NEWEST-CCUS Final Report

Professor Mathieu Lucquiaud, Principal Investigator, University of Edinburgh [to 03/2022] and University of Sheffield [from 04/2022]

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ACT2 NEWEST-CCUS project No 299683

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1. Identification of the project and report

Project title	ACT2 NEWEST-CCUS
Project ID	No 299683
Coordinator	The University of Edinburgh
Project website	https://www.newestccus.eu/
Reporting period	1st September 2019 to 28th February 2023

Participants

Organisation	Main contact(s) + E-mail	Role in the project
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University of Sheffield	Mathieu Lucquiaud - m.lucquiaud@sheffield.ac.uk Mohamed Pourkashanian - m.pourkashanian@sheffield.ac.uk	Project principal investigator; WP1 leader, WP2 and WP5 co-leader WP4 co-leader, contributor to WP1, WP2 and WP5
Sintef ER	Mario Ditaranto - Mario.Ditaranto@sintef.no	WP3 leader, contributor to WP1, WP2 and WP5
TNO	Peter van Os – Peter.vanos@tno.ul	WP4 leader, contributor to WP1, WP2 and WP5
University of Stuttgart	Joerg Maier - joerg.maier@ifk.uni-stuttgart.de	WP3 co-leader, contributor to WP1, WP2 and WP5
Carbon Clean	James Hall - james.hall@carbonclean.com	Contributor to WP2, WP4

2. Executive summary

NEWEST-CCUS project has extended the reach of climate action, by supporting the development of carbon capture utilisation and storage (CCUS) technologies for the waste-to-energy sector.
The effect of climate change and the increasing amount of waste produced are two challenges facing every country in the world. The project aims at de-risking, demonstrating and developing CO_2 capture technologies tailored for waste-to-energy plants worldwide.
This project harnessed European expertise and innovation to establish CCUS for Waste to Energy (WtE) as a substantial contributor to global climate action, and expand the range of fuel sources that are ready for use in combination with CCUS to create high-quality jobs while responding to the climate emergency.

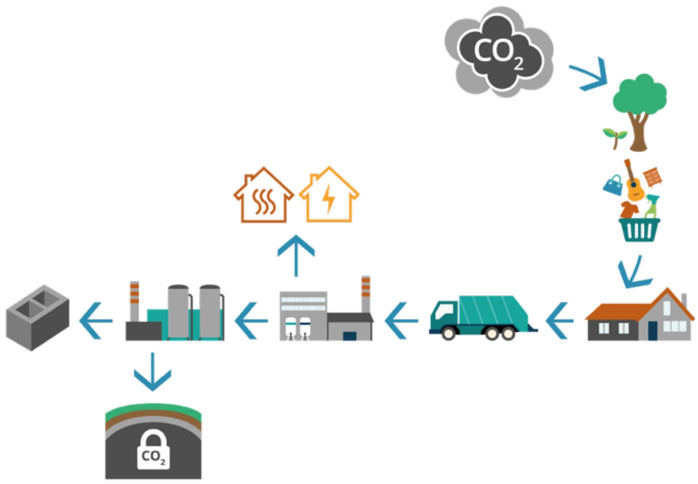

Figure1 . Carbon Capture Utilisation and Storage applied to the waste to energy sector will lead to negative emission

Innovation on the project focused on progressing the Technology Readiness Levels (TRLs) of technologies for Waste to Energy (WtE) sites through a combination of pilot-scale testing and modelling, including:

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- Oxy-firing technologies, focusing on developing circulating fluidised bed technology with the potential for higher efficiency with solid recovered fuels
- Membrane-based CO_2 separation, considering its application as a hybrid method using partial flue gas recirculation and oxygen enrichment
- Solvent-based post-combustion capture and, in particular, knowledge and technologies addressing the need to handle a more diverse range of combustion impurities in challenging fuel flue gases associated with typical WtE plants

The project reached the following seven targets.

1. Successful build-up, operation and tests of oxyfuel combustion concept at pilot scale combustor systems like grate/fluidised bed up to 200 kW – TRL 6 (in tasks 3.1 3.2)

The project Established the full overview of technical possibilities and limitations of oxy-fuel combustion capture applied to European waste-to-energy sector

2. Peer-reviewed publication on fundamental kinetic data in oxy-fuel atmospheres (in task 3.1)

The project bridged the gap of fundamental knowledge on oxy-combustion of waste and supply data for process modelling

3. Successful demonstration at pilot scale up to 200 kW – TRL 6 (in task 3.2)

Demonstrate and optimize oxy-fuel circulating fluidized bed combustion of SRF

4. TRL3 for the hybrid concept and quantitative benefit of the concept in terms of efficiency (in task 3.3)

Potential of CO_2 membrane based post-combustion capture and its combination in a hybrid concept with O_2 enrichment fully assessed in a WtE environment

5. Testing with Carbon Clean proprietary solvent, APBS-CDRMax®, with real flue gas generated by grade A waste wood at TERC facility – TRL 7 (in task 4.1)
6. Prove successful operation of a proprietary solvent solution from Carbon Clean Solutions Limited for WtE application (TRL7 at PACT, TRL8 at Twence) (task 4.2)

The project gained data on operational issues of solvent-based post-combustion CO_2 capture processes when operating with waste-derived flue gases.

7. Develop accessible evidence base on relative economic potential and environmental performance of different relevant technologies (in task 5.1 - 5.5)

The project established a common basis for CO_2 capture technology comparison for WtE applications
One target could not be met (Further development of a 3rd generation solvent solution solvent tailored to WtE flue gas by demonstrating STAR at TNO's lab facility plant – TRL 5, in task 4.3) because the solvent did not perform as expected.

3. Role and contributions of each project partners

Scottish Carbon Capture Storage (SCCS) at the University of Edinburgh coordinated / managed the project and dissemination activities and lead WP5 [Comparative technology and market assessments of CO_2 capture in the WtE sector]. NEWEST-CCUS's team from the University of Edinburg collected key performance data from the test campaigns at the Twence facility, developed the models and conducted process model simulations, techno-economic assessment to the investigated configuration and life cycle assessment of the relevant scenarios.

The University of Edinburgh (UEDIN) lead WP5 for which key performance data were collected from the test campaigns, UEDIN developed models and conducted process model simulations, techno-economic assessment to the investigated configuration and life cycle assessment of the relevant scenarios. Process modelling tools were developed by UEDIN and USTUTT. Results from process simulations were compared with experimental data from the test campaigns at Twente, SER, USTUTT and TERC pilot plants in WP3 and WP4, in order to mitigate the risks associated to the development and deployment of relevant WtE CCUS technologies at large scale. Process modelling and test campaigns provided the key performance parameters to conduct a techno-economic assessment and life cycle environmental impact assessment of the relevant scenarios.

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TNO: TNO lead WP4 and performed technical work in tasks 4.2 and 4.3. In task 4.2, TNO monitored the solvent's operational performance during the demonstration campaign at Twence. TNO used operational data of the CC solvent to benchmark against MEA.

The University of Sheffield (USHEFF): Run comprehensive testing at TERC, with CDRMax®, a proprietary capture solvent with WtE flue gas to gain the broadest and most detailed information concerning the comparative performance of the solvents and the impacts the waste and its impurities can have.

Sintef Energy Research (SER): WP3 leader, coordinator of work progress between all partners involved in WP3. SER used a Vertical Fired Reactor facility designed for oxy-fuel combustion mode and expertise in CFD modelling of large-scale furnace. Process evaluation of the hybrid capture concept.

The University of Stuttgart (USTUTT): USTUTT's main role laid within the pilot plant demonstration of the CO_2 capture technology oxy-fuel Circulating Fluidised Bed (CFB) combustion of Solid Recovered Fuel. USTUTT designed a 200 kW fluidized bed pilot facility for process demonstration in industrially relevant conditions (i.e. TRL6) and used within NEWEST-CCUS.

Carbon Clean (CC): The company supplied an inventory of solvent for the pilot scale testing 1 TPD at TERC and an inventory of solvent for the Demonstration of Solvent Performance at an Industrial WtE Facility at Twence. CC also provided expertise gained from test campaigns at the TCM, Norway and NCCC, USA to help design the test campaigns and analyse results and chaired NEWEST-CCUS's Expert Advisory Board.

RETURKRAFT: WtE plant owner in Kristiansand, gave access to the plant for pilot testing if decision is taken (see description) and will provide advisory services.

REG: (ex EGE) operates two sorting plants and one 50 kton/year biological (anaerobic digestion) treatment plant for food waste. Operating one waste-to-energy plant (two lines) and servicing three other lines, in total 400 kton/year for the household waste of Oslo. EGE is strongly involved in the Norwegian CapeWaste project and the Klemestrud project and will bring advisory services based on experience in its work on CO_2 capture assessment.

BIR: BIR Avfallsenergi As, is a part of the BIR group, a waste company owned by nine municipalities including the city of Bergen.

REMONDIS: Supplied SRF fuels to the project

KRV: Contribution of experience as WtE plant owner.

LHOIST: Expert in in-situ desulfurization and sorbent supplier for pilot oxy-CFB tests in WP3.
STEINMUELLER: Power plant engineering company that supports with knowledge on fluidized bed operation, super heater materials, high temperature corrosion.

FCC ENVIRONMENT (member of the EAG) provided real data from WtE plants to the project

TWENCE (member of the EAG) provided information on WtE plant size, flow chart, combustion, flue gas pre-cleaning, and the design of the CO_2 capture unit. This information was used to inform the planning of pilot scale test campaign in WP4, as well as the process assessment in task 5.2.

4. Short description of activities and final results

WP1 – Project Coordination and Management

Task 1.1 Project Implementation Plan

A project implementation plan was produced to manage and control organisational, developmental, and supporting processes, to assure a successful implementation of the project.

The plan contains the goals and objectives of the project, the organisation structure of the project, the responsibilities and roles of the partners, the management procedures and tools, including quality control of project deliverables, identification and mitigation of risk and the communication procedures and tools, including frequency of meetings.

The plan was updated during the project duration, recording Project Milestones, Tasks and Deliverables updates, and quality and risk register.

Deliverable 1.2 - Project Implementation Plan

Task 1.2 Communication Management

Internal communication, between project partners, was assured by quarterly project management meetings, to discuss project progress and any issues and organise external communication activities. Internal communication was facilitated by setting up a sharepoint, to enable collaborative work, and facilitate the exchange of information and data between project partners.

Communication with external stakeholders was achieved by 5 main types of targeted activities.

- **The project organised four industry workshops** with an extensive expert advisory group (30 members), composed of industry representatives (representative of the waste to energy association, waste management companies and plant operator, engineering companies), local authorities, Environmental agencies, Research and technology developers.
- **Twenty eight news articles in five Newsletters accompanied by four technology bulletins** were prepared to inform external stakeholders about the project progress, about key WtE project being developed, about test facilities for CCUS technology development and about policy recommendation.
- **Three public webinars** were organised to present key research outputs from the three technical work-packages. They were organized to enable interaction with a wide audience and included presentations followed by Q & A sessions.
- **One project website and two social media accounts (twitter and LinkedIn)** were used to reach all identified external stakeholders. Our target stakeholders included the wider public. The website keeps all public information in one place, and is structured to inform about CCS in the Waste to Energy sector, and to make public deliverables easy to access.
- **Project partners presented their work in five oral presentations at international conferences and published their work in seven scientific papers,** sharing new knowledge with the scientific and technical expert community.

Task 1.3 Operational Management

The project had a management process in place to monitor resources and expenditures, monitor milestones and deliverables, mitigate risk, manage deliverable deviation and quality; and maintain contractual agreement.

Task 1.4 Project reporting

The project submitted quarterly progress reports to national funders, and quarterly traffic light reports to ACT, a mid-term report and an end of project reports. In addition, the project attended regular meetings, and presented project updates to the national funders.

Deliverables D1.4 - progress reports (1.4.1 to 1.4.14)

Task 1.5 Impact management

An Expert Advisory Group was established to ensure the relevance of the research activity with developments at commercial level and to ensure that the NEWEST-CCUS programme identifies effective pathways for delivering maximum impact in the WtE sector. This approach enabled the project to work in close relationship with waste to energy plan operators, working with real data coming from incineration plants and from waste management companies, working with the European Association CEWEP on policy recommendation to accelerate the adoption of CCUS technologies in the Waste to Energy Sector.

WP2 – Dissemination and Achieving impact

Task 2.1 Communication and Dissemination Plan

The plan for communication and dissemination activities, described all communication and dissemination activities, together with a communications calendar listing when each item had to be delivered.

Deliverable D2.1 Communication Plan

Task 2.2 Strategy for user engagement

The project impact was maximised through a strategy for user engagement, in which relevant stakeholders were identified throughout the course of the project and invited to take part in workshops, discuss deliverables and share knowledge. Active user-engagement activities enabled the project to build up a wide range of industry- and policy-user relationships.

User engagement is about creating as many channels and contacts as possible; so that the project gets better understanding of the market and the WtE sector, and better preparation for the exploitation and commercialisation of the project's outcomes; ensuring overall a better project impact.

Deliverable 2.2 - Strategy for user engagement

Task 2.3 Project events and meetings

The project organised two face-to-face meetings: one Kick-off meeting in Edinburgh and one End of Project meeting in Sheffield in which all project partners, members of project teams, members of the General Assembly, and Expert Advisory Group members were invited. In these face-to-face events, the Project Management Board and the External Advisory Group also had the opportunity to meet face-to-face.

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With meeting restrictions, due to the covid pandemic, all other meetings were done online: the project had fourteen quarterly project management board meetings, three industry-focused technical workshops and one round table with industry members. Additionally, each work-package organised specific meetings to progress and coordinate technical work.

Deliverable 2.3.1-14 – report from project meetings

Task 2.4 Webinars

Three public webinars were organised to disseminate the research outcomes. All were recorded and are available on the website (see links).

- Carbon capture on solid recovered fuels – insights for the waste to energy sector (https://www.newestccus.eu/events/webinar-1-carbon-capture-solid-recovered-fuels-%E2%80%93-insights-waste-energy-sector).
- Carbon Capture and Storage for Waste to Energy: Evaluating climate impacts and technologies - (https://www.newestccus.eu/events/webinar-2-carbon-capture-and-storage-waste-energy-evaluating-climate-impacts-and-technologies).
- Testing of open and commercial solvents at Waste to Energy plants - (https://www.newestccus.eu/ waste-energy-plants).

Webinar 1 – This webinar explored the increasing role of standardised solid recovered fuels (SRF) in reducing CO_2 emissions from co-incineration-processes – such as cement and lime kilns and power plants – and supporting chemical recycling (i.e. gasification and pyrolysis) as well as the development of new technologies, including oxyfuel, etc.

Our speakers also presented results from the NEWEST CCUS project on oxy-CFB combustion of SRF at pilot scale. Studies have focused on the implications of temperature and inlet O_2 concentration on key process aspects, such as the formation of pollutants and reactor hydrodynamics. The influence of the aforementioned variables on corrosive depositions was also discussed.

Link: https://www.newestccus.eu/events/webinar-1-carbon-capture-solid-recovered-fuels-%E2%80%93-insights-waste-energy-sector.

Webinar 2 - This webinar presented a comparative techno-economic assessment of emerging and close to commercial CO_2 capture technologies in the Waste to Energy Sector (amine solvents, membranes and oxy-fired circulating fluidised bed). It also presented a case study of a UK Waste-to-Energy plant, in terms of energy performance and Life Cycle Assessment. An assessment of the potential for creating negative emissions in the European Waste to Energy Sector was followed by recommendations for stakeholders and policymakers. Attendees had the opportunity to ask questions after each talk.

Link: https://www.newestccus.eu/events/webinar-2-carbon-capture-and-storage-waste-energy-evaluating-climate-impacts-and-technologies

Webinar 3 This webinar presented the work on amine solvents. Amine solvents were tested at WtE plants and at plants under conditions relevant for WtE. One of the tested solvents was the well-known APBS-CDRMax® solvent, a proprietary solvent from NEWEST-CCUS project partner Carbon Clean. This webinar addressed the execution of the campaigns, the results that were obtained and discussed the performance of the tested solvents.

Link: https://www.newestccus.eu/events/webinar-3-testing-open-and-commercial-solvents-waste-energy-plants

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Task 2.5 Project website

The project website (https://www.newestccus.eu) is our main tool to disseminate information about the project, to report on our partner's research in CCUS to a wider audience and provide a single location for all Deliverables, Webinars, Newsletters and Articles with Twitter.

Website traffic sources. Over the 39 months of the project website, from website launch to end of project, the website attracted 10,551 users.

Please see the website analytics for the period 10 December 2019to 28 Feb 2023 in annex of this report.

Project results are available on the website:

- WP2 Results - (https://www.newestccus.eu/about-project/work-packages/wp2-results
- WP3 Results – (https://www.newestccus.eu/about-project/work-packages/wp3-results)
- WP5 Results – (https://www.newestccus.eu/about-project/work-packages/wp5-results)

Task 2.6. Exploitation Plan

An exploitation plan was developed for each partner to identify key exploitable results and associated their target end-users. The plan includes proposed measures to ensure maximum commercial and non-commercial exploitation of project results.

Deliverable: D2.6.2 Exploitation plan

WP3 – Tests on Oxy-fuel and Membrane Technologies

Task 3.1 Oxy-fuel grate technology (furnace combustion model development), led by SINTEF Energy Research (Norway) - completed.

The aim of the projects has been to study a potential capture technology based on oxy-fuel combustion where oxygen and CO2 is used instead of air in the waste incineration process at a potential new Waste-to-Energy (WtE) plant at the Haraldrud site. CO_2/O_2 oxidiser instead of CO2/N2 makes carbon capture much more efficient, practical because of much higher CO_2 concentrations to handle. WtE CCS will enable negative CO_2 emissions as MSW is largely biogenic.

This task was conducted using input and knowledge developed through the work of two projects CapeWaste and NEWEST-CCUS. Numerical full scale CFD simulations were performed for the Haraldrud WtE furnace under air conditions and under oxy-fuel conditions. The main focus has been on the conversion of the fuel bed. The simulation results indicated that for the conditions of this study the conversion and burn-out of the bed was at least at the same level under oxy conditions as when air is used as oxidiser under similar conditions. The results of the SINTEF lab-scale experiments also indicate that there is no unsurmountable showstopper for the further development of MSW oxyfuel combustion. The results in this study contribute to the further development of oxyfuel combustion as they confirm that stable combustion can be attained under different operating oxyfuel conditions, using both N2 and CO2, for a complex mixture [a model MSW].

Deliverable D3.1 – CFD simulation results of a full scale oxy-fuel MSW furnace

Link: https://www.newestccus.eu/about-project/work-packages/wp3-results

The work is also disseminated in a scientific paper: https://www.mdpi.com/1996-1073/14/17/5297

Tasks 3.2 Oxy-fuel combustion of SRF - completed

The results show that the observed pilot data during both combustion modes matches reasonably well the results obtained from stoichiometric combustion equations and process simulations. Combustion of pelletised SRF shows to be feasible with the current experimental set up at the 20 kW BFB reactor, without technical limitations posed by bed agglomeration issues, even after a few hours of continuous operation.

Sub-task 3.2.1 (lab scale oxy-BFBC 20kW) completed

The results and experience gained in the lab-scale BFB combustor will serve to choose promising experimental conditions for demonstration at the 200 kW CFB pilot facility combustor.

The task led to a report in which results from lab-scale BFB combustion experiments under air and oxy-fuel firing conditions are presented. Cold dosing experiments of four SRF candidates have been investigated in a first phase of the tests. A pelletised SRF from Spain (i.e. ECO-P) has been then used for the air and oxy-fuel combustion experiments. In the air combustion experiments, the influence of the reactor temperature over the ash behaviour and flue gas species has been investigated. For the oxy-fuel tests, the same process evaluation has been performed, though at a reference temperature (i.e. 850 °C) and at different inlet oxygen concentrations (i.e. 21 vol%db, 30 vol%db and 40 vol%db).

Deliverable 3.2.1 results from lab scale test on oxyfuel BFBC was delivered in Aug 2020
Link: https://www.newestccus.eu/file/167/download?token=VXD_ogaR

Sub-task 3.2.2 Demonstration of Oxy-CFBC 200kW – completed and Sub-task 3.2.3 Demonstration of in-situ desulphurisation 200kW - completed

These tasks led to a report which presents an experimental investigation on the air and oxy-fuel combustion of solid recovered fuel at a 200 kWth circulating fluidized bed facility. In the course of three experimental campaigns, the effects of combustion atmosphere and temperature on pollutant formation (i.e., NOx, SO2, and HCl) and reactor hydrodynamics were systematically studied. In contrast to air-firing conditions, the experimental results showed that oxy-fuel combustion enhanced the volume concentration of NOx by about 50% while simultaneously decreasing the fuel-specific NOx emissions (by about 33%). The volume concentrations of SO2 and HCl were significantly influenced by the absorption capacity of calcium-containing ash particles, yielding corresponding values close to 10 and 200 ppmv at 871–880 °C under oxy-fuel combustion conditions. In addition, the analysis of hydrodynamic data revealed that smooth temperature profiles are indispensable to mitigate bed sintering and agglomeration risks during oxy-fuel operation.

Deliverable 3.2.2 results on pilot plant SRF oxy-fuel combustion demonstration

Link: https://www.newestccus.eu/file/168/download?token=ax0KZrFR

Task 3.2.4 Investigation of corrosive deposition 200kW - completed.

Within the NEWEST-CCUS project (Project-Nr.: 299683), different carbon capture, usage, and storage (CCUS) technologies are to be investigated in the context of Waste-to-Energy (WtE) plants, aiming at achieving net-negative CO2 emissions. A promising possibility in this regard comprise oxy-firing technologies applied to fluidized bed systems, which introduce the potential for higher efficiency with solid recovered fuel (SRF) combustion. During oxy-fuel combustion, the fuel is fired using pure oxygen instead of air as the primary oxidant. Since the nitrogen component of air is not heated, fuel consumption is reduced, and higher flame temperatures are possible. The justification for using oxy-fuel is thus to produce a CO2-rich flue gas ready for sequestration.

This subtask led to a report which presents the results from corrosion measurements performed at USTUTT's 200 kW CFBC facility in air and oxy-fuel combustion conditions. The samples collected in the facility in both settings evidence a clear attack by corrosion phenomena. During oxy-fuel operation, the short exposure time in combination with the relatively high chlorine content of the fuel led to an insufficient buildup of an oxidic protective layer (i.e., oxide scale). Consequently, chlorine diffused through the porous oxide scale and attacked the material surface directly. Besides, increased HCl values were measured during oxy-fuel operation, postulating HCl as the driver of the corrosion mechanism. In contrast, the HCl content in the flue gas during air-firing was relatively low. Hence, the strong corrosion attacks here were more likely to be originated from alkali salt deposits. On the other hand, chlorine and sulfur (partially) infiltrated the protective metal oxide layer in both combustion settings, breaking it off by side reactions between sulfates, chlorides, iron, and alkalis.

Deliverable 3.2.3 – results of corrosive deposition on super-heater pipes

Link: https://www.newestccus.eu/file/169/download?token=IVcVQWCa

The project results from Germany were disseminated during a public webinar in March.

Webinar 1- Carbon capture on solid recovered fuels – insights for the waste to energy sector

Link: https://www.newestccus.eu/events/webinar-1-carbon-capture-solid-recovered-fuels-%E2%80%93-insights-waste-energy-sector

Task 3.3 Post and hybrid separation by CO_2 membrane applied to Waste-to-Energy

The project investigated the use of membranes in post-combustion and hybrid separation on waste to energy and transferred all test results to WP5 techno-economic analysis.

Overall the project NEWEST has been a real success, especially with the valuable combination of modelling and experimental data. The project has done substantial evaluation and validation of the oxyfuel concept for fluidized bed and grate furnaces and showed that this set of technologies are highly relevant for WtE plants. However, there is still a large amount of work to be done to address the full range of issue associated with oxyfuel for fluidized bed and grate furnace and more relevant data need to be obtained experimentally for the process modelling and LCA analysis, especially exploring the full range of potential waste qualities.

WP4 – tests on post-combustion capture with solvents

Task 4.1: Pilot scale testing at TERC 1tCO2/day facilities (USHEFF).

Two test campaigns at TERC (350 hours total) were planned on waste to energy combustor flue gas with solvent-based CO_2 capture plant, using a generic MEA solvent (35%) for 150 hours and a proprietary solvent from Carbon Clean, APBS-CDRMax®, for 200 hours with grade A waste wood.

Due to supply chain issues throughout due to COVID and Brexit, delivery of all the projects was delayed. NEWEST was started in good time to deliver the two planned test campaigns. However, due to an equipment failure on the CO_2 capture plant, only one test campaign (with APBS-CDRMax®) could be completed. The broken equipment had to be sourced from Italy (the original supplier), therefore took time and the plant could not be prepared for the second test campaign within the time scale of the project. However, the first test campaign went longer (~270 hrs) than planned (200 hrs) due to flue gas composition variability due to operational issues as a result of waste wood combustion such as slagging in the furnace. The flue gas composition variability affected the time required to settle the capture plant to steady state. The operational hours for the first test campaign were extended with the view to achieve a reasonable set of data for comparison with the second campaign. The plan was still to operate the second test campaign for the planned ~150 hours (potentially more) at our own cost. However, due to the above mentioned issues, the second test campaign could not be delivered.

Task 4.2: Demonstration of solvent performance at an industrial WtE facility (TNO, CC). The demonstration of proprietary solvent (Carbon Clean) - completed

The project aims is to accelerate the development and deployment of CO_2 capture technologies that are tailored for effective operation at Waste-to-Energy (WtE) plants. To achieve this objective, amine solvents were tested at WtE plants and at plants under conditions relevant for WtE. One of the tested solvents was the well-known APBS-CDRMax® solvent, a proprietary solvent from NEWEST-CCUS project partner Carbon Clean. The results were presented in a webinar which presented the execution of the campaigns, the results that were obtained and discussed the performance of the tested solvents.

Webinar 3 – testing of open and commercial solvents at waste-to-energy plants

Link: https://www.newestccus.eu/events/webinar-3-testing-open-and-commercial-solvents-waste-energy-plants

The results were also presented at GHGT 16 conference, October 2022; (Demonstration of solvent performance at an industrial WtE facility; Roberta Veronezi Figueiredo , Eirini Skylogianni, Peter van Os, James Hall, Thomas Yelland, Mathijs Vos, Juliana Garcia Moretz-Sohn Monteiro)

Task 4.3. Demonstration test of third generation (STAR) solvent system (TNO).

High pressure conditions were achieved, but the kinetics was very slow, cyclic capacity was low and crystal kept on forming which block the system – the operation had to stop and an alternative solvent to be found. Efforts were made to screening a number of existing solvents (not economical) and new solvents – Task completed

WP5 – comparative technology and market assessments of CO2 capture in the WtE sector

Task 5.1 Case study and framework selections for process modelling (UEDIN) - completed

The project reviewed the current state-of-the-art of energy recovery processes from municipal solid wastes and waste incineration technologies, and investigated the opportunities and challenges for the implementation of CCUS in the European WtE sector. A literature review focused on identifying the availability and composition of the potential waste feedstock and the geographical location of existing and planned WtE facilities in Europe. The project identified a set of case studies and defined a common framework that was shared and approved by the project partners.

Task 5.2 Process simulation for performance assessment (UEDIN, TNO, SER, USTUTT) - completed

Process simulation activities from NEWEST-CCUS coordinated with national programs for oxy-fuel Waste-to-Energy, i.e. the Norwegian CapeWaste and the German NuCA projects. This synergy allowed benchmarking of capture technologies within the same framework and mitigate the risks for large scale development and deployment of CCUS in the European WtE sector. For each CO_2 capture technology under consideration in WP 3 and WP 4, process simulations will be carried out to determine performance data of key process steps. The results were compiled to the comparative technology assessment in task 5.3.

Deliverable 5.2.1: Key performance and technical parameters from process modelling of MSW combustion in an air-fired grate boiler with amine-based carbon capture (UEDIN, M25)

At the Institute of Combustion and Power Plant Technology (IFK) of the University of Stuttgart, experimental tests with solid recovered fuel (SRF) were performed using a pilot-scale circulating fluidized bed oxy-combustor (oxy-CFBC). In parallel, a full-scale oxy-CFBC waste-to-energy (WtE) plant was designed using Aspen Plus®. The model was subsequently validated to serve as a computer tool to predict the oxy-combustion process' behaviour under various operational conditions. In this deliverable, the performance of the full-scale model is evaluated upon changes in (i) fuel composition, (ii) oxygen concentration in oxidizer and flue gas, and (iii) extent of gas pollutant treatment. The results included in this study contribute to a better understanding of the fundamental oxy-fuel knowledge with alternative fuels and may serve to guide future process design and scale-up.

Deliverable 5.2.2: Results from oxy-fuel CFBC process simulations (USTUTT, M25)
Link: https://www.newestccus.eu/file/166/download?token=BeT3Zsi-

The results included in this study contribute to a better understanding of the fundamental oxy-fuel knowledge with alternative fuels and may serve to guide future process design and scale-up.

Link: https://www.newestccus.eu/file/166/download?token=BeT3Zsi-

Deliverable 5.2.3: Benchmarking 2nd and 3rd generation solvents for CO_2 capture on WtE plants (TNO, M36)

Task 5.3 (UEDIN). Comparative assessment of technology report- completed.

This task led to a document with accompanying data that are available on request from Prof. Mathieu Lucquiaud (m.lucquiaud@sheffield.ac.uk) or Dr Camilla Thomson (c.thomson@ed.ac.uk). The report compiles and analyses key findings and results from the process simulations in order to conduct a comparative technical assessment of the investigated technologies in this project on the basis of several key performance indicators (KPIs). Two municipal solid waste combustion technologies are considered: (i) an air-fired moving grate boiler and (ii) an oxy-fuel combustion circulating fluidised bed boiler, both equipped with heat recovery for steam generation and electricity production in the steam turbines. For the WtE facility with a moving grate boiler, two post-combustion capture technologies are investigated: (i) amine-based chemical absorption with an aqueous solution of monoethanolamine (MEA) and with 2nd generation solvents and (ii) Membrane assisted CO_2 liquefaction. The KPIs considered in this comparison include energy consumption, carbon capture rate, cost analysis, operational availability and flexibility, capacity and versatility of feedstock, etc. These are categorized into quantitative and qualitative indicators in order to consider a broad range of factors affecting the feasibility of implementing carbon capture technologies in WtE facilities. This assessment presents some key metrics that are important and relevant for CCUS for WtE sector, policy makers, regulators and technology developers.

Deliverable 5.3: Report on the technical comparison of the investigated WtE CCUS technologies (UEDIN, M32)

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Task 5.4 (UEDIN-USHEFF). Scenario analysis and evaluation of potential market.

The project evaluated the potential market for CCUS on WtE in Europe and a credible potential for negative emission in Europe. Focusing on the current European Waste to Energy fleet and its total capacity and further assuming a set of criteria to determine whether and which WtE facilities are retrofittable with CCS. – completed.

This task led to a report which assesses the potential for generating negative emissions from WtE + CCS with focus on the European waste sector as a case study. This study shows that if the entire existing European WtE fleet (i.e. 100.9 Mt of installed capacity) was retrofitted with CCS, negative emissions in the range of -50.5 to - 70.6 MtCO_2/y would be generated per year, assuming a capture rate close to 100%. In its 2019 sustainability roadmap, CEWEP anticipates a total of 142Mt of residual waste generated in 2035 when meeting the thresholds for recycling (minimum of 65%) and landfilling (maximum of 10%) in accordance with the EU Circular Economy Package. It may admittedly not be possible to bridge the current ~30Mt gap in WtE capacity needed to treat the remainder of this residual waste, as some existing WtE plants come to the end of their life and others are newly commissioned. Yet, in theory, if enough WtE capacity where to be built and is retrofittable with CO_2 capture, a range of -71 to -99.4 MtCO_2/y of negative emissions can be achieved. When CCS limitations are considered, these ranges are naturally reduced, with a range between -20 to -30 MtCO_2/y achievable when all CCS considerations are taken into account.

Deliverable 5.4: Report on the techno-economic analysis of the potential market for WtE CCUS in Europe (UEDIN, M36)
Link: https://www.newestccus.eu/file/190/download?token=P1-9eLUW

Task 5.5. (UEDIN-USHEFF) Environmental impacts of WtE with CCUS in Europe. Life cycle assessment of four waste incineration plant configurations including carbon capture and storage – completed

Municipal Solid Waste (MSW) is primarily the refuse produced by households and other sources, not containing hazardous substances and which, due to its features and composition, resembles household waste. Aside from households, other sources for MSW are shops, offices, schools, graveyards, municipal green areas and infrastructure facilities. Recycling and recovery targets for MSW have been introduced nationwide in many European countries and, in order to achieve compliance, local authorities have conducted waste surveys to determine the composition of MSW. Consequently, more data on physical properties and chemical composition are available, yet there is a lack of standardization procedures to conduct analyses and report the results. This is of particular importance when considering the environmental impacts and net CO_2 emissions of energy-from-waste.

Deliverable 5.5.1: Report on the carbon content of WtE feedstocks (typically municipal solid waste) (UEDIN, M25) – this is an internal document

The project established a detailed life cycle assessment (LCA) of the environmental impacts of a state-of-the-art WtE facility equipped with amine-based CO_2 capture at ultra-high capture rates, shows that adding CCS can provide a significant improvement in climate change impact, and actually a net climate benefit. This is reported as a paper which is reported in Deliverable 5.5.2.

Deliverable 5.5.2: Report on the environmental impacts of WtE with CCUS in Europe (UEDIN, M33)

Link: https://www.newestccus.eu/about-project/work-packages/wp5-results

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The following table present an overview of financial results, per partner and per work package.

Table 1 - Overview of financial results per partner and per work package.

Partners	WP 1	WP 2	WP 3	WP 4	WP 5	Total	Comment / Specifications
United Kingdom (k€)							
The University of Edinburgh	145,614	96,218			347,121	588,953	
Carbon Clean				83,760		83,760	
The University of Sheffield	15,906	30,220		316,971	123,632	486,729	
Norway (k€)							
Sintef Energy Research		55,000	270,000		35,000	360,000	
Returkraft			10,000			10,000	
(ex EGE)			5,000			5,000	
The Netherlands (k€)							
TNO	32,485	44,295		395,327	67,877	539984	
Germany (k€)							
University of Stuttgart		16,223	322,101		60,331	398655	
Total	**194005**	**241956**	**607101**	**796058**	**633961**	**2473081**	

All figures in euro

5. Project impact

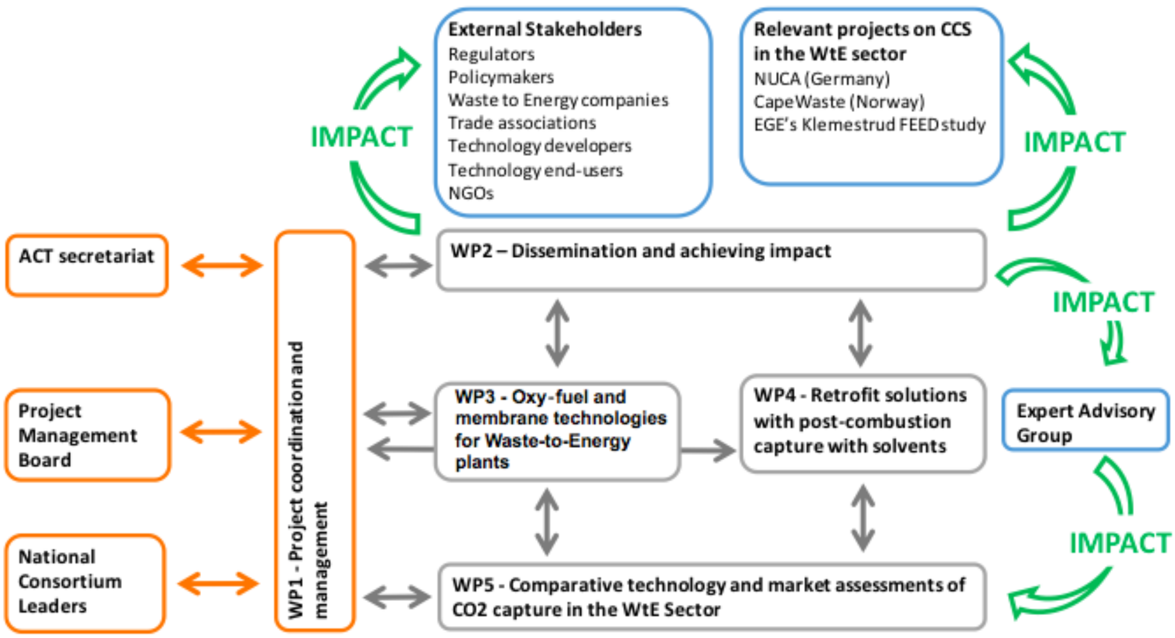

Figure 2. Overview of NEWEST-CCUS

Comment on the impact of the project, discussing the items below, if relevant for the project. Include a discussion of relevant market and policy developments and their potential impact.

- *Contribution to the facilitation of the emergence of CCUS*
- *Strengthen the competitiveness and growth of European companies*
- *Other environmental or socially important impacts, such as public acceptance*
- *Chances for commercializing the technology further*
- *Gender issues*

Addressing climate change and the sustainable management of ever-increasing amounts of waste are global challenges recognised by both the Paris Agreement and the EU Circular Economy Action Plan. Preventing waste is the best option for waste management, followed by reducing, reusing, and recycling. But this still leaves residual waste, which might be polluted, might not be good enough to

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recycle and could lead to further environmental damage if sent to landfill sites. Waste-to-Energy (WtE) plants, which are commonplace across Europe, provide an opportunity to recover value from this waste in a way that can also reduce its negative environmental impacts.

The NEWEST-CCUS project had significant impact on the application of CCUS technologies in the WtE sector, through pilot-scale testing and modelling, the evaluation of oxy-fuel technology for the WtE sector and assessment of membrane capture technology in advanced hybrid method, under typical WtE flue gas and at pilot scale.

The project collected data on solvent ageing and management options and built a framework for a comparative technology assessment. This work allowed the project to evaluate the potential for CCUS technologies and estimate its potential net atmospheric CO_2 removal when applied to the Waste to Energy Sector in Europe. The project demonstrated that CCUS technologies can play a crucial role in reducing greenhouse gas emissions, removing atmospheric CO_2 and contributing to achieving climate target.

The project is also contributing towards strengthening the competitiveness and growth of European Waste to Energy plant operators, waste management companies and carbon capture technology developers. CCUS is expanding very rapidly across Europe, new projects are being developed every month across several industry sectors, as more countries and companies commit to reducing their carbon emissions. The development of cost-effective CCUS technology, and a suitable business model, including reward for negative emission can provide a competitive advantage to European companies and position them as leaders in a global net zero emission market.

Regarding gender issues, the project ensured gender balance in its workforce and promoted equal opportunities and treatment for all employees. The project recognised the importance of diversity and inclusivity and highlighted the achievements of several project partners who happened to be celebrated woman in science.

In conclusion, the NEWEST-CCUS project has a significant impact on developing the case for the application of CCUS in the WtE sector, in strengthening the competitiveness of the UK and European WtE sector, reducing greenhouse gas emissions, removing atmospheric CO2, and creating economic and societal benefits. It is expected that expanding the range of fuel sources that are ready to use in combination with CCUS will create high quality jobs and respond to climate change concerns. The project's results will contribute to achieving climate goals and positioning the UK, Norway and Europe as leaders in the global market for WtE with CCUS.

6. <u>Implementation</u>

NEWEST-CCUS project results are contributing towards reaching Target 6 of the SET-Plan action 9: “At least 3 pilots on promising new capture technologies, and at least one to test the potential of sustainable Bio-CCS at TRL 6-7 study”

The NEWEST-CCUS project has been making significant progress in the field of carbon capture, utilization, and storage (CCUS) especially with the valuable combination of Modelling and experimental data and the experiences. The project aimed to develop innovative technologies and solutions for reducing carbon emissions from the waste-to-energy sector. The project's results have been aligned with the SET Plan Implementation actions, specifically number 9 on CCUS, and the mission innovation research priorities.

The SET Plan Implementation actions aim to accelerate the development and deployment of low-carbon technologies in Europe. Action number 9 focuses on CCUS, which is seen as a critical technology for achieving the EU's climate goals. The NEWEST-CCUS project has been working towards reaching Target 6 of the SET-Plan action 9: "At least 3 pilots on promising new capture technologies, and at least one to test the potential of sustainable Bio-CCS at TRL 6-7 study".

The project has also been aligned with the mission innovation research priorities, which are global priorities for research and development in clean energy technologies. The mission innovation priorities for CCUS include developing a full CCS chain for a representative portfolio of different capture, transport, storage and re-use technology options.

The NEWEST-CCUS project has been working towards these priorities by progressing the Technology Readiness Levels of innovative solutions for carbon capture in the Waste to Energy Sector. The project has tested oxy-firing technologies on circulating fluidized bed technology, membranes-based CO2 separation applied as a hybrid method using partial flue gas recirculation and oxygen enrichment and has tested solvent-based post combustion capture with waste fuel in a pilot plant. The project has subsequently built a framework for a comparative technology assessment and evaluated the potential for CCUS and NET atmospheric carbon removal in the WtE sector.

In addition to advancing new technologies, the NEWEST-CCUS project has also been engaging with industry to ensure that its results are relevant and applicable to the waste to Energy sector across Europe. The project has established a Expert Advisory Group, which is a group of 30 stakeholders including Waste to Energy plants operators, representative from the Confederation of European Waste-to-Energy Plants (CEWEP), representatives from engineering companies, research institutes, and environment regulators from Scotland, the UK, Norway, The Netherlands, and Germany. All members of this group discussed the project's results and their potential applications. This engagement has helped the project develop clear policy recommendations for the decarbonisation of the Waste-to-Energy Sector and ensured that the project's results are aligned with the WtE sector needs and priorities.

Overall, the NEWEST-CCUS project has been making significant progress in the field of CCUS. Its results have been aligned with the SET Plan Implementation actions and the mission innovation research priorities, and the project has engaged industry and policy makers in its work. These efforts are critical for accelerating the development and deployment of CCUS technologies, which are essential for achieving the EU's climate goals.

7. <u>Collaboration and coordination within the Consortium</u>

The NEWEST-CCUS project is a collaborative effort between 30 organisations: technology developers, technology users in the waste-to-energy sector, local authorities, regulators, policy makers, city planners, across 12 countries. The collaboration involves sharing knowledge, expertise, and resources to de-risk and accelerate the development and deployment of CO_2 capture technologies tailored specifically for WtE applications. In particular, NEWEST-CCUS contributed to de-risk promising technologies for CO_2 capture at WtE plants and delivered a reliable methodology for accounting for negative emissions associated with successful implementation of CCUS in the WtE sector.

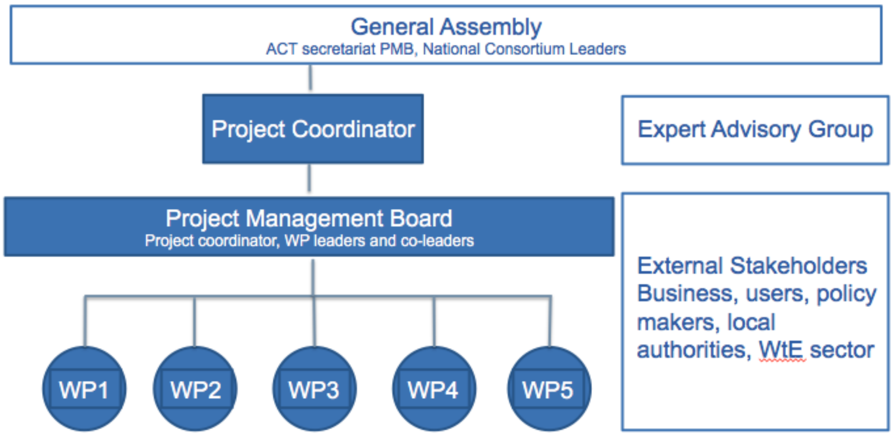

Figure 3. Schematic view of NEWEST-CCUS management structure

The coordination within the consortium was essential to ensure that all partners were working towards the same objectives and that the project was progressing despite the global Covid-19 pandemic. The management structures and governance procedures were designed to facilitate effective communication and decision-making and ensuring that each partner was aware of their responsibilities.

The effectiveness of management structures and governance procedures was critical to the success of the NEWEST-CCUS project. The consortium had clear guidelines and procedures for decision-making, risk management, and conflict resolution. The management structures was flexible enough to adapt to changing circumstances and ensured that all partners were supported in their work and contributed towards the project's success.

The added value of transnational collaboration on CCUS was significant. The collaboration allowed for the sharing of best practices, knowledge, and resources, between project partners from the United Kingdom, Norway, the Netherland and Germany, and with Expert Advisory group members across European countries. The transnational collaboration provided access to CCUS test facilities, expertise and resources, which helped achieve the project ambition.

In conclusion, the collaboration and coordination within the consortium was critical to the success of NEWEST-CCUS project. The effectiveness of management structures and governance procedures was essential to ensure that all partners were contributing, with knowledge, WtE plants data or work towards the common objectives. The added value of transnational collaboration on CCUS was significant and can help accelerate the development and deployment of CO2 capture technologies tailored specifically for WtE applications

8. Dissemination activities (including list of publications)

Date	Reference (Journal/issue, event); Title; Authors	*Type	Partners
2020	Energy Volume 198, 1 May 2020, 117352,; https://doi.org/10.1016/j.energy.2020.117352; Waste-to-energy technology integrated with carbon capture. Challenges and opportunities; Wienchol, Paulina;Szlek, Andrzej; Ditaranto, Mario;	SPa	SER
2021	Energies, 2021, 14(17), 5297; https://doi.org/10.3390/en14175297; Oxyfuel Combustion of a Model MSW—An Experimental Study; Michaël Becidan, Mario Ditaranto, Per Carlsson, Jørn Bakken, Maria N. P. Olsen, Johnny Stuen	SPa	SER
2022	ACS Omega 2022, 7, 10, 8950–8959; https://doi.org/10.1021/acsomega.1c07334 ; Oxy-combustion of solid recovered fuel in a semi-industrial CFB reactor: on the implications of gas atmosphere and combustion temperature; Joseba Moreno, Max Schmid, Steven Scharr, Günter Scheffknecht	SPa	USTUTT
2022	Energy Volume 248, 1 June, 2022, 123573; https://doi.org/10.1016/j.energy.2022.123573; Thermogravimetric and kinetic study of thermal degradation of various types of municipal solid waste (MSW) under N2, CO2 and oxy-fuel conditions; Wienchol P, Korus A, Szlęk A, Ditaranto M	SPa	SER
2023	Fuel Volume 332, Part 1, 15 January 2023, 126004 ; https://doi.org/10.1016/j.fuel.2022.126004 ; Thermal integration of Waste to energy plants with Post-combustion CO2 capture; Dan Su; Laura Herraiz; Mathieu Lucquiaud; Camilla Thomson; Hannah Chalmers	SPa	UEDIN
2023	Energies, Volume 16, Issue 4, February 2023, Article number 1909; DOI: 10.3390/en16041909; Research and Innovation Needs for the Waste-To-Energy Sector towards a Net-Zero Circular Economy; Dal Pozzo, Alessandro; Lucquiaud, Mathieu; De Greef, Johan	SPa	UEDIN
2023	Oxford Institute for Energy Studies OIES Paper CM01. March 2023; ISBN 978-1-78467-219-5; Waste Not, Want Not: Europe's untapped potential to generate valuable negative emissions from waste-to-energy (WtE) using carbon capture technology; Hasan Muslemani, Iain Struthers, Laura Herraiz, Camilla Thomson, Mathieu Lucquiaud	SPa	USHEFF
2021	GHGT15 conference; (March 25, 2021). Available at SSRN: https://ssrn.com/abstract=3812571 or http://dx.doi.org/10.2139/ssrn.3812571; Negative Emissions in the Waste-to-Energy Sector: An Overview of the Newest-CCUS Programme; Lucquiaud, Mathieu and Herraiz, Laura and Su, Dan and Thomson, Camilla and Chalmers, Hannah and Becidan, Michael and Ditaranto, Mario and Roussanaly, Simon and Anantharaman, Rahul and Moreno Mendaza, Joseba and Schmid, Max and Akram, Muhammad 7 and Finney, Karen N. and Pourkashanian, Mohamed and van Os, Peter and Veronezi Figueiredo, Roberta and Garcia Moretz-Sohn Monteiro, Juliana and Goetheer, Earl	OPa	UEDIN et al.
2021	1st FERIA Conference (Fuel and Energy Research and its Applications) September 2021; Waste to Energy with BECCS for the urban environment: Opportunities and challenges for development ; Dan Su, Hannah Chalmers, Mathieu Lucquiaud, Laura Herraiz	OPa	UEDIN
2021	IEAGHG 6th Post Combustion Capture Conference October 2021 ; Waste-to-Energy plant with carbon capture: key aspects to be considered in regional energy strategies ; Dan Su, Laura Herraiz, Camilla Thomson, Hannah Chalmers, Mathieu Lucquiaud	OPa	UEDIN
2021	The 10th Energy from Waste & Biomass (EfWB) Workshop host by Uniper's Engineering Academy, December 2021; Negative Emissions in the Waste-to-	OPa	UEDIN

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	Energy Sector: An Overview of the Newest-CCUS Programme; Laura Herraiz, Dan Su, Camilla Thomson, Hannah Chalmers, Mathieu Lucquiaud		
2022	GHGT 16 conference, October 2022; Demonstration of solvent performance at an industrial WtE facility; Roberta Veronezi Figueiredo , Eirini Skylogianni, Peter van Os, James Hall, Thomas Yelland, Mathijs Vos, Juliana Garcia Moretz-Sohn Monteiro	OPa	TNO
2020	NEWEST-CCUS Project report D3.2.1. August 2020, ; Deliverable 3.2.1 ; ba Moreno, Max Schmid ; https://www.newestccus.eu/file/167/download?token=VXD_ogaR	Del	USTUTT
2022	NEWEST-CCUS Project report D3.2.2, May 2022 - ; Results om pilot plant SRF oxy-fuel combustion demonstration; Joseba Moreno, Max Schmid https://www.newestccus.eu/file/168/download?token=ax0KZrFR ;	Del	USTUTT
2022	NEWEST-CCUS Project report D3.2.3, February 2022 – Results of corrosive depositions on super-heater pipes ; https://www.newestccus.eu/file/169/download?token=IVcVQWCa ;	Del	USTUTT
2022	NEWEST-CCUS Project report D5.2.2 , May 2022 , Results from oxy-fuel CFBC process simulations, Joseba Moreno, Max Schmid https://www.newestccus.eu/file/166/download?token=BeT3Zsi-	Del	USTUTT
2022	NEWEST-CCUS Project report D5.4 , February 2023, Techno-economic analysis of the potential market for waste-to-energy with CCUS technologies ; Hasan Muslemani, Iain Struthers, Laura Herraiz, Camilla Thomson, Mathieu Lucquiaud ; https://www.newestccus.eu/file/190/download?token=P1-9eLUW	Del	UEDIN
2023	NEWEST Webinar 1 ; 23rd March 2022 : Carbon capture on solid recovered fuels: Insights for the Waste-to-Energy sector https://www.newestccus.eu/events/webinar-1-carbon-capture-solid-recovered-fuels-%E2%80%93-insights-waste-energy-sector ; Mario Ditaranto, Thomas Glorius, Joseba Moreno	Web	UEDIN SER USTUTT
2023	NEWEST Webinar 2; 25th January 2023 : Carbon Capture and Storage for Waste to Energy: Evaluating climate impacts and technologies: https://www.newestccus.eu/events/webinar-2-carbon-capture-and-storage-waste-energy-evaluating-climate-impacts-and-technologies ; Mathieu Lucquiaud, Dan Su, Iain Struthers, Hasan Muslemani, Camilla Thomson	Web	UEDIN USHEFF
2023	NEWEST Webinar 3; 22nd February 2023 : Testing of open and commercial solvents at Waste-to-Energy plants : https://www.newestccus.eu/events/webinar-3-testing-open-and-commercial-solvents-waste-energy-plants : Peter van Os, Eirini Skylogianni, Muhammad Akram, Thomas Yelland	Web	UEDIN TNO USHEFF
2020	NEWEST-CCUS Technical Meeting 1, 18th June 2020 ; Negative Emissions in the Waste-to-Energy Sector: Technologies for Carbon Capture, Utilisation & Storage; Technical Meeting with members of the Expert Advisory Group – NEWEST-CCUS	WS	UEDIN SER TNO USHEFF USTUTT CC EAG
2021	NEWEST-CCUS Technical Meeting 2, 7th June 2021 ; Negative Emissions in the Waste-to-Energy Sector: Technologies for Carbon Capture, Utilisation & Storage; Technical Meeting with members of the Expert Advisory Group,	WS	UEDIN SER TNO USHEFF

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			USTUTT CC EAG
2022	NEWEST-CCUS Technical Meeting 3, 7th June 2022; Negative Emissions in the Waste-to-Energy Sector: Technologies for Carbon Capture, Utilisation & Storage; Technical Meeting with members of the Expert Advisory Group , CEWEP RENOVA – NEWEST-CCUS	WS	UEDIN SER TNO USHEFF USTUTT CC EAG
2022	NEWEST-CCUS Industry Workshop, 16th September 2022; Techno-economic analysis of the potential market for waste-to-energy with CCUS technologies; Roundtable - workshop with members of the Expert Advisory Group	WS	UEDIN SER TNO USHEFF USTUTT CC EAG
2020	avfallsbransjen.no 2020/05/28 ; Internasjonalt prosjekt vekker interesse i avfallssektoren; M.Ditaranto	PR	SER
2019	News article 20/12/2019 on newestccus.eu website: https://newestccus.eu/news/newest-ccus-online-portal-goes-live ;	NL	UEDIN
2020	News article 9/03/2020 on newestccus.eu website: https://newestccus.eu/news/capturing-co%E2%82%82-waste-energy-discussed-uk-parliament ;	NL	UEDIN
2020	News article 23/03/2020 on newestccus.eu website: https://newestccus.eu/news/statement-covid-19	NL	UEDIN
2020	News article 17/04/2020 on newestccus.eu website: https://www.newestccus.eu/news/technology-insight-1-bridging-gap-between-lab-and-large-scale-pilot-trials ;	NL	UEDIN
2020	News article 06/05/2020 on newestccus.eu website: https://www.newestccus.eu/news/newest-partner-secures-16m-low-cost-carbon-capture-innovation ;	NL	UEDIN
2020	EERA Bionenergy Newsletter Issue 13 Spring/Summer 2020, p. 19 ; FROM NEUTRAL TO NEGATIVE CO2 EMISSIONS	NL	SER
2020	News article 23/09/2020 on newestccus.eu website: https://www.newestccus.eu/news/technology-insight-2-capture-testing-solid-recovered-fuels-combustion ;	NL	UEDIN
2020	News article 19/10/2020 on newestccus.eu website: https://www.newestccus.eu/news/stuttgart-puts-oxy-fuel-technology-waste-energy-through-its-paces ;	NL	UEDIN
2020	News article 16/12/2020 on newestccus.eu website: https://www.newestccus.eu/news/steinm%C3%BCller-support-university-stuttgart%E2%80%99s-carbon-capture-research ;	NL	UEDIN
2020	News article 16/12/2020 on newestccus.eu website: https://www.newestccus.eu/news/global-recycling-firm-remondis-feeds-ifk%E2%80%99s-capture-experiments ;	NL	UEDIN
2021	News article 11/02/2021 on newestccus.eu website: https://www.newestccus.eu/news/partner-profile-sustainable-energy-and-powerful-solutions ;	NL	UEDIN

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2021	News article 16/04/2021 on newestccus.eu website: https://www.newestccus.eu/news/fortum-oslo-varme%E2%80%99s-ccs-project-takes-important-step-forward ;	NL	UEDIN
2021	News article 21/04/2021 on newestccus.eu website: https://www.newestccus.eu/news/wp5-focus-proof-positive-negative-emissions-waste-energy ;	NL	UEDIN
2021	News article 1/06/2021 on newestccus.eu website: https://www.newestccus.eu/news/norway%E2%80%99s-waste-energy-capture-project-features-iea-case-study ;	NL	UEDIN
2021	News article 28/07/2021 on newestccus.eu website: https://www.newestccus.eu/news/technology-insight-3-sintef-energy-researchs-oxy-fuel-combustion-research-facilities ;	NL	UEDIN
2021	News article 19/08/2021 on newestccus.eu website: https://www.newestccus.eu/news/latest-ccus-news-norway%E2%80%99s-waste-energy-sector ;	NL	UEDIN
2021	News article 9/11/2021 on newestccus.eu website: https://www.newestccus.eu/news/waste-energy-sector-gains-support-under-uk%E2%80%99s-carbon-capture-business-models ;	NL	UEDIN
2021	News article 11/11/2021 on newestccus.eu website: https://www.newestccus.eu/news/waste-sector-trade-body-joins-newest-ccus-advisory-group ;	NL	UEDIN
2022	News article 1/02/2022 on newestccus.eu website: https://www.newestccus.eu/news/technology-insight-4-tno%E2%80%99s-miniplant-onsite-co2-capture-services ;	NLV	UEDIN TNO
2022	News article 8/02/2022 on newestccus.eu website: https://www.newestccus.eu/news/no-time-waste-wte-operators-netherlands-turn-heat-decarbonisation ;	NL	UEDIN TNO
2022	News article 21/02/2022 on newestccus.eu website: https://www.newestccus.eu/news/blog-unlocking-power-co2-capture-solvents-waste-energy ;	NL	UEDIN TNO
2022	News article 25/03/2022 on newestccus.eu website: https://www.newestccus.eu/news/oslo%E2%80%99s-klemetsrud-project-secures-financing-significant-boost-waste-energy-and-ccs ;	NL	UEDIN SER
2022	News article 21/07/2022 on newestccus.eu website: https://www.newestccus.eu/news/momentum-builds-ccus-energy-waste-sector-across-europe ;	NL	UEDIN
2022	News article 12/08/2022 on newestccus.eu website: https://www.newestccus.eu/news/cewep-highlights-negative-emissions-potential-european-waste-energy ;	NL	UEDIN
2023	News article 19/01/2023 on newestccus.eu website: https://www.newestccus.eu/news/newest-ccus-researchers-explore-potential-lift-capture-rates-and-generate-heat-district-heating ;	NL	UEDIN
2023	News article 1/02/2023 on newestccus.eu website: https://www.newestccus.eu/news/newest-researchers-interviewed-oxford-institute-energy-studies-podcast ;	NL	UEDIN
2023	News article 21/02/2023 on newestccus.eu website: https://www.newestccus.eu/news/partner-news-carbon-clean-joins-flue2chem-project-convert-industrial-waste-gases-more ;	NL	UEDIN
2023	News article 27/02/2023 on newestccus.eu website: https://www.newestccus.eu/news/paving-path-negative-emissions-waste-energy-facilities ;	NL	UEDIN

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2023	News article/video 28/02/2023 on newestccus.eu website: https://www.newestccus.eu/news/experiments-terc-facilities-video ;	NLV	UEDIN
2022	Presentation of TNO's onsite CO2 capture service for industry on video: https://www.youtube.com/watch?v=x1-Jit1oNMw&t=22s	NLV	TNO UEDIN
2020	Technology Insight one, 17/04/2020 ; https://newestccus.eu/sites/default/files/newest-technology-insight-1-pact-uosh-final.pdf	TB	UEDIN
2020	Technology Insight two, 23/09/2020 ; https://newestccus.eu/sites/default/files/20200910_newest_technologybulletin_ustutt_final.pdf ;	TB	UEDIN
2021	Technology Insight three, 28/07/2021 ; https://newestccus.eu/sites/default/files/newest-technology-insight-3-sintef-final.pdf ;	TB	UEDIN
2022	Technology Insight four, 01/02/2022 ; https://newestccus.eu/sites/default/files/newest-technology-insight-4-tno-facilities.pdf ;	TB	UEDIN
2023	OIES Podcast – Carbon Capture from the Waste to Energy Sector, February 2023; https://www.oxfordenergy.org/publications/oies-podcast-carbon-capture-from-the-waste-to-energy-sector/ ;	Pod	USHEFF

*Type of publication: SPa =Peer reviewed Paper, PPa = Popular science presentation, Pat = Pattent application, Po = Poster, OPa = Oral presentation and paper, PoPa = Poster and Paper, O = Oral presentation, Web = Webinar, WS = WorkShop, V = Video,A = Abstract, B = Blog, I = Interview, PR = Press Release, Oth = Other (Newsletters articles = NL, Technology Bulletin = TB, Podcast = Pod)

The project was initiated by 6 partners from 4 countries. Following a continual process for end-user engagement, the project reached out to industry players, waste-to-energy plants operators, waste fuel producers, representatives of governmental environmental organisations, trade associations, and established a group of 30 organisations which contributed to the work achieved by NEWEST-CCUS. To name only a few:

The Confederation of European Waste-to-Energy Plants (CEWEP), contributed to all NEWEST-CCUS technical meetings, attending presentations and discussions. The project partners have built a strong and lasting relationship with CEWEP and agreed to work together in the future to inform industry members, policy makers and the general public and make recommendations on Policy to facilitate the adoption on CCUS technologies by the WtE sector.

Hafslund Oslo Celsio AS (ex FORTUM Olso Varme), took part in several technical meetings organised by the project, presenting their CCS project and discussing with project partners and other members of the EAG.

ARC, contributed to several technical meetings organised by the project. ARC receives combustible waste from approximately 600,000 citizens and 68,000 businesses, and supplies electricity and district heating back to the city. Waste that cannot be recycled is used at Amager Bakke to produce electricity and district heating for homes and companies in the Danish capital.

RENOVA, was an active and enthusiastic member of the EAG. The Renova Group is owned by ten municipalities in western Sweden and has facilities for treatment and sorting of waste and recyclable material in western Sweden.

Co-funded by the European Commission within the Horizon 2020

BIR, contributed actively to technical meetings and general assemblies organised by the project, with presentation, and with taking part in project discussions. BIR Avfallsenergi AS is a part of the BIR group, a waste company owned by nine Norwegian municipalities, including the city of Bergen

The Environmental Services Association, the UK's waste management association, was invited to the project's expert advisory group. ESA participated to technical meetings and contributed to discussion.

Government consultation. The project coordinated a consultation response on "The role of incineration in the waste hierarchy", in which the project partners stated that:

1. Waste incineration with heat recovery is the only technology that can handle bulk, heterogeneous, mixed, residual waste
2. Waste incineration with heat recovery should only be used for non-recyclable waste fractions that cannot be treated otherwise
3. Waste incineration produce 0.7 to 1.7 tones of CO_2 per tone of waste a typical large plant emits 0.5 Mt CO_2 per year
4. CCS can be retrofitted to an incineration plant and capture 99.7 %, preventing the CO_2 emitted by the plant reaching the atmosphere, and storing it securely and permanently in deep geological formations
5. Captured and stored CO_2 from the biogenic fraction of waste (about 50%) that is combusted counts as a greenhouse gas removal

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Annex 6: Final financial report

ACT Final Financial Report:									
Project name:									
Project number	No 299683								
Actual costs per country / per organisation									
Country	**ACT funding**	**Other public funds**	**Private funding, R&D institution**	**Private funding, industry**	**In-kind, R&D**	**In-kind industry**	**Other funds**	**Total after 3 years per org**	**Total after 3 years per country**
United Kingdom (k€)									**1,159,442**
The University of Edinburgh	501,040	87,913						588,953	
Carbon Clean						83,760		83,760	
The University of Sheffield	396,229	90,500						486,729	
Norway (k€)									**386,700**
Sintef Energy Research	350,100							350,100	
STATKRAFT VARME AS						7,100		7,100	
OSLO KOMMUNE ENERGIGJENVINNINGSETATEN						5,000		5,000	
RETURKRAFT AS						8,300		8,300	
AIR PRODUCTS AS						7,400		7,400	
BIR AS						8,800		8,800	
The Netherlands (k€)									**642,399**
TNO	431,987				210,412			642,399	
Germany (k€)									**398,127**
University of Stuttgart	318,502					79,625		398,127	
Total per funding	**1997858**	**178413**			**210412**	**199985**			**2586668**