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Editorial

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The Zero Waste utopia and the role of waste-to-energy

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While there is no doubt that the prevention of municipal solid waste (MSW) generation should sit at the top of any public policy, industrial strategy and individual behaviour, just like reducing the consumption of energy, this proposition might mislead the public into thinking that waste can suddenly disappear if only we had the will to make it happen. Despite these unattainable expectations, the 'Zero Waste' concept has become a viral and omnipresent phrase in recent years. A Google search of this term shows around half a million hits, as of March 2020, and countless government and non-governmental organisation initiatives worldwide. Zero Waste seems to be the only acceptable aim for today's politicians who embrace an environmentally friendly platform. As a result, countries and municipalities all over the globe have committed themselves to achieving the goal of Zero Waste. So far, however, nobody has managed it, and given the many scientific and practical roadblocks, no one ever will.

In many respects, the Zero Waste concept in the waste management realm seems akin to those seeking to create a perpetual motion machine, and to sell the idea to uninformed citizens. People are fascinated by the idea because it envisages the inspiration of consuming with a good conscience, leaving no garbage behind. Several hundred years ago, they were similarly captured by the idea of producing energy from nothing, using a perpetual motion machine. While the possibility of the latter has often been debunked, the potential to attain a Zero Waste state is still too broadly accepted by citizens and their government officials.

Against this background, this editorial addresses the idea of Zero Waste and the impossibility of its realisation, as well as the essential necessity of (a certain amount of) waste generation as a consequence of economic activity and consumption, due to its function as a sink for non-recoverable toxic and harmful substances.

First, an introduction to modern waste management is given, to clearly show that even the most sophisticated and well-developed programmes for waste reduction, collection, recycling, and treatment systems for waste cannot prevent the formation of at least a moderate, if not significant, residual waste stream.

Since the Zero Waste philosophy is often grounded in ideological environmental prejudices and opposition to proven and cost-effective elements of waste management – naturally, landfills and waste-to-energy (WtE) facilities – the (mostly unsubstantiated and often willingly wrong) related arguments are reflected on in the second part.

Well-performing waste management systems rest upon three main technical pillars:

- Recycling, including composting;
- Energy recovery;
- Landfilling.

All these elements are inevitable for the effective and efficient function of the entire MSW management system, but their relative ratio can change to a very wide extent. Waste reduction and material recycling are the main targets, aimed at retaining as many resources as possible in the loop. Only those residual waste fractions which are no longer available for material utilisation should be treated in WtE plants, especially if they are harmful or hazardous. For inert and mineral waste and hazardous concentrates from other waste treatment processes, specific landfills are needed as final sinks.

Recycling

According to the European waste hierarchy, recycling is the desired treatment option for waste that cannot be prevented or directly re-used. A key prerequisite for a high-quality recycling system is the source separation of materials that have market values. Typical material streams that are collected separately in households (and, to some extent, also at commercial sites) are glass, metals, paper and cardboard, (mixed) plastics and biowaste. Recycling points offer several further separate collection systems – for example, for wood, WEEE, batteries, hazardous wastes, building materials, etc.

In well-developed waste management systems, the collection and recovery rates are high and the quality of each stream tends to be good. Nevertheless, only the recycling of glass is close to becoming unlimited, if contaminants (typically additives used to deliver a specific colour) can be kept out of the material in the long run. All other materials can only be recycled to a certain extent or up to a limited number of cycles, due to several physical and other constraints, as discussed in Rigamonti et al. (2018).

The number of recirculation cycles for paper, for example, amounts, on average, to 3.5 in Europe and only 2.4 worldwide (ERPC, 2016). After the material is utilised, the degraded short fibres that cannot be incorporated into new paper products are used as fuel, normally by combustion at the site of paper mills to supply the energy for the paper-making process (and often by co-combustion of refuse-derived fuel (RDF)). Plastics show the lowest recycling rates of all separately collected bulk materials. In part, this is due to the wide variety of plastics in commerce, only some of which are recyclable. Depending on the collection system, a high share of non-recyclable material (considered contaminates to buyers) is collected together with the valuables. In Germany and in Italy, for example, the official input-calculated recycling rate is, therefore, high, but less than 50% of the introduced material is, in fact, recycled. So, despite the good intentions of citizens, a significant portion of the after-use materials they deposit in recycling bins ends up as waste. More than 50% are incinerated as auxiliary fuels in coal power plants as well as in cement kilns and as sorting residues in WtE plants (Consultic, 2016). On a European level, the main share of plastics is used for energy recovery (39.5%) and 30.8% is still sent to landfill (Plastics Europe, 2016).

These facts clearly show that 100% recycling has not been possible to achieve even after decades of evolution in the waste management industry, aimed at maximising diversion of wastes from WtE plants and landfills. Harmful contaminants are always collected alongside the valuables and must be segregated to protect man and the environment. Apart from glass and metals, the valuables themselves may lose their original properties and need to be excluded from the cycle. For these residuals, a safe final treatment or disposal method must be available in order to protect public health. The only options are WtE for organic substances and landfilling for minerals and hazardous residues.

WtE

The necessity of a sink for non-recyclable and harmful substances has been explained above. Therefore, WtE is a necessary and compatible partner of recycling, and not a competitor that some might claim. A modern recycling economy is reliant on ecologically friendly and affordable treatment options for the residues arising from the recycling processes.

WtE is also indispensable for the treatment of another large and problematic fraction: the residual waste. These remainders of our civilisation have to be treated in an environmentally sound manner. Modern WtE plants are the method of choice and the only reasonable option for this purpose in locations with sufficiently dense populations and with the resources and technical talent to build and operate such plants.

WtE plants are able to destroy toxic organic substances and to mineralise all organic components in the waste. This can be regarded as a ‘kidney function,’ which is necessary for all organisms to keep themselves healthy and functioning (Bertram, 2013). If there were no sink for these harmful substances, our society would poison itself by the concentration of toxic components in all anthropogenic mass flows and, as a result, in water, air and soil. This fundamental kidney function can be fulfilled by WtE only – mechanical or biological waste treatment options (like mechanical and/or biological treatment (MBT)) are not able to guarantee this fundamental requirement, let alone the fact that they are just an intermediate processing stage.

State of the art for WtE is the incineration in dedicated plants with energy recovery, highly sophisticated flue gas cleaning and maximum recovery of the process residues. Nevertheless, alternative thermal processes, like gasification, pyrolysis, liquefaction or plasma technologies, are often considered a better option for this purpose, because they allegedly offer higher efficiencies and, in some cases, also the possibility to produce chemicals or fuels. This is, however, not the case. It has been clearly proven that alternative thermal waste treatment processes are entirely unsuitable to treat residual waste (Quicker, 2015). Its non-homogeneous character is not appropriate for such complex approaches, however sensible they might be for industrial operations – and even assuming that the technological issues related to such non-homogeneous characteristics could be solved, one would still be confronted with lower performances and unfavourable economics (Consonni and Viganò, 2012). Only homogenous fractions with constant composition and very low impurities may be suitable input materials for these processes.

Landfilling

Landfilling sits at the lowest level of the European waste hierarchy. This means that waste fractions shall only be landfilled if they can be neither recycled nor used for energy recovery – that is, inert or mineral fractions. Even though landfilling is the least favourable option for waste treatment, it is nonetheless an indispensable element of a modern MSW management program. We need a sink for all mineral fractions that cannot be used in the cycle anymore, like polluted construction materials, contaminated soils, flue gas cleaning residues, asbestos, etc.

The preceding paragraphs make it evident that aiming for the establishment of a Zero Waste society is as impossible as the construction of a perpetual motion machine. But, in contrast to the thermodynamically impossible device, a lot of people, institutions and politicians are unwilling to accept the fact that Zero Waste is an unattainable utopia and cannot be realised in a world that operates according to the longstanding laws of physics. Nevertheless, in order to support their position and to show that Zero Waste is without alternative, its protagonists sometimes try to discredit other treatment options, especially WtE. Some of the most frequently spread myths and lies about WtE are briefly listed and refuted below.

Thesis: WtE prevents recycling

Zero Waste activists tend to claim that WtE is a competitor to recycling and subtracts recyclable materials from the cycle in order to feed the fuel needs of existing WtE installations.

In fact, the opposite is true. WtE supports recycling by two framework conditions. The first point is that recycling needs a sink for the non-recyclable residues (as previously described). The recycling system can function properly only if ecologically friendly options for the treatment of these fractions exist. The second point is an economic one. The costs for WtE are much higher than for landfilling and on a comparable level to recycling. As a result, there is no economic driver to switch valuable materials from recycling to WtE. If landfilling is the only alternative to recycling, like it is the case in many southern and south-eastern European countries, the economic incentive to divert resources, which would otherwise be recycled, to cheap landfills is high. The relationship between landfilling, WtE and recycling in the European Union countries is well known among practitioners. It shows that those countries with a highly developed waste management system, characterised by high recycling rates, have the highest share of WtE and the lowest percentage of landfilling.

There is actually a third point worth considering. The recycling programs are far from being well established worldwide, being affected by market fluctuations as well as by specific policies such as China's 'National Sword'. This might, and already has, stress a system that can work properly only if the full value chain is operational and healthy. Being able to rely on the WtE option guarantees to deal with such situations, without the need to store huge amounts of waste materials, with a consequent risk of uncontrolled fires.

Thesis: WtE emits CO_2 and intensifies climate change

WtE is carbon neutral when it comes to the combustion of the biogenic fractions such as paper, wood, and food waste. If landfilled, the degradation of such fractions would release methane, a more significant greenhouse gas than CO_2, in situations where full capture of the landfill gas is not achievable. Obviously, the combustion of waste plastics will release fossil CO_2, but the saved emissions from the displaced fossil fuels are offsetting, and this is especially relevant for high-efficient WtE facilities. Moreover, the recycling of low-quality mixed plastics streams, whenever that it is feasible, will hardly deliver a favourable greenhouse gas balance. Finally, in case a carbon capture and storage system is put in place at WtE facilities, they would become carbon negative!

Thesis: MBT is the better alternative

It is difficult, if not impossible, to establish a fair comparison between MBT and WtE, since the former is just a pre-treatment process that generates a number of outputs (as high as 80–90% in mass of the input), which require subsequent processing such as energy recovery, whether in a WtE plant or in co-combustion. Co-combustion in cement kilns is a fascinating option, but it can hardly be a structural one because, among others, of the reliance on a private sector that might be subject to market fluctuations and different dynamics. Moreover, MBT is not able to destroy toxic organic substances or to concentrate harmful inorganic ones – that is, it cannot act as a sink for pollutants.

Thesis: WtE affects the environment and human health by harmful pollutants

There is a general consensus that WtE has the lowest emission limits among all industrial facilities and WtE plants normally perform much better by orders of magnitude, sometimes even below the detection threshold of the instruments. WtE plants are the best monitored combustion plants, with atmospheric emissions continuously controlled and publicly reported. The effect of the residual emissions on the air quality is negligible, when compared, for instance, with the traffic emissions in surrounding areas (Lonati et al., 2019). Also, in comparison with landfills, the gaseous and liquid emissions from the latter are much more difficult to capture and contain.

Thesis: WtE is an extremely inefficient way of producing energy

Significant improvements have been achieved in recent years on the energy recovery efficiency of WtE plants. Large plants that produce only electricity can attain net efficiencies not too far from 30% – an impressive performance for a process where the waste-as-fuel input is very inhomogeneous and typically has a low heating value (lower than, say, coal) – a performance definitely higher than that achieved by small-scale biomass-fired plants. In addition, the combined heat and power operation is becoming mainstream, whether taking place at the service of district heating networks or of industrial facilities, yielding first-law efficiencies (sum of electric and thermal efficiency) of 80% and more.

The authors fully agree that society would be ideal if somehow we could operate an economy without waste. However, Zero Waste is clearly an unattainable chimera; it is, thus, irresponsible for government to structure programs to achieve a technological and economically infeasible objective, especially if by doing so it undermines the operations of well-established and functioning existing waste management systems. Proponents of Zero Waste are challenged to offer better achievable and certainly realistic alternatives.

The vital need of effective systems for dealing with residual waste streams, which include sinks for residuals, is demonstrated by the recent outbreak of Coronavirus, which is peaking as we compose this Editorial. For example, huge amounts of single-use, potentially contaminated items used to test for and treat COVID-19 patients are currently flooding the waste management system in many countries, and will do so whenever similar emergencies emerge in the future. The waste management sector must be structurally well prepared to effectively deal with such materials via combustion and secure landfilling when waste reduction and recycling alone cannot ensure the protection of public health and the environment.

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