

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

# CCS National Roadmap

[Slovakia]

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# Chapter 1. The 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 greenhouse gas (GHG) emissions by at least 55% by 2030 and reach net-zero GHG 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, accounting for 80% of emissions reductions. But to reach net-zero emissions, renewables and energy efficiency **need to be supplemented by CO<sub>2</sub> capture and storage (CCS), utilisation (CCU) and carbon dioxide removal (CDR)** (particularly bioenergy with CCS/CCU also known as BECCS/BECCU) **technologies** (Figure 1), particularly in sectors such as cement, chemicals, iron and steel, waste incineration, and power and heat production. To address emissions from other sources as well as historic emissions, the role of direct air capture with storage (DACCS) or utilisation (DACCU) should be further explored. While these technologies are distinct in some ways, they use the same components of the value chain: CO<sub>2</sub> transport, storage and utilisation. Together they can mitigate **20% of global CO<sub>2</sub> emissions**, but to do so, **the scale of their deployment has to increase significantly** (Figure 2) from the current 0.04 gigatonnes (Gt) of CO<sub>2</sub> per year to approximately 8.5 Gt of CO<sub>2</sub> per year in 2050<sup>1</sup>.

The **benefit of CDR processes is that they remove CO<sub>2</sub> from the atmosphere**, 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 COP26 Glasgow Climate Pact. There are however preconditions to be assessed, such as biomass for BECCS needs to be sourced sustainably, while DACCS requires access to abundant and low cost renewable energy.

The pace of progress in validating and deploying these technologies across sectors has been slow to date and in many cases with significant cost overruns. Currently, CCS, CCU and CDR plants **globally capture 40 megatonnes (Mt) of CO<sub>2</sub> per year<sup>2</sup>**, with **many more being developed. An increasing number of pilot and demonstration projects** focus on safety issues, environmental impacts and costs, and generate lessons learned to be used to further improve these technologies and bring their costs down.

To remain on track to reach net-zero emissions by 2050, activities and changes to the current status quo have to be significantly accelerated already in the current decade. That requires **activities at the national and regional levels to enhance the collective understanding** of the issues surrounding CCS, CCU and CDR, **build confidence** and massively **scale up CCS deployment to reduce costs** of these technologies and related infrastructure.

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<sup>1</sup> [https://irena.org/-/media/Files/IRENA/Agency/Technical-Papers/IRENA\\_Capturing\\_Carbon\\_2021.pdf](https://irena.org/-/media/Files/IRENA/Agency/Technical-Papers/IRENA_Capturing_Carbon_2021.pdf)

<sup>2</sup> Ibid.

Figure 1: Carbon cycle with the use of CCS/CCU, BECCS/BECCU and DACCS/DACCU technologies<sup>3</sup>

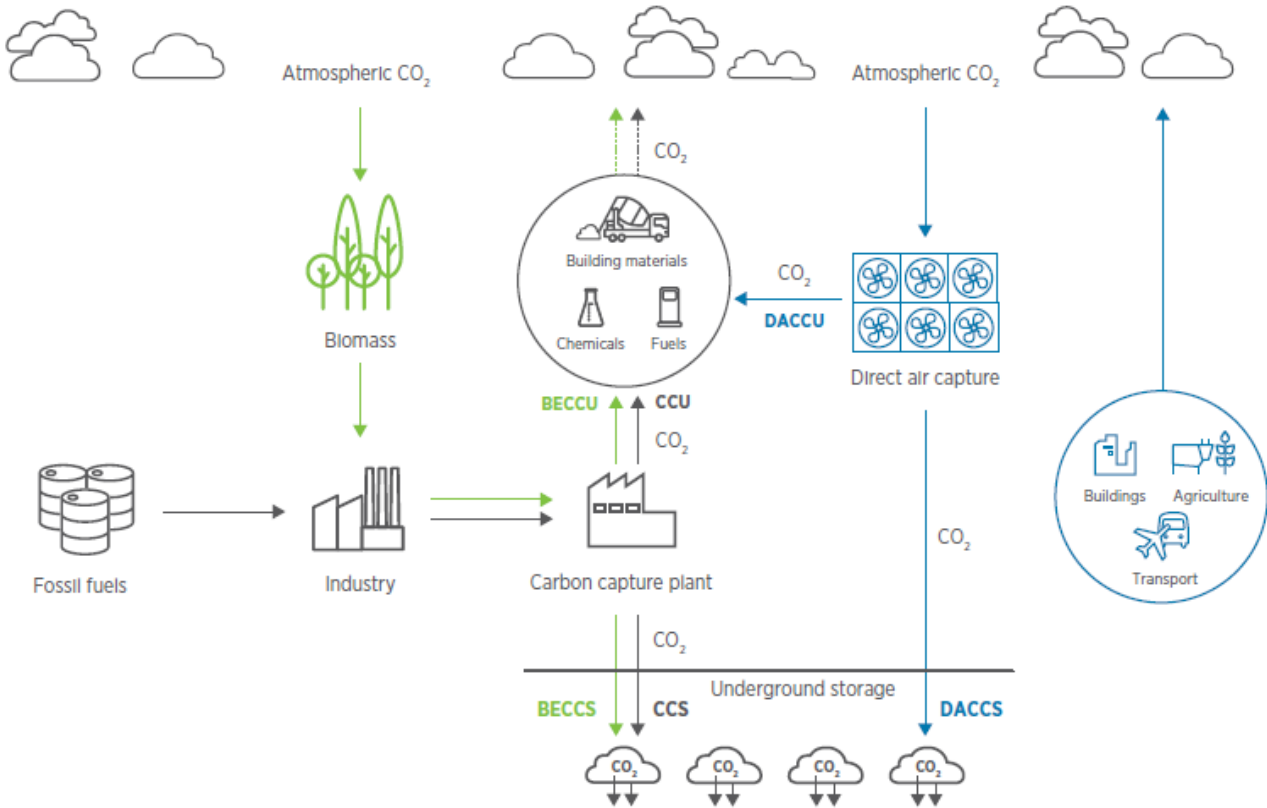
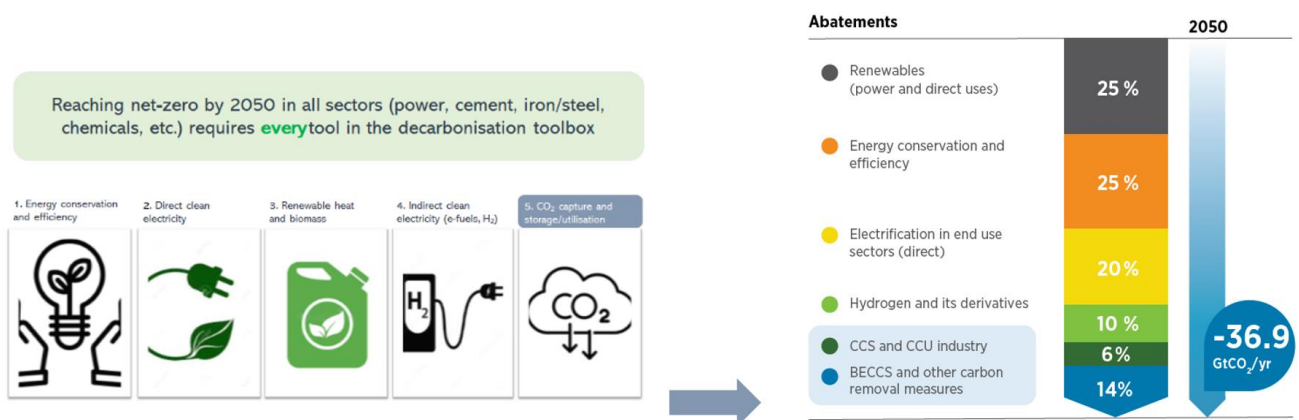


Figure 2: Carbon capture and storage as a part of the global decarbonisation toolbox<sup>4</sup>



<sup>3</sup> Ibid.

<sup>4</sup> Ibid.

## CCS deployment at the European level

The EU has put forward several mechanisms and instruments to enhance the understanding of various decarbonisation pathways consistent with the 1.5°C scenarios and trigger action. One of the mechanisms, the **European Strategic Energy Plan (EU SET-Plan)** aims to accelerate the development and deployment of low-carbon technologies. Its Implementation Working Group 9 (IWG9, or **CCUS SET-Plan**) specifically focuses on **strengthening international cooperation** and **speeding up the deployment** of CCS and CCU technologies. While Slovakia is a member of the EU SET-Plan, it is not a member of the CCUS SET-Plan.

CCUS SET-Plan estimates that under the 1.5°C scenario, **230-430 MtCO<sub>2</sub> per year would have to be captured and stored by 2030. This will increase to 930-1200 MtCO<sub>2</sub> per year in 2050.** BECCS itself would need to be scaled up **to capture and store approximately 30 MtCO<sub>2</sub> per year in 2030, increasing to 400 MtCO<sub>2</sub> per year in 2050**<sup>5</sup>.

In November 2021, CCUS SET-Plan published the CCUS Roadmap to 2030<sup>6</sup>, in which it advocates for the launch of the **EU strategy for CCS and CCU** as a pivotal component of net-zero GHG emissions goals. The Roadmap proposes also amendments to existing plans and regulations including **strengthening the role of CCS in National Energy and Climate Plans (NECPs), Trans-European Networks for Energy (TEN-E) Regulation, CDR accounting scheme and the CCU guidance.**

## Focus on Slovakia – Pathway Modelling

The first-ever study to discuss the decarbonisation pathway for Slovakia has been published in May 2022. A **joint study ‘Decarbonization of the Slovak economy by 2030’<sup>7</sup>** has been developed by **BCG, the Value for Money department under the Ministry of Finance and the Institute for Environmental Policy under the Ministry of Environment.** According to the study, the 2030 target of 55% emission reduction can be reached without CCS. At the same time, the study estimates that **CCS could capture up to 6 megatonnes (Mt) of CO<sub>2</sub> per year by 2030**, but Slovakia would have to rely on CO<sub>2</sub> storage abroad and would need long-distance transport infrastructure in place. However, as we pinpoint later in this roadmap, there is a great potential for local CO<sub>2</sub> storage.

The study also assesses the potential of CCS across the industry, suggesting prioritising the **cement and chemical** production, followed by the **iron and steel** in terms of their abated CO<sub>2</sub>. Considering economics, the study finds **chemical production with CCS cheaper** than cement and iron and steel production with CCS. It also estimates the potential of CCS for power and heat production and finds it the most expensive one with a low CO<sub>2</sub> abatement potential. This finding supports the development at the EU level, which considers power and heat production with CCS only coupled with biomass (BtE<sup>8</sup>) and waste (WtE<sup>9</sup>).

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<sup>5</sup> [https://www.ccus-setplan.eu/wp-content/uploads/2021/03/CCUS-SET-Plan\\_Review-of-CCU-and-CCS-in-future-EU-decarbonisation-scenarios\\_09.2020.pdf](https://www.ccus-setplan.eu/wp-content/uploads/2021/03/CCUS-SET-Plan_Review-of-CCU-and-CCS-in-future-EU-decarbonisation-scenarios_09.2020.pdf)

<sup>6</sup> [https://www.ccus-setplan.eu/wp-content/uploads/2021/11/CCUS-SET-Plan\\_CCUS-Roadmap-2030.pdf](https://www.ccus-setplan.eu/wp-content/uploads/2021/11/CCUS-SET-Plan_CCUS-Roadmap-2030.pdf)

<sup>7</sup> [https://www.mfsr.sk/files/archiv/35/Decarbonization-of-the-Slovak-economy-by-2030\\_study-062022.pdf](https://www.mfsr.sk/files/archiv/35/Decarbonization-of-the-Slovak-economy-by-2030_study-062022.pdf)

<sup>8</sup> Biomass-to-Energy

<sup>9</sup> Waste-to-Energy

## Chapter 2. Opportunities and barriers for deployment of CCS and related technologies in Slovakia<sup>10</sup>

### The energy mix and CO<sub>2</sub> emissions in the power and energy-intensive sectors in Slovakia

The energy mix is dominated by nuclear energy, followed by fossil fuels and hydropower:

Table 1: Slovak energy mix<sup>11</sup>

Nuclear	Fossil fuels	Hydropower	Renewables <sup>12</sup>
54%	22%	16%	8%

In 2018, total emissions were **43,5 MtCO<sub>2</sub>eq** out of which **22% was attributed to industrial processes and product use**, and **18% to manufacturing industries and construction**<sup>13</sup>. In 2019, emissions decreased to **40 MtCO<sub>2</sub>eq** out of which **34 Mt were CO<sub>2</sub> only (85% of total emissions)**<sup>14</sup>.

Table 2: Emission-intensive industries in 2018<sup>15</sup>

Energy and heat in the production of:	MtCO <sub>2</sub>
Steel and iron	3.4
Non-metallic materials (cement, lime and others)	1.5
Chemicals	0.5
Pulp and paper	0.3
Process emissions in the production of <sup>16</sup> :	MtCO <sub>2</sub>
Steel and iron	4.2
Chemicals	1.7
Cement	1.3
Lime	0.5

### Lack of policy and regulation for CCS/CCU

- **The EU CCS Directive** has been **transposed** into the Slovak law by **Act No. 258/2011 Coll.** on the Permanent Storage of Carbon Dioxide in the Geological Environment and Amending Certain Acts.

<sup>10</sup> This chapter is a summary of the national CCS report published under previous Work Package 3 of CCS4CEE project, see: <https://ccs4cee.eu/wp-content/uploads/2021/11/CCS4CEE-Slovakia.pdf>

<sup>11</sup> <https://www.mhsr.sk/uploads/files/BqDDclHi.pdf>

<sup>12</sup> Includes biomass and biogas, wind power, geothermal energy and solar photovoltaics.

<sup>13</sup> <https://faktaoklimatu.cz/infografiky/emise-sr>

<sup>14</sup> <https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>

<sup>15</sup> <https://unfccc.int/documents/227921>

<sup>16</sup> Including emissions from fuels used as a feedstock or for reduction purposes.

- The Ministry of Environment annually updates **areas of permitted geological exploration**. The exploration is limited and subject to the environmental impact assessment, with a **priority given to the storage of hydrocarbons, waste, geothermal and other energy sources**.
- **An implementing decree** of Act No. 258/2011 to regulate financial security for CO<sub>2</sub> storage **is currently missing and should be drafted**.
- **The Low-Carbon Development Strategy of the Slovak Republic until 2030 with a view to 2050** sees CCU and CCS as the last resort from the 26 possible measures to decarbonise the energy sector, which excludes the industry sector but supports CCS and CCU R&D funding.
- **National Energy and Climate Plan (NECP)** considers the use of large natural gas storage and transport infrastructure for future CO<sub>2</sub> storage and transport. This represents only one of the scenarios, with a priority given to natural gas.
- **National Hydrogen Strategy** mentions blue hydrogen as one of the possible ways of hydrogen production. CCS is however mentioned only in an indicative list of projects for basic and applied research. Geological storage research is needed to deploy blue hydrogen infrastructure.
- **The Recovery and Resilience Plan** does not include any reference to CCS or CCU.

### Level of experience in CCS/CCU

#### Research and development (R&D) projects

- Between 2004 and 2020, 5 major projects and studies were carried out.
- Mostly **theoretical exploration and assessment of geological CO<sub>2</sub> storage capacity** have been conducted. Utilisation via **mineral carbonation**<sup>17</sup> has been tested in the State Geological Institute of Dionýz Štúr – Košice. **None of the R&D projects have yet led to pilot projects.**

#### Pilot or demonstration projects

- **No pilot CCS/CCU project yet.** Several key stakeholders (such as SLOVNAFT and Duslo Šala) expressed interest in CCS during stakeholder consultations conducted during the CCS4CEE project. As of December 2021, no concrete steps have been taken.

#### Commercial projects

- **No commercial CCS/CCU project yet.**

### Status of CCS/CCU

#### CO<sub>2</sub> capture

- Due to missing transport, storage, or utilisation infrastructure, no capture projects have been piloted yet.

#### CO<sub>2</sub> transport

- Slovakia has a **large and dense infrastructure for natural gas** including large storage hubs (such as the facility Veľké Kapušany). However, NECP currently refers to them as theoretical CO<sub>2</sub> infrastructure modes. **No study or project focuses on the possibility to retrofit the infrastructure.**
- The prevailing view among stakeholders is the use of pipeline infrastructure for CO<sub>2</sub> transport. **In the short term, a preferred option is the use of railway corridors.**

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<sup>17</sup> Authors refer to this as „artificial carbonatization“, not carbonation.

## CO<sub>2</sub> storage

- The conservative estimate of storage capacity is over **1.7 GtCO<sub>2</sub>** in **saline aquifers**. Such an estimate is accompanied by a high level of uncertainty and requires further exploration. The [EU GeoCapacity project](#) excluded hydrocarbon fields and coal seams from their study due to their shallowness for CO<sub>2</sub> storage.
- Vienna Basin, bordering Czechia and Austria, is the largest hydrocarbon field in Slovakia. The recent ENOS project did not consider it possible storage because **the hydrocarbon fields allow storing only 6 MtCO<sub>2</sub> for CO<sub>2</sub>-EOR**<sup>18</sup>.

## CO<sub>2</sub> utilisation

- **Mineral carbonation** has been tested in the State Geological Institute of Dionýz Štúr – Košice and is considered a feasible way to utilise CO<sub>2</sub> in combination with waste material to create new stable products to further use as industrial materials<sup>19</sup>.

## Public perception

Slovakia has not been part of the EU 2011 Special Barometer on CCS and **no official EU or national public acceptance survey on awareness and perception of CCS has ever been carried out in Slovakia**. The final ENOS report concludes that the position of non-governmental organisations (NGOs) toward CCUS and CO<sub>2</sub>-EOR is generally unknown.

## Key stakeholders and their overall positions

### Research Institutions

- State Geological Institute (ŠGÚDŠ) in Bratislava and Košice and the Slovak Academy of Sciences engage in a **high activity** (pace-setters). ŠGÚDŠ is the main research institute for geological exploration and has been responsible for conducting all previous studies of storage capacities in Slovakia. Košice branch of ŠGÚDŠ focuses on the utilisation technologies including artificial carbonation. State technical universities were not interviewed in WP3.

### Governmental Institutions

- The Ministry of Environment and the Ministry of Economy are two main governmental bodies that should cover the role of CCS deployment but so far have engaged in a **low activity** (fence-sitters). According to the public record, they have not taken any proactive steps for the CCS deployment.

### Private sector

- SLOVNAFT (a part of the MOL parent company) is **very active (pace-setter)**. The US Steel Košice - the largest Slovak CO<sub>2</sub> emitter - engages in a **medium activity** (fence-sitter) and conducted a study on CO<sub>2</sub> carbonation in the past. Duslo Šala is engaged in a **medium activity** and conducted a study on the use of aquifers. Companies VÚRUP and NAFTA engage in a **medium activity** (fence-sitters). Cement company Považská Cementáreň engages in a **low-activity** (foot-dragger) and favours natural sequestration<sup>20</sup> and other decarbonisation technologies.

<sup>18</sup> [http://www.enos-project.eu/media/22618/enos-d67\\_final-version.pdf](http://www.enos-project.eu/media/22618/enos-d67_final-version.pdf)

<sup>19</sup> <https://www.geology.sk/wp-content/uploads/documents/foto/MS/SGM/cc/Slov%20Geo%20Mag%202013-1.pdf>

<sup>20</sup> Sequestration via land use, forestry and natural carbonation of cement products in their life-cycle.



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

The roadmap provides an overview of various ambitious policy actions along the innovation cycle, from research and development to the commercialisation of CCS technologies 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 (government, research organisations, academia and the private sector) and set up channels to access knowledge and exchange experience from international stakeholders. It also underlines the importance of cross-border activities and joint regional demonstration projects to increase stakeholders' prospects to access public and private funding.

## Technical note

Proposed actions are bundled under a common title with each action including a description, relevant stakeholders and a proposed time frame. There is no prescribed order of actions.

- Short-term – actions to be carried out between now and 2025.
- Mid-term – actions to be carried out between 2025 and 2030.
- Long-term – actions to be carried out after 2030.

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

Key action	Number	Approach	Stakeholders	Timeline
<b>Knowledge platforms</b>	A1.1	<ul style="list-style-type: none"> <li>A <b>national CCS-dedicated platform</b> should be created jointly by the private sector and the State Geological Institute (ŠGÚDŠ<sup>21</sup>) in the lead. The platform would be a leading partner in discussions with the government. It could manage an interactive online website in Slovak and English focused on knowledge sharing, targeting national and international stakeholders. The website can be linked to the CCUS SET-Plan website.</li> </ul>	Private sector, NGOs, civil society organisations, research institutions, Ministry of Economy, Ministry of Environment	Short-term
	A1.2	<ul style="list-style-type: none"> <li>The Ministry of Environment, the Ministry of Economy, the Slovak Chamber of Commerce and Industry and the Slovak Investment Holding should support the CCS-dedicated platform and share it via their official websites.</li> </ul>	Ministry of Environment, Ministry of Economy, Slovak Chamber of Commerce and Industry, Slovak Investment Holding, Slovak Investment and Trade Development Agency	Short-term
	A1.3	<ul style="list-style-type: none"> <li>ŠGÚDŠ should engage with <b>Norwegian stakeholders</b> that have been already cooperating closely with the Czech stakeholders. Norwegian research centres could also share their knowledge on the national CCS-dedicated platform.</li> </ul>	ŠGÚDŠ, private sector, NGOs, civil society organisations, research institutions, Ministry of Economy, Ministry of Environment	Short-term
	A1.4	<ul style="list-style-type: none"> <li>The Technical University in Košice, the Comenius University in Bratislava and other institutions and universities together with the private sector</li> </ul>	Universities, research institutions, private sector	Short-term

<sup>21</sup> This abbreviation is used in the rest of the roadmap.

		could cooperate with ŠGÚDŠ on developing new interdisciplinary <b>Bachelor/Master and PhD programmes and curricula</b> covering capture, transport and storage technologies.		
	A1.5	<ul style="list-style-type: none"> <li>The Slovak Government, ŠGÚDŠ and other stakeholders should organise a <b>national-level event to share</b> with the Slovak private sector and the wider public <b>the latest developments in CCS in the industry</b> in neighbouring countries and further afield.</li> </ul>	ŠGÚDŠ, Slovak Academy of Sciences, other research institutions, private sector	Short-term
<b>Engagement with international fora</b>	A2.1	<ul style="list-style-type: none"> <li>Private sector stakeholders, including SLOVNAFT, NAFTA, Duslo Šala, or CRH cementáreň Rozhožník, should join the <b>EU Zero Emission Platform (ZEP)</b> and/or <b>CO<sub>2</sub> Value Europe</b> (focused only on CCU) to benefit from the shared knowledge and have access to networking activities across the EU. The same stakeholder should join the <b>IEAGHG<sup>22</sup></b> to benefit from global knowledge sharing and networking.</li> </ul>	Private sector, research institutions	Short-term
	A2.2	<ul style="list-style-type: none"> <li>The Ministry of Economy should join the <b>global Carbon Sequestration Leadership Forum (CSLF<sup>23</sup>)</b> and disseminate international knowledge and best practice to national stakeholders.</li> </ul>	Ministry of Economy	Short-term
	A2.3	<ul style="list-style-type: none"> <li>The Ministry of Economy should <b>formally join the CCUS SET-Plan<sup>24</sup></b> that focuses on R&amp;I and establish a channel to regularly disseminate knowledge, upcoming activities and plans and actively seek feedback from national stakeholders.</li> </ul>	Ministry of Economy	Short-term
<b>Identifying industrial hubs, clusters, CO<sub>2</sub> transport networks</b>	A3.1	<ul style="list-style-type: none"> <li><b>Municipalities</b> could access the available support from the <b>EU Just Transition Fund regions</b> and include plans for CCS projects for selected waste incineration plants or high-emitting companies.</li> </ul>	Regional government, private sector	Mid-term
	A3.2	<ul style="list-style-type: none"> <li>Through the <b>national CCS-dedicated platform</b>, there should be a university collaboration to deliver the needed research tools, data and knowledge for industrial clusters.</li> </ul>	Universities, private sector, research institutions	Short-term
	A3.3	<ul style="list-style-type: none"> <li>The private sector could communicate the latest CCS development with the government and other institutions to initiate a closer inspection and identification of clusters/hubs in Slovakia, This could lead to recommendations for the government where to focus on cluster development.</li> </ul>	Private sector, research institutions, NGOs, government	Short-term

<sup>22</sup> International Energy Agency (IEA) Greenhouse Gas R&D Programme.

<sup>23</sup> Carbon Sequestration Leadership Forum, see: <https://www.cslforum.org/cslf/>.

<sup>24</sup> Slovakia is a member of the SET-Plan

	A3.4	<ul style="list-style-type: none"> <li>A <b>follow-up study on a cluster</b> identified in the ENOS<sup>25</sup> project on the possible CO<sub>2</sub> transport and possible storage in Czechia or Slovakia should be conducted.</li> </ul>	ŠGÚDŠ, Slovak Academy of Sciences, private sector	Mid-term
	A3.5	<ul style="list-style-type: none"> <li>A new <b>map</b> could reproduce existing knowledge from the EU-level projects (CASTOR, EU GeoCapacity and ENOS) and include further information such as available transport modes, existing infrastructure for gas transport and main road connections from large-scale CO<sub>2</sub> sources. The map could be incorporated into the website of the national CCS-dedicated platform.</li> </ul>	ŠGÚDŠ, Slovak Academy of Sciences, other research institutions	Mid-term
<b>Funding and financial support for RD&amp;D projects</b>	A4.1	<ul style="list-style-type: none"> <li>The government and respective ministries should allow for <b>direct financing</b> of RD&amp;D, pre-feasibility and feasibility studies and the exploration of saline aquifers from the state budget to scale up CCS deployment.</li> </ul>	Government, Ministry of Finance, Ministry of Environment, Ministry of Economy	Short-term
	A4.2	<ul style="list-style-type: none"> <li>The Ministry of Finance and the Ministry of Environment should redistribute revenues from the <b>EU ETS allowances</b> to also support CCS projects.</li> </ul>	Ministry of Finance, Ministry of Environment	Short-term
	A4.3	<ul style="list-style-type: none"> <li>Slovak stakeholders should consult Czech stakeholders to investigate how to <b>access the EEA/Norway Grants</b>. Bilateral cooperation on RD&amp;D CCS projects could be initiated by ŠGÚDŠ or SAV.</li> </ul>	ŠGÚDŠ, Slovak Academy of Sciences, private sector	Mid-term
	A4.4	<ul style="list-style-type: none"> <li>The Ministry of Environment with assistance from the Permanent Representation of Slovakia to the EU should develop <b>guidance</b> for interested stakeholders to <b>access operational programmes, Just Transition Fund, Modernization Fund and Innovation Fund</b>.</li> </ul>	Ministry of Environment, Ministry of Economy, Permanent Representation of Slovakia to the EU	Short-term
	A4.5	<ul style="list-style-type: none"> <li>The Ministry of Economy, the Ministry of Environment and the private sector should regularly invite the <b>European Investment Bank (EIB)</b> to share with national stakeholders the technical and funding process-related expertise, opportunities to access the project development assistance, including loan guarantees and create guidelines based on these recommendations.</li> </ul>	Private sector, Ministry of Finance, Ministry of Environment, EIB	Short-term
	A4.6	<ul style="list-style-type: none"> <li>The private sector should be better informed about the role of EIB as a financial enabler for first demonstration and commercial CCS projects. The Slovak Guarantee and Development Bank and/or Slovak Investment</li> </ul>	Slovak Guarantee and Development Bank, Slovak Investment	Mid-term

<sup>25</sup> Enabling Onshore CO<sub>2</sub> Storage in Europe, see: <http://www.enos-project.eu/>. Project results are briefly explained in previous publication of CCS4CEE project, see: <https://ccs4cee.eu/wp-content/uploads/2021/11/CCS4CEE-Slovakia.pdf>.

		Holding could initiate pilot small-scale capture projects, for example in WtE/BtE sector.	Holding, EIB and financial institutions	
<b>Storage site exploration</b>	A5.1	<ul style="list-style-type: none"> <li>The Ministry of Finance and the Ministry of Environment should allocate appropriate <b>funding to the State Geological Institute</b> to explore the most promising <b>saline aquifer sites</b> and confirm their potential.</li> </ul>	Ministry of Finance, Ministry of Environment, ŠGÚDŠ	Short-term
	A5.2	<ul style="list-style-type: none"> <li>The <b>CO<sub>2</sub> storage permitting process</b> should be incentivised for <b>depleted gas and oil fields</b>. Coal seams could be inspected for CO<sub>2</sub> storage in more detail.</li> </ul>	Ministry of Environment, government	Short-term
	A5.3	<ul style="list-style-type: none"> <li>Project consortia should consult Czech stakeholders to access external funding (EU or <b>EEA/Norway Grants</b>) and use it particularly for the <b>exploration of saline aquifers</b>.</li> </ul>	Private sector, research institutions, NGOs	Mid-term
<b>Bridging valleys of death</b>	A6.1	<ul style="list-style-type: none"> <li>There must be a concerted action at the EU level to pursue <b>PCI</b><sup>26</sup> that would finance the <b>pipeline infrastructure for CO<sub>2</sub> transport</b>.<sup>27</sup></li> </ul>	Ministry of Economy, European Commission, private sector, research institutions, Permanent Representation of Slovakia to the EU	Mid-term
	A6.2	<ul style="list-style-type: none"> <li>PCI could be developed for the CO<sub>2</sub> transport by local oil &amp; gas companies, either to transfer CO<sub>2</sub> to interim storage hubs (as planned in EU CCS Interconnector, Gdansk) or to connect the onshore storage locations with industrial hubs. These could seek the financial support from the <b>CEF</b><sup>28</sup> fund.</li> </ul>	Private sector, research institutions, Permanent Representation of Slovakia to the EU	Long-term
	A6.3	<ul style="list-style-type: none"> <li>The private sector, including SLOVNAFT, could pioneer the CCS technology as part of their strategy. In the case of SLOVNAFT, transport of CO<sub>2</sub> to Hungary could potentially initiate CO<sub>2</sub> capture and transport projects.</li> </ul>	Private sector, research institutions, Ministry of Environment, Ministry of Transport	Mid-term

<sup>26</sup> Project of Common Interest

<sup>27</sup> A new consortium has been launched by the Polish, Slovak, Hungarian and Romanian TSOs – transmission system operators – to develop hydrogen and CO<sub>2</sub> transport

<sup>28</sup> Connecting Europe Facility.

## B) Policy, standards and regulations

Key action	Number	Approach	Stakeholders	Timeline
<b>Policies</b>	B1.1	<ul style="list-style-type: none"> <li>The Slovak government should consult <b>examples of climate and CCS strategies and policies</b> with countries such as the UK, Denmark, Norway and Sweden.</li> </ul>	Government, Ministry of Economy, Ministry of Environment, research institutions	Mid-term
	B1.2	<ul style="list-style-type: none"> <li>The Slovak government should <b>follow the available evidence of CCS importance</b> (IPCC, IEA, IRENA, others) as one of the decarbonisation pathways in tackling climate change and benefiting also country's economy through new foreign direct investments and jobs creation.</li> </ul>	Government, Ministry of Economy, Ministry of Environment	Short-term
<b>Guidelines and standards</b>	B2.1	<ul style="list-style-type: none"> <li>The Ministry of Environment should request the <b>European Commission to publish CCS guidelines</b> on best practices on financial security mechanisms and permitting processes.</li> </ul>	Ministry of Environment, European Commission, Permanent Representation of Slovakia to the EU	Short-term
	B2.2	<ul style="list-style-type: none"> <li>Slovakia should explore the possibility to <b>join the ISO<sup>29</sup> CCS technical committee</b> that would enable it to access global knowledge, communicate such knowledge to national stakeholders and seek their feedback as well as shape standards development within the technical committee.</li> </ul>	ÚNMS <sup>30</sup> , Ministry of Economy	Short-term
<b>Regulatory framework</b>	B3.1	<ul style="list-style-type: none"> <li>The <b>Slovak CCS Act</b> (the transposed EU CCS Directive) should reflect the current CCS development and reconsider the importance of CO<sub>2</sub> storage as a part of decarbonisation pathways to reach net-zero emissions in 2050.</li> </ul>	Ministry of Economy, Ministry of Environment	Short-term
	B3.2	<ul style="list-style-type: none"> <li>The Ministry of Environment should <b>extend the areas with permitted geological exploration for CO<sub>2</sub></b> to enable geological surveys in prospective areas, including on the border with Czechia, Poland and Hungary.</li> </ul>	Ministry of Environment	Short-term

<sup>29</sup> International Organisation for Standardisation

<sup>30</sup> Slovak Office of Standards, Metrology and Testing or Úrad pre normalizáciu, metrológiu a skúšobníctvo Slovenskej republiky.

	B3.3	<ul style="list-style-type: none"> <li>The Ministry of Environment should start drafting the proposal for financial security (“<b>implementing decree</b>” of the Slovak CCS Act) to enable the commercial scale of CO<sub>2</sub> storage.</li> <li>The financial security regulation should support <b>first-movers</b> in CO<sub>2</sub> storage and set the security on a case-by-case basis.</li> </ul>	Ministry of Environment, Ministry of Economy	Short-term
	B3.4	<ul style="list-style-type: none"> <li>The transport of CO<sub>2</sub> by rail, truck and barge must be properly addressed by the TEN-T<sup>31</sup> Regulation which would enable the CCS first-mover to operate CO<sub>2</sub> capture and transport projects connected to the first CO<sub>2</sub> storage facilities.</li> </ul>	Ministry of Transport	Short-term
<b>Strategies for CCS application for industrial decarbonisation and climate neutrality of the economy</b>	B4.1	<ul style="list-style-type: none"> <li>The upcoming updated version of the <b>Slovak Long-Term Strategy for Climate (LTS)</b><sup>32</sup> and <b>National Energy and Climate Plan</b> should reflect the current CCS development. It should include CCS as one of the technologies pivotal to carbon-neutrality.</li> </ul>	Ministry of Economy, Ministry of Environment	Short-term
	B4.2	<ul style="list-style-type: none"> <li>New LTS should prioritise <b>CCS for the industry only</b> and discourage the deployment of CCS in the power sector unless it is biomass or waste-to-energy.</li> </ul>	Ministry of Environment	Short-term
	B4.3	<ul style="list-style-type: none"> <li>The Ministry of Economy, the Ministry of Environment and the Ministry of Investments, Regional Development and Informatisation should <b>jointly develop the national CCS strategy</b> in consultation with the CCS-dedicated platform.</li> </ul>	Ministry of Economy, Ministry of Environment and Ministry of Investments, Regional Development and Informatisation	Short-term
	B4.4	<ul style="list-style-type: none"> <li>Relevant stakeholders should jointly develop <b>sectoral decarbonisation strategies</b>, including for the chemical, cement and iron and steel industries.</li> </ul>	Private sector, Ministry of Economy	Mid-term
	B4.5	<ul style="list-style-type: none"> <li>The Ministry of Environment and the Ministry of Economy should enlarge their teams to include CCS-related tasks.</li> <li>The Ministry of Economy should establish a cross-governmental <b>Working Group</b> specifically focused on the CCS covering all industries.</li> </ul>	Ministry of Economy, Ministry of Environment	Short-term
	B4.6	<ul style="list-style-type: none"> <li>The Ministry of Economy should amend the <b>Slovak Hydrogen Strategy</b> to reflect the current CCS development and the production of <b>blue hydrogen</b>, despite the current natural gas market’s turmoil.</li> </ul>	Ministry of Economy	Short-term

<sup>31</sup> Trans-European Networks for Transport.

<sup>32</sup> The low-carbon development strategy of the Slovak Republic until 2030 with a view to 2050.

	B4.7	<ul style="list-style-type: none"> <li>The Ministry of Environment could promote <b>CCU mineralisation or carbonation activities</b><sup>33</sup> through the operational programmes, Modernisation Fund and Just Transition Fund. ŠGÚDŠ has tested these technologies and would benefit from available funding to bring the projects to the next stages.</li> </ul>	Ministry of Economy, ŠGÚDŠ	Short-term
<b>Enabling environment for CO<sub>2</sub> market</b>	B5.2	<ul style="list-style-type: none"> <li>The Ministry of Environment could negotiate a faster development of the <b>EU CCU guidelines</b> and inclusion of CCU solutions such as mineralisation or carbonation in the revision of the Renewable Energy Directive and the EU ETS.</li> </ul>	Ministry of Environment	Short-term
	B5.3	<ul style="list-style-type: none"> <li>Oil &amp; gas companies with the support of the Ministry of Economy could develop <b>intermediate CO<sub>2</sub> storage hubs for small-scale emitting facilities</b>. The hub would either enable CO<sub>2</sub> to be permanently stored nationally or transported to another storage facility abroad.</li> </ul>	Ministry of Economy, Ministry of Environment, private sector	Mid-term
	B5.4	<ul style="list-style-type: none"> <li>The <b>Slovak and Hungarian</b> governments could develop a <b>joint CO<sub>2</sub> transport strategy</b> to tackle the transboundary CO<sub>2</sub> transport issue. The private sector, including MOL group (SLOVNAFT as part of the group), should become an inherent part of the CO<sub>2</sub> transport route development.</li> </ul>	Government, Ministry of Economy, Ministry of Transport, Ministry of Environment, private sector	Mid-term
<b>Resilience of CCS strategies</b>	B6.1	<ul style="list-style-type: none"> <li>Any <b>amendments to the existing Slovak decarbonisation strategies</b> should reflect the international findings (IPCC, IEA and IRENA) which include CCS in all decarbonisation net-zero scenarios.</li> </ul>	Ministry of Environment, Ministry of Economy	Short-term
	B6.2	<ul style="list-style-type: none"> <li>The Ministry of Economy and the Ministry of Environment should allocate a staff member to cover the CCS topic to avoid any delays in developing and implementing the strategy.</li> </ul>	Ministry of Economy, Ministry of Environment	Short-term
	B6.3	<ul style="list-style-type: none"> <li>The Slovak Long-Term Strategy for Climate should prioritise <b>industrial CCS</b>.</li> </ul>	Ministry of Environment	Short-term

<sup>33</sup> Although they can store only a fraction of the potential of geological storage.



## C) Stakeholder engagement, cooperation & know-how dissemination

Key action	Number	Approach	Stakeholders	Timeline
<b>Engagement with stakeholders</b>	C1.1	<ul style="list-style-type: none"> <li>The national CCS-dedicated platform should benefit from the financial support from the Ministry of Finance and/or the Ministry of Environment. The financial support should be directed to developing a model by the Institute for Environmental Policy or Value for Money department, exploring macroeconomic and environmental consequences of deploying CCS in Slovakia and disseminating findings from such studies to all stakeholder groups.</li> </ul>	Ministry of Finance, Ministry of Environment, private sector, NGOs, civil society organisations, research institutions	Short-term
	C1.2	<ul style="list-style-type: none"> <li>Existing global studies from the IPCC, IEA, IRENA and others should be disseminated and external experts invited to Slovakia to forums, conferences and other events.</li> </ul>	Private sector, NGOs, research institutions, Ministry of Economy, Ministry of Environment	Short-term
<b>International, regional cooperation</b>	C2.1	<ul style="list-style-type: none"> <li>Municipalities and the private sector in <b>regions bordering other countries</b> could explore funding opportunities to estimate the CO<sub>2</sub> transport and storage potential (e.g., the Vienna Basin).</li> </ul>	Regional government, research institutions, private sector	Mid-term
	C2.2	<ul style="list-style-type: none"> <li>Slovak private (chemical/steel/cement) and the public sector should invite industrial stakeholders and research institutions from Norway and other front-running countries to learn the latest developments and best practices and engage with them. SARIO<sup>34</sup> or the Ministry of Economy could plan <b>study trips to countries</b> with deployed pilot and demonstration or commercial plants.</li> </ul>	Ministry of Economy, Ministry of Environment, private sector, research institutions, SARIO	Short-term
<b>Stakeholder cooperation</b>	C3.1	<ul style="list-style-type: none"> <li>The private sector, including SLOVNAFT, NAFTA and Eustream could build gas storage facilities that would enable CO<sub>2</sub> storage from small-scale</li> </ul>	Private sector	Mid-term

<sup>34</sup> Slovak Investment and Trade Development Agency

<b>towards CO<sub>2</sub> market</b>		sources. Larger volumes of CO <sub>2</sub> could be delivered to the permanent storage facilities at a later stage or transported to countries such as Hungary.		
	C3.2	<ul style="list-style-type: none"> <li>Scaling-up capture technologies could happen fast in the <b>chemical</b> sector (e.g., Duslo Šala). They can also use the captured CO<sub>2</sub> as an input in their operations. Slovak stakeholders should consult the Yara plant in Norway that produces ammonia and plans to retrofit its plant with the CO<sub>2</sub> capture.</li> </ul>	Private sector, research institutions	Mid-term
	C3.3	<ul style="list-style-type: none"> <li>The <b>cement and lime</b> sector could consult on pilot and demonstration CO<sub>2</sub> capture projects in Norway (Brevik), Germany (LEILAC 2 project) and Poland (Gorazdze) and seek international and national partners from academia and the private sector to set up a pilot CO<sub>2</sub> capture project in Slovakia.</li> </ul>	Private sector, research institutions	Mid-term

## D) Social aspects and public support

Key action	Number	Approach	Stakeholders	Timeline
<b>Building public support</b>	D1.1	<ul style="list-style-type: none"> <li>The Ministry of Economy and/or Environment and the foreseen CCS-dedicated platform should create a <b>communication strategy</b> to educate the public about the needs, pros and cons of the CCS deployment.</li> </ul>	Ministry of Environment, CCS-dedicated platform, ŠGÚDŠ, Slovak Academy of Sciences	Short-term
	D1.2	<ul style="list-style-type: none"> <li><b>High-emitting industries</b> are at the centre of current decarbonisation efforts. The <b>media</b> would welcome more proactive communication and dissemination of their efforts towards decarbonisation..</li> </ul>	Private sector, NGOs, civil society organisations, research institutions	Short-term
	D1.3	<ul style="list-style-type: none"> <li>ŠGÚDŠ should develop a <b>website dedicated solely to CCS</b> before the CCS-dedicated platform is online.</li> </ul>	ŠGÚDŠ, Slovak Academy of Sciences	Short-term
<b>Building awareness</b>	D2.1	<ul style="list-style-type: none"> <li>Podcasts, blogs and other <b>modern ways of communication</b> should be deployed. National CCS stakeholders should individually and/or collectively explore opportunities in the online world to share findings from their work with international experts.</li> </ul>	Private sector, Ministry of Environment, ŠGÚDŠ, Slovak Academy of Sciences	Short-term
	D2.2	<ul style="list-style-type: none"> <li><b>International experts</b> should be invited to Slovakia by the government and universities to share insights and findings from their work.</li> </ul>	Ministry of Economy, Ministry of environment, research institutions, universities	Short-term
<b>Improving fairness of the decision-making process</b>	D3.1	<ul style="list-style-type: none"> <li><b>Regional</b> governments should use existing schemes of <b>support for local communities</b> living in close vicinity to storage facilities of oil &amp; gas fields, where drilling and exploration happens.</li> </ul>	Regional governments, private sector	Mid-term
	D3.2	<ul style="list-style-type: none"> <li>The oil &amp; gas companies with the support of the State Geological Institute should <b>communicate to the general public</b> the international scientific conclusions on <b>negligible risks from the CO<sub>2</sub> storage leakage</b>.</li> </ul>	Regional governments, private sector, civil society organisations	Short-term
<b>Communication of costs, risks</b>	D4.1	<ul style="list-style-type: none"> <li>The common interest in CO<sub>2</sub> storage facilities should be stressed publicly.</li> </ul>	Ministry of Economy, Ministry of Environment, research institutions, private sector	Short-term

<b>and benefits of CCUS projects</b>				
<b>Making sure the CCS project fits within the local context</b>	D5.1	<ul style="list-style-type: none"> <li>CCS stakeholders can use <b>existing infrastructure</b> for coal and oil &amp; gas (routes for <b>transport</b>, for example), which is already inherently coupled with regions. The alignment with the <b>local needs</b> must be ensured.</li> </ul>	Private sector, regional governments	Mid-term
<b>Building trust in decision-makers and other relevant stakeholders</b>	D6.1	<ul style="list-style-type: none"> <li>The Ministry of Economy and the Ministry of Environment should stress the importance of CCS in the national decarbonisation strategy vis-à-vis the general public including its positive impact on the economy.</li> </ul>	Ministry of Economy, Ministry of Environment, research institutions	Short-term
	D6.2	<ul style="list-style-type: none"> <li>All stakeholders should regularly share success stories from international CCS pilot projects, emphasising the maturity of the technology and existing experience to learn from.</li> </ul>	Research institutions, private sector, Ministry of Environment, Ministry of Economy	Mid-term

## Chapter 4. Next and immediate steps

Despite the constantly rising EU carbon price since 2017, no decarbonisation strategy addressing hard-to-abate industry sectors has been developed by the Slovak government or the private sector. The CCS technology is perceived as an abstract technology and, as a consequence, lacks governmental support. With increasing commitments to reach net-zero emissions by 2050, this perception has started to shift. For the CCS to become a viable option in Slovakia, several conditions need to be met. First and foremost, the transfer of knowledge on the CCS RD&D must be disseminated, including attracting international project leaders to share lessons learned and the latest developments. The government should publicly demonstrate its support for CCS starting with RD&D and include it in the broader decarbonisation strategy.

To continue delving deeper into the technical and economic potential of the CO<sub>2</sub> storage in Slovakia and the required transport infrastructure, all stakeholders need to examine available funding opportunities including external funding in the form of research grants, private investments and direct funding from the government. Thus, the cooperation of all key stakeholders is a prerequisite for the successful deployment of the full-chain CCS projects in Slovakia.

### **Key immediate actions from Chapter 3 to be implemented:**

- The private sector and all key stakeholders should launch the CCS-dedicated platform which would become a strong and stable partner to the government and respective ministries in the debate on CCS development and deployment. The platform would be the main advisor for CCS inclusion in the revision of the state energy and climate strategies.
- The Slovak CCS stakeholders and the foreseen CCS-dedicated platform should join the EU CCS platforms (such as CCUS SET-Plan or ZEP Platform) or consider joining the international ones (IEA GHG, CSFL) to access new knowledge and lessons learned and ways to engage more directly.
- The Slovak government should consult other EU governments, and international platforms and fora to increase collaboration and more frequently disseminate knowledge and practical experience with CCS with national stakeholders at all levels.
- The Ministry of Environment and the Ministry of Economy should publicly recognise the importance of CCS and include CCS in the broader decarbonisation strategies of Slovakia.
- The government and respective ministries should allocate the budget including revenues from the EU ETS to CCS to enable RD&D activities, including pilot projects in CO<sub>2</sub> capture or storage.
- The Ministry of Environment should draft the implementing decree (regulating financial security for CO<sub>2</sub> storage) to the Slovak CCS Act and consider increasing areas with permitted geological exploration for CO<sub>2</sub> storage. The Ministry should give CO<sub>2</sub> storage in geological structures a priority.

