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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

SLOVENIA

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Glossary of Terms

CCS4CEE	**A project named "Carbon Capture and Storage for Central and Eastern Europe".**
CCS	**Carbon capture and storage.**
CCU	**Carbon capture and utilisation**
CO_2	**Chemical composition of a greenhouse gas Carbon Dioxide.**
CH_4	**Chemical composition of a greenhouse gas Methane.**
DAC	**Direct air capture.**
EIMV	**Elektroinštitut Milan Vidmar.**
ENERG	**European Network for Research in Geo-Energy**
ENOS	**A project named "Enabling onshore CO_2 storage".**
EU ETS	**European Union Emissions Trading Scheme.**
EUA	**European Union Allowance. A tradable unit under the European Union Emissions Trading Scheme (EU ETS).**
FREsmE	**A project named "From residual steel gases to CO_2".**
GDP	**Gross domestic product, a standard measure of the value added created through production of goods and services in a country over a certain period.**
GHG	**Greenhouse gas, a compound gas that traps heat or longwave radiation in the atmospheree.**
GW	**Gigawatt, a unit of energy equal to one billion watts, or 1000 megawatts.**
HSE	**Holding Slovenske Elektrarne, the largest Slovenian organiyation in the field of electricity.**
Kt/Mt	**Killo/thousand or Million tonnes of a greenhouse gas**
MEFco2	**A project named "Methanol fuel from CO_2".**
MJ	**Megajoule. A unit of work of energy equivalent to 1 million Joules.**
MOVECBM	**A project named „Monitoring and verification of CO_2 storage and ECBM in Poland".**
MW	**Megawatt, a unit of power equal to one million watts.**

NECP	**National Energy and Climate Plan.**
NGO	**Non-governmental organisation.**
NIC	**Slovenia's National Institute of Chemistry.**
ORACLE	**A project that will look at a carbon-free production of ammonia through utilisation of new technologies, including carbon capture.**
SIJ	**Slovenska Industrija Jekla.**
TEN-E	**The Trans-European Networks for Energy.**
TEŠ	**Thermal Powerplant Šoštanj.**
ZVO	**Zakon o varstvu okolja (Environment Act).**

Chapter 1. CCS and CCU: current state and past experiences in Slovenia

This chapter will capture the CCU and CCS landscape in the target country, as per the Country Template guidance document (Theme 2, section 1). It will be informed by background research and expert insights from targeted stakeholders.

1. Description of relevant domestic economic sectors

Relative to its size and population, Slovenia has a significant amount of ''heavy'' industry, which in return presents an important part the country's economy. However, the country's biggest CO_2 emitter remains a power generating facility, as will be explained later.

Energy-intensive industries in Slovenia are responsible for about a sixth of all final energy consumption in the country. Companies in these sectors employ around 27,500 people and generate 2.5% of Slovenia's GDP. The importance of the sector is emphasised, considering that most of their products are exported. It should be noted that a relatively small number of companies are responsible for most of the country's energy consumption in industry. In 2016, only 20 companies consumed half of all energy in the country's industry. That being said, environmental prospects of the sector remain optimistic, taking into account that in the period between 2005 to 2016, the industry reduced direct greenhouse gas emissions by more than 35% and process emissions by more than 20%.[1] Process CO_2 emissions could be captured and stored by such technologies, thereby ensuring the emissions are stored permanently (CCS). Alternatively, using electricity produced from renewables the captured CO_2 could also be used for the production of synthetic gas, which, however, does not permanently store the CO_2. The use of CC(U)S technologies is envisaged mainly in the cement and steel industry.[2]

The country's document on Industry strategy notes that the energy-intensive industry in Slovenia is very energy efficient compared to average plants in the EU and mostly uses the best available technologies (BAT). It further states that existing production units have been significantly improved, mainly in terms of reducing energy consumption per unit and increasing material productivity. From this point of view,

[1] Republika Slovenija, Ministrstvo za gospodarski razvoj in tehnologijo (16. 09. 2020), SLOVENSKA INDUSTRIJSKA STRATEGIJA 2021-2030 - Osnutek, Page 25, 26. (English: Republic of Slovenia, Ministry of Economic Development and Technology (16 September 2020), SLOVENIAN INDUSTRIAL STRATEGY 2021-2030 – Draft) Retrieved in Slovene from: https://www.gov.si/novice/2020-09-17-osnutek-slovenske-industrijske-strategije-2021-2030-v-javni-razpravi/

[2] Ministrstvo za okolje in prostor, Osnutek – Dolgoročna podnebna strategija Slovenije do leta 2050, Page 46. (English: Ministry of the Environment and Spatial Planning, Draft - Slovenia 's Long - Term Climate Strategy until 2050). Retrieved in Slovene from: https://www.gov.si/assets/ministrstva/MOP/Javne-objave/Javne-obravnave/podnebna_strategija_2050/dolgorocna_podnebna_strategija_2050.pdf

a major leap into a low-carbon circular economy is highly dependent on the development of new break-through technologies, which are not yet on the market or are in early stages of development. [3]

When it comes to certain already developed technologies, mainly CCS and CCU or production and use of hydrogen, the actors on the market are still waiting for an affordable and appropriate integration into the production processes of energy-intensive industries. For these technologies, the Strategy document acknowledges that it will be necessary to promote both development and innovation activities as well as demonstration activities and investment incentives for this purpose.[4]

While Slovenia has not had any pilot or demonstrative projects for CCS/CCU technology, the research activities in the segment have been ongoing, notably also by the National Institute of Chemistry. The industry actors on the market are aware of the advances in this segment within the EU and are mainly waiting for a favourable business case for CCS in their region and industry. Most of them, however, note that development of cross-national CCS infrastructure is critical for CCS in Slovenia, as CO_2 storage within the country is highly unlikely. Partly due to its very segmented potential storage locations, making the injections projects costly, and partly due to unfavourable public conceptions and regulatory/administrative hurdles.

Slovenia's Draft Document on the country's Long Term Climate Strategy until 2050[5] and also the Country's Integrated National Energy & Climate Plan[6] both envisage the use of CCS and CCU technologies, but only after 2040 according to the most optimistic carbon capture development scenarios.

The reason for such a statement in the country's most important environmental documents is the fact that price of emission allowances are expected to have the greatest impact on the development of technologies such as CCS or CCU. Indeed, at the time of preparation of the documents in 2020, the ETS allowance prices were not anywhere near the current prices as of June 2021.

The documents stated that, only if emission prices were to rise sharply (i.e. between 40 and 60 EUR / t CO_2) and if electricity demand couldn not be met by renewables, nuclear or gas-fired power plants, CO_2 capture and storage technologies would become commercially viable. This was not expected before 2040 and yet only a year after the preparation of these documents, the state of the market has shifted dramatically into what is now a compelling business case for CCS. The high price of emission allowances has caused a new impetus for CCS technologies among European steel, concrete, and other heavy industry companies. The benchmark emmission allowance price hit 57,65 euros a tonne on July 1, the highest since the carbon market launched in 2005.[7] While Northern Europe is many steps

[3] Ibidem, page 25.
[4] Ibidem.
[5] Ministrstvo za okolje in prostor, Osnutek – Dolgoročna podnebna strategija Slovenije do leta 2050, Page 46. (English: Ministry of the Environment and Spatial Planning, Draft - Slovenia 's Long - Term Climate Strategy until 2050). Retrieved in Slovene from: https://www.gov.si/assets/ministrstva/MOP/Javne-objave/Javne-obravnave/podnebna_strategija_2050/dolgorocna_podnebna_strategija_2050.pdf
[6] Integrated National Energy & Climate Plan of the Republic of Slovenia, translated by the European Commission, 2021, Page 124. Retrieved from: https://www.energetika-portal.si/fileadmin/dokumenti/publikacije/nepn/dokumenti/nepn_eng.pdf
[7] Data retrieved from: https://ember-climate.org/data/carbon-price-viewer/

ahead in this segment, work is also beeing progressed in other parts of Europe through various research and potential pilot scale projects.[89]

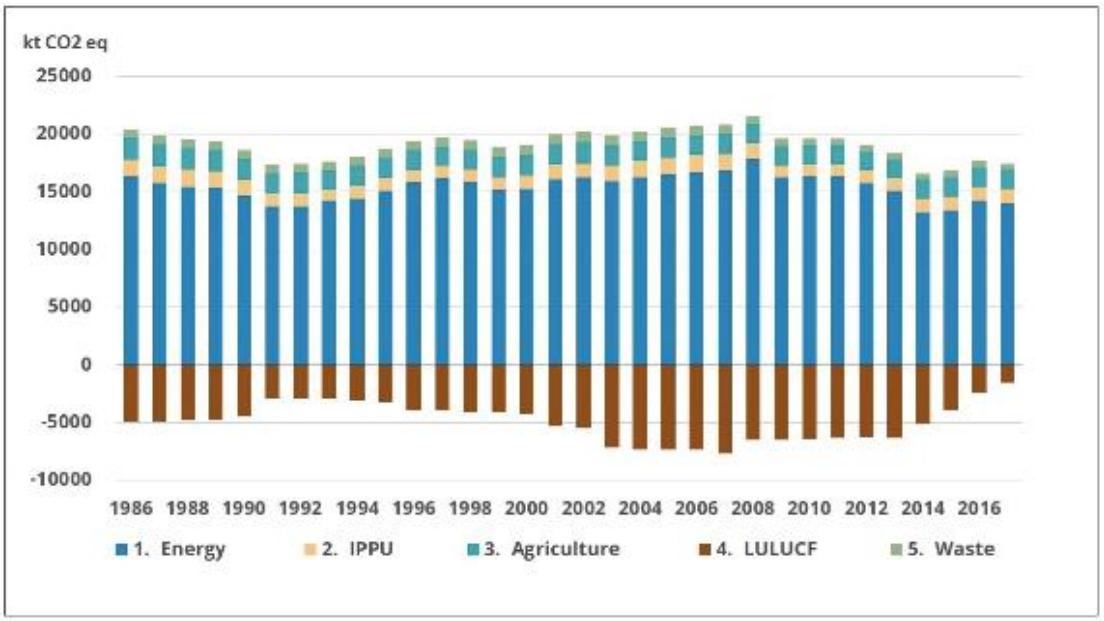
To make a preliminary observation, it is expected that within the new "CCS hub" approach in the EU, Slovenia is likely to play a role with an emphasis on the capture part, rather than storage, with transport options ranging from truck and train to temporary ship terminals or pipeline infrastructure, if and when the industry actors combine their efforts to seek government backing and favourable policy. All of this is indeed predicted to take place within the next few years, provided that the industry actors are assured of a predictable and stable business model for CCS in which they can be included into and of course sufficient storage capacity is and transport options are ensured.

1.1. Carbon-intensive sectors of the Slovenian economy

Total emitted CO_2 emissions in 2018 in Slovenia amounted to 15,9 Mt, which was 1,9% more than in 2017.[10] About half of these emissions come from point sources that could implement CCS technologies. In Slovenia's GHG emissions, the most important sector, by far, is Energy, which in 2017 accounted for 80.2% of total GHG emissions. In this sector emissions have decreased by 14.5%, compared to the 1986 benchmark. Within this sector, GHG emissions from the Energy Production Industry, as the biggest sub-sector, decreased overall by 28.1% from 1986 through 2017.[11]

Figure 1: GHG Emissions in Slovenia by sector

[8] Hočevar, Borut (10.5.2021), Časnik Finance, Začele so se priprave na zajem in hrambo ogljika v težki industriji naše regije. (English: Finance Magazine, Preparations have begun for carbon capture and storage in the heavy industry of our region). Retrieved from: https://oe.finance.si/8974918/Zacele-so-se-priprave-na-zajem-in-hrambo-ogljika-v-tezki-industriji-nase-regije
[9] IOGP (2021). Map of EU CCUS Projects. Retrieved from: https://www.oilandgaseurope.org/documents/map-of-eu-ccs-projects/
10 Statisticni urad RS. https://www.stat.si/StatWeb/news/Index/9065
[11] REPUBLIC OF SLOVENIA, SLOVENIA'S FOURTH BIENNIAL REPORT UNFCCC (March, 2020), Page 14. Retrieved from: https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf



Source: UNFCCC, 2020.[12]

From 1986 forward, GHG emissions from Industrial Processes at first fell sharply to reach their lowest value in 1993 (also due to Slovenia's road to independence at the time), but then started to rise again and were 6.0% above the 1986 level in 2007. Due to the global financial crises and lower industrial production, emissions in 2009 were 28.2% below the 1986 emissions but in the period 2010 – 2017 slowly increased again by 20%. The main source of the country's GHG emissions overall is Slovenia's Mineral industry, of which the production of cement and lime alone contributed almost 40% of the GHG emissions in this sector.[13]

The most important GHG of this sector was carbon dioxide, with a share of 66.0% in this category, followed by HFCs with 29.6%, N2O with 1.7%, and PFC and SF6 with 1.4% and 1.3%, respectively.

A significant proportion of Slovenia's CO_2 emissions, about 25%, however, occur during the combustion of coal in the Šoštanj thermal power plant (TEŠ), but according to preliminary estimates, the geological composition in that area is not suitable for the injection and storage of carbon dioxide.[14]

1.2. Major CO_2 emitters in Slovenia

The actors in the Slovenian Energy Intensive Industry include companies such as cement manufacturer Salonit Anhovo (708.513 tCO_2 in 2020); the Slovenian Steel Industry group – SIJ (181.967 tCO_2 in 2020);

[12] REPUBLIC OF SLOVENIA, SLOVENIA'S FOURTH BIENNIAL REPORT UNFCCC (March, 2020), Page 14. Retrieved from: https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf
[13] Ibidem, page 15.
[14] Hočevar, Borut (11.4.2021), Časnik Finance, Evropa se pripravlja na transport in shranjevanje ogljika. Kaj pa mi? (English: Finance Magazine, Europe is preparing for carbon transport and storage. What about us?)
Retrieved in Slovene from: https://oe.finance.si/8973837/Evropa-se-pripravlja-na-transport-in-shranjevanje-ogljika-Kaj-pa-mi .

limestone producer ,IGM Zagorje (59.514 tCO_2 in 2020), paper producer Vipap Videm Krško (90.056 tCO_2 in 2020) aluminium producer Talum (118.851 tCO_2 in 2020). From the power generation sector, facilities such as Termoelektrarna Šoštanj (3.760.438 tCO_2 in 2020) andEnergetika Ljubljana (530.836 tCO_2 in 2020) are among the main CO_2 emitters.[15]

From the main actor in the cement industry, Salonit Anhovo there are clear ambitions for implementation of CCS in their facility as they are planning to introduce a package of technological solutions that will lead to a 15% reduction in carbon footprint by 2025. Notably, their decarbonisation strategy also includes the introduction of a pilot plant for capturing and processing of carbon dioxide by 2028 with which they aim to reduce the remaining CO_2 emissions. They are exploring different capture principles as well as applications, [16] Their production process is highly energy-intensive, with energy costs representing up to 40% of total product cost.

The main two Slovenian companies in the Iron & steel sector are SIJ Slovenian Steel Group and Štore Steel. The SIJ group of companies has 3.400 employers and a yearly turnover in the range of 570 million €. The company Štore Steel has 520 employers and a yearly turnover in the range of 101 million €.[17]

According to the World Steel Association, carbon dioxide emissions in the SIJ Group are 22 percent lower than in comparable global steelworks. If they continue at the current rate of reduction of CO_2 emissions by 2030, they will have to buy about 1.2 million emission allowances. At current prices, this is more than 63 million euros. Many arguments support the prediction that emission allowance prices could rise to one hundred euros, which is twice as much as they are now. In return, this would make the case for supporting green technologies by grants and in the form of substantial state aid. Given the expected technological changes in industry and society, they also expect a significant increase in electricity prices. Demand for secondary raw materials will increase, which will be reflected in rising prices. [18]

The paper industry in Slovenia has about 110 companies and about 4,200 employers. It has a combined turnover of around 706 million euros. The industry is strong in export markets. According to the data of Slovenian statistical office (SISTAT) for 2015, the use of fuels and energy in the Pulp, paper and printing industry was 205 ktoe, which represents 19.1% of the Slovenian production industry. The main energy carriers in this sector were natural gas with the share of 47%, electricity with 32%, coal with 17% and wood with 3%.[19]

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[15] Slovenian Environment Agency (2020). *Poročilo o izpolnitvi obveznosti upravljavcev naprav v Sloveniji za leto 2020.* Retrieved from*: https://www.gov.si/assets/organi-v-sestavi/ARSO/Podnebne-spremembe/Porocilo_o_izpolnitvi_obveznosti_za_leto_2020.pdf*

[16] Hočevar, Borut (11.4.2021), Časnik Finance, Kako razmišljajo o zajemu in hrambi ogljika v slovenskih Podjetjih. (English: Finance Magazine, How Slovenian companies see carbon capture and storage). Retrieved from: https://oe.finance.si/8974950/Kako-razmisljajo-o-zajemu-in-hrambi-ogljika-v-slovenskih-podjetjih

[17] EU MERCI, HORIZON 2020 Project Nr. 693845 , Analysis of the industrial sectors in different Countries: Slovenia, page 23. Retrieved from: http://www.eumerci-portal.eu/documents/20182/38527/8+-+Slovenia.pdf

[18] Hočevar, Borut (11.4.2021), Časnik Finance, Kako razmišljajo o zajemu in hrambi ogljika v slovenskih Podjetjih. (English: Finance Magazine, How Slovenian companies see carbon capture and storage). Retrieved from: https://oe.finance.si/8974950/Kako-razmisljajo-o-zajemu-in-hrambi-ogljika-v-slovenskih-podjetjih

[19] EU MERCI, HORIZON 2020 Project Nr. 693845 , Analysis of the industrial sectors in different Countries: Slovenia, page 12. Retrieved from: http://www.eumerci-portal.eu/documents/20182/38527/8+-+Slovenia.pdf

For Slovenia's main CO_2 emitter in the Energy sector – Termoelektrarna Šoštanj - measures have already been taken to modernise the thermal power sector in terms of technology. By 2014, Units 1–3 were permanently shut down in the Šoštanj Thermal Power Plant (TEŠ), in 2015 a new coal-fired Unit 6 started to operate and will gradually replace the production of all other existing units of the power plant. In 2018, TEŠ Unit 4 also stopped operating. The Contract on the Arrangement of Mutual Relations between the Government of Republic of Slovenia and Šoštanj Thermal Power Plant from 2012 predicts a gradual reduction of GHG emissions, stating an emissions ceiling of annual CO_2 emissions from the units 5 and 6 for the 2016–2054 period. The upper ceiling will be reduced, considering the initial value; it will be 28% lower by 2030, 40% lower by 2035 and 52% lower by 2040. TEŠ Unit 5 is expected to operate until 2030. The NECP envisages gradual abandonment of the use of domestic and imported coal for energy purposes or its reduction by at least - 30% by 2030. The precise timetable for abandoning the use of coal in Slovenia, including shutting down the Velenje Mine and Unit 6 will be determined by the strategy for the abandonment of coal use and restructuring of coal regions according to the principle of fair transition, which will be adopted by 2021.[20]

2. Assessment of geological potential for CCS

Underground sequestration of CO_2 can primarily occur in either saline aquifers, depleted oil and gas reservoirs or un-mineable coal seems, at depths larger than 800m. Storage capacities depend on a number of factors, mainly on the geological structures, as well as public awareness and acceptance. Slovenia has a complex geological structure, both from a structural and tectonic point of view. However, storage capacities should be looked at and understood both from a theoretical, effective and likelihood of it being used perspectives.

Research into potential for underground CO_2 storage in Slovenia started in the early 2000s and has to-date yielded results which shows that although Slovenia is a small country it has storage sites within its territory.

First estimates from the 2006 CASTOR study identified 35 such potential locations for storage in aquifers, however, it was acknowledged that few information on deep geological structure of Slovenia was available and verified at the time, thereby yielding these results based on established assumptions. CO_2 storage capacities were thereby set at 147 Mt CO_2 for aquifers, and 2.2 Mt CO_2 for hydrocarbon fields. Within the EU GeoCapacity project, which assessed the European capacity for geological storage of CO_2 it was found that there is **92 Mt of CO_2 storage capacity[21] in deep saline aquifers and 2 Mt in depleted oil and gas fields**. Theoretical capacities were also calculated to be up to 200 Mt.[22]

[20] REPUBLIC OF SLOVENIA, SLOVENIA'S FOURTH BIENNIAL REPORT UNFCCC (March, 2020), Page 44. Retrieved from: https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf

21 The EIMV (2010) study on CO2 capture readiness of Unit 6 in Thermal powerplant Sostanj noted that optimistic storage capacities in Slovenia exceed 500 Mt CO_2.

22 Geoinzeniring (2016).

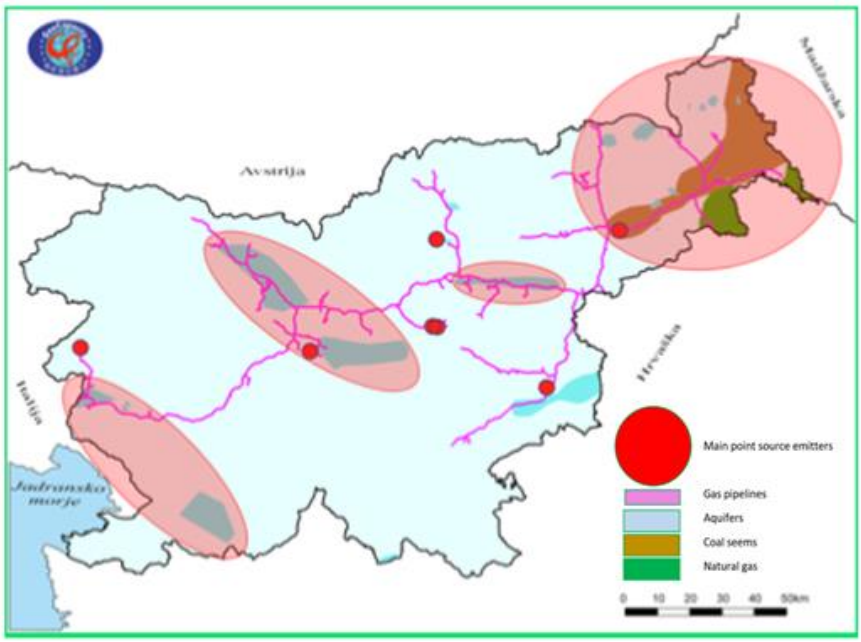
While the project did not find options for storage within unmineable coal seams, an EIMV (2010) suggested that coal seams storage capacity should not be discounted and be assessed, in particular for the Velenje coalmine. The coalmine was also part of a 2008 study named MOVECBM[23] which found that CO_2 injection created new swelling and fractures in the coal[24]. Slovenia's capacity for CO_2 storage in unmineable coal seems is essentially limited because of low permeability and swelling.

It should be noted that the 92 Mt CO_2 capacity estimates were done on few reliable data for each particular aquifer, thereby estimates were done primarily on a theoretical level for three of the individual aquifer locations (Pečarovci, Dankovci and Besnica strcture) with their storage capacity being at 63 Mt. More reliable data, however, is available for assessment of storage capacity of hydrocarbon fields, with two most notable ones being oil and gas fields Dolina and Petišovci in the NE part of Slovenia, with their total capacity being between 1.8 and 5.3 Mt.

To this end it is important to state that further practical research is required to confirm effective storage capacity, as well as that there has been no additional research conducted on CO_2 storage capacities in Slovenia since 2010, with currently no plans identified to do so. However, if effective storage capacity assessment would be true, the identified sites could hold for 20+ years of Slovenia's stationary emissions.[25]

Figure 2: Possible CO_2 storage locations in Slovenia

[23] Monitoring and certification on CO_2 storage and ECBM in Poland.
[24] W.F.C van Wageningen et al., 2009. Report and modeling of the MOVECBM field tests in Poland and Slovenia. Energy Procedia 1 (2009), 2071-2078.
[25] Geoinzeniring (2016), *Tehnologija zajema in skladiščenja CO2 (CCS)*, 7. Možnosti za CCS v Sloveniji. Predstavitev v okviru predmeta Okoljska geologija, Univerza v Ljubljani, 13. december 2016.

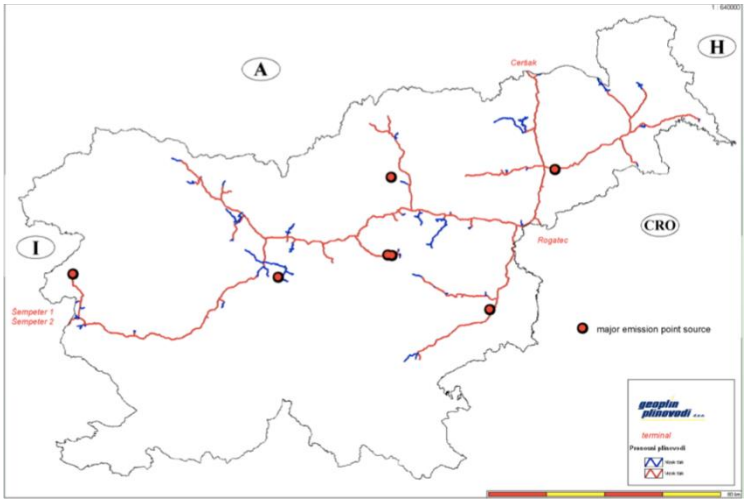


Source: Geoinzeniring (2016).

It is worth mentioning that despite some uncertainties regarding total storage capacities, geological features would allow for a small-scale pilot project to be carried out on the Slovenian territory[26]. To this end it is worth nothing that current legislation forbids all CO_2 underground storage. Furthermore, as Rutters (2013) suggests, Slovenia's pipeline infrastructure is relatively favorable.

Figure 3: Existing pipeline infrastructure in Slovenia

[26] Rutters, H. and the CGS Europe partners (2013) – State of play on CO_2 geological storage in 28 European countries. CGS Europe report No. D2.10, June 2013, 89p.



Source: GeoInzeniring (2016).

Their potential use or re-use of pipelines, however, has to-date not been assessed for CO_2 transport purposes. Given the current legislative barriers, and as suggested by interviewees in this project, it is likely that there will be a need for additional CO_2 pipeline infrastructure that would enable connection between Slovenian largest stationary emitters to connect to storage capacities abroad or connect to pipeline infrastructure and potential storage sites in neighbouring countries.

While underground CO_2 storage in Slovenia is highly unlikely to occur, there are options in neighboring countries. Within the EU GeoCapacity project it was found that Croatia's storage capacities range from 2.899 Mt – 4.256 Mt (theoretical), Hungary's from 616 Mt – 1.037 Mt (effective), and Italy's from 6.550 Mt – 13.031 Mt. Italy could prove to be a destination point for captured CO_2 as some storage capacities are situated near the Slovenian border. Nevertheless, as discussion during the workshop held for this project suggested, it is unlikely that any on-shore storage is to occur in neighboring countries as well. In this respect, it was mentioned that Italy and/or Croatia could be destination countries for Slovenia's captured CO_2, if off-shore storage sites are developed and/or terminals for further transport are constructed.

3. Description of implemented and planned projects

The state of implemented and planned projects In Slovenia can be seen as somewhat fragmented, and at different stages of development. Much of the work is focused on CO_2 capture or CO_2 storage, however, there are presently no projects in development beyond the initial idea stages. Most of Slovenia's work, thus far, has involved participation In European consortia on different aspects of the CCU/CCS value chain. The following is a selection of some key identified potential projects for Slovenia and past participation in European-wide projects. Planning and implementation of actual projects in Slovenia will greatly depend on the acknowledgement and support from the government for initial pilot and

demonstration projects in the upcoming years. This view has been shared by stakeholders who were part of the CCS4CEE project.

CO_2 capture

Salonit Anhovo:

The company is a cement manufacturer and one of the largest emitters of CO_2 in Slovenia. Within their goals to become a carbon neutral cement producer their plan is to have a pilot CO_2 capture project between years 2025-2030 to explore technology's potential, and build a full-scale project by 2035.

The company understand that to reach this goal partnerships with other stakeholders, and countries, will be needed, and crucial in this respect will be initial government support. At present they are considering CCU, however, if appropriate storage sites and/or transport infrastructure is developed they are likely to consider CCS as well.

It has been calculated that a full-scale CO_2 capture project would require up to 300% more electricity needs compared to present consumption, or 1.6-4 MJ/kg CO_2 captured. In total this would amount to 4 TWh of power to convert 700 kt CO_2 to CH4, for example.

As it relates to costs, market analysis was made based on current available industry data, and include a range from 75-180 EUR/tonne for the entire value chain components of CCS, while if looking at maturity cost assessment for carbon capture costs would range between 45-70 EUR/tonne of CO_2, if physical post-combustion technology is chosen, 60-120 EUR/tonne of CO_2 if chemical post-combustion technology is chosen, or 45-80 EUR/tonne if integrated capture technology is used.[27]

To make a step forward they acknowledge the need for both intra-country but in particular transborder regional clusters to be developed. Clusters will give all of them a higher security and better efficiency in terms of costs.

Kemijski Institut (National Institute of Chemistry)

The NIC considers CCU/CCS as key pathway in the energy transition and decarbonisation efforts and Is involved In development primarily within the context of international pilot and demonstration projects in various parts of either CCU, power to gas, power to liquid, as well as upstream hydrogen introduction and storage process in energy intensive industry. Below are some of the past and current international projects related to CCU/CCS that NIC is or was involved in:

ORACLE: a project, funded by Horizon 2020, that will look at a carbon-free production of ammonia through utilisation of new technologies, including carbon capture. NIC is together with the Jožef Stefan Institute (IJS) a partner within this project that will run for three years starting from May 25th, 2021.

[27] *Vuk, T. (2021). Salonit Anhovo – Road to carbon neutrality. Presented at the seminar »The current landscape of CCS in Slovenia« on 30. 6. 2021.*

MEFco2: a project looking at producing green methanol as energy vector from captured CO_2 and hydrogen produced using surplus renewable energy.[28] NIC was the project concept originator and the largest public partner

FREsmE: a project looking at synthesis of methanol from CO_2 extracted from iron furnaces for marine fuels. The project completed in June of 2021,[29] with the NIC providing research into catalysis, modelling and engineering aspects.

The NIC is also involved in a UNESCO Cooperation Programme looking at educating young scientists on the innovative approaches for capture and utilisation of CO_2 in the context of circular economy, and readily works on papers and thesis related to various aspects of CO_2 capture and utilisation. As other stakeholders have identified, the NIC also believes that what Is missing in Slovenia is a serious lack of pilot and demonstration projects.

Energetika Maribor

Energetika Maribor, heat and electricity producer and distributer, is currently considering as part of their decarbonisation plans at possibilities of CO_2 capture and storage at their proposed waste-to-energy plant in Maribor, that would allow for production of about 20 MW of heat and 4 MW of electricity to be generated from burning of 45.000 tonnes of mixed municipal waste per year. The technology for the plant has not yet been selected, however, the plan is to start operations in 2030. From planned heat production of 81.085 MWh the goal would be to capture up to 16.049 tonnes of CO_2 per year.

CO_2 storage

Geoinženiring, which provides geotechnical, geological and geophysical research, design, consulting and engineering services, has over the years participated in a number of European consortia in projects that looked at CO_2 capture and storage, including the CASTOR (2005-2006), EU GeoCapacity (2006-2008), CGS Europe (2010-2013), ENOS-Enabling Onshore CO_2 storage (2016-2020) projects.[30] However, while there are no ongoing projects, the company remains part of the ENERG (European Network for Research in Geo-Energy) and CO_2 Geonet networks in which it is ready to provide its expertise on CO_2 geological storage and limiting the knowledge gap, as well as foster interaction and information exchange.

Premogovnik Velenje, Slovenia's largest coal mine and Erico (now Eurofins Erico), an environmental research company, were also involved in a project MOVECBM, whose objective was to improve the understanding of CO_2 injected in coal and migration of methane through which reliable and safe CO_2 storage could be ensured. A small-scale injection was performer at the Velenje coal mine to Investigate adsorption, desorption and migration processes for local coal conditions[31].

28 More about the MefCO2 project: http://www.mefco2.eu/mefco2.php
29 More about the FREsmE project: http://www.fresme.eu
30 See Geološko skladiščenje CO2 | Geoinženiring d.o.o. (geo-inz.si) for more information on past activities of CO2 storage.
31 See Final Report Summary - MOVECBM (Monitoring and verification of CO2 storage and ECBM in Poland) | Report Summary | MOVECBM | FP6 | CORDIS | European Commission (europa.eu) for more infomration on the project and results.

4. Legislation and regulation relevant for CCS deployment

Directive 2009/31/EC on the geological storage of carbon dioxide, which establishes a legal framework for the safe use of CCS technologies in the European Union, has been transposed into the legal order of the Republic of Slovenia via the Energy Act[32] and particularly addresses in its Chapter 10, the transport of CO_2 and access to CO_2 infrastructure.[33]

The Environmental Protection Act[34], which presents the Country's umbrella document, addresses the fundamental prerequisite for sustainable development and protection against environmental stress. Within this scope, the Act lays down a framework: the fundamental principles and measures of environmental protection, environmental monitoring, economic and financial instruments of environmental protection, as well as public services for environmental protection and other issues related to environmental protection.

In regard to CCS provisions in the Environmental Protection Act, one must especially mention Article 166a, which states that "In the territory of the Republic of Slovenia and in its continental shelf, the injection and storage of carbon dioxide streams (geological storage of carbon dioxide) is prohibited."

The Environmental Protection Act plays an important legislative role in achieving climate objectives. The Environmental Protection Act (ZVO) provides a legal basis for all other legislation in the area of environmental protection that indirectly or directly influences GHG emissions. For example, in the areas of waste, environmental certificates, comprehensive assessment of environmental influences, environmental management of organisations, economic and financial environmental instruments (e.g., the environmental tax on environmental pollution, GHG emissions allowance trading), etc. [35]

The environmental inspection service is responsible for supervision of the implementation of the Environmental Protection Act and all relevant implementing regulations; the competences of the environmental inspection service also include authorisation to prohibit the operation of plants or equipment, the revocation of environmental certificates, etc. In case of infringement, the Act stipulates the payment of fines. [36]

The legal basis addressing environmental tax for air pollution due to CO_2 include also the Decree on environmental tax on carbon dioxide emissions.[37] The environmental tax instrument has been introduced in order to internalise the external costs of climate change due to CO_2 emissions, from manufacturing industries and construction, and, being an economic instrument, was aimed at reducing CO_2 emission through the fuel price and therefore aimed at reducing environmental pollution. The Decree

[32] Energy Act (EZ-1), Energetski zakon (Uradni list RS, št. 60/19 – uradno prečiščeno besedilo, 65/20 in 158/20 – ZURE)
[33] Renata Karba, dr. Jonas Sonnenschein, Andrej Gnezda (23. 2. 2021), Project LIFE IP CARE4CLIMATE, Politično-zakonodajno ozadje blaženja podnebnih sprememb, page 32. Retrieved from: https://www.care4climate.si/_files/1420/Umanotera-2021-Politicno-ozadje-PS-2021-04-23.pdf
[34] Environmental Protection Act (Official Gazette of the Republic of Slovenia, No. 39/06 – official consolidated text, 49/06 – ZMetD, 66/06 – Constitutional Court Decision, 33/07 – ZPNačrt, 57/08 – ZFO-1A, 70/08, 108/09, 108/09 – ZPNačrt-A, 48/12, 57/12, 92/13, 56/15, 102/15, 30/16, 61/17 – GZ, 21/18 – ZNOrg and 84/18 – ZIURKOE)
[35] REPUBLIC OF SLOVENIA, SLOVENIA'S FOURTH BIENNIAL REPORT UNFCCC (March, 2020), Page 77. Retrieved from: https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf
[36] Ibidem.
[37] Decree on environmental tax on carbon dioxide emissions (Official Gazette of the Republic of Slovenia, No. 48/18)

on environmental tax on carbon dioxide emissions, which imposes an obligation to pay environmental tax for air pollution due to CO_2 emissions was updated in 2018, although no major changes were introduced. The unit of air pollution with CO_2 emission remains €17.3 €/t of CO_2. It is planned that CO_2 tax will increase (at least 5% per year) and approach the ETS coupon price by 2030. Companies included in the EU ETS system (holders of permits to emit greenhouse gases) are exempt from this environmental tax.[38]

Chapter 2. Slovenia's outlook for CCS and CCU

1. Summary of stakeholder engagement

Significant attention was given to gathering a representative sample of stakeholders' perceptions, understandings and outlooks towards CCS and CCU development (potential) in Slovenia, as well as in the region. Following the review of the relevant literature on wider climate change as well as specific CCS/CCU literature, a list of key stakeholders was made. This included relevant institutional actors, namely the Ministry of environment and spatial planning and Ministry of infrastructure, the largest power plant in Slovenia (TEŠ), the largest Slovenian organization in the field of electricity (HSE), several largest emitters of CO_2, including a cement and aluminium manufacturers, as well as national research institutions, in the fields of geology and chemistry, and two largest universities in Slovenia. A second level of stakeholders (academic/research institutions, and NGO/civil society) was then made so as to gather as holistic assessment as possible. Overall, over 20 interviews were made through Zoom and MS Teams or in-person, and follow-up information was provided via e-mails in some cases. The views and perceptions were also gathered in a workshop and a seminar where other stakeholders were also present. Overall, the views and perceptions summarized below show a holistic and balanced representation of the status of CCS/CCU in Slovenia.

2. Stakeholder positions on CCS and CCU

Following the process of stakeholder engagement, via interviews and holding two workshops and seminars, a general conclusion can be made that for the most part the stakeholders can be classified as fence-sitters. There is an overarching consensus of the potential of CCS/CCU technologies to contribute to reaching EU's climate goals among the stakeholders, albeit that same potential is then questioned

[38] REPUBLIC OF SLOVENIA, SLOVENIA'S FOURTH BIENNIAL REPORT UNFCCC (March, 2020), Page 33. Retrieved from: https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf

when applied in the context of Slovenia's pathway towards climate-neutrality by 2050. The leading concern of the potential of CCS/CCU to be applied in Slovenia is the economics and costs associated with the development, followed by a current lack of a business case for developing carbon capture for the purpose of CO_2 storage, and public opposition. In general, there were no perceived legal and regulatory barriers, albeit there is consensus that CO_2 storage is highly unlikely to occur in Slovenia, given that current Environment Act does not allow for CO_2 storage in Slovenian territory. Following the held workshops and seminars, as part of the stakeholder engagement process, it was understood that investment into CO_2 ccapture equipment would still take place even without the transport and storage component developed (yet). For this, however, early government support for pilot projects will be important. Furthermore, it was agreed that development of industrial clusters with shared infrastructure would enable CCS technology development, in Slovenia, the CEE region and elsewhere.

Public opposition was also identified as a potential high barrier in the future when projects develop. To this end there was agreement among stakeholders that early engagement activities are key to obtaining trust and improving public's awareness and understanding of the CCS/CCU technologies.

The main reason why certain stakeholders are identified as fence-sitters is that:

- they are either actively involved in research activities of various aspects related to CCS/CCU (i.e. IJS, Geological Survey of Slovenia, Milan Vidmar Institute, Geo-Inzeniring), however they are not actively promoting and arguing for the development of the technology/process. Whereas their position can be neutral, their activity and influence can be high. IJS for-example was involved with preparation of the NECP and the LTS in Slovenia, both documents acknowledging the role of CCS in reaching Slovenia's climate targets,

- they do not inhibit or promote the development of CCS/CCU in Slovenia. Often the underlying reason is limited understanding of the associated potential, costs, issues, etc. ,

- they acknowledge the potential of CCS/CCU, however, they are awaiting government policy and financial support for early pilot projects in particular. This sentiment is largely viewed by the industry and private sector actors, who view that they cannot go at it alone, or at least see that government support would expedite the development of CCS/CCU in Slovenia,

- they are in-charge of policy development that could encourage CCS/CCU development, however, they do not have plans to actively promote it (i.e. Ministry of environment and spatial planning, and Ministry of infrastructure).

Nevertheless, there are stakeholders in Slovenia who can be classified as **pace-setters**, as they:

- actively are looking at developing CCS/CCU technology. Their main arguments for justifying investing into CCS/CCU are economic as well as climate related (i.e. TEŠ, HSE). Rising cost of EUA prices being a leading issue that is driving the current momentum,

- are actively involved in research and awareness raising activities related to CCS/CCU. The National Institute of Chemistry, for example, is considered a pace-setter as they are involved or looking to be involved in international projects, as well as aiming to develop a pilot direct-air capture (DAC) project by 2025.

There are also stakeholders who can be considered **foot-draggers**, namely the NGO community. Their primary assumptions and arguments against CCS/CCU are that:

- CCS reduces the efficiency of electricity generation and that CO_2 storage is not allowed in Slovenia, putting the economic justification of investing in CCS under question,
- CCS would prolong the use of fossil fuels which is against the set climate goals,
- CCS is an expensive and untested solution.

In respect to the **foot-draggers**, it should be noted both that these views were expressed in the context of applying CCS to the existing TEŠ power plant, and do not fully take into account the potential of CCS/CCU being applied on energy intensive industries. Nevertheless, their activity and influence can be considered medium or high, given the size of their following and impact in other environment/climate areas. To this end, there was agreement among stakeholders that the NGO, and wider civil society, must be engaged more thoroughly in order to increase the momentum for CCS/CCU technology development in Slovenia.

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

3.1.1. Overall prospects for CCU/CCS in Slovenia

In Slovenia's NECP it states that "if emission allowance prices rise significantly (i.e., between EUR 40 and 60/t CO_2) and if electricity demand is not replaced by renewable, nuclear or gas power plants, then carbon capture and storage (CCS) technologies will become commercially interesting, but this is not expected before 2040." A large majority of respondents were able to identify the role CCS is set to potentially play in Slovenia in the context of climate change mitigation, in that it is included in the National Energy and Climate Plan. They also shared the perception that CCS could play a role post 2040. However, while NECP does acknowledge that CCS could be applied to CO2 intensive industrial sectors, it does not examine the role applying CCS could play in this sector. Similarly, stakeholders, apart from those from the industrial sector, showed limited view - either were not aware or not fully understood how CO_2 capture could be applied or used for. Following the interviews, workshop and seminar, the role of CCU/CCS in the industrial sector was raised in the minds of the stakeholders that were engaged.

In the context of CCU vs. CCS, however, there is a fairly wide agreement between stakeholders that CCU is the driver for the development of CCS, in particular within the industry sector, and noted that the technology also has an important role to play as a climate mitigation tool. Its impact, however, will

depend on the policy certainty and government support in the upcoming years, as well as the speed at which costs of CO_2 capture technologies can come down elsewhere around the world.

In general, within CCU/CCS deployment, prospects for CO_2 storage in Slovenia are seen as extremely low, however, if CO_2 pilot projects are supported and developed, it could lead to larger-scale projects that would be aimed at storage, in countries outside Slovenia, as opposed to utilisation. For that to occur, perception of the stakeholders is that business-cases will have to be made, and common infrastructure developed with neighboring countries.

3.1.2. The role of CCU/CCS in sector integration

Sector integration and the development of common and shared infrastructure was viewed as essential in developing CCU/CCS in Slovenia. To-date all the work that has occurred in CCU/CCS field has been initiated at the individual project level, or at individual institutions, who in some cases attempted to form consortia to bid for government or European funding. In other words, until recently, little attempt was made to seek out possible sector integration pathways to deliver development of CCU/CCS in Slovenia. In this respect, stakeholders extremely welcomed the CCS4CEE project in that it brought together all the activities occurring in this field. Bringing together energy producers, distributers, and users together and developing common projects could lead to a faster development of CCU/CCS and consequently greater efficiency and lower CO_2 emissions. In particular, CCU/CCS could play a significant role in integrating the industrial sectors, through hydrogen and synthetic fuel production, as well as impacting the waste industry through application of CO_2 capture and storage onto proposed waste to energy projects, thereby leading to a decarbonized energy system.

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

In general, while relatively high, there was initial lack of awareness of all the different EU policy and financial instruments available. The EU ETS was identified as the key mechanism and driver of CCU/CCS project development, given the larger than expected rise in the cost of EUA price. The Trans-European Networks for Energy (TEN-E) was identified by one stakeholder as a possible way of supporting investments into CO_2 pipelines, and after its revision hopefully also other means of CO_2 transport. In addition, several stakeholders identified the Innovation Fund and sustainable taxonomy seeing CCS as a green investment. On the other hand, however, there was limited awareness of the fact that as of 2021 CCU fuels were encouraged through the Renewable Energy Directive (RED2) and that under NextGenerationEU mechanism, through REACT-EU, InvestEU, and/or Recovery and Resilience Facility, is eligible for financial support.

3.1.4. Perceived deployment barriers and risks

There was a general consensus among stakeholders that there are no major legal or regulatory barriers for deployment of CCU/CCS in Slovenia, albeit current Environment Act prohibiting CO_2 storage in the Slovenian territory. To this end, stakeholders agreed that also due to potential public opposition CO_2 transport would be best utilized through industrial cluster development and shared infrastructure with

neighboring countries. On the other hand, lengthy permitting and other administrative practices were perceived as potential barriers to deployment.

Another barrier includes the current lack of government funding for initial CO_2 capture projects. While the current legislation, and the Climate Fund, include potential for funding such projects, there is no indication from the relevant government institutions that there are plans to actively fund such projects in the future. This was perceived as holding back developing momentum to CCU/CCS deployment.

Given the historical context of large infrastructure projects, public mistrust and potential opposition was one of the barriers that would have to be overcome before projects begin to be developed. Albeit this is currently not considered a major issue yet.

4. Stakeholder recommendations for CCU/CCS

4.1. Regulation

Slovenia does not have its own specific regulation on CO_2 storage, as the CCS Directive (2009/31/EC) was directly transposed into Slovenian legislation. This was done through the Energy Act (EZ-1). Slovenia's current view, and that of stakeholders, is that CO_2 will not be stored on its territory. This is stated also in Article 166a of the Environmental Protection Act (ZVO-1) in that "it shall be prohibited to inject or store flows of carbon dioxide (geological carbon dioxide storage) on the territory of the Republic of Slovenia and in its epicontinental belt."

One of the recommendations made by stakeholders has been that Article 166a of the ZVO-1 could be amended in the following way: "it shall be prohibited to inject or store flows of carbon dioxide (geological carbon dioxide storage) on the territory of the Republic of Slovenia and in its epicontinental belt, **except in abandoned oil and gas fields and geological areas where there are natural sources of carbon dioxide.**"

Yet other recommendations made was that or the government could adopt specific guidelines on CO_2 capture and storage or CO_2 use, as well as subsidize CO_2 capture technologies to some extent.

For the most part, however, the legal and regulatory framework for CCU/CCS in Slovenia is viewed to be sufficient. Rather, burdensome administrative procedures are identified as a larger barrier for further development of CCU/CCS.

4.2. Technology

For CCU/CCS to take place in Slovenia, the following recommendations for technological advancements were also made:

- Introduction of natural gas reform and hydrogen production,

- introduction of up to 20% of hydrogen into the gas network, because all existing technological devices with this mixture of hydrogen and methane work without problems (including gas engines),
- Introduction of hydrogen filling stations for trucks and cars,
- Introduction of molten carbonate fuel cell (MCFC) for combined heat and power (CHP), because CO_2 capture is part of the MCFC fuel cell operation process,
- Utilising CO_2 combined with surplus electricity produced from renewable energy sources.

4.3. Infrastructure

Article 486 of the Energy Act (EZ - 1) states that "in the territory of the Republic of Slovenia, the transport of captured carbon dioxide shall be permitted through the pipes of the transmission and transport networks in the territory of the Republic of Slovenia." In this respect it was recommended that it would be sensible to set up such a network to potential CO_2 storage sites or set up a center for further transport. It would also be sensible to evaluate options and prepare a national strategy for CO_2 capture and common transport and storage of Slovenia's largest CO_2 emitters.

4.4. Market

One of the key issues for stakeholders, preventing CCU/CCS to be deployed in Slovenia, and elsewhere, are unfavorable investment conditions. Current capture technology, for example, represents a high investment cost that is not recovered economically thereby making it unattractive for private investors. The cost side is essential for the technology itself, as it will make sense to capture the CO_2 if the price of the emissions covered will be lower than the price of the emissions. Some of the recommendations made, include:

- removal of CO_2 tax and introduction of a stock exchange through trading in CO_2 emission allowances, and consideration of abandoning the free allocation of CO_2 coupons,
- subsidies by the government for initial CO_2 capture projects.

4.5. Financial frameworks

Co-financing of projects through subsidies or direct funding from Slovenia's Climate Fund was identified as a key framework to start deploying CCU/CCS in Slovenia. This would allow for initial projects to be developed, leading up to potential larger projects and other EU funding mechanisms to be used.

4.6. Inter-sectoral and regional collaboration

The current Energy Act states the conditions and provisions for CO_2 transport across Slovenia. In this respect, it would be invaluable to also link up with neighboring countries, in particular Italy and Croatia, to develop CO_2 transport systems. Integrating larger systems over a wider area would bring more economic benefits and potential for further system development.

4.7. Social aspects

It is necessary to promote the capture of CO_2 and introduction of these technologies in the context of CO_2 neutral development and economy, and in the context of mitigating climate change. At present, social knowledge of CCU/CCS is very limited in Slovenia. In this case it would go a long way to set up a pilot project where it would be possible to practically present and evaluate the feasibility and economic viability of such a project. In order for CCS technology to gain public support, everyone must play their part. As such, stakeholders agree that government must increase its support and communication activities of the technology/process. Furthermore, through initial project funding government, project developers and civil society sector must step together through various engagement activities.

Chapter 3. CCS and CCU: Public acceptance in Slovenia

1. Public discourse on climate change and emission reductions from industries based on fossil fuels

The issue of climate change has gained significant social and political momentum in Slovenia over the last several years. This shift has largely been driven by the engagement from the civil society and environmental non-governmental organizations (NGOs). It has largely been seen in the amount of news and media coverage on various issues related to climate change, protests, as well as political parties taking up the issue which in the past was addressed, however not to the same extent as today.

The narrative in this context is largely focused on reducing emissions from power generation and transport, with the latter being the most pertinent sector for Slovenia given it represents the largest sources of emissions, contributing 31.7% of total GHG emissions and being the sector where emissions are still rising; whilst other sectors (i.e. industry, agriculture, waste) have seen their emissions fall compared to 1990 levels.[39] Agriculture is also put to the forefront as the sector that will be difficult to decarbonize, followed by emissions reductions from industries based on fossil fuels.

[39] UNFCCC (2020). *Slovenia's 4th Biennial Report*. Retrieved from: https://unfccc.int/sites/default/files/resource/4BR_2020_EN_SLOVENIA.pdf

By far the most prevalent issue in discourse on climate change is the use of and future of coal and thermal powerplant Šoštanj. In this context, other often discussed issues include the future of nuclear power and the construction of planned hydropower plants on the Sava river as sources of electricity generation. Industry, in particular cement manufacturing and steel production, appear in the discourse largely as part of other environmental issues, such as air and water contamination, and less so in the context of emission reductions. A recent report on energy intensive industries in Slovenia, for example, rightfully shows the importance of this sector in terms of emissions as well as contributions to the Slovenian economy, while acknowledging that key role in large-scale decarbonisation of industry will be played by research, development and innovation[40]. To this end and the extent it is mentioned in limited public discourse, CCU/CCS is not seen as one of these options. Key ways of reducing emissions from industries based on fossil fuels, from a public perspective, are seen as a combination of use of renewable and low-carbon energy sources for electricity source, and improved energy efficiency processes. Industry representatives, on the other hand, also recognize the potential role of CCU/CCS – given sufficient government support for pilot and demonstration projects in the upcoming years.

2. Social acceptance issues at the national and local level

The role of social acceptability or opposition in Slovenia is significant and can fundamentally be divided into two levels: i) public support for climate policy in general and ii) past experience with infrastructure projects. While at the national level support, or better said need for climate policy has been increasing over the past several years, past experience with large infrastructure projects, namely the investment into Unit 6 of the thermal powerplant Šoštanj (TEŠ6), which started operating in 2015, has led to a rise in mistrust in proposed climate and energy policies and related projects. The Unit 6 investment and construction was the largest infrastructure project in Slovenia at the time, with increasing costs and suspected corruption and irregularities associated with it.

At the local level, experience related to construction of wind farms shows that local communities are an important stakeholder, which cannot be ignored by investors. In 2019, a proposed construction of 15 wind turbines in the eastern part of Slovenia in Mislinja, Zreče and Slovenska Bistrica, was met with intense opposition from local communities citing concerns over the potential irreparable impact on the natural environment, including on the image of their communities, as well as on the future development of sustainable tourism in the area41. While the proposed project is still active, it has been delayed number of times. On the other hand, the municipality of Krško is home to the nuclear powerplant and is perceived by the local communities largely as positive as it employs local people and because the municipality receives yearly compensation for limited use of area.

[40] Umanotera (2018). Energetsko intenzivna industrija v Sloveniji: poraba energije, dodana vrednost, delovna mesta. Retrieved from: https://www.umanotera.org/wp-content/uploads/2019/01/Energetsko-intenzivna-industrija-v-Sloveniji.pdf
[41] RTV (2019). *Postavitev vetrne elektrarne na Rogli naj bi zelo negativno vplivalo na naravo*. Retrieved from: https://www.rtvslo.si/lokalne-novice/stajerska/postavitev-vetrne-elektrarne-na-rogli-naj-bi-zelo-negativno-vplivala-na-naravo/506444

The Slovenian Ministry of infrastructure recently issued an energy permit for a second unit of the Krško nuclear powerplant unit of 1.1GW and estimated production of 9.000 GW of electricity per year42. While this is not yet a final decision on the investment and construction of the project, the decision has already been met with intense national opposition. This is related to the perception that the decision has been made prematurely and without sufficient public consultation, as well as result of the estimated project cost of 5-6 billion EUR. Relating to the sentiment of a level of mistrust which resulted following the investment into Unit 6 of the Šoštanj thermal powerplant, the future of nuclear energy in Slovenia is likely to remain a prevalent social acceptance issue in Slovenia over the upcoming years.

As such, as it relates to social acceptance in the national discourse, the prevailing issue remains a certain sentiment of mistrust in government institutions43, large infrastructure projects and the conduct of several industrial companies, namely Salonit and Lafarge Cement44. The mistrust in relation to industrial companies relates in large part to their monitoring activities and transparency in this regard. The polluters themselves are the ones who have to report their emissions, and according to legislation, orders operational and other monitoring of emissions. Local communities, and several NGOs mistrust the results of such measuresments on the basis of poor air quality in the vicinity of these companies, and in light of potential indirect influence of the client/company on the implementation of monitoring and measurements. In this respect, they argue that a stricter and more frequent monitoring should be performed to ensure the local communities of the impacts of the industrial activitiy to their health and environment.4546 While industrial companies note that they perform all monitoring in accordance with their environmental permits, the perception that there is a level of mistrust in the general public was confirmed by several stakeholders who formed part of the workshop and seminars related to the CCS4CEE project in Slovenia, as a potential issue for developing CCU/CCS projects. Nevertheless, participants agreed that public engagement and communication is key in all aspects of both policy and infrastructure development.

As was also pointed out during the workshop and the seminar, at the local level, given that Slovenia is a country with a significant proportion of Natura 2000 sites, a network of areas protecting threatened species and habitats, as well as with many sparsely populated settlements and towns, without engagement from investors at early planning stages, social acceptance of infrastructure development activities could also pose a barrier.

[42] Euractiv (2021). First green light for new Slovenian nuclear power station unit. Retrieved from: https://www.euractiv.com/section/politics/short_news/first-green-light-for-new-slovenian-nuclear-power-station-unit/

[43] Reporter (2020). Vrtovec: Zaradi nezaupanja Slovencev v državne ustanove bi lahko Slovenija infrastrukturni sklad oddala v zunanje upravljanje. Retrieved from: https://reporter.si/clanek/slovenija/vrtovec-zaradi-nezaupanja-slovencev-v-drzavne-ustanove-bi-lahko-slovenija-infrastrukturni-sklad-oddala-v-zunanje-upravljanje-786097?fb_comment_id=3005082412932027_3005294156244186

[44] Dnevnik (2012). Zavajajoče meritve industrijskih onesnaževalcev. Retrieved from: https://www.dnevnik.si/1042542609,

[45] Zagovorniki okolja (2020). *Analiza ureditve, izvajanja in prakse merjenja emisij v zrak; težave in predlogi za Slovenijo*. Retrieved from: http://zagovorniki-okolja.si/2020/08/03/analiza-ureditve-izvajanja-in-prakse-merjenja-emisij-v-zrak-tezave-in-predlogi-za-slovenijo/

[46] IUS-Info (2016). *Majcnova v Kanalu o okoljski problematiki zaradi Salonita Anhovo*. Retrieved from: https://www.iusinfo.si/medijsko-sredisce/dnevne-novice/168258

3. Perceptions of CCU/CCS technology: key narratives

Discourse on the potential and use of CCU/CCS technologies and applications in Slovenia has been limited. To a greater extent, this discourse was limited to its applications in the power sector and the Unit 6 of the thermal powerplant Šoštanj. Looking at the available media coverage on CCU/CCS, the key narrative is that investing in additional 280 – 400 million EUR for the installation of carbon capture equipment onto Unit 6[47] is irresponsible, knowing that CCS reduced production efficiency and that storage of CO_2 in Slovenia is prohibited[48]. Doing so would prolong the use of coal as an energy source and would only be indicative of "greenwashing".[49] Yet, CCU has been mentioned sparsely in the context of climate change and circular economy.[50]

There are no CCU/CCS studies available nor studies which focus on the perception of CCU/CCS in Slovenia. Upon review of the media coverage and relevant literature there is limited mention of application of CCS in the industry sector.[51]

When looking at social acceptance issues related to climate change and other energy and industrial projects in that respect, there is a difference between the national and local narratives. While in the Krško region there is a fair level of support for the nuclear power plant, including potential construction of the second reactor, the general level of acceptance is different when looking at the national level as a whole. As there have been no comprehensive studies done to determine whether at this level it would be exemplary of a case of not-in-my-back-yard (NIMBYism), the Slovenian government and primary investors GEN Energija have indicated that before the final decision is made, a public debate will be done to achieve widest possible social consensus on the issue.

In the workshop held as part of this project the prevailing narratives on CCU/CCS included:

- CCS has the potential to play a role in the decarbonisation of the Slovenian industry sector, and less so in the electricity generation. The extent to which CCS would play a role in Slovenia depends on whether there will be government support for initial pilot and demonstration projects for CO_2 capture projects, which would then potentially evolve into CCS, if infrastructure developed in the region as well.

- CCU/CCS is not presented in a compelling enough way to the wider public. More efforts would need to be made in terms of advocacy and engagement.

[47] Government of the Republic of Slovenia (2020). *Integrated National Energy and Climate Plan of the Republic of Slovenia*. Retrieved from: https://ec.europa.eu/energy/sites/default/files/documents/si_final_necp_main_en.pdf
[48] Ekodezela (2020). Nevladniki: Vlada ignorira največji vir izpustov toplogrednih plinov. Retrieved from: https://www.ekodezela.si/eko-okolje/nevladniki-vlada-ignorira-najvecji-vir-izpustov-toplogrednih-plinov/
[49] Greenpeace (2020). TEŠ: Manjkajoče poglavje v podnebnih načrtih Slovenije. Retrieved from: https://www.greenpeace.org/slovenia/sporocilo-za-javnost/2517/tes-manjkajoce-poglavje-v-podnebnih-nacrtih-slovenije/
[50] Etri (2019). Krožno gospodarstvo in podnebni cilji. Retrieved from: https://etri.si/clanek/krozno-gospodarstvo-in-podnebni-cilji/
[51] Delo (2018). *Je rešitev zajemanje in shranjevanje ogljikovega dioksida*?. Retrieved from: https://www.delo.si/novice/znanoteh/je-resitev-zajemanje-in-shranjevanje-ogljikovega-dioksida/

- Other renewables (i.e. solar and hydro) and alternative fuels (i.e. hydrogen) are seen as preferable over CCU/CCS in Slovenia as a decarbonisation solution both for the energy intensive industry and the power sector. For the energy intensive industries, CCU is seen both as a decarbonisation tool and a tool to generate additional revenues and it is likely to take precedence over CCS (at least until transport and storage infrastructure solutions are established).

- It is unlikely that CO_2 storage will occur in Slovenia, thus, it will be vital for industry to connect with neighbouring countries to utilise shared infrastructure.

4. Institutional views on CCU/CCS

Institutional views can be separated to those of public and private entities, with the former presenting more implicit and the latter explicit positions on CCU/CCS. As mentioned in sections above and as was expressed as part of the stakeholder engagement part of this project, the government institutions, namely the Ministry of environment and spatial planning and the Ministry of infrastructure, acknowledge the potential role that CCS could play in helping Slovenia reach its long-term climate goals. This is evident with the inclusion of the technology in the National Energy and Climate Plan and the Long-Term Climate Strategy, two key climate documents. Furthermore, research institutions such as the National Institute of Chemistry and the Geologic Survey of Slovenia continue to participate in numerous research projects related to CO_2 capture, which can be indicative of relative support for the technology.

On the other hand, private entities, in particular Salonit Anhovo, a cement manufacturer, has been one of the only institutions to have explicitly stated that it intends to develop CCU/CCS as part of its long-term decarbonisation plan. In this respect their goal is to start with a pilot CO_2 capture unit with the CO_2 to be utilised in some way, while they would consider storing the CO_2 at a later stage if appropriate transport and storage infrastructure, that would make economic sense, would be developed. Private sector entities presently view the main issue with developing CCU/CCS, in Slovenia and elsewhere, as a lack of favourable investment conditions, given the high current CO_2 capture costs, and virtually non-existent government support to develop these technologies. Private sector entities included in this project agree that setting up pilot and demonstration projects would go a long way in sending a strong signal to the industry and the general public that the technology is safe and can and should contribute to the fight against climate change.

5. Gaps in public discourse on CCU/CCS

To the extent that CCU/CCS has been mentioned in public discourse, namely by several NGOs, and regarding its application to power generation, it has been limited to that end also to its drawbacks and not to its advantages.[52] NGO's have based their position on the level of distrust related to monitoring, transparency and infrastructure investment issues. With extremely limited discourse on CCU/CCS

[52] Focus (2015). Zajemanje in skladiščenje ogljika. Retrieved from: https://focus.si/kampanje-in-akcije/zajemanje-in-skladiscenje-ogljika/

technologies and their potential applications in general, there is therefore a great need to increase activities related to increase in social knowledge, acceptance and advocacy.

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