Pre-Processing of Municipal Solid Waste before Anaerobic Digestion - CAPEX and OPEX as model calculation

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Abstract

Processing of **M**unicipal **S**olid **W**aste (MSW) before **A**naerobic **D**igestion (AD) is highly considerable in terms of capital expenditure (CAPEX) and operational expenditure (OPEX). The paper determines different process options like “Standard” and “AdvancedBioSolids” and characterizes the process options. The “Standard“ option is relatively simple and comprises only few process steps. The “AdvancedBioSolids” option is more complex and refines the biosolid fraction by segregating inorganic items and other non-digestibles in a multi-stage dry refining process.

Model calculation of mass balance and product quality is based on a typical composition of MSW in western urban settlements, this is e.g. 41 mass-% of digestible biomass. The quality of digestible biomass going from pre-processing to digestion is increased from 71,2 %, achieved by a “Standard” process to, 93,9 %, achieved by an “AdvancedBioSolid” process.

The calculation of CAPEX is done for annual capacities of 180.000 t/y and of 310.000 t/y. As a result CAPEX for mechanical equipment for pre-processing is 15 to 30% of CAPEX for total mechanical equipment, this means pre-processing plus digestion, combined-heat and power (CHP) and emission reduction installation. Calculation of OPEX is done by summarizing all operational costs deriving from the pre-processing plus digestion, CHP and emission reduction. As a result higher CAPEX for pre-processing installation leads to lower OPEX. OPEX as a function of CAPEX for pre-processing can be seen as a graph of different gradient.

The paper finalizes with a draft of a catalogue of pre-processing steps and their relevance for product quality and yield. Decision makers of authorities and companies get a hint of what is relevant in terms of process evaluation and meeting the targeted figures of OPEX.

1 Processing of Municipal Solid Waste before Anaerobic Digestion

1.1 Flow sheets

Processing of Municipal Solid Waste (MSW) before Anaerobic Digestion (AD) is commonly done in processes comprising a screen cut and metal separation. The screen cut applies cut- sizes of about 40 to 60 mm, and metal separation applies magnetic and eddy-current separation. The process flowsheet of a so- called “Standard” – process can be summarized as follows:

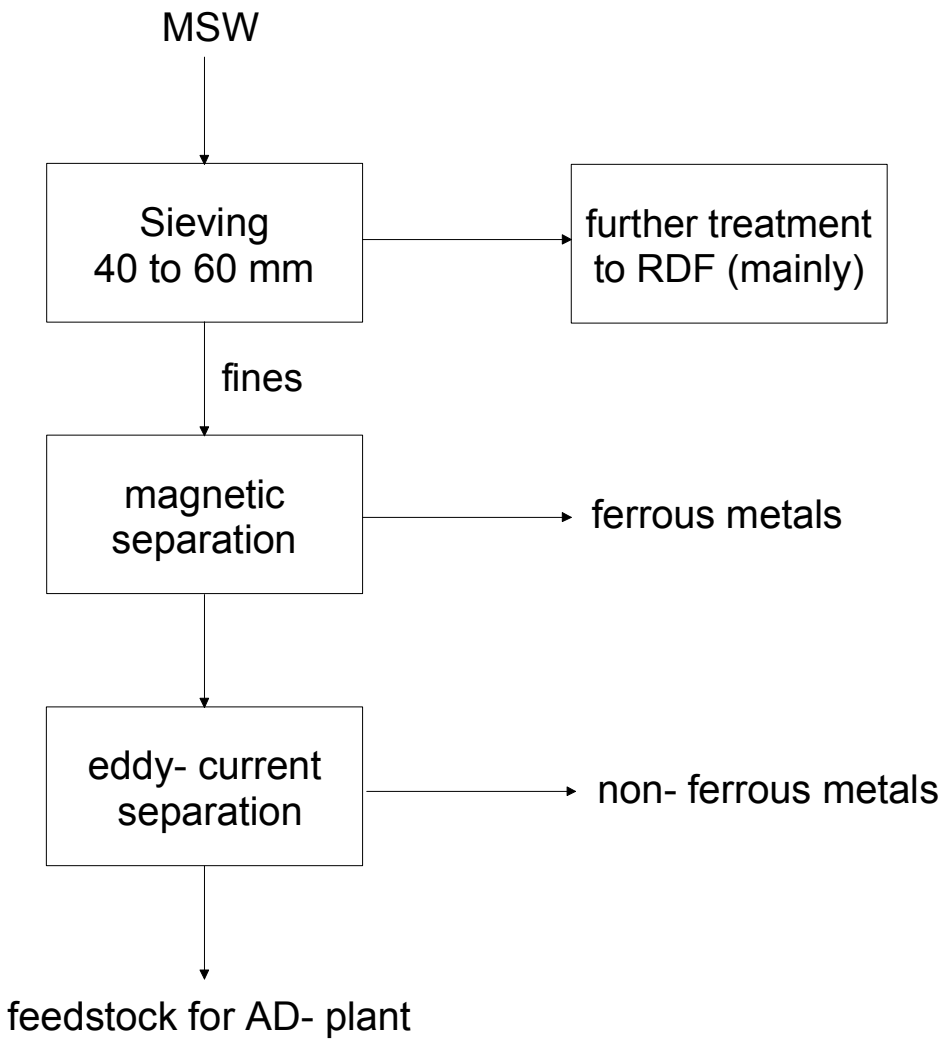
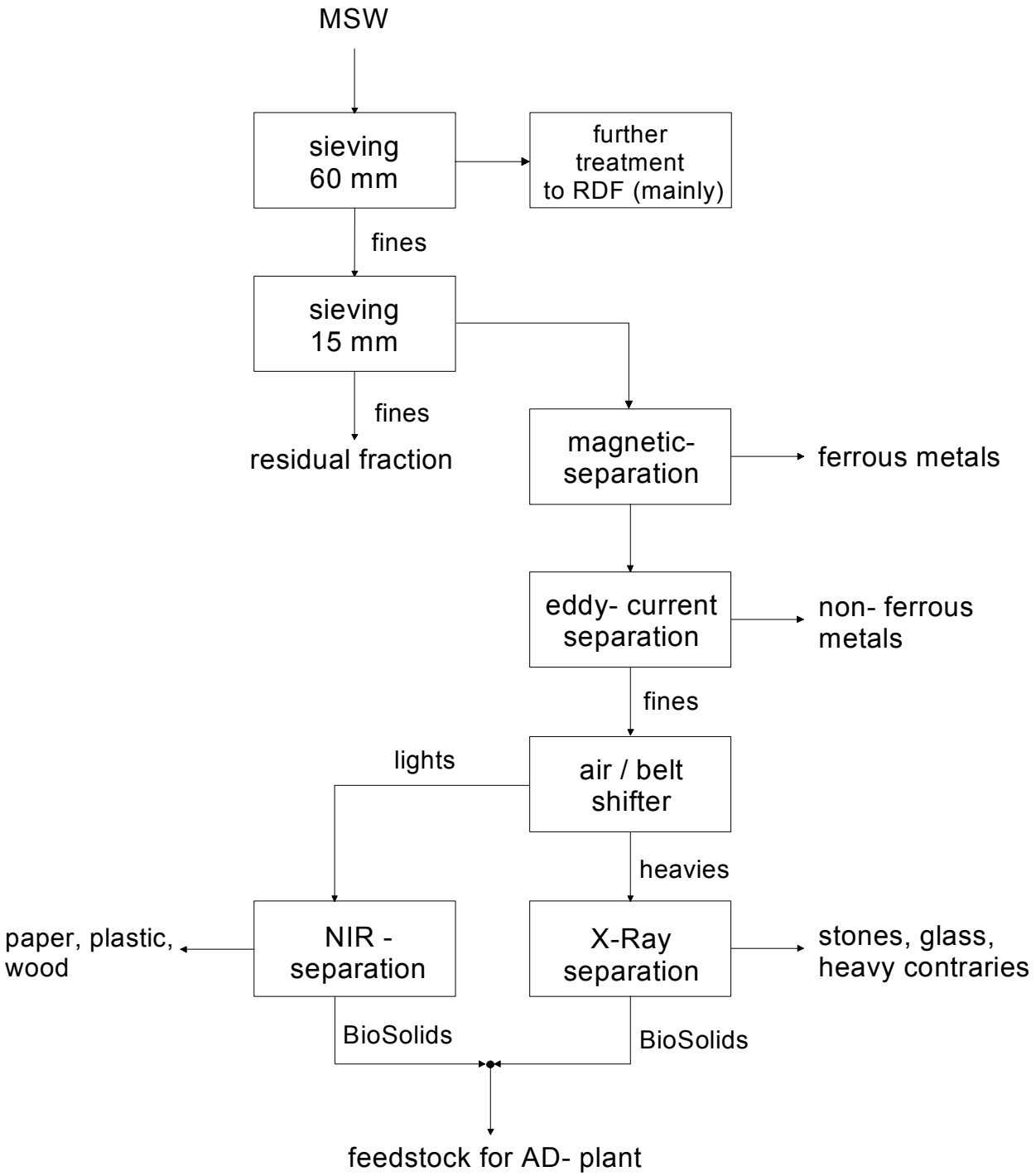


Figure 1 Flow sheet MSW

The composition of the feed for the AD- plant is roughly 2/3 digestible organic items and 1/3 other items, mainly inert items like glass, stone, ceramic etc. and non- digestible organics like plastic, fibres etc. The quality of the feed for the AD- plant can be enhanced in terms of the grade of digestible biomass by using a more sophisticated dry mechanical pre- processing. The process flowsheet of a so- called “AdvancedBioSolids” – process can be summarized as follows:



Fgure 2 Flow sheet „AdvancedBioSolids“

1.2 Mass- balance and Qualities

The composition of the feed for the AD- plant is given in table 1 as a comparison between the “Standard”- process and the “AdvancedBioSolid”- process based on a process model. The process model is based on an average composition for MSW (1) and sorting efficiencies of process equipment documented in the HTP database.

Table 1 Composition of MSW input (curbside) and feed for the AD- plant depending on the type of pre- processing (dry- mechanical).

	Input MSW-	feed to AD- plant	
	curbside collection (1)	Standard process (2)	Advanced Bio Sold process (2)
kitchen and garden waste (Bio Solids)	41%	71,20%	93,90%
paper / cardboard	18%	4,20%	1,10%
metal cans	3%	0,00%	0,00%
plastic	7%	2,00%	0,60%
glass	7%	4,70%	1,10%
wood	5%	0,50%	0,50%
sand, stones, ceramic	5%	6,80%	0,50%
textiles	3%	0,00%	0,00%
whitegoods, nappies, miscellaenous, non combustables	11%	10,60%	2,30%
	100%	100%	100%

(1) Analysis of household waste compositions for England, Dr. J. Parfitt, WRAP 2002

(2) HTP - database

The first column from the left gives an exemplary composition of MSW derived from curbside collection. In this case an average composition of household waste in England was chosen. The second and third column from the left shows the composition of the feed for the AD- plant produced by pre- processing in a “Standard” and an “Advanced-BioSolid” process. Whereas the commonly applied “Standard”- process shows a grade of only 71,2 % digestible biomass the “AdvanceBioSolid”-process increases the grade up to 93.9 %. The “Standard”- process feeds the wet- mechanical AD- plant with a ma-

terial containing 11,5 % heavies (glass, stone, sand, ceramic), 4,2 % paper fibres and 2,0 % plastics. Those items cause significant operational problems and costs. The “AdvancedBioSolids”- process decreases those items significantly to 1,6 % heavies, 1,1 % paper fibres and 0,6 % plastics.

The loss of digestible biomass by the “AdvancedBioSolids”- process is less significant. The “Standard”- process feeds 88,9 % of the total digestible biomass of MSW to the AD- facility whereas the “AdvancedBioSolid”- process feeds 82,1 % of the total digestible biomass to the AD- plant. The biogas- production is not affected significantly. The mass- output of pre- processing to AD is reduced from 51,4 % to 35,4 % which leads to higher overall plant- capacities and lower CAPEX and OPEX.

2 CAPEX and OPEX as model calculation

CAPEX and OPEX for a MSW- AD- plant is calculated on the basis of four scenarios.

Scenario 1: 180.000 t per year capacity
Standard- process

Scenario 2: 180.000 t/y capacity
AdvBioSol- process

Scenario 3: 310.000 t/y capacity
Standard- process

Scenario 4: 310.000 t/y capacity
AdvBioSol-process

2.1 Capital Expenditure (CAPEX)

CAPEX is calculated for mechanical and electrical works only. CAPEX of civil works, such as infrastructure, halls and office space is not calculated as it is not affected by the choice of a process option. Figures may vary depending on a specific site or project more or less. In general the figures give an estimate for a project developed from scratch, based on AD- plants built and operated in Germany mainly.

Table 2 CAPEX of scenario 1 and 2, annual capacity 180.000 t MSW.

	process option Standard	ADVBioSol
pre-processing	5.500.000,00 €	7.000.000,00 €
AD-plant	17.500.000,00 €	16.500.000,00 €
emission-control	2.800.000,00 €	2.800.000,00 €
process control	1.100.000,00 €	1.100.000,00 €
total	26.900.000,00 €	27.400.000,00 €

CAPEX for pre- processing rises by 1.5 Mio. or 27 % from 5.5 Mio. € to 7.0 Mio. € whereas the overall CAPEX rises by just 0.5 Mio. € from 26.9 Mio. € to 27.4 Mi. €

Table 3 CAPEX of scenario 3 and 4, annual capacity 310.000 t MSW.

	process option Standard	AdvBioSol
pre-processing	8.250.000,00 €	11.250.000,00 €
AD-plant	26.200.000,00 €	21.500.000,00 €
emission-control	4.200.000,00 €	4.200.000,00 €
process control	1.600.000,00 €	1.600.000,00 €
total	40.250.000,00 €	38.550.000,00 €

CAPEX for pre- processing rises by 3.0 Mio. € or 36 % from 8.25 Mio. € to 11.25 Mio. € whereas the overall CAPEX drops by 1.8 Mio. € from 40.25 Mio. € to 38.55 Mio. €

Savings of CAPEY for the AD plant is possible because of a significant lower mass throughput, 35,4 % instead of 51,4 %, without much loss of biomass and biogas production for mainly the contraries are separated.

Calculation of OPEX is done on the basis of the following assumptions:

- The lifetime of the plant is 15 years. The interest rate of capital is 4.5 %.
- The runtime of the plant is 7 days a week, 24 h daily in a four shift pattern. This applies for the AD-, emission control and CombinedHeatPower (CHP) - plant. The reception hall and pre- processing is being operated on weekdays only.
- Biogas is being used in a CHP unit. Electricity of CHP is consummated by the plant itself, the surplus of electricity into the grid are calculated with 0,065 €/ kWh.
- Heat from CHP is being used to warm up the digesters. The surplus of heat is not distributed or marketed any further.
- The number of operating personal is 16 people per shift for the 180.000 t/y scenarios respectively 22 people per shift for the 310.000 t/y scenarios. A plant manager and four people are calculated for each scenario additionally.
- Operational costs of civil works, infrastructure and material transport (internally) are not calculated in accordance to CAPEX calculation where those costs are left blank as well.
- Costs or returns for process products such as metals, rdf, adgeslota are nit calculated.

Figures of OPEX ranges from 27,00 €/t, 310.000 t/y AdvBioSol- process, to 35,00 €/t, 180.000 t/y Standard- process. Table 4 gives an overview.

Table 4 OPEX of an MSW- AD- plant dependent on capacity and process option.

	180.000 t/y		310.000 t/y	
	Standard	**AdvBioSol**	**Standard**	**AdvBioSol**
OPEX (absolute)	35,0 €/t	33,1 €/t	29,7 €/t	27,1 €/t
OPEX (relative)	100%	-5%	100%	-9%

Savings of OPEX are mainly due to the economy of scale, a loss of about 5,00 €/t by increasing the capacity from 180.000 t/y to 310.000 t/y. Beside savings due to choosing a more sophisticating dry- mechanical processing are -5 % respectively -9 %.

3 Summary and main findings

Investors, plant- operators and construction firms should look at dry mechanical processing before Anaerobic Digestion (AD) with more emphasis. More sophisticated dry-mechanical processing leads to

- higher grades of BioSolids and lower grades of non- digestible items in the feed of the AD- plant.
- lower operational expenditures- OPEX, sometimes even lower capital expenditures- CAPEX and
- higher process reliability, particularly in the AD- part of the plant, by preventing contraries from being fed to the digesters.

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