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CCS TECHNOLOGIES AND THE GREEN FUTURE: CLIMATE SOLUTIONS AND GREEN JOBS

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Abstract. The paper takes as its starting point the current climate changes that require the implementation of those technologies that significantly reduce greenhouse gas emissions and carbon capture and storage (CCS) represents one of the most promising solutions for supporting the energy transition and accelerating the decarbonization process. Unlike other green technologies, CCS has the advantage of being able to be applied in industries that are difficult to decarbonize, thus the implementation of these technologies has the potential to contribute decisively to achieving climate objectives, and the development of CCS infrastructure generates significant opportunities, by creating jobs in areas such as engineering, research, construction, monitoring and maintenance of storage systems. CCS is emerging not only as a technological solution to mitigate climate change, but as a strategic element that completes the energy mix and supports the gradual integration of renewable sources, as a catalyst for the structural transformation of the labor market. The integration of these technologies represents a strategic element in the transition to a sustainable economy, with benefits for both the environment and socio-economic development.

Keywords: *climate change, CCS technologies, green jobs, measures, solutions.*

JEL code: *Q54, Q55*

Introduction

CCS technologies play a key role in the transition to a net low carbon economy, thus contributing to achieving global goals to combat global warming. It represents a set of processes designed to capture carbon dioxide (CO_2) emitted into the atmosphere and store it safely underground to prevent the negative effects of climate change. In the long term, the climate benefits are real if the projects are well designed, regulated and monitored - permanence of storage, minimization of leakage.

In addition to its role in mitigating emissions, CCS can facilitate the energy transition by integrating with other innovative technologies, such as carbon capture and utilization (CCU) or blue hydrogen production, which uses natural gas but captures and stores the resulting CO_2. Thus, CCS not only reduces the carbon footprint of existing industries, but also provides a strategic bridge towards a circular economy and net-zero emissions.

CCS is emerging as a major element of the global strategy to combat climate change, complementing energy efficiency efforts, the transition to renewable sources and innovations in the field of direct carbon capture from the atmosphere (DAC - Direct Air Capture).

Implementation of CCS technologies

The implementation of CCS (Carbon Capture and Storage) technologies is a complex process that involves the development of an integrated infrastructure for the capture, transport and safe storage of carbon dioxide (CO_2) emitted by industrial activities and fossil fuel-based power plants. This technology is considered essential for achieving international climate goals, especially in hard-to-decarbonize industries.

For effective implementation, the following are required:

• clear legislative framework – regulations on storage safety, monitoring and long-term accountability are essential;

• financing and incentives – high costs require state support or public-private partnerships;

• public acceptance – informing local communities to avoid social opposition to projects;
• access to infrastructure – pipelines, compressor stations, storage capacities, etc.

Globally, there are operational CCS projects, such as:
• Sleipner (Norway) – one of the first commercial projects, operational since 1996;
• Boundary Dam (Canada) – the first CCS project at a coal-fired power plant;
• Gorgon (Australia) - Natural gas - the largest onshore geological storage project.

At EU level, there are operational/nearly operational CCS/CCUS projects in the EU/European Space (including Norway), 2024–2025 (Table 1)

Table 1: CCS/CCUS Projects in the EU / European Space, 2024-2025

Country	Design	Stage / Observations	Estimated capacity /
Norway	Northern Lights - part of the Longship program	- operational - first CO_2 injection announced for 2025 - represents first complete system integrated CO_2 transport and storage system in Europe	- phase 1: ~1.5 million tons of CO_2/year - planning for expansion up to ~5 million tons/year
Netherlands	Porthos CCS Project	- in construction , almost operational - industrial hub in the Rotterdam area; the first major CCS common infrastructure project in the EU	- investment : ~ € 1.3 billion - capacity >1 million tons of CO_2/year
Sweden / Norway	Stockholm Exergi carbon capture + Northern Lights (cross-border capture and storage)	Joint project - CO_2 capture in Sweden (central bioenergetics Värtaverket), transport and storage in Norway - operationalization estimated : 2028	~800,000 tons of CO_2/year - integration in the Northern Lights network
Denmark	Greensand Project	First Denmark's offshore CCS project - with pilot injections in 2023 and extension until 2025 - partnership with INEOS Wintershall Dea.	initial capacity : ~1.5 million tons of CO_2/year - expansion planned up to 8 million tons/year
Great Britain	Net Zero Teesside & HyNet North West	Advanced industrial projects , funded in part of UK Government (Cluster Sequencing) - in construction phase in 2024–2025	- Teesside: ~4 million tonnes of CO_2/year - HyNet: ~10 million tons of CO_2/year total potential
Germany	Project Delta (Northern Germany)	- in development phase advance - includes infrastructure for transporting CO_2 to offshore deposits in the North Sea	- estimate : ~1 million tons of CO_2/year - collaboration international with Norway
France	Dunkirk CCUS Hub (ArcelorMittal & Air Liquide)	Major industrial project in North France , with capture from the steel mill and offshore storage planned for 2026	Estimate : ~1.5 million tons of CO_2/year - integration with European CO_2 transport networks

Source: Authors' data processing based on Country reports on the implementation of the CCS Directive, 2023

According to the table, it is noted:

• functional projects - among the oldest and most efficient CO_2 capture and storage projects (Sleipner and Snøhvit in Norway), are already operational, which demonstrates the feasibility of CCS technologies;

• projects in development - in advanced stages of development, to become operational in the next 1-2 years (Porthos - Netherlands, Acorn - United Kingdom). They focus on the infrastructure necessary for the transport and storage of CO_2, having a significant capacity and an important impact in reducing industrial emissions;

• future projects - are in the planning or pre-implementation phases, with objectives to reduce emissions in the industrial and energy sectors (in European countries, including Denmark, France, Spain and Italy).

These projects benefit from the support of the European Union and are closely linked to the ecological transition strategies of the respective states.

We can conclude that in terms of the implementation of CCS technologies, progress is noted until 2024, but it is important to note that the implementation of CCS projects is a continuous process and will be influenced by economic, political and technological factors.

Currently, in Romania there are no fully operational “capture + transport + geological storage” projects that work with all components; we have a few pilot projects, feasibility studies, obligations and plans. (Table 2)

Table 2: CCS/CCUS projects in Romania

Project / initiative	Stage	Scope	Observations
Getica CCS	Study / project proposed	CO_2 capture from thermal power plants Turceni , pipeline transport and injection in an aquifer saline in Olten	The project non-functional due to LACK funding and the withdrawal of government support
Petrobrazi – OMV Petrom / ConsenCUS	Pilot / demonstration	Tests CO_2 capture, obtaining high-quality CO_2 purity , and reuse / transformation (use) into a product chemical (potassium formate)	Design under Horizon 2020, which includes a pilot plant at the refinery Petrobras . There is none. still geological storage part operational
ALIGN-CCUS	A national / regional research / planning / feasibility study project	Capture, transport, storage, use, but at the study level in region Oltenia for identification CO_2 transport routes , storage options, including in reserve PETROLEUM	It is not operational ; preparatory role , definition of possible infrastructure , cost estimates , etc.
GeoEcoMar	A project national research / methodology	Develop monitoring methodologies for sites potential geological CO_2 storage sites, identification ANY leaks , etc.	Preparation support for actual storage projects will be started ; part of the infrastructure REQUIRED legislative

Source: Authors' data processing based on Country reports on the implementation of the CCS Directive - Romania, 2023

Table 2 highlights that at this moment, in Romania, regarding CCS/CCUS, there is no fully operational project, with all components, although the geological potential is high. There are pilot projects and advanced studies that could lead to operationalization in the future (after 2025-2030), if financing, regulations and political support are real.

OMV Petrom announced that, starting with 2026-2027, it will allocate significant budgets for carbon capture and storage projects, increasing by 200-300 million euros/year.

EU authorities and current regulations (Net Zero Industry Act) impose significant obligations on large producers (OMV Petrom, Romgaz) regarding CO_2 storage capacity by 2030; companies announce major investment plans, but the transition to these projects depends on financing, infrastructure and agreements (transport, permits).

The report “The Carbon Capture and Storage Opportunity for Romania” – Clean Air Task Force (CATF), recommends the development of a national strategy dedicated to CCS, the establishment of clear targets for CO_2 capture and storage, the development of CCS clusters and the creation of a competitiveness plan for Romanian industry. The Clean Air Task Force (CATF) analysis, from June 2025, confirmed that there are no active CCS projects with all components in Romania, although the geological potential is large.

Solutions and recommendations for improving the implementation of CCS technologies in the European Union

These initiatives demonstrate the applicability of CCS in various industrial sectors and their relevance in supporting global climate goals. Data from 2024 confirm the upward trend in investments and projects at various stages of development.(Table 3)

Table 3: Solutions to improve the implementation of CCS technologies at EU level

No.	Scope of action	Proposed solutions	Specific recommendations for the EU	Expected benefits
1	Legislative framework and regulatory	Simplification and harmonisation of CCS regulations between Member States	Creating a common European framework for the authorisation, transport and storage of CO_2	Reducing bureaucracy and accelerating project implementation
2	Financing and economic incentives	Expansion of funding programs through the Innovation Fund, Horizon Europe, BECCS, etc.	Introducing direct subsidies and tax credits for CCS investments	Increasing economic attractiveness for investors
3	Transportation and storage infrastructure	Development of a cross-border pipeline network and CO_2 storage sites	Coordination between Member States for regional CO_2 hubs	Reducing logistics costs and increasing efficiency
4	Research and technological innovation	Investments in direct air capture (DAC), new absorbent materials, integration of CCS with green hydrogen	Public-private partnerships for developing more efficient CCS solutions	Accelerated technological progress and lower costs
5	Social acceptance and public communication	Information campaigns on the safety and benefits of CCS	Involving local communities in the decision-making process	Increasing public trust and reduction social opposition
6	Integration with other policies EU climate	Synergies between CCS and ETS (EU Emissions Trading System), Net Zero Industry Act, Fit for 55	Introducing clear capture and storage targets in national climate strategies	Coherence and efficiency in achieving climate goals
7	Industrial development and cooperation	Promoting industrial clusters that use CCS	Stimulating cooperation between large industries (energy, cement, steel)	Economies of scale and faster implementation
8	Monitoring and safety	monitoring system of storage sites	The use of satellite technologies and advanced sensors for leak tracking	Ensuring long-term safety and public transparency

Source: Authors' data processing based on Country reports on the implementation of the CCS Directive, 2023

Also, our country has the target of developing a carbon storage capacity of ~ 9 million tons of CO_2/year by 2030, together with companies that produce hydrocarbons (OMV Petrom, Romgaz), which requires the identification of solutions to improve the implementation of CCS technologies at the national level. according to the EU Net Zero Industry Act. (Table 4)

The table provides a detailed and realistic strategy for the adoption of CCS technologies in Romania. Through precise regulations, financial assistance, infrastructure improvements and partnerships between various sectors, Romania has the potential to become a regional leader in the application of these technologies to reduce CO_2 emissions. These initiatives will contribute not only to the achievement of national and European environmental objectives, but also to the creation of a favorable environment for investments in the green technologies sector.

Table 4: Solutions for improving the implementation of CCS technologies in Romania

No.	Scope of action	Proposed solutions	Specific recommendations for Romania	Benefits
1	Legislative framework and regulatory	Developing clear legislation on CO_2 capture, transport and storage	MATCHING the national framework to EU directives and establishment of a CCS regulatory authority	Clarity legally and accelerating pilot projects
2	Financing and economic incentives	Creating a national fund for negative emission technologies	Fundraising European funds (Innovation Fund, PNRR, Horizon Europe) and tax incentives for companies	Financial support for first-time applicants CCS commercial projects
3	Infrastructure and logistics	Mapping of geological storage sites (Black Sea , onshore areas)	Development of an integrated network of CO_2 pipelines at regional level (Romania–Bulgaria–Hungary)	Cost and transportation optimization BORDER
4	Research and innovation	Developing partnerships between universities , institutes and industry	Supporting CCS pilot projects in energy sector, cement and steel	Increasing national innovation capacity and know-how
5	Public acceptance and information	Education campaigns and transparency on CCS safety	Involvement of local authorities and communities in the areas concerned	Increasing public trust and reduction local opposition
6	Climate policies and national strategies	CCS integration in National Energy and Climate Strategy (NECP)	Setting clear targets for annual CO_2 capture and storage	Contribution to achieving 2050 climate goals
7	Industrial partnerships	Creation of CCS industrial clusters (e.g. Oltenia, Galați , Constanța)	Collaboration between the majors emitters and energy infrastructure operators	Fast implementation and cost reduction through synergies
8	Monitoring and safety	Implementation of a storage site surveillance system with sensors and satellite data	Creation of a national public CCS registry with open access	Operational safety and transparency for citizens

Source: Authors' data processing based on Country reports on the implementation of the CCS Directive - Romania, 2023

The impact of widespread use of CCS technologies on job creation

CCS can generate a wide range of jobs — from construction and engineering to operation, monitoring and services. Maximizing socio-economic benefits, however, requires active policies: training, local content, plans for affected communities and financing mechanisms. (Table 5)

having an increased quality:

- will be well paid and qualified (engineers, geologists, technicians), requiring training programs for the local workforce;

- the construction stages will generate many temporary jobs; operation generates fewer permanent jobs, but can be stable over long periods of time.

National Long-Term Strategy: This strategy estimates the creation of 53,000 new jobs by 2050, of which 40% by 2030, in areas such as production, construction, installation, operation and maintenance of renewable energy technologies.

Table 5: Jobs generated by CCS/CCUS projects in Europe

Country / Project	Phase PROJECT	Number of jobs (generated/estimated)
United Kingdom/Net Zero Teesside Power (NZT)	Construction, operation	3,000 seats in construction; operating seats
United Kingdom - Ellesmere Port, decarbonized cement project	Construction , operation captures ~1.2 million tons of CO_2 per year	qualified places
Great Britain/ HynetNorth West project Heidelberg Materials UK	Construction , operation	500 seats in construction phase, protection of ~200 existing places; permanent places in operation
EU area in general (modeling)	Macro - level projections	Estimated ~ 330,000 jobs created + secured (fuel supply, production CCS equipment , operation installations & storage) in scenarios with extended CCS .
UK, CCS transport/storage sector	Estimate for 2025–2030	~ 3,000 direct jobs in an additional year just for transportation & storage , ~ 15,000 direct seats in CCS sector in certain years (if projects develop according to plan)

Source: Authors' data processing based on Recommendations for transitional measures to drive CCS deployment in Europe, 2024

The new jobs that emerge from the implementation of CCS technologies are highlighted as

In Romania, projects being in the planning stage or investment/incipient phase, the probability of jobs is high, but still unclear. (Table 6)

Table 6: Jobs generated by CCS/CCUS projects in Romania

Design	Project / Investments	Jobs	Observations
Romania – OMV Petrom Project / National CCS Strategy	Petrom plans investments in CCS projects of approximately € 100-150 million /year (in 2026-2027), increasing to € 200-300 million /year	There is no data.	Job projection details are needed : both in the design phase , as well as the construction and operation phases
Romania – Heidelberg Materials (Fieni cement factory)	The company announced intention to submit CCS project for the Fieni plant, with onshore storage, financed through the Modernization Fund.	No data available	- Missing resource estimates necessary human resources - There is no deadline when will start operation fill

Source: Economica.net, 2025; e-nergia.ro, 2025

According to Table 6, the OMV Petrom or Heidelberg Materials projects could generate significant jobs if fully implemented — but this depends on regulatory conditions, financing, local capacity, etc.

It is stated that 5.7 million new jobs could be created across Europe by 2030 as a result of accelerated investments in digital and sustainability, according to the Report entitled “Europe’s new dawn - Reinventing industry for future competitiveness” which noted that Europe is well positioned to capitalize on future development opportunities due to its strengths in key industries, including CCS technologies.

Conclusions

Although CCS technologies are still in the early stages of development and deployment, they have great potential to become a key component in the transition to a green economy. Pilot projects are already underway, and ongoing research in the field aims to reduce costs and improve their efficiency.

As CCS technologies are developed and widely deployed in the European Union, the capacity to reduce CO_2 emissions will increase significantly. In addition, some major projects have already been integrated into decarbonisation strategies and play an important role in achieving the EU's 2050 climate neutrality objectives.

CCS technologies are considered essential in the global solution mix to reduce greenhouse gas emissions and meet international climate goals. However, their success depends on economic,

technological and political factors, and the development of a global infrastructure for CO2 storage remains a major challenge.

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