CarbNETs: CO_2 Capture, Thermal Energy Management, and Electrification Using Net-Zero Industrial Technologies for Decarbonisation

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Abstract

Decarbonising hard-to-abate industrial sectors requires integrated technological solutions that reach beyond single-process emission reduction and address entire carbon, heat, water and material flows. CarbNETs is a Slovenian flagship research and development programme that deals with CO_2 capture, thermal energy management and electrification using net-zero industrial technologies for decarbonisation. It was designed to accelerate transition from fossil-based industrial systems toward circular, electrified and climate-neutral value chains. The programme connects leading research organisations and industrial partners from emission-intensive sectors, including cement, glass, metals, papermaking, chemicals, advanced materials, mobility, biotechnology and waste management.

CarbNETs is structured around five interconnected pillars: (i) advanced CO_2 capture, (ii) CO_2 conversion to green platform chemicals, (iii) carbon-smart materials from secondary streams, (iv) circular management of waste heat and water, (v) and techno-economic and life-cycle-based process development. The programme will develop technologies from TRL 3 to TRL 6,

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including upgraded hot potassium carbonate absorption, electroswing adsorption, membrane-based CO_2 separation, magnetically heated catalytic reactors, direct electrochemical and photocatalytic CO_2 capture, bio-based sorbents, mineral carbonation, waste heat recovery systems and circular water reuse modules.

The programme targets to improve the performance of industrially relevant processes, including high-efficiency CO_2 capture, rapid sorbent regeneration, production of high added value mineral/organic products from CO_2, dynamic CO_2 conversion compatible with renewable electricity, and recovery of low-grade industrial waste heat. CarbNETs aims to achieve at least 30% waste heat recovery, reduce energy demand for sorbent regeneration by at least 25%, improve process efficiency by at least 15%, and demonstrate measurable CO_2 emission reductions and utilisation through integrated heat utilisation. In parallel, captured CO_2 and secondary raw materials will be converted into value-added products such as green chemicals, biochar, graphene, mineral carbonates and bio-based thermoplastic composites, as well as assessing the potential of obtaining advanced materials from industrial wastewaters.

By combining CO_2 capture, utilisation, electrification, thermal energy management and circular material flows, CarbNETs provides a unique cross-sectoral platform for industrial decarbonisation. Its integrated approach supports the European Green Deal, Fit for 55, the circular economy transition and the development of scalable net-zero industrial technologies. The expected outcomes will include new pilot-scale technologies, circular business models, strengthened science-industry collaboration and practical pathways for reducing emissions in sectors where decarbonisation remains technically and economically challenging.

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