RAMBØLL

Bright ideas.
Sustainable change.

# EfW technologies and debunking common myths

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# RAMBOLL IN BRIEF

- Independent engineering, architecture and consultancy company
- Founded 1945 in Denmark. +18,000 experts.
  Present in 35 countries
- Owned by Rambøll Fonden – The Ramboll Foundation

- Partner for Sustainable Change

- 2000 experts globally within the Energy
  125 staff dedicated to EfW & CC
  (Singapore, Australia, UK, Denmark, Germany, Switzerland)

- **We work with all parts of the waste value chain**.
- Involved in EfW projects in 45 countries (200+ units)
- Involved in +100 CCU/CCS projects

# Technology choices for different kinds of residual wastes

Straw,
wood chips
(clean biomass)

Dry recyclables

Wood waste

rejects

**Organic waste**

Separate slide

MRF

Recycled products

Incl. e.g. chemical recycling of plastic

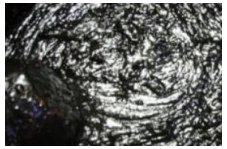
rejects

Mixed residual waste
MSW & C&IW

Recycled products

RDF

Tyres



Oil sludge

MRF

Recycled products

**Thermal conversion technologies**

Grate-based (waste) thermal combustion

Gasification syngas-to-X

Special technologies (e.g. thermal upcycling of residual plastic)

Grate-based biomass thermal combustion
LOW RISK EMISSIONS

Fuel for Cement replacing e.g. coal

# Thermal Technologies for different kinds of residual wastes

***Technology choice depends on feedstock***

**E-fuels gasification biomass combustion tech**

**Grate-based thermal incineration =WELL PROVEN**

**More strigent emission requirements**

**More difficult to control size, contaminants, composition, etc.**

**Less homogenous**

**Straw, wood chips (clean biomass)**

**Wood waste**

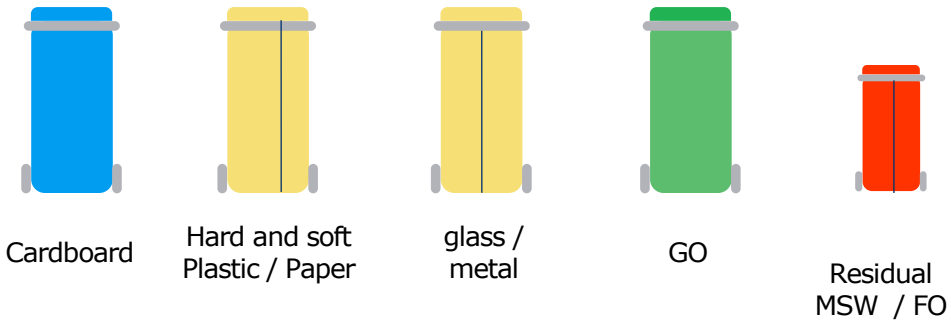
**Mixed residual waste MSW & C&IW**

# Residual waste – landfill or EfW, alternatives?


recovery is often ~5-10% (15%)

1.5-2% metals
15% IBA

**Dirty MRF Drivers:**
- Recycling goals
- reduced amount of plastic
- dirty MRF an alternative to changing collection infrastructure?

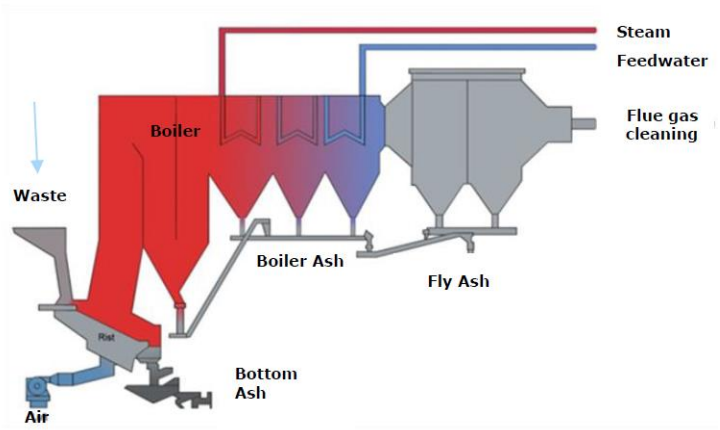



**Deterrants:**
- financial viability?
- Quality of off-products?
- What happens to the MRF, when source separation improves?

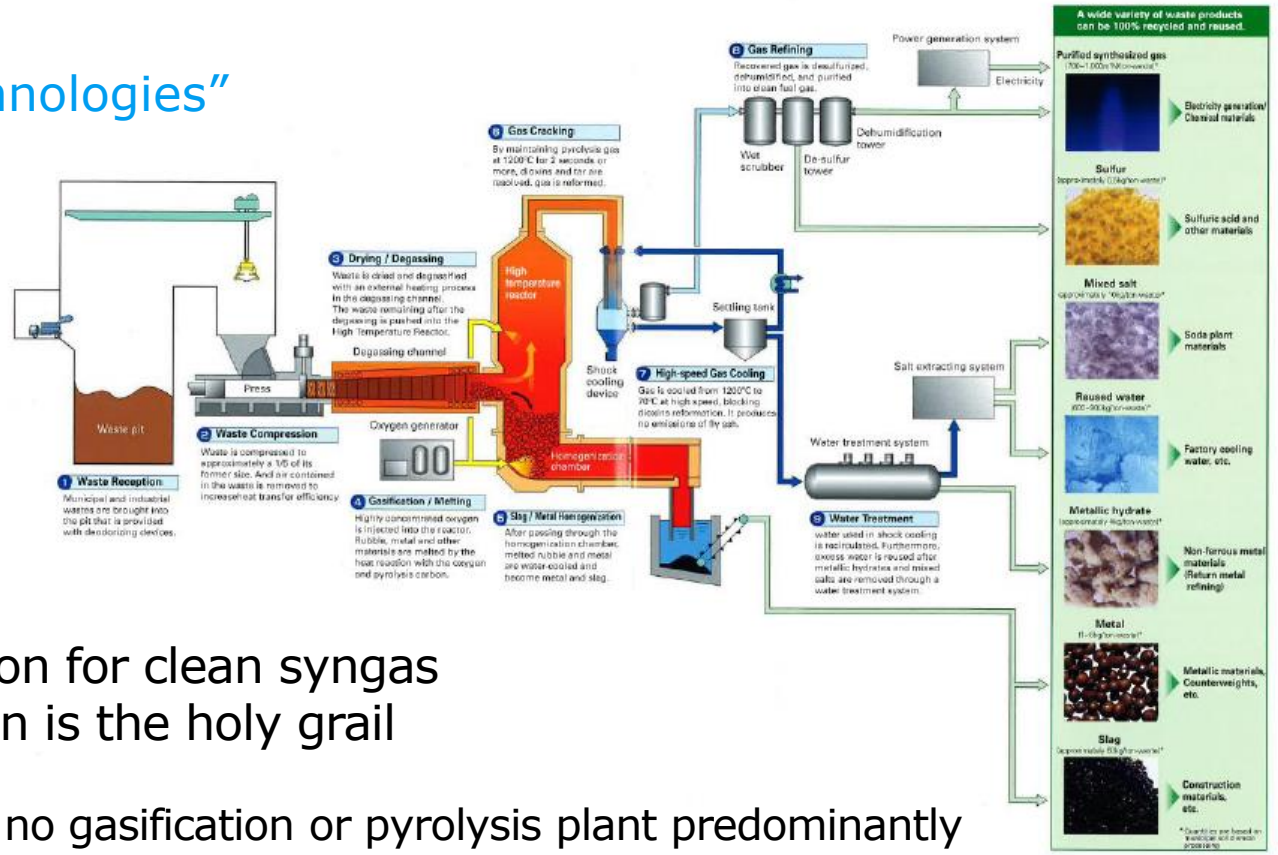
**EfW capacity plan for this part**

# Technology assessment

- Gasification assessment
- Be careful of "new fantastic (gasification) technologies"
- low capex solutions
- small scale vendors




Traditional grate-fired




Gasification for clean syngas production is the holy grail

In Europe, no gasification or pyrolysis plant predominantly processing mixed residual waste is known to have passed a successful commissioning demonstrating the expected functionality and performance.

Note: many "gasifiers" combust this gas immediately to make steam.
Output is heat and power
(like grate-fired techn.)

# CHOICE OF technology
# Markets and technologies

- Globally around 2,200 Waste to Energy plants in commercial operation processing MSW/C&I
- Conventional moving grate technology:
  - Europe; ~525 plants
  - US; ~75 plants
  - Japan; ~1,100 plants
  - China/Korea/Taiwan; ~350 plants
- Alternative technologies:
  - Fluidized bed, incineration; <50 plants
  - Thermal gasification; <10 plants outside Japan (R&D) / <100 plants in Japan
  - Plasma gasification; <10 plants in Japan
  - Pyrolysis; <10 plants in Japan

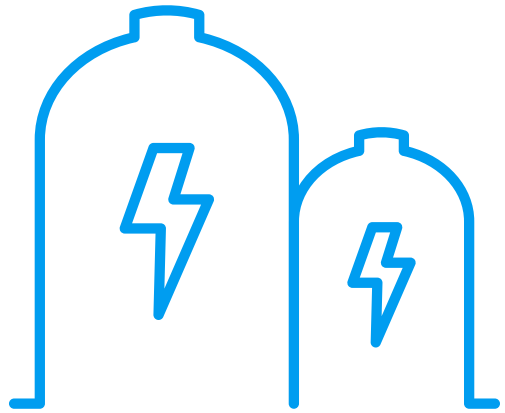
# Organic waste -> Anaerobic Digestion

Production costs / Cost of material

| Manure | | Solids | | Liquids | | High energy |
|---|---|---|---|---|---|---|
| **Manure** | **Deep litter** | **Agricultural residues** | **Agricultural produce** | **Municipal food waste** | **Industrial waste** | **Oils and fats** |
| *Livestock manure from different animals, e.g., pigs, cattle or poultry* | *A mix of manure and natural aggregates (e.g. straw) typically from keeping livestock* | *Residues from land cultivation e.g., straw and canes left after harvesting crops* | *Food crops (e.g., sugar beet or maize) and other agricultural crops (e.g., cereals)* | *Organic fraction of waste from households, incl. food waste* | *Food industry waste, e.g., waste from slaughter-houses or dairies* | *Various animal and vegetable oils, fat and glycerine* |

High volumes of input sourced locally due to relatively low cost of material per yield and relatively high cost of transport per yield

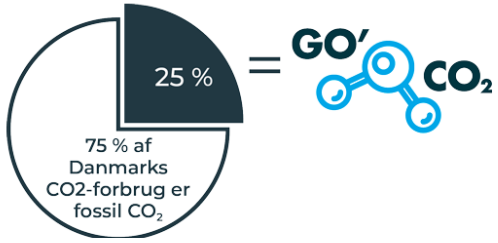
Lower input volumes that can be sourced globally due to the relatively low cost of transport per yield and high cost of material per yield



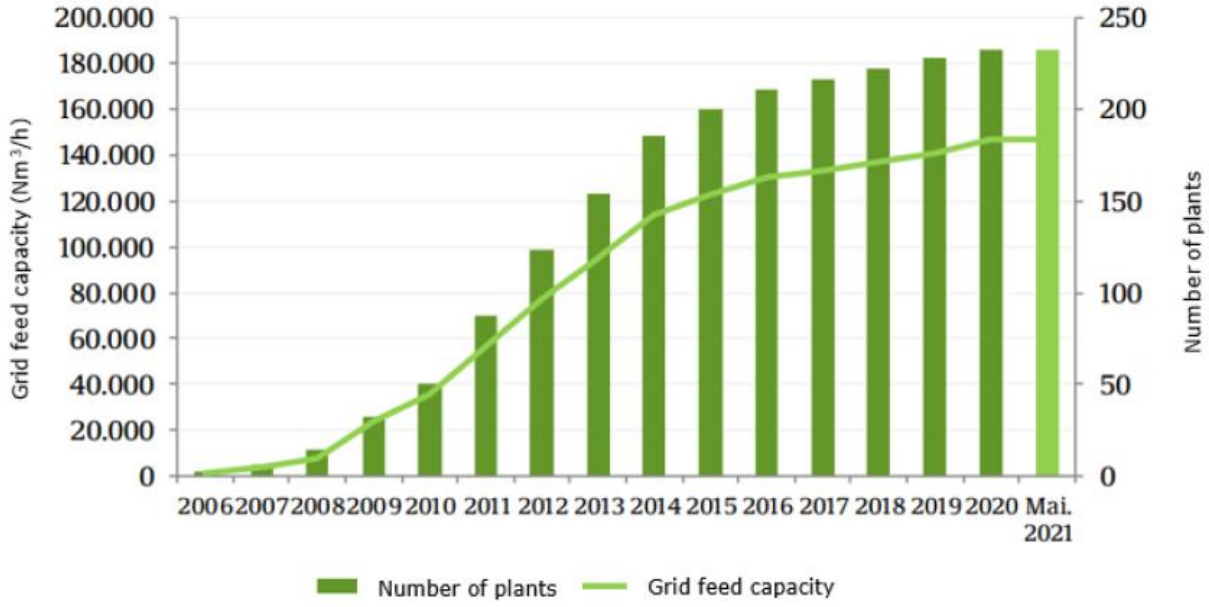
**Organic waste incl. FO/GO**

**AD** **Composting**

***Renewable N-gas from organic waste***




Biomethane was ~40%
total N-gas in 2022 in DK (~100% 2030)




e 2-6: Biomethane plants in Germany and grid feed capacity[7]

# EfW Introduction + Debunking the myths – EU Experiences with Energy from Waste

# Why Waste Management?



## WASTE IS CONSTANTLY GENERATED IN OUR SOCIETIES

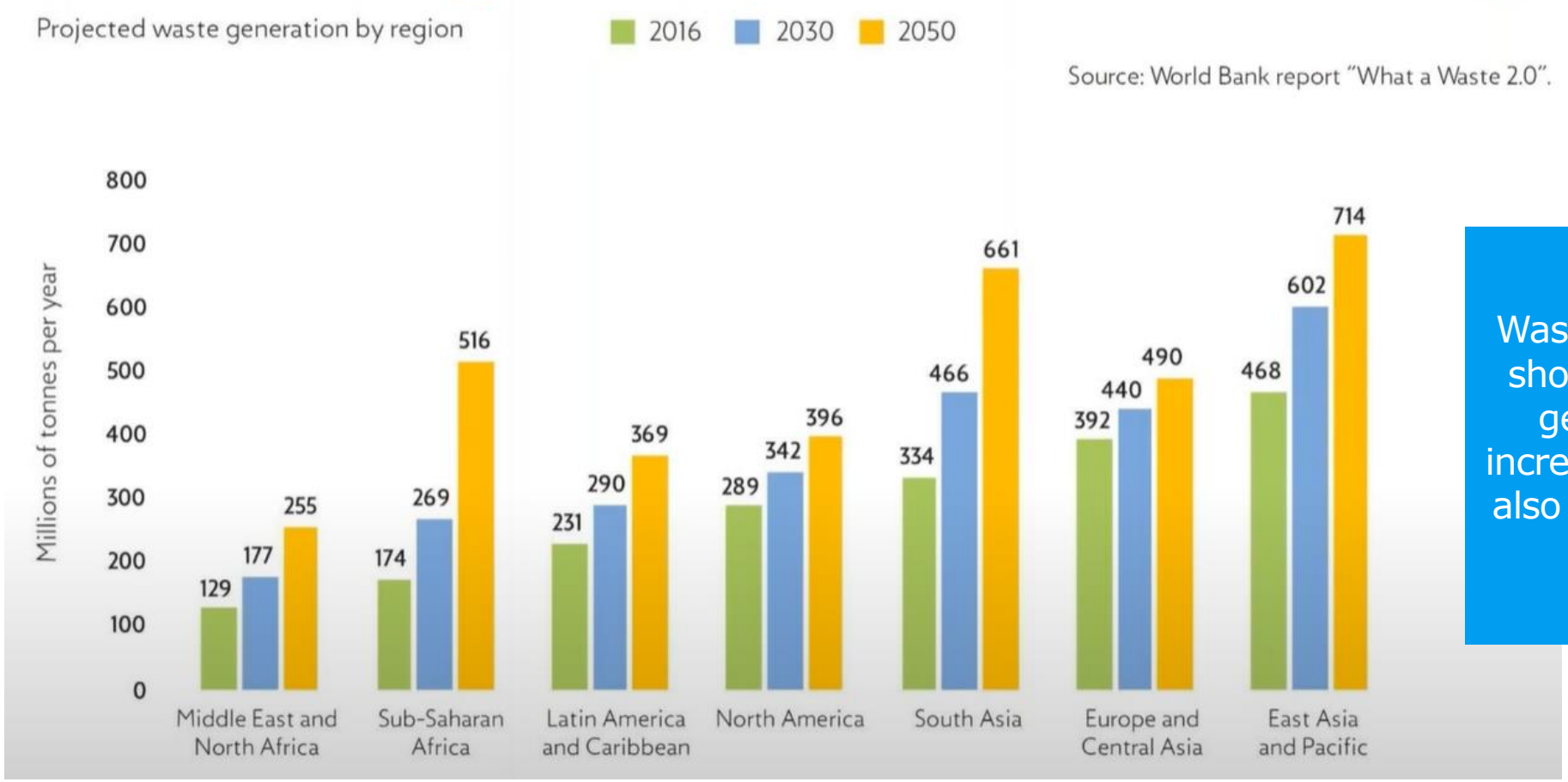
It is a **product** of

- Urbanization
- Economic development
- Growth in population

Waste will not magically **disappear**, and it cannot leave the surface of the earth.

If we do not manage it, it will **accumulate** and eventually **end up in nature**.

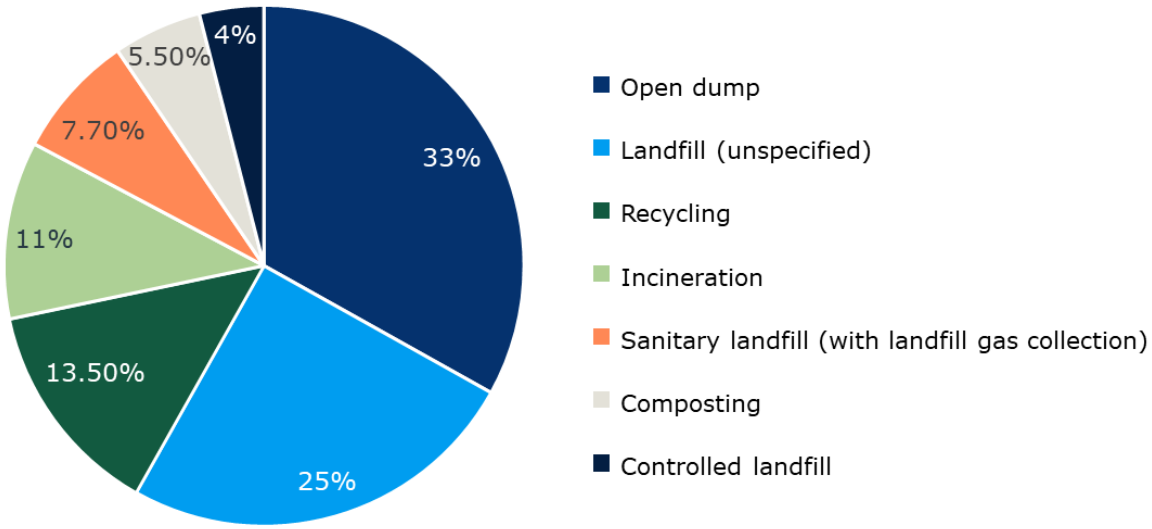
# Projected Waste Growth




Waste projections show that waste generation is increasing globally, also in EU and the pacific.

Sources: Based on material from ESWET – European Suppliers of Waste to Energy Technology – https://eswet.eu/

# Global Trends




Global waste treatment and disposal (2016).

Notes: Open dump also includes uncollected waste and waste in waterways. 'Other' is typically open burning of waste.
Sources: Silpa Kaza, Lisa Yao, Perinaz Bhada-Tata, and Frank Van Woerden: *What a waste 2.0 – A Global Snapshot of Solid Waste Management to 2050* (2018)

## CURRENT WASTE MANAGEMENT IN THE WORLD

37% is disposed in landfills.

11% is incinerated.

19% is recycled or composted.

33% of the current waste generation is dumped and not managed.

➔ **This means approx. 660 million ton waste ends up in nature and waterways.**

## CO2e EMISSIONS

**1.6 billion ton $CO_2e$** are emitted from solid waste treatment and disposal. These are primarily from open dumps and unmanaged landfills. This corresponds to approx. **5% of the worlds total GHG emissions.**

If the waste management is not improved, the **GHG emissions** are estimated to **increase to 2.6 billion ton $CO_2e$ in 2050.**

# What is Energy from Waste?

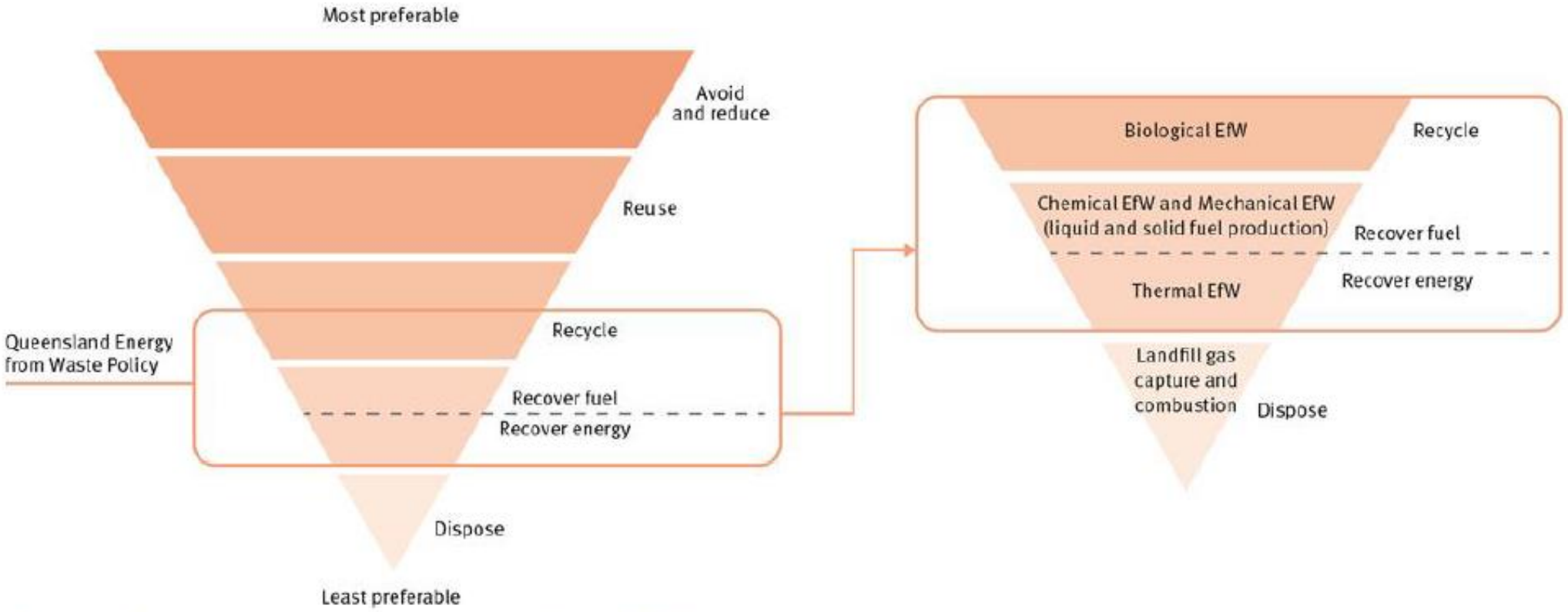



*Figure 1: Queensland's waste hierarchy (left) and EfW hierarchy (right)*

Sources: Queensland's Waste Management and Resource Recovery Strategy – https://www.qld.gov.au/

| Process |
|---|
| **Biological EfW** |
| Anaerobic digestion |
| Fermentation |
| **Chemical** |
| Transesterification |
| **Mechanical EfW** |
| Mixed waste sorting and blending for fuel production |
| **Thermal EfW** |
| Combustion Thermal |
| Gasification |
| Pyrolysis |

**Ramboll is engaged in projects throughout the entire waste hierarchy, to define the right strategies and solutions at different levels.**

# What is Energy from Waste Fuels:

## Example QLD EfW guideline

- vegetable waste from agriculture and forestry
- vegetable waste from the food processing industry
- fibrous vegetable waste from pulp-making
- uncontaminated wood waste and biomass waste, including forestry residues, sawmill residues and bagasse.

These waste materials pose a low risk of harm to the environment and human health due to their origin, low levels of contaminants, and consistent composition. Processing these materials will still need to comply with Queensland's environmental regulatory requirements.

## Example NSW EfW policy statement

### 3. Eligible waste fuels

Eligible waste fuels are those that are considered by the EPA to pose a low risk of harm to human health and the environment due to their origin, composition and consistency.

The following wastes are categorised by the EPA as eligible waste fuels:

1. biomass from agriculture
2. forestry and sawmilling residues
3. uncontaminated wood waste
4. recovered waste oil
5. organic residues from virgin paper pulp activities
6. landfill gas and biogas
7. source-separated green waste (used only in processes to produce char)
8. tyres (used only in approved cement kilns).

Legislation is key to properly address and define waste and treatment requirements

Low risk fuel (biomass)

Waste or biomass?

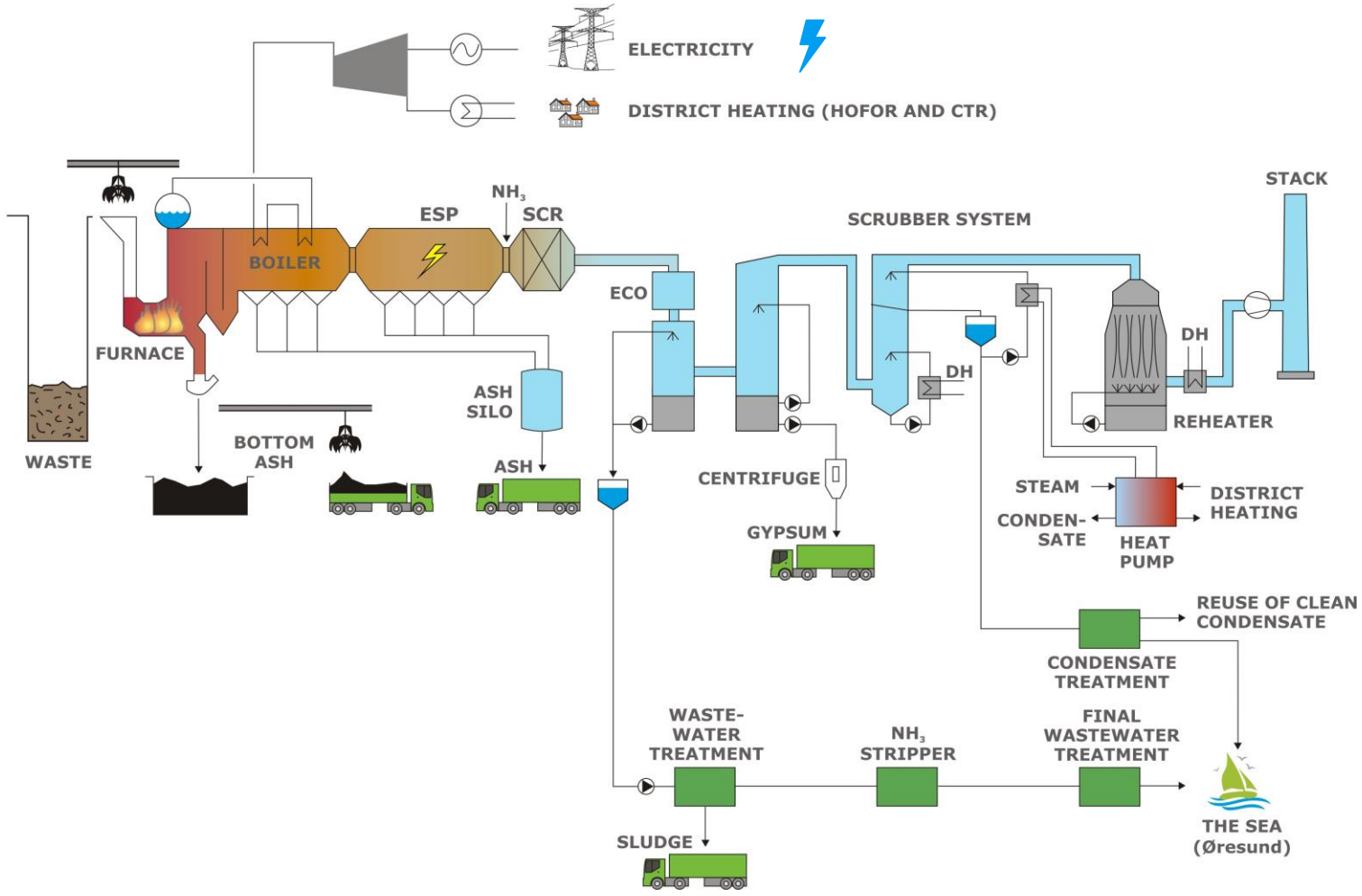
MSW Red Bin

# What is Energy from Waste

Thermal power plant fuelled by residual non-pretreated garbage (Mainly MSW and C&I) with a strong environmental profile and materials recovery in bottom ashes


Source: CEWEP

# What is Energy from Waste




Thermal power plant fuelled by residual waste (mainly MSW and C&I) with advanced flue gas treatment process, reducing the environmental profile and materials recovery in bottom ashes.

From waste to electricity, heat and clean water – Amager Bakke combined heat and power producing plant is able to treat more than 400,000 tonnes of waste every year. Flue gas condensation and heat pumps will be established to optimise the production of heat.

Source: Copenhill – Amager Bakke EfW facility Ramboll

# Visual Impressions – It’s a Process Plant

Source: https://a-r-c.dk/amager-bakke/

**Visual impressions of Amager Bakke Energy from Waste Facility in Copenhagen (Copenhill).**

Pictures (from left to right and top to bottom):

1. Waste reception bunker from the crane control room;
2. Advanced flue gas treatment process;
3. View of Amager Bakke form the nearby harbour;
4. Inside of a boiler section where the energy of the flue gases is recovered, the facility raises the bar for resource optimisation with an energy efficiency of 107%.

# EfW production and waste streams

**1000 kg of residual waste**

(2.8 MWh)

**Energy from Waste Facility**

**800-900 kWh of electricity** to the grid or industrial partner

**Bottom Ash 150-200 kg** for road construction

**Metals 15-20 kg** for recycling

**Flue Gas Treatment residues**

≈ 40kg for disposal

Source: Elaborated by Ramboll, based on typical figures from existing Energy from Waste facilities.

# Resource Recovery

Through **liberation** of material, **WtE enables material recovery** from bottom ash

## Recovery of Metals

- Iron
- Aluminum
- Non-ferrous metals e.g., copper, zinc
- Precious metals e.g., gold, silver

## Potential European WtE plants

- 1’200’000 t/a Iron
- 250’000 t/a Aluminum

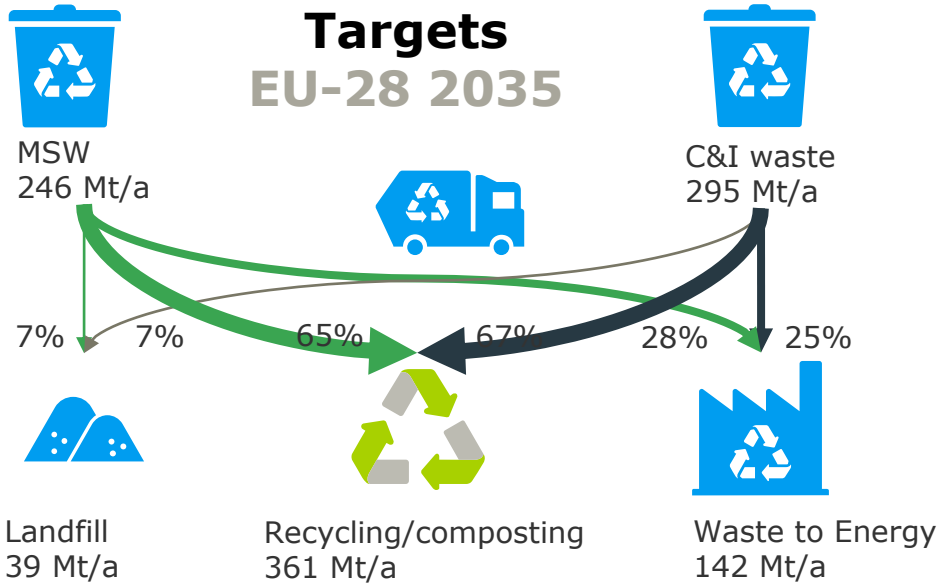
## Recovery of bottom ash slag as building material

- Bottom Ash Gravel is an excellent product in Road Construction
- Bottom ash as building material officially approved by the National Highway Authority in Denmark
- Substitution of virgin gravel/sand, which is becoming rare in many parts of the world

Source: 1. Potential European WtE plants: http://thebeautyinthebeast.eu/turninng.-trash-into-gold/ 2. Pictures: www.supersort.ch 3. https://woodresources.com/materials/.

# Waste to Energy in Circular Economy

## EU figures:




EU 2018: **96 Mt of waste** where **thermally treated** in **492 WtE plants**; the capacity of waste incineration is approx. **101 Mt/a.**

Even if **EU recycling targets of 65% until 2035** are met, there will be a **WtE capacity gap of 41 Mt/a** or a need of **205 new WtE plants** in EU until 2035.

In line with the EU Landfill Directive , Member States must reduce the amount of municipal waste sent to landfill to 10% or less of the total amount of municipal waste generated by 2035.
https://www.eea.europa.eu/en/analysis/indicators/diversion-of-waste-from-landfill

**100% recycling is not possible**, there are always non-recyclable fractions that need to be treated in WtE such as **toxic substances** (e.g. harmful additives in plastics) or **composite materials** (plastic-metal conglomerate) or **metal-plastic mixtures..**

**Stable renewable energy**
The biogenic part of residual waste accounts for approximately 50% of the energy content in the waste, and represents **green renewable energy**

**Avoidance of waste streams to nature + managed nationally**

Avoidance of synthetic waste streams to nature such as plastic to oceans with strong negative impacts on the ecosystem


Sources: Jo Van Caneghem, Karel Van Acker, Johan De Greef, Guido Wauters, Carlo Vandecasteele: *Waste-to-energy is compatible and complementary with recycling in the circular economy*, in: Clean Technologies and Environmental Policy 21 (2019)
Trinomics for EEA: *Emerging Challenges of Waste Management in Europe – Limits of Recycling* (2020) http://trinomics.eu/wp-content/uploads/2020/06/Trinomics-2020-Limits-of-Recycling.pdf
CEWEP: *Waste-to-Energy Plants in Europe in 2018* (2021), https://www.cewep.eu/waste-to-energy-plants-in-europe-in-2018/ (accessed 22-10-2021)
Marc J Rogoff (MSW Management): *The Current Worldwide WTE Trend* (2019), https://www.mswmanagement.com/collection/article/13036128/the-current-worldwide-wte-trend (accessed 22-10-2021)

# MYTH 1

Increasing source separation &
emerging technology and legislation driving
greater waste reduction / circularity

=>

Large scale Energy from Waste is not needed

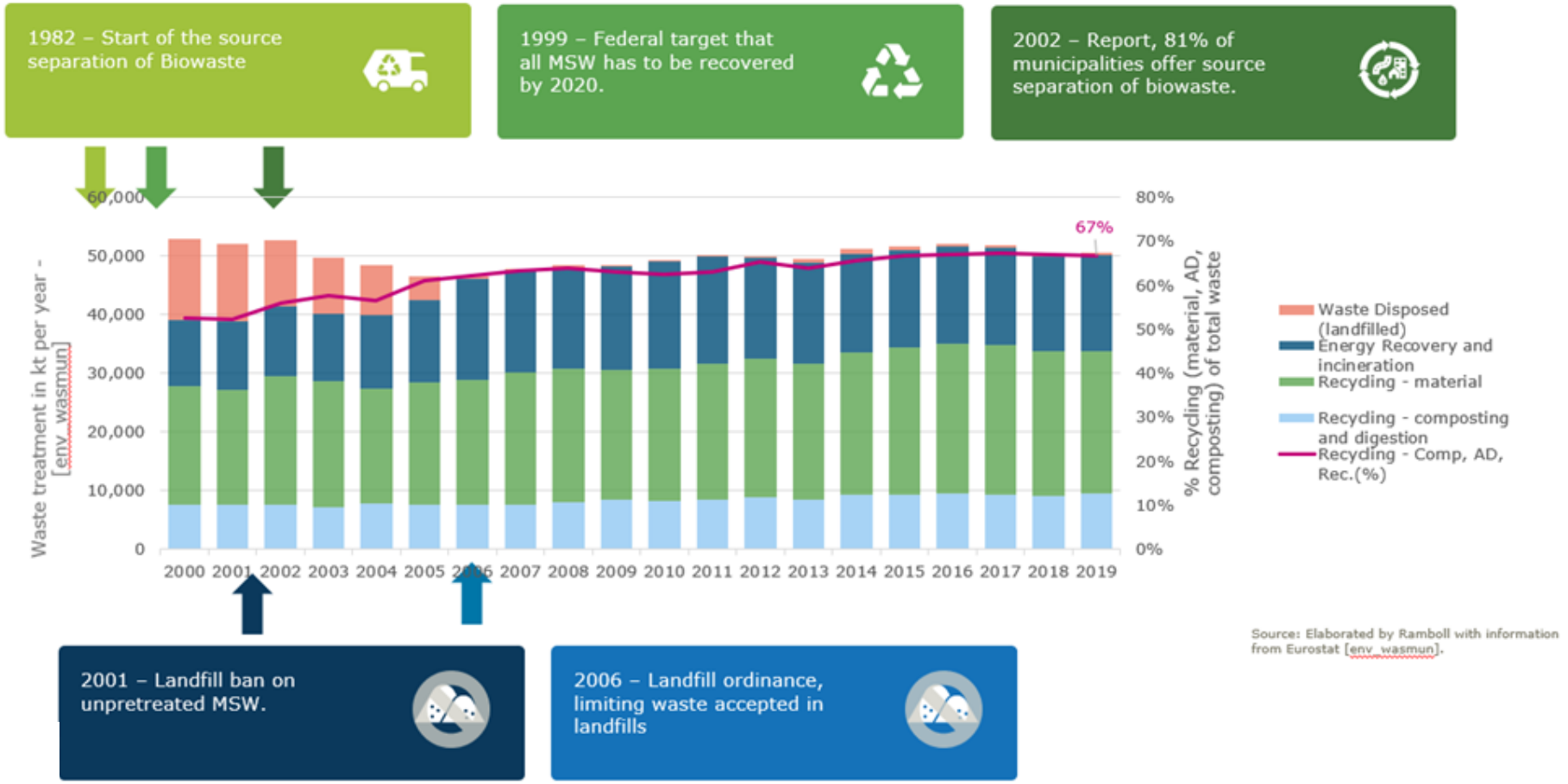
**NOT TRUE… SEE FOLLOWING SLIDES**

# High Landfill Diversion Rates Very Difficult to Achieve Without EfW

**Germany Example - MSW**:

- 40 years since source separation of bio waste was implemented
- Still only 67% diversion from landfill (recycling)

  However, comparable to Australia long term goal for MSW (~70%)
- **80-90% diversion from landfill is very difficult without EfW**




Source: Elaborated by Ramboll with information from Eurostat [env_wasmun].

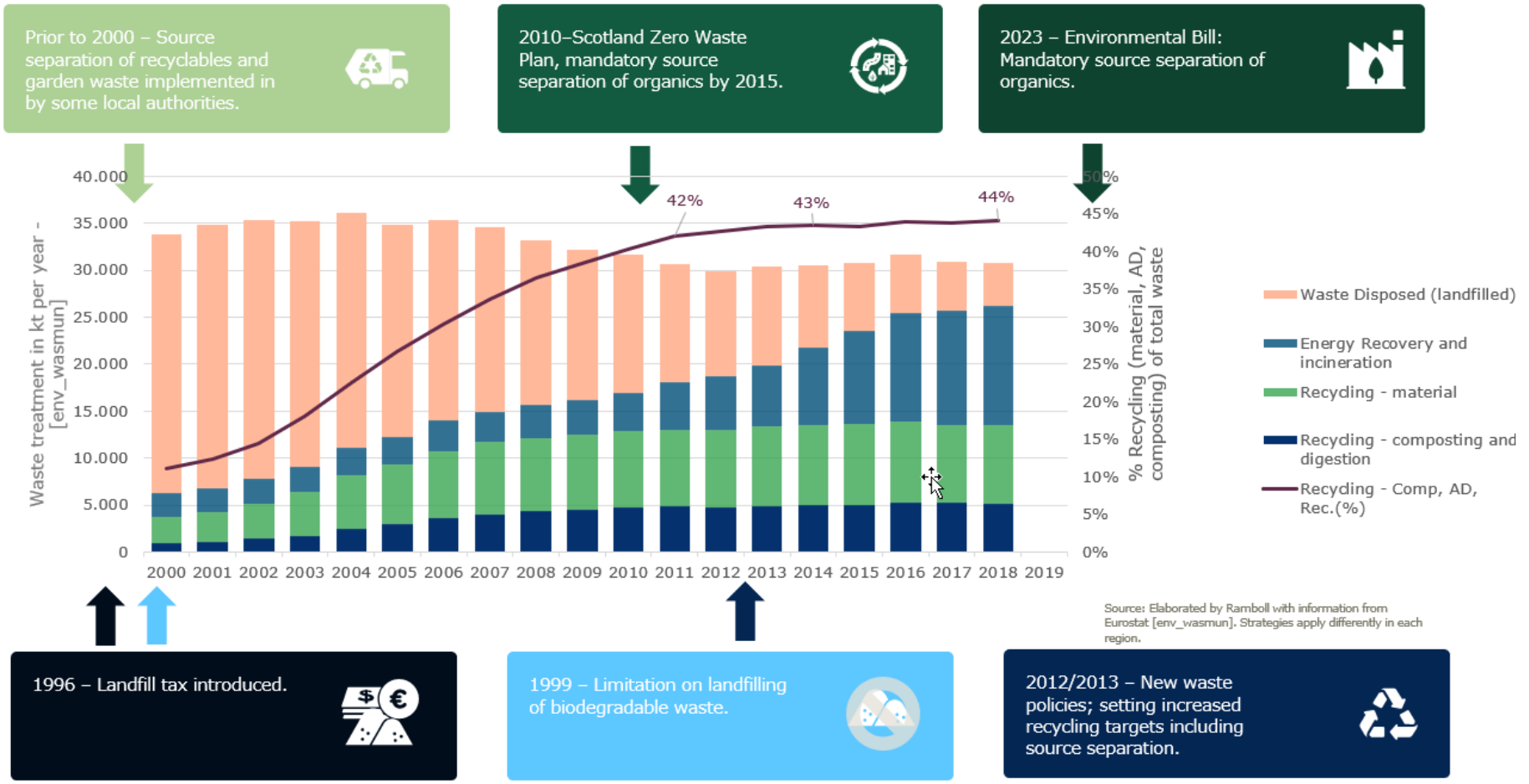
Source: Elaborated by Ramboll, based on data from Eurostat [env_wasmun database].

# High Landfill Diversion Rates Very Difficult to Achieve Without EfW

**UK Example – MSW**:

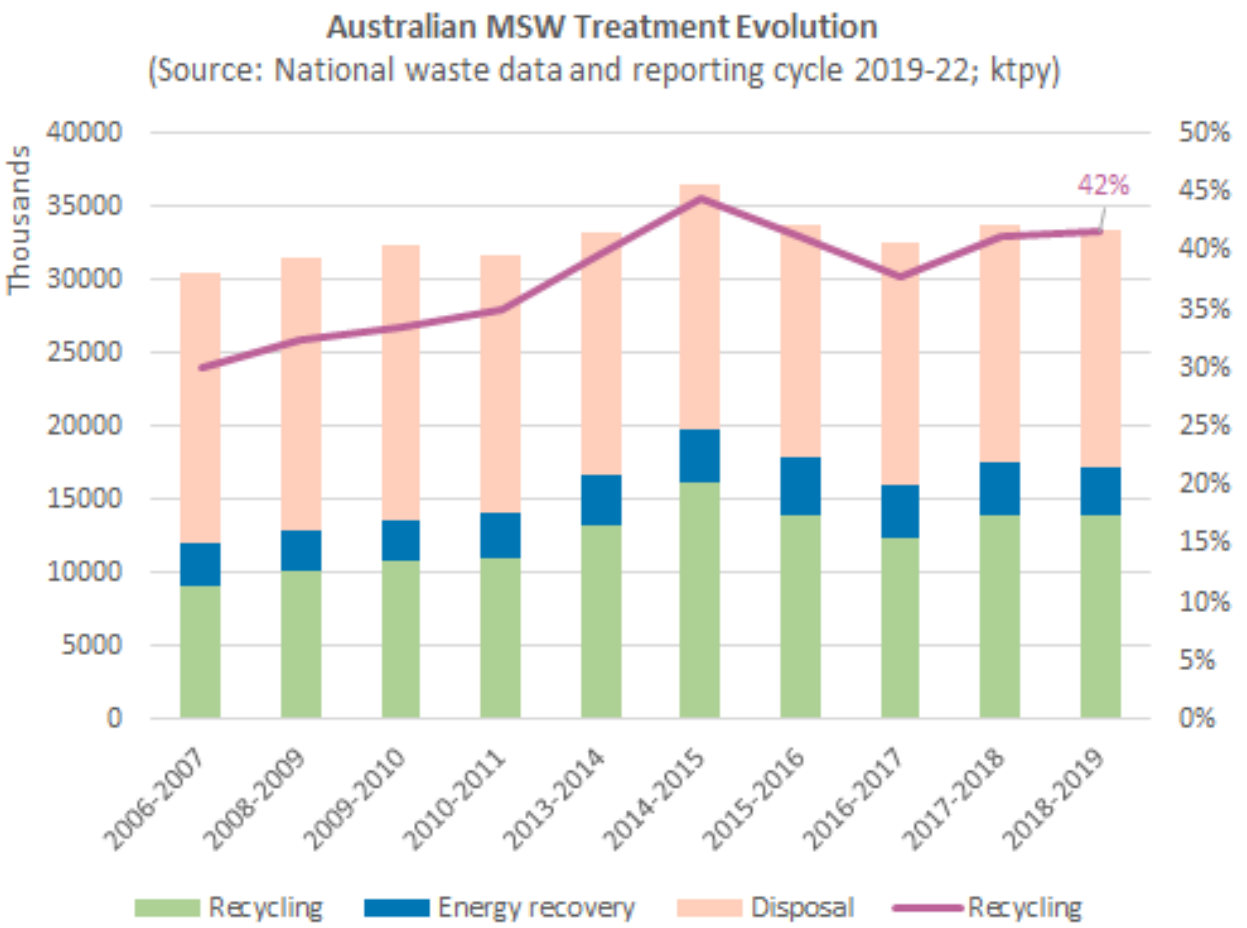
- UK still has some 15% that goes to landfill, and recycling seems to have stagnated at 44%
- High landfill diversion and recycling requires strong efforts
- Recycling **collection** may be up to 65%, but includes contaminants, etc.

*Product manufacturers (waste producers) and retailers need to change the packaging and products to increase product lifespan, help better repair, re-use and recycling.*




Source: Elaborated by Ramboll, based on data from Eurostat [env_wasmun database].

# Australia Seems to Have a Long Way to Go
## (Different in Different States)




*Source: Elaborated by Ramboll with National Waste Report 2020 - https://www.awe.gov.au/environment/protection/waste/national-waste-reports/2020*

**National Waste Policy Action Plan 2019**

Target 3: 80% average resource recovery rate from all waste streams by 2030

**NSW Energy from waste infrastructure plan:**

Over the next 20 years, waste volumes in NSW are forecast to grow from 21 million tonnes in 2021 to nearly 37 million tonnes by 2041.

# MYTH 2

Burning inhomogeneous waste fuels containing plastics leads to dangerous emissions that are harmful to humans and the environment

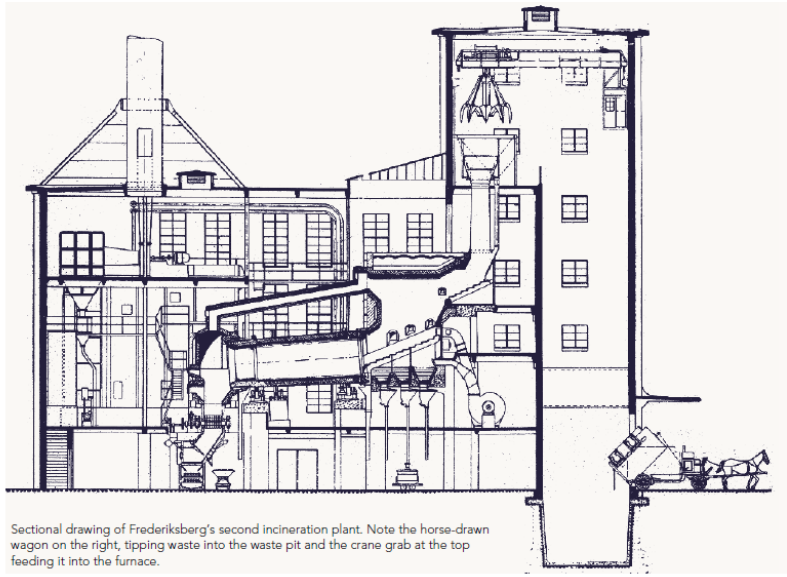
**NOT TRUE… SEE FOLLOWING SLIDES**

# History of Waste to Energy emission legislation
## DK Example:

- 1903
  Denmark's first incineration plant
- 1980s first dioxin study by Danish EPA (Varde)
  ~34g/year TEQ
- 1986: DK legislation
  * 2s 875C / Aux burners
  * limits for CO, dust, HCl, HF, SO2,
  Pb, Cd, Hg + instrumentation and monitoring

**=> A recognition of emission legislation for waste**

- 1989 2 EU directives on (municipal and hazardous) waste incineration plants
- Waste incineration directive (2000/76/EC)
- Industrial Emissions directive (2010/75/EU)
- WI BREF conclusions dec 2019
  (19 BREFs in total)



Sectional drawing of Frederiksberg's second incineration plant. Note the horse-drawn wagon on the right, tipping waste into the waste pit and the crane grab at the top feeding it into the furnace.

1934 Frederiksberg

1903 Frederiksberg

(Pictures:
100 years of waste incineration in Denmark)

- Australia is generally adopting EU rules & benefit from >100 years experience in EU
- World best practice & strictest environmental legislation

# Waste to Energy Facts
## Emissions: Dioxin as Example

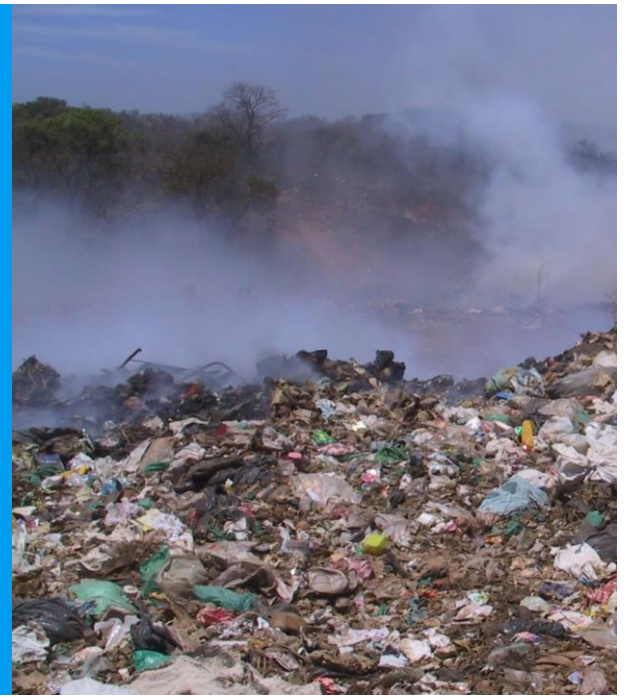
Dioxin emitted in 2004 to air by open burning in US is **630 g TEQ*/y**

Dioxin emitted in 2004 to air by Residential Wood Burning in US is **60 g TEQ*/y**

Dioxin emitted in 2004 to air by Municipal Waste Incineration in US is **10 g TEQ*/y**

Max. Amount of Dioxin that is allowed to be emitted by an European Waste-to-Energy plant is **0.06 ng/m³**

Amount of Dioxin for which a 50% risk to die on intake is assumed **70'000 ng (for 70 kg person)**



**Between 1990 and 2007 industrial emissions of newly formed dioxins, furans and PCBs were reduced in the European Union by 80% (Third progress report on the Dioxin Strategy, 2010).**

*Toxic Equivalents, or TEQs, are used to report the toxicity-weighted masses of mixtures of dioxins. The TEQ method of dioxin reporting is more meaningful than simply reporting the total number of grams of a mixture of variously toxic compounds because the TEQ method offers toxicity information about the mixture.

Sources:
US EPA and National Academy of Science
WI BREF: *BAT 2019/2010 establishing the best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for waste incineration*

# Waste to Energy Facts
## Emissions: Dioxin as Example

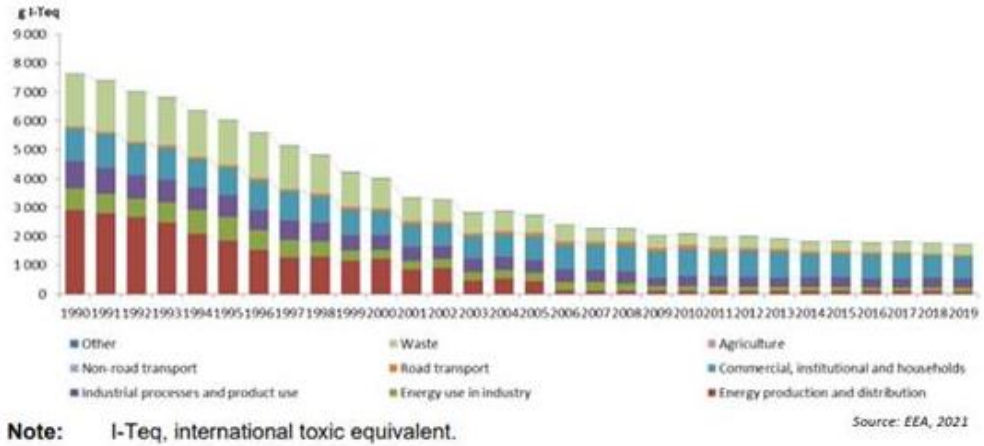
### Dioxins and Waste-to-Energy Plants – State of the Art

European-wide overview of long-term analysis of dioxins in WtE plant surroundings

1. European WtE sector one of the most strictly regulated industries in terms of pollution prevention and control.
   - → Today, WtE dioxin emissions account for **less than 0.2% of the total industrial dioxin emissions**[1]
   - → Stringent limits for monitoring of dioxins during **different operating stages**

1989: Specific stringent legislation for WtE plants to prevent and control pollution.

2019: Publication of Waste Incineration BAT Conclusions with even more ambitious emission limits for dioxins and furans




Source: EEA, 2021

**Note:** I-Teq, international toxic equivalent.

**Great historical decline**

**Other sources more prominent**

[1] European Pollutant Release and Transfer Register, https://industry.eea.europa.eu/

[2] Best Available Techniques (BAT) Conclusions for waste incineration: Commission implementing decision (EU) 2019/2010 of 12 November 2019

# Waste to Energy Facts
## Emissions: UK Tolvik report

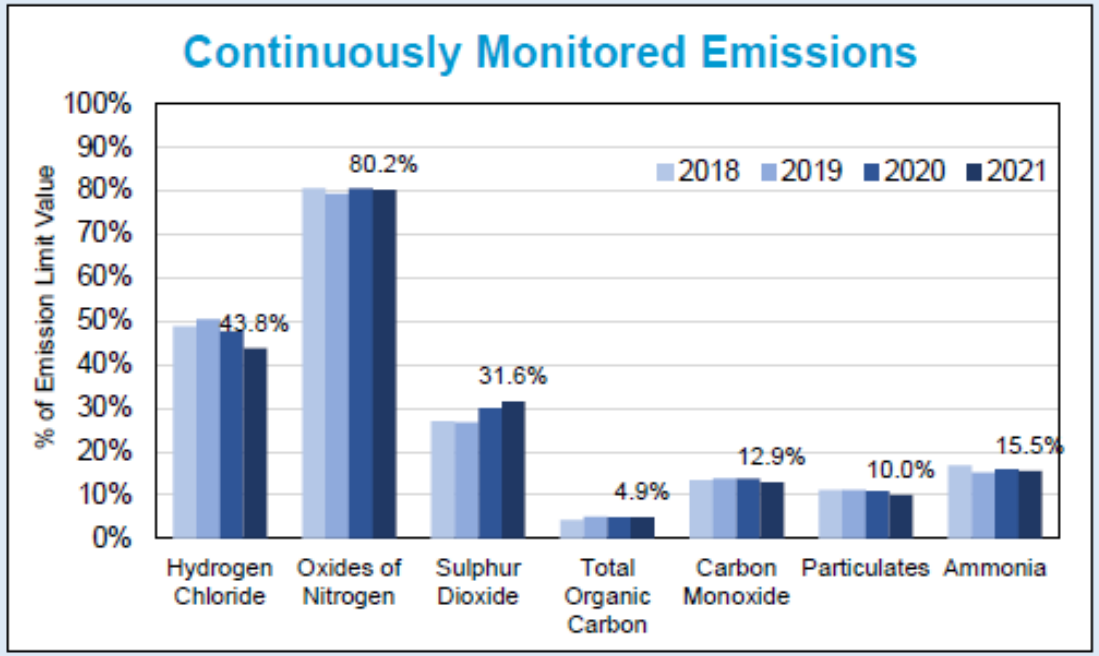



*Figure 28: Continuously Monitored Emissions to Air Source: APR*

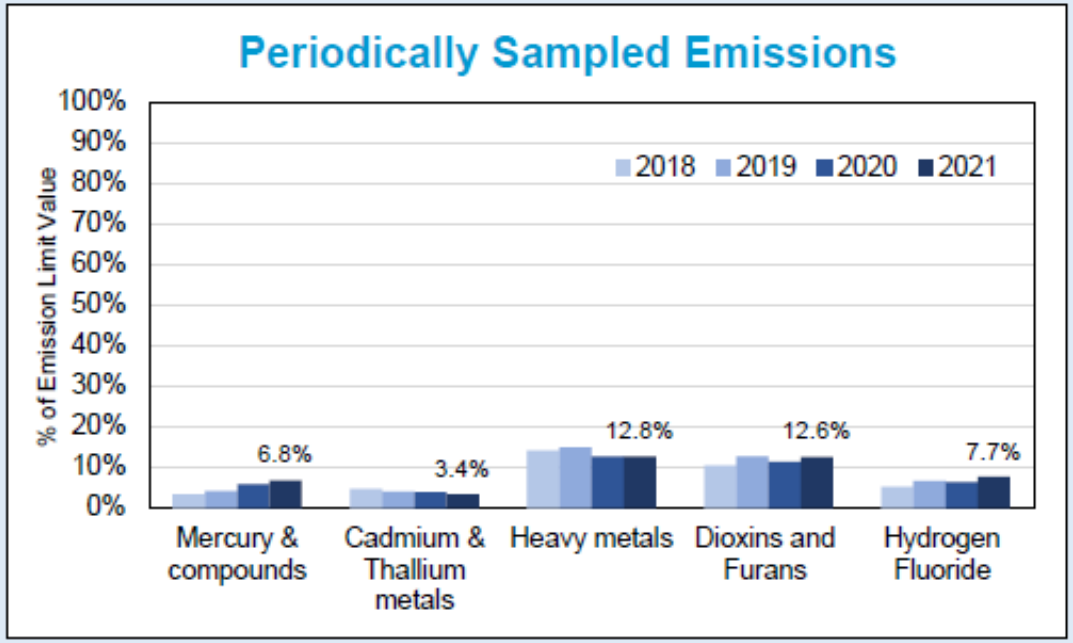



*Figure 29: Periodically Monitored Emissions to Air Source: APR*

Sources:
https://www.tolvik.com/published-reports/view/uk-energy-from-waste-statistics-2022/

# Waste to Energy Facts
## Health impacts

Waste-to-Energy plants **do not have** a negative impact on the health of people.

Percentage of employees working in a WtE plant with an increased concentration of heavy metals (cadmium, lead, mercury) in their blood is **0%**

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Difference of the concentration of dioxin- and furan in blood lipids of persons employed in WtE plants compared to the normal population is **0%**

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Percentage of persons that smoke at least 20 g tobacco/day with increased concentrations of cadmium in their blood is **100%**

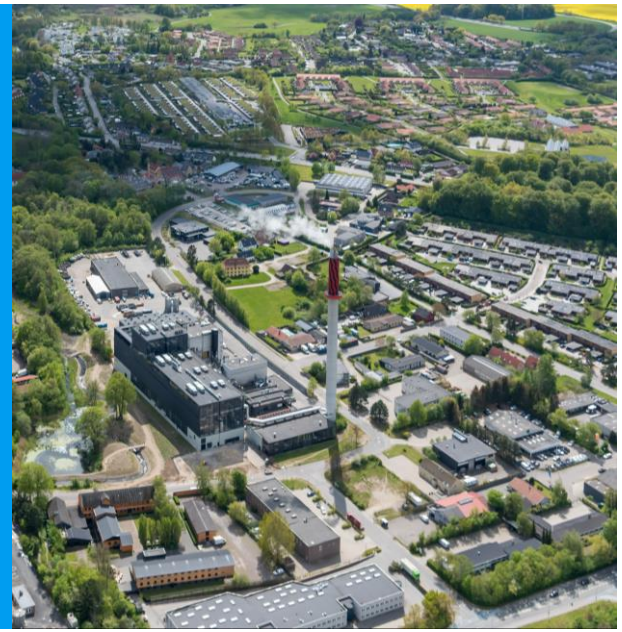
Sources:
Percentage of employees working in the Waste-to-Energy plant in Bamberg, Germany with an increased concentration of heavy metals (cadmium, lead, mercury) in their blood (0 %) – Keine erhöhten Schwermetallgehalte (PB, Hg, Cd) im Blut des Betriebspersonals eines Müllheizkraftwerks, Dieter O. Reimann und Claus-Dieter Bloedner, Müll und Abfall 3/85
Difference of the concentration of dioxin- and furan in blood lipids of persons employed in Waste-to-Energy plants compared to the normal population (0 %) - Staub – Reinhaltung der Luft 55 (1995), Springer Verlag

# Waste to Energy Facts
## The Location

Waste-to-Energy plants are **not** dangerous because of their emissions. Therefore, they are placed in the immediate neighbourhood of residential areas in most European cities.

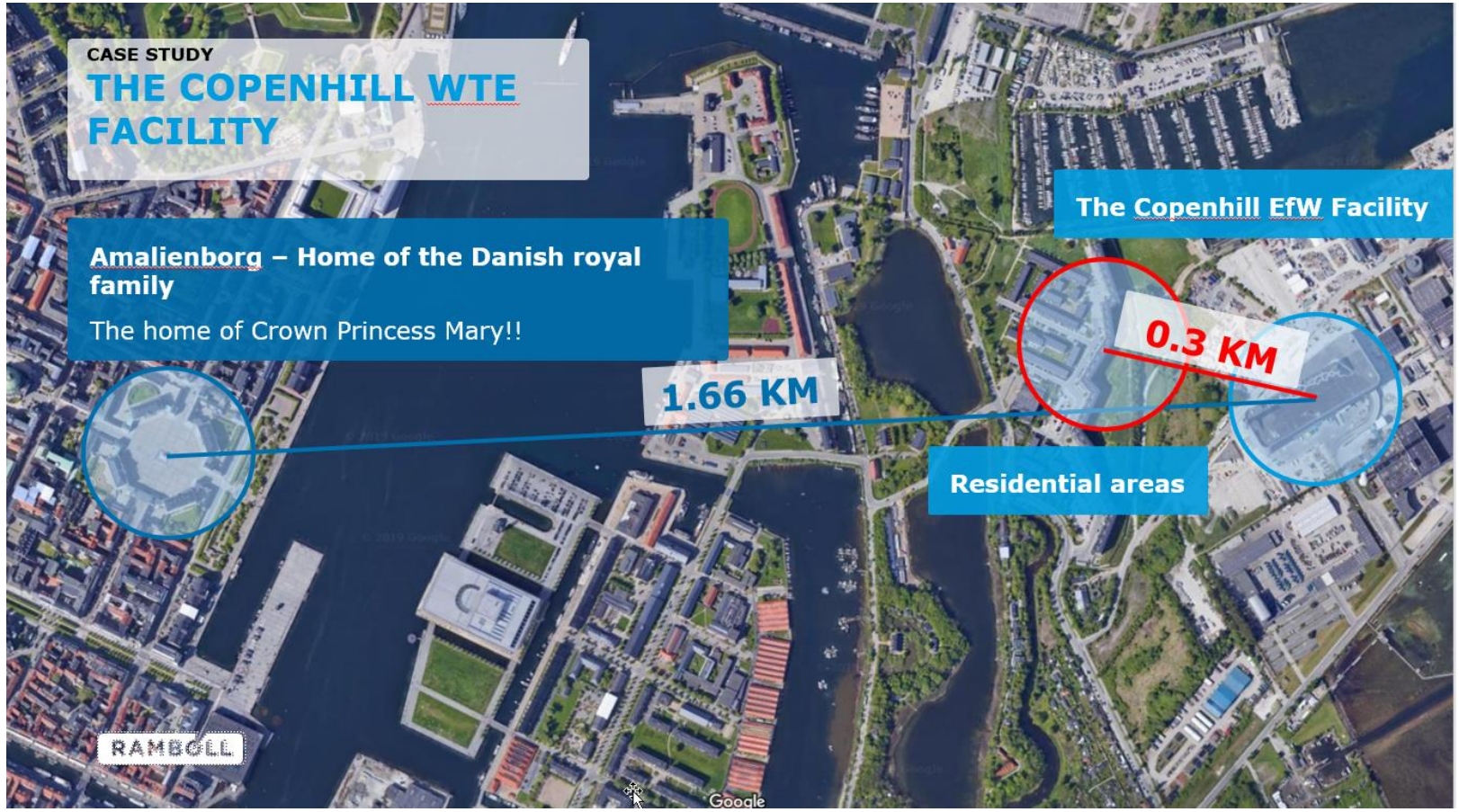
Percentage of Waste-to-Energy plants in Switzerland that are located in the city or in the immediate neighbourhood of residential areas is **87%**

Percentage of Zurich's population that voted for the extension of the Waste to Energy plant in the centre of the city is **75%**



Sources:
Percentage of Waste-to-Energy plants in Switzerland that are located in the city or in the immediate neighbourhood of residential areas (87%) - http://vbsa.ch/anlagegruppen/kva/
Percentage of Zurich's population that voted for the extension of the Waste to Energy plant in the centre of the city (75%) - http://www.gemeinderat-zuerich.ch/geschaefte/detailansicht-geschaeft?gId=d585af78-b096-4667-aede-a32e2853dac4

# Waste to Energy Facts
## The Location

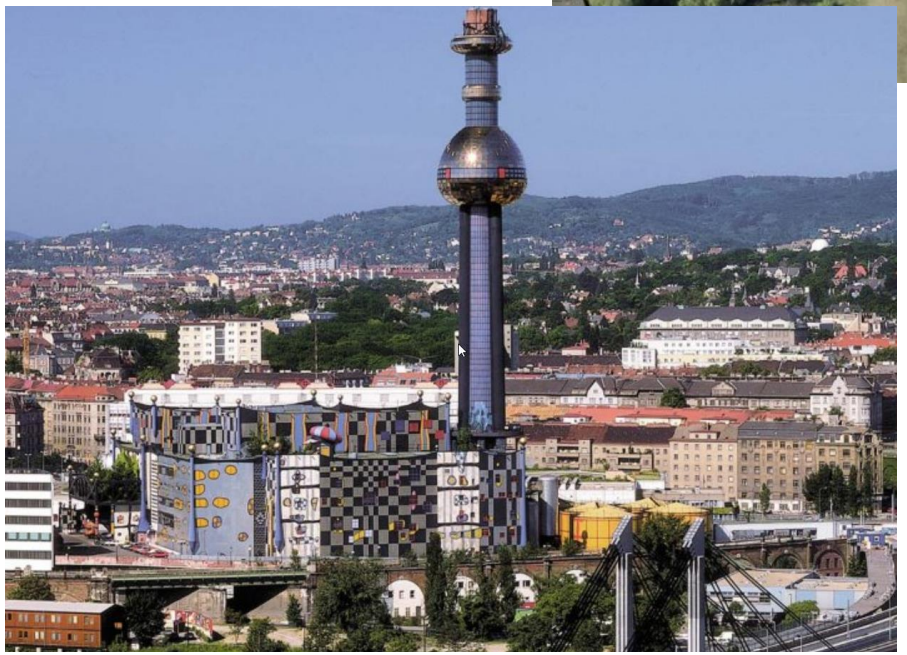



Waste-to-Energy plants are **not** dangerous because of their emissions. Therefore, they are placed in the immediate neighbourhood of residential areas in most European cities.

# Waste to Energy Facts
## The Location

CopenHill
Denmark
(private photo)

Hørsholm, Denmark
(photo: Danish Energy ministry)



Spittelau waste treatment station, Vienna, Austria

**In Paris there are 3 EfW plants close to hyper center (25,000 inhabitants/km2)**

# MYTH 3

Residual waste has no energy content…

…especially when plastics are source separated increasingly in the future

**NOT TRUE… SEE FOLLOWING SLIDES**

# Waste Calorific Value

| **Fuel** | **Lower heating value (LHV)** [MJ/kg] |
|---|---|
| Coal | 25-35 |
| wood chips (fresh) | 9-12 |
| Wood waste | 12-18 |
| Residual household waste<br>(EU and probably also Australia) | 7-14 (midpoint 10-12) |

Separation of materials with
High LHV

**EU data suggest energy content in residual waste is not changing much**

Separation of organics with
Low LHV

Sources:
https://www.sciencedirect.com/topics/engineering/net-calorific-value
https://www.researchgate.net/figure/LHV-s-versus-moisture-content-of-wood-11_fig2_257177200
https://www.diva-portal.org/smash/get/diva2:471435/FULLTEXT01.pdf

# MYTH 4

Large scale waste-to-energy
is not mature technology

**NOT TRUE… SEE FOLLOWING SLIDES**

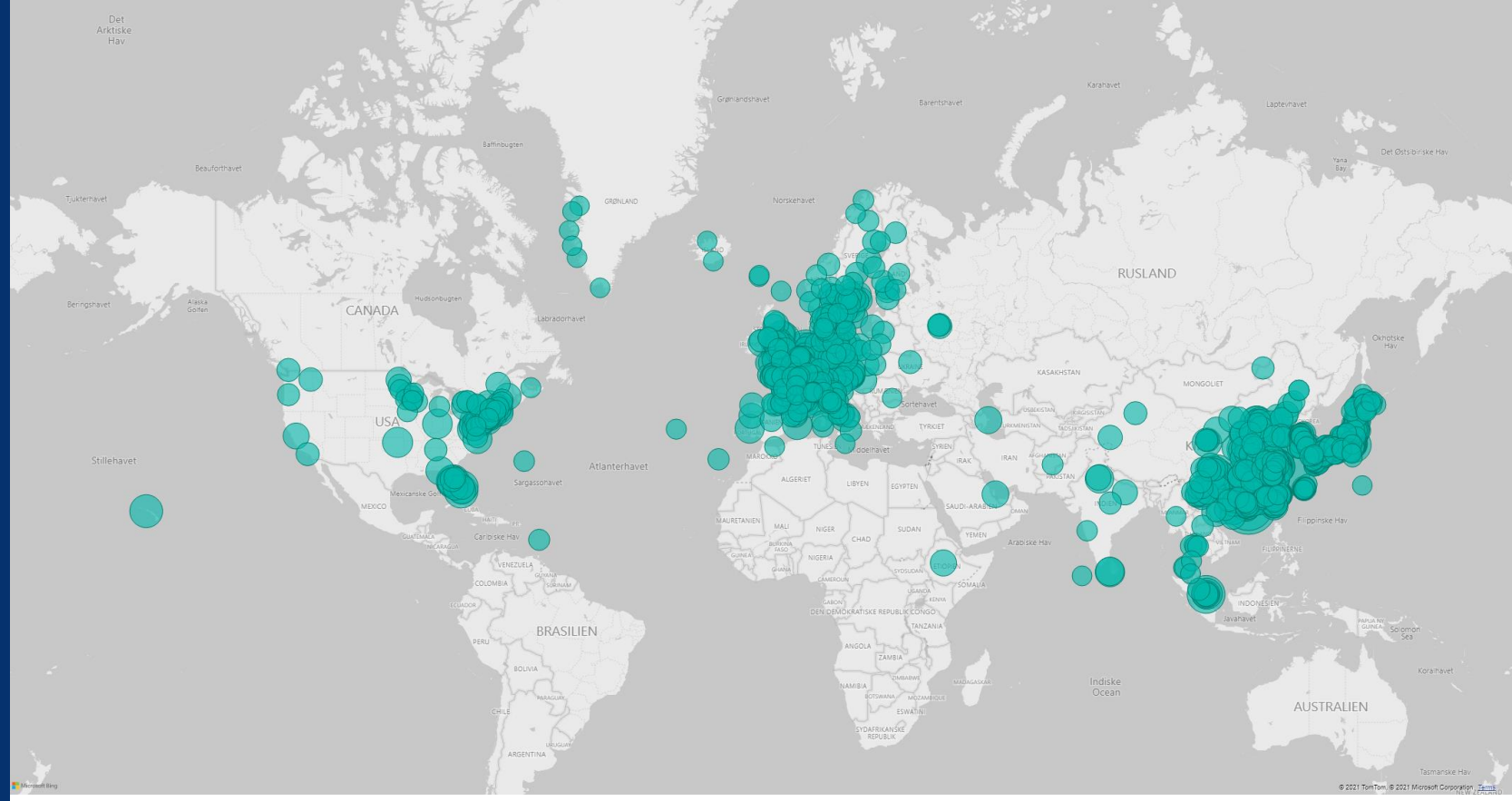
# Moving Grate is Proven Technology

- ✓Moving grate combustion
- ✓Energy recovery through steam boiler and steam turbine
- ✓Flue gas treatment with EU IED and BREF compliance (strictest control of emissions to air)

Link to Ramboll homepage with various information and introductory movies:
https://ramboll.com/services-andsectors/energy/waste-to-energy

Links to examples of existing UK facilities (both have introductory movies):
https://www.ubbgloucestershire.co.uk/

https://www.dublinwastetoenergy.ie/




**4,000+**

Boiler lines in operation

**10**

MJ/kg average NCV

RAMBØLL Bright ideas. Sustainable change.

# Bright ideas. Sustainable change.

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