Conditions for an economical production and use of alternative fuels

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Abstract

Basically, the entire pre- and co-processing needs to be worked out carefully before alternative fuels can be used. It begins with the technical assessment of the pyroprocess in the cement plant, as well as the assessment of the waste sources and its composition from which the alternative fuel shall be obtained and the number of impurities to be disposed of in a safe manner.

Part of the preparatory work is also the pe-engineering, the forecast of qualities and its assurance under the operational conditions. It is strongly discouraged to be persuaded to buy a system without these preliminary works. The individual requirements for each pyroprocess of cement production and the thermal potential in the waste composition determine the technical and financial expenditure for the conditioning plant and thus the profitability of such a project.

The economic viability of such a project is largely determined by the enforcement of legal requirements and a sound disposal fee on a proper calculation basis. It has to be noted that the contract periods are not determined by the purchaser of the alternative fuels (i.e. the cement plant), but by the reliable access to the waste, including its disposal fees. A cement plant is not interested in being supplied with poor AF qualities over long contract periods, but it is much more interested in a quality-oriented bonus-/malus system on which regular settlements can be made. The terms of these purchase agreements must be negotiated individually.

It is shown how such terms depend on the level of the disposal fee and at what point the purchase of fuels will switch to a sufficient gate fee to the cement work. Finally, it is shown how a contractual basis for supply and billing can be created.

Keywords

#economical basis #cement production #kiln #pre-processing #waste derived fuels #HCF #RDF #SRF #co-processing #pre-combustion #calciner #main burner #quality assurance #CO_2 #settlement #disposal fee #gate fee

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1. Initial situation

As one of the most energy-intensive industries, the cement industry contributes approx. 6% to global CO_2 emissions. This is on one hand due to the CO_2 containing limestone in the raw material, which accounts for approx. 90% of the entire mass flow, and on the other hand to the use of fossil fuels, which account for approx. 10% of the intake to the rotary kiln.

These fuels are used to decarbonize the raw meal and to form the minerals of the semi-product clinker. This burnt clinker shall be ground into a standardized cement using electricity and by additional gypsum, fly ash, slag or other aggregates. Subsequently, packaged and shipped [9] to the ready-mix plant to produce concrete for the final customer.

The concrete is installed in the structure using electricity and remains there for several decades, during which CO_2 re-carbonates by the binders' surface, and until the structure will be demolished.

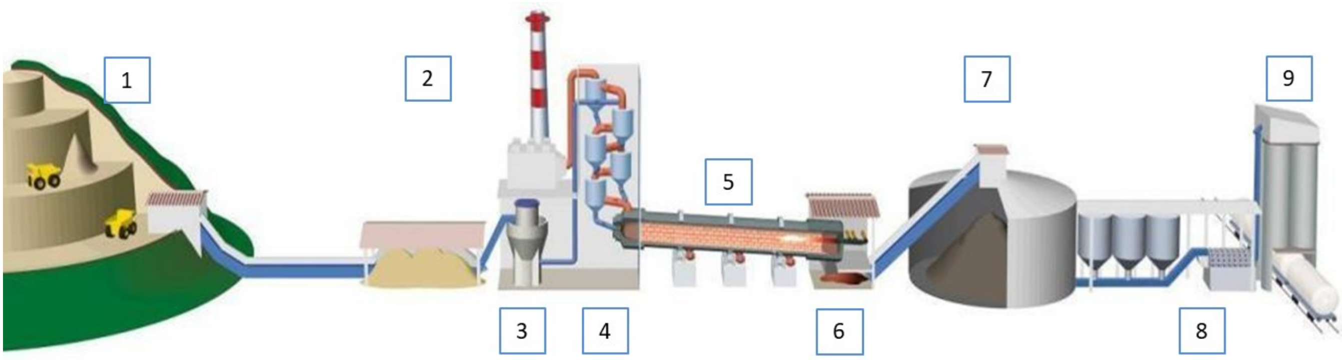
To minimize CO_2 emissions down this chain, the cement industry has committed itself to reducing approximately 38% of its total emissions by 2050. The measures identified are based on the important pillars of

- Operation of highly efficient and energy-saving equipment,
- Substitution of raw material with CO_2-free raw materials, and
- Co-processing, i.e. the use of waste-derived alternative fuels.

Co-processing is the generic term for the material and thermal use of suitable and pre-processed wastes, which are converted and quality-assured to alternative fuels and raw materials (AFR).

Starting from the quarry [1], calcareous sludges, e.g. from the de-carbonization of process water in power plants, siliceous forms of foundry sand or aluminum-containing sludges from clay, these mineral wastes can be used as raw material substitutes.

This fine ground raw meal [2, 3] is fed to the calciner [4] at the entrance of the calciner [4], and is falling against the hot exhaust gas into the rotating kiln [5] at approx. 1000°C. Than the iron- and aluminum-containing components react to form a melt and provide calcium and silicon with the necessary matrix to form clinker minerals at a flame temperature of ~2.000°C.



1 quarry (raw material)	4 calciner (decarbonization)	7 clinker silo
2 raw meal blending	5 rotary kiln (clinker formation)	8 admixtures and cement grinding
3 raw meal grinding	6 clinker cooler	9 dispatch

After the clinker minerals have been formed, the clinker granules are abruptly cooled down [6] and stored in silos [7]. To obtain cement, the clinker will be ground with gypsum, e.g. from flue gas desulfurization, as well as fly ashes from power plants, blast furnace slag or similar, to produce standardized cement on the mill [8].

The highest production costs are nearly 30 % and are fuel costs, so cost-efficient alternatives have always been sought, and with them the waste management industry and its ability to provide cost-efficient alternative fuels.

In Europe, the use of waste-derived alternative fuels started in the 1970th with used oil, and is today subject to a huge range of waste sources and the corresponding directives. From a legal point of view, co-processing in a clinker burning process is strongly focused towards the restrictive requirements of air pollution control. A basic requirement for a reasonable use is therefore the maintenance of a temperature of at least 850°C for more than 2 seconds. In accordance to these requirements, in general there are several entrance points available to feed the kiln process best.

Most often, the calciner is used for feeding the low-grade RDF, which is simply prepared and of poor quality. However, setting up this feed point nevertheless requires a sound preparatory work to evaluate the bottlenecks and possibilities in the entire process and respectively in the calciner in terms of e.g. temperature profile, oxygen supply, mixing, residence time and its burnout behavior or with the view to pre-processing to the particle size. The investment is enormous and the construction as well as the preliminary work should therefore be well prepared.

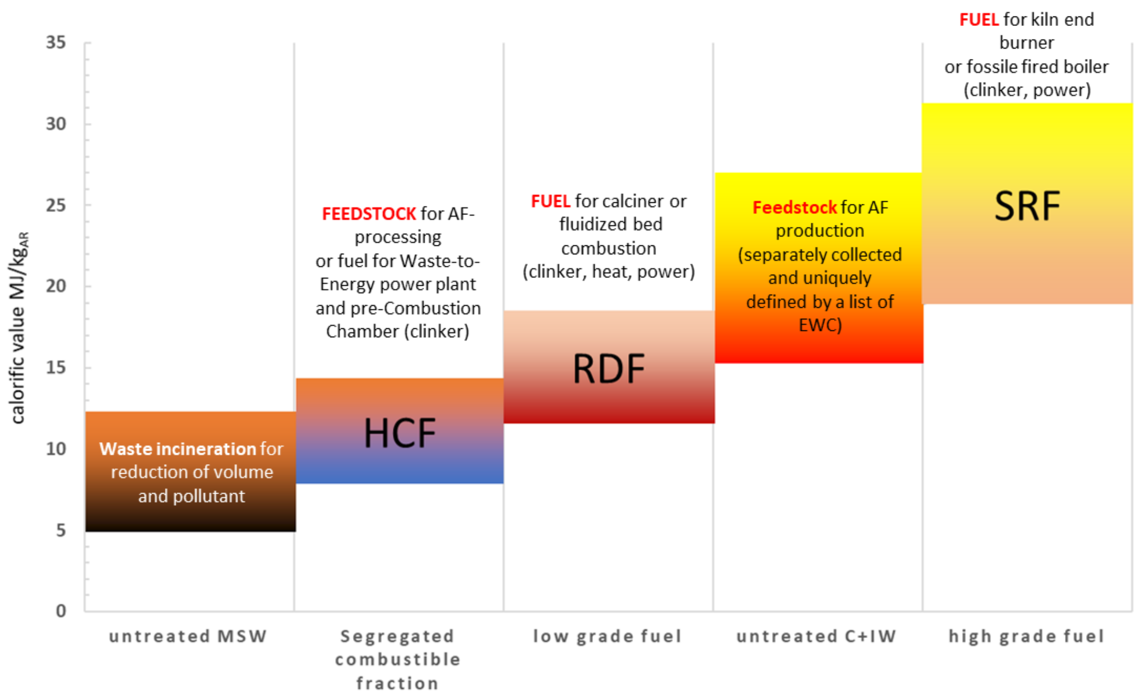
High-grade SRF is easier to feed via a satellite burner or sinter zone burner at the end of the kiln. However, this requires a higher degree of pre-treatment and a calorific value similar to lignite and does not tolerate 3D particles, which even affects the clinker quality by reductive burning conditions.

In the latest years precombustion chambers are designed to be fed with a so-called high calorific fraction (HCF) in a grainsize of roughly 300 mm. These materials are difficult to process or to burn, such as windmill blades, sticky tar, resin or coarse wooden biomass.

2. Definitions

Many different definitions, fancy names or careless statements cause confusion or even lead to public and political rejection. Therefore, it is essential to use the right terms in the right context.

This implies not simply referring to waste, but dubbing them as waste-derived or better as alternative fuel. This has nothing to do with concealment, but is due to the fact that enormous investments are made beforehand to convert waste into a specified and quality assured fuel that has to meet the requirements of a thermal production process. If this attitude is not in place from the beginning, the use of waste becomes a kind of waste disposal and the pyro-process will not accept alternative fuels after a certain thermal substitution rate (TSR).



With regard to the envisaged valorization process several qualities shall the derived from waste. For the process of clinker burning and production of electricity there are several terms and specifications:

HCF – High Calorific Fraction, which is the combustible fraction with a higher calorific value than untreated MSW. After sorting out materials for recycling and segregating unsuitable impurities and water containing organics, the grain size is <300 mm and its cv will range upto 15 MJ/kg.

It is the feedstock for a Waste-to-Energy plant (WtE) to produce process stream and electrical power. Or it will directly be used in a so-called pre-combustion chamber, which is linked to the calciner at the rotary kiln or shall furtherly be blend and processed to

RDF – Residue Derived Fuel. This low-grade fuel, RDF suits best directly for the calciner to decarbonize the lime containing raw meal at a long retention time (>5s). It's mainly processed on the second step out of HCF, and in a grain size between 60-120mm, and a cv ~13-19 MJ/kg.

SRF – Solid Recovered Fuel can simply be processed from purely collected industrial and commercial waste or -with a little more effort of cleaning and blending- from RDF. It is free of 3D-particles and is processed to get shortest retention time in the burner flame. Due to its proportions of waste-derived compounds its cv can range similar to lignite (22±2 MJ/kg) or much higher.

3. Minimum requirements

Definitions and other issues are one part of the entire process that needs to be worked out carefully before alternative fuels can be used.

It begins with the basic technical determination of the pyroprocess in the cement plant, as well as the determination of the waste composition from which the alternative fuel is obtained and the number of impurities to be disposed of in a safe manner. Part of the preparatory work is also the knowledge of the mechanics and its physics behind, the quality assurance up to the right feeding or operational issues. It is strongly discouraged to be persuaded to buy a system without these sound preliminary works.

The individual requirements for the pyroprocess of cement production and the thermal potential in the waste composition determine the expenditure for the conditioning plant and thus the profitability of such a project. Profitability is determined by several factors, which will be discussed in more detail below.

4. Economical frame

The decarbonization of limestone to produce cement clinker and the CO_2-allowances are the two cost drivers and the main reasons for using alternative fuels and raw materials. Depending on the technology the clinker burning process varies from ~6 $kJ/kg_{clinker}$ (wet process) to ~3 $kJ/kg_{clinker}$ (dry process).

Since the first oil price „shock“ in 1979 the cement industry started to seek for cheaper energy, and switched from oil to lignite, which also marks the specification of properly conditioned waste derived AFs, today. The largest benefit of AF is by saving primary energy costs, which are accounting around 26% of the manufacturing costs. In addition to modernizing the plant equipment by using highly efficient technologies (e.g. cooler), the use of CO_2-neutral fuels offers a quick option to save costs, as well. Consequently dry and preprocessed wood, paper, natural rubber, textiles etc. are most of interest with regard to its neutrality, but its generated fuels must match mandatorily the energy demand of the thermal process.

With regard to financing the entire waste management in many countries the authorities levy the disposal fee by a certain percentage of consumption of e.g. water, gas or estate taxes and transfer the responsibility inclusive the budget to private companies. Although this financial budget is partly insufficient to cover all costs, the risk of corruption vulnerability is high due to the lack of legal enforcement and strict control.

E.g. in Europe, the disposal service is awarded by tender to obligatory state certified companies, which are politically controlled and on the basis of the legal regulations. The waste disposal fee shall follow the polluter-pays-principle, which has at least two main functions: first, to cover all the costs of a reliable and legally compliant waste disposal, and second, to encourage people to reduce their amount of waste they produce by saving their own money.

In the case waste cannot be avoided all subjects of collection, transport, stuff management, sorting, conditioning, recycling until quality monitoring, thermal use, waste incineration or sanitary landfilling are subsumed in this disposal fee.

In order to obtain reliable figures, the current situation is reviewed every five years as part of a waste management plan. This includes determining of the number of inhabitants, the amount of waste per capita or the composition of the waste.

So, the waste producer is the responsible owner and has to cover all the costs. The fees are directly linked to each individual collection and bin, which means you pay depending on the legal requirements and annual needs.

In the following, different scenarios are used to show which economic opportunities and possibilities exist to lead a project to success. The general conditions shall be assumed as follows:

On the side of the waste management industry:

- ✓ a mechanical-biological treatment plant (MBT) is designed for an annual capacity of 180,000 t of municipal solid waste (MSW),
- ✓ composting is not taken into account for the first,
- ✓ the depreciation period for the plant is 20 years for the building, 7 years for fixed installations and 3 years for movable equipment.

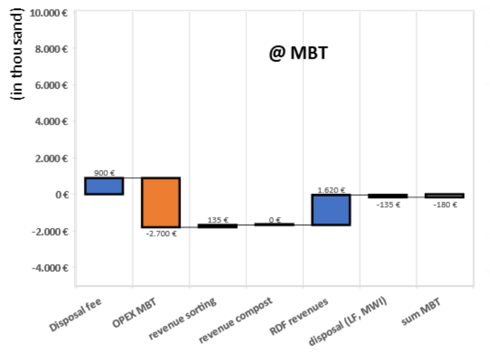
On the side of the exploiting cement plant are exemplarily taken into account:

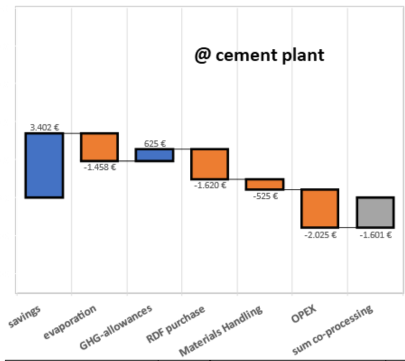
- ✓ Savings of primary energy,
- ✓ Savings of CO_2-certificates related to the non-fossil portion of biomass,
- ✓ Thermal loss due to water input,
- ✓ AF-gate fee or purchase price,
- ✓ New investments for AF handling,
- ✓ Additional operating expenditures e.g. due to laboratory, NO_x-reduction, kiln lining, energy loss due to moisture, operation of bypass etc.

All costs are calculated as per ton.

In the first case, which is the current starting situation in most cases, the polluter-pays-principle does not apply, i.e. the disposal fee remains at its known low level. A simple MBT technology is installed which will produce a low-grade fuel (RDF) with a high moisture content and a low level of calorific value, but a high content of biomass.

In order to establish a reliable waste management system, the cement plant is willing to subsidize the system by purchasing RDF, even though its quality is at the lowest tolerable level.





			t/y	€/t	T€/y
		Disposal fee	180.000	5 €	900.000 €
		OPEX MBT	180.000	-15 €	-2.700.000 €
amount	5%	revenue sorting	9.000	15 €	135.000 €
amount	35%	revenue compost	31.500	0 €	0 €
	45%	RDF revenues	81.000	20 €	1.620.000 €
		disposal (LF, MWI)	27.000	-5 €	-135.000 €
		sum MBT		-1 €	-180.000 €

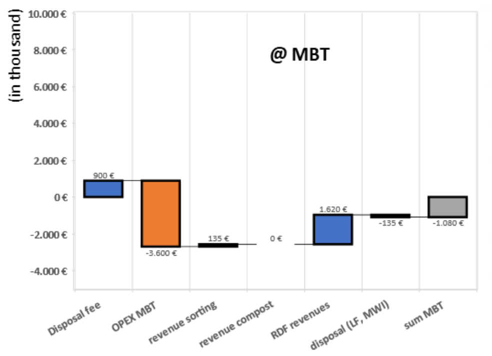
			t/y	€/t	T€/y
co-processing	70%	savings	56.700	60 €	3.402.000 €
thermal loss	30%	evaporation	24.300	-60 €	-1.458.000 €
biomass content	25%	GHG-allowances	13.892	45 €	625.118 €
		RDF purchase	81.000	-20 €	-1.620.000 €
1.500.000 €	2,0	Materials Handling	81.000	-9 €	-525.000 €
		OPEX	81.000	-25 €	-2.025.000 €
		sum co-processing		-28 €	-1.600.883 €

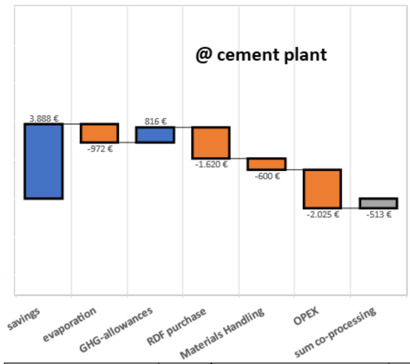
By a quick review of the calculations, this project to producing alternative fuels in a simple MBT will fail, even despite financial support from the cement plant.

The damage caused by the introduction of moisture into the thermal process by the poorly treated RDF and the initial costs cannot be compensated by the savings in avoidance of fossil fuel and its reduction in GHG allowances. The financial loss is about 9 times higher on the plant side than on the conditioner side.

At this point, it must be clearly stated that the economic viability of such a project depends essentially on the enforcement of the legal framework and the certainty of the disposal fees, which must cover all the costs of a reliable and integrated waste management system that includes collection, sorting and conditioning up to the long-term operation of a sanitary landfill.

Under the existing contractual conditions and further subsidization by the cement plant, the MBT will be upgraded to produce more suitable RDF for the calciner.





			t/y	€/t	T€/y
		Disposal fee	180.000	5 €	900.000 €
		OPEX MBT	180.000	-20 €	-3.600.000 €
amount	5%	revenue sorting	9.000	15 €	135.000 €
amount	35%	revenue compost	31.500	0 €	0 €
	45%	RDF revenues	81.000	20 €	1.620.000 €
		disposal (LF, MWI)	27.000	-5 €	-135.000 €
		sum MBT		-6 €	-1.080.000 €

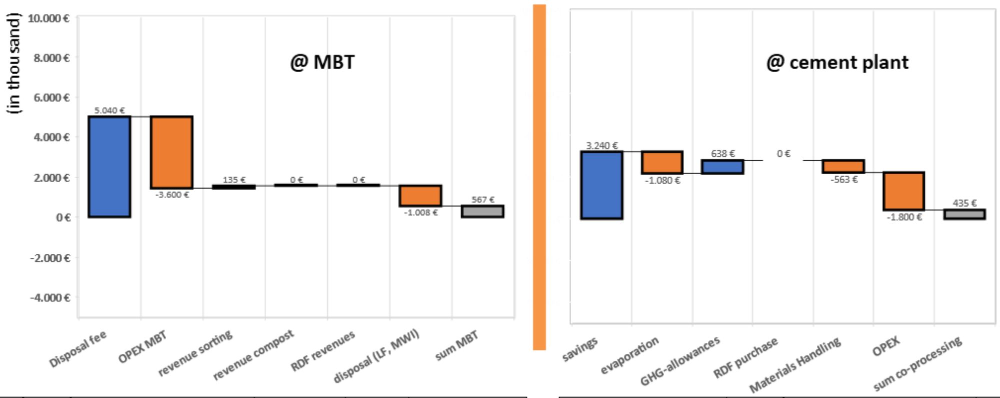
			t/y	€/t	T€/y
co-processing	80%	savings	64.800	60 €	3.888.000 €
thermal loss	20%	evaporation	16.200	-60 €	-972.000 €
biomass content	28%	GHG-allowances	18.144	45 €	816.480 €
		RDF purchase	81.000	-20 €	-1.620.000 €
1.500.000 €	2,0	Materials Handling	81.000	-9 €	-600.000 €
		OPEX	81.000	-25 €	-2.025.000 €
		sum co-processing		-8 €	-512.520 €

On one hand, upgrading the MBT will generate a better RDF quality with a higher biomass content and a lesser introduction of moisture, and consequently a higher thermal substitution rate at the cement plant. Its losses will be halved, but will still remain negative.

On the other hand, the costs in the MBT will rise up to six times than before reconstruction and will bring it to its knees.

This means that the disposal fees have to be raised - significantly!

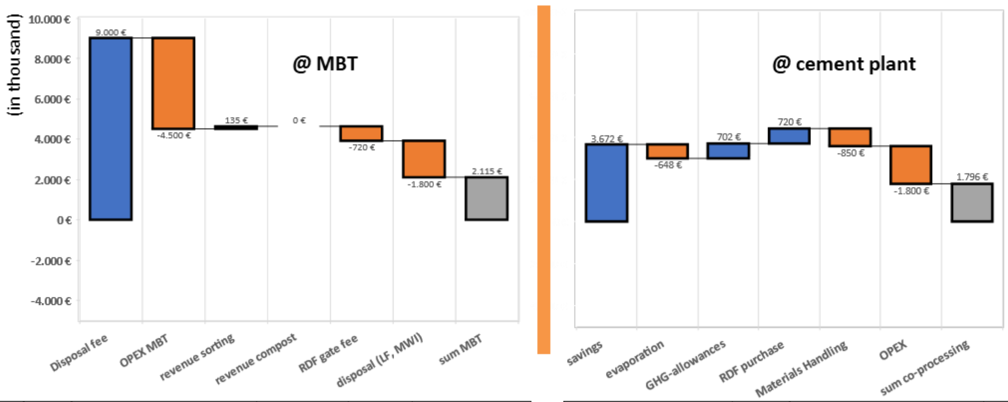
In addition, in this theoretical example, the cement plant shall waive a gate fee and on subsidizing the costs of the MBT in order to bring the calculation into a balance for both sides.



			t/y	€/t	T€/y
		Disposal fee	180.000	28 €	5.040.000 €
		OPEX MBT	180.000	-20 €	-3.600.000 €
amount	5%	revenue sorting	9.000	15 €	135.000 €
amount	35%	revenue compost	31.500	0 €	0 €
	40%	RDF revenues	72.000	0 €	0 €
		disposal (LF, MWI)	36.000	-28 €	-1.008.000 €
		sum MBT		3 €	567.000 €

			t/y	€/t	T€/y
co-processing	75%	savings	54.000	60 €	3.240.000 €
thermal loss	25%	evaporation	18.000	-60 €	-1.080.000 €
biomass content	26%	GHG-allowances	14.175	45 €	637.875 €
		RDF purchase	72.000	0 €	0 €
1.500.000 €	2,0	Materials Handling	72.000	-10 €	-562.500 €
		OPEX	72.000	-25 €	-1.800.000 €
		sum co-processing		8 €	435.375 €

Nevertheless, the resulting financial cushion will be too tight for both partners to cover even the smallest expenses such as additional repairs or such investments for a sufficient equipped laboratory or the operation of a sanitary landfill. Finally, an MBT is a splitting plant, from which several streams are leaving to recycling, compost and customized alternative fuels. But, also non-recycables and impurities have to be disposed of in a safe manner on a sanitary landfill or even incinerator. These investments have to be covered by the polluter-pays-principle, as well.



			t/y	€/t	T€/y
		Disposal fee	180.000	50 €	9.000.000 €
		OPEX MBT	180.000	-25 €	-4.500.000 €
amount	5%	revenue sorting	9.000	15 €	135.000 €
amount	35%	revenue compost	31.500	0 €	0 €
	40%	RDF gate fee	72.000	-10 €	-720.000 €
		disposal (LF, MWI)	36.000	-50 €	-1.800.000 €
		sum MBT		12 €	2.115.000 €

			t/y	€/t	T€/y
co-processing	85%	savings	61.200	60 €	3.672.000 €
thermal loss	15%	evaporation	10.800	-60 €	-648.000 €
biomass content	26%	GHG-allowances	15.606	45 €	702.270 €
		RDF purchase	72.000	10 €	720.000 €
3.000.000 €	3,0	Materials Handling	72.000	-14 €	-850.000 €
		OPEX	72.000	-25 €	-1.800.000 €
		sum co-processing		29 €	1.796.270 €

In this last example, the polluter-pays-principle is valid, and the appropriate disposal fee will cover all the investment into a suitable technology to produce RDF with a suitable quality. The cement plant will extend its reception and storage facility to guaranty a continuous supply and will get a gate fee to compensate its higher investments such as SCR- or SNCR-technology to reduce NO_x-emissions.

Finally, an additional WtE-plant to produce power may complete this system to ensure a public and private cooperation for an integrative, safe and reliable waste management.

5. How to draw up a supply contract

As already mentioned, the contract periods are not determined by the cement plant, but by the reliable access to the waste, including its disposal fees. A cement plant is not interested in being supplied with poor AF qualities over a long contract period, but rather in qualities and on demand.

Later, when the MBT is in operation and the cement plant is continuously supplied, these qualities must meet the agreed specification of the clinker production process and will also be the basis for its frequent billing. The terms of these purchase contracts are usually negotiated individually and monitored by regular inspections at the reception on the cement plant side. Incidentally, this billing model can be extended or shortened as desired according to the agreed bonus/malus system.

This also shows very clearly that it is always worthwhile to assess the composition and properties of the intended input waste in detail in advance and to design the processing plant accordingly, which has a huge impact on the investment, in order to produce customized RDF qualities for the calciner or SRF for the main burner.

Quality assurance according to defined standards will provide the required parameters for cross-checking. For this purpose, the statistical median and the 80th percentile have proven to be useful by means which both sides can bill in a certain rhythm.

The following shows when several parameters have been agreed upon, which are analyzed regularly during the delivery period. Finally, these are set in advance as the settlement basis and tolerance, so that a settlement is based on these results or their deviation.

In the following example, four typical parameters (calorific value, and the content of chlorine, moisture and biomass) are identified by this individual cement plant. This billing basis can be extended or shortened as desired for individual supply contracts.

			calorific value (inferior)	
		<16 MJ/kg	16 MJ/kg	>16 MJ/Kg
Correction factor	per t per MJ/kg	-2,00 $	0,00 $	1,00 $
			chlorine content	
Concentration		< 0,9%	0,90%	> 0,9%
Correction factor	per t per 0,1%	3,00 $	0,00 $	-3,00 $
			moisture content	
Concentration		< 20%	20%	> 20%
Correction factor	per t per %	1,50 $	0,00 $	-1,50 $
			biomass content	
Concentration		<30%	30%	>30%
Correction factor	per t per %	-2,00 $	5,00 $	2,00 $
Settlement basis per ton (delivery contract):				**10,00 $**

Example 1:		Median value/ month	in accordance to committed norms	
	calorific value MJ/kg	17,32		2,64 $/t
	chlorine	1,14%		-7,20 $/t
	moisture	30,0%		-15,00 $/t
	biomass content	31,8%		8,60 $/t
			Purchase price for plant:	**-10,96 $/t**
Example 2:		Median value/ month		
	calorific value MJ/kg	22,00		12,00 $/t
	chlorine	0,50%		12,00 $/t
	moisture	12,0%		12,00 $/t
	biomass content	15,0%		-25,00 $/t
			Purchase price for plant:	**11,00 $/t**

Here **Example 1** shows the consequences if the promised specification is not met. However, **Example 2** also shows how much profit can be made if the system is designed and operated, properly.

And, this also shows very clearly that it is always worthwhile to assess the waste composition and its properties precisely beforehand and to design the processing plant to this, i.e. to invest in order to produce tailor-made qualities and to ensure their quality and continuous supply.

The entire system only works in a sustainable manner and for the benefit of the society if both sides are aware of the context and consequences.

More detailed contract templates can be found on https://wltp.eu/activities/ and in the appendix of the WLTP Directional Compass: Alternative Fuels Handbook for Project Managers

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