Circular economy, recycling and end-of-waste

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Editorial

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Increased economic activities and raw material consumption during the last century led to material and energy import dependency in many countries and regions of the world, among them the European Union (EU). The EU has been importing between 20% and 30% of all resources – around 42% of natural gas, 56% of coal and 88% of oil, 50% of copper, 85% of bauxite, 89% of iron ore and 100% of a wide range of hi-tech metals (EEA, 2012). Another consequence of the increased materiality of human consumption is a vast increase of the quantities of waste generated that has to be managed properly. Looking only at the EU, an average of over 1.8 t of waste was generated per capita on an annual basis in 2016 (excluding mineral wastes), 27% of which was municipal solid waste (European Commission - Eurostat, 2017). These quantities of waste represent a challenge for EU member states, but at the same time it is an opportunity to alleviate problems of material (and, partially, of energy) scarcity. In the light of the China ban for the import of certain waste types, the policy of building up recycling loops for waste within the own legislation once again proved to be the right path.

The problem of import dependency regarding materials can, to some extent, be alleviated by material recovery of waste. This is emphasised through EU waste management policies, which aim to reduce health and environmental impacts of waste management and to improve resource efficiency. The Waste Framework Directive (European Commission, 2008) created boundary conditions for an increased material recovery by setting a waste hierarchy that defines recycling as a preferred option for waste recovery. The circular economy package (European Commission, 2015) currently being implemented made the next step in that direction by introducing a 'closing the loop' concept of material/product lifecycle and measures that cover the whole life cycle of materials, from production and usage through waste management and ultimate disposal, to the market for recovered resources and recovery. 'Closing the loop' between the end of the life of the product and its production enables circulation of resources, materials and products, and keeps its material and/or energy and economic value within the economy for as long as possible.

The circular economy package clearly puts an emphasis on closing the loop on the material side. In this context, George et al. (2015) developed their circular economy model, which takes into consideration pollution and recyclable material input, next to economic parameters. The model concludes that economic growth alone cannot maintain/improve existing environmental quality (contrary to waste Kuznets Curve (Ichinose et al., 2015)) and to do so the recycling ratio needs to be increased.

Therefore, increasing the rate of recycling is a central objective in the implementation of effective and environmentally sound, waste management systems throughout the world. From an environmental engineer's perspective, recycling includes the substitution of primary resources by secondary resources. In order to make sense from an environmental perspective, recycling should reduce environmental impacts of the overall product/service provision system assessed based on the life cycle assessment approach. This is where crucial functions of the waste management sector come into play: Provision of secondary resources for sustainable material cycles while securing the removal of pollutants and materials with no markets, and diversion of those to appropriate sinks.

The options and quantitative potentials of recycling of the various wastes are very much dependent on the recyclability of goods and the definition of what is to be conceived as 'recycled'. More generally, the definition of the interface between the waste and the product sphere is a central element in the operative implementation of waste management in the various legislations around the world.

At present there are considerably different approaches regarding the national implementations of legislative stipulations with respect to recycling. Whereas there are national implementations deeming the quantity of separately collected recyclables as 'recycled', other national implementations only allow for counting the output of sorting plants, respectively, the input in the effective recycling process as 'recycled'. These different approaches make comparisons of recycling rates difficult and even meaningless, as any step down the processing chain of wastes/recyclables, from collection down to the effective substitution of primary materials, leads to quantitative losses and thereby decreases the practically achievable recycling rate. The same recycling-situation of a specific waste stream can for example result in a recycling rate of anything between 40% and 80% based on the different rules for reporting recycling rates. Therefore, mandatory standards with regards to recyclability and clear definitions regarding recycling become even more important when quantitative recycling targets are defined. This has been acknowledged during development of the circular economy package (European Commission, 2015) and continues to be addressed in the ongoing implementation.

Recycling of waste involves secondary resources – materials that may resemble waste – to cease being considered as waste (end-of-waste; EoW) and to enter the product-sphere. The relevance of this is to which sphere of legislation the certain material belongs. For waste materials, all waste sector-related legislation has to be applied to and for products (non-waste) to which all product-related legislation applies. The transition from waste to product can take place within a process into which the secondary material enters as a waste input. A different option is that the EoW status is achieved prior to a certain process using the respective secondary resource. In that case the secondary material must not only meet certain EoW (i.e. quality specifications) criteria, but also criteria laid out for the marketing of substances and criteria also applicable to any other primary substance, such as the obligations set out in the REACH-Directive (No. 1907/2006) (European Commission, 2006).

Regarding the EoW, the European Commission directive of 2008 (European Commission, 2008) set out the grounds by which a material, which is recovered or recycled from waste, can be deemed to be no longer a waste. According to the directive, a certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in accordance with the following conditions:

1. the substance or object is commonly used for specific purposes;
2. there is an existing market or demand for the substance or object;
3. the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
4. the use of the substance or object will not lead to overall adverse environmental or human health impacts.

The purpose of defining EoW criteria is to facilitate and promote recycling, ensuring a high level of environmental protection, reducing the consumption of natural resources and the amount of waste sent for disposal, as well as obtaining materials from specific waste streams that could be freely traded as (secondary) materials in the open market. Currently, the recycling of certain wastes is sometimes hampered by several factors that could be overcome by determining when a waste ceases to be a waste and becomes a secondary product.

To achieve the EoW status, companies need to be able to demonstrate that all four mentioned criteria are met. Many times, there is no fixed formal requirement from the regulator, so companies cannot rely on a specific procedure but are free to provide the evidence that a certain secondary material meets the EoW criteria. This is normally perceived as a risky approach, since it leaves businesses more open to future challenges by regulators (Renewable Energy Association, 2018) and/or citizens.

The first criteria, which also implies that 'the product (substance or object) should be distinctly different from original waste', creates a degree of subjectivity in the assessment. What degree of transformation (physical, chemical or biological) should be considered as sufficient is not yet entirely clear and opens up space for different interpretation.

The third point, which could also translate as that 'the product can be used in same way as non-waste alternative', is the criteria that is usually assessed through comparison with an appropriate 'virgin' material. That requirement to compare the recovered material with a virgin equivalent can pose substantial problems and sometimes even a major barrier to certification.

The European Commission acknowledges these problems on uncertainties (about the status of a material as a waste or a product) stating in its Communications (European Commission, 2018):

> For some waste streams such criteria have been set at EU or national level. However, the scope of these rules and clarity on how they operate is lacking. The complexity of waste streams, recovery processes and recovered materials means that end-of-waste criteria that are applicable to whole waste streams are not easy to establish. Consequently, many recovered materials are traded and used in the absence of established end-of-waste criteria and therefore under unclear legal circumstances and without transparency.

Following that, the European Commission put in its plans the obligation to facilitate closer cooperation between existing chemical and waste management expert networks and prepare an online EU repository for all adopted national and EU EoW and by-product criteria. It will also launch a study to gain a better understanding of Member States' practices as regards implementation and verification of provisions on EoW as a basis for possible guidelines.

So far, the EU has developed EoW regulations for: iron, steel and aluminium scrap, glass cullet and copper scrap. Independently, some national regulators acknowledged EoW status for different materials, like recycled low-density polyethylene (LDPE) plastic, solid recovered fuel (SRF), tyre bales, biodegradable waste, gypsum, inert aggregates (construction and demolition waste), etc., while for other materials/products the regulators decide on a case-by-case basis whether certain waste has ceased to be waste in accordance with the end-of-waste conditions.

To conclude, it is clear that using wastes as resources is a necessary part of the circular economy, provided they can be used without harm, and so 'the end of waste' (with its criteria and regulations) should be seen as a powerful tool in reaching a full circular economy and not be its barrier. Therefore, within the EoW criteria should be specified, clearly and undoubtedly, when certain waste ceases to be waste and obtains a status of a product (or a secondary raw material), and these criteria should be universally harmonised and acknowledged EU-wide. In addition to the waste-related regulations, the regulators must also look at the regulations dealing with the product sphere, such as the REACH directive (No. 1907/2006) (European Commission, 2006) in order to identify, avoid and potentially adapt stipulations that are hampering the installation of material cycles by making use of secondary materials from the waste sector.

The articles presented in this special issue of *Waste Management & Research* deal with the topics of circular economy and recycling. Some of the articles were presented at the conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES), which was held in July 2018 in Novi Sad, Serbia (SDEWES SEE). These and other articles published in this special issue address many aspects of waste recycling and thereby demonstrate the many different issues that need to be tackled as a part of our efforts towards improving the situation regarding the management of waste.

The SDEWES Conference, sponsored by UNESCO, is a leading conference in the field of energy, sustainable development and environment in the region. The next SDEWES conference will be held on 1–6 October 2019, in Dubrovnik, Croatia. It will be dedicated to the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by de-coupling growth from natural resources and advancing towards a knowledge-based economy, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding energy, transport, water, environment and food production systems and their many combinations. More details regarding the conference can be found at http://www.dubrovnik2019.sdewes.org/.

Authors are welcome to submit their research findings in the context of recycling, recyclability and EoW to *Waste Management & Research*, as the relevance of these types of subjects increases in the light of the development of the waste sector continuously.

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