for broadening the waste contractor´s routing options for the resulting waste streams and thereby allowing for savings in the overall waste management costs for the specific waste streams looked at.

# 4. Economic evaluation

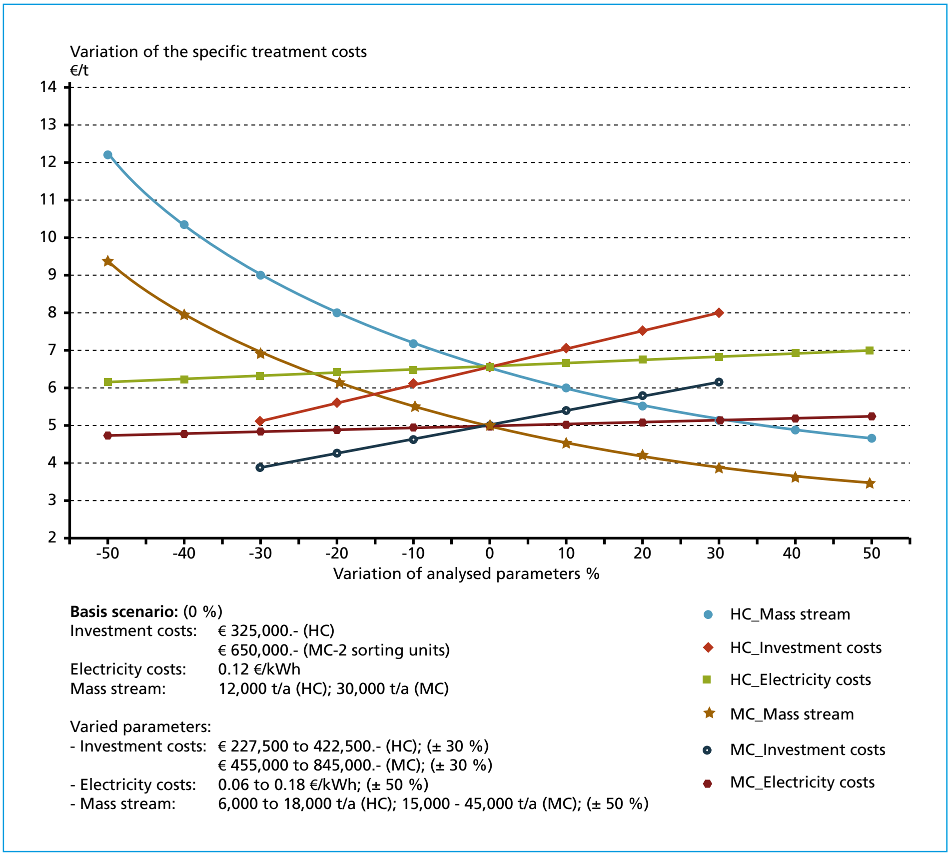
## 4.1. Methodology

In order to evaluate the economic benefit of implementing a sensor-based sorting step into a mechanical treatment plant scenario analyses have been performed taking into consideration the new routing options based on the quality of the generated waste streams. The scenario analyses are based on the variation of a number of parameters including the investment costs of the NIR sensor-based sorting step to be implemented, the mass stream of the waste to be treated and the costs for electricity needed for the operation of the additional processing step. Furthermore, the influence of the fractionation of the resulting output streams as well as the specific costs/revenues for the treatment/utilization or disposal of the generated output waste streams depending on the routing option chosen has been evaluated. The economic analysis is based on the prevailing Austrian cost situation in the waste and resources sector.

The general principle of the economic evaluation is based on analyzing the influence of the variation of the mentioned parameters (x-axis) on (1) the specific treatment costs for the additional processing step (y-axis) and (2) on the overall cost reduction that can be achieved compared to the reference scenario (i.e. the prevailing situation without sensor-based sorting step) (y-axis) for the waste management of the waste streams looked at by varying defined parameters in between a defined range (x-axis).

## 4.2. High calorific (HC) and middle calorific (MC) waste stream from a mechanical treatment (splitting) facility (case 1)

In figure 7 the influence of the varied parameters (i.e. investment costs, electricity costs and mass stream) on the specific treatment costs for the additional processing step for the high calorific fraction (HC, > 120 mm) and the medium calorific fraction (MC, 20 – 120 mm) is displayed.



**Basis scenario:** (0 %)
Investment costs: € 325,000.- (HC)
€ 650,000.- (MC-2 sorting units)
Electricity costs: 0.12 €/kWh
Mass stream: 12,000 t/a (HC); 30,000 t/a (MC)

Varied parameters:
- Investment costs: € 227,500 to 422,500.- (HC); (± 30 %)
  € 455,000 to 845,000.- (MC); (± 30 %)
- Electricity costs: 0.06 to 0.18 €/kWh; (± 50 %)
- Mass stream: 6,000 to 18,000 t/a (HC); 15,000 - 45,000 t/a (MC); (± 50 %)

Figure 7: Influence of the variation of the investment costs, electricity costs and the mass stream for the HC- (> 120 mm) and the MC-fraction (20–120 mm) on the specific treatment costs for the additional processing step

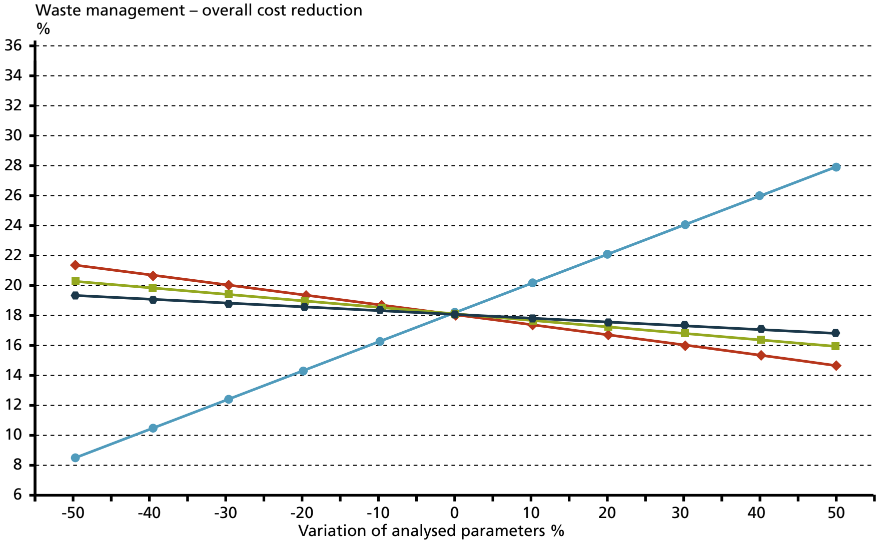
Source: Data for basis scenario according to Curtis, A.; Felber, J.; Haider, R.; Pomberger, R.: Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria), 2011

Compared to a defined basis scenario (starting point: 0 % on the x-axis), only one parameter (e.g. only the investment costs) is varied at a time (a range of -50 % to +50 % variation on the x-axis is considered, except for the investment costs due to the fact that a range of +/-30 % is more realistic in that case). The specific treatment costs in the basis scenario were calculated with investment costs of € 325,000.- for the HC-fraction and € 650,000.- for the MC-fraction (2 sorting units due to the larger mass stream). The variation of these costs also considers the required peripheral installations for sensor-based sorting. The operation costs further consist of annual labour costs (€ 4,000.-) electricity costs (0.12 €/kWh) and maintenance costs (€ 6,750.- (HC-fraction) respectively € 13,500.- (MC-fraction)) (Data for basis scenario according to Curtis [3]). The results of the evaluation show specific treatment costs in the basis scenario of about 6.50 €/t for the HC-fraction and 5 €/t for the MC-fraction. By analyzing the influence of varying the investment costs, the electricity costs and the annual mass stream it was observed that a variation of the mass stream has the most significant influence on the specific treatment costs for both waste streams. With an increased annual mass stream of 50 % a reduction of the specific treatment costs of about 2 €/t for the HC-fraction respectively 1.50 €/t for the MC-fraction compared to the basis scenario could be achieved.

Furthermore, the influence of varying parameters on the reduction potential of the overall costs for the management of the respective waste streams compared to a reference scenario has been analyzed. In figure 8 the reference scenario represents the current situation for the HC-fraction with specific utilization costs of 0 €/t (+ 80 €/t for transport and further SRF-processing as well as 7 €/t for landfill tax). This reference scenario is compared to the scenario with the newly opened options for the utilization/treatment of the processed waste streams. Those waste streams are in detail Reject 1 (PVC enriched fraction), Reject 2 (biogenic carbon enriched fraction) and Passing 2 (fossil carbon enriched fraction). The varied parameters for the scenario analysis are the specific treatment/utilization costs for the different waste streams considering the current market situation. The mentioned prices are primarily influenced by the quality of the waste stream which leads to the fact that Reject 1 (PVC) has comparatively high specific treatment costs (120 €/t incl. transport costs). Due to the better quality of Reject 2 (biogenic) and Passing 2 (fossil) the specific costs are assumed at -10 €/t (incl. transport costs) respectively -5 €/t (+80 €/t for transport and further SRF-processing as well as 7 €/t for landfill tax). Specific costs with values lower than 0 €/t represent revenues for the recovery of this generated waste stream for the waste contractor (e.g. the specific treatment/utilization costs for Reject 2, figure 8). The fractionation of the output streams which is also analysed is based on the results achieved in pilot scale processing tests; it is nearly the same for both waste streams (Reject 1: about 5 %, Reject 2: about 20 %, Passing 2: about 75 %).

By analysing the economic evaluation of the HC-fraction it was observed that an overall cost reduction in the basis scenario (0 % on the x-axis) of 18 % compared to the reference scenario can be generated. Furthermore, it was found that an increase of the mass fraction of the fossil output stream has the largest influence on the economisation which is caused by the fact that the mass fraction of the fossil output stream is much higher compared to the other fractions (PVC/biogenic output) and also the costs for the further management of this waste stream (including further SRF-processing) are relatively high. Under optimized conditions (i.e. maximising the biogenic fraction and minimizing the fossil fraction) an overall cost reduction of nearly 28 % compared to the reference scenario can be achieved.

The same principle is used for the economic evaluation regarding the MC-waste stream which is analysed in figure 9. The input parameters for the reference and basis scenario are adjusted according to the quality of the MC-waste stream. The lower SRF quality of the MC-waste stream (lower calorific value than the HC waste stream) leads to higher specific treatment costs for the reference scenario (75 €/t including transport costs, but no need for further SRF processing) as well as for Passing 2 (40 €/t including transport costs). The quality of the Reject 1 and Reject 2 separated from the MC- waste stream equals the quality of the respective fractions separated from the HC- waste stream, therefore the specific treatment costs have been assumed to be the same in both cases.



**Reference scenario:** 0 €/t (+80 €/t transport costs/SRF processing; +7 €/t landfill tax)
**Basis scenario:** (0 %)
Specific treatment costs for:

| | |
|---|---|
| - additional processing step: | 6.54 €/t |
| - Reject 1 (PVC): | 120 €/t (incl. transport costs) |
| - Reject 2 (biogenic): | -10 €/t (incl. transport costs) |
| - Passing 2 (fossil): | -5 €/t (+80 €/t transport costs/SRF processing; +7 €/t landfill tax) |

Mass fraction of Reject 1/Reject 2: 5 % / 20.9 %

Varied parameters: (± 50 %)
Treatment costs for:

| | |
|---|---|
| - Reject 1 (PVC): | 120 €/t (60 €/t to 180 €/t) |
| - Reject 2 (biogenic): | -10 €/t (-15 €/t to -5 €/t) |
| - Passing 2 (fossil): | -5 €/t (-7.5 €/t to -2.5 €/t) |

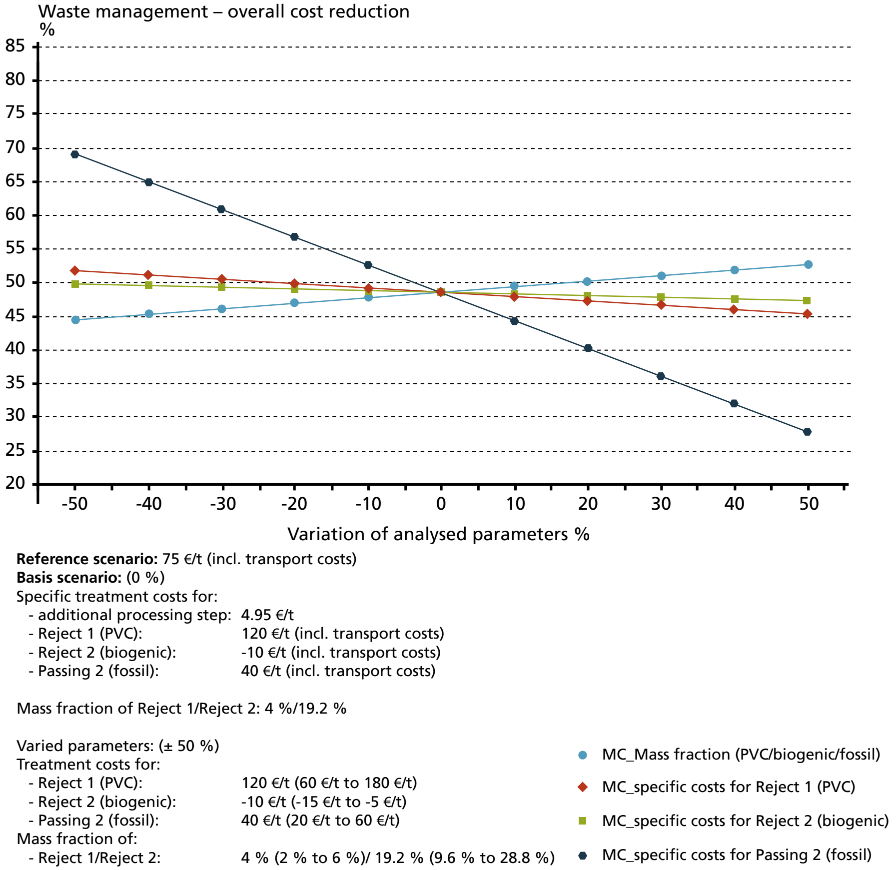
Mass fraction of:

| | |
|---|---|
| - Reject 1/Reject 2: | 5 % (2.5 % to 7.5 %)/ 20.9 % (10.5 % to 31.4 %) |

Figure 8: Influence of the variation of the specific treatment/utilization costs/revenues and the mass fraction for Reject 1/Reject 2 and Passing 2 of the HC-fraction (> 120 mm) on the overall cost reduction compared to the reference scenario

Source: Data for basis scenario according to Curtis, A.; Felber, J.; Haider, R.; Pomberger, R.: Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria), 2011

Regarding the results of figure 9 an overall cost reduction of nearly 50 % in the basis scenario (0 % on the x-axis) compared to the reference scenario can be generated by implementing NIR sensor-based sorting into the mechanical waste treatment plant. Additionally, it was found that a variation of the specific costs for Reject 1 and Reject 2 only has marginal influence on the overall cost reduction (about ±3 %). A higher influence is given by the variation of the mass fraction for the generated waste streams. By maximising the biogenic waste stream (Reject 2) an overall cost reduction of about 53 % can be achieved. The determining key factor for a beneficial economisation is obviously given by a variation of the specific treatment costs for Passing 2. Under optimized conditions (which means -50 % parameter variation on the x-axis for the specific treatment costs of the Passing 2) cost reductions of 70 % compared to the reference scenario could be generated.



**Reference scenario:** 75 €/t (incl. transport costs)
**Basis scenario:** (0 %)
Specific treatment costs for:
- additional processing step: 4.95 €/t
- Reject 1 (PVC): 120 €/t (incl. transport costs)
- Reject 2 (biogenic): -10 €/t (incl. transport costs)
- Passing 2 (fossil): 40 €/t (incl. transport costs)

Mass fraction of Reject 1/Reject 2: 4 %/19.2 %

Varied parameters: (± 50 %)
Treatment costs for:
- Reject 1 (PVC): 120 €/t (60 €/t to 180 €/t)
- Reject 2 (biogenic): -10 €/t (-15 €/t to -5 €/t)
- Passing 2 (fossil): 40 €/t (20 €/t to 60 €/t)

Mass fraction of:
- Reject 1/Reject 2: 4 % (2 % to 6 %)/ 19.2 % (9.6 % to 28.8 %)

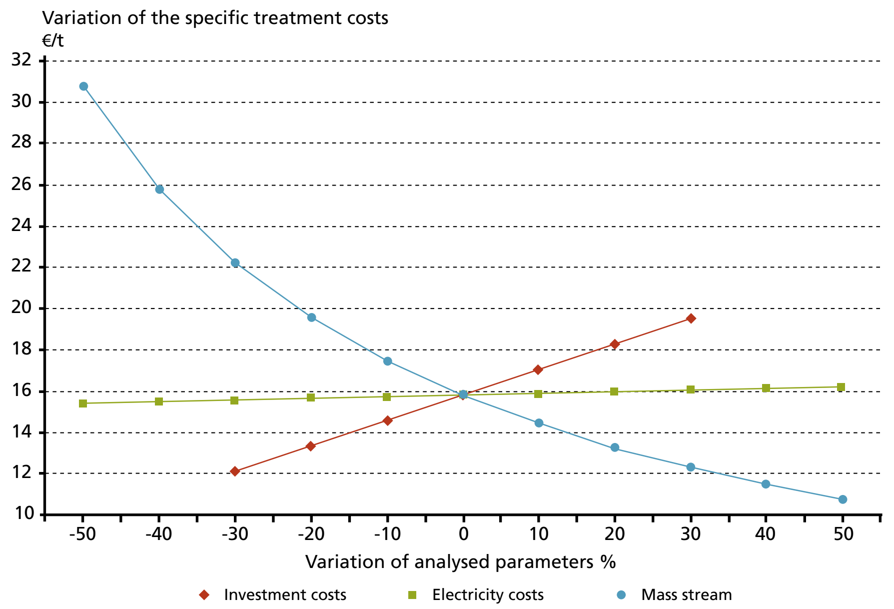
Figure 9: Influence of the variation of the specific treatment/utilization costs/revenues and the mass fraction for Reject 1/Reject 2 and Passing 2 of the MC-fraction (20-120 mm) on the overall cost reduction compared to the reference scenario

Source: Data for basis scenario according to Curtis, A.; Felber, J.; Haider, R.; Pomberger, R.: Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria), 2011

## 4.3. Heavy fraction (HF) from a mechanical biological waste treatment plant (case 2)

The following figures (figure 10 to figure 12) represent the results of the economic evaluation for a heavy fraction resulting from ballistic separation (particle size 20-80 mm) that was processed by sensor-based sorting in order to generate a high calorific fraction (light fraction (LF)) and a non-combustible fraction (heavy fraction (HF)) which can be disposed of at Austrian landfill sites. Again the same principle as in case 1 for the HC- and MC-waste stream is used in order to analyse those parameters with the most important influence (1) on the specific treatment costs for the additional processing step and (2) on the overall cost reduction for the waste management of the waste stream looked at compared to the reference scenario.

The specific treatment costs in the basis scenario of figure 10 were calculated with investment costs of € 275,000.- and further operating costs including annual labour costs of € 4,000.-, electricity costs of 0.12 €/kWh and maintenance costs of € 6,750.- per year with an annual mass stream of 4,000 t/a. The results in figure 10 show specific treatment costs for the additional processing step of 16 €/t. By analyzing the influence of the varied parameters (i.e. investment costs, electricity costs and the annual mass stream) in detail, it was observed that in this case also a variation of the annual mass stream has the most significant influence on the specific treatment costs. By an increase of the annual mass stream of 50 % the specific treatment costs could be reduced to 11 €/t.



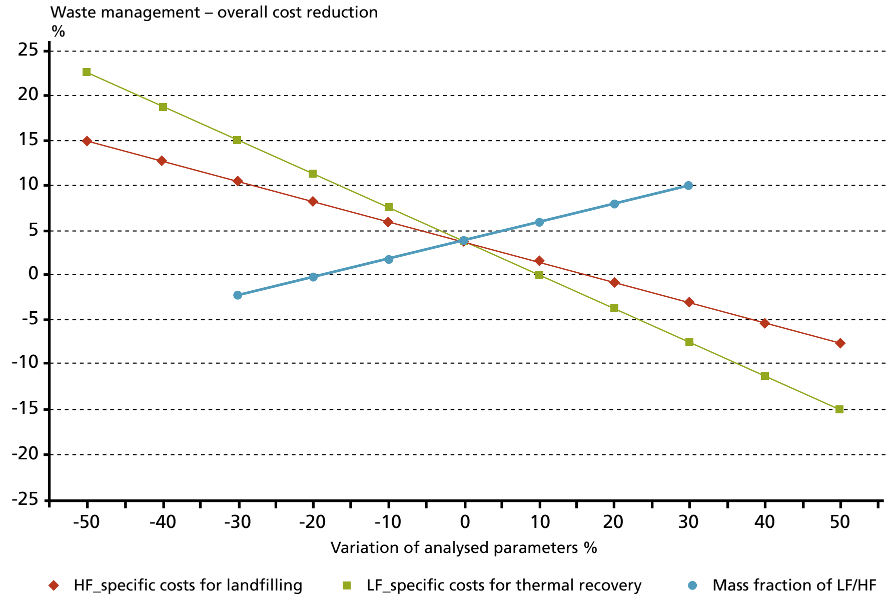
**Basis scenario:** (0 %)
Investment costs: € 275,000.-
Electricity costs: 0.12 €/kWh
Mass stream: 4,000 t/a

Varied parameters:
- Investment costs: € 192,500 to 357,500.-; (± 30 %)
- Electricity costs: 0.06 to 0.18 €/kWh; (± 50 %)
- Mass stream: 2,000 to 6,000 t/a; (± 50 %)

Figure 10: Influence of the variation of the investment costs, electricity costs and the mass stream for the heavy waste fraction (HF, 20-80 mm) on the specific treatment costs for the additional processing step

Source: Data for basis scenario according to Curtis, A.; Felber, J.; Haider, R.; Pomberger, R.: Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria), 2011

Figure 11 and figure 12 are focusing on the overall cost reduction that can be achieved due to the new routing options for the generated output waste streams (i.e. HF and LF). The main difference between the figures is given by the specific treatment costs for the landfilling of the HF. In figure 11 it is assumed that the generated waste stream of the HF is disposed of at a municipal waste landfill site while figure 12 shows the option of landfilling the HF on a construction waste landfill site. Which one of the landfill types can be used depends on the quality of the output streams and must be assessed specifically. The reference scenario shows the prevailing situation with specific treatment costs of 80 €/t (incl. transport costs) for thermal treatment in both figures. The varied parameters in the scenario analyses are the specific treatment costs of the light fraction (50 €/t incl. transport costs), the specific costs for landfilling of the HF (78 €/t for the municipal waste landfill respectively 27 €/t for the construction waste landfill) including transport costs and landfill tax. Furthermore, the influence of a varied fractionation for the LF/HF was analysed. The values in the basis scenario (LF/HF: 60/40 %) as well as the range of variation (±30 %) are based on the results of the pilot scale tests according to Meirhofer et al. [7].



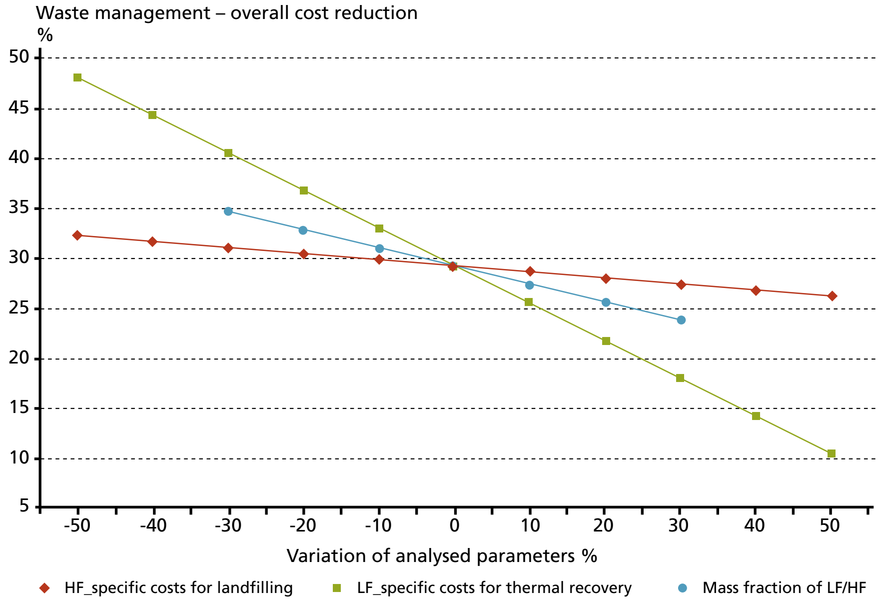
**Reference scenario:** 80 €/t (incl. transport costs)
**Basis scenario:** (0 %)

| | |
|---|---|
| Specific costs for: | |
| - additional processing step: | 15.80 €/t |
| - landfilling of the heavy fraction: | 78 €/t (incl. transport costs and landfill tax) |
| - thermal treatment of the light fraction: | 50 €/t (incl. transport costs) |
| Mass fraction of LF/HF: | 60/40 % |
| Varied parameters: | |
| - Specific costs for: | |
| - landfilling of the heavy fraction: | 78 €/t (39 €/t to 117 €/t); (± 50 %) |
| - thermal treatment of the light fraction: | 50 €/t (25 €/t to 75 €/t); (± 50 %) |
| - Mass fraction of: | |
| - LF/HF: | 60/40 % (42/58 % to 78/22 %); (± 30 %) |

Figure 11: Influence of the variation of the specific costs for landfilling of the heavy fraction (HF) on a municipal waste landfill, specific costs for thermal treatment of the light fraction (LF) and the mass fraction of LF/HF on the overall cost reduction compared to the reference scenario

Source: Data for basis scenario according to Curtis, A.; Felber, J.; Haider, R.; Pomberger, R.: Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria), 2011

By implementing sensor based sorting as an additional processing step the scenario in figure 11 shows an overall cost reduction based on these relatively conservative assumptions of about 5 % compared to the reference scenario which can be considered as comparatively low. Furthermore, it was observed that an increase of the specific costs for the thermal recovery of the LF of 10 % respectively 20 % for the specific landfill costs would even lead to additional costs for the waste contractor if sensor based sorting is implemented into the mechanical treatment plant. Under these conditions no beneficial economisation can be achieved. Determining key factors for a beneficial economisation are obviously cost reductions for the specific thermal treatment costs of the LF. Varying these costs for an average mass content of 60 % for the LF by about -50 % results in an overall cost reduction which is about 20 %-points larger than in the basis scenario.



**Reference scenario:** 80 €/t (incl. transport costs)
**Basis scenario:** (0 %)
Specific costs for:
- additional processing step: 15.80 €/t
- landfilling of the heavy fraction: 27 €/t (incl. transport costs and landfill tax)
- thermal treatment of the light fraction: 50 €/t (incl. transport costs)

Mass fraction of LF/HF: 60/40 %

Varied parameters:
- Specific costs for:
  - landfilling of the heavy fraction: 27 €/t (13.5 €/t to 40.5 €/t); (± 50 %)
  - thermal treatment of the light fraction: 50 €/t (25 €/t to 75 €/t); (± 50 %)

- Mass fraction of:
  - LF/HF: 60/40 % (42/58 % to 78/22 %); (± 30 %)

Figure 12: Influence of the variation of the specific costs for landfilling of the heavy fraction (HF) on a construction waste landfill, specific costs for thermal treatment of the light fraction (LF) and the mass fraction of LF/HF on the overall cost reduction compared to the reference scenario

Source: Data for basis scenario according to Curtis, A.; Felber, J.; Haider, R.; Pomberger, R.: Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria), 2011

Due to the lower costs for landfilling in the scenario of figure 12 a more beneficial economisation could be achieved for implementing sensor-based sorting (appr. 30 % cost reduction compared to the reference scenario). The overall cost reduction is primary influenced by a variation of the specific costs for the thermal treatment of the LF and could be increased to 48 % compared to the reference scenario by a parameter variation of -50 % on the x-axis.

## 5. Summary and conclusion

Based on processing trials it has been shown that sensor-based NIR-sorting is applicable for the processing of heterogeneous output waste streams (HC, MC) of a mechanical splitting plant treating commercial and pre-treated waste (case 1). Furthermore, it was shown that this technology is also capable of separating high calorific components from a heavy fraction (HF) resulting from a ballistic separation step in the mechanical stage of a mechanical-biological waste treatment plant (case 2). In the former case the objective was the reduction of PVC going along with a reduction of pollutants as well as the fractionation of biogenic components from the waste stream in order to broaden the marketing options specifically with regard to recovery. In the latter case the objective was to generate a heavy fraction that can be landfilled in compliance with the current legal situation in Austria without prior thermal treatment. Consequently, in both cases the motivation of evaluating the NIR sensor-based sorting technology was to investigate its capability for broadening the waste contractor´s routing options for the resulting waste streams and thereby allowing for savings in the overall waste management costs for the specific waste streams looked at.

Subsequent economical scenario analyses have shown that based on realistic assumptions with regard to the investment and operation costs as well as prevailing market conditions with regard to treatment/utilization costs for the resulting output waste streams in Austria (basis scenario) savings in comparison to the prevailing waste handling for the specific waste streams looked at (reference scenario) can be achieved. Sensitivity analyses have furthermore identified the crucial parameters for the economic viability of the integration of sensor-based NIR-sorting in the specific cases looked at.

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