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Waste Incineration in the Future

Summary of the Position Paper of the ProcessNet Expert Group "Waste Treatment and Recycling"

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Executive Summary

A society oriented towards a circular economy is an important and declared goal of the European Commission in view of measures against climate change and the limited availability of raw materials.

Efforts to increase the proportion of reusable products and to optimise reusability and dismantability, for example through changes in the choice of materials or the design of products, are necessary. They contribute to sustainably improving the recycling of products and thus to increasing the materially recyclable share in municipal waste. At the same time, there will continue to be waste streams and residual materials for which recycling is not possible for technical, economic or ecological reasons.

Here, thermal waste treatment makes an important contribution to a circular economy, using established thermal processes, to close the gap between (direct) material recovery, chemical recycling and the raw material and energy needs of industry, in an economic way and with low emissions.

Thermal waste treatment already provides simultaneously in the form of waste and sewage sludge incineration plants:

- Safe and sustainable elimination of environmental pollutants, e.g. POP[1], from the delivered waste
- Active health protection, inter alia, in the sense of hygienisation, especially with increasing urbanisation and the rising demands for comprehensive services of general interest (municipal waste hygiene)
- Preparation for the recovery of raw materials from fractions that could not be recycled by now
- Low-cost and low-emission provision of heat or cold
- Utilisation and provision of electricity from residual materials that cannot (currently) be recycled.

Thermal waste treatment is already an important component in achieving the goals of the EU's Green Deal. Through consistent further development and increased efficiency, in the coming years, in addition to providing energy and recyclables, it will, through combination with

- further reduced emission levels
- combined heat and power
- CO_2 capture
- Methanol synthesis (in conjunction with green hydrogen)

be a carbon source of the future. It will thus help to gradually dispense with primary fossil carbon sources and provide basic materials for a raw material cycle that is as completely closed as possible.

Waste becomes raw material, "thermal waste treatment" becomes "thermal raw material production", which enables

- reduced dependence on (fossil) raw materials and their producing countries,
- CO_2 neutrality,
- sustainable production and industry

and thus contributes to safeguarding the health, economic power and current standard of living of our society in the future.

1 POP: Persistent Organic Pollutants

Summary

Recycling loops have been established for many materials, for example for paper, glass and numerous metals. Nevertheless, residual materials remain that cannot be put to direct material use with the current state of the art technology.

The energy demand must also be seen in connection with the material cycle. Energy is needed for both manufacturing and recovery processes. In line with the circular economy, material and energy belong inseparably together. The goal must be to make the energy required for production and recovery climate-neutral. It can be assumed that thermal waste treatment as well as other chemical, physical and biological processes will continue to be used in the future, either individually or in combination, depending on the complexity of the material flows to be treated.

Thermal waste treatment fulfils several tasks in this interaction. It is

- the conversion stage for the destruction of environmentally hazardous substances, utilising existing potential for energy production and the recovery of valuable materials,
- the process for removing pollutants from the material cycle,
- the link between material conversion and energy.

Since its foundation, the ProcessNet expert group "Waste Treatment and Materials Recovery" (AuW) has been committed to the principle of sustainable resource protection.. The aim of the position paper "Waste incineration in the future" is to create a factually sound basis, free of economic interests, for the upcoming discussion on the future role of thermal waste treatment in connection with the buzzword "circular economy".

The position paper "Waste Incineration in the Future" addresses the following topics in detail with current contributions:

- Waste streams, legal and energy policy framework conditions and perspectives.
- Process engineering for thermal waste treatment – main thermal processes
- Process engineering for thermal waste treatment – Exhaust gas purification
- Recovery of materials

The core statements of the position paper on these issues are summarised below.

Waste flows, legal and energy policy framework conditions

Thermal waste treatment plants provided almost 320 PJ of final energy (corresponding to 90 billion kWh) in Germany in 2015, of which around 70% was heat and around 30% electricity. This results in a share of waste-based energy in Germany of 3.7% of final energy consumption. Together with the refuse-derived fuel (RDF) power plants, the plants for the thermal treatment of municipal waste have a share of about 50% of this.

For selected groups of materials, such as paper, glass or PET beverage bottles, mechanical recycling is already possible today, but sustainable recycling processes do not yet exist for many products. On the one hand, new recycling processes for the recovery of valuable materials will become established, such as processes for the recovery of monomers from plastic fractions with pyrolysis. On the other hand, it can be assumed that the development of new materials, also in connection with the further development of assembly and manufacturing processes, will change the quantities and composition of individual waste streams. However, a significant change in the total amount of waste to be treated is hardly to be expected in the next few years.

The operation of thermal waste treatment plants today represents a branch of industry with one of the comparatively highest regulatory densities.

The foreseeable developments aim at a further reduction of emission values, optimised energy utilisation, recycling of end products from thermal treatment as well as the opening towards technologically related energy services, provided that the political framework conditions for this are created.

Resource efficiency and recovery of recyclable materials

For a functioning circular economy, thermal waste treatment is an indispensable component. This is clearly illustrated by the final products of thermal waste treatment: after post-processing, bottom ash can be used as a secondary building material. The separation of elemental metals such as iron, aluminium and copper from bottom ash is an important contribution to the circular economy. The fine fraction of bottom ash contains metals in concentrations that correspond to those of natural deposits. The utilisation of this potential requires a further expansion of processing technology. The ash from the incineration of municipal sewage sludge will be an important secondary source for phosphate from dwindling natural deposits for the production of mineral fertilisers and other phosphate-containing products in the future.
Thermal waste treatment also succeeds in removing non-recyclable sorting residues and materials contaminated with pollutants, which accumulate despite the high level of development of the treatment processes, from the material cycle. There is currently no competition between thermal waste treatment and functioning recycling, as the costs for thermal waste treatment are much higher.

Energy policy framework conditions

The thermal waste treatment plants will certainly not compensate for the shutdown of all coal and nuclear power plants, but they can contribute to a secure base load supply of electricity in local grids alongside the generation of electricity from biogas and hydropower plants. To this end, it is necessary to strengthen the idea of interconnection and to ease the restrictions imposed by cartel law in order to avoid regional bottlenecks in supply and disposal caused, for example, by overhaul shutdowns. At the same time, waste incineration plants basically have the possibility to adapt electricity and heat generation to demand within certain limits.

In the context of the utilisation or incineration of municipal waste in thermal waste treatment plants, the energy extraction from the incineration process and the hot flue gases is the most important energetic approach. Here, the combustion process, e.g. the excess combustion air, the cooling process of the flue gases and the boiler or energy technology, must be considered in connection with the efficiency.

Today, thermal power plants with solid control fuels (e.g. coal) achieve electrical (fuel) efficiencies of up to 46%. Special materials, steam circuits and process conditions in the steam cycle, live steam pressures of 260 to 270 bar and live steam temperatures of 600 to 640 °C have to be realised to make these efficiencies possible. In addition, steam that has already been expanded via the turbine is reheated several times during the process and fed to the different turbine stages. These optimised plants are designed for the highest possible yield of exergy, i.e. electrical power, and are adapted to the fuel band in terms of process and materials. However, if such a plant is also used to generate steam or heat energy (combined heat and power, CHP), the share of exergy, i.e. electrical power, is reduced when the fuel utilisation on the heat side is increased. Thus, these CHP plants cannot be compared one-to-one with purely electrically operated plants..

For thermal waste treatment plants, optimisation to such high steam parameters and electrical efficiencies is not possible due to the following points:

- The fuel waste is subject to short-term qualitative fluctuations or the fuel band and process-damaging accompanying substances in the waste lead to corrosion in the boiler. The processes are thus subject to physical and chemical limits.
- Waste as a fuel has such a wide range of pollutants, calorific values and fuel parameters that it cannot be used for optimised plants. However, the delivered waste cannot be rejected or even refused due to the obligation to accept it and must therefore be incinerated.
- The fuel waste contains high levels of chlorine, alkali and alkaline earth compounds which, due to their melting and corrosion behaviour, set the limits for the steam process and thus for the live steam temperature and live steam pressure. The boiler materials are only able to withstand attack by these substances below 450 °C for a certain period of time (until repair).

Due to the resulting low steam parameters, a maximum electrical efficiency of approx. 25 - 35% is physically possible. In order to achieve higher fuel utilisation, the additional extraction of heat in the form of steam or hot water is therefore unavoidable. The advantage of waste incineration resulting from cogeneration in connection with base-load operation over 8,000 h per year is thus tied to an optimal heat and steam user (site). The choice of location for a waste incineration plant must take this framework condition into account. Moreover, these utilisation criteria are anchored in the 17th BImSchV and the

Commission's Implementing Decision (EU) 2019/2010 of 12.11.2019. In CHP operation, efficiencies of 65 % and more are thus possible.

A prerequisite and aid for a sensibly planned mode of operation in a network or within municipal supply structures is an advanced digitalisation of the combustion process. A wide range of sophisticated sensor technology is available to enable targeted plant optimisation by evaluating the process data collected.

Process engineering of thermal waste treatment - Main processes

The process combination of incineration, energy utilisation and exhaust gas cleaning, which is almost widespread used in Germany and Europe, has established itself as universal and reliable. Despite elaborate efforts, alternative processes for the thermal treatment of mixed waste based on pyrolysis or gasification have so far always proved to be unfeasible on a large scale.

Multi-stage processes that use, for example, pyrolysis and gasification in separate reactors for the thermal treatment of waste have once again become more prominent in the course of the discussion on "chemical recycling". Today research in collaboration with industrial partners must prove that these technologies generate products (oils, synthesis gas, coke) from certain waste fractions that can be economically included into the material cycle and the value chain. This proof has yet to be provided on a large scale.

Process engineering of thermal waste treatment - Exhaust gas purification

Exhaust gas cleaning behind waste incineration plants had its beginnings with the increased construction of such plants and the increasing air pollution in the 1960s.

Today, no one questions the necessity of exhaust gas purification and it has become an accepted matter of course.

The motivation for today's developments lies not only in the efficient separation of pollutants but also in issues such as energy efficiency, minimisation of input materials and the recovery of valuable materials from exhaust gas purification. This is also where the future challenges are seen, mainly in the choice of location for new plants to utilise synergies.
The development of processes and individual process stages in the past decades today offers a multitude of possibilities for the separation of one and the same pollutant.

Today's exhaust gas purification systems are usually one-of-a-kind due to the constantly increasing emission requirements and the retrofitting that is often necessary as a result.

An existing, but also future challenge for waste gas purification processes will be increased energy efficiency. This means that for future site considerations and planning, the plants must be located where a corresponding infrastructure for energy utilization (e.g. district heating) is available. Due to the very efficient multi-stage waste gas purification, the plants do not represent an environmental burden. On the contrary, the parallel use as a leisure facility is becoming more and more common, as for example at the newly built Amager plant in Copenhagen with a ski slope on the plant roof and a climbing wall on the building facade.

Nevertheless, there are also further developments, such as the new development of DeNOx catalysts, which as low-temperature catalysts for the first time advance into temperature ranges < 150 °C and thus enable an upstream, lime-based dry sorption process without additional heating, which was previously the domain of processes operated with sodium bicarbonate.

In addition to energy efficiency, current discussions point to a renaissance of the recovery of valuable materials from exhaust gas, but this time not focussed on the recovery of e.g. gypsum or hydrochloric acid, but on the transfer of the combustion product CO_2 back into the carbon cycle, for example - after CO_2-gas scrubbing and a subsequent conversion - in the form of methanol.

As has already been shown in the case of energy efficiency, it is not a matter of developing completely new systems or processes, but rather of intelligently combining existing processes and using synergies.

In this sense, a symbiosis can be created in the provision of the CO_2 (valuable material) from the exhaust gas to the volatile regeneratively generated electrical energy for the methanol synthesis.

Another approach for the utilisation of the CO_2 present in the flue gas has already been successfully put into practice in Twence in the Netherlands through the on-site production of sodium bicarbonate from CO_2 and soda ash as an additive for flue gas purification.

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