# How waste-to-energy plays an essential role in the circular economy

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The European Commission's "circular economy package" defines a circular economy as an economy that focuses on maintaining the value of products, materials and resources in circulation for as long as possible, thus minimizing waste generation and resource consumption. The transition towards a circular economy is believed to create new business opportunities and jobs and will imply innovative, more efficient ways of producing and consuming. It is also presumed that a circular economy will save energy and will avoid irreversible damages to the environment and to society caused by the consumption of resources at a rate that exceeds the earth's capacity to renew them (European Commission, 2015). This way, the circular economy is a valuable concept with commendable objectives that are however not always obvious to realize in the present economic and social context. Yet, a first onset on how to establish a circular economy is given in the same European Commission's "Circular Economy Package". The most concrete of the proposed actions are the legislative proposals on waste, including long-term targets to reduce landfilling and to increase preparing for "re-use and recycling" of key waste streams such as municipal solid waste (MSW) and packaging waste.

Waste-to-energy (WtE), i.e. dedicated waste combustion with high energy recovery according to the R1 formula defined in annex II of Directive 2008/98/EC, figures on a lower level in the waste hierarchy than waste prevention, re-use and recycling, which all three perfectly fit in the circular economy. Moreover it is not obvious that WtE maintains materials in the economy for as long as possible and it is believed by many people to compete with re-use and recycling. Therefore it will be argued that WtE, which to date fulfills an essential role in sustainable waste treatment, will continue to play an essential role in the circular economy. Furthermore, the pitfalls of a circular economy that focusses merely on material cycles disregarding other environmental, economic, energetic and social aspects will be pointed out.

A first argument showing that **WtE** plays an essential role in the circular economy is that it **combusts, or at least should combust only waste that to date cannot be recycled**. Indeed, for some waste types, recycling is not feasible due to obvious technical reasons such as insufficient separate collection; impossible sorting or purification; shortening of fibres of plastics, paper, or textile upon recycling, so that these materials may only be recycled a limited number of times; and of course non-existence of methods to produce a recycled product or material at a reasonable cost. These technical reasons go often hand in hand with and are difficult to separate from economic reasons, e.g. a low market value of the recycled product or material because it does not meet the quality and/or function standards or requirements of the costumer; higher energy consumption of the recycling process than of the production process from virgin materials; high Capex and Opex for separate collection, separation, decontamination and pre-treatment of the waste resulting in a recycling cost that is higher than the cost of production from virgin materials. An example is household packaging waste, for which high recycling rates can be obtained, however only for material types that are easy to separate. In Flanders for instance, the overall recycling rate for household plastic packaging is limited to about 35% (Jaarverslag Fost plus, 2016) because only easy to separate PET and HDPE bottles and flasks are collected separately, whereas e.g. plastic foil, bags, yoghurt pots, etc. composed of different polymer types incompatible for recycling, are, for the time being, excluded from the separate collection scheme and are collected as residual waste, which is treated in WtE plants. For other waste types, recycling is not the best treatment option due to environmental, safety and health reasons. E.g.in case the waste contains toxic substances, recycling will dissipate these substances over the recycled products where they form a continuous source of human exposure. Examples are the dissipation of POPs such as PCBs in the food chain e.g. illustrated by the Belgian dioxin incident in 1999 or the dissipation of toxic PBDEs in plastic recycled from WEEE (Zennegg et al, 2014).

Data on applied MSW treatment methods reported by Eurostat for the year 2015 show that in certain European regions such as Germany and Flanders, re-use and recycling rates of almost 70% are obtained. In a zero landfill scenario and in the present technological and economic context however, these high recycling rates go along with incineration of the non-recyclable MSW (remaining 30%) in WtE plants. These data clearly show that **WtE does not compete with recycling, but with landfill, which is lower in the waste hierarchy**.

For waste containing toxic substances, WtE is preferred over recycling because (1) WtE destroys organic toxic substances; if however waste contains high concentrations of organic toxic substances, specific high temperature combustion techniques such as a rotary kiln with primary combustion chamber are applied in practice to guarantee a complete destruction and (2) WtE retains heavy metals in the solid residues, which are stabilized and solidified and subsequently stored in a safe sink. This way, **in the circular economy, WtE is essential in keeping materials and the environment free from toxic substances**.

Perhaps somewhat unexpectedly, **WtE also allows for material recovery and recycling from non-recyclable waste**. The combustion of one t of residual MSW typically yields between 200 and 250 kg of bottom ash (BA). Due to recent improvements in BA treatment methods and legislative incentives, more than 90% of WtE BA can be recycled: the recovered ferrous and non-ferous metals are recycled by secondary metal recyclers and the remaining inorganics fraction is used as building material.

**WtE can generate energy with high efficiency, and as the circular economy obviously needs energy, WtE may partly feed it**. Indeed, a WtE plant is generally equipped with a steam boiler for energy recovery from the hot combustion gases. The steam generated in the boiler can be applied in a Rankine power cycle, generating electricity using a turbine, as in a fossil fuel power plant. Part of the electricity may be used internally, the rest is usually supplied to the grid. The net electrical efficiency achieved in state-of-the art WtE plants is generally around 20 to 25%, which is modest compared to conventional coal power plants. The overall energy efficiency of a WtE plant can however be increased by (1) applying low pressure steam or hot water from the condenser after the turbine is applied as heat source in a combined heat and power (CHP) scheme or by (2) using the high temperature steam from the boiler directly as a heat source, which affords a possible overall energy efficiency up to 80%. Whereas in case (1) the hot water or low pressure steam can be used for e.g. public heating purposes in district heating networks, in case (2), high pressure steam can be used in industrial applications e.g. for unit operations in the chemical industry.

Legislators should be aware that a one-sided focus on increasing recycling volumes can lead to a quality deterioration and dissipation of toxic substances in recycled materials. Instead of only increasing recycling volumes, elimination of toxic substances in consumer goods should be the first priority in the transition towards a circular economy. In this regard, WtE fulfils an essential role as a gatekeeper, by destroying and eliminating toxic substances from the material cycles. Furthermore, WtE offers a treatment method for waste that is, e.g. because of its heterogeneous composition, today not recyclable from an economic point of view, whilst recovering valuable energy and materials, thus co-enabling the circular economy.

The ultimate solution towards a complete sustainable circular economy is eco-design that not only takes into account the technical and functional specifications, but also considers the end-of-life aspects of products. Although in an ideal scenario WtE can be phased out completely because all material streams are clean and their recycling is economically viable, we think it is more realistic to assume that WtE will still remain necessary, at least for many decades, if it can be phased out at all. Indeed, the problem is that for new materials, although often designed as green alternative to highly contaminating materials, the true environmental and health impact is often only discovered after many years (e.g. asbestos, CFCs, PCBs, etc) during which the material cycles and/or the environment have already been contaminated. Hence, in the future, even with eco-design, WtE is likely to remain a necessary, even essential part of the circular economy, albeit to a lesser extend then is actually the case.

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