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

Assessment of current state, past experiences and potential for CCS deployment in the CEE region

[Czech Republic]

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Abbreviation	Explanation
BAT	Best Available Techniques
BECCS	Bioenergy carbon capture and storage
CAPEX	Capital expenditures
CCS	Carbon capture and storage
CCS4CEE	Carbon capture and storage for Central and Eastern Europe (project acronym)
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization and storage
CGS	Czech Geological Survey
CO_2eq	CO_2 equivalent
EEA	European Environment Agency
EOR	Enhanced oil recovery
EU ETS	The European Union Emissions Trading System
EVA	Economic value added
GDP	Gross domestic product
GEUS	Geological Survey of Denmark and Greenland
IGCC	integrated gasification combined cycle
IRIS	International Research Institute of Stavanger
NACE	Nomenclature générale des Activités économiques dans les Communautés Européennes
NTNU	Norwegian University of Science and Technology
OPEX	Operating expenditures
PSH	Pumped storage hydroelectricity
SWOT	Strengths, weaknesses, opportunities, and threats (analysis)
TCCS	Trondheim CCS Conference
TRL	Technology Readiness Level
VŠB	Technical University of Ostrava

Table no. 0 - List of abbreviations

Chapter 1. CCS and CCU: current state and past experiences in the Czech Republic

1. Description of relevant domestic economic sectors

The Czech Republic is highly industry-dependent country with large share of automotive industry in the national GDP. In Table no. 1, see the overall GDP of the Czech Republic. In 2019, 25% of the gross value added of the national economy was created in the manufacturing industry.[1]

GDP identity from the production side - 2019 (EUR Million)						
	Output	**Intermediate consumption**	**Gross value added**	**Taxes on products**	**Subsidies on products**	**Gross domestic product**
TOTAL	501,244	299,092	202,152	25,651	-3,882	223,921

Table no. 1 – 2019 GDP (production side)[2]

Carbon intensive industries and their output, as well as net value added, can be seen in Table no. 2, where selected NACE[3] activities are presented. Although the manufacturing of vehicles and machinery is not an emissions-intensive sector per se, one has to remember that other activities, such as manufacturing of metal, plastic or glass products are connected to the automotive sector, too.

As you can see in Table no. 2, the output of vehicle manufacture (NACE 29) has a share of more than 10 % of the total output of the national economy, followed by metal products (NACE 25), machinery and equipment (NACE 28), rubber and plastic products (NACE 22) and chemical products (NACE 20). These industries can be considered those which are the most carbon intensive of the manufacturing sector, alongside the cement industry. Further detail about the emission intensities is given below in Figure no. 1.

According to the financial analysis of Ministry of Industry and Trade for 2019 and representative sample of Czech corporations (2089 corporates with the highest amount of assets), the manufacturing sector had a share of 80% of the total industrial value added and the economic value added (EVA) of EUR 329 million. According to the total sum from the Czech Statistical Office, the manufacturing sector was responsible for almost 90% of the total output of the industry in 2019. See Table no. 3.

[1] https://apl.czso.cz/pll/rocenka/rocenkavyber.makroek_sektor
[2] Ibid.
[3] “Nomenclature générale des Activités économiques dans les Communautés Européennes” - i.e. classification of the economic activities

Non-financial activities - production of 2019 (EUR million)			
	NACE	**Output**	**Gross Value Added**
Mining of:			
Coal and lignite	5	1,344	611
Other	8	745	299
Manufacture of:			
Paper and paper products	17	3,316	958
Chemicals and chemical products	20	11,035	1,882
Basic pharmaceutical products and preparations	21	1,992	812
Rubber and plastic products	22	11,509	3,637
Other non-metallic mineral products	23	6,099	2,304
Basic metals	24	7,473	1,348
Fabricated metal products, except of machinery and equipment	25	15,922	5,802
Machinery and equipment	28	14,614	4,649
Motor vehicles, trailers and semi-trailers	29	51,887	10,812

Table no. 2 – Selected non-financial activities according to NACE[4]

Non-financial corporations – Industry 2019 representative sample (EUR Million)					
	Mining, quarrying	**Manufacturing**	**Energy**	**Water & waste**	**TOTAL**
Revenues	3%	70%	26%	2%	190,777
Net value added	2%	80%	14%	4%	29,818
EVA	-195	329	93	-257	-30
Output*	1%	89%	7%	3%	209,190

*Total industrial output according to Czech Statistical Office

Table no. 3 – Non-financial corporations analysis[5]

1.1. Carbon-intensive sectors of the Czech economy

CO_2eq emissions of 2018 are seen in Table no. 4 according to the report of the European Environment Agency from May 2020[6], and are divided by Eurostat sector divisions. Total CO_2eq emissions in 2018 were 129.39 MtCO_2eq. Comparing the years 2018 and 2003, total emissions experienced a 14% decrease. Although the manufacturing industry witnessed a decrease of 50%, the industrial processes and product use grew by 8% compared to 2003. From the CCS perspective, the most emission intensive industries (steel, refinery, chemical and cement) are included in the category of "Industrial processes and product use" (these could be also partly included in the "Manufacturing industries and construction", yet the division is not precisely set), and the power industry is included in the category of "Energy industries". The sector of

[4] https://apl.czso.cz/pll/rocenka/rocenkavyber.socas
[5] https://www.mpo.cz/cz/rozcestnik/analyticke-materialy-a-statistiky/analyticke-materialy/financni-analyza-podnikove-sfery-za-rok-2019--255382/
[6] https://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-15

"Industrial processes and product use" is then divided into the respective industries in Figure no. 1, which shows how many emissions were attributed to these industries in 2018.

CO_2eq emissions	2003	2008	2013	2018	2003-2018 difference	
Energy industries	62.45	61.53	55.17	51.07	-11.38	-18%
Transportation (incl. aviation)	16.00	19.59	17.11	20.30	+4.3	+27%
Industrial processes and product use	15.01	16.61	14.91	16.26	+1.25	+8%
Institutions, households, agriculture	17.52	13.81	14.33	13.15	-4.37	-25%
Manufacturing industries, construction	19.94	16.20	10.09	9.96	-9.98	-50%
Agriculture	8.04	8.45	7.99	8.61	+0.57	+7%
Waste management	4.29	4.51	5.37	5.70	+1.41	+33%
Others	7.52	7.55	5.70	4.33	-3.19	-42%
TOTAL	**150.76**	**148.25**	**130.66**	**129.39**	**-21.37**	**-14%**

Table no. 4 – Czech CO_2eq emissions from 2003 to 2018[7]

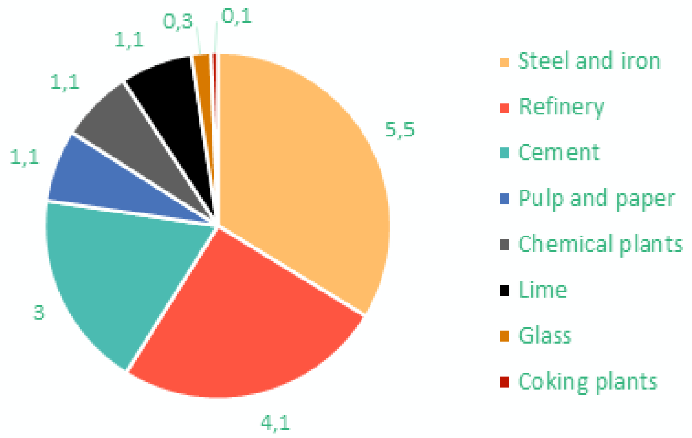

Figure no. 1 – Detail of verified emissions across the industrial sector in 2018 ($MtCO_2eq$)[8]

1.2. Major CO_2 emitters in the Czech Republic

The carbon intensive industries and their corresponding highest emitting corporations can be seen in Table no 5. The aim of the table is to present the companies with the highest verified emission according to the European Commission and the European Union Transaction Log for 2020 and 2019 (EU ETS). Worth noting vis-à-vis the Table is that the emissions statistics provided may represent the number of verified emissions of one legal entity which could have multiple stationary sources of emissions.

[7] https://faktaoklimatu.cz/infografiky/emise-cr
[8] Hladík V. in: https://www.sintef.no/globalassets/project/tccs-11/tccs-11/sproceedings-no-7.pdf

2020 and 2019 verified emission of carbon intensive corporations (ktCO_2eq)					
	2020	2019		**2020**	2019
Steel industry			**Cement industry**		
Třinecké železárny, a.s.	**2,878**	2,694	Českomoravský cement, a.s.	**1,161**	1,241
Liberty Ostrava a.s.	**2,341**	2,455	CEMEX Czech Republic, s.r.o.	**565**	594
VÍTKOVICE STEEL, a.s.	**69.7**	72.1	Cement Hranice, a.s.	**544**	585
Saint-Gobain Construction Products CZ a.s.	**49.6**	50.6	Lafarge Cement, a.s.	**476**	495
Chemical industry*			**Lime Industry**		
Unipetrol RPA, s.r.o. - Petrochemie	**2,230**	2,469	Vápenka Čertovy schody a.s.	**361**	391
UNIPETROL - AGROCHEMIE	**644**	751	Vápenka Vitošov, s.r.o.	**296**	300
UNIPETROL Rafinerie Kralupy	**442**	520	LB Cemix, s.r.o.	**147**	150
UNIPETROL Rafinerie Litvínov	**321**	420	CARMEUSE CZECH REPUBLIC s.r.o.	**96.1**	124
DEZA	**289**	295	HASIT Šumavské vápenice a omítkárny, s.r.o.	**28.1**	29.6
Lovochemie, a.s.	**248**	271			
Paper Industry			**Glass industry**		
Mondi Štětí a.s.	**374**	387	AGC Flat Glass Czech a.s.	**297**	308
KRPA Paper	**30.6**	33.4	O-I Czech Republic, a.s.	**85.0**	85.0
Olšanské papírny akciová společnost	**26.7**	26.3	VETROPACK MORAVIA GLASS	**75.5**	74.9

*Refinery and chemical plants

Table no. 5 – 2020 verified emissions of selected corporations[9]

In relation to the power sector, Czechia remains highly dependent on lignite and nuclear power reactors. According to the Energy Regulatory Office, approximately 40% of the gross output of power plants was generated using lignite and 35% using nuclear power in 2019. See Table no. 6.

Energy source of power plants gross output – 2019						
Lignite	Nuclear	Natural gas	Other gases	Black coal	PSH[10]	Renewables[11]
40%	35%	6%	3%	2%	1%	12%

Table no. 6 – Fuel source of gross output in power plants[12]

The use of coal and natural gas and their respective proportions on the power plant gross output is shown in Table no. 7. This Table shows that there are a very limited number of regions with carbon intensive power plants. The percentages show how large a share of the respective fuel sources in Table no. 6 is used the respective regions.

[9] https://ec.europa.eu/clima/ets/napInstallationInformation.do
[10] Pumped storage hydroelectricity
[11] 3% biogas, 3% biomass, 3% photovoltaic electricity, 2% hydropower, 1% wind electricity
[12] https://www.eru.cz/documents/10540/5381883/Rocni_zprava_provoz_ES_2019.pdf/debe8a88-e780-4c44-8336-a0b7bbd189bc

Share of the sources used in regions – 2019		
Fuel	Share	**Region**
Lignite	58%	Ústecký
	17%	Středočeský
	15%	Pardubický
	6%	Karlovarský
Natural gas	70%	Ústecký
	9%	Moravskoslezský
	9%	Středočeský
Black coal	91%	Moravskoslezský
	6%	Olomoucký

Table no. 7 – Share of the sources from Table no. 6 used across regions[13]

2020 and 2019 verified emissions of power plants in regions (ktCO$_2$eq)							
Karlovarský	MWe	**2020**	2019	Moravskoslezský	MWe	**2020**	2019
Vřesová (lignite + natural gas)	239	**3,264**	3,875	Elektrárna Dětmarovice (black coal)	600	**376**	518
Elektrárna Tisová, a.s. (lignite + natural gas)	289	**415**	609	TAMEH Czech s.r.o. (black coal)	254	**1,649**	1,931
				Elektrárna Třebovice (black coal)	174	**753**	735
Olomoucký				Pardubický			
Teplárna Přerov (lignite + natural gas)	52	**172**	216	Elektrárna Chvaletice a.s. (lignite)	820	**2,242**	3,715
Olomouc (lignite + natural gas)	49,6	**286**	290	Elektrárny Opatovice, a.s. (lignite)	378	**1,455**	1,405
				Synthesia a.s.* (natural gas + lignite)	75	**221**	244
Středočeský				Ústecký			
Elektrárna Mělník 3 (lignite)	500	**722**	1,447	Elektrárna Počerady, a.s. (lignite)	1000	**4,554**	4,717
Kladno (lignite + biomass)	473	**1,749**	1,832	Elektrárna Tušimice 2 (lignite)	800	**3,729**	4,281
Elektrárna Mělník I (lignite)	240	**1,347**	1,178	Elektrárna Prunéřov 2 (lignite)	750	**2,849**	3,222
Tamero Invest* (natural gas)	98,7	**397**	403	Elektrárna Ledvice 4 (lignite)	660	**2,209**	2,449
ŠKO-ENERGO Teplárna Mladá Boleslav* (lignite + biomass)	88	**379**	363	Elektrárna Prunéřov 1 (lignite)	440	**586**	1,906
Elektrárna Mělník 2 (lignite)	?	**861**	1,312	Elektrárna Ledvice (lignite)	110	**535**	223

*Corporate power plants

Table no. 8 – Power and heat plants in regions and their emissions[14]

[13] https://www.mpo.cz/cz/energetika/statistika/energeticke-bilance/krajske-energeticke-bilance--260319/
[14] https://ec.europa.eu/clima/ets/napInstallationInformation.do

Table no. 8 provides data on the individual power plants and their verified emissions in 2020, and also gives an overview about the potential size of the carbon capture market. The power plants and their respective electric power (in MWe, as of 2018) are included in the power plant overview document of the Ministry of Industry and Trade released in 2021. Emissions are verified by the European Commission and the European Union Transaction Log for 2020 and 2019 (EU ETS).

An advisory group to the Czech government called the 'Coal Commission' was founded in 2019 in order to prepare a phasing-out list of the lignite-fueled power plants.[15] Both the Minister of the Environment and the Minister of the Industry and Trade lead the Commission. At the end of 2020, the Commission recommended the Government set the deadline for phasing-out the lignite-fueled power plants in 2038.[16] In May 2021, the Government agreed and ordered the creation of more detailed decarbonization plan regarding the phasing-out of lignite power generation.[17]

- In 2020, Prunéřov I became the first coal-fired power plant to stop operating.[18]
- The phasing-out process will continue in 2021 and 2022; the second lignite-fueled power plant to close will be Mělník 3 this summer, followed by Dětmarovice in late 2022 or 2023.[19]
- Originally, the Počerady power plant was planned to be phased-out in recent years, yet after a change in ownership at the beginning of 2021 – from ČEZ to Sev.en Energy – planning has shifted and the plant will continue operating for a longer time-period, potentially until the planned phase-out in 2038. Modernization of Počerady should start immediately and an exemption from mercury emissions limits (specified by BAT[20]) has been requested by Sev.en Energy for a period of at least 4 years during the modernization.[21]
- Mělník 1 (also coal-fired) was modernized in 2020 in order to comply with the new BAT limits in 2021.[22]
- Modernization of Opatovice finished in 2016. It remains fully lignite-fired and requests the BAT exemption from mercury and nitrogen oxide emissions limits as well. Further modernization towards natural gas use and waste-to-energy is in progress.[23]
- Prunéřov 2 was modernized in 2016 and Tušimice 2 in 2012. Both these lignite-fueled power plants plan to operate until the 2038 phase-out deadline and use all the lignite from their own Libouš mine.[24]

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[15] https://www.mpo.cz/cz/energetika/uhelna-komise/uhelna-komise--248771/
[16] https://www.mpo.cz/assets/cz/rozcestnik/ministerstvo/kalendar-akci-vse/2021/2/Zapis-z-jednani-UK-_4-12-2020_.pdf
[17] https://www.mpo.cz/cz/rozcestnik/pro-media/tiskove-zpravy/doporuceni-uhelne-komise-o-konci-hnedeho-uhli-v-roce-2038-projednala-vlada--261557/
[18] https://energetika.tzb-info.cz/20892-v-cr-byl-oficialne-ukoncen-provoz-prvni-hnedouhelne-elektrarny-prunerov-i
[19] https://moravskoslezsky.denik.cz/podnikani/cez-konci-s-cernym-uhlim-a-zacne-propoustet-domacnosti-na-karvinsku-ceka-plyn-20.html
[20] BAT – Best Available Techniques for combustion power plants set the emission limits for different pollutants. In: https://ec.europa.eu/environment/pdf/31_07_2017_news_en.pdf
[21] https://forbes.cz/elektrarna-pocerady-miliardare-tykace-dostala-emisni-vyjimku-a-vice-casu-na-modernizaci/
[22] https://oenergetice.cz/elektrarny-cr/v-elektrarne-melnik-i-konci-dostavba-odsirovacich-linek-za-15-mld-kc
[23] https://sdeleni.idnes.cz/zpravy/jsou-elektrarny-opatovice-zdrojem-tepla-bez-starosti-i-do-budoucna.A210406_135955_zpr_sdeleni_okov
[24] https://www.cez.cz/cs/pro-media/tiskove-zpravy/skupina-cez-pokracuje-na-ceste-k-emisni-neutralite-elektrarna-prunerov-i-patri-historii-jeji-lokalita-ovsem-daleke-energeticke-budoucnosti-86825

- In Ledvice, a new block has been operating since 2017 and it uses the lignite from nearby Bílina mines. The block will also likely need to phase out use of coal by 2038.[25]
- Vřesová and Tisová power plants use primarily lignite for power generation and went through a series of modernizations in the last years, with the possibility of future use of biomass.[26]
- Recently, there is an ongoing debate and a tender for the construction of a new nuclear power plant block in Dukovany (1200 MWe), because the Czech Government relies on future nuclear energy capacity. It should cover the decrease in electricity generation capacity caused by coal phase-out

As ČEZ[27] and other stakeholders aim to reduce the emissions in the power sector mainly through renewables and natural gas (coal will be phased out in 2038), there is no pressure for CCS deployment in the coal-fired power sector. However, it could be potentially deployed in the power sector even with the use of natural gas or biomass, yet there is neither financial nor government incentivization for it.

2. Assessment of geological potential for CCS

According to the literature review that follows, the Czech Republic and its geological pattern provide CO_2 storage capacity which could enable the deployment of CCS technology. As is the case in the rest of continental Europe, the main capacity is in saline aquifers, but hydrocarbon fields are also available.

In 2018, the total CO_2 emissions were equal to 110 $MtCO_2$, equating to around 85% from the total CO_2eq reported.[28] According to the latest storage capacity estimate by the Czech Geological Survey, the Czech Republic has a CO_2 storage capacity of 766 $MtCO_2$ in saline aquifers (in Central Bohemian Upper Paleozoic basins, Vienna Basin and the Carpathian Foredeep), 33 $MtCO_2$ in hydrocarbon fields and 54 $MtCO_2$ in coal fields (mainly in the Upper Silesian Basin). These data are illustrated in Table no. 9, which also stresses the difference between conservative estimates and potential storage from database estimates (up to 2863 $MtCO_2$ storage capacity in saline aquifers). This difference is caused by a utilisation of different storage efficiency coefficients and demonstrates the high level of uncertainty in estimation of storage capacities in saline aquifers that usually suffer from lack of available geological data.

[25] https://www.cez.cz/cs/o-cez/vyrobni-zdroje/uhelne-elektrarny-a-teplarny/uhelne-elektrarny-a-teplarny-cez-v-cr/elektrarna-ledvice-58177
[26] https://www.suas.cz/aktuality/10-suas/aktuality/942-sokolovska-uhelna-investuje-do-ekologie
[27] ČEZ is one of the main energy providers in the Czech Republic.
[28] https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

CO_2 emissions		**Year(s)**	**Average CO_2 emissions (Mt)**
CO_2 emissions from large point sources in database		2005	78
Total CO_2 emissions		2006	128
CO_2 storage capacity	**Pyramid class**	**Conservative estimate (Mt)**	**Estimate in database (Mt)**
Storage capacity in aquifers	Effective	766	2863
Storage capacity in hydrocarbon fields	N/A	33	33
Storage capacity in coal fields	Effective	54	54
Total storage capacity estimate	**Effective**	**853**	**2950**

Table no. 9 – EU GeoCapacity results for the Czech Republic[29]

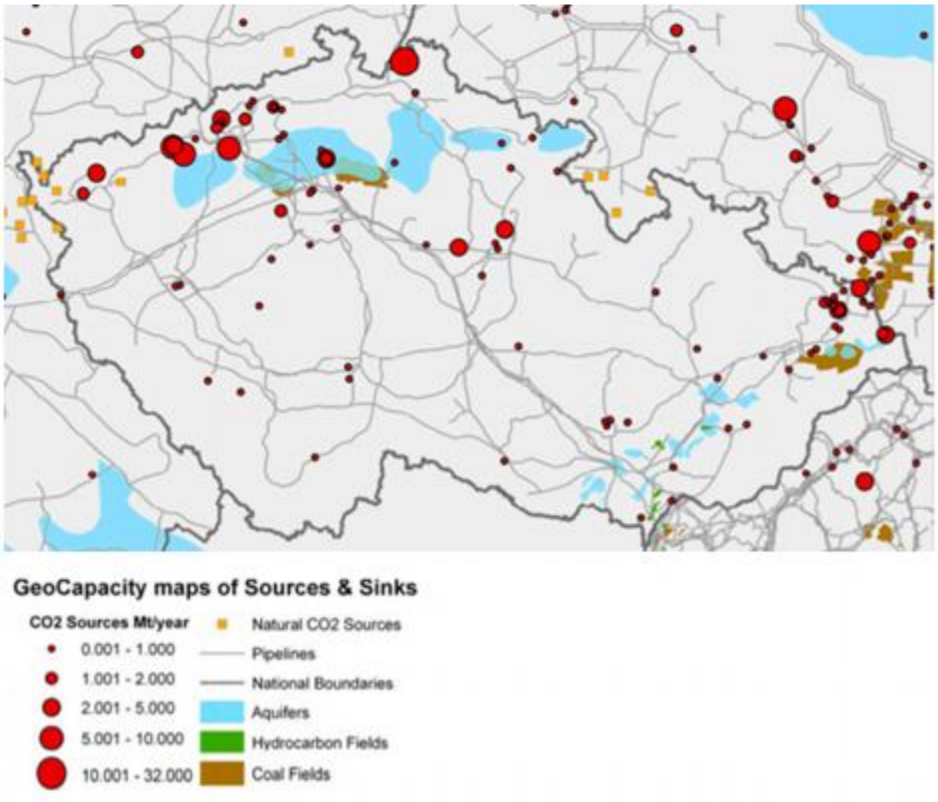

Figure no. 2 – GeoCapacity map of CO2 sources and sinks of the Czech Republic[30]

[29] Hladík V. in: https://beepartner.cz/konference/5_Vit%20Hladik_CO2_storage%20conditions%20in%20CZ.pdf
[30] http://www.geology.cz/geocapacity/publications/D42%20GeoCapacity%20Final%20Report-red.pdf

In Figure no. 2, the saline aquifers can be seen relatively close to the highly industrial regions of the Czech Republic, as well as the hydrocarbon and coal fields in the eastern part of the country. Although the Czech Republic has quite high capacity estimates, the research and geological assessments of concrete geological structures have mostly been done in cooperation with oil and gas companies in the eastern part of the country, focusing on depleted and nearly-depleted hydrocarbon fields. The estimated capacity of saline aquifers is much higher, yet no investments or planned projects exist according to the publicly available information. During the project workshop, this was mentioned and confirmed by the CCS-leading geologist from the Czech Geological Survey. As we assume from the location of high-emitting companies (see Figure no. 2), there are possibilities for deploying CCS/CCU clusters, especially in the northwest and eastern part of the Czech Republic. However, no such projects exist as of June 2021, and specific conditions and issues are connected to the possible deployment of the CCS/CCU technology in the Czech Republic, which will be described later.

From the perspective of gas transport and existing pipeline system, it must be noted that the Czech Republic transfers gas from Russia to Central Europe. The pipeline system is quite dense and robust, as can be seen in Figure no. 3. It connects Slovakia and Germany, through border transfer stations in the Czech Republic and abroad, too. Also, one transmission line interconnects the Czech Republic and Poland. According to the national gas transmission operator, there is a development plant until 2030 which counts on the possibility of future hydrogen transport. It mentions "blue" hydrogen with connection to CCS/CCU, however, no mention is given regarding the possibility of CO_2 transport itself.[31] We may assume that for such a small country, the gas transmission system is very robust and could serve the purpose of CO_2 transport. During the workshop, it has been mentioned that the southern transit pipeline (Waidhaus–Břeclav) is not operating and could represent a possibility for future testing and experiments with CO_2 transport.

Figure no. 3 – Czech gas transmission system[32]

[31] https://www.net4gas.cz/files/rozvojove-plany/ntyndp21-30_cz_201110schvalen.pdf
[32] https://www.net4gas.cz/en/transmission-system/

Another possibility of CO_2 transport is railway transportation. Although it may be more costly compared to the use of a pipeline system, it could be a short-term solution until the CO_2 pipeline system is finally built, or in the case of smaller-scale CO2 transport projects. In Figure no. 4, railway transport networks are illustrated. In the top map, the blue lines represent the Trans-European Transport Networks. In the bottom map, the coloured lines represent the cargo transport networks with specific requirements for cargo transport. It is important to note that both the gas pipelines system and railway networks were built hand in hand with heavy industry and its needs, so the highly industrialized regions in the Czech Republic have good access to both of these services.

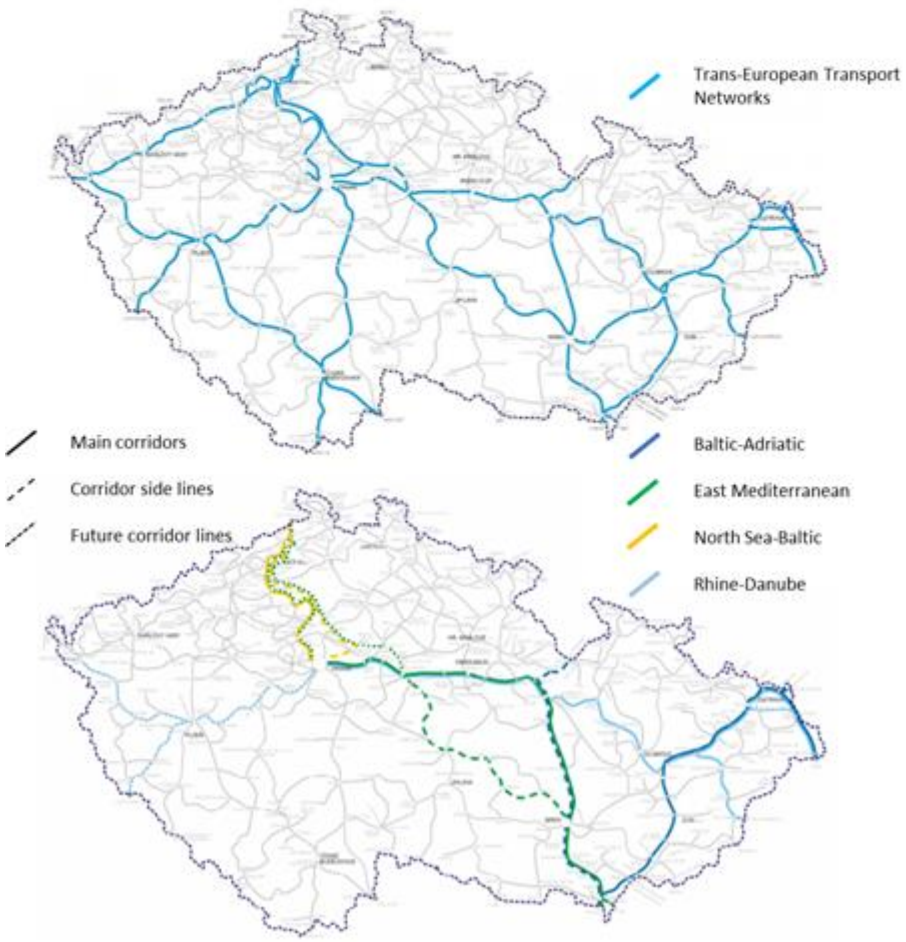

Figure no. 4 – Railway corridors[33]

3. Description of implemented and planned projects

A broad range of geological studies, laboratory experiments and research have been done in the last 15 years in the Czech Republic. However, no CCS pilot projects have been initiated so far. Table no. 10 gives a quick overview of the

[33] https://www.mdcr.cz/getattachment/Ministerstvo/Zadost-o-poskytnuti-informace-(1)/Poskytnute-informace/Plan-implementace-ETCS-na-zeleznici/Narodni-implementacni-plan-ERTMS-ceska-verze.pdf.aspx

research projects in the Czech Republic, which were presented by a collection of authors at the Czech Technological University in Prague. Later in this chapter, we focus on selected studies, which are part of the table. Not all of the projects from the table are described either due to lack of publicly available information or because stakeholders did not highlight their importance. New projects are also added at the end of this chapter.

Starting points of CCS research	
2004-2005	CASTOR project
2005	The first CCS study for Ministry of the Environment of the Czech Republic
2006-2008	EU GeoCapacity project
2006-2010	CO_2NET EAST project
2009-2012	TIP project (Ministry of Industry and Trade) – the first research project about capture and storage CO_2 after fossil fuel combustion
Capture	
2012-2016	Research of oxyfuel combustion in stationary fluidized bed boiler for CCS technology
2013-2017	Low-emission energy system with CO_2 capture
2015-2017	Research of high temperature CO_2 sorption from flue gas using carbonate loop
2015-2016	Study of CCS pilot technologies for coal fired power plants in the Czech Republic
2017-2019	Research of NOx reduction in flue gas within the oxyfuel combustion CCS technology
Storage	
2008-2010	Possibilities of CO_2 geosequestration in deep mines
2009-2010	TOGEOS Towards geological storage of CO_2 in the Czech Republic
2013-2015	Development and optimization of methodologies for the research of CO_2 barriers as one of the basic ways of reducing greenhouse gases in the atmosphere
2016-2020	ENOS Enabling onshore CO_2 storage
CCS chain	
2009-2013	Research and Development of the Methods and Technologies of CO_2 Capture in the Fossil fuelled Power Plants and CO_2 Storage in Geological Formations in the Czech Republic
2011-2015	Research and development of methods and technologies of CO_2 capture from flue gas and design of a technical solution for conditions in the Czech Republic
Industry	
2007-2008	Inventory of potential underground storage sites for CO_2 in the neighbourhood of the ArcelorMittal plant in Ostrava / Czech Republic
2011	Study of Condition Assessment for CCS – ČEZ group – Prunéřov II – Power plant – lignite
2013	Expert assessment of the CCS conditions in a "source 880 MWe CCGT Power Plant in Počerady"
Norway grants	
2015-2017	Research of high temperature CO_2 sorption from flue gas using carbonate loop
	Study of CCS pilot technologies for coal fired power plants in the Czech Republic
	REPP-CO_2 Preparation of a Research Pilot Project on CO_2 Geological Storage in the Czech Republic
	Carbon Capture & Storage – Sharing Knowledge and Experience
	Phase behaviour in CCS systems

Table no. 10 – Czech CCS projects[34]

[34] Pilař, Hladík and Vitvarová in https://uefiscdi.gov.ro/resource-81064

The European geological projects were important and served as the pioneering projects for the CCS deployment and future research in the Czech Republic:

Project acronym: CASTOR

Project title: CO_2, from capture to storage

Project duration: 2004-2005

From the Czech perspective, this European project was the first to initialize the CCS/CCU knowledge dissemination and geological survey towards the CO_2 storage capacity estimation. The 'CO_2, from capture to storage' (CASTOR) project was an integrated project of different EU countries (coordinated by France) and was initiated in order to prove the economic and environmental benefits of CCS technology. The aim was to improve the then known methodologies for CO_2 capture and sequestration and to provide new ways for the whole chain CCS demonstration. The project aimed to show how to capture and store 10% of European CO_2 emissions. However, due to differences in the technology readiness level of the capture, as well as transport and storage technologies across the EU member states, different goals were set in the respective countries. Ultimately, the project aimed to disseminate the knowledge and acceptance of the CCS/CCU technology across the EU.[35] In the Czech Republic, Czech Geological Survey was responsible institution to gather the geological data for Czech Republic regarding the possible CO_2 storage potential as well as to create a database of stationary emission sources.

Project acronym: EU GeoCapacity

Project title: Assessing European Capacity for Geological Storage of Carbon Dioxide

Project duration: 2006-2008

EU GeoCapacity was another project in the continuous effort to estimate the CO_2 storage capacity across Europe, including the Czech Republic, where Czech Geological Survey made a follow-up geological assessments, expanding the CASTOR project. The coordinator of the project was GEUS (Geological Survey of Denmark and Greenland) and the Czech Geological Survey was responsible for the Czech part of the project. Important members of the End-User Advisory Group in the project were the ČEZ energy provider and MND oil&gas company.

In addition to the main project objective – the creation of a pan-European CO_2 storage database – part of the project was designed to enable and demonstrate how large-scale CCS can be applied in the industries. With regard to the techno-economic aspects of the technology, it was also necessary to explore the geological structures in detail. It would only be possible to deploy full-chain CCS projects with the precisely mapped possible storage sites. In the Czech Republic, the project included two techo-economic evaluation studies – those being the case studies of Ledvice–Žatec and Hodonín–Hrušky – but these cannot be considered fully optimized CCS feasibility studies (non-technical valuations and identifying gaps in knowledge).[36]

[35] Information about the project retrieved from: https://cordis.europa.eu/article/id/87911-up-up-and-away-or-not
[36] Information about the project retrieved from: http://www.geology.cz/geocapacity/project/impact

Some further geological work was done in cooperation with the Norwegian partners via Norway grants:

Project acronym: TOGEOS[37]

Project title: Towards geological storage of CO_2 in the Czech Republic

Project duration: 2009-2010

From the geological projects, TOGEOS can be considered very important because it specifically targeted the saline aquifer storage sites. They represent the largest possible storage capacity in the Czech Republic. The project was coordinated by the Czech Geological Survey together with the Norwegian partner IRIS – the International Research Institute of Stavanger. The screening and evaluation of geological structures were performed in the area of Central Bohemian Permian–Carboniferous Basin where the major deep saline aquifers are located. Based on the previous findings of CASTOR and GeoCapacity, the aquifers offer the largest storage possibility in the Czech Republic. Initial static geological model of Central Bohemian Basin was built. Based on that, a preliminary reservoir model was created, and simulations were run. As of October 2021, there are still many stationary emission sources located in or close to the area.[38]

The Czech Republic was also a part of an European CO_2 transport system research and development study:

Project acronym: CO_2Europipe

Project title: Towards a transport infrastructure for large-scale CCS in Europe

Project duration: 2009-2011

One of the first European initiatives regarding CO_2 transport in the EU was the CO_2 Europipe project. ČEZ was the partner responsible for the Czech case studies and hypothetical scenarios of CCS/CCU deployment on European level. The project focused on mapping the possible CO_2 transportation across the Europe with regard to the 2020-2050 emission reduction. Different scenarios were created in order to find how large-scale CCS infrastructure could be introduced by 2020 and what pipeline infrastructure would have been needed by that time. According to the techno-economic analyses, the project concluded that shipping would play a major role in the first years of full-chain CCS because the pipeline infrastructure investment would not be justified by relatively low CO_2 volume in many countries, including the Czech Republic.[39] Table no. 11 gives an overview of the estimated cost parameters for transport. The costs were calculated based on the report of Zero Emissions Platform[40] and should have been interpreted with an accuracy of about 30%. The scenarios include both lower and higher volume of $MtCO_2$ transported per year and different lengths of constructed pipeline. A pipeline diameter of 10 inches was selected for the case study, which would be appropriate even for the low volume scenario. Moreover, such costs were calculated for flat terrain with no hills, mountains or no costly drainage.[41]

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[37] Information about the project retrieved from: http://www.geology.cz/togeos/
[38] https://www.sciencedirect.com/science/article/abs/pii/S1750583611001411
[39] Information about the project retrieved from: http://www.co2europipe.eu/Publications/CO2Europipe%20-%20Executive%20Summary.pdf
[40] https://www.globalccsinstitute.com/resources/publications-reports-research/the-costs-of-co2-capture-transport-and-storage-post-demonstration-ccs-in-the-eu/
[41] http://www.co2europipe.eu/Publications/D4.4.3%20-%20CEZ%20CO2%20transport%20test%20case.pdf

It is possible to see that with the same pipeline length of 80km, larger volumes of CO2 transported per year yields lower cost per tonne CO2. It is caused by combination of factors. For example, the cost per inch/km decreases with a longer pipeline, as well as decreasing with a larger volume of CO2 transported per year. Although CAPEX increases with longer pipelines, it increases less than the km length increases. Moreover, OPEX is equal for both volume scenarios with 80 km long pipelines. It depends on the length of pipeline only.

Volume (Mt/year)	**1,25**			**3,61**	
Pipeline length (km)	**20**	**25**	**80**	**80**	**600**
Cost per tonne CO_2 (Euro)	0,78	0,94	2,72	2,23	7,87
Cost in thousand Eur/inch/km	8,76	8,68	7,91	7,34	4,57
CAPEX (in Million Euro)	9,98	10,19	12,49	20,56	78,72
OPEX (in Million Euro)	0,12	0,15	0,48	0,48	3,6

Table no. 11 – Estimated cost parameters for pipeline CO_2 transport in the Czech Republic[42]

The following map (Figure no. 5) describes one of the scenarios created by ČEZ for the CO_2 transport from lignite-fuelled power plants (brown boxes) and, at that time, one planned lignite-fuelled power plant (blue box). The scenario counted on the possibility of CO_2 storage in two selected aquifers, which are marked by shaded green circles in the Figure.

Figure no. 5 – CO_2 transport to aquifer storage units near the power plants[43]

The scenario gives an overview of 2030-2044 period with the green lines indicating the pipeline infrastructure built before 2030 and the blue lines representing the new pipeline infrastructure to build in the 2030-2044 period. However, in the project's conclusion, the difficulties associated with deploying CCS/CCU technology for power plants were

[42] Ibid.
[43] Ibid.

stressed – mainly the limited coal reserves and limited information about storage capacities. In later years, ČEZ stopped its activities regarding the CCS/CCU deployment.

Another European project served as a follow-up to the EUGeoCapacity:

Project acronym: CO2StoP

Project title: Assessment of CO_2 Storage Potential in Europe

Project duration: 2012-2013

A follow-up project to the EU GeoCapacity provided another possibility for estimating the CO_2 storage capacities across Europe. Due to a limited budget, the project was largely based on EU GeoCapacity data, with mostly minor updates in some of the participating countries. Confidential data from the EU GeoCapacity database were excluded because CO2StoP strictly collected only publicly available data. Due to this, even during the latest CO_2 storage conferences, EU GeoCapacity results are usually presented by the Czech leading CCS stakeholders and geologist as the most recent national assessment of CO_2 storage potential.

The project created an interactive map and database of geological structures feasible for CO_2 storage. Also introduced was a new tool for calculating the theoretical storage capacity and injection rates. [44]

In the Czech Republic, Czech Geological Survey was the institution responsible for delivering updated information and geological data for the project. The map of geological storage potential for CO_2 in the Czech Republic produced in CO2StoP can be seen in Figure no. 6.

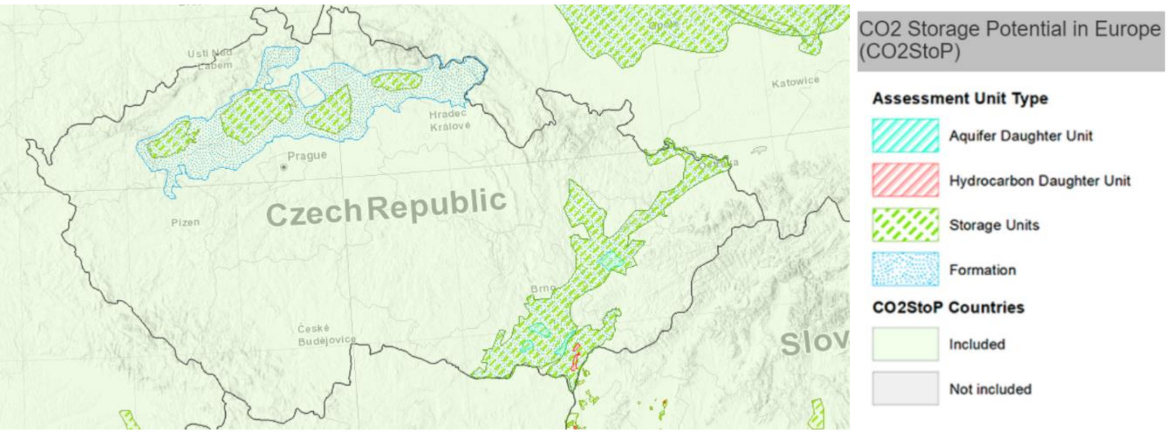

Figure no. 6 – CO2StoP map of the Czech Republic[45]

[44] Information about the project retrieved from: https://ec.europa.eu/energy/sites/default/files/documents
[45] https://ec.europa.eu/energy/sites/default/files/documents/56-2014%20Final%20report.pdf

2009-2014 EEA & Norway Grants (CZ) – CZ08 Carbon Capture and Storage (CCS), CZ09 Czech-Norwegian Research Programme

CZ08 CCS – Programme Title: Pilot Studies and Surveys on CCS Technology

The bilateral cooperation of the Czech Republic and Norway continued in the 2009-2014 EEA and Norway grants projects, which were implemented between 2015 and 2017. They focused both on specific research on capture technologies, as well as overall CCS chain deployment.[46]

Project acronym: Hitecarlo

Project title: Research of high temperature CO_2 sorption from flue gas using carbonate loop

Project duration: 2015-2017

- Coordinator: University of Chemistry and Technology Prague (Faculty of Environmental Technology)
- Partners: Czech Technical University in Prague (Faculty of Mechanical Engineering), Nuclear Research Institute ÚJV Řež, a.s.
- Total budget ca. 0.7 mil. € (grant ca. 0.5 mil. €)
- Main objective: Development of the high temperature decarbonatation technology in laboratory scale and design of the technology in pilot scale
- Results: publications, presentations, papers – very technical content

This project was very important for the prospect of deploying the capture technology in the future. The project focused on the technology of CO_2 removal from flue gas using calcium-based sorbents at high temperatures. The sorbents for this process were collected from different sites in the Czech Republic and monitored by three different experimental apparatuses. Based on another apparatus, the material-corrosion in the process of high-temperature carbonate loop was monitored. The researchers designed and created a small pilot device. Moreover, documentation for the manufacture of the device was prepared.[47]

Project title: Study of CCS pilot technologies for coal-fired power plants in the Czech Republic

Coordinator: Czech Technical University in Prague (Faculty of Mechanical Engineering)

Partners: ÚJV Řež, a.s., SINTEF Energy Research

Project duration: 2015-2017

[46] https://www.eeagrants.cz/en/closed-programming-period/eea-and-norway-grants-2009-2014/programmes/norway-grants-2009-2014/cz08-carbon-capture-and-storage/prg-cz08-general-information

[47] Information about the project retrieved from: https://www.eeagrants.cz/en/closed-programming-period/eea-and-norway-grants-2009-2014/

Main objectives:

- Design and conduct techno-economic analysis of the precombustion technology integrated into a coal power plant in the Czech Republic
- Global techno-economic assessment of three basic types of CCS technologies (oxyfuel, post-combustion, pre-combustion) applicable in Czech conditions.

Although coal-fired power plants are inevitably being phased out, this project showed how CCS would be helpful in case of operating coal-fired plants for longer time periods. The project was designed to provide a techno-economic study of CCS applied to a local power plant Vřesová. It was the only coal fired integrated gasification combined cycle power plant (IGCC) in the Europe. Different capture methods were evaluated as well as different transport possibilities to both local and foreign storage site (in Germany).[48]

Hypothetical costs of transport were calculated based on real prices of transport at that time. The cost evaluation of the export systems showed that, partly due to the difference in transport distance between the two technologies, the train-based export was also more costly than the pipeline export (4.1 versus 1.2 €/tCO_2 in the Czech storage case – 50 km away from the emission source via railway – and 10.8 versus 6 €/tCO_2 in the European transport hub case – 200 km via railway). In the Czech storage case, the cost evaluation of CO_2 conditioning and transport resulted in costs of 10.5 and 18.3 €/tCO_2 for the pipeline and train options respectively. In the European hub scenario, these CO_2 conditioning and transport costs were estimated at 15.4 and 24.9 €/tCO_2.[49]

Results for the base case were that the best option for CO_2 capture were the low-temperature and rectisol methods, with a cost of CO_2 capture and conditioning (i.e. purification and other chemical processes) below €54 per ton of CO_2 avoided. The scenario of CO_2 stored locally would be cheaper. Transport by pipeline was the cost-optimal solution for investigated storage alternatives.

Project acronym: REPP-CO2

Project title: Preparation of a Research Pilot Project on CO_2 Geological Storage in the Czech Republic

Coordinator: Czech Geological Survey (CGS)

Partners: IRIS – International Research Institute of Stavanger, VŠB – Technical University of Ostrava, ÚJV Řež, a.s., Research Centre Řež (CVŘ), Miligal, s.r.o., Institute of Physics of the Earth, Masaryk University in Brno (ÚFZ)

Project duration: 2015-2017

Main objectives:

- To significantly contribute to the development of the CO_2 geological storage technology in the Czech Republic - advancement of the Technology Readiness Level (TRL) of CO_2 geological storage in the Czech conditions from TRL4 (technology validated in laboratory) to TRL5 (technology validated in relevant environment)

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48 Information about the project retrieved from: https://eeagrants.org/archive/2009-2014/projects/CZ08-0004
49 Roussanaly et al. in: https://www.researchgate.net/profile/Simon-Roussanaly/

- Update storage capacity estimates in the Carpathian region, re-assessment of storage capacities; no new structures revealed.

REPP-CO2 project focused on the CO_2 storage in the Vienna Basin and made some very important steps towards storage in this region. More specifically, the LBr-1 site has been studied and prepared for future pilot project. The project was considered the flagship because it should have allowed for a follow-up pilot projects of CO_2 storage in the Czech Republic. Specifically, a depleted and abandoned hydrocarbon field was selected for dynamic modeling and simulations of CO_2 injection. The LBr-1 site modeling resulted into the important conclusion that it was suitable for storage and further preparations for the implementation of a pilot project. At the same time, however, several complicating factors were revealed, including lack of some important types of geological data (additional exploration would be required to prepare the storage site for operation) and uncertainties regarding the status of abandoned legacy wells.[50]

Project acronym: CCS-ShaKE

Project title: Carbon Capture & Storage – Sharing Knowledge and Experience

Coordinator: Masaryk University Brno

Partner: Norges Teknisk-Naturvitenskapelige Universitet (NTNU)

Project duration: 2015-2017

Masaryk University Brno was the coordinator of the project. Together with NTNU, one of the leading Norwegian universities in the CCS/CCU research area where the renowned TCCS conferences take place, they created a project to disseminate the knowledge of CCS/CCU in the Czech Republic across both governmental and educational institutions. The purpose of the project was to disseminate the knowledge of CCS across different stakeholders, be it university students, university professors, politicians or ministries. A long-term exhibition called "Let's put CO_2 back underground" at the VIDA! Science centre in Brno was also part of the project. The representatives of the Senate (upper chamber of Czech Parliament) could hear a presentation called "Is carbon capture and storage (CCS) technology an effective tool in the fight against climate change?" and discuss the possibilities of the technology in the EU.[51]

Project acronym: CCSphase

Project title: Phase behaviour in CCS systems

Coordinator: Institute of Thermomechanics AS CR, v. v. i.

Partner: SINTEF Energy Research AS

Project duration: 2015-2017

[50] Information about the project retrieved from: http://www.geology.cz/repp-co2/english

[51] Information about the project retrieved from: https://www.eeagrants.cz/en/closed-programming-period/eea-and-norway-grants-2009-2014/

A purely technical and laboratory study was conducted in order to understand the behavior of the fluids that would be required in order to transport and store the CO_2 in the geological structures. The CCSphase project promoted further collaboration between the Czech Republic and Norway, specifically between the Institute of Thermomechanics of the Czech Academy of Sciences and SINTEF ER. The goal of the project was to better understand the behavior of fluids involved in the CCS technology. Phase equilibria and transient phase behavior for fluid mixtures relevant for CCS were studied. The institutions created different models of the behavior and published such results in renowned scientific journals and conferences. It helped to disseminate the knowledge amongst researchers of both countries and to look for ideas for further collaboration.[52]

From the European Horizon 2020 project “ENOS”, focusing on the onshore CO_2 storage in Europe, the specific parts focused on CO_2-EOR and CO_2 storage risks were partially implemented in the Czech Republic:

Project acronym: ENOS

Project title: Enabling Onshore CO_2 Storage in Europe

Project duration: 2016-2020

The project “Enabling onshore CO_2 storage in Europe” was aimed at deepening the knowledge of onshore storage and use of CO_2 for enhanced oil recovery, too. Different sites across the EU were chosen to create new injection models, and possibly building a demonstration unit. One of the tasks was to initiate a public discussion and engage the respective stakeholders across the countries. The project took the site-specific and local socio-economic boundaries into account and different technologies and possibilities were studied in different countries.[53]

The Czech Geological Survey was the Czech participant in project consortium, and LBr-1 was one of the project test sites. LBr-1 site-related work in ENOS followed up with results of the REPP-CO2 project (see above) and focused on risks connected with possible CO_2 leakage via abandoned wells and through faults, and on trans-boundary effects of CO_2 storage at LBr-1 that is situated very close to the Czech-Slovak border (see Figure no. 7 showing the location of the LBr-1 storage site).

Another important part of ENOS was a transnational study of possible CCS/CCU cluster deployment in the Vienna Basin on the borders with Slovakia and Austria. For this region, CO_2-EOR was specifically the studied method of CO_2 storage. The result of this part of the project was a roadmap for basin-scale CO_2-EOR development in three countries (the Czech Republic, Slovakia and Austria) as a cluster-based assessment. The study is very important for initiating the debate about CCS in all three countries. A map illustrating possible CO_2-EOR development in the Vienna Basin, based on the roadmap, is presented in Figure no. 8.

[52] Information about the project retrieved from: https://eeagrants.org/archive/2009-2014/projects/CZ09-0014
[53] Information about the project retrieved from: http://www.enos-project.eu/

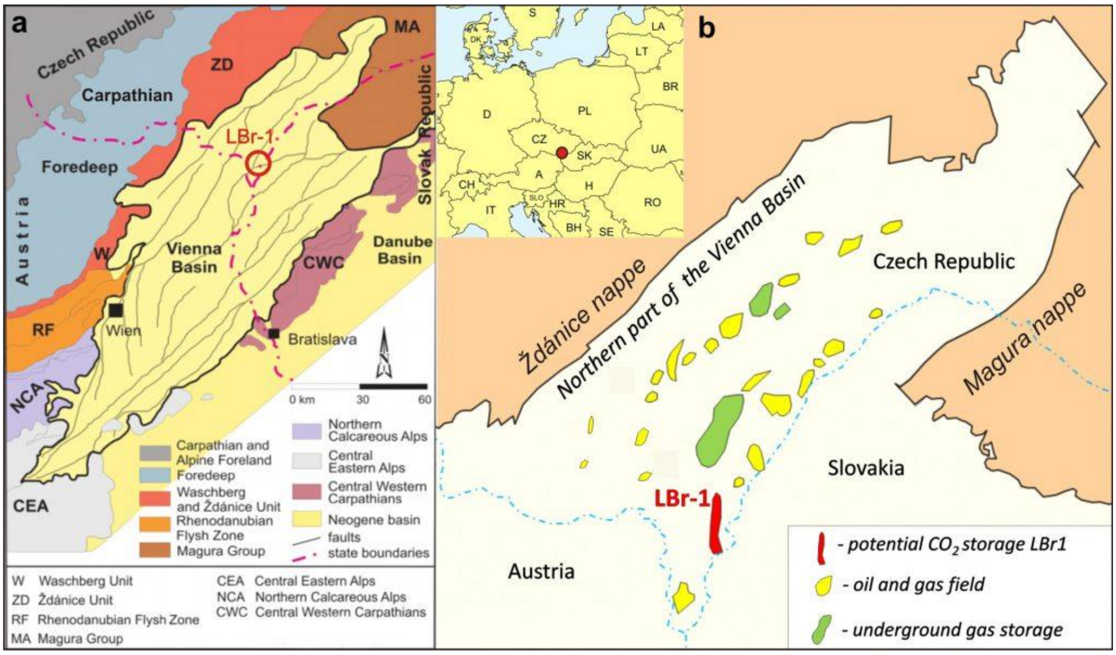

Figure no. 7 – Location of the Vienna Basin and the LBr-1 site (from the ENOS project)[54]

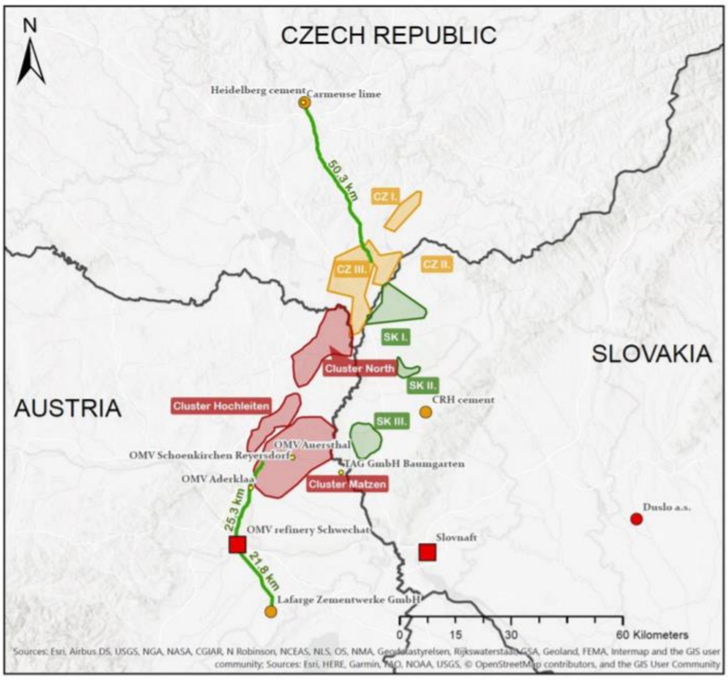

Figure no. 8 – Vienna Basin clusters for CO_2-EOR[55]

[54] https://eurogeologists.eu/piessens-developing-testing-demonstrating-onshore-storage
[55] http://www.enos-project.eu/media/22618/enos-d67_final-version.pdf

The following projects are in the process of implementation. One of the largest and best-equipped centers for the capture technologies in the Czech Republic is operated by the Czech Technical University in Prague. They have an ongoing, future-oriented project:

Project acronym: Bio-CCS[56]

Project title: Research centre for low-carbon energy technologies – Bio-CCS/U

Project duration: 2018-2022

As biomass may play a crucial role in the energy sector of the future, the Czech Technical University in Prague focuses on the use of different types of biomass and the respective ways of CO_2 capture. The research is focused on oxyfuel combustion of different biomass sorts. Another task is the oxy-gasification of biomass. The final task is to utilize the captured CO_2 and produce liquid fuels. Tasks will be carried out at different levels of the project – be it the preparation of biomass, separation of gases from the final CO_2, modelling, and process characterization.[57]

Another project focuses on the bilateral cooperation and knowledge transfer in the business and industry:

Project title: CCUS CZ-NO technological cooperation of companies in the field of CO_2 capture, storage and utilization

The project focuses on bilateral cooperation between the Norwegian technological stakeholders involved in the CCS/CCU deployment (lead by Technology Centre Mongstad) and Czech industrial companies interested in the technology. The project is coordinated by BeePartner consulting company based in the Czech Republic. One of the outputs was the recent CCUS CZ-NO conference held in April 2021. The main points of the discussion were CO2 capture, CCS and hydrogen, industrial clusters, successful CCUS projects, possibilities of the Czech Republic and financial support for CCUS in the Czech Republic.[58]

One of the most recent projects focuses on the capture technology:

Project acronym: METAMORPH

Project title: Advanced hybrid organic-inorganic nanofibers for CO_2 capture and photocatalysis

Project duration: 2021-2024

The aim of the project is to create a new solution for simultaneous carbon capture and photocatalysis. As a part of the Norway Grants project, Czech company InoCure cooperates with the University of Chemistry and Technology in Prague as well as Jan Evangelista Purkyně University in Ústí nad Labem. The project is supported by SINTEF AS (Norway). Jointly,

[56] Information about the project retrieved from: http://energetika.cvut.cz/en/bio-ccs-projekt/
[57] Pilař, Hladík and Vitvarová in https://uefiscdi.gov.ro/resource-81064
[58] https://beepartner.cz/konference.php

the final product of easily deployable membrane-based system should be tested in simulated industrial settings. If the techno-economic analysis allows, METAMORPH could be scaled-up throughout the industries.[59]

Finally, the ongoing project coordinated by the Czech Geological Survey can lead to the first Czech pilot storage project:

Project acronym: CO2-SPICER

Project title: CO_2 Storage Pilot in a Carbonate Reservoir

Project duration: 2020-2024

This project represents one of the most important steps towards CCS/CCU full chain deployment in the Czech Republic. The Czech Geological Survey leads the projects together with MND (leading oil & gas company in the Czech Republic), cooperating with the NORCE Norwegian Research Centre and two other Czech research partners. The aim of the project was recently presented at the TCCS-11 conference, which took place in Trondheim. The aim is to perform the necessary steps towards realization of a first CO_2 storage pilot project in the Czech Republic and Central and Eastern Europe. If successful, it could lead to a follow-up project that would be the realization of the storage pilot itself, including CO2 injection. It also aims at increasing the technological readiness level of CO2 storage in Czechia and is part of a long-term work of the interested stakeholders in the Czech Republic, mainly the Czech Geological Survey. [60]

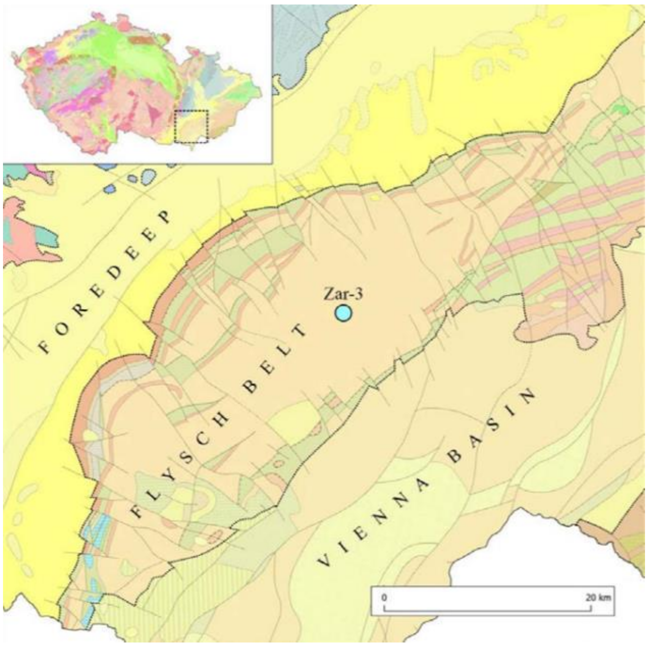

Figure no. 9 - Location of the CO2-SPICER project site[61]

[59] Information about the project retrieved from: https://eeagrants.org/archive/2014-2021/projects/CZ-RESEARCH-0020
[60] Information about the project retrieved from: https://co2-spicer.geology.cz/cs/o-projektu
[61] Ibid.

The main activities will cover all the necessary steps needed to prepare the geological storage pilot project, including (among others) building a 3D geological model, assessing the storage risks, preparing a monitoring plan or simulating various CO2 injection scenarios.[62]

4. Legislation and regulation relevant for CCS deployment

The main European directives and decisions regarding the CCS are as follows: **Directive 2009/31/EC of the European Parliament** and of the Council from 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006. In the rest of the report, this directive will be referenced simply as the EU CCS directive. Another important EU regulation is the Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012 that is in force from 1/1/2021.

Czech legislation which shapes the possible CCS deployment is described below:

Act on the Storage of Carbon Dioxide into Natural Rock Structures and on Changes of Some Acts

Act No. 85/2012 Coll.[63] – (CCS Act) - according to the CCS act, it was prohibited to commercially implement Carbon and Capture Storage into rock structures until 01/01/2020. Only projects with capacity limited up to 100,000 tonnes were permitted for research, development and new technology experiments. This ban originally inserted into the CCS Act during the legislative procedure in the Senate (upper chamber of the Czech Parliament) ceased to exist from 01/01/2020. Another original part of the transposed act limits the commercially stored amount of CO_2 in one site per year to 1 Mt. This restriction effectively limits storage only since 2020, when the commercial storage restriction ceased to exist.

However, the implementing decree of the CCS act that would set the financial guarantee for the storage facilities is missing. Therefore, no direct steps can be taken regarding the CCS deployment other than for the research purposes with the total project quantity of stored carbon dioxide less than 100,000 tonnes. According to the information from the Ministry of Environment, the legislative work on the decree will commence in 2021.

Moreover, the national transposition of the EU CCS Directive does not fully address transboundary issues of CO_2 storage and may create obstacles for use of storage sites on the borders. It is prohibited to store CO2 where transboundary leakage of CO_2 could occur. In the Czech Republic, the limitation of the amount of stored CO_2 per site and year (1 Mt) could be removed with relatively small amendment in the legislation – simply by changing the wording of the Act. The transboundary issue is more complicated and would limit the cooperation with all neighbouring countries – Slovakia, Poland, Austria and Germany.

[62] Hladík V. in: https://www.sintef.no/globalassets/project/tccs-11/tccs-11/sproceedings-no-7.pdf
[63] Collection of laws.

Act on the Protection and Use of Mineral Resources

Act No. 44/1988 Coll. – (Mining Act) is an act that complements the Czech CCS Act in the questions regarding CO_2 storage. According to this Act, CO_2 injected in order to achieve an enhanced recovery of oil or different hydrocarbons (be it methane or ethane) cannot be counted as CO_2 stored. It restricts the injection of CO_2 into areas with exclusive deposits (containing minerals and raw materials other than natural gas or oil) which are reported by the Ministry of the Environment.

Act of the Czech National Council on geological works and on the Czech Geological Survey

Act No. 62/1988 Coll. – describes all the essentials of geological exploration and obligatory steps that must be done in order to assess the potential storage structures.

Act on Environmental Impact Assessment and on Amendments to Certain Related Acts

Act No. 100/2001 Coll. – (Environmental Impact Assessment Act) determines in which cases the impact assessment must be done and what type of CCS project must be communicated directly with the Ministry of the Environment.

We have reviewed following documents with the aim to identify any references to the CCS deployment:

National Energy and Climate Plan[64] – the document counts on future development and possible deployment of CCS/CCU technologies, however, at present, the focus is on already available technologies. The plan focuses on maintaining the high density of gas infrastructure and counts on future trends. However, the CCU/CCS is mentioned only as one of the possibilities in combination with natural gas or synthetic gases as synthetic methane, biomethane, hydrogen and others. The wording does not favour CCS/CCU in any way and only keeps it as a distant option which is currently not perceived as feasible.

National Hydrogen Strategy[65] (as of June 2021 only a draft) – the most up-to-date version of the draft counts on the possibility of low-emission hydrogen, so called “blue” hydrogen, with the use of CCS/CCU technologies. It also gives specific examples of SWOT analyses, on future use of CCS/CCU. However, it explicitly states that: “Efficient and cheap technologies for CCS are not yet available and the Czech Republic does not have suitable geological conditions for massive CO_2 storage. CCU is even less technologically mature.”

Recovery and Resilience Plan[66] – as the plan covers mainly the mid-term recovery activities and development, CCS would not play any crucial role in it. Yet it would have made sense to comment on the preparatory phases of future CCS/CCU deployment, because of the long lead time required for deploying the full CCS value chain. However, the low interest in CCS from the perspective of the government is demonstrated by the fact that CCS is completely omitted in the Recovery and Resilience Plan.

[64] https://ec.europa.eu/energy/sites/ener/files/documents/cs_final_necp_main_en.pdf
[65] https://www.komora.cz/legislation/85-21-vodikova-strategie-ceske-republiky-t21-6-2021/
[66] https://www.planobnovycr.cz/o-planu

Chapter 2. Czech Republic's outlook for CCS and CCU

1. Summary of stakeholder engagement

The Czech CCS/CCU technology is going through a continuous development towards the first possible pilot project of carbon storage. There are subjects involved in the development of geological research and exploration and possible future application of CCS/CCU in the industry. Thanks to the projects implemented in previous years, there is a pool of stakeholders interested in the discussions on the CCS deployment. Those stakeholders were identified based on publicly available data as well as their involvement in past and current CCS projects. Stakeholders were invited to attend the project workshop about CCS/CCU. After the workshop, most of the attendees and also newly identified stakeholders were invited for one-on-one interview so the important aspects and information could be clarified. The main stakeholders were the following:

1.1. Research institutions

Czech Geological Survey

A leading research institution in the field of geology was the key stakeholder to invite to our project. The leading geologist and carbon storage debates' initiator represented the institution. The institution as well as its leading CCS researcher has **high** relevance and influence, as they are leading geological studies and projects for carbon storage in the Czech Republic.

Czech Technical University in Prague

One of the leading technological universities in the Czech Republic. Having a team of scientists with focus on carbon separation and capture technologies, they have **high** relevance and influence. The university is represented by a professor with significant work and achievements in the field of decarbonization and energy sector solutions. In recent years, it has become also the workplace with the currently highest technological advancement for carbon capture experiments in the Czech Republic.

University of Chemistry and Technology in Prague

Another leading technological university with focus on chemistry. The university has **high** relevance and influence, leading the research area of carbon separation in chemical processes and capture technologies. The professor representing the university has a life-long experience with gas capture technologies (mainly the adsorption technologies) and climate protection.

1.2. Governmental institutions

Ministry of Environment

The Ministry of Environment is the most important stakeholder from the Czech state administration with **high** relevance and influence on CCS. It is the regulatory body in the area of CCS – initiating the secondary legislation to the CCS Act. It is also leading the support for decarbonization and fight against climate change through the Innovation Fund or Modernization Fund.

Ministry of Industry and Trade

The Ministry of Industry and Trade has **high** relevance and influence as it is administrating the agenda of industry decarbonization and national and European programmes for energy and industry through innovations. The Ministry is also preparing the update of the National Energy and Climate Plan and new draft of Hydrogen Strategy, where CCS could play a role with "blue" hydrogen.

1.3. Private sector

MND a.s. (formerly known as Moravské naftové doly[67])

MND is the leading oil and gas company in the Czech Republic. It has **high** relevance and influence as it is leading the geological exploration works towards CO_2-EOR and storage deployment and further full-chain CCS/CCU deployment in the Czech Republic. MND cooperates on the current geological research and project called CO2-SPICER, which could lead to the pilot project for carbon storage in the Czech Republic.

Českomoravský cement, a.s.

The company is part of the Heidelberg Cement parent group, which can be considered the pioneer of CCS in cement industry, having projects across the world in different stages of development. **High** relevance and influence was assigned to the company. In the Czech Republic, it is also the largest CO_2 emitter in cement industry with two different plants and stationary emission sources.

Ocelářská unie a.s.

A representative organization for the steel industry. The industry itself is the largest emitting industry in Czech Republic (see table no. 5). The organization has **medium** relevance and influence. Although it advocates for the interest of steel industry in the areas of decarbonization and emission allowances purchase, its influence on the technology used in the respective companies and the selected path of decarbonization is low.

ENERGETIKA TŘINEC, a.s.

Energetika Třinec is a power plant based in the area of Třinecké železárny (a steel company), which is the largest CO_2 emitter in the Czech industry sector and also the owner of the power plant. The power plant provides energy for both the steel company and also the city of Třinec - the base fuel is lignite and black coal. However, the plant uses natural gas and biomass, too. The company has **high** relevance and influence.

[67] Moravian oil mines.

Association for District Heating of the Czech Republic

Another umbrella organization, which associates the heat plants in the district heating system. It has **medium** relevance and influence. It is advocating for the interest of heat plants and heat production in centralized system that are affected by the CO_2 emission allowance price. Small-scale sources under 20 MW are not included in the EU ETS.

PREOL, a.s.

The company is a member of Agrofert parent group and it is one of the largest biofuel producers in the Czech Republic. It has **medium** relevance and influence, as it is not one of the largest CO_2 emitters in the industry. However, their technological advancement does not offer any further decarbonization possibilities and CCS/CCU is being discussed throughout the concern strategy.

BeePartner a.s.

A private consulting company based in Moravia region, to the north from the planned location of storage pilot project. It has **medium** relevance and influence, as it is one of the first companies to offer consultations regarding the CCS/CCU deployment in the Czech Republic, as well consultation regarding the EU and national funds for innovation and decarbonization. The company is coordinating a project aimed at assisting companies planning carbon capture.

C-Energy Planá s.r.o.

A private heat plant and energy provider with **high** relevance and influence. The company focuses on renewable energy generation and storage and according to publicly available information, they also plan the CCS deployment in the future, however, without any further specification. The representative of the company also claims the company to be the first heat plant to prepare for low-carbon economy in the heating sector of the Czech Republic. Moreover, their preliminary techno-economic analysis shows positive net present value with regard to the rising price of emission allowances; CAPEX and OPEX related to CCS seem feasible for the company.

2. Stakeholder positions on CCS and CCU

2.1. Research institutions

Research and development institutions play a crucial role in the CCS/CCU deployment in the Czech Republic. The teams of geologists, engineers and chemists from the Czech Geological Survey, the Czech Technical University in Prague and the University of Chemistry and Technology in Prague are leading the research. All of them have **high** activity and influence and all were involved in recent projects concerning either the geological research on CO_2 storage or carbon capture technology development. Therefore, all can be considered as **pace-setters**. Czech Geological Survey, represented by the leading carbon storage researcher, is also the institution that has done most for communication of CCS towards Czech public. Czech Geological Survey and its leading CCS researcher represent the Czech Republic at all the important CCS/CCU conferences abroad, including the recent TCCS-11. Czech Geological Survey is also administering a webpage dedicated to the CCS technology that also gathers information on all the other projects implemented in the Czech Republic. All scientists from the universities consider CCS/CCU very important technologies for prolonging the time when we should phase out coal, because this technology enables both coal-fired and natural gas-fired heat or power plant to work and capture the respective emissions. However, they also consider it crucial for all the types of energy plants, especially for waste-to-power and biomass-fired sources in the future. Research institutions were also supported by the government for pursuing continuous research in the field of CCS/CCU; however, from the perspective of commercial application, the institutions were unable to get the necessary financing and no other development took place. According to the representative of Czech Geological Survey, a cooperation with a private company takes place in order to create a full CCS chain project in the future, yet he is not able to disclose the information right now. Throughout the interviews, one of the possible private companies disclosed its ongoing project to deploy the CCS in the nearest years – C-Energy.

2.2. Governmental institutions

Both the Ministry of Environment and the Ministry of Industry and Trade are not fully persuaded by the possibility of quick deployment and availability of CCS/CCU technology in the short-term perspective. So far, the Ministry of Environment prefers other decarbonization paths that are aimed at prevention of CO_2 emissions. It sees a role for CCS especially in the hard-to-abate sectors and in the elimination of process emissions, but refuses its deployment in the energy sector, mainly in connection with fossil fuel powered plants. Still, the Ministry of Environment has a priority to phase out every fossil fuel-fired source and to limit the emissions from hard-to-abate sources via technological innovations, and CCS is not seen as a long-term solution. If the carbon capture would take place, the Ministry of Environment would prefer utilization of CO_2 in industry as a by-product and not storage in the geological structures. The Ministry of Environment supports CCS plans of companies through the former NER 300 grant and the recent Innovation Fund. The Ministry of Industry and Trade supported CCS research and development, however, CCS/CCU technologies play only minor role in the official national documents such as the National Energy and Climate Plan or in the draft of the Hydrogen Strategy. Both these governmental institutions have **medium** activity and can be considered as **fence-sitters**. As of first half of 2021, their interest in CCS/CCU is purported through a promise that in the future, the technology may be necessary to achieve the net zero emission of CO_2; however, the current steps taken towards its deployment are not sufficient to achieve it.

2.3. Private sector

The majority of private stakeholders have a rather sceptic view on CCS/CCU deployment in the Czech Republic – mainly because of the perceived deployment barriers and risks further described in section 3.4. On the other hand, MND oil and gas company is strongly supporting CCS, being the only private company with **high** activity and influence, cooperating on the up-to-date CO2-SPICER project with the Czech Geological Survey. The company is a **pace-setter** involved in the storage side of CCS and also in the dissemination of CCS knowledge and activities in the Czech Republic. The company researches on CO_2 injection, which could be used for their EOR activities. Another company with **high** activity and influence is C-Energy, also considered a **pace-setter**, which cooperates with the Czech Geological Survey and MND on the future industrial application of CCS in their processes, however, no further information could be disclosed.

Other companies already involved in the CCS/CCU debate are PREOL and BeePartners, both of which can be considered to have **medium** activity and influence. PREOL is a biofuel producer and CCS/CCU is one of the last technological advancements, which could help them to reduce the emissions further. The company already created a hypothetical scenario of possible deployment, as well as communicated with the Czech Geological Survey about the nearby saline aquifers use for the storage purposes. However, these are only hypothetical scenarios, yet the company may be considered a **pace-setter**. Within the Agrofert group, they also mentioned the Ethanol Energy company, which should be deploying a CCU technology soon, yet the specification of the project is still confidential, and the company wishes not to disclose it. BeePartners is a consulting company that leads a project financed from the Fund for Bilateral Relations of EEA and

Norway Grants and supports the private sector with CCS/CCU deployment via knowledge sharing and grant planning of grant proposals. It may be considered a **pace-setter**.

The other companies from private sector form a group of **fence-sitters.** The main reason for that is that the companies (Energetika Třinec, Českomoravský cement[68]) or their associations (Steel Union, Association for District Heating of the Czech Republic) do not see any possibility to deploy CCS/CCU soon, while the costs of deploying such technology are high and no infrastructure and storage possibilities exist in the Czech Republic. From these companies, Energetika Třinec is the highest emitter of CO_2 (the company is part of a steel company), and they have an ongoing cooperation with local Nuclear Research Institute (ÚJV Řež – which also cooperated on the CCS/CCU projects in the past) researching CO_2 separation methods. From this perspective, Energetika Třinec has **medium** activity and influence.

The other companies and umbrella companies have rather **low** activity and influence, as the CCS/CCU are still underdeveloped technologies from their perspective, and they cannot focus on something still rather abstract. The price of emission allowances was mentioned in order to stress the financial point of view – if the price will continue to rise, the focus on CCS could deepen and there will be additional financial incentive for the companies to deploy CCS. While there is no infrastructure and no storage projects in the country and it is also impossible to find a nearby storage projects abroad, the companies support other ways of decarbonization and other emission cutting technologies. The trust in CCS/CCU deployment in the upcoming years will likely be low, however, pioneering companies, such as MND or C-Energy, could encourage other stakeholders.

3. In-depth stakeholder perceptions of the CCU and CCS landscape

3.1. Overall prospects for CCU/CCS in target country

Based on the workshop and individual interviews, we find that the majority of stakeholders are waiting for other institutions, and mainly EU-level decision makers and funding, to fully appreciate and support the full CCS/CCU supply chain across the EU. Although there are many fence-sitters among the companies, there are also those who already plan and create scenarios for CCS/CCU deployment. It is mainly the Czech Geological Survey, which pushes forward deployment and provides consultation for the private sector. As stated by the representative of the Geological Survey, the technology readiness level for CO_2 storage in Czech Republic may be at level 4, max. 5 (TRL-4, TRL-5) with the CO2-SPICER project to lead to the first demonstration project in the future. The capture technologies are also not "news" to local research institutions, which give an opportunity for more scientists and engineers to join the development process and cooperate with private sector. The support for several projects from the Norwegian government through the Norway Grants is also important.

From the whole CCS chain – capture, transport, and storage – we see that capture technologies are already being used commercially throughout the global market. There are still advancements made by Czech research institutions (such as patents commercially used in the industry for CO_2 reduction) and such new innovative solutions could be applied later once the pilot projects take place. The transport methods are not developed yet in the Czech Republic. Attendees of

[68] Shortly before publication of the report, Českomoravský cement (part of Heidelberg Cement parent group) disclosed information about planned full-chain CCS project in cooperation with Czech Geological Survey. The storage location is in Moravia (southeast of the Czech Republic) and it is a different depleted hydrocarbon field than the one included in CO2-SPICER project). Therefore, they can be considered **pace-setters** in the Czech Republic. However, during our workshop and personal interview, this information was still classified.

the workshop assumed that the already existing pipeline system may be used for CO_2 transport too, though there are some technological hurdles for the adaptation of the pipelines originally constructed mainly for the natural gas transport. In the past, CO_2Europipe project was conducted in order to understand the potential of full transport chain in the EU; however, no further development took place in the Czech Republic from that time of hypothetical study. On the other hand, possibilities for CO_2 storage have been explored quite well by other projects. The ongoing CO2-SPICER project could lead to the pilot project of carbon storage, eventually turning into a demonstration phase. This project should run until 2024. The demonstration of local storage possibilities in depleted hydrocarbon fields is a necessary step towards higher TRL; however, as the representative of the Czech Geological Survey adds, the largest CO_2 storage potential is in the saline aquifers in the northern and eastern parts of the Czech Republic. This potential needs to be proven by additional geological exploration, and, unfortunately, there are no planned projects in this direction on the horizon. C-Energy is planning to deploy a full-scale CCS project in the future[69], but the specific location of the project was not disclosed. The company has done the preliminary project methodology and techno-economic analysis.

3.2. The role of CCU/CCS in sector integration

As the power sector is largely dependent on coal-fired and nuclear power plants and the coal-fired plants are in the phasing-out process, no further CCS/CCU development is expected in the field of power generation. Incentives for the CCS deployment in case of the power plants fueled by natural gas are missing, even though that the Czech government counts on gas as a fuel for the transition period. However, a possibility of CCS/CCU still remains an option. It is similarly the case for the heat plants, biomass-fuelled plants (possibility of BECCS) and waste-to-energy. It is mainly the steel, chemical, refinery and cement industry to be a part of international holdings with common strategies and goals, which could use the advantage of integration regarding possible CCS projects. As could be seen in Figure no. 1, the stationary sources do create a possibility for clustering (for transport of the CO_2, too), but so far there has been no initiative to achieve such clusters because of the underdeveloped CCS environment in the Czech Republic. The large emitters try to reduce their emissions with already available technologies and business-as-usual scenarios. In the future, there may be a chance of cluster creation in the area of the Vienna Basin or in the area of the Upper Silesian Basin, as well as close to the saline aquifers in the Central Bohemian Upper Paleozoic Basins.

3.3. Awareness of EU policy and financial instruments for CCU/CCS

As described in the first chapter, there were many geological studies and research conducted in the past. The EU projects CASTOR, GeoCapacity or CO2StoP were financed and supported by EU funds and the respective financial instruments. The Czech government supports research and development, yet as it was prohibited until 2020 to commercially store CO_2, no incentives or national financing was offered for CCS deployment. The Czech Geological Survey and research institutions highly appreciate the possibilities given by Norway Grants Fund and EEA. The workshop and personal interviews did not offer any other solution for financing except of those already mentioned and the former NER 300 and the current Innovation Fund and EU Horizons. CCS technology was not included into the Czech Republic's National Recovery Plan, however the intention to deploy so-called blue hydrogen might pave the way for the CCS financing in the future.

3.4. Perceived deployment barriers and risks

First and foremost, it is the economic barrier of high CAPEX investments and underdeveloped CCS chain in the Czech Republic that undermine the perspectives for quick CCS/CCU deployment. Although there were many geological studies

[69] And Českomoravský cement, too. See the previous footnote.

made and the CO2-SPICER project is on a good track to lead to the pilot carbon storage project, the private sector still perceives the technology as immature and very abstract, as there is no clear path to transport and store the CO_2. Proven, larger-scale storage capacity, especially in saline aquifers, is currently not yet available. Financial barriers are the number one concern of the private sector. Yet there are also small legislative obstacles, mainly because of the missing implementing decree of the CCS Act, which define the financial security for the CO_2 storage. Without it, the law itself is not applicable and CO_2 cannot be really stored in any commercial project.

The support from the Ministry of Environment seems inadequate and puts the CCS on the very last place of priorities towards net zero future. As the capture technologies exist (still, they remain very expensive and difficult to retrofit on the existing plant equipment), without proper infrastructure for full-scale CCS, they will not lead the private sector to faster implementation of CCUS. Another barrier is the insufficient knowledge and lack of data regarding saline aquifers, which represent the largest storage potential in the Czech Republic but have not been explored to reduce the uncertainty concerning their proven storage capacity that would allow realisation of pilot and/or demonstration projects. The limitation of amount to be stored in one storage site per annum – 1 Mt of CO_2 – is also a barrier from some future perspective, and CO_2-EOR is not legislatively well described in order to count as a CO_2 stored. A risk on its own is the lack of social acceptance in the carbon-intensive regions, where storage would also make the best economic sense.

4. Stakeholder recommendations for CCU/CCS

4.1. Regulation

It is important to draw up the implementing decree of the CCS Act setting the rules for financial security that will operationalize storage of CO_2 from the legislative point of view. Also, CCS/CCU technologies need to become a priority for low-carbon national economy. The transnational transportation and storage rules should be made unanimous to allow storage projects across borders (this would allow for smooth cooperation, for example in the Vienna Basin). The legislative burden around building and construction should be decreased in order to build the infrastructure for CCS full chain faster. CO_2 pipelines should become constructions with public benefit so the preferential rules for land purchase can be applied.

4.2. Technology

CCS/CCU technologies already exist, and it is possible to install or retrofit capture units tailor-made for specific plants in the industries, especially with the best available technologies. However, according to some stakeholders, it is mostly about reducing the risk of possible leakage from storage sites. The cost of the technology should decrease gradually, but the overall recommendation would be for national and supranational incentivization and support of the CCS deployment and further financing opportunities. Investment in securing proven, larger-scale storage capacity in saline aquifers is strongly needed. The increasing price of emission allowances is also a stimulus for faster CCS deployment, and the possible price threshold of 100 EUR/tCO_2 (for emission allowances) represents the turning point for most stakeholders.

4.3. Infrastructure

The infrastructure exists in part but it is currently inadequate. There is a gas pipeline system, which would require new investments (an unused gas pipeline connecting the Southern parts of the Czech Republic exists, and after adaptation could be used for the CO_2 transport). However, building a new pipeline system would have to be projected with regard to the geological patterns, legislative burden of the building and construction law, and the protected landscape areas. The railway network is very dense (second in Europe after Belgium), but the OPEX of railway transportation is worse than that of pipelines for CO_2 transport. Although storage potential exists, evidenced by quite high estimated capacity in saline aquifers and depleted gas fields, they are not always very close to the emitters themselves, therefore transport would play a crucial role in achieving the CCS/CCU deployment on the national and international level. Therefore, the infrastructure should be adapted and the new one built with national and European financial support.

4.4. Market

As mentioned in the previous chapter, financial barriers are still the most significant barriers to any further development of the CCS market. The question mark is connected to the price and the overall number of emission allowances allocated to the respective emitters in the Czech Republic, which will shape the pace of CCS/CCU deployment. A scenario in which the financial burden could be mitiaged is via allowing the CO_2 to be sold as a by-product to specialized companies, yet such a market does not exist in the Czech Republic and would need to develop.

4.5. Financial frameworks

As long as CCS/CCU deployment does not offer a positive net present value (in the eyes of interviewed stakeholders), the EU funds and programmes and EEA/Norway grants were proposed to be the main source of financial support for CCS/CCU projects. Investors themselves would not invest such money in the Czech Republic when no clusters exist in order to deploy the technology with shared costs. More visible and easily attainable EU funding should be promoted for CCS/CCU deployment, which would need to cover part of the project costs. National funding is generally lacking, except limited R&D support.

4.6. Inter-sectoral and regional collaboration

No clusters exist as of 2021 and regional collaboration is highly dependent on the emission sources in the region. The Vienna Basin and Upper Silesian Basin offer a possibility for future international collaboration, and the Central Bohemian Upper Paleozoic Basins offers a possibility for a transport and storage cluster in the northwestern Czech Republic. One potential route would be to build a convenient gas pipeline system connecting the areas where emitters have the stationary sources with larger-scale storage sites (see Figure 1). To create a long-term collaboration in a regional cluster, further reliability and technological readiness of the carbon transport and storage must be achieved.

4.7. Social aspects

As the knowledge about the CCS/CCU technology is still not widespread, there is much work needed. We assume that without proper dissemination and social acceptance, it will be impossible to deploy CCS among industries. The already existing large emitters have issues with social acceptance, thus building storage capacities near the already existing emitters could cause more disputes. Public discussion needs to be intensified in order to secure better social acceptance.

Chapter 3. CCS and CCU: Public acceptance in the Czech Republic

Decarbonization and net-zero economy

As we highlighted in the first chapter, the Czech economy is highly industrialized and based on emission intensive industries. Even though the industries are emission intensive, CCS offers the possibility of good employment throughout the regions of the Czech Republic given that CCS is a technology that requires both high investments and high labour input . In this sense, it can be argued that from the perspective of employment, CCS would be seen as relatively positive technology to deploy. With that in mind, it is imperative that the industrial decarbonization is aligned with the needs and rights of employees. The question remains how it would be perceived by people living near the storage sites.

From the recent EU Special Barometer on climate change[70], it is obvious that Czech respondents are aware of the issue of climate change. 87% of respondents agree that reduction of greenhouse gas emissions is a necessary step towards low-carbon economy. More than 75% of them agree that the EU funds based on the National Recovery and Resilience Plan should be allocated mainly to new green investments. However, as was stressed in the chapter “Legislation and regulation relevant for CCS deployment”, there is no envisaged support for CCS/CCU projects in the National Recovery and Resilience Plan. Overall, more than 80% of respondents agree with the ambitious targets for renewable energy use in 2030.[71]

In 2019[72], the public opinion in the Czech Republic was much more positive towards the use of nuclear energy compared to the EU average. 27% of respondents agreed that the EU energy policy should focus on making the nuclear energy safe and secure, compared to 18% of the EU average. Moreover, only 29% of the Czech respondents thought that shifting from fossil fuels to renewable energy sources as a way to combat climate change should be part of the EU energy policy, compared to the EU average of 41%. Future price of the electricity also plays a crucial role. While only 33% of Czech respondents thought that the EU should invest and develop new clean technologies (compared to the EU average of 47%), more than 50% of respondents wanted the EU to ensure low future prices of electricity (compared to the EU average of 37%). This could be due to lower income or disparities across regions, where incomes differ.[73] On the other hand, the electricity prices for households in Czechia are still lower compared to the EU average, 14.6 ct/kWh compared

[70] https://ec.europa.eu/clima/sites/default/files/support/docs/cz_climate_2021_en.pdf
[71] Ibid. The survey did not point to the proposed „Fit for 55“ limits, it pointed to the previous 2030 set of goals (not mentioning any specific numerical targets).
[72] https://europa.eu/eurobarometer/surveys/detail/2238
[73] https://www.euractiv.com/section/energy-environment/news/czech-coal-mining-regions-confronted-with-hidden-energy-poverty/

to 20.4 ct/kWh in 2017.[74] Only 2.7% of Czechs were reported to be unable to keep their home adequately warm compared to the EU average of 7.3%.[75]

Perception of CCS/CCU

The 2011 Special Barometer on CCS[76] showed that Czech respondents were mostly unaware of the CCS technology. Only 6% of respondents heard about CCS before and knew what it was, compared to the EU average of 10%. More than 75% of respondents never heard about it before compared to the EU average of 67%. At that time, the geological exploration and work on the storage possibilities in the Czech Republic was still quite a new topic. The first geological studies were done as part of European projects (CASTOR and EU GeoCapacity) from 2004 to 2008.

After the respondents were given information about CCS, 77% of them thought of CCS technology as a mandatory technology for coal-fired power plants compared to only 60% of the EU average. The preferred location for storage was mostly the near surrounding of the power plant. 71% of the Czech respondents thought that it would help to improve the air quality compared to the EU average of 53%, however, almost 70% of them would be concerned with and worried about underground CO_2 storage near their home (closer than 5 km) compared to the EU average of 61%. At that time, 85% of respondents were willing to continue using natural gas as a fuel for power plants compared to the EU average of 80%, and 42% of them were willing to continue using coal compared to the EU average of 43%.

In the latest conclusions from ENOS project (please see the chapter "Description of implemented and planned projects"), there is no specific social acceptance issue mentioned in the Czech Republic. Yet it was not the primary aim of the project, so no further mapping of social acceptance was done. However, conflicts of interests are mentioned, especially those regarding the building of linear constructions (pipelines) and protection of natural resources.[77]

There are no new opinion polls specifically asking about the acceptance of the CCS technology. Given the absence of public discourse on the issue, we cannot anticipate significant changes in the public opinions on CCS.

Specific local projects

Given the absence of any CCS pilot project, we focus on different projects involving the exploitation of the Czech subsurface or projects which may raise the public awareness regarding the environment.

One of the recent environmental issues connected to mining activities in the Czech Republic is the future lithium mining in Cínovec village in Krušné Hory mountains. In 2017, there was a political dispute about the Geomet company, which owned the mining rights and shortly after, ČEZ became the majority owner of the Geomet company, co-owned by foreign company EMH – European Metals Holding. The plan is to extract and produce 22,500 tonnes of lithium carbonate yearly.[78] After the 11 years of geological exploration and survey, the project is in the process of environmental impact

[74] ct/kWh stays for cents paid per 1 kWh of electricity. See https://www.energypoverty.eu/indicator?primaryId=1478&type=bar&from=2012&to=2013&countries=EU,AT,BE,BG,CH,CY,CZ,DE,DK,EE,EL,ES,FI,FR,HU,HR,IE,IS,IT,LT,LU,LV,MT,NL,NO,PL,PT,RO,RS,SE,SI,SK,UK&disaggregation=none
[75] https://www.euractiv.com/section/energy-environment/news/czech-coal-mining-regions-confronted-with-hidden-energy-poverty/
[76] https://europa.eu/eurobarometer/surveys/detail/848
[77] http://www.enos-project.eu/media/22618/enos-d67_final-version.pdf
[78] https://ekonomickydenik.cz/lithium-z-cinovce-zpracujeme-v-lomu-u-mostu-planuji-cez-a-emh/

assessment and if possible, Geomet company plans to start the extraction in 2025.[79] The crushing of ore could be done in the mine itself, transporting the ore by linear constructions – pipeline system – to the place of further ore processing.[80] Public petition against the project has been circulating in the media with little effect. The main impetus of those signing the petition was their concern over the possibility of environmental degradation due to a decrease in air quality, as well as deforestation or noise pollution. Petition signers also felt as though pipeline itself would then be the cause of another case of deforestation given the need to clear land away from of the mine so that a pipeline might be constructed.[81] From the CCS perspective, it points to the fact that the environmental impact assessment of the project must be done carefully. Creating new mines and new linear constructions is perceived as an issue by the public, vastly because of the possible environmental degradation (feared by the public).

Another environmental issue garnering public attention is the planned permanent nuclear waste storage facility. In the Czech Republic, there is no permanent (long-term) storage facility for nuclear waste. Currently, used nuclear fuel is stored in the intermediate storage facilities of nuclear power plants. In the last years, there were seven locations selected for possible deep and permanent storage.[82] However, no further development is seen, because the respective communities and municipalities refuse to build a permanent nuclear storage in such close proximity to them. After 23 years of search for the final location, there is no conclusion made - yet this is rather due to extensive work which takes place with deciding the location for nuclear waste storage in every country. The situation is monitored by the Platform Against the Underground Storage of Radioactive Waste.[83] In the last update from Administration of Radioactive Waste Repositories[84], there are four locations recommended to the Czech government.[85]

With regards to fossil fuels, protests were run against the coal mine in Turów, Poland, and its operations. The coal mine is located very close to the border with the Czech Republic and causes issues with water distribution and air quality in the region.[86] Although Poland continue to operate the coal mine against the decision of Court of Justice of the EU, it now hopes to settle the row through an agreement with the Czech Republic.[87] The public opinion is straightforward – no deterioration of air and water quality is accepted and cannot be traded-off, and this opinion is presented in every protest run against the coal mine. It is not a surprise that local environmental NGOs fight for the fast phase-out of fossil fuel powered plants and perceive the growing EU ETS price and more ambitious climate goals as a sign for fast green transition.[88]

[79] https://www.idnes.cz/usti/zpravy/lithium-tezba-cinovec-krupka-nesouhlas-zivotni-prostredi.A210603_131722_usti-zpravy_grr
[80] Ibid.
[81] Ibid.
[82] https://oenergetice.cz/technologie/uloziste-jaderneho-odpadu-obecny-popis-situace-v-cr
[83] https://www.nechcemeuloziste.cz/cs/aktuality/kam-s-jadernym-odpadem-hleda-se-uloziste-a-uz-dlouho.html
[84] Governmental organization created by the Ministry of Industry and Trade in 1997.
[85] https://www.surao.cz/zuzovani/
[86] https://www.irozhlas.cz/zpravy-domov/podcast-vinohradska-12-polsko-turow-tezba-uhli-uhelna_2105170600_miz
[87] https://www.reuters.com/business/energy/poland-sees-possibility-reaching-agreement-with-czechs-turow-mine-2021-06-17/
[88] https://www.greenpeace.org/czech/clanek/14007/uhelny-prumysl-konci-na-novou-vladu-ceka-revoluce-v-energetice/

Institutions

According to the CCS workshop and publicly available information, it is apparent that the research and educational institutions in the Czech Republic are in favour of CCS technology. Institutions such as the Czech Geological Survey, Czech Technical University, University of Chemistry and Technology, or nuclear technology centre ÚJV Řež have been members of international research network on CCS/CCU for more than 15 years.

On the other hand, CO_2 storage is perceived as rather problematic in the onshore conditions. During the transposition of the EU CCS directive, which became effective in Czech law in 2012, the Mining Authority was not willing to accept the responsibility for CO_2 storage in the Czech Republic. It wanted to enact a new act, which would not make the Mining Authority responsible for the CCS operations, as the CCS technology is not primarily connected to mining operations.[89] Moreover, commercial CO_2 storage was not permitted until 2020. Before 2020, only research projects with limitation of 100,000 tonnes of CO_2 stored were permitted. ČEZ, an energy provider, joined the first research projects towards CCS deployment in the CEE region[90] and, in 2007, planned to build two demonstration low-carbon power plant units in the very beginning of CCS debates in the Czech Republic[91]. However, ČEZ was also aware of the high costs and the need for further financing.[92] Eventually, ČEZ decided not to continue in the process of CCS deployment[93] and started to focus on other pathways of decarbonization, such as building new nuclear reactors, strengthening the cumulative storage capacity for natural gases (phasing out coal faster than planned) or building new sources of renewable energy, especially photovoltaic power plants.[94]

During the first EU financial schemes feasible for CCS technology – the NER300 programme – no financial support was given to any European CCS project.[95] In the Czech Republic, the Czech Geological Survey started a very successful cooperation with Norwegian partners and the Czech Republic had the financial sources from EEA & Norway Grants for several research projects. In one of the projects, CCS ShakE (please see the chapter "Description of implemented and planned projects"), the task was to communicate the CCS topic across governmental and educational institutions. Media coverage also led to publishing of several articles focused on CCS.[96] However, it was communicated in a way that much more support for CCS is needed in order to deploy it. As of October 2021, there is no conceptual support from the government. CCS is only occasionally mentioned by the government and the respective ministries in the prospective areas of research and as a field of interest regarding technological innovations. Furthermore, there is no single document published by the Czech Government that comprehensively assesses CCS technology.

Because of the recently growing price of EU ETS emission allowances, the media is speculating what the role of CCS could be in the upcoming years. In a recent article, the Mining Authority comments on the issue of CCS and its relative

[89] https://ceskapozice.lidovky.cz/tema/bansky-urad-prohral-bitvu-bude-dohlizet-na-geologicke-ukladani-co2.A111027_105109_pozice_41739
[90] https://www.cez.cz/edee/content/file/vzdelavani/ccs___co2.pdf
[91] https://www.cez.cz/en/media/nuclear-power-plant-news/cez-is-considering-two-localities-for-modern-low-emission-technologies-hodonin-and-north-bohemia-77860
[92] https://www.cez.cz/en/media/press-releases/cez-proposes-a-new-source-for-financing-co2-capture-and-storage-70080
[93] The reason was mainly the insufficient level of geological exploration, high costs for CO_2 capture and transport, missing pipeline infrastructure and need of further financing.
[94] https://www.cez.cz/webpublic/file/edee/2021/06/prezentace-cista-energie-zitrka-1-20210630-130438.pdf
[95] https://www.euractiv.com/section/energy/news/eu-funded-carbon-capture-storage-efforts-failed-say-auditors/
[96] https://ekolist.cz/cz/publicistika/nazory-a-komentare/ema-wiesnerova-proc-eu-jeste-nema-funkcni-projekt-ccs

price to other technologies, stressing the relatively high capital and operating expenditures of it.[97] Another development worthy of note is the Czech Government's receiving of a recommendation from the Czech Coal Commission on the phasing-out process of fossil-fuelled power plants by the end of 2038. Depsite this, the government has not confirmed the date yet.[98] The late deadline supports the overall way of thinking about fossil fuels in the Czech Republic, favouring the use of natural gas. The CCS technology can be applied to gas-fuelled or biomass-fuelled power plants, too. If gas and biomass is supported as a transition solution before phasing out even these types of power plants, CCS could play a significant role in operations of such power plants. In recent media article, bioenergy-based CCS (BECCS) is being criticized[99] for excessive capital expenditures and no real negative emissions achieved. Furthermore, it speculates about the effect of BECCS on natural diversity and drought because of increased harvesting and water use, as well as decrease in soil water retention. For CCS deployment in the Czech Republic, such negative publicity hinders the process. Unfortunately, until any CCS pilot project is successfully operated in the Czech Republic, speculations about CCS attainability, utility and operability are likely to persist among politicians and private sector companies. The Czech Geological Survey and MND try to reflect the newest advancements in CCS technology in the CO2-SPICER project[100] leading towards the first pilot project in the future.[101] In relation to social acceptance, there is no visible negative wave against the CCS technology or, more specifically, CO_2 storage. However, until the pilot projects are undertaking, and more attention is paid to the topic, a comprehensive assessment of societal perceptions of the technology is not possible.

Need for knowledge dissemination

As was aforementioned, there is no recent public opinion poll or other sociological research covering the CCS technology and its acceptance in the Czech Republic. The last poll was part of the special EU Barometer in 2011. The existing environmental issues (use of fossil fuels, biomass, mining the mineral reserves, i.e. lithium ore, or nuclear waste storage) do raise concerns of the public, yet not in the same way as we could expect from the CO_2 storage. Gas infrastructure has always been an important part of the Czech economy. As such, if CO_2 transport and storage were to be perceived as part of gas infrastructure innovations then it could be viewed in a more positive light. Another factor potentially improving perceptions of CCS is better highlighting it as a priority mechanism in tackling climate change. CCS is usually presented by the Czech Geological Survey representatives, and they speak about natural storage facilities where gases (or different hydrocarbons) have been stored for millions of years, or saline aquifers, which is a liquid not usable for any other purpose. If such a "label" of natural carbon management persists, it should hopefully not cause any public opposition. In an industrialized economy such as the Czech Republic, ensuring current employment and keeping the heavy industry business going could lead to ongoing support for CCS/CCU.

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[97] https://www.info.cz/zpravodajstvi/cesko/vice-nez-doporuceni-uhelne-komise-ovlivni-rok-odchodu-od-uhli-zvysujici-ceny-emisnich-povolenek-rika-predseda-banskeho-uradu

[98] https://www.irozhlas.cz/zpravy-domov/vlada-uhli-2038-uhelna-komise_2105210953_ada

[99] The original research and source of the information given in the media article comes from the Potsdam Institute for Climate Impact Research in Germany. The author of the media article agrees with the source. See https://ekolist.cz/cz/zelena-domacnost/zpravy-zd/lecbu-klimatu-planety-uhlikove-negativnimi-plodinami-by-pacient-neprezil?fbclid=IwAR2UL1gDrac5gMTNKY6JLEZMHfTpVY6_KAl1D5hZOfo61uaoxZPwK9pYgqM

[100] https://co2-spicer.geology.cz/sites/default/files/2021-04/CO2_SPICER_Tiskova-zprava_cz.pdf

[101] Please see https://www.seznamzpravy.cz/clanek/kam-s-uhlikem-miliardar-komarek-ho-chce-na-jizni-morave-ukladat-pod-zem-166832, https://www.byznys-energie.cz/clanek/penize-ze-sklenikovych-plynu-nastala-zlata-uhlikova-horecka, or https://www.tydenikhrot.cz/clanek/vrat-se-pod-zem-v-cesku-vznika-unikatni-projekt-na-podzemni-ukladani-emisi-z-prumyslu-co2-spicer.