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The *Building momentum for the long-term CCS deployment in the CEE region* project is funded by Iceland, Liechtenstein and Norway through the EEA and Norway Grants Fund for Regional Cooperation.

BUILDING MOMENTUM
FOR THE LONG-TERM CCS DEPLOYMENT
IN THE CEE REGION

CCS National Roadmap

Hungary

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Implemented by: WiseEuropa, BELLONA EUROPA, EPG ENERGY POLICY GROUP, CIVITTA, Institute for European Integration
Supported by: EUROPEUM INSTITUT PRO EVROPSKOU POLITIKU INSTITUTE FOR EUROPEAN POLICY
Co-financed by: NIW
Sfinansowano przez Narodowy Instytut Wolności - Centrum Rozwoju Społeczeństwa Obywatelskiego ze środków Programu Rozwoju Organizacji Obywatelskich na lata 2018 – 2030
PROO

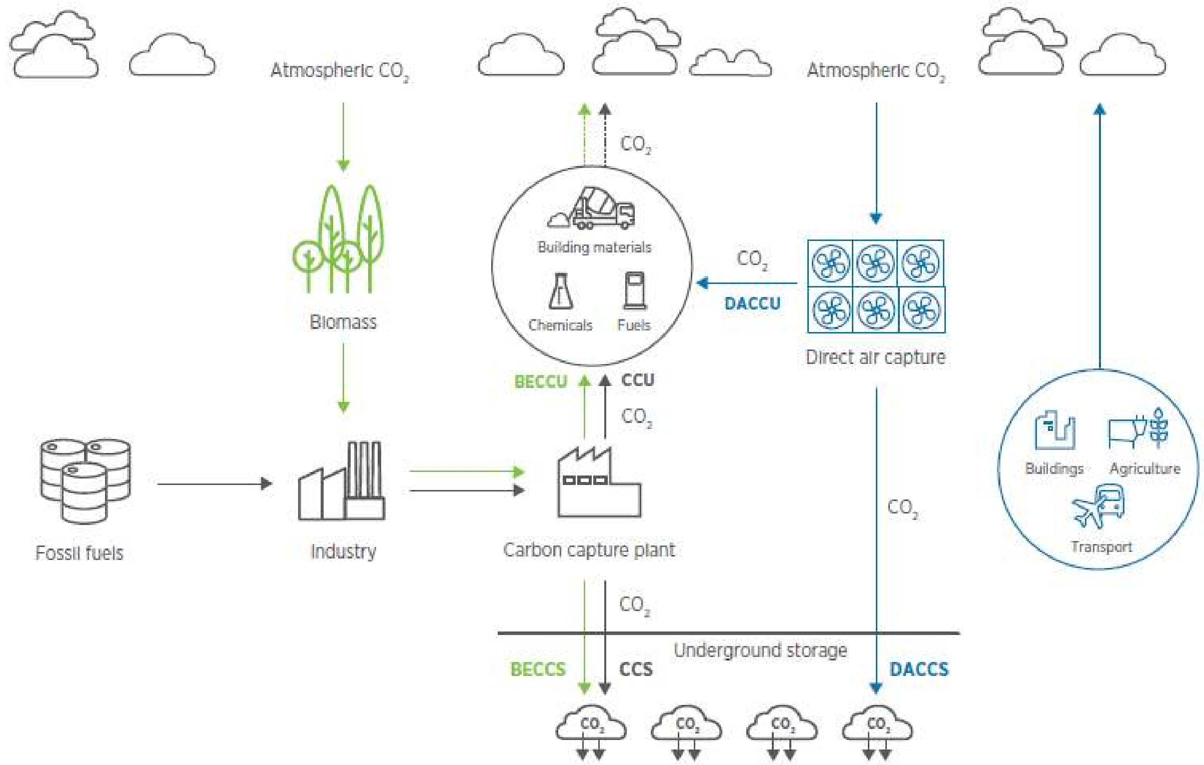
Chapter 1. Role of CCS in decarbonisation pathways

In 2019, the EU launched the European Green Deal to transform the EU into a modern, resource-efficient and competitive economy, cut GHG emissions by at least 55% by 2030 and reach net-zero emissions by 2050. Many 1.5°C compatible scenarios have assessed these targets and shown that a credible but narrow pathway exists and will require the use of all decarbonisation tools available. **Renewables and energy efficiency** are key components of that pathway and account for 80% of emissions reductions and provide solutions to many sectors including power, transport and energy-intensive industries. But to reach net-zero, renewables and energy efficiency **need to be supplemented by CO_2 capture and storage (CCS) and utilisation (CCU) and carbon dioxide removal (CDR)** (particularly bioenergy with CCS/CCU (BECCS/BECCU)) **technologies** (Figure 1) in sectors such as power and heat, cement, steel, chemicals production and waste incineration. In addition, to address emissions from other sources as well as historic emissions, direct air capture with storage (DACCS) or utilisation (DACCU), can also be deployed. These technologies together can mitigate **20% of global CO_2 emissions**, but to do so, **the scale has to increase significantly** (Figure 2), from the current 0.04 Gt of CO_2 per year to circa 8.5 Gt of CO_2 per year in 2050 (IRENA, 2021).

The benefit of CDR processes is that they remove CO_2 from the atmosphere, they do not simply reduce what was added, and in combination with long-term storage can result in negative emissions. As such they are a critical component of net-zero pathways in the European Green Deal and most recently in line with the Glasgow Climate Pact. There are preconditions to be assessed: biomass for BECCS needs to be sourced sustainably, while DACCS requires access to cheap renewable energy.

All these technologies utilise the same components of the value chain: the CO_2 transport, storage and utilisation.

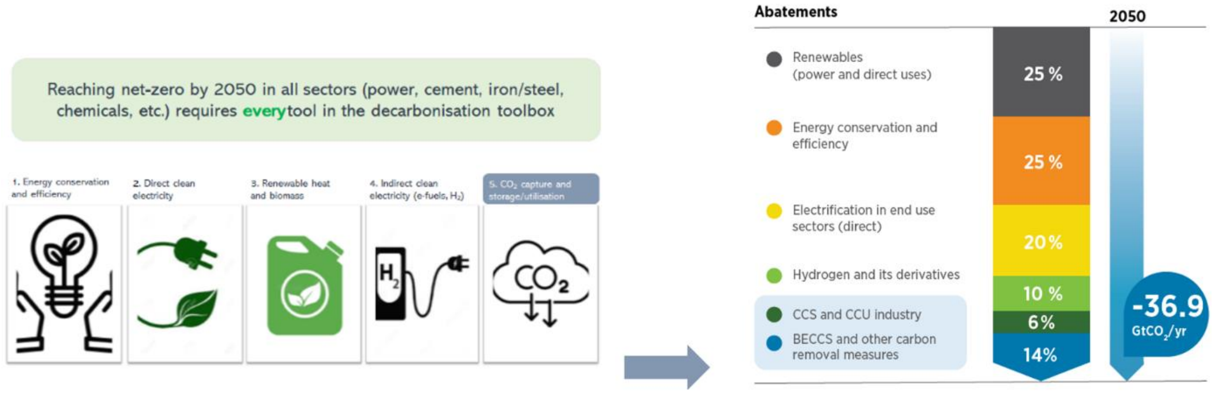
Figure 1: Carbon cycle with the use of CCS/CCU, BECCS/BECCU and DACCS/DACCU technologies[1]



Source: (IRENA, 2021)

[1] https://irena.org/-/media/Files/IRENA/Agency/Technical-Papers/IRENA_Capturing_Carbon_2021.pdf

Figure 2: Carbon capture and storage as a part of the global decarbonisation toolbox[2]



Source: Based on IRENA (2021)

The pace of progress in validating and deploying these technologies across sectors has been slow to date and in many cases with significant costs overruns. There are currently many commercial CCS, CCU and CDR plants globally capturing 40 Mt of CO_2 per year (IRENA, 2021), with many more being developed and an increasing number of pilot and demonstration projects that focus on safety issues, environmental impacts and economic costs, while generating lessons learned to be used to further improve these technologies and bring their costs down.

This current momentum to speed up energy and industrial transition considers these technologies as its necessary component of the transition and **activities at the national and regional levels** may help to **enhance the collective understanding** of the issues surrounding CCS, CCU and CDR, **build confidence** and **scale up their deployment** to **reduce costs** of these technologies and related infrastructure.

Although Hungary does not have a national strategy for implementing CCS/CCU technologies recently the political will to deploy these technologies strengthened. The Hydrogen Strategy published by National Government involves the large-scale production of low-carbon (or blue) hydrogen. The strategy also highlights that a stimulating regulatory environment and support system will be established with regards to the CCS technology associated with hydrogen production. Furthermore, according to the working document of the National Clean Development Strategy looking ahead to 2050 highlights that the widespread deployment of CCUS technologies is required to achieve the climate goals.

[2] Ibid.

Chapter 2. Opportunities and barriers for deployment of CCS and its related technologies in Hungary

Emissions

- Total emissions of greenhouse gases in Hungary have substantially decreased compared to 1990 and 2005; however, they have grown since 2013.
- The total emissions in Hungary reached 64.6 Mt of CO_2-eq in 2019, with the energy sector (including electricity, heat and transport) contributing 72%, industrial processes and product use (IPPU) 12% and agriculture 11%. The waste sector contributed 5%.
- From the manufacturing industries, fuel combustion in the production of iron and steel, cement and chemicals contributed 0.4%, 2.6% and 0.8% of total CO_2 emissions in 2019, respectively.
- In addition to their emissions from fuel combustion, these manufacturing sectors also contributed 2.5% (iron and steel production), 2.1% (cement production) and 4.9% (chemicals production) of total CO_2 emissions in 2019.[3]
- Domestic primary energy supply is dominated by fossil fuels (mostly natural gas and petroleum products) or energy imports; only 16% is met by nuclear and 12% by renewable energy.
- Hungary's largest emitters in 2020 were Mátrai Erőmű (lignite power plant, 4.2 $MtCO_2$), MOL (oil and gas, 3.1 $MtCO_2$), Nitrogénművek (fertilizer, 1 $MtCO_2$), ISD DUNAFERR (iron and steel, 0.7 $MtCO_2$), Királyegyházi Cementgyár (cement, 0.5 $MtCO_2$) and Duna-Dráva Cement (cement, 0.5 $MtCO_2$).

Storage and transport

- The geological potential for CO_2 storage in Hungary is significant (97 Mt CO_2 in depleted hydrocarbon reservoirs and 750 Mt CO_2 in deep saline aquifers).
- Most suitable hydrocarbon reservoirs with high storage potential are mainly located in the vicinity of high emitting industrial polluters in the northern part of the Great Plain or in Southern Hungary.
- Brown coal sites are not suitable due to their geological characteristics (small size, shallow settlement, and connections to open hydrodynamic systems).
- The absence of suitable surface storage and transport systems are important barriers to CCS deployment; although there are experimental demonstration storage facilities, transport to injection sites is not the main activity promoted by the hydrocarbon industry.

Experience

- No classic CCS project has been implemented in Hungary to date; however, the country has been at the forefront of developing Enhanced Oil Recovery (EOR) based on CO_2, and water recapture was pioneered in Hungary in the 1960s, and Enhanced Gas Recovery (EGR) based on CO_2 injection was tested and applied from 1986. Although EOR is not universally classified as a CCU or CCS

3 Data from 2019 is considered more representative then recent 2020 values due to the COVID-19 impacts.

technology, the experience accumulated in EOR applications can be transferred to CCS implementation in the future.

- Hungarian oil and gas company MOL has a proven track record of CO_2 injection underground due to EOR projects, for example in Croatia.
- Nitrogénművek, the largest fertilizer producer in Hungary, would be able to capture 99.99% of its CO_2 emitted, but there have not been customers or storage potential for it yet.
- Hungary has participated in three international EU-funded CCS projects so far:
    - The EU GeoCapacity project, which aimed to apply advanced evaluation techniques and complement the datasets of the subsurface geology of Europe with emissions, infrastructure and storage site mapping to enable source-to-sink matching across Europe
    - The Pan-European coordination action on CO_2 geological storage initiative (CO_2 Geological Storage project), which promoted CCS deployment through networking and cooperation across Member States and Associated Countries
    - The CASTOR project, whose goal was to develop and validate all innovative technologies needed for CCS.
- In addition to these EU projects, the University of Pécs and the University of Miskolc lead research projects including CCS.

Legal and regulatory frameworks

- Hungary integrated Directive 2009/31/EC on the geological storage of CO_2 in May 2012, through a Government Decree aiming to create consistency between the Hungarian regulations on mining, EU ETS, environmental protection, and waste management.
- The key regulatory requirements for the establishment of CO_2 storage are:
    - Storage capacities must be assessed every five years
    - Access to the transport network must be ensured
    - Storage sites must be inspected by both the operator and the Mining Inspectorate.
- Hungary is committed to phase out coal-based electricity production by shutting down the Mátra Power Plant, the only lignite-fired power plant in the country, in 2025.

Stakeholders

- Hungarian industrial stakeholders can be categorized into two groups:
    - Stakeholders who have the potential to implement CCS and a strong interest in its widespread deployment. MOL and Siemens[4] have the potential to deploy CCS technology from the technological or ownership side. MOL plans to reduce its emissions by deploying CCS technology if the economic environment is appropriate.
    - Those large emitters that are sceptical about CCS technologies, but keen to deploy on-site utilization technologies without storage, or simply apply low-carbon technologies. Mostly CCGT-plants, cement factories and the fertilizer company, Nitrogénművek form this group. Nitrogénművek has large amount of high-purity CO_2 which can serve as a marketable product.
- Recommendations from stakeholders include:
    - A clear, transparent and predictable legal framework for the long term
    - The application of mature capture technologies rather than new, lesser-known ones
    - Regional, national and international level collaborations on infrastructural developments

[4] Siemens' CCU innovation aims for the reuse of captured CO2 as a heat transfer medium in a geothermal power plant to be built in the future.

- Project-based support for CCS projects like guaranteed benefit or profit share agreements that could secure the return on investments for industry actors.
- The development of centralized atmospheric CO_2 capture plants based on Direct Air Capture (DAC) in logistically optimal locations without investing in CO_2 transportation infrastructure
- Providing accurate and helpful information to raise public awareness and gain acceptance of CCS technologies.

- A cross-industry coordination needs to be facilitated by the government, to bridge the gap between market players' multidisciplinary competencies. High CO_2 emitters are engaged in CO_2 capture capabilities, but beyond the gates of their industrial facilities they have no competence in how to transport the CO_2 to storage sites, nor in the treatment and injection of CO_2 in the depleted reservoirs.
- There is a risk for market players related to any innovative technologies. Once the government helps kick-start some pilot projects and these projects prove successful, more stakeholders will invest in CCS opportunities.
- Stakeholders think that existing hydrogen technologies equipped with CCS/CCU could complement green hydrogen technologies and accelerate energy transition; however, hydrogen production must become competitive with other products and a stable regulatory environment is also essential.

Social acceptance

- Based on a public consultation launched by the Government in November 2019, 92% of the respondents supported the statement that Hungary had to achieve carbon neutrality by 2050.
- Public awareness of CCS is lower relative to other green technologies.
- Public acceptance is of key importance in deploying CCS technologies in Hungary, given the recent public concern about Paks II nuclear power plant expansion; a large majority of Hungarians fear the risks posed by the project.

National strategies

- According to the working document of the National Clean Development Strategy looking ahead to 2050, CCS and CCUS technologies will have an important role in achieving climate neutrality by 2050; nevertheless, high carbon prices will be key to incentivise large-scale CCS activity in Hungary.
- Hungary announced its National Hydrogen Strategy in June 2021. While on the long term the strategy focuses on green hydrogen, Hungary does not ignore opportunities for low-carbon hydrogen production including hydrogen production with CCS, or blue hydrogen. The strategy highlights that a stimulating regulatory environment and support system will be established for CCS technology required for hydrogen production.

Recent news

- The Paks II nuclear power plant expansion project's licensing has been delayed at the end of September 2021. The Hungarian Atomic Energy Authority (HAEA) prolonged the review deadline of the application as more time was required to verify the documents and asked for more information. Paks II plays crucial role in the National Energy and Climate Plan of Hungary as the currently operating nuclear reactors of Paks I, generating almost the 50% of domestic electricity, are planned to be shut down by 2037. The possible shutdown of Paks II would imply the total rethinking of the Hungarian energy strategy and the potential role of CCS.

Chapter 3. Policy roadmap for the scaled-up deployment of CCS and its related technologies in Hungary

The roadmap provides an overview of various ambitious policy actions along the innovation cycle, from research and development to potential commercialisation of these technologies in order to reach climate targets set by the EU and national strategies. While the roadmap aims to create an enabling environment to deploy CCS projects, it increasingly focuses on ways to develop transferable knowledge and skills by national stakeholders (governments, research organisations, academia, private sector) in one or more stages along the carbon capture, transport, storage and utilisation chain, and create linkages to gain knowledge and experience from more experienced stakeholders across the globe. It also underlines the importance of cross-border activities and joint regional demonstration projects to increase stakeholder access to funding considering their different geographies.

A) Scaling-up RD&D activities and building national knowledge and experience

Key action	Approach	Stakeholders	Timeline
Knowledge platforms	- Facilitate a knowledge platform to promote CCS in Hungary. The primary initiative should come from the government, but technical and market related knowledge sits with the companies who are either large CO_2 emitters or have experience in delivering projects in mining or other geological tasks. [5]	Led by: National government Stakeholders included: energy companies, large CO_2 emitters, academia, NGOs, companies with experience in mining or other geological tasks (technical and market knowledge).	Short-term
Engagement with international fora	- Government should engage more actively in international fora to channel in best practices, regulatory and technological know-how to Hungary. Improve engagement with international fora, join ZEP platform, IEAGHG, Clean Energy Ministerial (and its CCS group), Carbon Sequestration Leadership Forum, EERA CCUS, ECCSEL, European Climate Foundation CCS Hub (for NGOs) and CO_2 GeoNet.[6]	Led by: National government	Short-term

[5] The stakeholders agree that these initiatives should be facilitated at government level due to its complexity and the number of potential stakeholders involved. Market players lack the means of bringing together all stakeholders.
[6] Hungary has been engaged in a few forums so far: (1) GeoCapacity project (2002 -2006); (2) CO_2 Geological Storage project (CGS Europe) (2011-2013); (3) European Value chain for CO_2 (ECCO) (2008-2011); (4) European Strategic Energy Technology Plan (SET-Plan) (2007-).

Identifying industrial hubs/clusters/CO_2 transport networks	- Infrastructure development for CO_2 transport must be coordinated across stakeholders that could be done by the government by establishing a CCS platform where CO_2 emitters, technology providers, companies with capabilities to transport and store CO_2 can devise a plan and deliver CCS projects. - CO_2 transport infrastructure investments to be co-ordinated by the government, but who is best placed to carry out the project depends on the location of the carbon capture, its proximity to storage sites, the best technology option for transportation (pipeline or other modes of transport). Some existing pipeline infratsructure can potentially be repurposed for CO_2 transmission. The role of the government in the infratsructure build-out is co-ordination, facilitation, to establish the best private or public candidates who can implement the CO_2 transportation investments.[7]	Led by: National government, Stakeholders included: large CO_2 emitters, companies with technical knowledge	Short-term
	- Launch cross-industry consultations, and work with existing ones like the Hydrogen Association. Industrial stakeholders need to be involved, because they have a required technology knowledge and project delivery capabilities.	Led by: National government, Stakeholders included: large CO_2 emitters, companies with technical knowledge	

[7] There are industrial CO_2 emitters in Hungary who claim that they are ready for CCS solutions, that the technology is available and financially viable at current market prices and ETS quota prices. They are looking for partners who are capable to transport and store the captured CO_2 because they do not believe that it is their responsibility and tehy are best placed to build the necessary infrastructure to transport CO2 as they do not invest in projects outside their properties. These emitters are a good place to launch CCS projects, but the CCS value chain has to be established, which requires co-ordination and regulatory certainty.

	- Consultations should define the needs of industry players in terms of financing, regulatory environment, technological standards, infrastructure requirements, map out responsibilities. Stakeholders should synchronise their CCS investment plans with each other, establish a timeline consistent with technological capablities, identify those stakeholders for whom the CCS solutions offer the most advantage at the lowest cost. This process should identify the 'low hanging fruits' of the CCS potential, ranging from industrial CO_2 emitters with the highest purity of CO_2, and the proximity to CO_2 storage sites.	Led by: National government, Stakeholders included: large CO_2 emitters, companies with technical knowledge	
Funding and financial support for RD&D projects	- Offer a more stable financial and taxation framework to support CCS projects, including more active innovation grants. Reliable long-term financial support offered to CCS projects are needed. Subsidizing R&D activities related to CO_2 capture or storage could further incentivize innovation.[8]	Led by: National government	Short-term
	- Support pre-financing of CCS projects in the European Union's funding discussions.	Led by: National government	
	- Adopt required legal framework for subsidising CCS projects.[9]	Led by: National government	

[8] There was an initiation to implement a "flag ship" project of CCS in 2009 with the participation of MOL, Matra Power Plant (RWE) and MVM, a collaborative and promising project which finally ended with no success due to low and unpredictable ETS price environment. More certainty about costs and revenues associated with CCS solutions could largely facilitate the viability of this technology. The high risk profile combined with a low expected return on investments work against the business viability of such projects.

[9] The government already aims to establish the regulatory framework for CCS in 2022.

	- Some CCS solutions are thought to be financially viable already at the current ETS prices and investment cost (in case of the 'low-hanging fruits', that is, in case of industrial emitters facing the least cost capture and transport opportunities), but in most cases current ETS levels and expected ETS price volatility do not yet provide sufficient incentives for stakeholders to launch CCS projects. In those cases government is to provide additional financial support through public tendering.	Led by: National government Stakeholders included: MOL, Linde Gáz Magyarország, large CO_2 emitters	
	- Government should respond to the needs expressed by stakeholders, with CCS tenders, clarified regulation, financial support. Government should establish a financing framework which provides credible foundations for long-term project planning by stakeholders. Since the pay-off time of CCS projects tend to be longer than ten years, it is crucial for the financial viablity of these investments to reduce regulatory uncertainty as much as possible.	Led by: National government	
	- Open a tender for pilot CCS projects. The tender can take place by end-2023 if the required legal framework is adopted by the government in 2022.[10]	Led by: National government Stakeholders included: energy companies, large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge)	
	- Provide state funding for the costly exploration of potential storage sites, especially in case of saline acquifers. The exploration of deep saline aquifers is high-cost;	Led by: National government Supported by: Hungarian Mining and Geological Survey (MBFSZ)	

[10] Hungary is lagging behind as several EU Member States have already announced significant national subsidies giving them a competitive advantage in the technology change. Furthermore, Hungarian stakeholders have less appetite to invest in new, immature technologies than others in the region. They demand higher subsidies to take more risk and open to new markets.

	however, the storage potential is vast. Private companies cannot afford to invest in such risky projects.[11]	Stakeholders involved: industrial operators with exploration experience and licenses (e.g. MOL)	
	- Implement the Carbon Contracts for Differences (CCfD) mechanism that bridges the cost gap between conventional and low carbon alternative technologies.[12]	Led by. National government	
Storage site exploration	- Conduct more geological exploration on saline aquifers and depleted hydrocarbon reservoirs. [13]	Led by: Hungarian Mining and Geological Survey (MBFSZ) Supported by: National government Stakeholders involved: industrial operators with exploration experience and licenses (e.g. MOL)	Short-term
	- In-depth exploration of specific storage sites (both depleted gas reserves and aquifers) and calculate the actual implementation costs of CCS.[14]	Led by: Hungarian Mining and Geological Survey (MBFSZ)	

[11] In Norway there is great government support for the exploration of new oil fields in exchange of high taxes on extraction. This way oil companies face lower exploration risk but lower reward as well.
[12] The revision of the ETS proposes the use of CCfDs as a complementary instrument within the Innovation Fund (revision-eu-ets_with-annex_en_0.pdf (europa.eu) pg. 61).
[13] Currently, about 25 depleted oil and gas fields have been identified as suitable for CO_2 storage. Long-term storage is safer in aquifers as CO_2 dissolves in salty water and mineralizes, but they are not yet explored in Hungary, only theoretical aquifer storage capabilities has been determined which are thought to be quite large.
[14] The potential investors can financially assess the value of a CCS project more accurately if the stes are explored.

		Supported by: National government Stakeholders involved: industrial operators with exploration experience and licenses (e.g. MOL)	
	- Prioritize the use of geological storage sites.[15]	Led by: National government, Hungarian Mining and Geological Survey (MBFSZ)	
Bridging the valley of death	- Establish cross-industry coordination of CCS value chain to benefit from the comparative advantages of the industries, including CO_2 emitters and competent companies for transport and storage.[16]	Led by: National government Stakeholders included: energy companies, large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge)	Short-term
	- Start with small pilot projects and scale up over time. For Hungary it makes sense to start small and upscale over time building on experiences and knowledge gathered in the process, as starting at small scale would come with less risks which makes it more likely to kick-start CCS in Hungary. - Launching pilot CCS projects proves feasibility to investors. There is a risk for market players related to any innovative technologies. Once the government helps to	Led by: Large CO2 emitters with technological knowledge and capacity (e.g., MOL) Supported by: National government, Hungarian Mining and Geological Survey	

[15] Storage sites must be seen as tradable commodities because there are multiple ways to use them (storing CO_2, gas, hydrogen...). Hungary participated in the CASTOR project that, as part of its mission, collected storage data from Hungary and from seven other EU countries and integrated them into a Geographic Information System (GIS).
[16] All aspects of the CCS value chain and the required technological and regulatory requirements are available between stakeholders. The relevant capabilities for transporting CO_2 lie with MOL, FGSZ (the natural gas transmission operator owned by MOL) as well as road freight companies. Storage related capabilities are present in companies with experience in oil and gas extraction, particularly MOL.

	launch some pilot projects and these projects prove successful, more stakeholders will invest in CCS opportunities.		
	- Use existing strong technological and knowledge basis for R&D around CCS (e.g., EOR experience) with lower technology-related risks compared to other unproven decarbonisation solutions.	Led by: companies with experience in mining or other geological tasks (technical and market knowledge)	

B) Policy, standards and regulations

Key action	• Approach	Stakeholders	Timeline
Policies	- Support clear regulatory framework and strict emissions reduction targets at an European level. High ETS prices facilitate the process, but due to their volatility they don't provide strong enough long-term incentives.	Led by: National government	Short-term
	- Inspiration can be found in the past in Hungary (CO_2 used for EOR) and abroad where CCS projects are underway, especially in Norway.[17]	Led by: National government Stakeholders included: large CO_2 emitters	
	- Establish a market for low-carbon alternatives, e.g. requiring the use of low-carbon hydrogen in transportation, or the use of low-carbon fertilisers in agriculture.	Led by: National government Stakeholders included: large CO_2 emitters, fertilizer/steel/cement/energy companies, companies with technological knowledge	
Guidelines and standards	- The government should elaborate a standard licensing process for CCS projects. Administrative burdens for CCS projects are high. There are no guidelines for the licensing process of CCS projects at national or EU level, it is done case-by-case.	Led by: National government Stakeholders included: large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge)	Short-term

[17] The Ministry for Innovation and Technology is planning to go forward with the regulation more proactively than the European Commission by proposing new CCS-related legislation to government and Parliament in 2022. The Ministry sees Norway as an example for building the regulatory framework for CCS projects.

Regulatory framework	- A clear, transparently reliable, and economically predictable regulatory framework with reliable long-term financial support offered to CCS projects is needed. The volatile political support demonstrated by the changing role of CCS in the national plans holds back investment.	Led by: National governments	Short-term
	- Evaluate the legal framework with a test application to explore whether there are gaps or inconsistencies in the CCS application process and to gain experience for both regulatory and market side. The legal framework to start CCS projects is already established; however, it has never been tested in practice.[18]	Led by: Hungarian Mining and Geological Survey Stakeholders included: National government, energy companies, large CO_2 emitters, companies with technological knowledge	
	- Reduce administrative burdens for the construction of new pipelines.[19]	Led by: National governments	
	- Clarify and communicate the role of CCS in the CO_2 emission accounting as part of the EU ETS. Stakeholders are not fully aware of the accounting method for CO_2 emission calculation, they do not know what avoided emissions can be deducted from their account, thus, paying the ETS price for the stored or utilised CO_2 as well.[20]	Led by: National government	

[18] Government Decree on geological storage of CO_2 entered into force in 2012 integrating the EU CCS Directive into the national legislation. It aims to create consistency between the Hungarian regulations on mining, CO_2 quota trading, environmental protection and waste management. Current legal framework and also permitting and royalty systems are set by the Mining Act of 1993 (1993. évi XLVIII. törvény [Bányászati tv.]) and the 203/1998. (XII. 19.) government regulation (Korm. Rendelet a bányászatról szóló 1993. évi XLVIII. törvény végrehajtásáról) on the implementation of the Mining Law. Performing mining activities is strictly regulated by the Hungarian Mining and Geological Survey (MBFSZ).

[19] Some stakeholders believe that only pipeline or railway transportation could be feasible methods to deliver CO_2 to the storage site.

[20] CCS and (to a lesser extent) CCU allows market participants/polluters to avoid purchasing emission allowances as long as CO_2 is stored permanently either in geological formations or chemically bound in a limited number of products.

Strategies for CCS application for industrial decarbonisation and climate neutrality of the economy	- CCS is a required solution to provide low-carbon hydrogen in sufficient volumes to meet the goals set by the National Clean Development Strategy.	Led by: National government Stakeholders included: Companies with technical knowledge and capacity	Short-term
	- Develop the national CCS strategy through consultations with the stakeholders to improve engagement, raise awareness and promote CCS, like in case of hydrogen production.[21]	Led by: National government Stakeholders included: large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge)	
	- The National Energy and Climate Plan can be updated to incorporate the strategy required for CCS roll-out	Led by: National government	
Enabling environment for CO_2 market	- Promote the inclusion of CO_2 mining in the ETS. Since mining high pressure CO_2 is less expensive than CO_2 capture and not covered by the ETS, captured CO_2 can not compete with it in a market for industrial CO_2 (e.g., used in the food industry). While mined high pressure CO_2 is already transportable after extraction, industrial CO_2 must be captured and pressurized before transportation, which makes it more costly and hence less competitive.	Led by. National government	Short-term

[21] The governement sees CCS as an intermediate tool to absorb emissions while the green technologies mature. The main application area of CCS is hydrogen production as the technology to produce green hydrogen is not available at scale yet. The advantage of blue hydrogen is that steam methane reforming and CCS are already available technologies.

	- Promote the phase-out of free allowances in the ETS and communicate clearly their evolution. Although ETS covers industrial emissions, allowances are allocated for free in significant volumes, which weakens the incentives for CCS. If, however, free allocations will be phased out, ETS prices are expected to increase and financial incentives for CCS will strenghten. It is important that these ETS expectations are well communicated to stakeholders.	Led by: National government Stakeholders included: Market players covered by the ETS	
Resilience of CCS strategies	- Set up a department in the Hungarian government responsible for developing a long-term CCS strategy in line with the EU/national climate strategy to make CCS more resilient to changes in regulatory directions.	Led by: National government	Short-term
	- Government should clarify its plans related to the role of CCS in Hungary's long-term decarbonisation plans. Hungarian stakeholders often refer to CCS as a bridging technology until renewables can be deployed at scale nation-wide.	Led by: National government	

C) Stakeholder engagement, cooperation & know-how dissemination

Key action	• Approach	Stakeholders	Timeline
Engagement with stakeholders	- Set up an advocacy platform focusing specifically on the deployment of CCS projects.	Led by: energy companies, large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge).	Short-term
	- Government to hold consultations with CCS stakeholders about the ETS outlook, communicate and educate industry players about the ETS framework, future decarbonisation plans and how CCS-related solutions can fit into Hungary's decarbonisation plans.	Led by: National government	
	- The government should co-ordinate the hydrogen and CO_2 market. The government has the potential to bring the stakeholders together.[22]	Led by: National government Stakeholders included: energy companies, large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge)	

[22] In 2020 the Hydrogen Platform (currently the Hungarian Hydrogen Technology Association) was established to coordinate the building of a hydrogen economy; however, a cooperation with the government is still necessary.

	- Communicate the experience and references related to the assessment and control of CO_2 leakage and geological risks.[23]	Led by: Industry experts Communication target: National government, public	
International/ regional cooperation	- Negotiate inclusion of CCS projects in the Important Projects of Common European Interest (IPCEI) initiative.	Led by: National governments Negotiating partner: European Commission	Short-term
	- Support an EU level CCS strategy in discussions with EU institutions and other Member States.	Led by: National government Stakeholders included: energy companies, large CO_2 emitters, companies with experience in mining or other geological tasks (technical and market knowledge)	
Stakeholder cooperation towards CO_2 market	- Build long-term partnerships with guarantees across companies to optimise the application of CO_2 capture and transport capacities and to ensure that the partnership is beneficial for all parties.[24]	Led by: Large CO_2 emitters, companies with technological knowledge and capacities	Short-term

[23] There are safety concerns which need to be taken very seriously. However, prior and current experience with natural gas storage facilities (there are 5 UGS in Hungary with 6,5 billion m3 working capacity) and also the CO_2 extraction, treatment and injection around 65-year experience in EOR utilization of petroleum industry are very good references to assess and control CO_2 leakage and geological risks.

[24] There is an imbalance in the CO_2 market in Hungary as companies who could capture their CO_2 emissions at low cost do not have the know-how and the infrastructure for the transportation and storage of CO_2, and the ones who would be capable to deploy CCS can only capture CO_2 at a high cost. Hence, a partnership would be required to start a feasible CCS project to further decrease the risks of the project implementation.

D) Social aspects and public support

Key action	• Approach	Stakeholders	Timeline
Build public support	- Leverage the existing public awareness of CO_2 injection to build further public support for CO_2 storage. The potential CCS storage sites are located in areas where the oil industry has been present for a long time. The population in the neighbourhood is familiar with the injection of CO_2 underground because of EOR activities.[25]	Led by: Oil and gas companies with potential storage sites	Short-term
Building awareness	- Start national survey to measure the public awareness of CCS and develop CCS awareness campaigns.[26]	Led by: National government	Short-term
Improving fairness of the decision-making process	- Ensure the long-term support of the local communities and the cooperation with the local authorities.[27]	Led by: Local authorities, large CO_2 emitters Supported by: National government	Short-term
Communication of costs, risks and	- The benefits of CCS could be communicated by providing green certificates to the products where CCS is used to capture CO_2. These certificates	Led by: Large CO_2 emitters	Short-term

[25] In Nagylengyel in 1998 there was an accident related to EOR. The malfunction of an oil well lead to CO_2 leakage and the CO_2 flowed to a populated valley nearby. Three villages had to be evacuated and the repairs took three days. Nevertheless, the accident did not lead to a change in public perception related to CO_2 injection and the operation of the well continued until depletion.

[26] The stakeholders believe that storing CO_2 underground will not inflict public resistance as currently CO_2 is not seen as a harmful substance. Nevertheless, the intensified communication about the negative impact of CO_2 on climate might alter this and it would be seen as a harmful substance.

[27] MOL is already injecting CO_2 underground in a highly populated area in Ivanic, Croatia. The company closely cooperates with the local authorities to ensure good relationship with the local communities. The company supports the community in various ways, e.g., building sport facilities. Furthermore, the company gives job to numerous people, thus, most households are well aware of the benefits and risks of CO_2 injection.

benefits of CCS projects	could give a guarantee to the consumers that CCS helps to reduce emissions.		
Making sure the CCS project fits within the local context	- Assess the risk profiles of the potential storage site during the licensing procedure, ensure that health, safety and environmental risks are assessed and managed.	Led by: Hungarian Mining and Geological Survey	Short-term
Building trust in decision-makers and other relevant stakeholders	- Conduct a pilot project to convince both decision-makers and stakeholders that CCS is a feasible technology to reduce emissions and it is safe.[28]	Industry stakeholders – build pilot project	Short-term

[28] Completing a pilot project would be an important milestone in the deployment of CCS in Hungary since currently there are great uncertainties about the potential costs of capturing, transporting and storing CO2. Furthermore, the pilot project could also prove that CO2 can be stored underground safely, earning public trust, while the financial and social risks are relatively low in case of a small project.

Chapter 4. Next and immediate steps

Regulatory framework

- Set up a new department responsible for CCS in the national government that also facilitates a platform for the stakeholders.
- Regulation must establish a market for low-carbon alternatives, e.g. requiring the use of low-carbon hydrogen in transportation, or the use of low-carbon fertilisers in agriculture. If a market for low-carbon products is established, producers will be more confident that their investments in CCS solutions will pay off. Furthermore, products with lower CO_2 intensity due to CCS need to be identified by low-carbon certificates so that producers of these low-carbon alternatives can market these products accordingly, receiving a higher unit price or incur other market advantages by more favorable contracting terms.
- Details of CCS related regulation need to be worked out, including technical standards for CO_2 capture, transportation and storage solutions, legal framework, subsidies.
  There is an urgent need for the clarification of the role of CCS related projects, especially blue hydrogen, in the European and national climate strategies. According to feedback form stakeholers, blue hydrogen could be the most imporant application of CCS in Hungary. This must include a detailed definition of CCS, low-carbon and green technologies, and communicated clearly to all stakeholders.

Market conditions and coordination

- National governments have a crucial role in coordinating the CO_2 market and in bringing the relevant stakeholders together to realize CCS projects in Hungary. The responsible ministry (currently the Ministry of Innovation and Technology) should facilitate an industry wide CCS platform, integrating the national hydrogen strategy and the role of blue hydrogen with other CCS applications.
- Ensure level playing field in the hydrogen market. Currently there aren't any subsidies for blue hydrogen projects, only for green ones. Although blue hydrogen production is not entirely emission free, it could serve as an interim technology while green technology matures. A subsidy proportional to the avoided emissions could foster the development of a hydrogen market.
- Hydrocarbon reservoirs are well explored but the currently known storage potential is limited. A geological survey should be launched to explore the full potential for CO_2 storage.
- Support clear regulatory framework and strict emissions reduction targets at a European level. Stable and high ETS prices are essential for stakeholders to invest in CCS technologies. Although ETS prices have been at all time high recently, volatility increases the risks associated with the returns of the projects. Stakeholders do not invest in long-term projects as EU regulations and climate targets are uncertain.

Longer-term actions

- Launch small-scale pilot projects located at depleted hydrocarbon reservoirs to prove the feasibility of CCS and build trust in all stakeholders. The pilot project could be built at an emissions source where capture costs are low and is located close to the potential storage sites.
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Iceland Liechtenstein Norway grants

The *Building momentum for the long-term CCS deployment in the CEE region* project is funded by Iceland, Liechtenstein and Norway through the EEA and Norway Grants Fund for Regional Cooperation.

Implemented by: WiseEuropa, Bellona Europa, EPG Energy Policy Group, Civitta, Institute for European Integration

Supported by: Europeum Institut pro evropskou politiku / Institute for European Policy

Co-financed by: NIW

Sfinansowano przez Narodowy Instytut Wolności - Centrum Rozwoju Społeczeństwa Obywatelskiego ze środków Programu Rozwoju Organizacji Obywatelskich na lata 2018 – 2030

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