Thermal treatment methods for waste recycling in Germany

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Abstract

Waste recycling in Germany is regulated by the national waste cycle and management act (KrW-/AbfG). Recycling under ecological and technical aspects should be prefered to land disposal. The disposal of waste with high organic content or leakage of contaminants has been prohibited since 1 June 2005 by the waste disposal act which particularly refers to domestic waste.
Major aim of the legislation is to strongly reduce waste residues and to treat the problematic part by means of recycling or incineration. Therefore, energetic, material and raw material recycling are to be applied commonly in order to meet the requirements. Lately, much effort is made to advance thermal treatment technology in Germany. Therefore, the following speech contains a survey of gasification and pyrolysis methods for material/raw material as well as energetic recycling.

Key words:
- Legal initial position
- Thermal processes for utilization (recycling)
- Material -, raw material-recycling, energetic recycling
- Masses and energy balances
- Permission of the plant
- View

1. Legal Requirements to Recycling

In Germany wastes with higher content of organic material should not be disposed on landfill.
Under „Waste Storage Ordinance“ from 20.02.2001 there are the following limits for the loss of ignition

Disposal site class I	max 3 %
Disposal site class II	max 5 %

Wastes, which exceed these values, are to been incinerated or – if possible - recycled.

At the recycling you have to differ between:

- material-recycling (the use of the unchanged material)
- raw material-recycling
  (the use of a raw material, which is produced of the waste in a special process)
- energetic-recycling (the use of the energy content of the material in thermal processes).

General there is no priority for one kind of recycling. But there exists some exceptions:
In Germany – as in other countries of the European Union – there are special wastes with high calorific values, which have to be recycled as material in legal fixed contingents. However the raw material recycling is equally allowed. Here are two examples for legal required waste recycling in the German waste law.

(1) End-of-Life Vehicles Act, 21 June 2002

From January 2006 recovery and reuse of at least 85 % of the material of end-of-life vehicles (10 % material recycling of the non-metallic components from dismantling, 70 % metal-recovery, 5 % of material- or energetic-recycling of the light fraction from shredders (SLF)).

[Table 1] Recycling rate of Pflicht an Dismantling and shredding operation

Recycling Criteria	Up to the end of 2005 Re-use & Recycling **	Deadline after the regulation			
		10. 01. 2006		01. 01. 2015	
Annual recycling rate according to ELV-regulation (weight %)	~ **70%**		**85%**		**95%**
Reyclingprocesses Re-use + material recycling Energetic recycling *	~ **70%**	80% 5%	**85%**	85% 10%	**95%**
Distribution of recycling rates (+) Dismantling process Shredding process	~ **70%**	70% (+) 10% (+) 5%	**85%**	70% (+) 10% (+) 15%	**95%**

* It can also with the raw material recycling are accomplished, if it by energetic recycling is not accomplished

** Re-use of spare parts + material recycling of ferrous(Fe) and non-ferrous(NF)-Metals

[ERT]

(2) Ordinance on the Avoidance and Recovery of Packaging Wastes

Packaging wastes have to be taken back from the seller or distributor and it must recycled in material way. The followings contingents of material-recycling had to be fulfilled:

glass	75 %
sheet metal	70 %
aluminium	60 %
paper, cardboard	70 %
composite material	60 %.

These values represent high and stringent contingents of material-recycling. In many cases they reach the limits of what is reasonable in regard to economy and ecology. The way out of this problem can be a raw material-recycling by a thermal process.

2. Thermal Processes for Recycling

Wastes can be recycled by some thermal processes. These processes are:

- Incineration — only energetic-recycling possible,
- Pyrolysis — energetic- or raw material-recycling possible,
- Gasification — energetic- or raw material-recycling possible.

Another possibility, which had to be mentioned, is the use of pre-treated wastes in blast furnaces. Because the content of carbon in the waste have the effect of chemical reduction this kind of recycling is valid as a raw material-recycling.
Now I want to describe two processes in Germany, which have significance in the treatment of fractions of domestic waste and industrial and hazardous wastes:

- ConTherm-Pyrolysis as a pre-treatment of low-contaminated wastes (with high caloric value) for the co-incineration in coal fired power plants
- SVZ-Gasification as raw material-recycling of wastes.

Description of the Processes

(1) Pyrolysis:

At pyrolysis a degasification of the organic components takes place by indirect heating in oxygen-free atmosphere. The products of the process are: pyrolysis-gas (contains also a mix of oil and tar) and solid residues (coke, metals, and minerals)

The pyrolysis always consists of several process stages:

1. stage	Shredder.
2. stage:	Degasification of the organic components in a pyrolysis reactor In most cases a rotary kiln with indirect heating is used.
3. stage:	Treatment of pyrolysis-gas and coke. There are the following possibilities:
	<u>Pyrolysis-gas</u> a) Incineration and energetic use b) Condensation of the gas to get the oil- and tar-fraction. For example: pyrolysis of used tyres.
	<u>Coke</u> a) Incineration and energetic use, b) Gasification with the gas to produce a synthesis gas.

The temperature of the pyrolysis-stage is between 400 ^{o}C and 700 ^{o}C.

(1) Gasification:

This means a partial oxidation of the organic contents of the waste. The products are synthesis gas (without oil and tar – because of the high temperature) and solid residues (melted minerals and metals).The synthesis gas consists of carbonmonoxid, carbondioxid, hydrogen, water, some methane.

Also the gasification consists of several process stages:

1. stage	Pre-treatment of the waste (mechanical or thermal)
2. stage	Gasification in the reactor
3. stage	Energetic- or material-recycling of the synthesis gas (gas motor, gas turbine, incineration, synthesis of methanol)

3. Selected Recycling-Plants in Germany

3.1. ConTherm-Pyrolysis-Plant in Hamm (North Rhine Westphalia)

Example for „energetic-recycling“

In unit C of the power plant „Westfalen“ (high temperature about 1,500 degrees, melted slag) of the RWE-Power Company with a capacity of 769 Megawatt, about 9,5 % of the required hard coal are replaced by a special prepared substitute fuel.
This is a matter of co-incineration of wastes. The wastes are energetic-recycled.
But before the wastes can co-incinerated in a power plant, they had to be converted into a fuel with the characteristics of hard coal. For this purpose the pyrolysis is the only appropriate process. In Hamm the ConTherm-Process, which started the large-scale operation in connection to unit C of the power plant in the year 2001, is specially developed by RWE Power for the pyrolysis of wastes.

(1) Process

The centre of the ConTherm-Plant are two parallel operated external heated rotary kilns with a flow rate of altogether 100.000 t/a. There the shredded wastes are degassed at approx. 500 °C under exclusion of air. The inflammable pyrolysis gases are cleaned from dust and supplied then directly to the unit C and burned there. The carbon-rich fraction is separated from the solid residues and also given to the coal mill of unit C as substitute fuel. The metals are also separated and recovered

The advantages of the procedure in relation to the direct incineration are:

- Use of the high energetic efficiency of the power station (approx. 38 %) with the employment of the wastes and thus saving of fossil sources of energy. The correspond efficiency of waste incineration is only about 20 %.
- Separation and utilization of the metals in good quality,
- Melting down of the remaining residues,
- Safe destruction of organic pollutants at the high burn temperature of 1,500 °C in the power station,
- Use of the existing infrastructure.

(2) Wastes

The following wastes may be treated in the ConTherm plant:

- • residues from the waste paper treatment and paper production,
- • waste from the assortment of packaging wastes,
- • light fraction from the mechanical/biological domestic refuse treatment,
- • high caloric industrial wastes,
- • mixture from aforementioned materials.

(3) Permit of the Plant

Because the coal-fired power stations do not have the special facilities to emission control, which are demanded at a thermal waste treatment plant, the additional emissions, which result from the co-incineration, can only been minimized by excluding contaminated wastes.

To find out the limits and the applicable wastes for this process the approval authority utilized extensive data over the composition of wastes. Thus it was shown for example that the content of mercury was too high in different wastes and would lead to problems (excess of the exhaust limit values). These wastes did not get permission for the ConTherm plant.

3.2 SVZ – Waste-Gasification in SVZ - Sustec Verwertungs-Zentrum(recycling center)

Example for “raw material-recycling”

The SVZ-plant for recycling of waste by gasification followed from a coal gasification plant in the eastern part of Germany, which supplied large parts of the former GDR at the time before the reunification with gaseous fuel. The old gasification units are partially still used, partially are units of the newest technology in use.
In the year 2002 approx. 300,000 t at solid wastes were treated with 3 different systems of gasifiers and produced approx. 100,000 t of methanol (CH_3OH). The methanol is marketed in chemistry and plastic industry at customary prices, where the methanol is used predominantly for the production of new plastics. In August 2004 the price on the world market was about 230. - EUR/t methanol.
There is also a surplus of electric energy - also after deduction of the internal consumption.
With this system - gasification and methanol production - the organic components of wastes are converted into new raw materials, which can be used without restrictions for different new products. Therefore this procedure is classified - regarding the aforementioned regulations - also as "material-recycling".

The following wastes are treated in the plant:

- Sewage sludge,
- Shredder-Light-Fraction,
- Plastic wastes,
- Contaminated wood,
- Electronics wastes,
- Sorted fractions of domestic refuse (e.g. dirty packaging wastes)
- Tar sludge,
- Lacquer and paint remainders,
- Liquid and pasty industrial wastes (oils, tars, suspensions, solvent mixtures, problematic waste water).

For the correct operation of the plant the acceptance criteria for the wastes are substantial. The following table shows the pollutant limit values for the acceptance of solid wastes

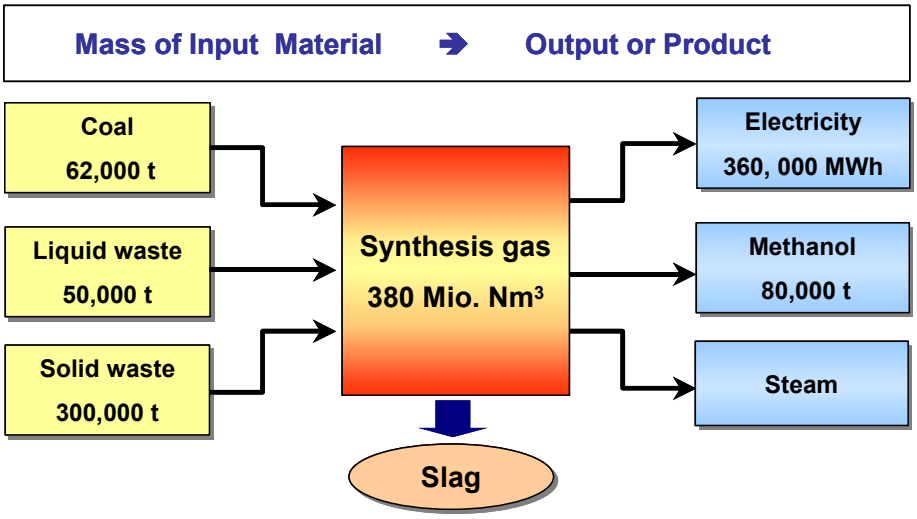
[Table 2] Limiting values

Limiting values for contaminants	[mg/kg]
arsenic	2,000
lead	100,000
cadmium	50,000

chromium	20,000
copper	200,000
nickel	50,000
mercury	200
zinc	100,000
t in	50,000
cyanide	500
polychlorinated biphenyls	500
chlorine / halogenide	10
Dioxine / Furane [micro g /kg]	50

It shows that the gasification process with efficient gas cleanup is very flexible regarding high pollutant contents in the wastes. The SVZ-Plant is a recycling plant, which is equipped however with the efficient gas purification system of the waste incineration plants and which keeps the strict emission-values.

To time 15 % coal and 85 % wastes are treated in the plant. The energetic efficiency for the methanol production is difficult to determine. After a report of the ZSW (Centre for Solar power and Hydrogen Research, Germany) from August 2004 it is approx. at 50 %. In the same report also costs for the methanol production with the SVZ are mentioned. They are estimated on 150, - to 180, - EUR/t methanol.



Source: SVZ/ UFOP , Fig. Add.: ERT

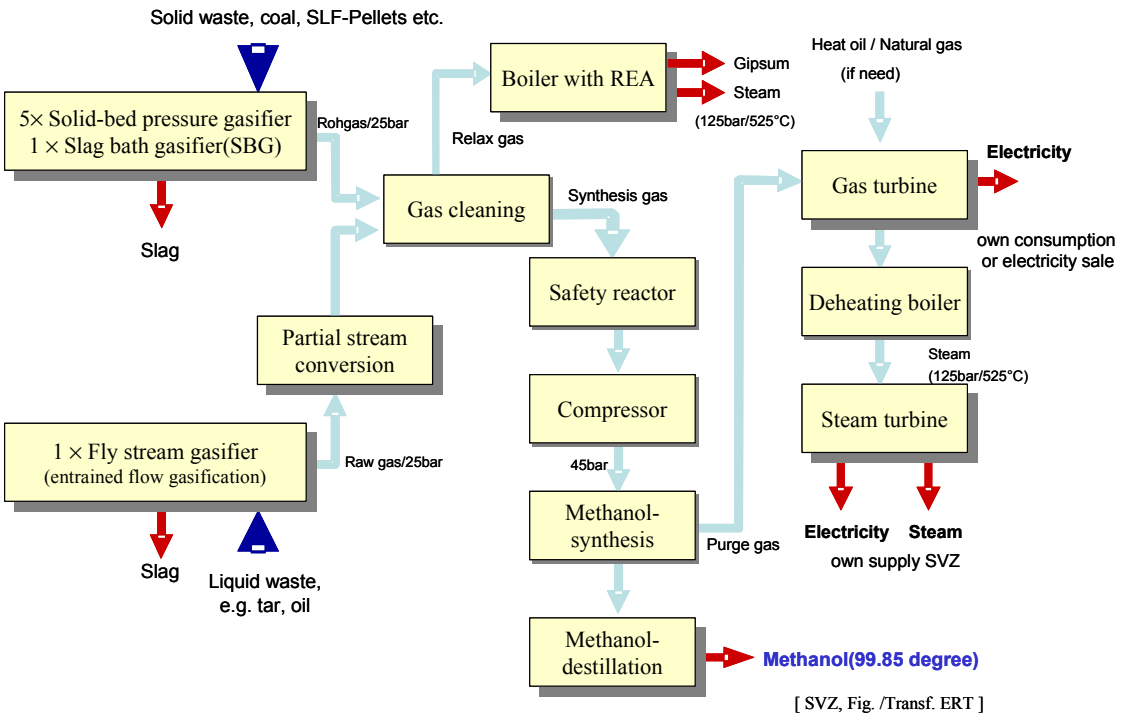
< Fig.1 > Input material and production flows of SVZ in 2003

In the gasification plant different systems are used:

- 5 solid-bed pressure gasifier (capacity for each gasifier 15 t/h)for solid wastes,
- 1 British-Gas/Lurgi (BGL) slag-bed gasifier (capacity 35 t/h) for solid wastes,
- 2 fly stream gasifier (capacity for each gasifier 16 t/h) for liquid and pasty wastes.

The gasification in the reactor is run with steam/oxygen mixtures at high process temperatures, high pressure and in reducing atmosphere. Thereby all hydrocarbons up to the molecular level are split independently of kind of refuse or fluctuations in the composition.
By the conditions of the reaction (high temperatures and shock cooling of the synthesis gas) all organic pollutants (dioxins and furane, polycyclic aromatic hydrocarbons, Biphenyle, and A.) are completely destroyed. The heavy metals are fixed in the slag of the solid residues, and this will prevent any leaching.

The produced synthesis gas is transformed in a separate process to methanol. Contaminated rest-gases coming from the gasification process (approx. 5-10 % of the total amount) and Purgegas from the methanol production are converted to energy and electricity over a boiler and a gas turbine. The electricity will be sold - after deduction of the necessary quantity for the internal requirement of the plant - to general electricity mains.



<Fig. 2> Flow-Chart of SVZ-Plant

The characteristics of the three different gasifiers are summarized in the following table:

[Tab. 3] Gasifier of SVZ-Plant

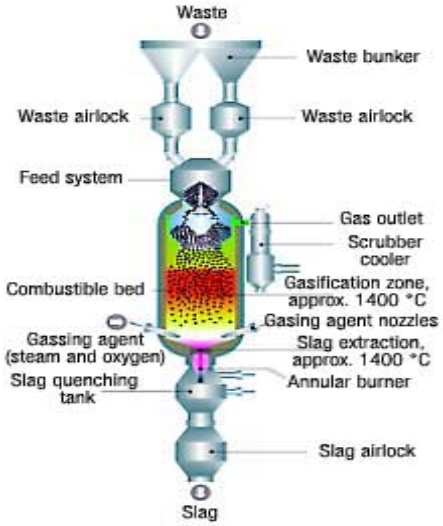
Gasifier	Solid-bed pressure	Fly-stream	Slag-bed
quantity at SVZ	5	2	1
flow-rate t / h	12 - 15	15	35
temperature	1.200 - 1.300 °C	1.600 - 1.800 °C	1.450 °C
operating pressure	25 bar	25 bar	25 bar
gasification agent	steam, O_2	steam, O_2	steam, O_2
solid residues	sintered slag	molten slag	molten slag

The special advantages of the waste gasification are:

- The solid residues are transformed into a molten slag.
- The heavy metals contained in the wastes cannot any more be eluted.
- The gasifiers are small and compact aggregates.
- They can start and shut down very fast.
- There are very small emissions in the off-gas because of the nearly complete destruction of toxic materials during the process.

The slag-bed gasifier is of special interest. It is the further development of a gasifier used by the companies British-Gas und Lurgi for coal gasification. The apparatus was scaled up and adapted to the specific requirements of a waste gasification. There are other special developments, so the waste-feed-system as well as the slag discharge, which is heated over a ring burner to make a liquid slag possible. The gasifier is since the year 2003 in large-scale operation.

BGL(British gas - Lurgi)-Gasifier or
Slag bed gasifier (SBG)



System parameter and technical data of SBG:

➢System parameter
- Diameter: 3.6 m
- Operating pressure: 25 bar
- water coolant of double coat etc.

➢ Technical data
- Throughput: 27 – 32 t/h
- Gas amount: 35 000 Nm_/h
- Gasification end temperature: 1 600 °C
- Steam amount: 6 –9 t/h
- Oxygen amount: 6 000 Nm_/h
- Slag throughput: ≤ 7.5 t /h
- Raw gas temperature: 500-700 °C
- Temperature after cleaning < 200 °C

[SVZ]

<Fig. 3 > Slag bed gasifier (SBG) or BGL of SVZ

Mass- and energy balance SVZ :

At the example of the gasification of 1 Mg plastic waste (carbon content approx. 70 %; Hu = 33.7 MJ/kg) data of the mass- and energy flows are to be given:

[Tab. 4] Mass balance / - flows at the gasification of scrap plastics

Input substance for Gasification			Output (products)					
			Interim output (products)			Final output (products)		
Substance	kg	%	Substance	kg	%	Substance	kg	%
▪ Scrap plastics (Incl. carbon 700kg)	1000	40.7	Synthesis gas	861	35.1	*Methanol	596	24.3
						Pure gas	265	10.8
▪ Oxygen	517	21.1	Relax gas	1266	51.6	Waste gas & Exhaust, others	1266	51.6
▪ Chemical	120	4.9						
▪ Water	817	33.3	Others (slag, waste water)	327	13.3	slag	182	7.4
						Waste water	145	5.9
Total	**2454**	**100**		**2454**	**100**		**2454**	**100**
* Methanol: 99.08 purity, ca. 226 kg carbon, Hu_{CH3OH} = 19,7 MJ / kg								

[Data source: SVZ, Tab.: Berghoff, Kim / ERT]

[Tab. 5] Energy flows at the gasification of plastic waste

Input of Energy		Products of energy		Efficiency
Criteria	MWh	Criteria	MWh	%
Scrap plastics + others	9.36	Methanol	3.31	35.4
		Electric current	0.98	10.4
		Heating energy	0.28	3.0
Total	**9.36**		**4.57**	**48.8**

[Data source: SVZ, Tab.: Berghoff, Kim / ERT]

Pre-treatment of the wastes (SVZ) :

Thus the solid wastes are applicable in the gasifier they had to meet certain conditions regarding

- material density,
- mechanical firmness,
- piece size,
- thermal stability

Therefore most wastes had to been pre-treated accordingly. At the SVZ the appropriate facilities for this purpose exists. As examples should be mentioned:

• Old wood:	chopping, metals remove, sieving
• Shredder-Light-Fraction (SLF):	cutting, sieving, metal separation (magnet), air separation, pelletization
• Mixed scrap plastics:	cutting, metal separation, air separation, secondary cutting, pelletization
• Sewage sludge:	drying process, mixing with other wastes, forming of briquettes

4. Summary and Outlook

In Germany the deposit is forbidden by waste with organic portions in principle. The cause for it is the harmful environmental effects and the high land consumption of the dumps. The recycling of waste received – apart from the waste incineration – therefore a high value. For the certain wastes, also in large quantities result, the recycling ratios are legally determined.

At present she endeavours the disposal economy, to develop the appropriate techniques, in order to be able to use these wastes materially or energetically (raw material or energetic recycling).

In Germany, two methods for recycling of high amounts of hazardous waste have been established. Both methods have their own specific advantages. One method is the ConTherm-Technology with approximately 100,000 t of hazardous waste are treated per year. Pyrolysis at about 500 °C leads to a degasification of waste. The products, pyrolysis gas and pyrolysis coke, can be treated energetically with high energetic efficiency at a slag-tap plant by common combustion with coal. The slag-tap plant is usually located at the same factory premises and benefits from a 10% substitution of coal by waste material. Initially, slag-tap plants were not designed for waste combustion. For that reason, the input material of the ConTherm-plant should be of high quality, i.e. highly contaminated waste is not suitable for this type of processing.

Another technology is represented by the SVZ plant – “Schwarze Pumpe”. About 300,000 t of solid waste and 60,000 t of liquid and paste-like waste are degasified at approx. 1,600 °C. The synthesis gas is to be cleaned and transformed to methanol at a separate plant. This processing method can be regarded as “material recycling” since methanol is a demanded raw material in chemical industry.

The **SVZ-Process** is highly flexible towards type and composition of waste due to the process control and the installed flue gas purification. Nevertheless, in most cases waste pre-treatment is needed. The gasification plant contains a fixed bed, slagging and entrained flow gasification. Five fixed-bed gasifiers (capacity 15 t/h), one slagging gasifier by British Gas Lurgi (BGL) (capacity 35 t/h) and two flue stream gasifier (capacity 16 t/h) are available [SVZ].

Possible input materials for slagging and fixed-bed gasification are solid wastes such as old plastics, Shredder-Light-Fractions (SLF), clearing sludge, municipal waste, domestic-like industrial waste, old rubber, old wood, rests of lacquer and paint, high calorific residues from mechanical-biological waste treatment, waste pellets from mixtures of tar and clearing sludge as well as other waste materials with hydrocarbon content.

Liquid and paste-like waste such as waste oil, tar/water mixtures and hydrous slurry products with high solid content are to be treated in the flue gas reactor. With the SVZ using technology after long development in between worked satisfactorily. In the future however the older aggregates (fixed bad gasifier and air flow gasifier) must be replaced.

A first step with the introduction of the new BGL-slagging bed gasifier was made successful. Further the capacity of the plant is to be extended. For example becomes the present capacity for Shredder-Light-Fraction (SLF or ASR) of 105,000 t/a (pellets) around 33% on 140,000 t/a increases. Thus an important step is done, around the ratio of 5% at SLF/ASR, to be used must, also to fulfill.