RAMBØLL

Bright ideas.
Sustainable change.

Waste Expo Australia – 2022 Waste Summit Conference

Lessons Learnt from EU Experiences with WtE

Anthony Douglas
Ramboll Australia (Energy)
Senior Consultant -- adouglas@ramboll.com

Content

1. Global waste projections
2. Why legislation is key for the WtE sector
3. WtE and resource recovery & WtE's place in the circular economy
4. Why high landfill diversion without WtE isn't achievable
5. Ramboll BIOMA technology: Measuring and monitoring CO_2 emissions from WTE facilities: biogenic vs. fossil
6. Carbon Capture in the WTE context

Ramboll in Brief

- We are your '**Partner for Sustainable Change**'
- Independent engineering, architecture and consultancy company
- Founded 1945 in Denmark
- 16,000+ employees. Present in 35 countries
- Particularly strong presence in the Nordics, the UK, North America, Continental Europe, Middle East and Asia Pacific
- **We are not beholden to shareholders**, we are owned by Rambøll Fonden – The Ramboll Foundation
- Internationally recognised world-leading consultancy with 1800 staff within the energy space, and **more than 110 experts focused on WtE/EfW and Carbon Capture**
- 2500 staff globally within Environment & Health incl. 60 experts in Australia
- Involved in WtE projects in 45 countries (160+ units)

- **Ramboll work with all parts of the waste & resource chain**
- **Independent from technology providers**
- Our values revolve around sustainability

Why Waste Management?

WASTE IS CONSTANTLY GENERATED IN OUR SOCIETIES

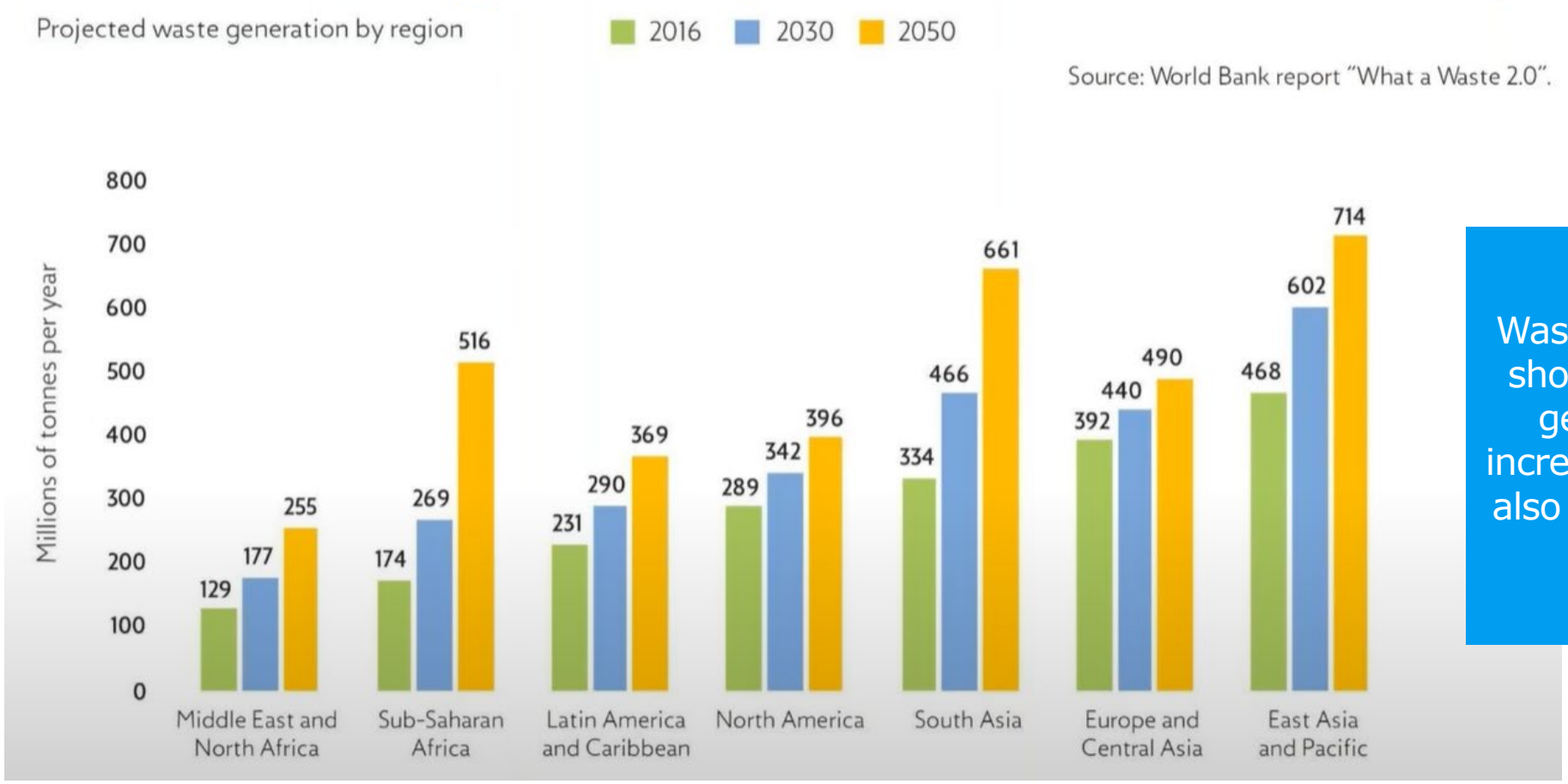
It is a **product** of

- Urbanization
- Economic development
- Growth in population

Waste will not magically **disappear**, and it cannot leave the surface of the earth (other than as emissions to the air).

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

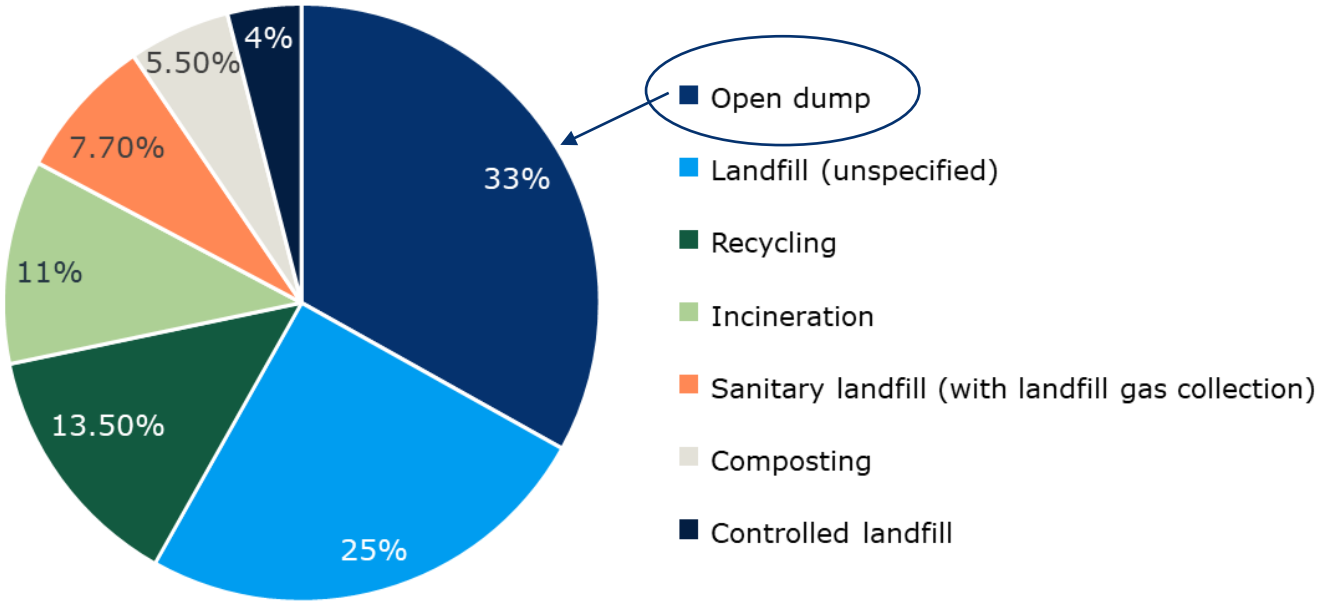
Projected Waste Growth



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 tonnes waste ends up in nature and waterways.**

CO_2-e EMISSIONS

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

Why legislation is key for the WtE sector

- **In most developed countries, and many developing countries, WtE is critical infrastructure**
  - Often large-scale facilities
  - Grid connected electricity generators
  - Require significant investment costs (CAPEX and OPEX)
  - Long-term waste supply contracts with municipal authorities + private sector
  - Planning and environmental approvals are costly and time consuming
  - Complex legal, commercial, financial and stakeholder management aspects
  - By-products can be processed for reuse, but require approvals and compliance with local regulations and standards
  - A small portion of by-products require treatment prior to disposal
  - Social Licence to Operate – gaining trust and demonstrating that the development will add value to the community
- **Investors do not like uncertainty, but in Australia the regulatory & policy landscape is uncertain**
  - Each Australian State has or is developing their own policies, guidelines, regulations
  - Each State EPA has their own approach / pathway to assess works approval/licence applications
  - Each State has a different approach to managing by-products (End of Waste)

Why legislation is key for the WtE sector

- The Victorian waste to energy framework (2021) identifies the role of thermal WtE in achieving Victoria's 2030 circular economy targets (i.e. 15% reduction in per capita waste, 80% resource recovery for ALL waste streams and 50% reduction in organic waste to landfill), but then places a cap and new (additional) licencing process on thermal WtE

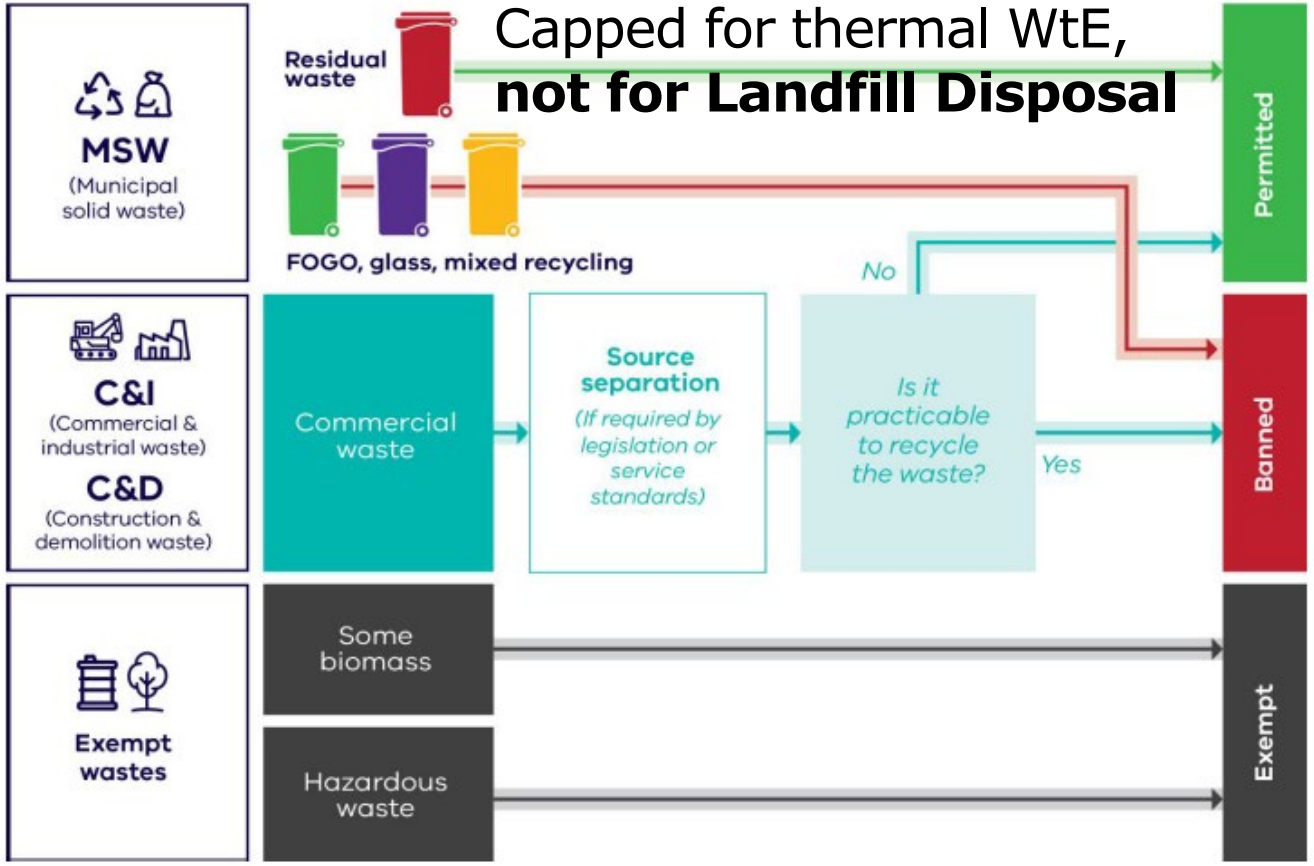


Figure 2: Summary of permitted, banned and exempt wastes under the waste to energy framework.

Source: *Victorian waste to energy framework* (2021)

Why legislation is key for the WtE sector

Different definitions of eligible waste fuels/refuse derived fuel:

Example of the current 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 of the current 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).

Current legislation determines what material is "waste" and therefore legislation is key to properly address and define waste and waste treatment requirements

Low risk fuel (biomass)

Waste or biomass?

MSW Red Bin

Why legislation is key for the WtE sector

- **In contrast, the EU has a common set of directives for each member state to adhere to, or face penalties**
  - 2008/98/EC Waste Directive
  - 2010/75/EU Industrial Emissions Directive (IED)
    - WI-BREF (Best Available Techniques Reference Document for Waste Incineration) 2019
    - WI BATC (Best Available Techniques Conclusions for Waste Incineration) 2019
  - WA and Victoria have largely adopted the IED, while current NSW legislation has chosen to adopt alternative requirements, making it very challenging for a thermal WtE facility designed to BATC to comply (while millions of tonnes of waste continue to go to landfill disposal)

  - Less commonality on approaches to regulating the primary solid residue by-product from thermal WtE (bottom ash (IBA)) e.g. UK, Denmark reuse most of the IBA, while Switzerland require it to be landfilled. Air Pollution Control residues are generally taken to a controlled landfill or stabilized prior to disposal:
  - The two WA WtE developments are both progressing strategies to reuse their IBA
    - Avertas Energy (Kwinana) will use an off-site BluePhoenix IBA processing facility
    - East Rockingham will use an on-site IBA maturation and processing facility
    - All parties are working with the regulator and potential offtakers on a 'End of Waste' outcome

Waste to Energy and Resource Recovery

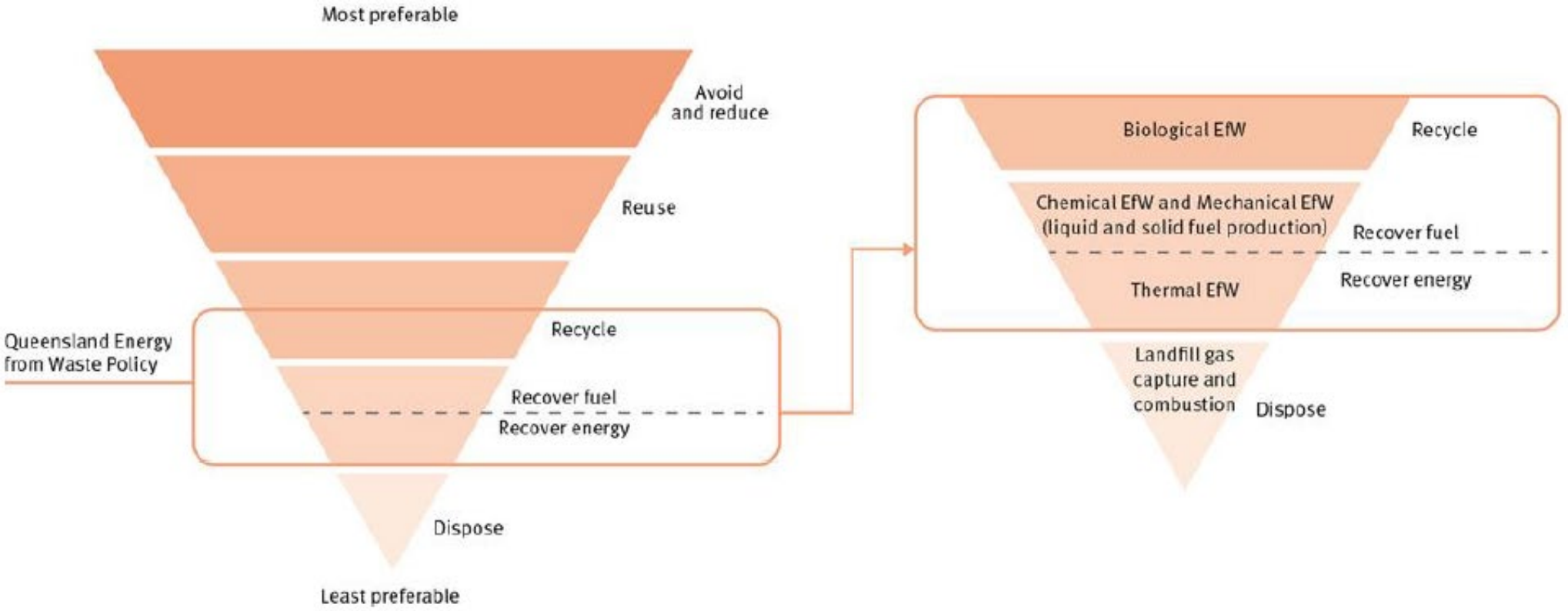


Figure 1: Queensland's waste hierarchy (left) and EfW hierarchy (right)

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

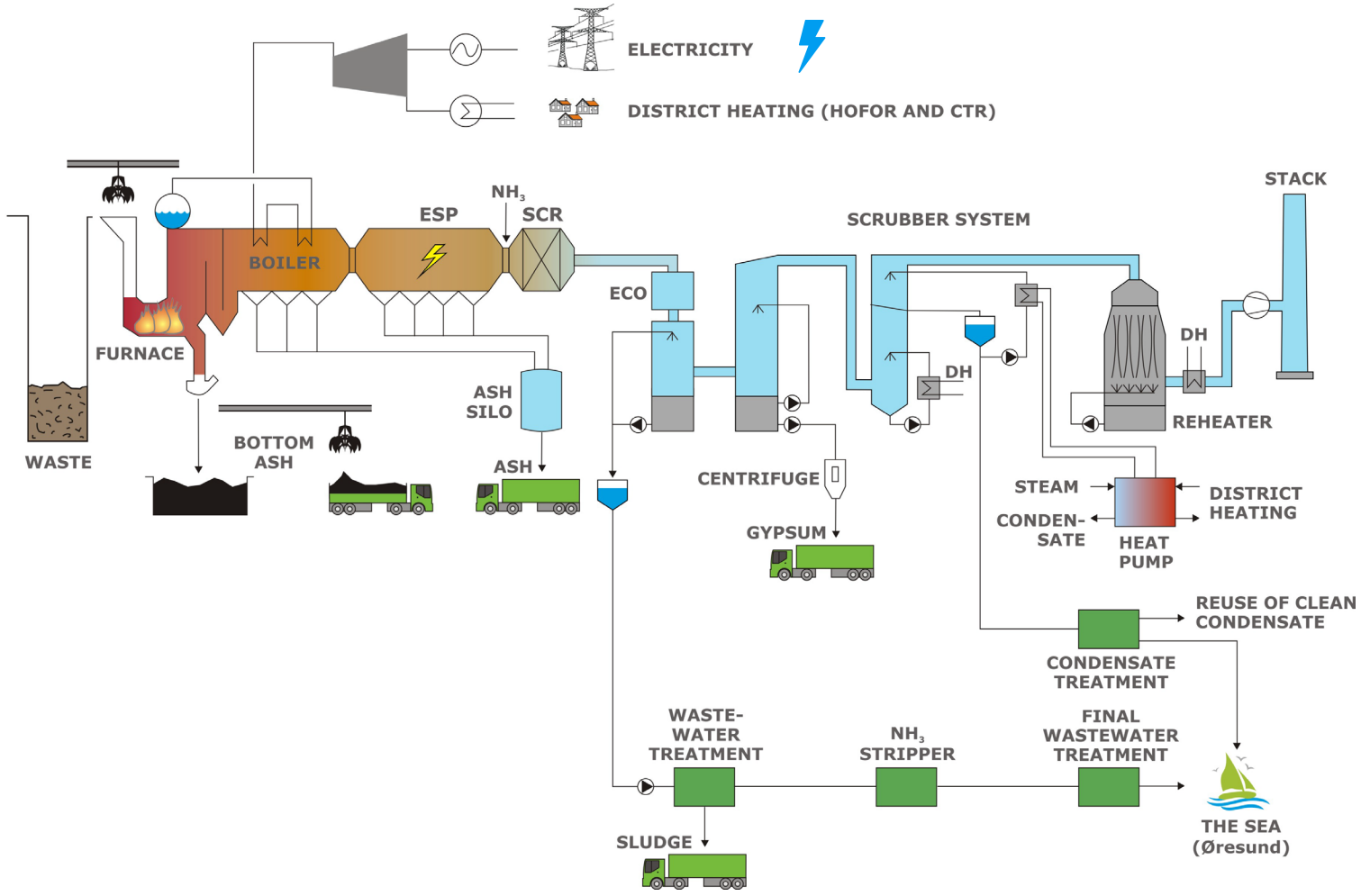
Ramboll is engaged in projects throughout the entire waste hierarchy, to define the right strategies and solutions at different levels.

What is Waste to Energy?

Thermal power plant fuelled by residual non-pretreated garbage (mainly MSW and Commercial & Industrial waste) with stringent environment emission controls and materials recovery in bottom ash/recyclable metals

Source: CEWEP

What is Waste to Energy?



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% (Lower Heating Value basis)**.
   - Recovers water from flue gas condensation for reuse and avoids imported water

WtE production and waste streams

1000 kg of residual waste

(2.8 MWh*)

*Represents the total energy content of 1t of waste @ 10MJ/kg

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

Air Pollution Control 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

European WtE plants (Potential)

- 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 for use 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/.

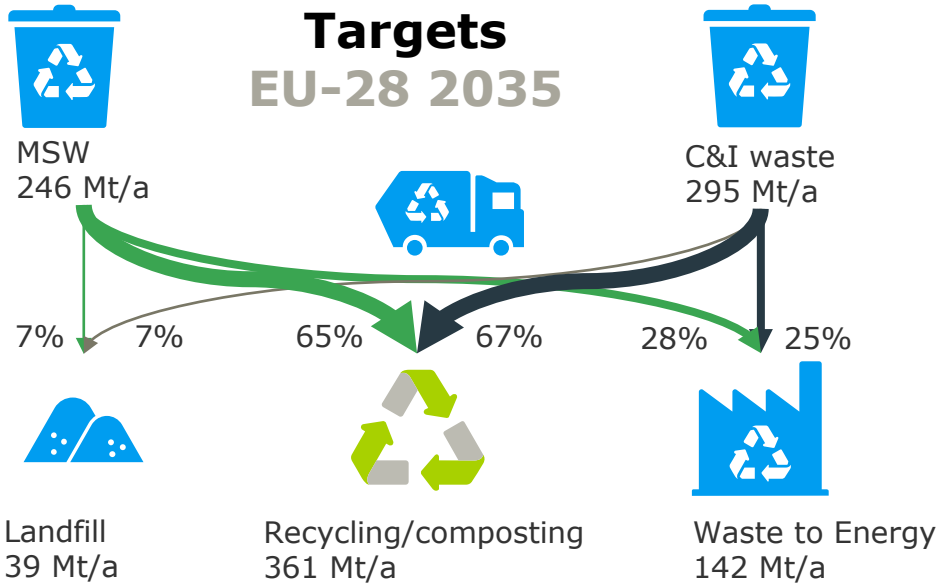
WtE is Part of the Circular Economy

- Ramboll believe WtE should be accepted as part of **Australia's arsenal of technologies** needed to achieve landfill diversion and recycling targets.
- **Sink for recycling rejects**
- Opportunity to **dispose of non-recyclable** materials safely and sustainably
- **Respect the waste hierarchy** by at least recovering energy/metals, from what would **otherwise have gone to landfill**

Sources:
1) https://ec.europa.eu/jrc/en/news/research-helps-europe-advance-towards-circular-economy, accessed 08.03.2021 and
2) https://www.cewep.eu/waste-to-energy-cycle/, accessed 08.03.2021

Waste to Energy in the 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 **200+ new WtE plants** in EU until 2035.

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

Prevents waste streams from entering nature + waste is managed locally

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

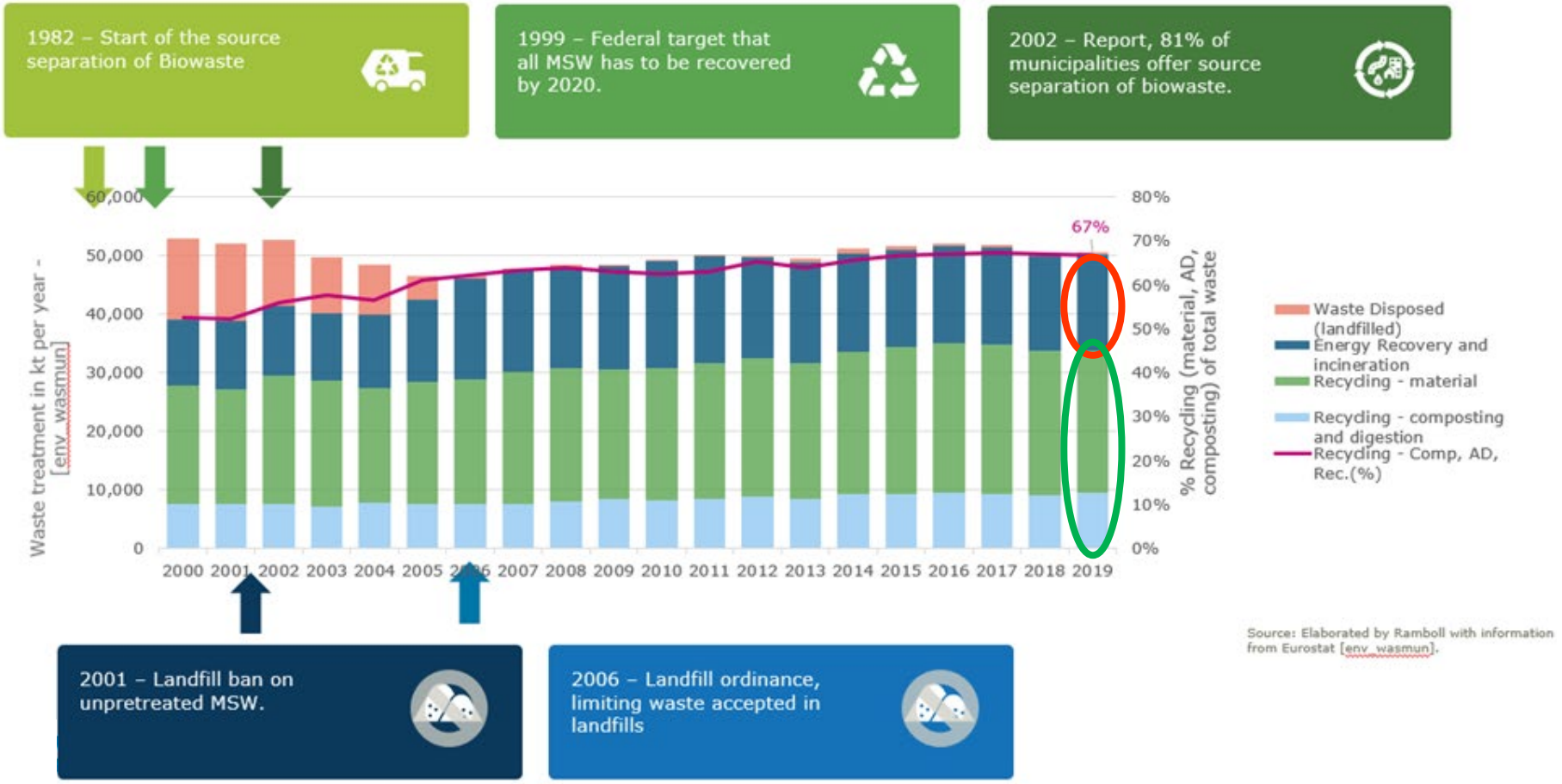
Sources: Jo Van Caneghem, Karel Van Acker, Johan De Greef, Guido Wauters, Carlo Vandecasteele: *Waste-to-energy is compatible and complementary with recycling in the circular economy*, in: Clean Technologies and Environmental Policy 21 (2019)
Trinomics for EEA: *Emerging Challenges of Waste Management 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)

High Landfill Diversion Rates (for MSW) Very Difficult to Achieve Without WtE

Germany Example – Residual 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 (80%)
- **80-90% diversion from landfill is very difficult without WtE**

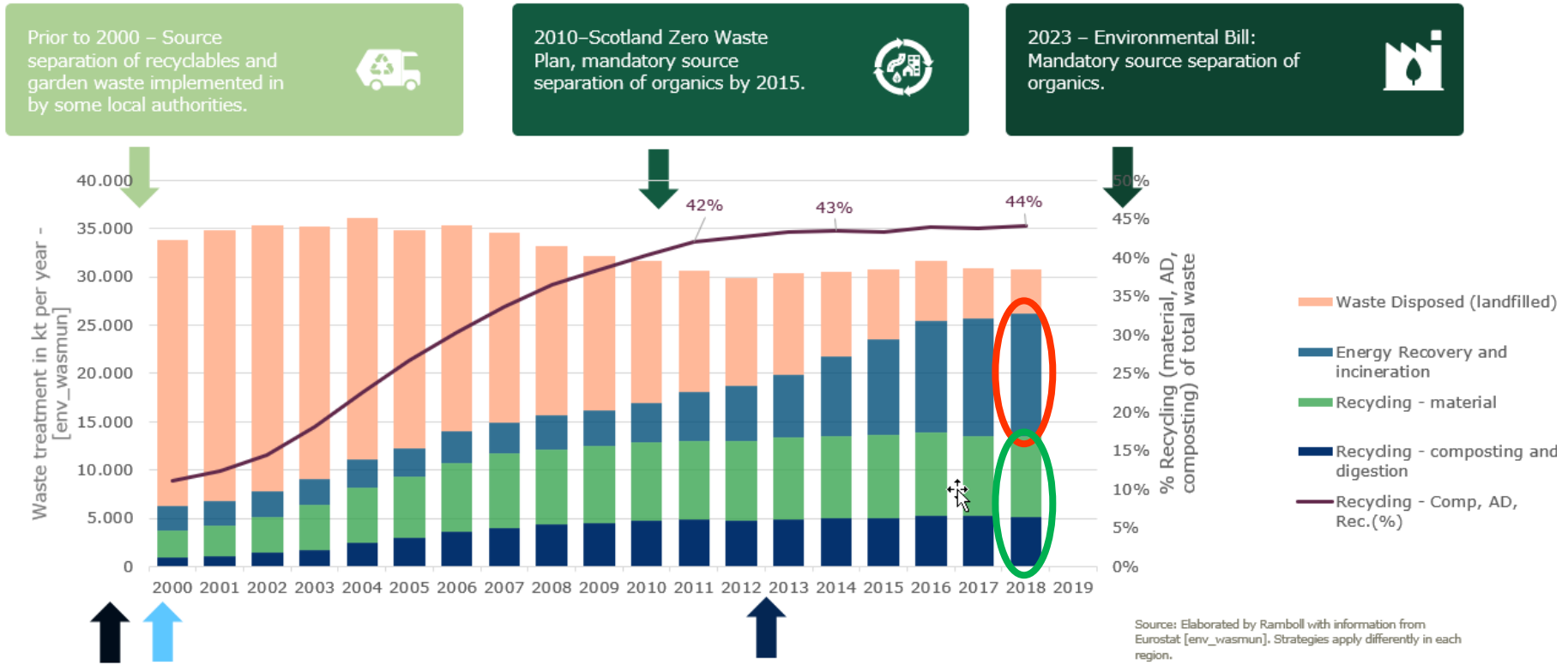


Source: Elaborated by Ramboll, based on data from Eurostat [env_wasmun database].

High Landfill Diversion Rates (for MSW) Very Difficult to Achieve Without WtE

UK Example – MSW:

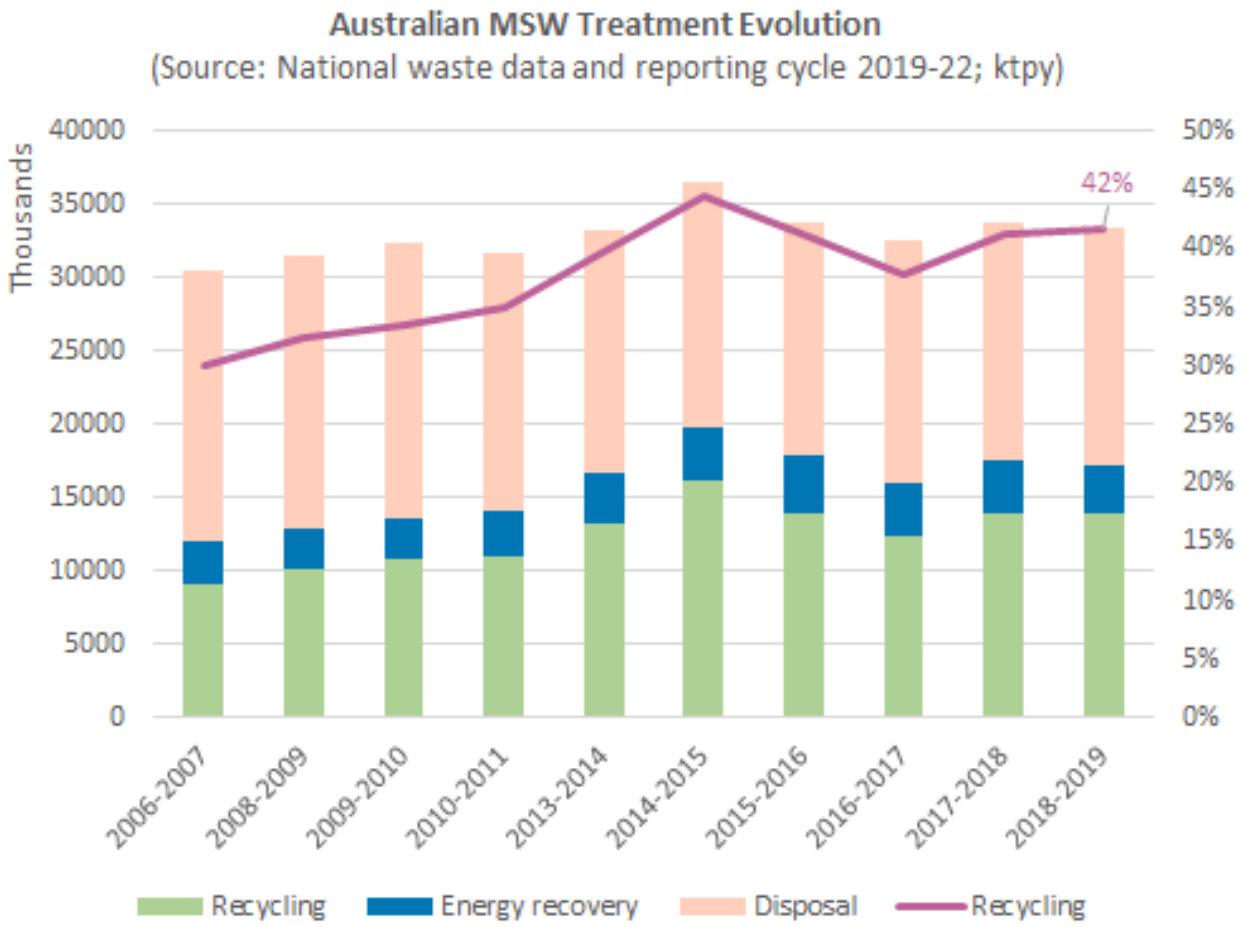
- UK still has some 15% that goes to landfill, and recycling seems to have stagnated at 44%
- High landfill diversion and recycling requires strong efforts
- Recycling **collection** may be up to 65%, but includes contaminants, etc.



Source: Elaborated by Ramboll with information from Eurostat [env_wasmun]. Strategies apply differently in each region.

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

Australia Seems to Have a Long Way to Go for MSW
(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

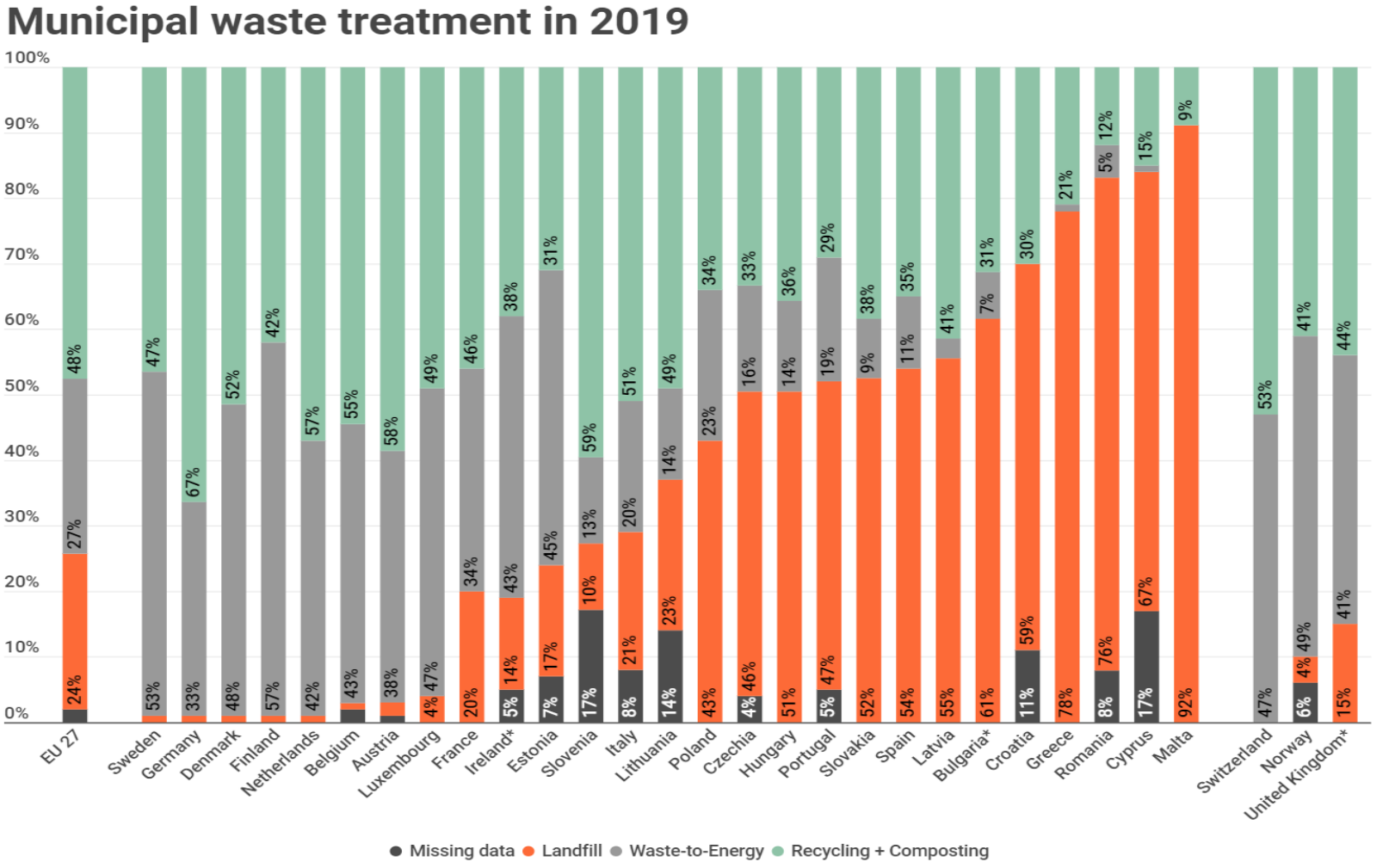
National Waste Policy Action Plan 2019

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.

Waste to Energy and Recycling are Not Opposites



Kilde: Eurostat - Data Explorer
https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

*: 2018 data (last available)

Energy from Waste and Recycling are Not Opposites

The countries with the highest **recycling** rates (50-70%)… also have the highest **waste-to-energy** rates (30-50%)…

Country	Recycling +Composting	Waste-to-energy
Germany	67%	31%
Austria	58%	39%
Belgium	54%	43%
Netherlands	54%	44%
Switzerland	53%	47%

Source: https://danskaffaldsforening.dk/affaldtal

EU Eurostat - 2018 figures

By 2022-23 Denmark will be sorting in 10 Fractions at Household Level and still WtE is Needed to a Large Degree

Currently (7) fractions are recovered <u>separately</u> at source:

- Garden waste
- Plastics (also soft)
- Metal
- Glass
- Cardboard
- Paper
- Residual Waste

Adding (3) extra material flows:

- Drinking cartons (with plastic) Textiles (1.6.2023)
- Hazardous items (batteries, paint, etc)
- Kitchen waste (2022)

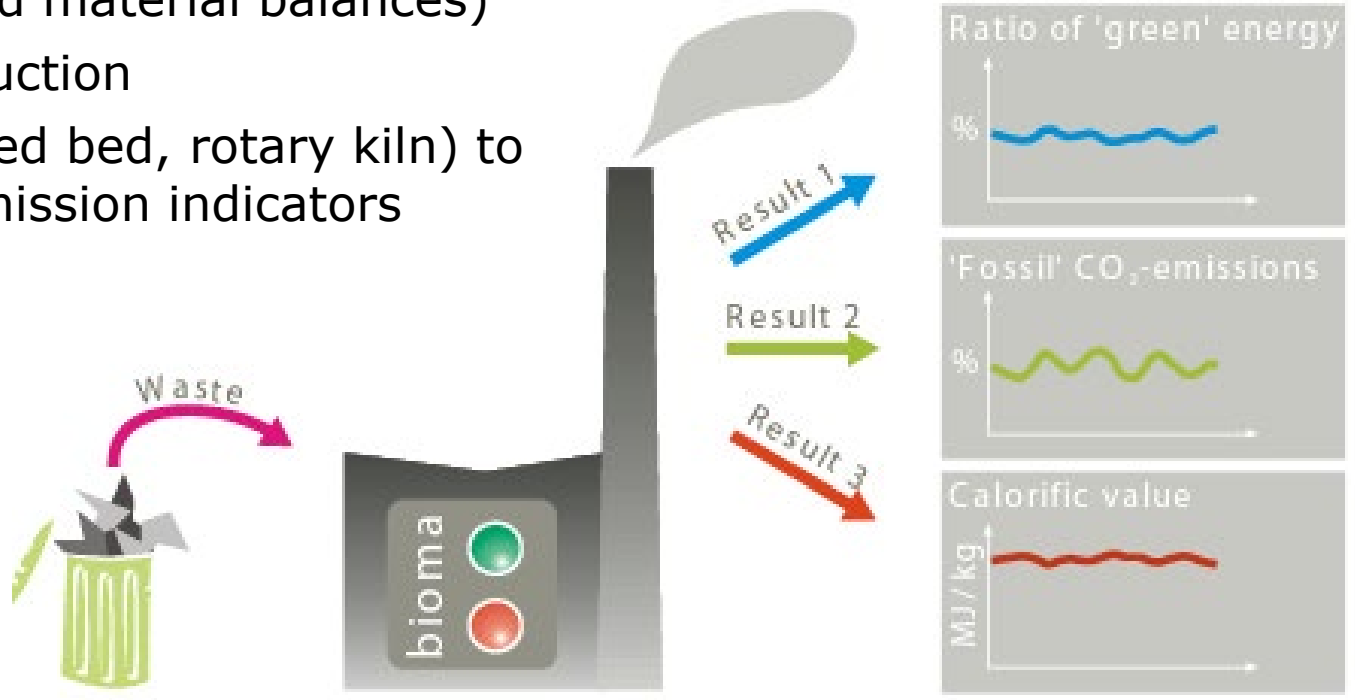
Many Waste Management Initiatives (including WtE) are Needed to Reduce Resource Loss to Landfill

- Increased source separation
- Community education
- Improvements to product manufacturing practices
- Material Recovery Facilities (MRF)
- Anaerobic Digestion (AD)
- Waste to Energy (WtE) facilities

Ramboll BIOMA Technology

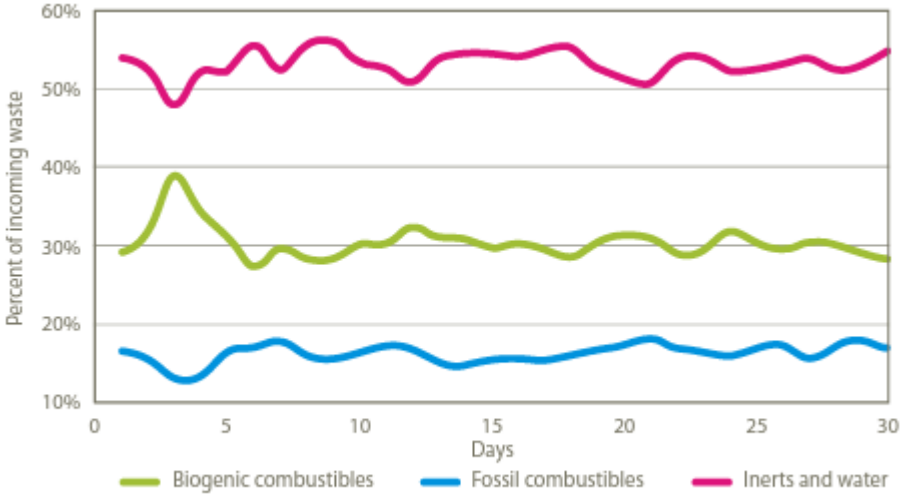
A certified tool for online CO_2 origin determination; measuring and monitoring biogenic and fossil derived CO_2 emissions from WTE facilities

- **BIOMA software**
  - Developed by Vienna University of Technology and Ramboll
  - Uses the Balance-Method (system heat and material balances)
  - Compares O_2 consumption with CO_2 production
  - Allows WtE facilities (grate furnace, fluidised bed, rotary kiln) to monitor various key energy and carbon emission indicators



Ramboll BIOMA Technology

- **BIOMA software outputs:**
  - CO_2 emissions from fossil and biogenic sources
  - Ratio of carbon content in the waste from fossil and biogenic sources
  - Lower/upper heating value of the waste feed
  - Carbon content of the waste feed
  - Ratio of the energy output from fossil and biogenic sources
  - Ash content of the waste feed
  - Water content of the waste feed
  - Inert mass fraction (moisture free) in waste feed
  - Biogenic mass fraction (ash and moisture free) in waste feed
  - Fossil mass fraction (ash and moisture free) in waste feed – indicates plastics content
  - Ratio of energy produced from biogenic fraction (moisture free) to total energy produced



Trend of incoming waste composition throughout a month

ACCEPTED BY

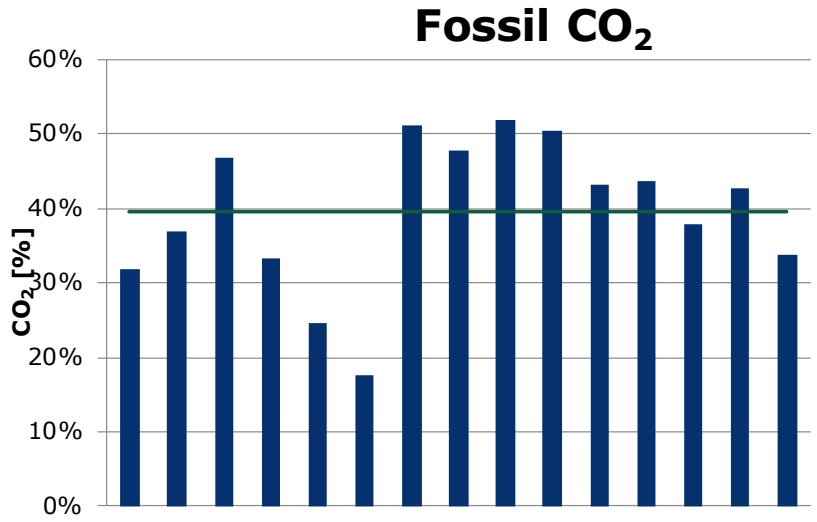
- Austria: Authority for Electricity Labelling
- Belgium: Public Waste Agency (OVAM)
- Switzerland: Environmental Protection Agency (BAFU)
- Denmark: Danish Energy Agency
- UK: Ofgem (UK Energy Authority)
- Sweden: Regional Authority for Stockholm

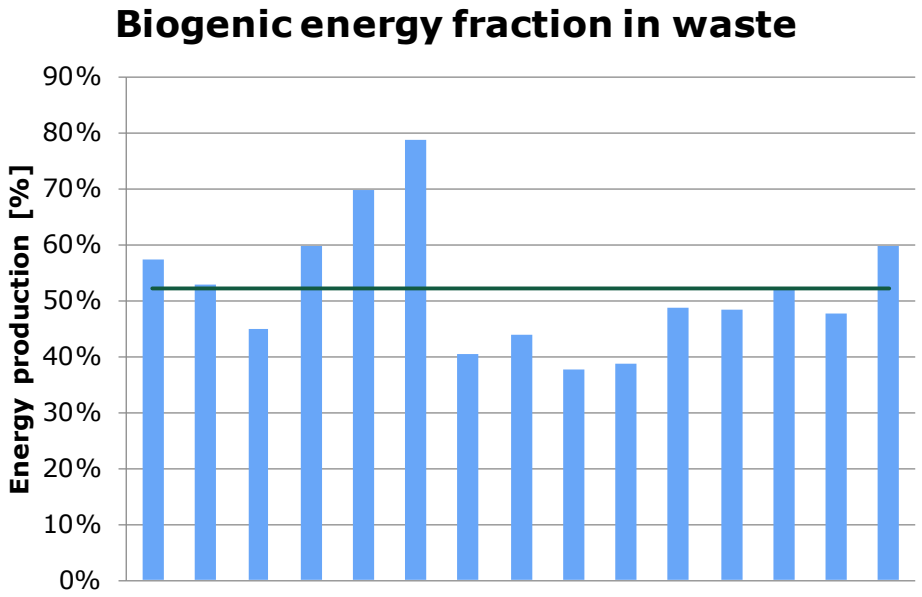
Ramboll BIOMA Technology

- Example outcomes (on a facility average basis) from various UK and EU located WtE facilities from 2021

- **Advantages**
  - Biogenic energy production (for green certificates/Large-scale Generation Certificates)
  - Fossil CO_2 emission determination
  - Waste characterisation (e.g. water and plastic content)
  - Automated online data processing and reporting
  - Evaluates measurements and reports if they are plausible
  - Easy to use, requires minimal training

See https://ramboll.com/-/media/files/rgr/documents/brochures/abc/bioma-software-gr%C3%B8n.pdf?la=en





Carbon Capture in the WtE Context

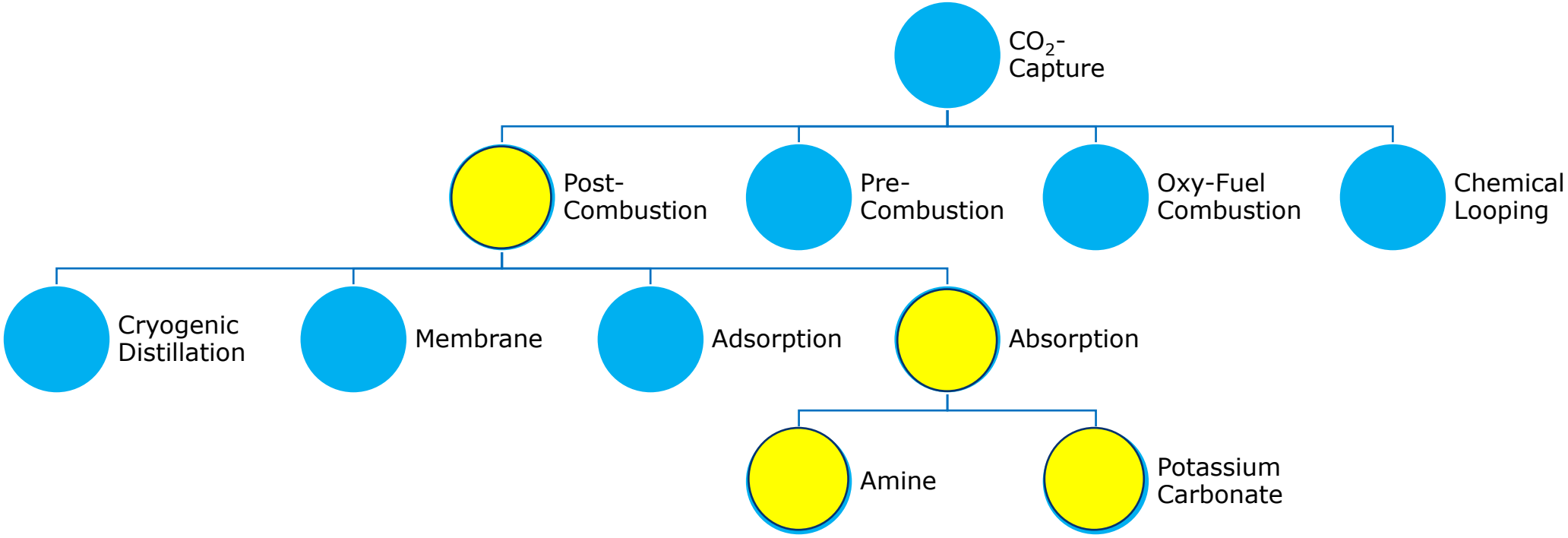
- **Key points:**
  - WtE avoids $CO_{2\text{-}e}$ emissions (e.g. avoids methane (x25) emissions from landfill, and baseload fossil fuel power generation), however,
  - Combustion of non-biogenic (fossil fuel derived) materials releases non-biogenic CO_2

- Ramboll has a Carbon Capture Competence Team within Ramboll Energy division
  - We are assisting multiple customers with Carbon Capture Usage & Storage (CCUS) options

- CO_2 emissions from WtE are considered 'hard to abate'
  - Low pressure flue gas
  - Low concentrations of CO_2 (due to high concentration of nitrogen)
  - High temperature flue gas

- Once captured, the CO_2 can potentially be used ("CCU") or stored ("CCS") or a bit of both ("CCUS")

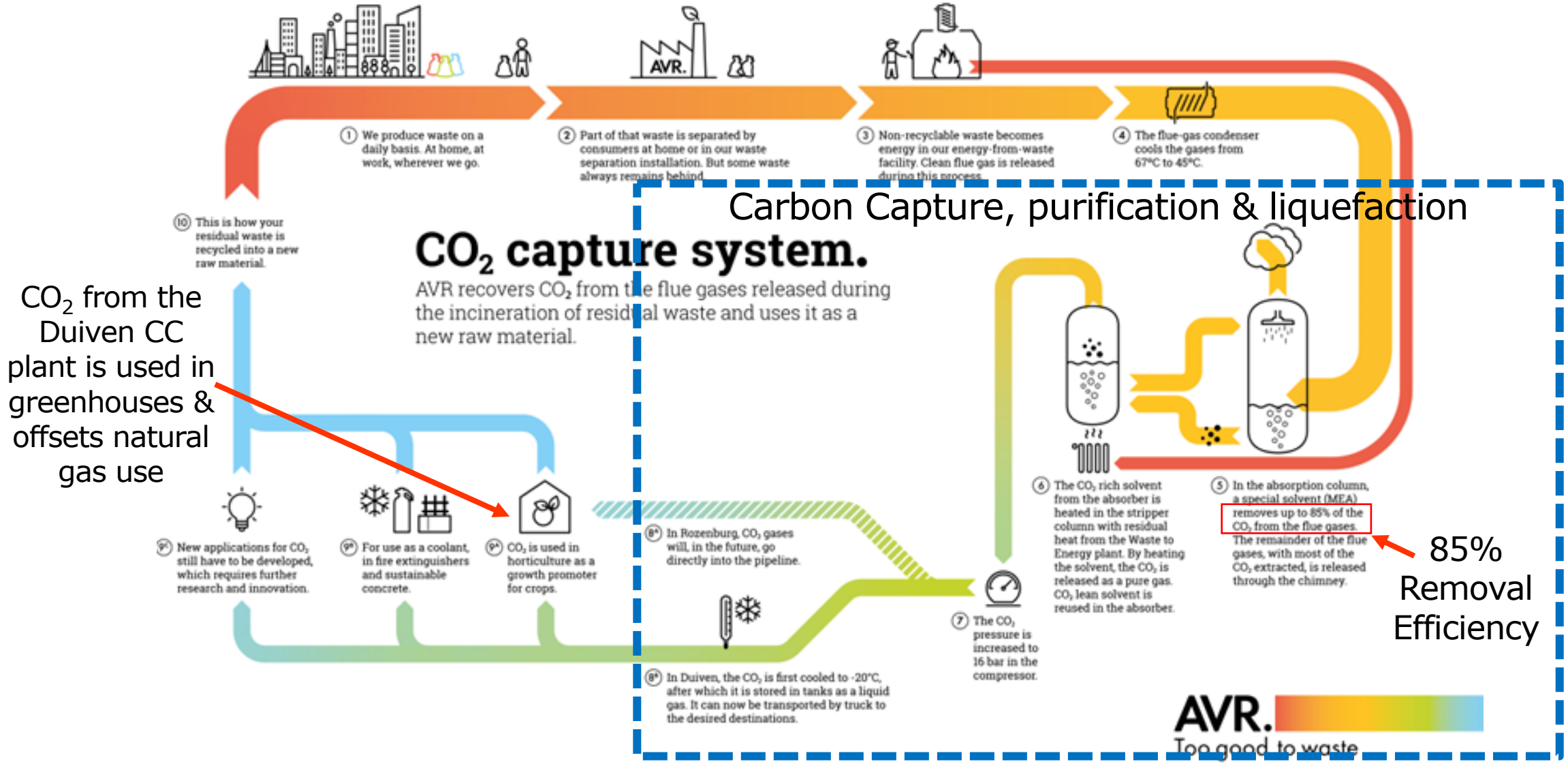
Carbon Capture in the WtE Context



- High CO_2 capture rates 85-90% are possible for Adsorption processes

Carbon Capture in the WtE Context – Case Study

Amine absorption CC WtE reference facility: AVR Duiven WtE (the Netherlands) 60,000tpa CO_2 (~50% CC)



Source: https://www.avr.nl/en/optimal-process/co2-capture-plant/

Carbon Capture in the WtE Context – Case Study

Amine absorption CC WtE reference facility: AVR Duiven WtE (the Netherlands) 60,000tpa CO_2 (~50% CC)

Source: https://www.avr.nl/en/optimal-process/co2-capture-plant/

Carbon Capture in the WtE Context

- **Key points:**
  - **Post-Combustion CO_2 Capture is proven, mature technology but emerging for flue gas**
    - This technology has been applied in energy generation facilities (Boundary Dam & Petro Nova coal combustion flue gas, CO_2 for EOR) and one WtE plant (AVR Duiven, WtE flue gas with CO_2 used in greenhouses),
    - Drivers: The EU Green Deal (Regulation (EU) 2021/1119: European Climate Law and associated legislation), and local Member State legislation e.g. local carbon taxes to reach 2030 and 2050 emission reduction goals.
  - **Not currently commercially viable for WtE without effective carbon pricing** (i.e. to incentivise abatement, disincentivise landfill) **and viable utilisation & storage options**
    - Expensive:– high capital cost to implement AND consumes energy (to either compress the flue gas or to regenerate the absorbent) i.e. loss of revenue, together => higher gate fee
    - What do you do with the captured CO_2?
  - **Non-biogenic CO_2 needs to be sequestered OR used to replace fossil derived CO_2**
    - Integrate with horticultural greenhouses to grow food
    - Other industrial processes e.g. carbonation (mineralise the CO_2)
    - Underground storage e.g. CarbonNet in Victoria, or Carbfix process (How it works - Carbfix) injection of CO_2 dissolved in water deep underground where it reacts with rock (basalt) formations to mineralise the CO_2

Bright ideas. Sustainable change.

RAMBØLL

Anthony Douglas
Resident of Melbourne

Ramboll Australia (Energy Division)
Senior Consultant

0403 229 814
adouglas@ramboll.com

Ramboll Australia Pty Ltd.
100 Pacific Hwy, North Sydney
&
Level 7, 41 St Georges Terrace, Perth

ACN 095 437 442
ABN 49 095 437 442

Rambøll Energy Denmark

Hannemanns Allé 53
DK-2300 København S

https://dk.ramboll.com/energi