Municipal-Waste-To-Energy Potential

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Summary

The article summarizes possibilities of energy recovery from municipal waste. It describes the history of incineration and energy recovery from municipal waste in Czechoslovakia and then in the Czech Republic. The attention is paid to the three currently operated plants for energy recovery from municipal waste in the Czech Republic (ZEVO Malešice, SAKO Brno and TERMIZO Liberec). The following are the characteristics of the planned plants for energy recovery from municipal waste in the Czech Republic. All these plants operate essentially based on grate boilers with flue gas treatment at the highest technical level. The article also lists other technologies which can be used for energy recovery from municipal waste – these are gasification and pyrolysis units and plasma technology. The conclusion of this contribution is devoted to the current and future situation in the area of energy recovery from municipal waste in the Czech Republic.

Keywords: municipal waste, energy use, boilers, gasification, pyrolysis, plasma technology

1. Incineration and energy recovery from municipal waste in our area

The **first municipal waste incinerator** with energy recovery was built in the Czech Republic in Brno in 1904–1905. The incinerator had seven combustion chambers in conjunction with the Babcock-Wilcox steam boiler, behind it the Parson turbine was integrated with an output of 300 kW, connected to a three-phase AC generator with an output of 220 kW. In full operation, the incinerator burned an average of 27.5 tonnes of waste per day; 1 kg of waste produced about 1.14 kg of steam with a pressure of 9 atm. In the 30ies, the incinerator was extended and served its purpose until 1941, when it was destroyed during the allied air raid over the city of Brno.

The **second municipal waste incinerator** was built in Prague in 1930–1933. The Prague incinerator station of solid waste, heating and power plant were put into operation in 1934. Refuse collection vehicles carted the waste into four containers for temporary storage. Subsequently, the waste was transported to a waste sorting plant and then to a building of combustion batteries with two boilers whose capacity was 200 tonnes per day. The combustion batteries allowed for the production of 6 to 25 tonnes of steam per hour. The steam was supplied to surrounding businesses as well as to its own power plant with two turbine generators of 5 MW each. During the World War II, a next boiler with an output of 45 tonnes per hour was built. Later the incinerator was modernized and expanded. The total reconstruction of the incinerator ran from 1959 to 1982, but it was not too successful. At the beginning of the 70ies, there was only an old sorting plant, two original turbine generator units and two cranes at a slag dump in the incinerator plant. The capacity of the incinerator was 80 to 100 thousand tonnes annually. The boiler room had two boilers of 15 tonnes per hour, the first one combusted the waste and the other coal and black oil to ensure peak supplies of heat.

At the end of the 80ies of the 20th century, the incinerator was reconstructed again. Within the plant, four powder granulation high pressure boilers were installed with a chamber for waste incineration. The fifth boiler was intended for black oil. The total installed thermal capacity was 251.2 MW. At that time the incinerator burned MSW (municipal solid waste), brown coal and black oil. After the reconstruction the incinerator could dispose of up to 45 tonnes of waste per hour. The operation of the incinerator in Vysočany was closed in 1997.

In the post-war history a large municipal waste incinerator was put into operation in **Brno** (now **SAKO Brno, a.s.**) as the first in the former Czechoslovakia. The incinerator was built in the years 1984–1989. Originally, the incinerator had three ČKD Dukla boilers with cylindrical grates. The total capacity of the incinerator was **240 thousand tonnes** of waste per year. Since 1998 the incinerator has also produced electricity using the equipment with an output of 400 kW_e.

In the years 2008–2011, the incinerator underwent large renovation and modernization (for around EUR 72 million), when two new lines for waste incineration were built. Each line includes a steam boiler with a rated output of 45 TPH of steam. The maximum incineration power of the grate of each boiler is 16 tonnes per hour, the minimum one is then 8 tonnes per hour. The total incinerator capacity is **248,000 tonnes** of waste per year for the heating value of waste of 8–9.6 MJ/kg. The municipal waste incinerator SAKO Brno, a.s. was officially re-opened on 7th September 2011 [1]. The renovated plant of the Brno incinerator (see Fig. 1) can satisfy up to 30% of steam consumption in the city of Brno.

Each boiler is equipped with an internal incineration reverse grate by Martin GmbH, developed specifically for the incineration from municipal solid waste; the boiler itself is of water-tube kind with natural circulation, three-pass design with two drums. The modern operation of the Brno incinerator meets stricter emission limits than required by current legislation on air quality protection.

The **treatment of flue gas**, resulting from the incineration of waste, has the following steps:

The flue gas generated during the incineration of waste is fed to the top of an absorber at the outlet from the boiler at a temperature of 195°C. The flue gas treatment is based on a semi-wet type system, and along with technical and operational measures also addresses issues of heavy metals, dioxins and other persistent organic pollutants. The CNIM-LAB semi-wet type system consists in injecting fine-atomized aqueous lime slurry into the flue gas stream at a temperature of 195°C. The result is a series of chemical reactions taking place during gradual evaporation of water between the parallel flow of hot gaseous acidic components of flue gas and alkaline sorbent which is a lime slurry aerosol. The result is a very fine powder which is separated from the flue gas on fabric filters. Into the flue-gas duct of each line before absorbers, the activated carbon is forced

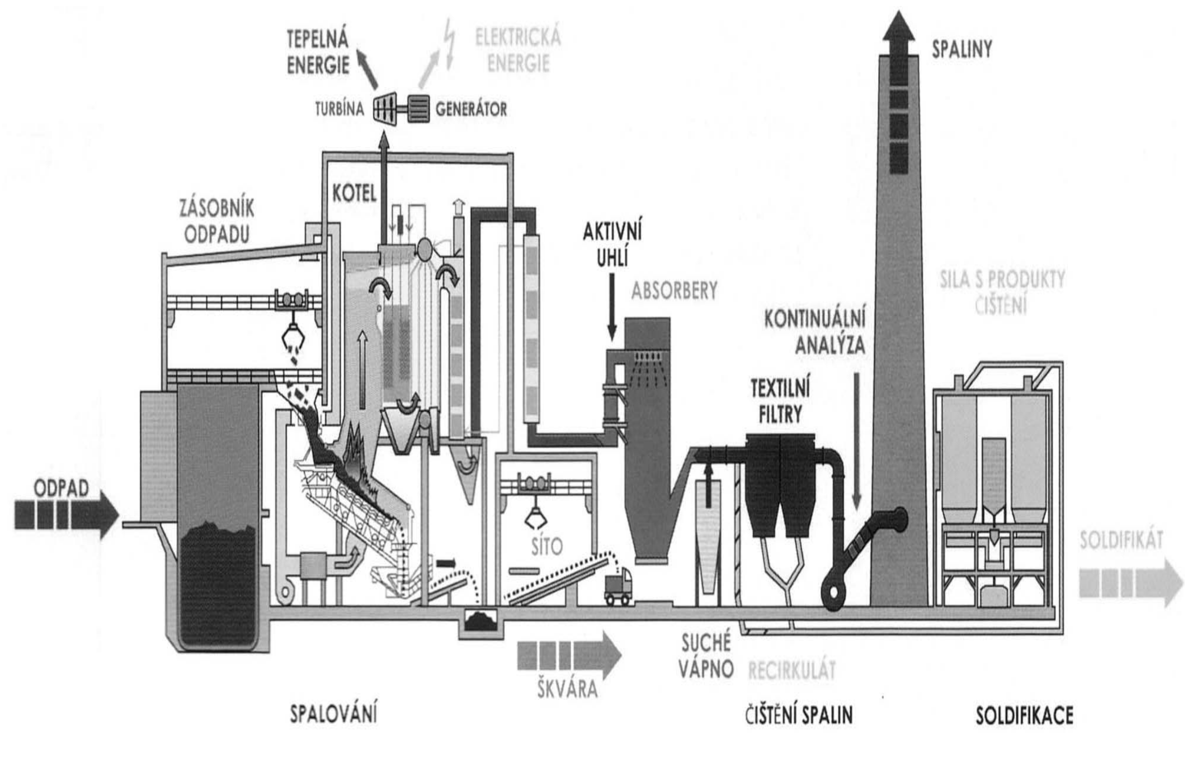

Fig. 1 Scheme of municipal waste incinerator of SAKO Brno, a.s. [1]

Rys. 1. Schemat pieca do spopielania odpadów SAKO Brno [1]

LEGEND:

TEPELNÁ ENERGIE – THERMAL ENERGY
ELEKTRICKÁ ENERGIE – ELECTRICAL ENERGY
SPALINY – FLUE GAS
TURBÍNA – TURBINE
GENERÁTOR – GENERATOR
ZÁSOBNÍK ODPADU – WASTE HOPPER
KOTEL – BOILER
AKTIVNÍ UHLÍ – ACTIVATE CARBON
ABSORBÉRY – ABSORBERS
KONTINUÁLNÍ ANALÝZA – CONTINUOUS ANALYSIS
SILA S PRODUKTY ČIŠTĚNÍ – STORAGE BINS FOR TREATMENT PRODUCTS
TEXTILNÍ FILTRY – FABRIC FILTERS
ODPAD – WASTE
SÍTO – SCREEN
SOLIDIFIKÁT – SOLIDIFICATE
SPALOVÁNÍ – INCINERATION
ŠKVÁRA – CINDER
SUCHÉ VÁPNO – POOR LIME
RECIRKULÁT – RECIRCULATE
ČIŠTĚNÍ SPALIN – FLUE GAS TREATMENT
SOLIDIFIKACE – SOLIDIFICATION

down under pressure, to the surface of which the heavy metals and dioxins are mainly bound which were not removed by the previous reactions.

If necessary to capture the increased concentrations of acidic components of the flue gas, in addition to the semi-wet type system, the dry type flue gas treatment system can be run, during which a dry hydrate of lime is fed into the flue-gas duct before the fabric filter to increase the efficiency of the neutralization reaction. The flue gas, including fly ash, reaction products of neutralization and residua of unreacted reagents are led through the flue-gas duct on the fabric filter. Prior to entry into the chimney with a height of 125 m, the cleaned flue gas is subjected to a continuous analysis.

The construction of a new incinerator for disposal from municipal solid waste in Prague was considered already in the late 70ies. The construction itself was commenced in September 1988. The **Plant for energy recovery from municipal waste (ZEVO) Malešice** was put into operation in the fall of the year 1998. There were four steam boilers by ČKD DUKLA in the incinerator, with a capacity of 15 tonnes of waste per hour each. The total capacity of the incinerator is 310 thousand tonnes of waste per year. This capacity is used from two thirds only. In 2010, a new co-generation unit was put into operation, allowing increased production of energy from waste. The incinerator delivers about 1,000 TJ of thermal energy annually to Pražská teplárenská, a.s., and produces about 90,000 MWh of electricity per year. The output of the installed turbines is 17.6 MW_e.

ZEVO Malešice has four identical lines, two of which were in operation previously and two of them were shut down, but in winter three of them worked if there was a high enough demand for heat. It is now moved to 3 + 1 after the adaptation with the co-generation [2].

About 2 years ago, the flue gas treatment system in ZEVO Malešice was reconstructed. Now the plant disposes of a top multi-stage flue gas treatment system. The flue gas is first fed to a spray dryer for pre-treatment of dust particles, acidic components and heavy metals. The effect of the first stage is also the fact that water is evaporated from a washing suspension so that the waste leaves the system in the solid phase only. The flue gas continues passing to an electrostatic precipitator where particles are removed (the second treatment stage). Behind the electrostatic precipitator, a new combined catalyst (SCR – selective catalytic reactor) is integrated, where the degradation of nitrogen oxides and oxidative decomposition of dioxins and furans take place ($DeNO_x$ and DeDiox catalytic reactor). The flue gas is thus deprived of nitrogen oxides, dioxins and furans, and is pre-treated in terms of acidic components, and particles are removed. Further it proceeds into the two-stage wet flue gas treatment system. There is a so-called pre-scrubber placed here, which dissociates chlorides, iodides, bromides and fluorides, and in the next stage the absorption SO_2 and SO_3 takes place as well. Thus, it is a five-stage flue gas treatment system. As regards the achieved emission levels, it is clear that all emission values are below ten per cent of the allowed limits, only CO reaches 30% and NO_x 70% of the level of emission limits [2].

A last modern municipal waste incinerator in the Czech Republic was put into operation in **Liberec (TERMIZO a.s.**). The construction was commenced in 1997; the trial operation started in 1999 and was completed in 2000 by final building acceptance. The incinerator has a capacity of 96,000 tonnes of waste per year, has one incineration line with a moving grate of the Von Roll system with a capacity of 12 tonnes per hour. The made preheated water steam is supplied to a local heating system.

Currently the construction of other municipal waste incinerators is considered, which would partly address the issue of waste management at regional levels. In all the cases the usage of conventional grate boilers is considered.

The projects in the Moravia-Silesian Region (**KIC Odpady**) and the Pilsen Region (**ZEVO Chotíkov**) are developed the most.

The project preparation of the KIC Odpady, a.s. incinerator (**Regional Integrated Centre of Waste Management**) is at an advanced stage. The project has passed the assessment of the impacts of construction on the environment; land-use and building proceedings. The incinerator should be put into operation in 2015. Currently, its realization is suspended due to the action against the validity of the building permit filed by a civic association. The incinerator design parameters are 192,000 tonnes of used municipal waste; the turbine output is 15 MW_e. There are two variants of the overall energy balance. The first variant assumes 90 GWh of electricity per year and 576 TJ of heat per year when taking out heat in hot water. The second, more likely option assumes the supplies of 20 GWh of electricity per year and 1,152 TJ of heat per year when taking out heat in steam of 1.1 MPa.

The planned **Plant for energy recovery from municipal waste** (ZEVO) **in Chotíkov near Pilsen** should also operate in a cogeneration mode. Up to **100,000 tonnes of municipal waste** per year should be used for energy recovery. Its commissioning is planned for 2015. Currently, the project passed the environmental impact assessment, planning procedure and building permit.

The Highlands Region prepares the project **Integrated waste management system in the Highlands Region** whose part is a municipal waste incinerator as well.

Other upcoming projects:

- The company United Energy, a.s. is preparing the construction of plants for energy recovery from waste at the premises of the **Komořany heating plant** with an annual capacity of 100 to 150 thousand tonnes of waste. The commencement of operation is also planned for 2015.
- Further construction of the municipal solid waste (MSW) incinerator being considered is located at the premises of the **Opatovice power plant**. Its capacity should be about 100,000 tonnes of incinerated waste and the heat should be used in the agglomeration of Pardubice and Hradec Králové.

2. Gasification of waste

The essence of gasification is the conversion of carbonaceous materials at higher temperatures (above 800°C) into combustible gaseous substances under the supply of under-stoichiometric amount of air or other oxidising agent. The gasification is a strongly endothermic process. The **advantage** is that due to the high temperatures there are no problems with the formation of toxic dioxins, furans and polycyclic aromatic hydrocarbons. The reducing environment prevents the formation of nitrogen oxides [5].

The gasification is partial combustion of organic compounds forming gases which can be used as a raw material (using reform processes) or as a fuel. The gasification processes are suitable for the treatment of municipal waste, some hazardous waste and dried sewage sludge.

Very interesting structures are e.g. gasification units working in the plant for energy recovery from municipal waste of the company Kazusa Clean Systems Co., Ltd. The plant was built in Kisarazu City, in the Japanese Prefecture of Chiba, by the firm Nippon Steel Engineering Co., Ltd. [6].

In the gasification furnace, the temperature of up to 1,800°C is reached in the melting zone (here municipal waste is melted in the last phase), while the leaving slag is granulated in a water trough and then crushed. From the slag, metals are obtained by magnetic separation, and the rest is used in civil engineering.

The gas comes into the combustion chamber, where it is burned. Flue gases are fed to the waste heat boiler which produces superheated steam driving the turbine and the generator, producing electricity. Units are available with a capacity of 100 or 125 tonnes of municipal waste per day. The company Kazusa Clean Systems Co., Ltd. has 2 units in place for processing 100 tonnes of municipal waste per day and 2 units for processing 125 tonnes of municipal waste per day. The output of the generators is then 3,000 kW_e and 5,000 kW_e [6].

Flue gases are cleaned in a multistage process as is the case of the ZEVO Malešice plant and, also, as projected for the *Plant for energy recovery from municipal waste Chotíkov (ZEVO Chotíkov)*, including the SCR – the $DeNO_x$ and DeDiox catalytic reactor.

3. Pyrolysis

Pyrolysis is the thermal decomposition of organic materials in the absence of oxygen-containing media (air, carbon dioxide, water vapour) which leads to the formation of gaseous, liquid and solid fractions. This process is an alternative to combustion.

The essence of this method is that organic compounds are less stable at higher temperatures. High molecular substances are decomposed to low molecular ones, which leads to their breakdown into volatile products and coke. Pyrolysis is carried out at the temperatures ranged from 150°C to 1,000°C. According to the temperatures, we distinguish:

- Low-temperature pyrolysis (reaction temperature up to 500°C),
- Medium-temperature pyrolysis (reaction temperature from 500°C to 800°C),
- High-temperature pyrolysis (reaction temperature above 800°C).

Advantages of pyrolysis processes [7]: Easier and less capital-intensive plants, produced fuels are easily merchantable, than heat and steam, there is only a small fraction of gaseous products of incineration compared to the same amount of fuel.

Disadvantages of pyrolysis processes: Sometimes more expensive operation, sometimes a problem to remove the pyrolysis residue (pyrolysis coke), liquid hydrocarbons.

Pyrolysis can be used in addition to the thermal treatment of municipal waste and sewage sludge also to treatment of plastic waste and used tires.

For a long time, the pyrolysis and gasification of coal are considered to be very promising also in the field of energy recovery from waste. Although research in this area is quite wide and technological development is well advanced, neither of these technologies is still established in the waste area so that the future operator could get it complete, as we say “turnkey”. This is currently a big problem, because there is nothing in this field in the Czech Republic the entrepreneurs could equipped with the intended operations for treatment of waste (municipal waste, tires) that they would like to operate as a plant for waste energy recovery [4].

One of the plants that is, however, offered in our country for tire processing (other types of waste can be used as well), is the M3RP pyrolytic line from the supplier AmbientEnergy LLC (USA), the SCOGEN manufacturer (India) [8]. Another plant is the one from the SIMUL trust, a.s. company, with a trade name PTR, which is able to use both waste rubber materials, tires and municipal waste, and a variety of other waste (sewage sludge, waste oil, plastics, biomass) [9].

4. Plasma technology

Plasma systems require temperatures around 5,000 to 15,000°C. These high temperatures accompany the conversion of electrical energy into heat forming plasma. Plasma is a mixture of electrons, ions and neutral particles (atoms and molecules). The ionized, conductive gas of high temperature occurs by the interaction between the gas and the electric or magnetic field. Rapid chemical reactions are promoted by high temperatures. Plasma is a source of reactivity. Hot plasma can be created by a passage of direct or alternating electric current through the gas between electrodes through the use of the radio magnetic field without using electrodes or microwaves.

When injecting hazardous substances such as PCBs, furans, pesticides, etc. into plasma, these substances decompose into atomic components. The process is used to modify organic compounds, PCBs and HCB (hexachlorobenzene). The effectiveness of this technology is higher than 99.99%. The process of plasma methods is expensive and operationally challenging.

There are different kinds of plasma technology [7]: Plasma arc in argon, inductively coupled plasma radio waves (ICRF), alternating current (AC) plasma, plasma arc in carbon dioxide, microwave plasma, plasma arc in nitrogen, plasma arc in water.

A substantial disadvantage of the plasma technology is that no reference unit for the use of mixed municipal waste exists for the technology as a whole, and the equipment is not operationally tested. Plasma technologies generally use MMW rarely only.

5. Conclusion

Currently, we get only about **3.6 million GJ of energy** at the average calorific value of mixed municipal waste (MMW) of about 10 MJ/kg and the **actual annual burning about 360 thousand tonnes of MMW**. According to well-known balances and overviews of the current waste management and following the strategy of development of waste management, it is stated that in 2020 it will be necessary to operate the plants for energy waste recovery with a total annual processing capacity of **2.0 million tonnes of MMW**. With an average calorific value of mixed municipal waste, we obtain at least 20 million GJ of energy (potential energy) per year through the energy recovery of that amount of waste [11].

The capacity of three municipal waste incinerators in our country is about **600 thousand tonnes of waste** (MMW) per year. The use of selected and modified municipal waste in cement plants through the gasification and in biogas stations is about **350 thousand tonnes** per year.

Thus, from 2 million tonnes, **600 thousand tonnes** can be processed in existing incinerators, **in the three planned incinerators another 400 thousand tonnes**, and in other energy waste recovery plants, **350 thousand tonnes** of municipal waste. To the year 2020, about **650 thousand tonnes** of mixed municipal waste still remains, which we will not be able to put on landfills.

It should be noted that the waste energy recovery saves e.g. an equivalent of the brown coal volume, which would otherwise have to be extracted and consumed in power plants and heating plants. It should also be pointed out that no matter how well cleaned flue gases from power plant processes are, their quality is incomparable with that of treated flue gases from waste energy recovery processes. The above facts should be taken into account in drafting the energy policy in the Czech Republic for the next period.

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Potencjał paliw z odpadów komunalnych

Artykuł podsumowuje możliwości odzysku energii z odpadów komunalnych. Opisuje historię spalania oraz odzysku energii z odpadów komunalnych w Czechosłowacji oraz późniejszych Czechach. Zwrócono tu uwagę na trzy obecnie działające zakłady odzyskiwania energii w Czechach (ZEVO Malesive, SAKO Brno oraz TERMIZO Liberec). Następnie przedstawiono charakterystykę planowanych zakładów odzyskiwania energii z odpadów komunalnych w Czechach. Wszystkie te zakłady pracują bazując na kotłach rusztowych z obróbką gazów wylotowych na najwyższym możliwym poziomie technologicznym. Artykuł zestawia również inne technologie, które mogą być zastosowane do odzyskiwania energii z odpadów komunalnych – należy do nich gazyfikacja i piroliza oraz technologia plazmowa. Podsumowanie tej pracy jest poświęcone obecnej oraz przyszłej sytuacji w obszarze odzysku energii z odpadów komunalnych w Czechach.

Słowa kluczowe: odpady komunalne, wykorzystanie energetyczne, kotły, gazyfikacja, piroliza, technologie plazmowe