Negative Emissions in the Waste-to-Energy Sector: Technologies for CCUS

ACT Knowledge Sharing workshop, 9th June 2022, Rotterdam, NL

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Project Partners

NEWEST-CCUS

THE UNIVERSITY of EDINBURGH

SCCS

carbon clean
TECHNOLOGY TO ACHIEVE 'NET ZERO'

SINTEF

The University Of Sheffield. Energy Institute.

University of Stuttgart
Germany

ifk

TNO innovation for life

- 6 partners from 4 countries
- 3 years, €2.7M total with €2.2M from ACT
- Expert Advisory Group (~30 members) to ensure industrial relevance: technology end-users, technology developers, SMEs, trade associations, regulators, policymakers and NGOs

Strategy for Users Engagement
Expert Advisory Group, chaired by Carbon Clean

NEWEST-CCUS

<u>WtE plant operators / Waste management</u>

BIR (NO)
FCC Environment (UK)
HVC (NL)
KRV (AT)
REG (NO)
REMONDIS (DE)
Returkraft (NO)
SUEZ (Fr)
Stratkraft (NO)
Twence (NL)
ARC Amanger RC (DK)
KHK SA (PO)
KVA-Linth (CH)
Renova (SE)
Westenergy (FI)

<u>Technology/Engineering/Testing</u>

Air Products AS (NO)
Carbon Clean (UK)
Doosan Babcock (UK)
Rheinkalk-Lhoist (DE)
Steinmüller (DE)
HZ Innova (CH)
TCM (NO)

<u>Trade Association / Regulatory bodies</u>

CEWEP (EU)
SEPA (UK)
UK CCC (UK)
BFE (CH)
ODNZKG (NL)
ESA (UK)

<u>Universities</u>

SJTU (CN)

<u>Energy/ Utilities</u>

Sembcorp (UK)

Project Progress to date

Milestone 1
- D1.1 Consortium Agreement
- D1.2 Project Implementation Plan

Milestone 2
- D2.1 Communication Plan
- D2.2 Strategy for user engagement
- D2.3 Minutes from meetings
- D2.4 Webinar guidance
- D2.5 Project website
- D2.6 Exploitation plan

Milestone 3
- D2.3.2 Minutes from meetings
- D2.7.1 Newsletter

Milestone 4
- D2.3.3 Minutes from meetings
- D3.2.1 20 kW lab scale oxy-BFBC pre-tests

Milestone 5
- D2.7.2 Newsletter and researcher's blog

Milestone 6
- D5.1.3 Case study and framework for process modelling

Milestone 7
- D1.4.7 Quarterly report
- D2.3.7 Minutes from meetings

Milestone 8
- D1.4.8 Quarterly report
- D2.3.8 Minutes from meeting

Milestone 9

Milestone 10
- D1.4.10 Quarterly report
- D2.7.4 Newsletter

Research

WP3

Oxyfuel and membrane technologies

- Exploiting synergies between Norway's CapeWaste project, Germany's NuCA project and NEWEST-CCUS on oxyfuel technology adaptation
- Assessing membrane capture technologies
- Pilot-scale testing at industrial facilities to consider use with waste-to-energy

WP4

Retrofit solutions with post-combustion capture with solvents

- Tackling challenge of trace metals and combustion aerosols in flue gases
- Addressing data gap on solvent ageing and management options
- Testing proprietary solvent at pilot scale and at industrial facilities, and novel solvents at lab scale

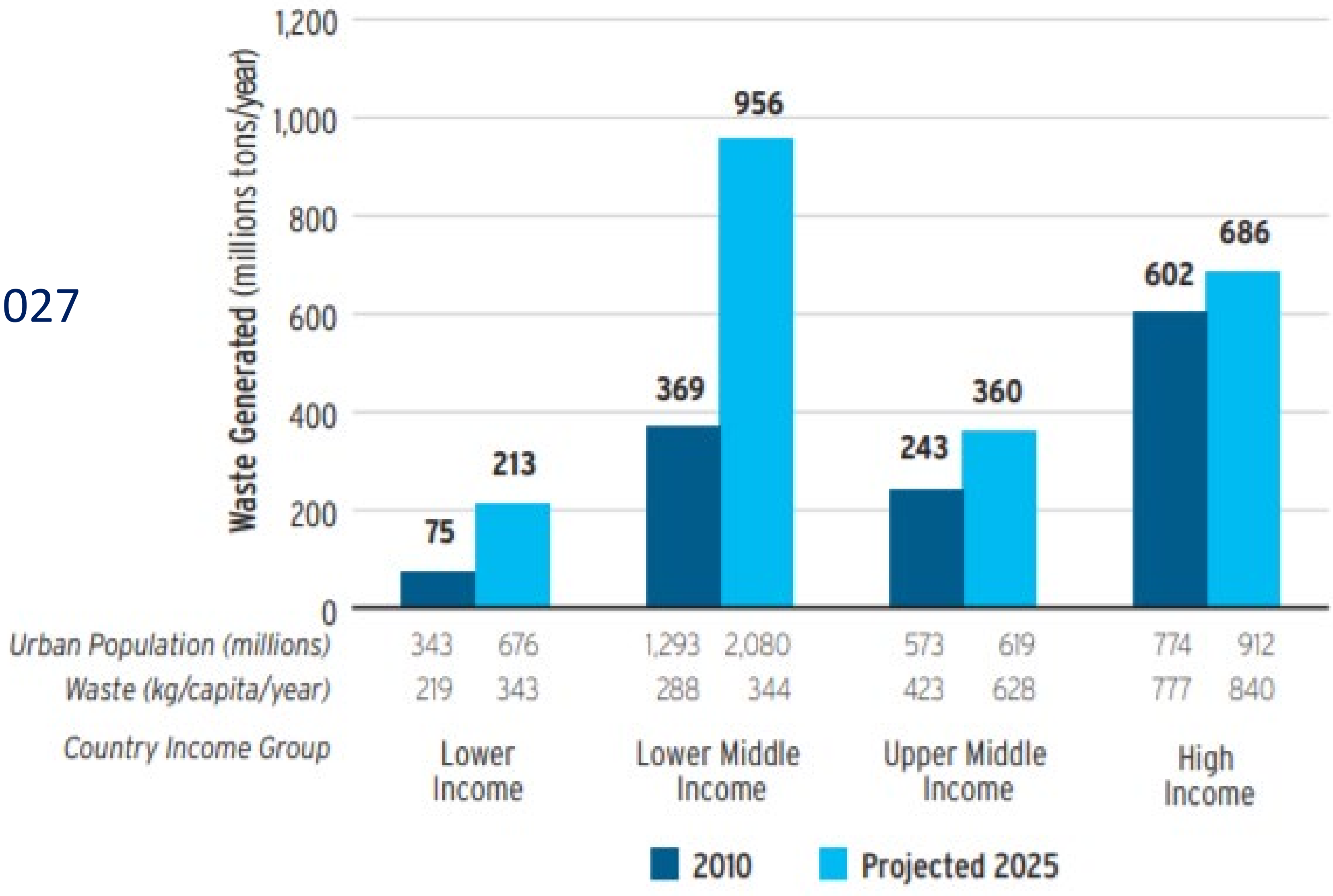
WP5

Comparative technology in waste-to-energy sector

- Building a framework for a comparative technology assessment using results from WP3 and WP4
- Assess the potential for negative emissions and the size of the market for CCUS in the European waste-to-energy sector
- Sharing results with technology developers and local regulators

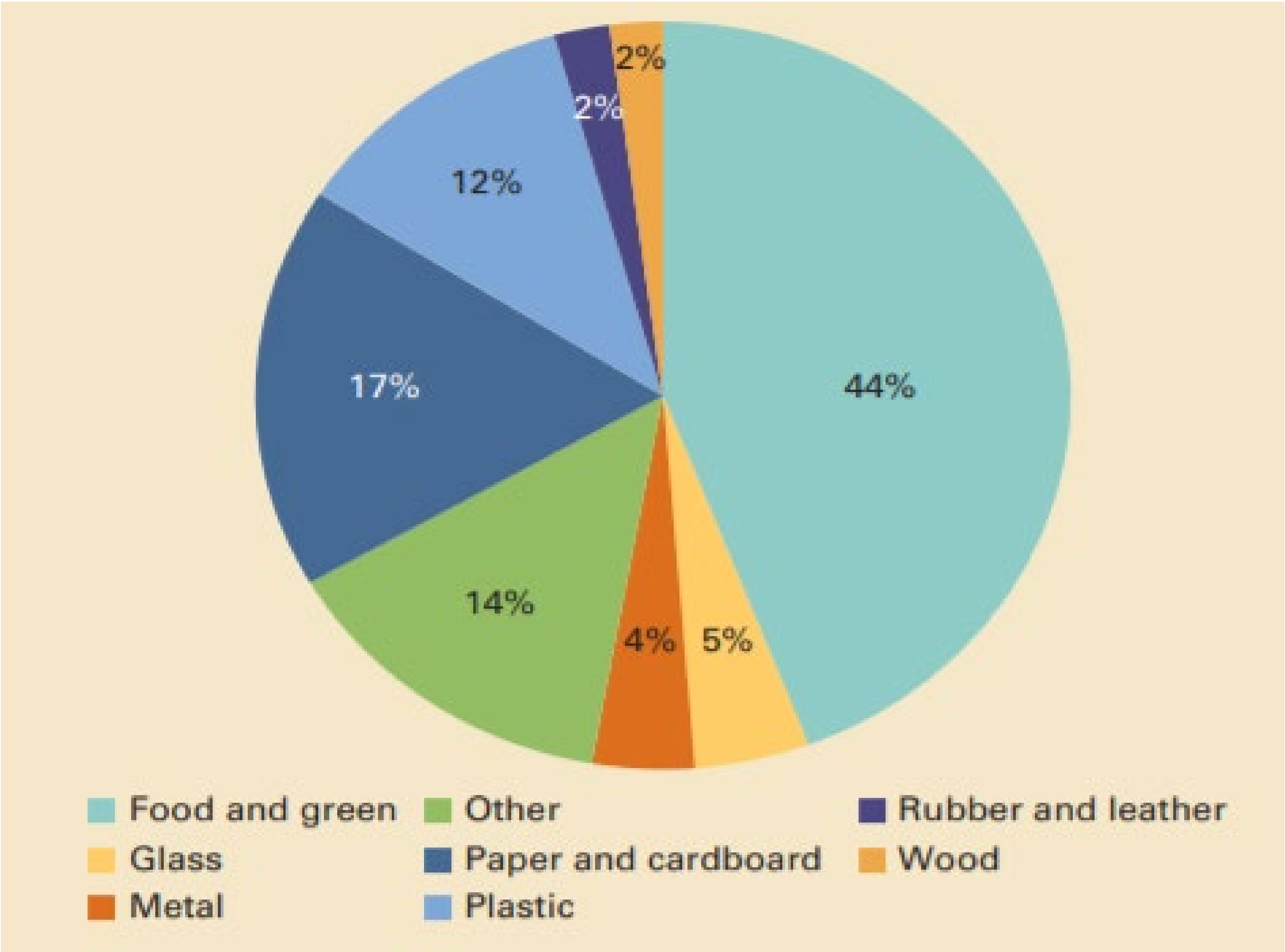
THE WASTE RESOURCE IS EXPECTED TO GROW GLOBALLY

2,700 Waste to Energy plants expected to be operational by 2027
530 million tonnes capacity
(Ecoprog, 2018)



Urban Waste Generation by Income Level and Year, *Hoornweg et al., 2012*

OVER HALF OF GLOBAL WASTE IS BIOGENIC CARBON



Global Waste composition
(Kaza et al. 2012)

Net Climate Benefit of WtE with CCS - zero direct CO_2 emissions

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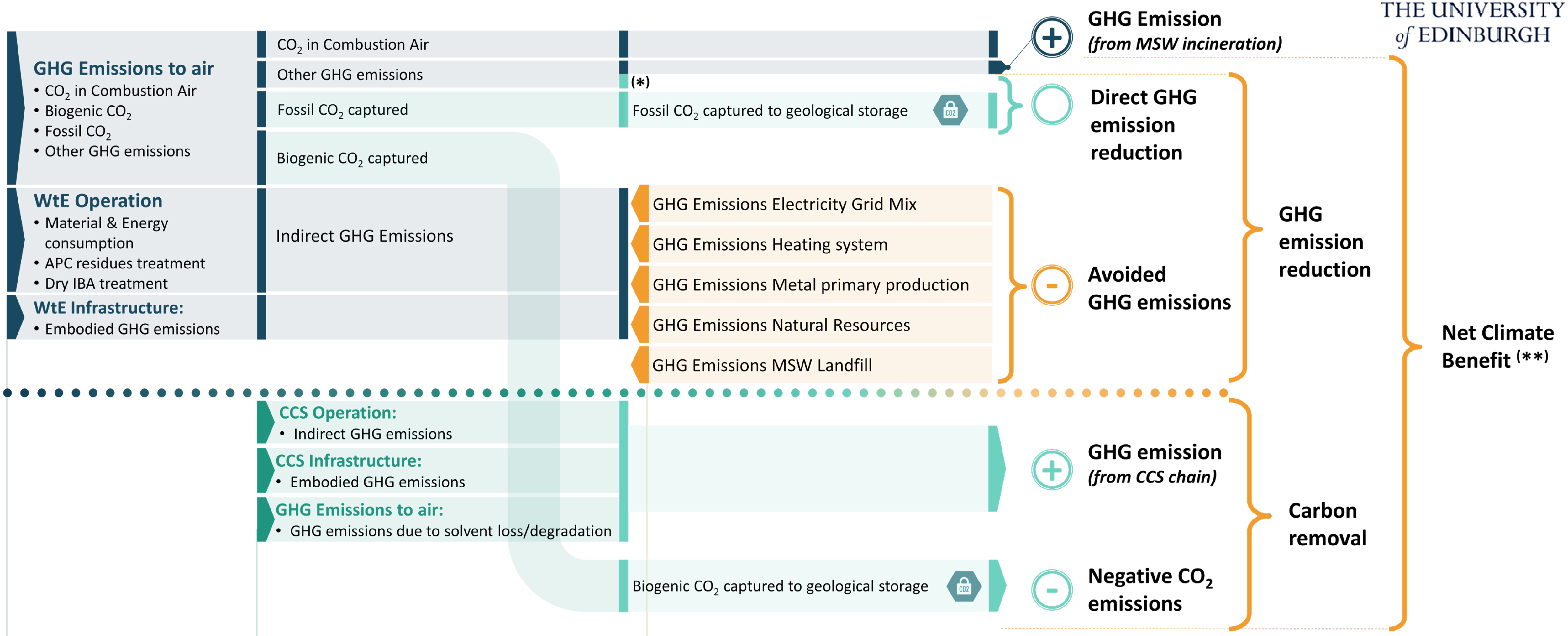
Zero direct Emissions: No residual CO_2 emissions other than CO_2 from combustion air. All fuel CO_2 is captured.



WtE Facility

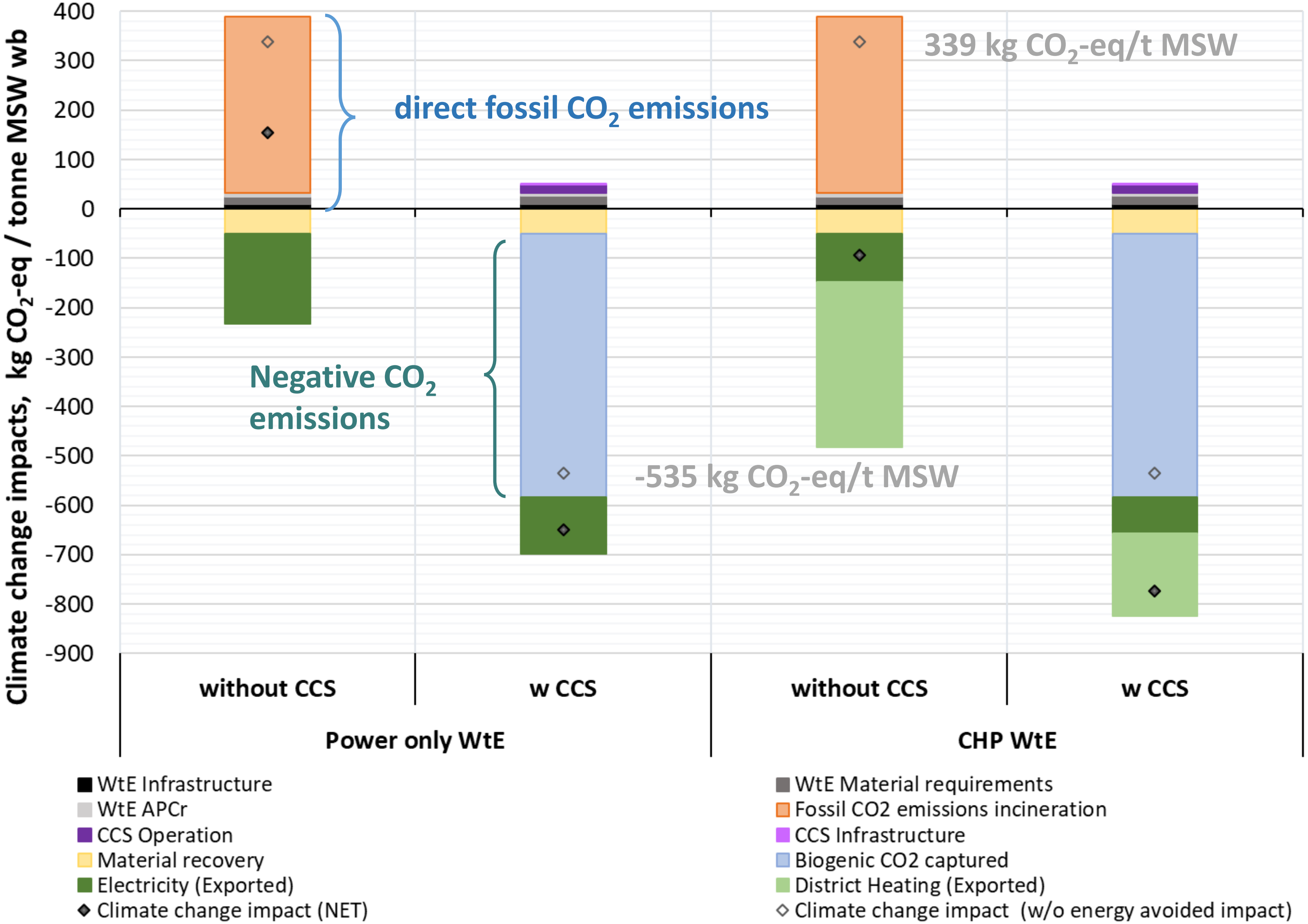
CCS

Avoided GHG emissions:
- Energy Recovery
- Material recovery
- Avoided MSW to landfill

(+) *Positive flow – negative contribution to net climate change*
(-) *Negative flow – positive contribution to net climate change*
(○) *Zero flow – No contribution to net climate change*

(*) CCS contributes to emission reduction of other pollutant such as SO_2, NOx, HCl and HF
(**) Unit of metric: metric ton carbon dioxide equivalent (tCO_2-eq) in a specific period of time or per metric tonne of MSW treated
IBA: Incineration bottom ash | APC: air pollution control residues
Note: Schematic representation, flow diagram not to scale

Net Climate Benefit of WtE w CCS - zero direct CO_2 emissions – UK plant



- CCS reduces the climate change impact of a WtE plant from

  339 kg CO_2-eq/t MSW to

  -535 kg CO_2-eq/t MSW

  (w/o included avoided GHG emissions from energy export)

- The **net climate benefit** account for

650 kg CO_2-eq/t MSW in a power-only WtE CCS plant

774 kg CO_2-eq/t MSW in a CHP WtE CCS plant,

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Oxy-fuel combustion of Solid Refuse Fuel at IFK's 200 kW Circulating Fluidised Bed facility

University of Stuttgart Germany

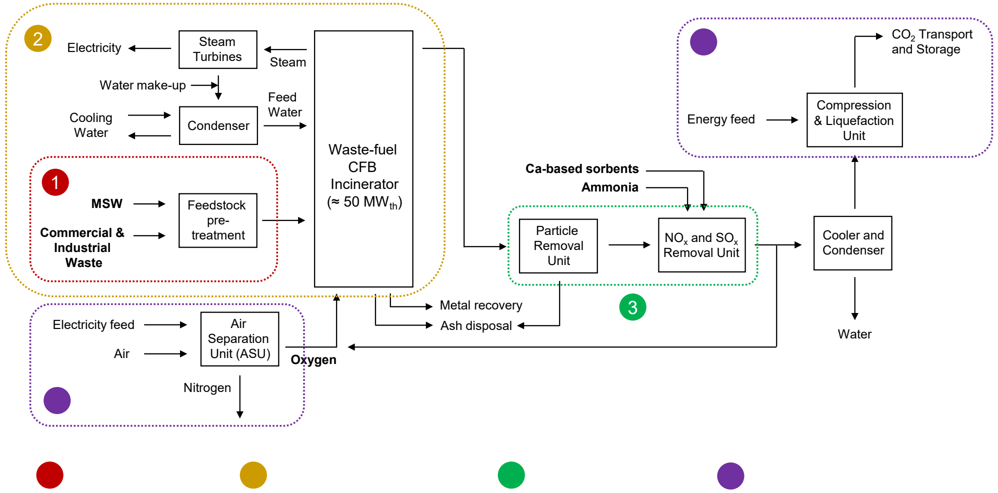
ifk

Task description	Research scope/conditions	Main results
Lab scale bubbling fluidized bed (BFB) combustion of SRF	• Cold dosign experiments (4 SRFs) • Combustion experiments (2 SRFs) ○ Air combustion (800/850/900 °C) ○ Oxy-fuel (OXY 21/30/40 @ 850 °C)	• Cold dosing of shredded SRF (< 650 kg/m^3) difficult to achieve • Pelletized SRF successfully combusted in air and oxy-conditions • Good correlation between experiments and calculated data
Demonstration of oxy-CFBC at the 200 kW pilot facility	• Air combustion tests • Oxy-fuel combustion tests (OXY 28/35/40/45) @ 850<T<920 °C • Gaseous emissions • Hydrodnymic performance	• Standalone oxy-CFBC of SRF for more than 8h at OXY45 demonstrated • Oxygen-to-fuel ratios of 1.4 required to supress CO formation • At oxy-fuel conditions: ○ NO_x emissions decrease (by ca. 33%) ○ HCl is promoted (by ca. 500%)
Investigation of corrosive depositions at the 200 kW pilot facility	• Air combustion (10 h 30 min) • Oxy-fuel combustion (ca. 1 h) • Air-cooled deposition probe ○ T_{probe} ~ 480 °C ○ $T_{fluegas}$ ~ 750 °C • Sample material: X20CrMoV11-1	• Corrosion phenomena clearly identified in air oxy-firing modes ○ Air combustion: corrosion attacks due to alkali salt deposits ○ OXY28: corrosion attack due to HCl. Damage occurs in a very short time

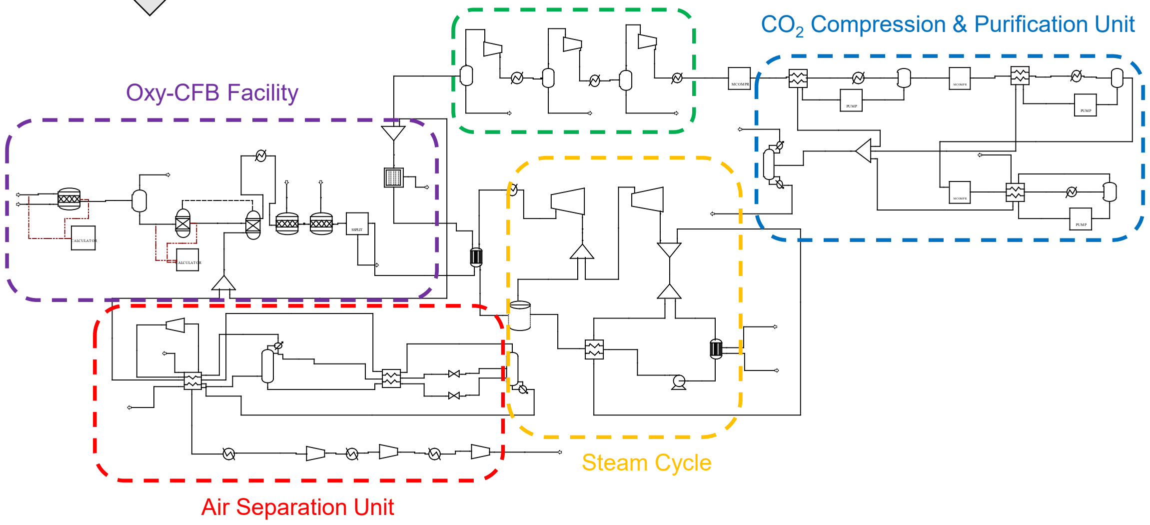
Process simulation of oxy-fuel CFBC of SRF

University of Stuttgart
Germany

Full-scale oxy-CFBC WtE model (133 kton CO2/year) by Aspen Plus®



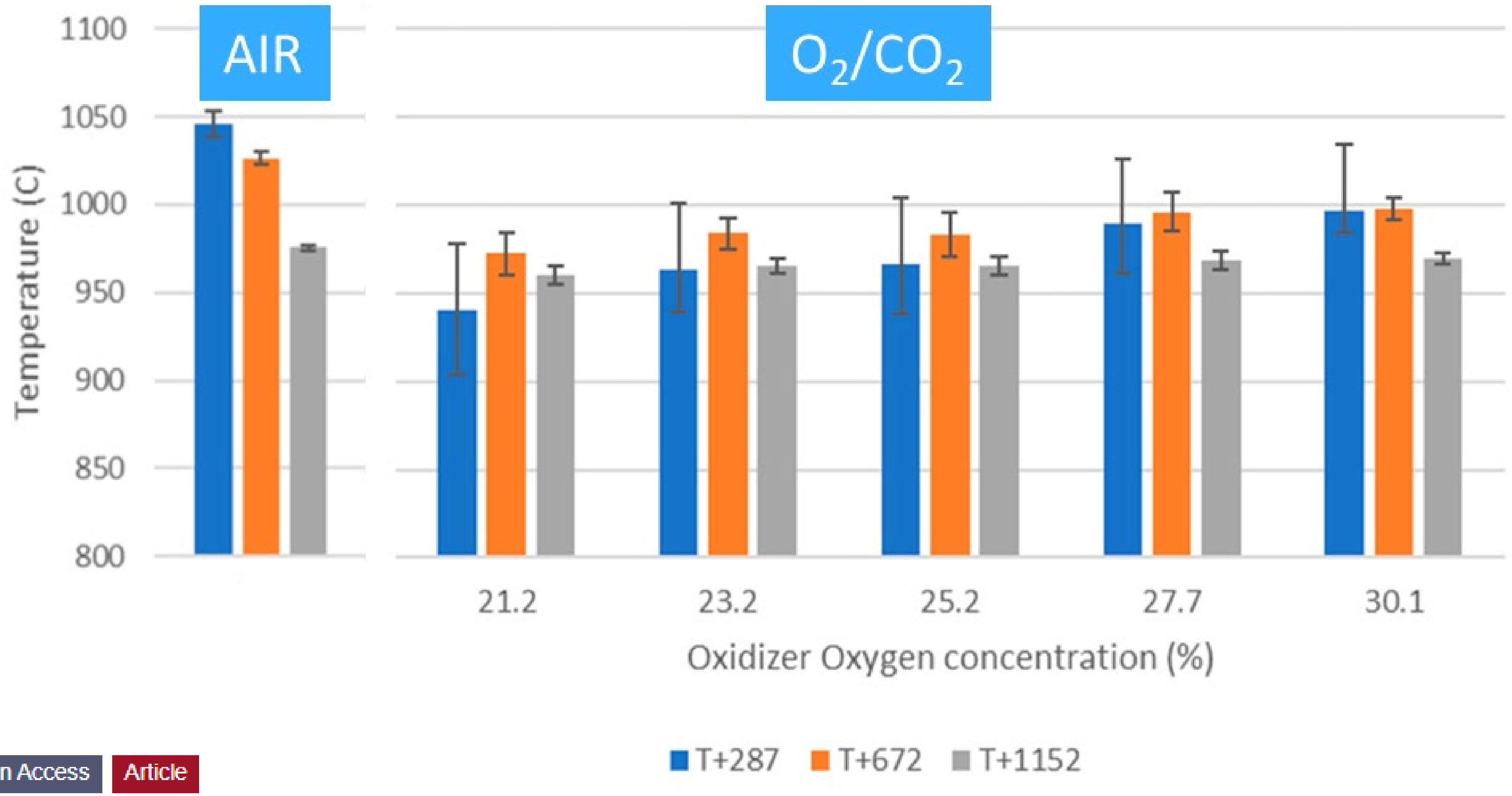
* *Fuel combustion reaches chemical equilibria*
* *Side reactions with fuel-ash are neglected*

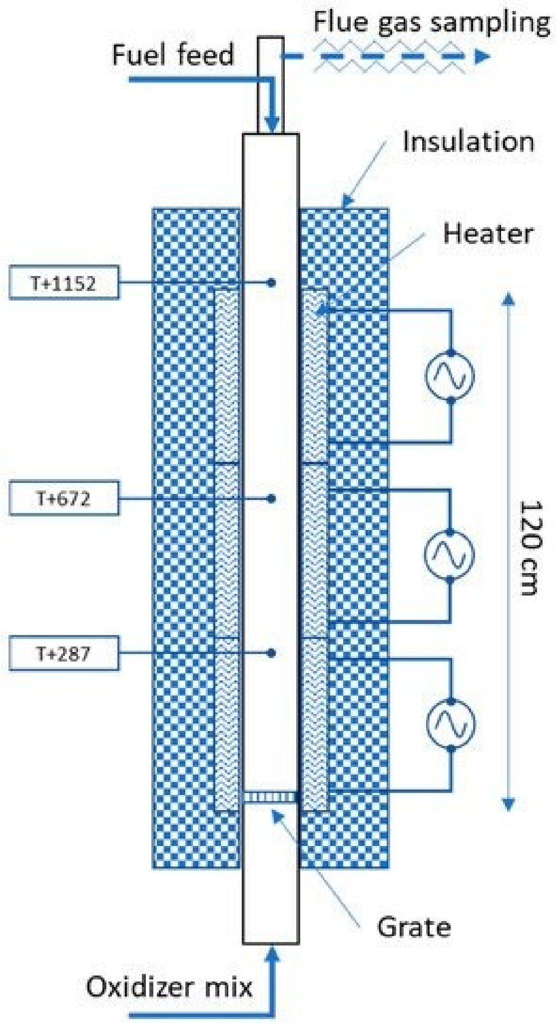


- Satisfactory validation of a full-scale oxy-CFB combustion model with pilot plant data (200 kW)
- Almost all fuel-S converted to SO_2. NO_x concentrations depend on fuel-N as well as catalytic activity between bed material and fuel ash
- Linear behavior of $y_{O_2,in}$ with $v_{recycled}$. Increase of excess oxygen poses dilutes flue gas composition moderately
- NO_x and SO_2 can be reduced by 99% with 0.6 kmol/h of NH_3 and CaO, respectively

Oxy-fuel grate furnace technology

Fundamental oxy-fuel combustion of MSW





Open Access Article

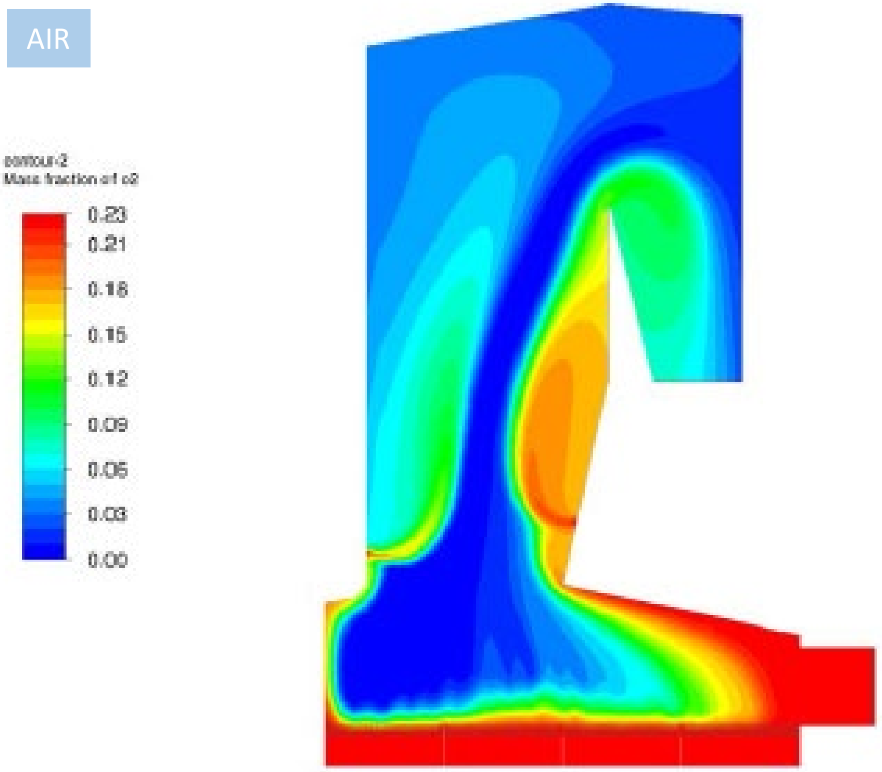
Oxyfuel Combustion of a Model MSW—An Experimental Study

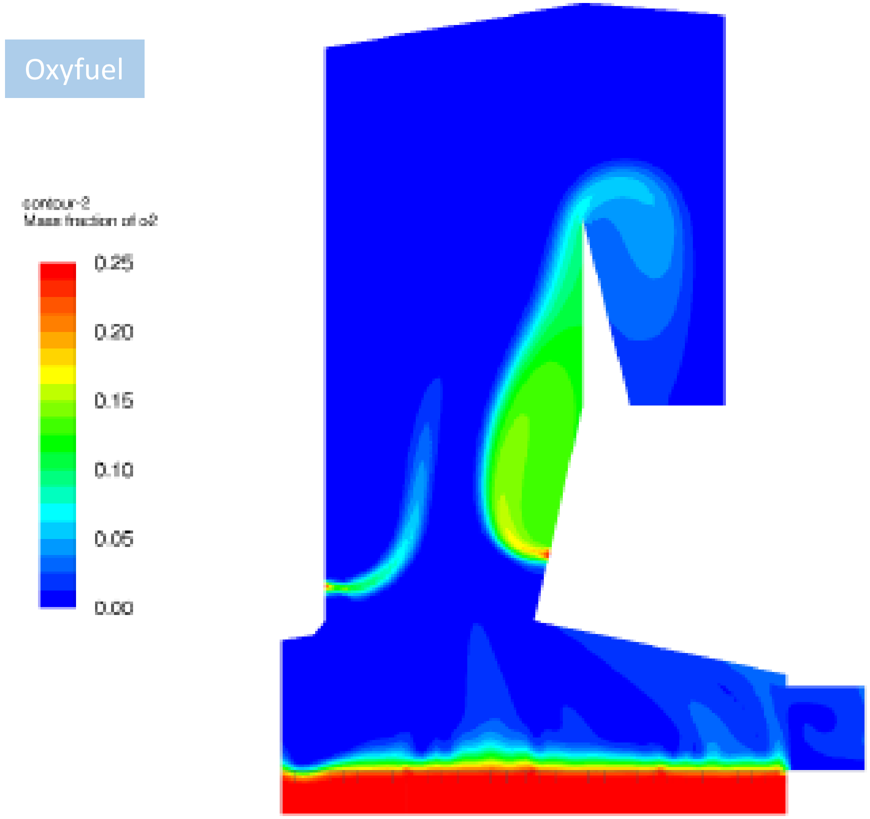
by Michaël Becidan [1,*], Mario Ditaranto [1], Per Carlsson [1], Jørn Bakken [1], Maria N. P. Olsen [1] and Johnny Stuen [2]

Oxy-fuel grate furnace technology

Full scale plant simulation by CFD

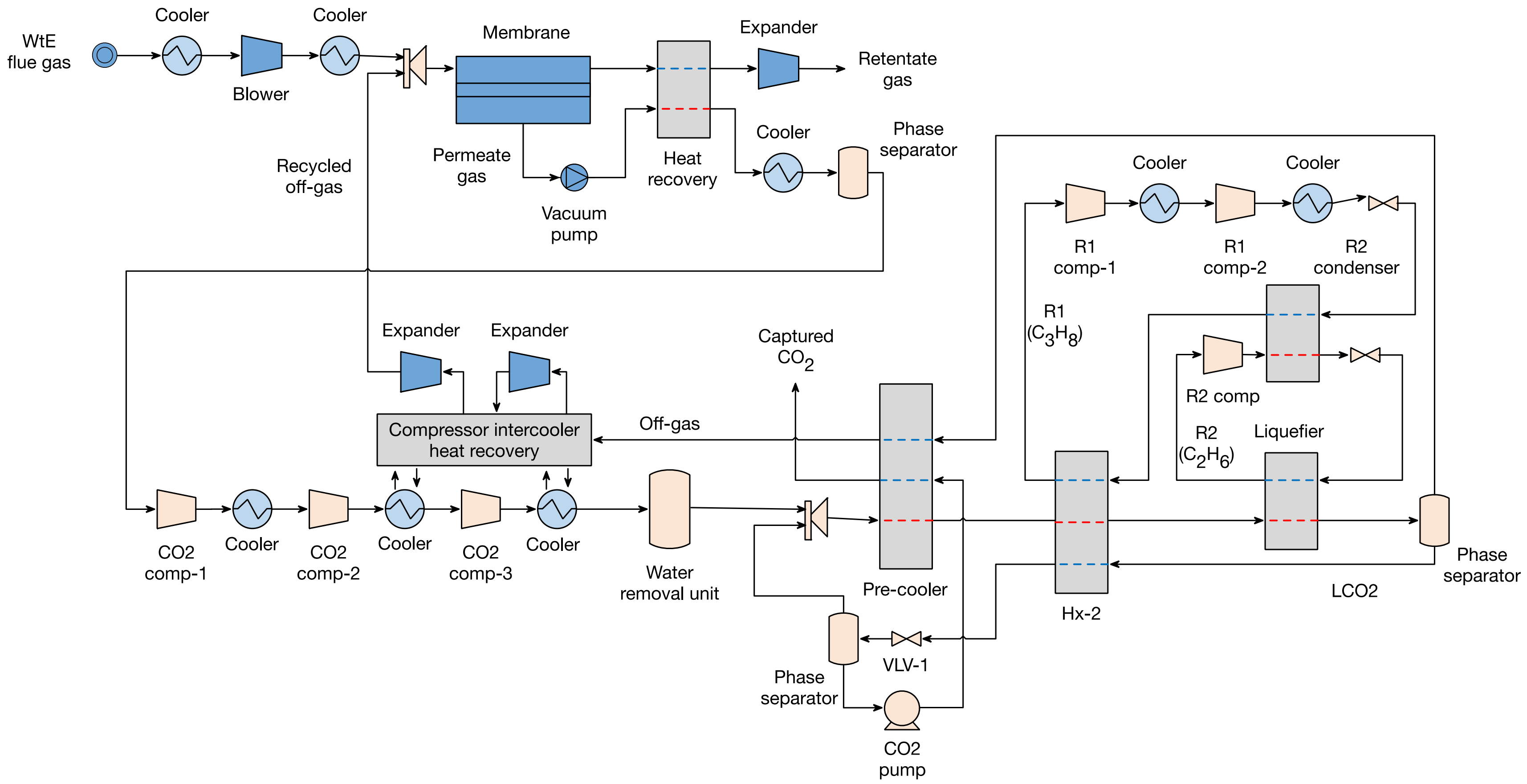
- Implementation of newly developed fuel bed model combustion
- Effects of oxidizer distribution on conversion and burn-out of the bed
- Comparison with the reference air case





Post and hybrid separation by CO2 membrane applied to Waste-to-Energy

- Membrane assisted liquefaction process modelled
- Systematic process design approach was used where designs with multiple stages and different recycle strategies were employed.
- Results indicate that simple cascade process is optimal.
- Capture rates higher than 90% increase capture penalty significantly



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Demonstration at WtE facility

Operation with new solvent
Carbon Clean commercial solvent (2 months operation)
Liquifying CO_2

Support Full Scale implementation - TNO
Online support (liquid and gas analysis)
Gas: FTIR (composition), ELPI (aerosols)
Liquid: Mini-ATR, analysis of samples

Derisking, modelling

Propose a solvent management strategy

Demonstration on-going!


Twence (Hengelo, NL)

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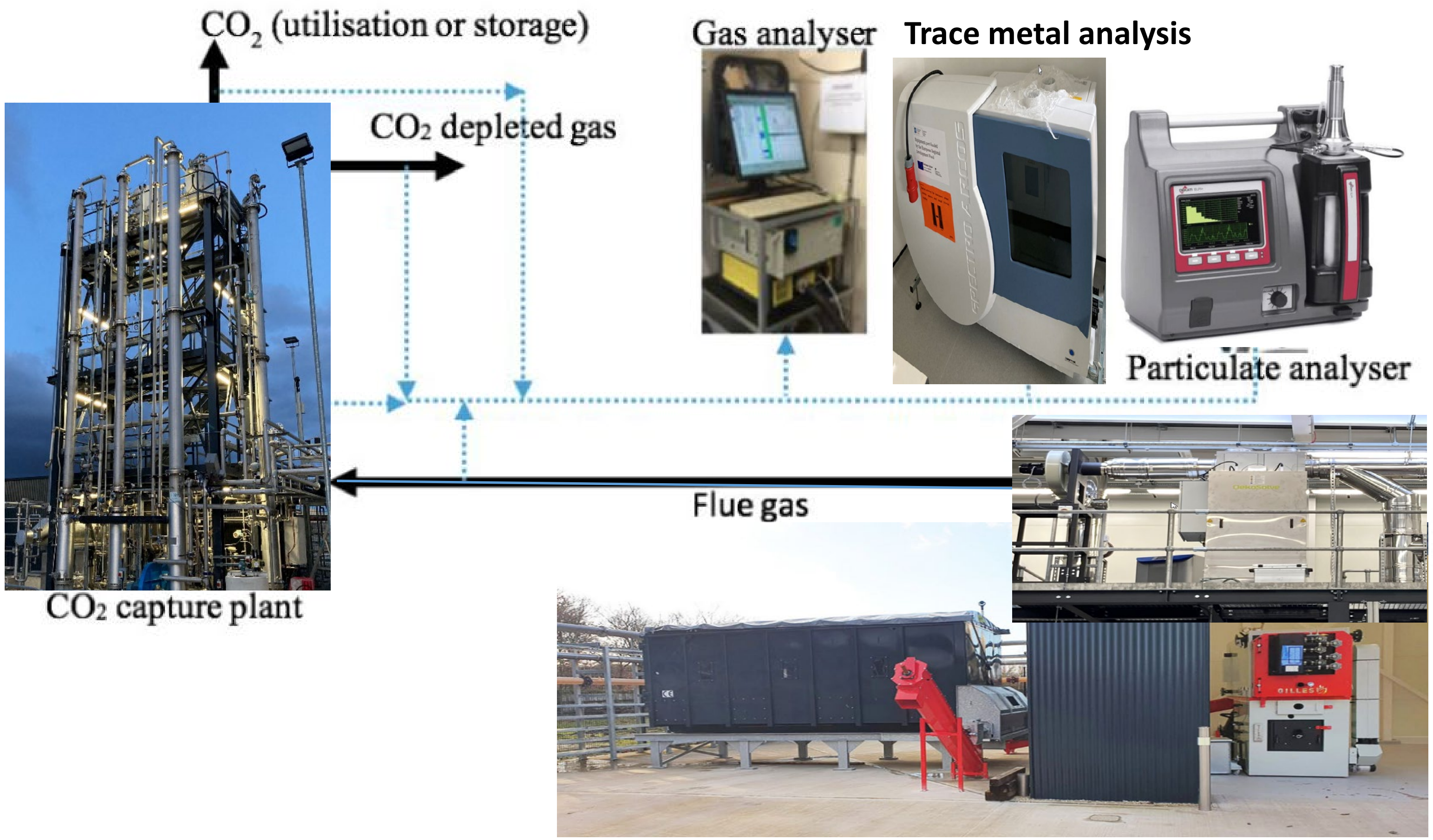
TECHNOLOGY TO ACHIEVE 'NET ZERO'

- Understand the effect of trace metals and combustion aerosols on CO_2 capture solvents
- Integrating waste combustor to post-combustion CO_2 capture at pilot-scale
- Measure release profiles of trace metals as entrained aerosols
- Measure particle size distribution and particle concentration from combustion, specifically sub-micron particles (PM1)
- Quantify impacts of fuel on (i) a generic amine solvent, and (ii) a proprietary solvent
  - 35%wt MEA
  - proprietary solvent: Carbon Clean
  - Two different Grade A waste wood
  - Tests planned for Jul-Aug 2022



Process & Analytical measurements:

Solvent analysis:

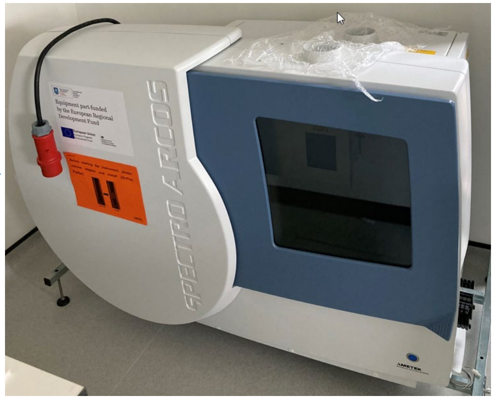
Mettler Toledo auto titrator
- Fast loop sampling
- MEA solvent concentration
- CO_2 concentration and loading

Jumo online oxygen analysis (continuous online analysis)
- Lean (desorber outlet)
- Semi-rich (absorber 2 outlet)
- Rich (absorber 1 outlet)

Fe analysis:
HACH Colorimeter (manual sampling and analysis)

Gas analysis

DEKATI ELPI+(Electrical Low Pressure Impactor):
- Real-time measurement of particle size distribution and concentration at 10 Hz sampling rate
- Measuring range 6nm to 10µm



Inductively Coupled Plasma – Optical Emissions Spectrometer (ICP-OES):
- Can identify the emissions spectra of various non-volatile metals and major, minor, trace and ultra-trace volatile elements
- Elements that may cause operational issues, toxic, easily vaporised, high concentrations

Multipoint analysis by Gasmet FTIR:
- Absorber 1 inlet and outlet
- Absorber 2 outlet,
- Water wash outlet;
- Desorber outlet (CO_2 product)

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Maximum Potential carbon removal from the European waste sector

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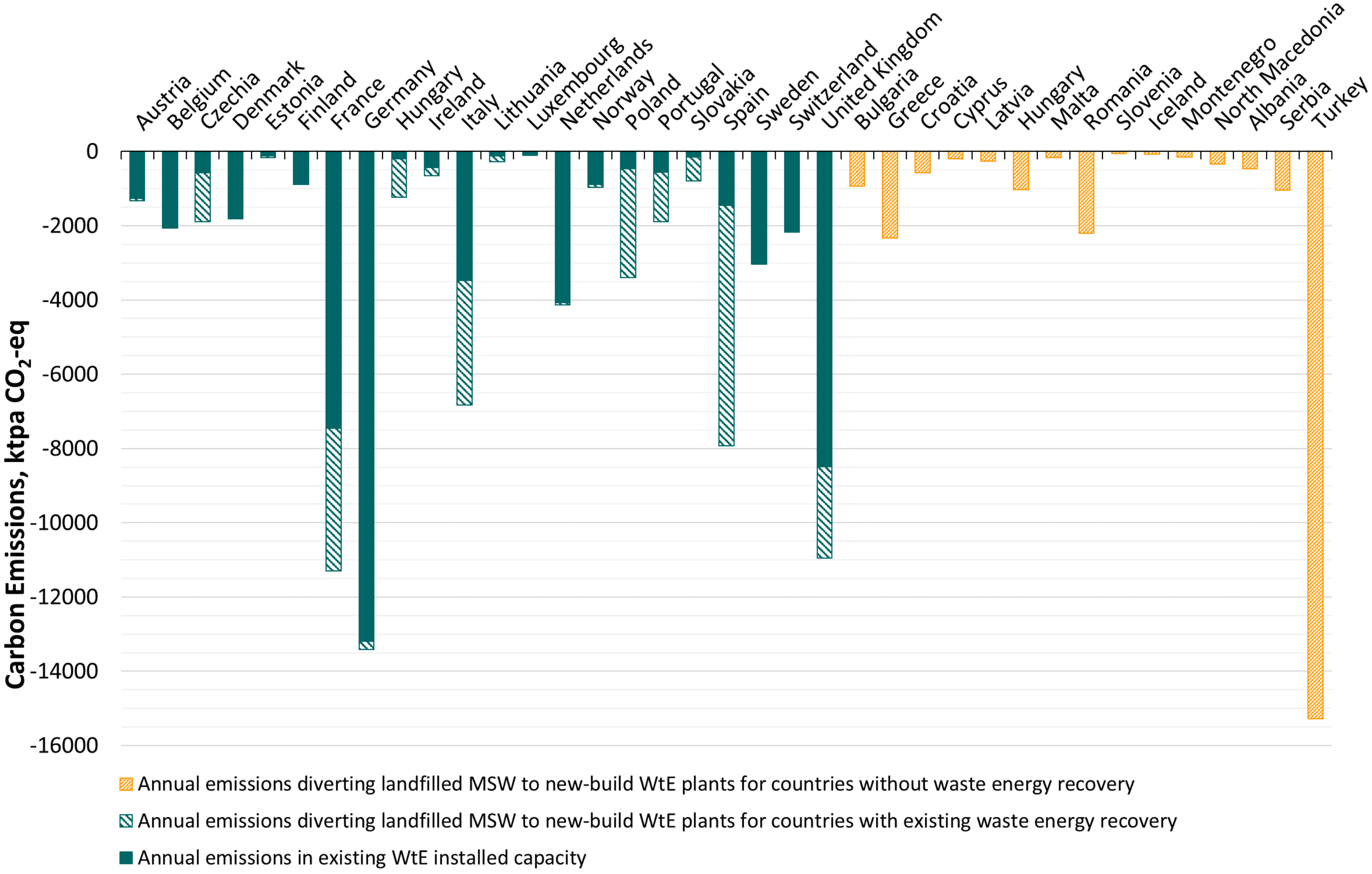
- If all existing WtE plants in Europe (492 facilities treating 99 Mtpa of MSW) are retrofitted with CCS can achieve a carbon removal of the order of **52 Mtpa CO_2-eq**(*)
- An additional **removal of 49.43 Mtpa of CO_2-eq** (*) is possible if all waste currently landfilled is used in WtE CCS facilities.
- This does not include the avoided GHG emissions of diverting waste from landfilling

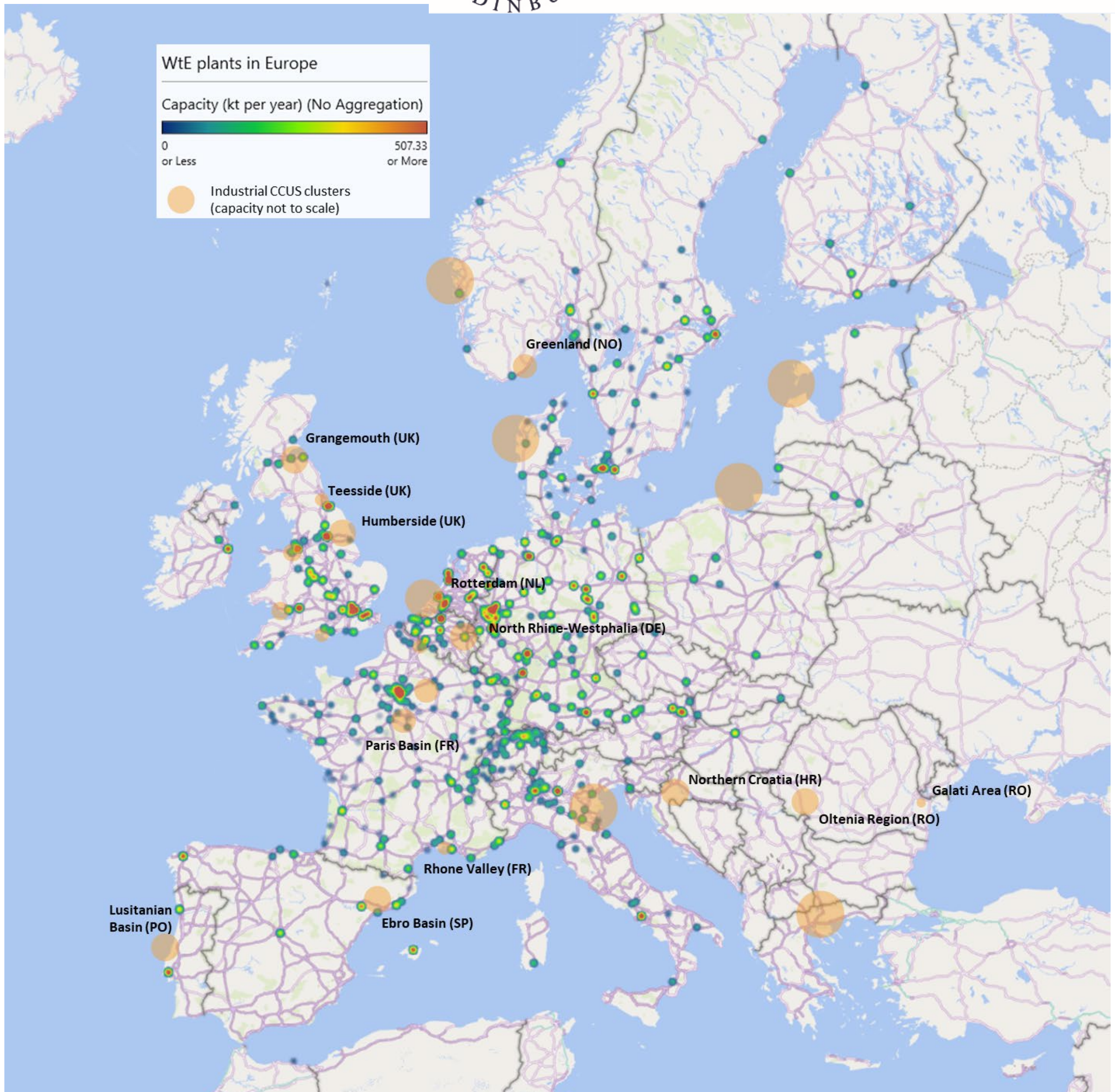
(*) Considering a net climate change benefit of -535 kg CO_2-eq/t MSW and 60% biogenic carbon ratio. Without avoided emissions for energy recovery.



Assessing Negative emissions in the European waste sector

Ongoing activity, using the following methodology

- Mapping existing WtE facilities
- Mapping CCS Clusters, CO_2 export terminals, geological CO_2 storage site
- Review space requirements at plant level vs CO_2 capacity
- Build waste resource scenarios : energy recovery vs landfill, recycling & C^{14} % of waste composition vs income
- Build waste management policy scenarios

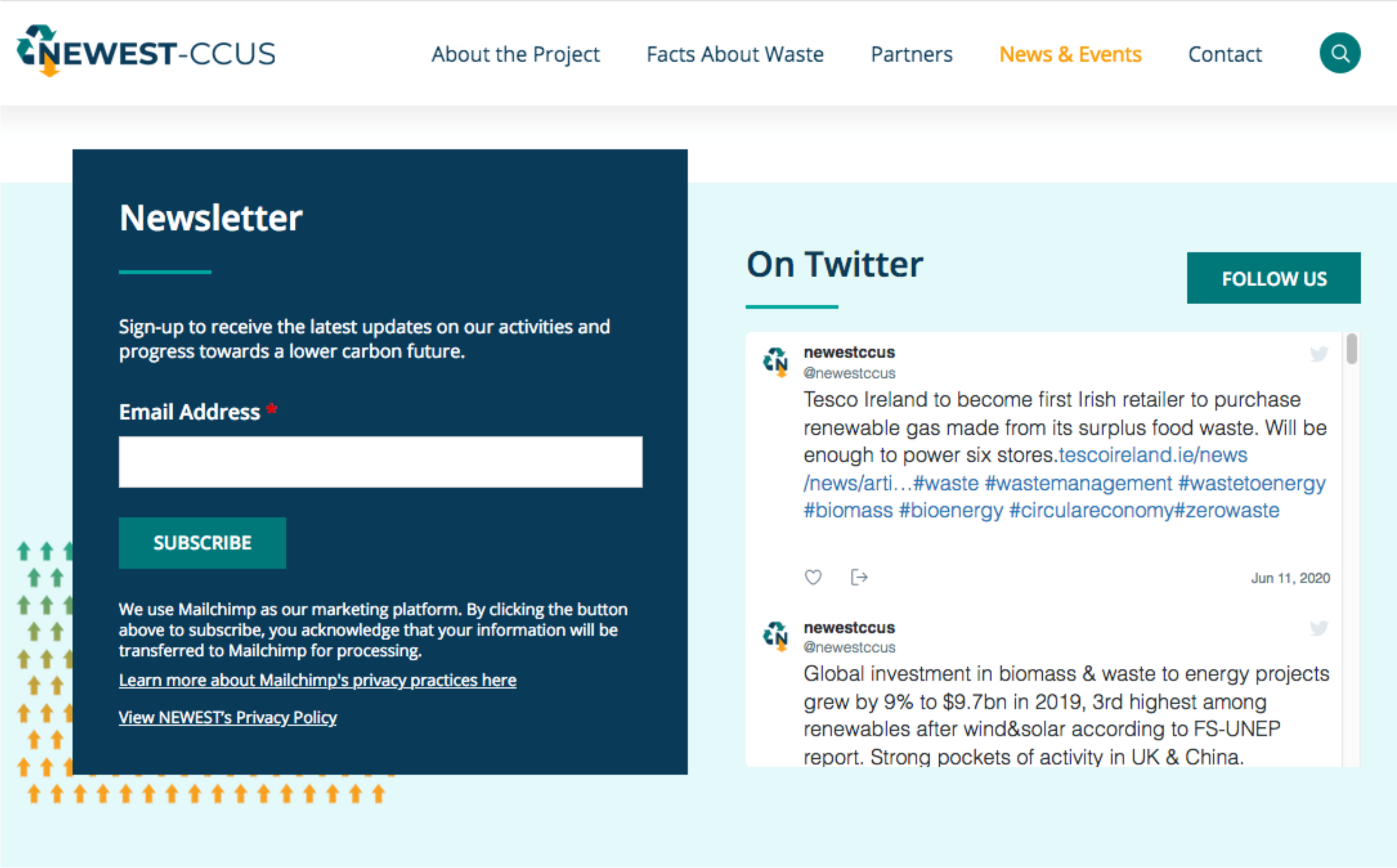


The case for Waste to Energy with CCUS

- The value to society of waste in a net-zero society may be its biogenic content
- Negative emission from biogenic waste could become a strategic resource.
- Unlike ‘conventional’ BECCS, without impacts on food security or land availability.

Moving WtE with CCS forward in the 2020s

- Derisk technologies for challenging fuels -> long term testing
- Use CCS to achieve zero residual CO_2 emissions -> 100% capture
- Value ‘embedded’ negative emissions at local and national level
  - -> Improve reporting of biogenic emissions from waste
  - -> Business models for negative emissions
- Understand public acceptance: WtE ≠ CCS ≠ WtE&CCS ≠ WtE&CCU



Please register to the newsletter

Invite your colleagues and contacts

Follow the project:

Twitter: @newestccus

LinkedIn:
https://www.linkedin.com/company/newest-ccus

Acknowledgements

NEWEST-CCUS project (Project No. 299683) is funded through the ACT programme (Accelerating CCS Technologies) with financial contributions from: The Research Council of Norway (RCN), Norway; The Federal Ministry for Economic Affairs and Energy (BMWi), Germany; Netherlands Enterprise Agency (RVO), Netherlands; and the UK Department for Business, Energy & Industrial Strategy (BEIS)

Department for Business, Energy & Industrial Strategy

The Research Council of Norway

Bundesministerium für Wirtschaft und Energie

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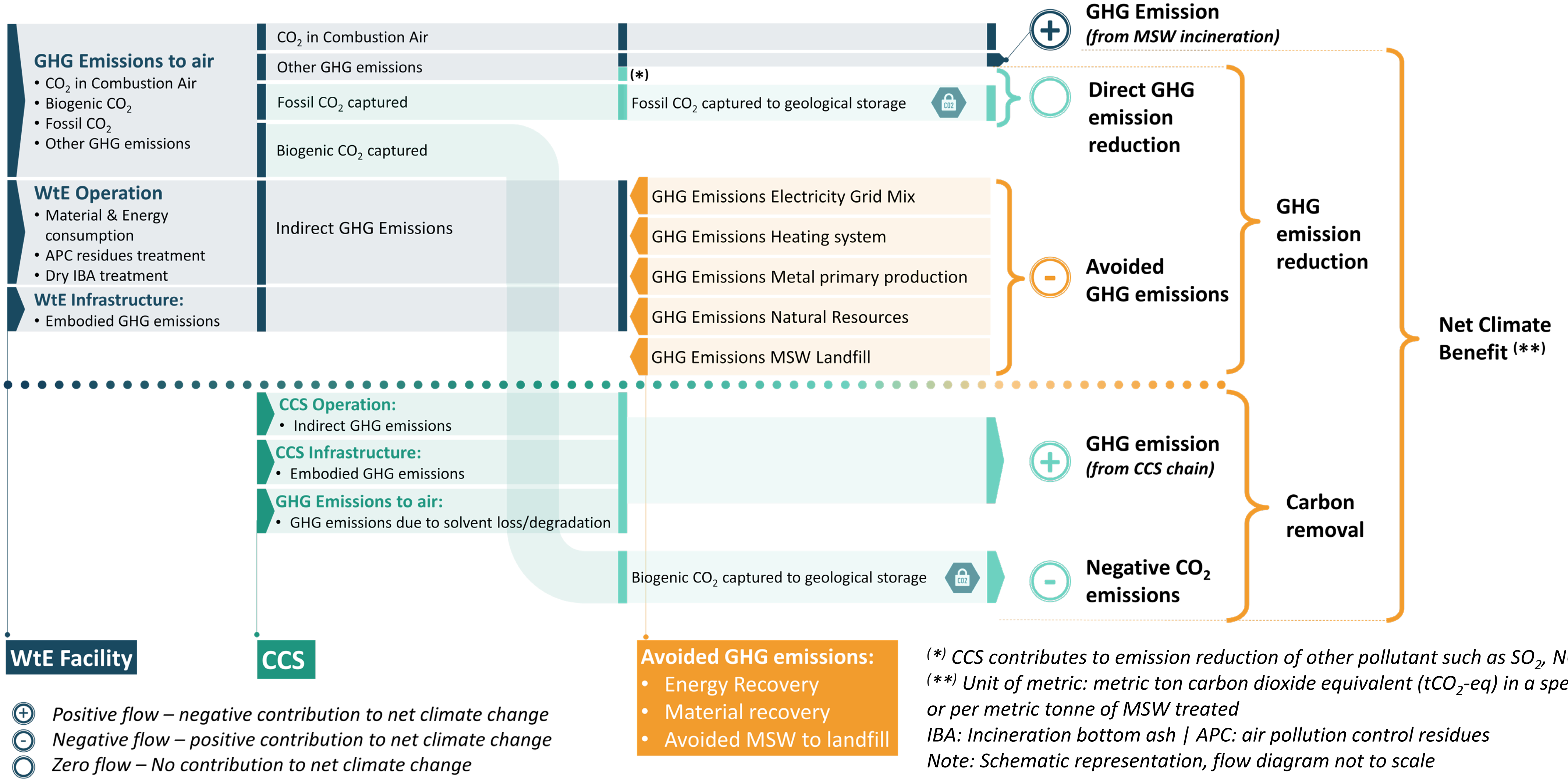
Net Climate Benefit of WtE with zero direct CO_2 emissions

Zero direct Emissions: No residual CO_2 emissions other than CO_2 from combustion air. All fuel CO_2 is captured.



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