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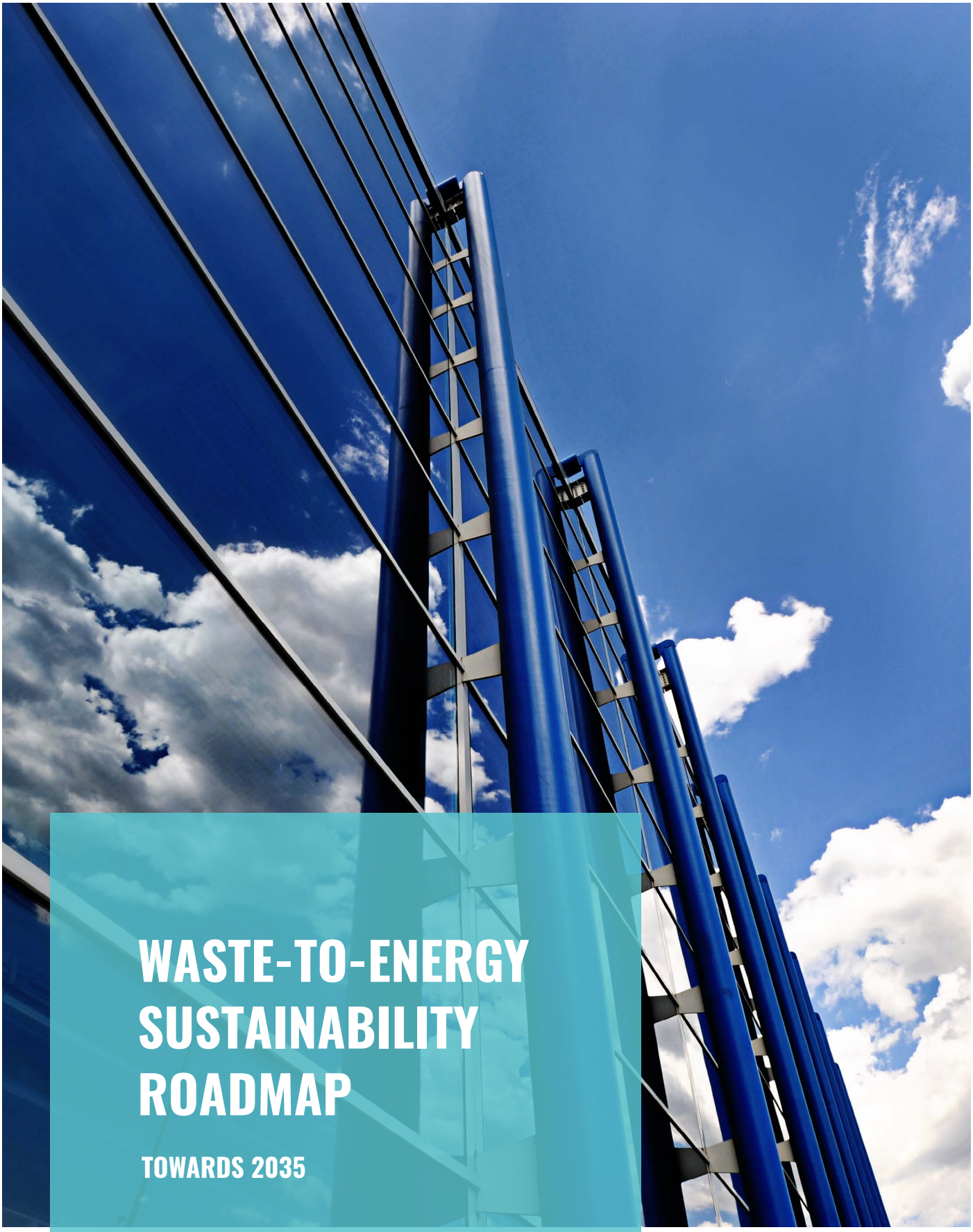


WASTE-TO-ENERGY SUSTAINABILITY ROADMAP

TOWARDS 2035

CONTENTS

FOREWORD

We are honoured to present CEWEP's first Sustainability Roadmap, outlining the Waste-to-Energy (WtE) sector's vision for 2035 and showing the essential services our industry provides to society by:

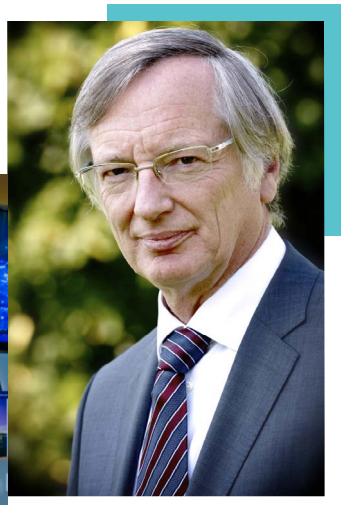
- Guaranteeing secure treatment of municipal and similar commercial and industrial waste
- Decontaminating recycling streams by acting as a sink for pollutants
- Generating local, renewable energy
- Recovering metals and minerals from the bottom ash of WtE plants
- Supporting quality reuse, remanufacturing and recycling
- Reducing society's dependence on landfills

Today's linear economic model generates mountains of waste. It involves the extraction and processing of virgin raw materials, while products and packaging are used and then thrown away.

In the past, Europe sent millions of tonnes of paper, cardboard, plastics and textiles overseas for processing with different variations of quality. In 2018, China imposed strict limits on recycling impurities, leaving Europe to clean up its act and improve its internal capacity to sort and recycle waste, as well as to find ways to keep recycling streams clean.

In a shift away from a linear economic model, the European Union adopted the Circular Economy Package in 2018. The package introduces new waste management targets. For municipal (household) waste, it sets a 10% cap for landfilling and a recycling target of 65% by 2035.

While there are already some moves towards a more circular model, product design will not be reinvented overnight. To successfully close the loop, we must focus on quality as well as quantity. As Europe seeks to address its waste challenges, WtE will continue to provide essential waste treatment where recycling is not appropriate and to offer a source of secondary raw materials and energy for the circular economy.



WtE also contributes to the EU's 2030 targets for greenhouse gas emissions reduction (at least 40% reduction from 1990 levels) and for renewable energy (at least 32% share) adopted in 2018.

This Sustainability Roadmap demonstrates our industry's commitment to waste recovery and clean energy production, as well as our role in reducing environmental pollution and creating skilled jobs. We are proud of these achievements and the role we play in European society.

CEWEP would like to thank its members for their input and support in developing this first Roadmap. We look forward to pursuing an open dialogue with policymakers, NGOs and community stakeholders to support the transition to a more circular and sustainable future for Europe.

BY PAUL DE BRUYCKER

President, CEWEP

AND ELLA STENGLER

Managing Director, CEWEP

VISION

Our vision is for a well-functioning circular economy in 2035 where quality recycling is steadily increasing and landfilling is limited to a minimum. WtE (incineration with energy recovery) has an essential function and is recognised as an enabler of the circular economy.

The WtE sector has a pivotal role to play in moving towards a resource-efficient, low-carbon, circular economy. WtE is an established and important **renewable energy provider** for both electricity and heat **from residual materials which are not recycled in practice**.

THE PATH TO 2035

We envision an **integrated waste management system** with WtE as a cornerstone of the **circular economy**. We **keep valuable resources out of landfill** and treat the waste that cannot be reused or recycled without impacting human health and the environment.

Our technology and processes will become increasingly **resource-efficient**. **Clean minerals** and **metals** will be recycled from bottom ash. **Carbon dioxide (CO_2)** from the flue gas is captured and used where appropriate and sustainable. Our industry continues to **pursue best practices,** to implement best available techniques (BAT) and develop **innovative technologies** to improve efficiency and reduce emissions.

One of our goals is for **WtE plants to be recognised as a reliable clean energy source** and to be fully integrated into clean local energy infrastructure by 2035.

The WtE sector is committed to **engaging with neighbouring communities** to help reduce their dependence **on fossil fuels**. We engage in dialogue to learn more about people's needs and to discuss the social and economic benefits WtE can bring to local communities, including **skilled and secure jobs**.

Photo: ISVAG plant, Belgium

1. INTRODUCTION

Many of the products used in our society are not designed to be robust, easily-repaired or upgraded and are often made from mixed materials which cannot be easily recycled. While we should do everything we can to adopt new technologies and policies which minimise waste creation, current production methods and consumption patterns will continue to generate residual waste which is contaminated or too low quality to recycle.

The success of recycling relies significantly on efficient collection. Even if all waste streams were separately collected, it is not possible to recycle 100% due to some poor-quality materials.

In line with the waste hierarchy, WtE is the most environmentally-sound treatment for recovering value from residual waste. The circular economy needs an outlet for residual waste that is not recycled in practice. Such low-quality waste is rejected by recycling facilities because it cannot be recycled in a technically, economically or environmentally feasible way, for example, degraded material that has already been recycled several times. By cooperating with partners across the whole value chain, the WtE sector prevents this waste from going to landfill.

CEWEP firmly stands for the environmentally-safe thermal treatment of waste (residual waste, sorting residues, recycling rejects etc.) and supports a sustainable waste hierarchy that applies lifecycle thinking as set out in Article 4 of the EU Waste Framework Directive. The general environmental protection principles apply, including:

- Precaution and sustainability
- Technical feasibility and economic viability
- Protection of resources
- Overall environmental, human health, economic and social impacts

When prevention, reuse and recycling are not possible, the remaining residual waste, including rejects from sorting and recycling, should be safely treated.

WtE is designed to thermally treat residues from households, industry or commerce by incinerating them under strictly-controlled conditions to generate energy. It helps to ensure the recycling/remanufacturing cycle is not contaminated. WtE acts as a sink for pollutants that must be safely destroyed, such as sanitary waste or infectious waste from hospitals. It guarantees reliable waste treatment, 24 hours a day, all year round, as well as the delivery of baseload energy.

This Sustainability Roadmap sets out how CEWEP and its members provide the safe treatment of residual waste, the development of high-quality, cost-effective recycling routes and how the WtE sector contributes to climate protection and the transition to a circular economy. The Roadmap also outlines:

- The limits of sorting and recycling and the essential role WtE plays in the waste management landscape of a circular economy
- Opportunities for the WtE sector to adopt innovative technologies
- How EU policymakers could design more sustainable environment, energy and related policies and oversee their successful implementation

Photo: SIDOR plant, Luxembourg

2. WASTE-TO-ENERGY IN EUROPE

2.1 WASTE IN THE EU: WHERE ARE WE HEADING? PROJECTIONS FOR 2035

Currently there are around 500 Waste-to-Energy plants operating across Europe, treating more than 96 million tonnes of waste annually. CEWEP represents over 400 of those plants in its membership.

The transition towards a more circular economy is only just beginning. In 2017, less than half of Europe's municipal waste was recycled or composted while a quarter of its municipal waste was landfilled – the equivalent of landfilling the volume of Wembley Stadium every week.

In the future, better and more widespread source-separated collection of waste is expected to help reduce mixed waste streams. European waste legislation supports this trend. However, taking into account the demographic and economic changes which will impact the amount of waste produced, it is unclear how much of a reduction in waste generation is truly feasible. For example, a recent publication from the World Bank suggests that waste generation in Europe will continue to grow *(World Bank Book What a Waste 2.0, 2018, p.25-26)*.

When the municipal waste recycling targets in the Circular Economy Package are reached, there will still be a need to treat residual waste that cannot be recycled in an environmentally-sound way.

Municipal waste is only a small part of the whole waste volume, representing around 10%. In industrialised countries, around 50% of the waste treated by WtE comes from commercial and industrial (C&I) waste, for which there are currently no targets set.

CEWEP assessed the capacity needs for waste treatment in Europe in 2035, assuming that the 65% recycling target of municipal waste would be met and even more ambitiously that 68% of non-hazardous commercial and industrial waste would be recycled. With this scenario in mind, CEWEP calculated that around 142 million tonnes of residual waste treatment capacity would be needed by 2035[1] *(calculations peer reviewed by Prognos)*.

Current WtE capacity in the EU is about 90 million tonnes and the capacity for co-incineration mostly in cement kilns is around 11 million tonnes[2]. This leaves a gap of approximately 40 million tonnes which must be closed if ambitious recycling and landfill reduction targets are to be met.

[1] In the calculation it was assumed that landfilling would decrease to an average of around 7%, based on the 10% limit to landfilling set by the 2018 Waste Framework Directive and considering that several Member States already achieve levels considerably below 10%.

[2] Includes hazardous and non-hazardous waste. The waste treatment capacity available in cement kilns depends on market drivers of the cement industry that do not take into account the needs of the waste sector. This makes the long-term waste treatment capacity in co-incineration difficult to predict.

WASTE-TO-ENERGY IN EUROPE 2017

WtE plants operating in Europe (not including hazardous waste incineration plants)

Waste thermally treated in WtE plants (in million tonnes)

Data supplied by CEWEP members and national sources.

*Includes plant in Andorra and SAICA plant

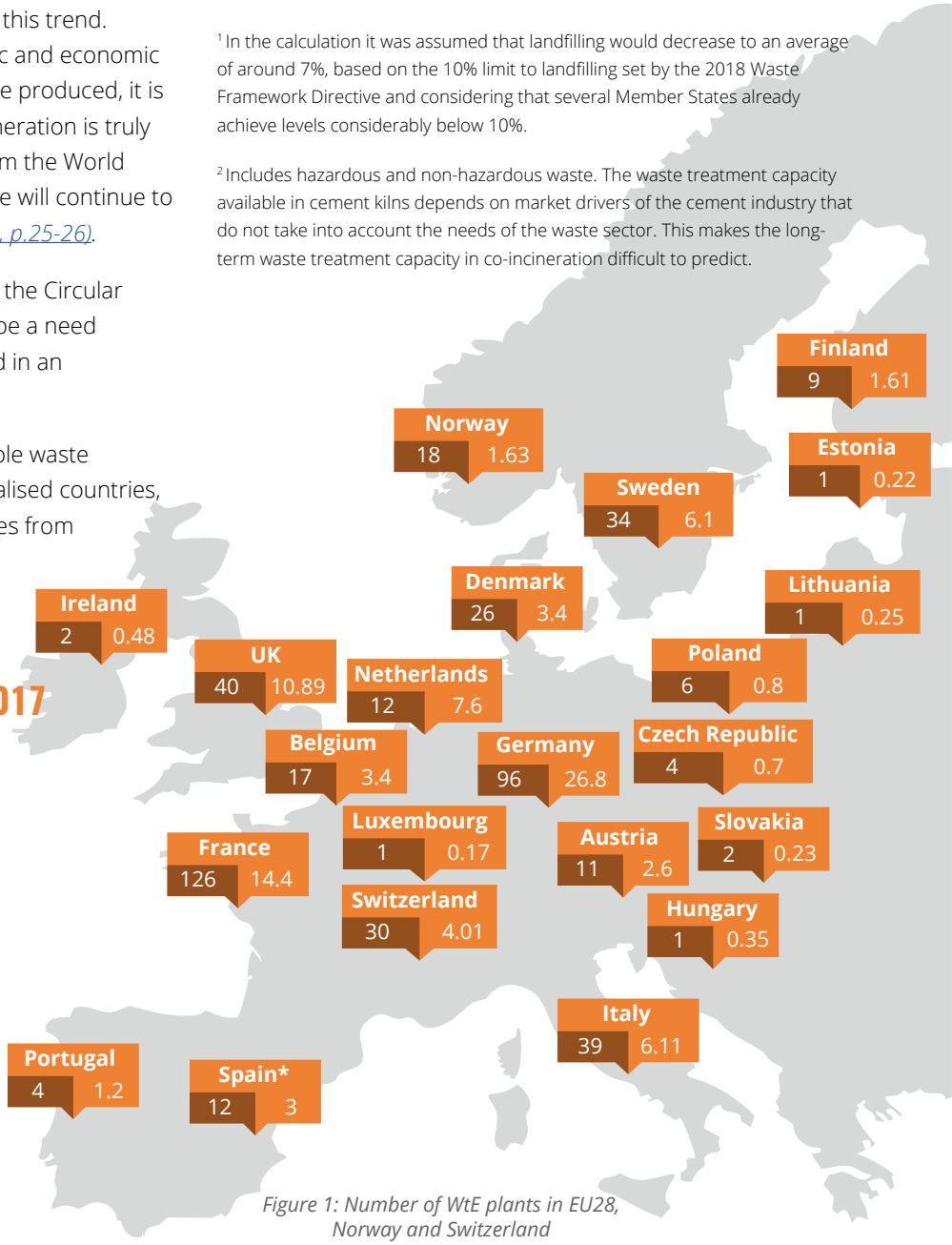
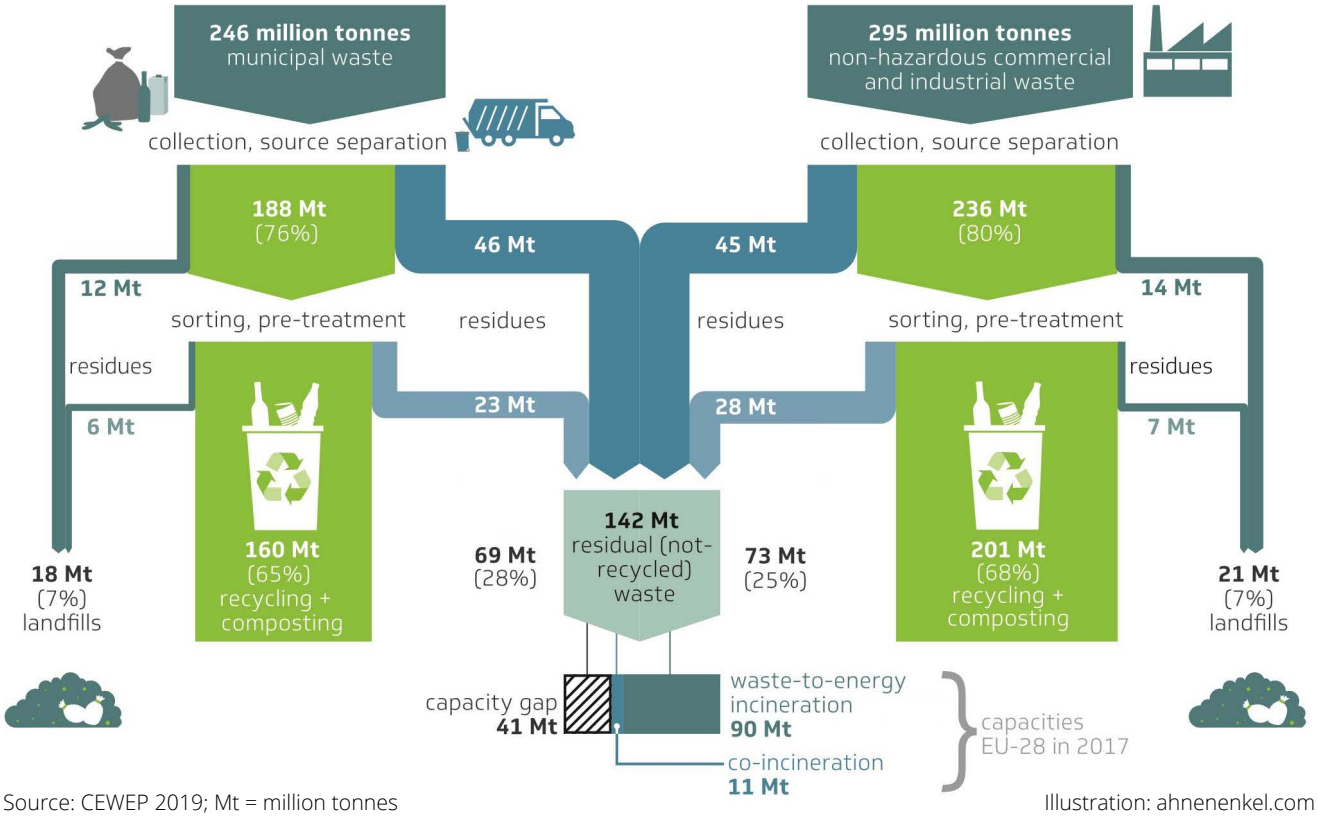


Figure 1: Number of WtE plants in EU28, Norway and Switzerland

THE CIRCULAR ECONOMY PACKAGE SCENARIO WITH AMBITIOUS TARGETS FOR COMMERCIAL WASTE: 2035



Source: CEWEP 2019; Mt = million tonnes

Illustration: ahnenenkel.com

Figure 2: Estimated waste treatment capacity needs in 2035

A debate is needed on how to bridge this gap in Europe to avoid unsustainable routes for these waste streams, such as dumping, open fires or exports to countries with low social and environmental standards.

WtE capacity will be needed to help fill this gap, which will be most apparent in Southern and Eastern Europe, and to maintain high-quality recycling streams. If this gap is filled with WtE by 2035, CEWEP estimates that WtE plants could contribute to the sustainable energy market by supplying heat to 22 million people and electricity to almost 28 million people. 115 million tonnes of CO_2 equivalent emissions could be saved by treating this waste in WtE plants. This is more than the total annual CO_2eq emissions from fossil fuels in Belgium.

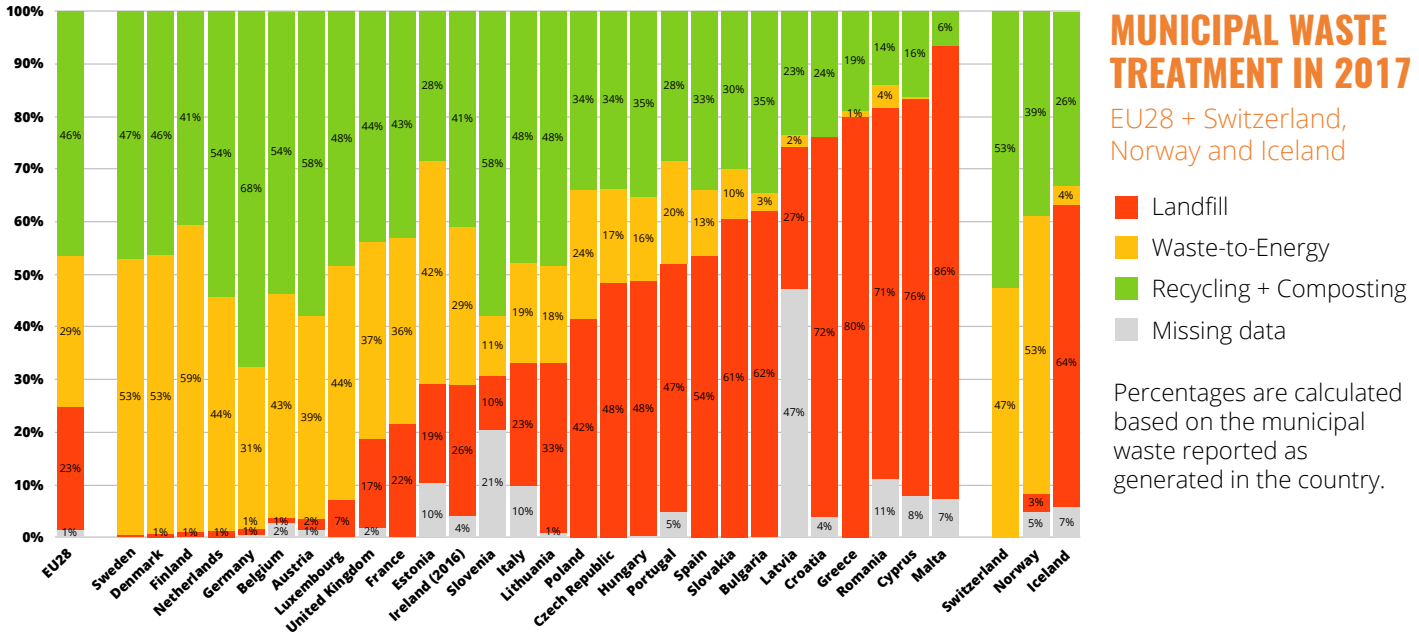
WHY CAN'T WE REUSE, RECOVER AND RECYCLE EVERYTHING?

Recycling mixed materials is not always the right solution. This is because of their complex composition or pollutants, especially in the case of some plastics. Some material is so degraded or contaminated that reusing or recycling it does not provide the best environmental outcome according to lifecycle thinking. The amount of resources required to clean and process the material outweighs the value of low-quality recyclates which would be recovered. Paper, for example, can only be recycled a limited number of times. While paper fibres in Europe are used on average 3.6 times, the paper industry calculates that 22% of all paper products are impossible to collect or recycle *(European Declaration on Paper Recycling 2016-2020: Monitoring Report, 2017)*.

Recycling is a commodity business which fluctuates with supply and demand. For recycling to be economically viable, there needs to be enough quality source material and a stable market where recyclates can compete with virgin materials.

2.2 SUSTAINABILITY AND WASTE-TO-ENERGY

2.2.1 Reducing landfilling and supporting quality recycling



MUNICIPAL WASTE TREATMENT IN 2017

EU28 + Switzerland, Norway and Iceland

- Landfill
- Waste-to-Energy
- Recycling + Composting
- Missing data

Percentages are calculated based on the municipal waste reported as generated in the country.

Figure 3: Municipal waste treatment in 2017 (EU28 + Iceland, Norway and Switzerland). CEWEP graph based on Eurostat figures, 2019

Almost half of EU Member States are still heavily reliant on landfilling. Valuable resources are being buried with the risk of contaminating soil and groundwater. Decomposing waste in landfills generates methane – a greenhouse gas 28 times more potent than CO_2.

During 2001-2017, landfill rates in the EU28 fell sharply while recycling rates rose considerably. WtE treatment rates also increased, but less than recycling. This shows that WtE and recycling work well together to reduce landfilling.

Furthermore, with increasing recycling rates, WtE will be needed to treat the rejects from recycling and sorting facilities, as well as the residual waste remaining after source separation. This is the case for municipal waste as well as commercial and industrial waste. According to Eurostat, based on all waste volumes, more than 83 million tonnes of sorting residues are generated every year *(Eurostat, 2019, 2016 data).*

Residual waste should be treated near to where it is generated. In cases where the local treatment capacity is not sufficient to divert it from landfills, it is still more environmentally-sound to temporarily send it to efficient WtE plants with spare capacity elsewhere. Lifecycle criteria are important and should be considered.

MUNICIPAL WASTE TREATMENT 2001-2017

EU28, based on Eurostat 2019

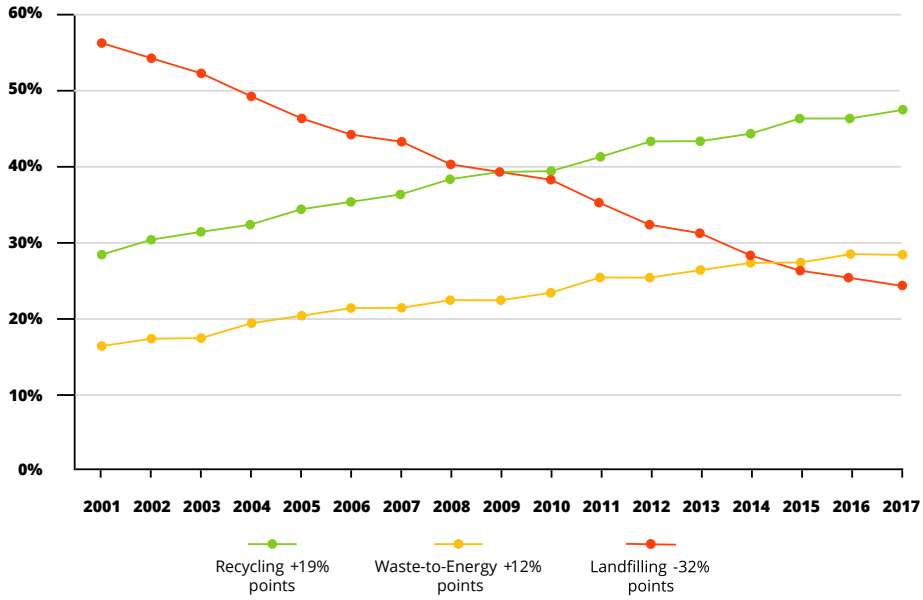


Figure 4: Municipal waste treatment 2001-2017 in EU28

Graph by CEWEP, Source: Eurostat 2019

2.2.2 Producing renewable energy locally and paving the way to decarbonisation

Currently, EU28 WtE plants produce enough electricity to supply almost 18 million people per year. WtE can provide a local source of baseload power that complements intermittent renewable energy sources such as wind or solar while at the same time making Europe less dependent on fossil fuel imports.

Most WtE plants are combined heat and power (CHP) plants which provide heat to urban district heating networks, as well as electricity. Today, WtE in EU28 is able to provide around 15 million people with heat annually. Future developments will further replace traditional fossil fuels which are used for heating or cooling.

Energy production from waste saves greenhouse gas emissions because it replaces conventional fossil fuels. Additionally, the biodegradable (organic) part of the waste input is renewable. The exact amount depends on the waste input which is determined by consumer behaviour, local waste management systems etc. Despite growing source separation of bio-waste, there is still a biodegradable fraction in the residual waste that is too contaminated for composting or other recycling, such as greasy paper e.g. from fries or sanitary products. Using the biodegradable fraction of waste to produce energy does not contribute to sustainability concerns like deforestation or land use change.

WHAT ABOUT PLASTICS?

From a climate point of view, plastic waste is not a desirable input for WtE as it contributes to fossil CO_2 emissions. However, WtE plants accept residual plastic waste as a service to society in order to help prevent landfilling and its exports to countries with lower environmental and social standards. WtE helps avoid marine and soil pollution with nano-, micro- and macroplastics.

Plastic waste can contain toxic elements e.g. phthalates, flame retardants, heavy metals and persistent organic pollutants which can only be destroyed at high temperatures in controlled conditions. In these cases, WtE plants can act as a sink for pollutants by removing these substances from the circular economy.

WTE'S CONTRIBUTION TO THE ENERGY CYCLE ANNUALLY

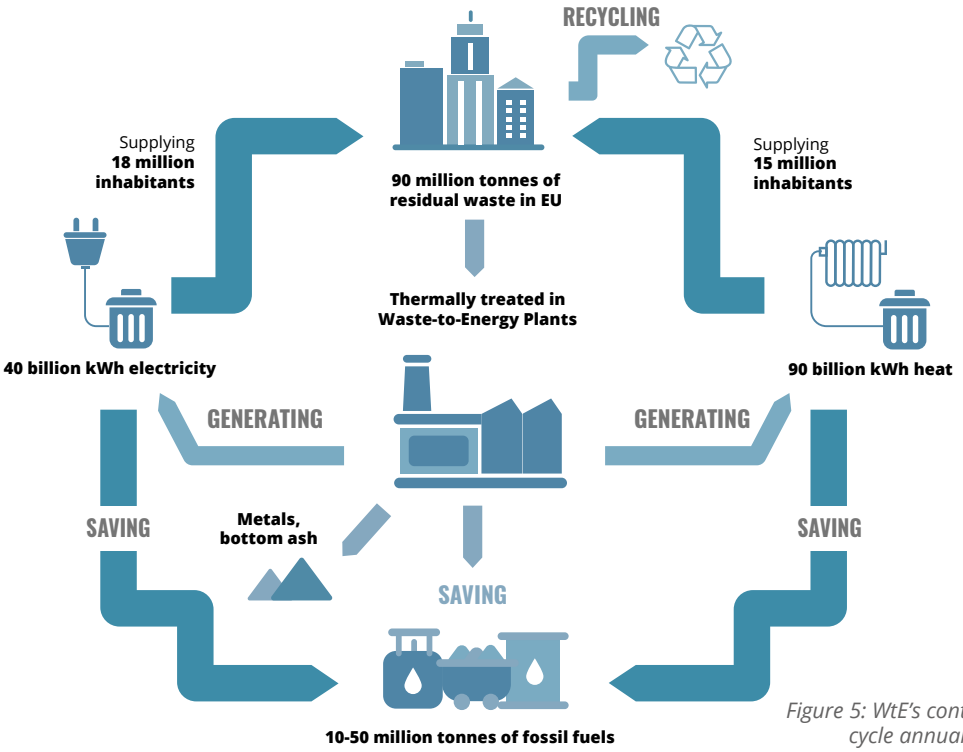


Figure 5: WtE's contribution to the energy cycle annually (CEWEP data, 2017)

2.2.3 Providing recycled materials

Bottom ash is collected from the bottom of the furnace of WtE plants after waste has been thermally treated in the plant. This ash is a source of ferrous and non-ferrous metals which can only be recycled after incineration. As an example, the amount of iron recovered from European bottom ash each year could be used to build about 6,000 wind turbines.

More than 3 million tonnes of CO_2 equivalent emissions are saved by recovering metals from bottom ash each year *(CEWEP calculation based on EdDE-Dokumentation 17, Metallrückgewinnung, October 2015).* After the metals are removed, the remaining mineral share of the bottom ash can be used as secondary raw materials in road construction or as a covering layer on landfill sites. This could help to address concerns raised by the United Nations Environment Programme (UNEP) about the high volume of virgin sand and gravel being extracted from the natural environment *(Global Resources Outlook, 2019, p.133)*.

Recycled metals from WtE bottom ash are included in EU recycling targets yet recovered minerals are not, despite offering an alternative to extracting virgin resources. CEWEP is working with policymakers to have recovered minerals recognised in the same way as metals.

2.2.4 Achieving low emissions

The environmental standards for WtE plants have evolved significantly over the decades. State-of-the-art pollution control technologies and procedures ensure that emissions from WtE plants meet very strict requirements, set within EU law. The industry uses flue gas cleaning systems to remove particulate matter (PM), acids and other gases, organic compounds, heavy metals and other substances which come from treated waste.

WtE is one of the most strictly-regulated and transparent industrial sectors. Multiple studies have found no evidence of a negative impact of WtE on health or the environment. Only a very small fraction of air emissions in Europe comes from WtE plants. Data collected by the European Pollutant Release and Transfer Register shows that dioxin emissions from WtE (considered as a marker for incineration of waste in the past) account for less than 0.2% of the total industrial dioxin emissions, not considering road transport. WtE's contribution would be even more negligible if transport was included in these statistics.

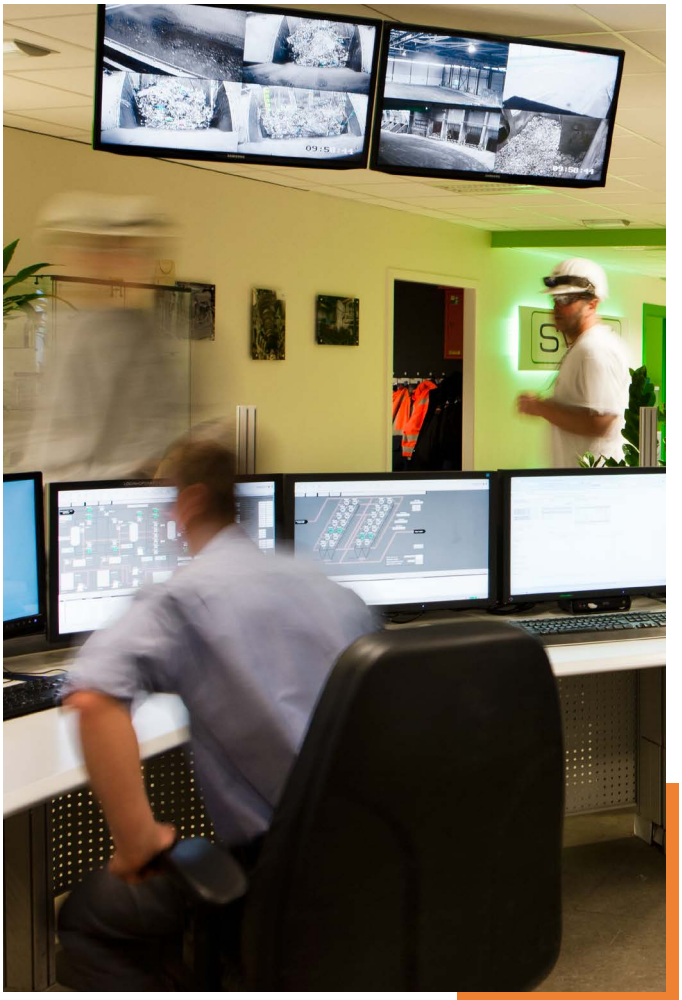
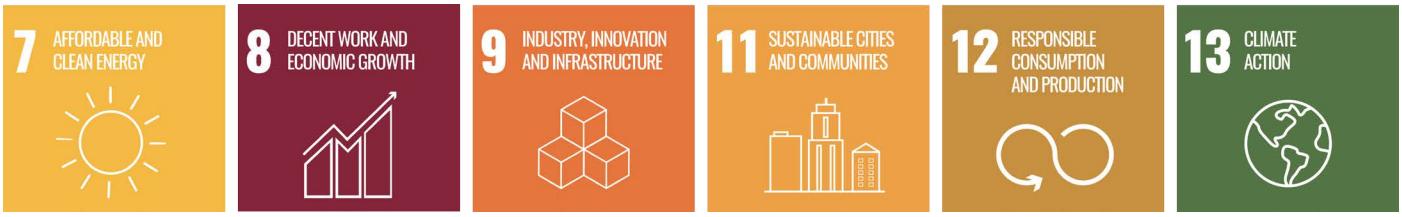


Photo: Indaver Doel plant, Belgium

The technical basis for WtE permits in Europe is set by the Best Available Techniques (BAT) included in the BAT Reference document (BREF), revised in 2019. The ongoing review of this technical document every 8 years ensures that WtE plants achieve the lowest possible emission levels using the latest pollution abatement techniques and procedures.

3. INNOVATION SHOWCASE

These examples demonstrate how CEWEP members are contributing to the following United Nations Sustainable Development Goals (SDGs) through innovation and leadership.



3.1 GOVERNMENT AND INDUSTRY PARTNERSHIP ON BOTTOM ASH RECYCLING

European WtE plants produce approximately 20 million tonnes of bottom ash annually. Bottom ash is made of the incombustible part of treated waste.

In 2012, the Dutch Ministry of Infrastructure and Environment signed a Green Deal on bottom ash with the WtE sector, represented by the Dutch Waste Management Association. The agreement aims to have 100% of raw materials recovered from bottom ash put to high-grade use by 2020.

The Dutch Green Deal has attracted interest from around Europe as an example of cooperation between the government and the WtE industry in achieving circular economy goals. It has provided impetus for the Dutch WtE sector to invest in innovative technologies to improve bottom ash quality so that it can be used without additional precautionary and aftercare measures. By classifying processed bottom ash as having the same quality as primary construction materials, the bottom ash can now substitute virgin raw materials like sand or gravel.

In 2017, the first batch of paving stones made using clean bottom ash from the Twence WtE plant were produced for use in a sustainable building complex in Hengelo.

3.2 INDUSTRIAL SYMBIOSIS DELIVERS RENEWABLE HEAT

In the Port of Antwerp, WtE facilities process 1 million tonnes of waste annually, converting the waste into energy and materials. Electricity is supplied to 170,000 households, but until recently only some of the excess heat was used.

Until 2019, the chemical industries in the Port of Antwerp were using individual gas-fired boilers in their processes. These boilers were responsible for thousands of tonnes of CO_2 emissions. ECLUSE is a collaborative project to deliver steam from local WtE plants to six industrial companies through a high-pressure pipeline. The project which came online in 2019 replaces fossil-based energy with steam from WtE, improving the efficiency of the WtE plants and ensuring a cost-effective and long-term energy supply for neighbouring industries.

ECLUSE supplies at least 5% of the renewable heat produced in the Flanders region, ensuring CO_2 savings of at least 100,000 tonnes each year, similar to the CO_2 savings from 50 standard 2.3 MW wind turbines.

"Ashland uses steam to initiate chemical reactions, create added value and make useful daily products. Any financial savings that may result from stopping our own gas boilers due to the connection to the ECLUSE network are beneficial. However, more important is the responsibility for a sustainable policy taken by Ashland and the other customers of the steam network: saving tonnes of CO_2, preserving employment and environment by working even more effectively within the chemical cluster."

Dr Erik Van Hove, Plant Manager of Ashland Specialities, a chemical plant and client of ECLUSE

3.3 CLEANER AIR FOR WUPPERTAL IN GERMANY

Wuppertal Stadtwerke put ten new fuel cell-powered buses on the road in 2019. The vehicles use emission-free hydrogen gas produced locally, using electrolysers powered by the AWG Waste-to-Energy plant in Wuppertal. The hydrogen filling station is located near the plant. This development is an important first step towards diesel-free public transportation and electromobility as well as improving air quality.

This is not the first time AWG has aimed for better air quality and greater energy efficiency. In 2018, the district heating network in Wuppertal was connected to the WtE plant. At the same time, a coal-fired power plant in the Wuppertal valley was shut down. The combined effect was a considerable reduction in CO_2 emissions and other pollutants.

"Hydrogen fuel cells are highly-efficient energy converters. They have great potential for avoiding CO_2 emissions, reducing dependence on fossil fuels and contributing to economic growth."

Ulrich Jaeger, Managing Director, Wuppertal municipal utility Mobil

Photo: AWG plant, Germany

4. CALL TO POLICYMAKERS

CEWEP CALLS ON POLICYMAKERS TO:

1. Recognise WtE as an essential part of a circular economy and apply the waste hierarchy based on lifecycle thinking

Waste management systems must take lifecycle thinking into consideration and aim for the best overall environmental outcome when applying the waste hierarchy.

Diverting waste from landfills is an essential step in moving waste treatment up the waste hierarchy.

In 2017, about 58 million tonnes of municipal waste were still landfilled in Europe, rising to almost 200 million tonnes if other waste streams are considered.

Now that targets are set for Municipal Waste, future EU waste legislation needs to set targets for landfill diversion and recycling for commercial and industrial waste. Quality recycling is key. The European Commission's Communication on the Interface Between Chemical, Product and Waste Legislation (2018) emphasises the importance of recycled material quality. Further policy developments must recognise WtE's key role for treating waste that is contaminated with substances which are not fit for recycling.

At the same time, metals and minerals from WtE bottom ash can be recycled to substitute primary resources.

2. Count minerals recycled from the bottom ash in recycling targets, as well as metals

The new EU Waste legislation allows Member States to count metals recycled from bottom ash towards achieving their recycling targets, which encourages the WtE sector to further improve its metal recycling efforts.

However, the mineral fraction of the bottom ash is not yet explicitly recognised in EU waste law. While public-private-partnerships like the Dutch Green Deal on bottom ash are a stepping stone towards the use of the processed mineral fraction of bottom ash, EU-level incentives to allow the materials from bottom ash to re-enter the material loop are needed.

3. Recognise WtE's contribution to climate protection as a holistic approach which avoids landfilling and replaces fossil fuels

In addition to avoiding greenhouse gas emissions from landfills, WtE helps achieve policy objectives by replacing fossil fuels in conventional power plants with renewable energy generated from partially biodegradable residual waste. This enables WtE plants to contribute to the EU's renewable energy target of 32% under the EU 2030 Climate and Energy Framework.

CEWEP calculates that WtE plants could produce 190 TWh of energy by 2035, enough to supply more than 50 million people with heat and electricity and to replace 10% of the energy supplied by the coal sector today.

In many European cities, WtE contributes significantly to district heating networks (about 90 TWh per year). There is a major opportunity for further improvement by linking more heat or process steam customers to WtE plants. The Heat Road Map Europe 2050 suggests that the potential is 200 TWh per year by 2050 for heat alone.

While the Efficiency Criterion (the R1 formula) introduced in the 2008 EU Waste Framework Directive has incentivised WtE investments in efficiency, further policy changes are needed to improve infrastructure for district heating and cooling as well as to promote the efficient integration of WtE plants into local heat and power grids.

Photo: Returkraft plant, Norway. Photo by Kjell Inge Soereide

WASTE-TO-ENERGY SUSTAINABILITY ROADMAP

TOWARDS 2035

Front and back cover photo: Turin plant, Italy

The voice of Waste-to-Energy

CEWEP (Confederation of European Waste-to-Energy Plants) is the umbrella association of the operators of Waste-to-Energy plants, representing about 400 plants from 23 countries. They make up more than 80% of the Waste-to-Energy capacity in Europe.

Our members are committed to ensuring high environmental standards, achieving low emissions and maintaining state of the art energy production from remaining waste that cannot be recycled in a sustainable way.

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2019