NET-ZERO INDUSTRIES
MISSION

Project Title	**Advanced Carbon Capture for Steel Industries Integrated in CCUS Clusters (C4U)**
Industry Partner	ArcelorMittal Carmeuse Technologies Johnson Matthey Kisuma Chemicals BV
Industry Sector	Iron & Steel
Technology Pathway (Primary)	CCUS
NIM Pillar	Technology Demonstration
Source	NIM Awards 2024
Description	Funded by the EC H2020 Program and ranking 1st in the specific Call, C4U is an interdisciplinary holistic project involving collaboration between leading industrial end users, technology developers, engineers, social scientists, policy & business specialists across 8 countries in Europe, Canada, China and USA. The project addresses all the essential elements required for the optimal integration of CO2 capture in the iron and steel industry as part of CCUS industrial clusters. The above involves the successful development & extensive TRL7 demonstration of two highly energy efficient, cost competitive, and environmentally benign solid sorbent CO2 capture technologies, CASOH (Calcium Assisted Steel mill Off-gas Hydrogen production) & DISPLACE (high temperature sorption-DISPLACEment process using hydrotalcites for CO2 sorption and recovery of steam), for decarbonising blast furnace gas, and other emission sources, targeting up to 94% of the total emissions along with their optimal design for full scale integration into the world's largest iron and steel manufacturer ArcelorMittal plants. Using a whole system approach, C4U accounts for the impact of the quality of the captured CO2 on the safety and operation of the CO2 pipeline transportation network & storage infrastructure, while also exploring utilisation opportunities based on integration into the North Sea Port CCUS industrial cluster. Recognising the fact that CCUS in the steel industry will not materialise in the EU without overcoming social-economic barriers, we have developed innovative long-term risk based business models, strategic marketing plans & life cycle assessment for the industrial cluster. We have also developed societal readiness narratives through research and engagement with the variety of relevant end users, local stakeholders and policy makers to help accelerate CCUS rollout.
Innovations Employed	From a technological perspective, the diverse characteristics and vast quantities of CO2 streams present significant challenges for efficient decarbonization, necessitating dedicated capture technologies. High energy penalties, capture medium durability, and environmental impact are major drawbacks to be addressed. C4U tackles 94% of the emitted CO2 streams by employing two capture technologies that use environmentally benign and highly stable gas-solid separation/regeneration processes. These technologies utilize

NET-ZERO INDUSTRIES
MISSION

Project Title	**Advanced Carbon Capture for Steel Industries Integrated in CCUS Clusters (C4U)**
	hydrotalcites and pioneering Ca-Cu looping to significantly reduce the energy penalty through their ability to: 1. recover heat at very high temperatures, which can then be used for energy demanding processes within the steel plant (e.g., reheating furnaces and CO2 free power generation) 2. co-produce H2/N2 fuel, which can contribute to the decarbonization of energy intensive processes in the steel mill or be used in the manufacture of high value products
Dimension of Novelty	It was new to the International Market
Innovation Collaboration	University College London (UCL) (UK) Swerim (Sweden) Radboud University (Netherlands) Spanish National Research Council (Spain) University of Manchester (UK) POLIMI (Italy) TNO (Netherlands) ERM Federal Institute for Geosciences and Natural Resources (Germany) INFERIS (France) Centre for European Studies (Belgium) Wood (Italy) Climate Strategies
Intellectual Properties	The background IP relating to the CASOH and DISPLACE capture technologies are subject to European & US patents, EP09382169, US8506915B2, EP2305366B1 & US20150014595A1 held by the project partners CSIC & TNO. Knowledge management & IPR are overseen by the project's Innovation Management & Exploitation Board paying special attention to the identification of the Foreground contributed to the project. IP is managed according to the C4U Consortium Agreement, which includes Background list. Provisions are in place for access rights to both pre-existing and new knowledge. The ownership of new results is discussed and agreed within the Core Management Team, taking into account the partners' efforts. All project partners have access to all results for further developments and implementation into products, processes & services framed within dedicated agreements between the results owner(s) and the user specifying the purpose and terms of use, as well as confidentiality conditions.
IP Links	
Timetable & Progress	Development started 2014-2015 Both the DISPLACE and CASOH capture systems have undergone extensive pre-commercial scale TRL7 test campaigns under real industrial settings respectively

NET-ZERO INDUSTRIES
MISSION

Project Title	**Advanced Carbon Capture for Steel Industries Integrated in CCUS Clusters (C4U)**
	decarbonising 800 Nm3/hr & 300 Nm3/h of steel mill Blast Furnace Gases (BFG; see Results section).
Financing (Public/ Private)	The project received EC funding in April 2020 through the Horizon 2020 pro-gramme Call: H2020-LC-SC3-2018-2019-2020 (BUILDING A LOW-CARBON, CLIMATE RESILIENT FUTURE.
Finance Links	https://cordis.europa.eu/project/id/884418/results
Project Phase TRL	TRL 7
Problems to be Solved and Risks to be Managed	• Exceeding allocated budget for the construction of both pilots • Delays in procurement of key components & materials for the construction of pilots due to COVID & abiding by in-house purchasing rules • Attracting suppliers' interest in the fabrication of bespoke one-off pilot scale components • Uniform heat distribution in pilot reactors • Failure of the CASOH pilot high pressure BLast Furnace Gas (BFG) preheater • Gas leakage from the CASOH reactor seal gasket • Representative sampling of gases targeted for CO2 capture & the CO2 product stream & their accurate onsite composition analysis • Reaching target economic and energy performance indicators for the industrial scale, integrated processes • Stakeholder fatigue during societal readiness & system dynamics interviews • Main project risk: Balancing the different technological, economic, societal & safety requirements to ensure successful deployment.
Preliminary or Final Results Achieved	CASOH has so far accumulated 550 hrs (another 1450 hrs ongoing) TRL7 operation achieving a remarkable 98% decarbonisation of BFG from ArcelorMittal plant, converting CO to CO2 and capturing it with CaO. With CO2 levels reaching <1% in the H2/N2 product gas, minimal heat losses, excellent capture material performance & high purity CO2 recovery during calcination stages, CASOH stands out as a promising breakthrough technology for the decarbonisation of the steel industry. DISPLACE has undergone 3 test campaigns:C4U-SEWGS (Sorption Enhanced Water Gas Shift), C4U- Walking Beam Furnace& C4U-DISPLACE, accumulating 2000 hrs 24/7 operation. The C4U-SEWGS campaign marks a pioneering achievement in using recycled & decarbonised gases for reheating steel, showcasing smooth catalyst activation & flexible operation for various steam-to-carbon and capture ratios. The C4U-DISPLACE campaign demonstrated post combustion CO2 capture at >98% purity, demonstrating excellent TRL7 performance.
CO2 Emissions Reduction Potential - Implementation and Future Market	The C4U business model presented in the project's Exploitation and Dissemination Plan, is based on direct sales & third party exclusive and/or non-exclusive royalty bearing licensing of its commercially exploitable products. These outputs include its capture technologies, CO2 solid sorbent materials and cluster pipeline network flow simulation software.

NET-ZERO INDUSTRIES
MISSION

Project Title	**Advanced Carbon Capture for Steel Industries Integrated in CCUS Clusters (C4U)**
	Assuming an average EU steel production of 168 Mt/year, the estimated CO2 emission reduction potential during 2030-2050 through the deployment of C4U capture technologies is ca. 823 Mt. With this in mind, an Exploitation Roadmap identifying the follow-up path from the project's status at TRL7 to TRL9 deployment by 2032 is being produced. A high level licensing revenue forecast for each C4U capture technology based on installing in ~50% of the total 45 primary steel making sites (BF/BOF route) in EU-28 member countries by 2050, is estimated at €255 million, assuming 3% of the estimated full-scale CAPEX at TRL9.
Market Positioning	The C4U capture technologies will be targeted for manufacturing and licensing to major power sector technology providers such as Mitsubishi, WOOD (a current C4U partner), TechnipFMC, Davy Process Technology, Thyssenkrupp Industrial Solutions, and Worley. These companies will be invited to the C4U Commercial Exploitation Conference, hosted by partner CEPS in Brussels on March 25. Additionally, the C4U capture technologies can contribute in several ways to generate value and create new market opportunities: • avoided CO2 emissions for end-users, reducing costs in the presence of a carbon tax • revenues for engineering service contractors (e.g., Wood) related to CO2 capture and associated production units (H2, ammonia, urea, power) • additional revenues for end users (e.g., ArcelorMittal) from value added products (e.g., H2, ammonia, urea, power) derived from off gases • improved social acceptance of the industrial site due to lower carbon impact; and local job creation.
Project Location	North Sea Port CCUS industrial cluster (Belgium / Netherlands)
Project & Technology Links	The C4U Project