ROUTING DEPLOYMENT OF CC(U)S IN THE BALTIC SEA REGION

Monika Ivandic[1*], Alla Shogenova[2], Farid Karimi[3], Adam Wójcicki[4], Kazbulat Shogenov[2]
[1]Uppsala University, Uppsala, Sweden
[2] Tallinn University of Technology, Tallinn, Estonia
[3]Novia University of Applied Sciences, Finland
[4]Polish Geological Institute – National Research Institute

* Corresponding author e-mail: monika.ivandic@geo.uu.se

Abstract

Much potential exists in the Baltic Sea region (BSR) regarding CC(U)S and at least on the research side, there has been a steady stream of activities over the years. Potential storage sites are localized in the Baltic Basin within several countries such as Sweden, Latvia, Lithuania, Poland and Russia. However, the BSR is still lagging behind in deploying a large-scale CC(U)S due to the national policy and regulatory frameworks which create unfavorable conditions for the technology, as well as the low public awareness and acceptability in most of the countries in the region. Consequently, CO_2 injection is forbidden in Lithuania, CO_2 storage on an industrial scale is banned in Estonia, Latvia and Finland and some federal states of Germany, while in Denmark, Poland and Sweden is permitted with limitations. However, it should also be noted that some positive developments and attitudes towards CC(U)S have also taken place recently in some of the BSR countries. This paper provides an overview of the current CC(U)S status and development in the BSR.

Keywords: *CCUS, Baltic Sea Region, CO_2 storage, CCS regulations, Social acceptance, CCS*

1. CC(U)S in the Baltic Sea Region

Deployment of full-scale CC(U)S on a global scale is key to meet the objectives of the Paris Agreement and mitigate climate change [1]. In the power sector, CCS is considered to be a key technology for fossil fuel-based generation, critical for delivering the deep emission reductions needed across fossil fuel-based power and many industrial applications while providing the opportunity for “negative emissions” [2]. It could also help the security of supply in a clean electricity system with increasing shares of variable renewable energy (VRE).

In the Baltic Sea Region (BSR), deployment of full-scale CC(U)S requires regional cooperation with equal conditions, standards, information, framework and understanding. Implementation of the technology on a regional scale for clusters of CO_2 emitters using common transboundary transport and storage infrastructure can significantly decrease the overall costs and affect public attitude. Moreover, an establishment of storage hubs to sequester CO_2 from several emission sources might be necessary to achieve large-scale deployment. A good example is the Northern Lights project in Norway, which offers an infrastructure for transport and storage of CO_2 across Europe, and the pilot capture plants planned by Fortum in the BSR: Fortum Oslo (Norway), Stockholm Exergi (Sweden), Klaipeda (Lithuania) and Zabrze CHP (combined heat and power; Poland) [3]. Northern Lights is the transport and storage component of the Longship project, promoted and supported by Norwegian State. Although the project has been developed under circumstances that are unique to Norway, the experience is relevant for the setup and development of other CC(U)S projects. It demonstrates that, with long-term cooperation between state agencies, research institutions, academia and industrial partners, it is possible to develop CCS technology further and deploy a full-scale project.

The knowledge gained in the Northern Lights may be especially relevant for the BSR, which forms not only a political but a natural geographical area for collaboration needed for such a large-scale infrastructure development. Issues such as economic and environmental concerns, and safe transport and storage solutions are key areas of common regional interest. There will be a clear need for the use of joint and transboundary solutions for transportation and storage of CO_2 between the BSR countries. For example, since Russia and Germany are two of the largest CO_2 emitters on aggregate-level in the world, with 1792 Mt and 703 Mt of CO_2 emitted in 2020, respectively, and Poland is one of the largest CO_2 emitters in Europe (318 Mt/year) [4], the BSR needs to scale up development and deployment of CCUS as a climate change mitigation measure to meet the Paris Agreement and the EU climate goals. Regarding the geological storage possibilities, potential storage sites are localized in the Baltic Basin within the borders of several countries such as Sweden, Latvia, Lithuania, Poland and Russia. A study conducted by Anthonsen et al. [5] shows that Denmark, Norway and Sweden alone have the theoretical capacity to store the total CO_2 emission from all European stationary point sources as mapped by the EU GeoCapacity project [6], though mostly under the North Sea. However, in the BSR CO_2 storage on an industrial scale (>100 Kt per year) is currently either permitted with different limitations (Denmark, Germany, Poland, Sweden) or prohibited for various reasons (Finland, Estonia, Latvia and Lithuania), or CC(U)S laws are not yet introduced (Russia and Belorussia). Thus, enabling policy and regulatory changes for industrial-scale projects are required in the entire region.

This paper gives an overview of the current situation in the BSR regarding both the possibilities and obstacles for implementation of the CC(U)S technology in the region.

2. The need for the CC(U)S technology in the BSR

The EU´s CCS strategy presented in the Commission's proposal for 2030 climate and energy policy framework acknowledges the role of CCS in reaching the EU's long-term emissions reduction goal. As process-related emissions are unavoidable in some sectors, CCS may be the only option available to reduce direct emissions from industrial processes on the scale needed in the longer term. Moreover, as the key technology in the clean energy transition, during which fossil fuels still have the major share in the global primary energy consumption, the CC(U)S can help countries to ensure their energy security and security of supply. For instance, in the example of Estonia, an increase of CO_2 emission allowance price up to 25-30 Euro per ton in EU ETS in 2019 has led to an increase in the oil-shale based energy price, making it not competitive to the cheaper Russian energy. As a result, the largest Estonian national energy company Eesti Energia was forced to decrease energy production to reduce the high CO_2 emissions by five million tons in 2019 [7].

CC(U)S projects could also cooperate with renewable energies and produce revenues through CO_2 use options. For instance, considering that Finland is a large consumer of power and heat (per capita), the country has a unique opportunity to integrate CCS with combined heat and power (CHP) plants. Also, as Finland is a large consumer of biomass, adding CCS to bioenergy solutions, i.e., bioenergy carbon capture and storage, (BECCS), would enable removal of (biomass originated) CO_2 from the atmosphere. Furthermore, Finland's electricity supply depends on import of electricity from Russia which imposes security risk to the country whereas a clean energy system utilising CC(U)S could decrease this dependency on the non-EU energy supply. When it comes to the Finnish technology developers and providers, CCS could provide a significant market share in the future, such as in the area of oxyfuel combustion and chemical looping combustion. However, as the Finnish bedrock does not have any formations suitable for underground storage of CO_2, other alternatives need to be considered. Several options for using CO_2 as a raw material for production of inorganic carbonates, chemicals and fuel components also seems promising [8].

Bioenergy is far more widespread in Sweden than in any other country in the region. By introducing various incentives like a CO_2 tax, green electricity certificates, tax exemption of biofuels for transport and direct investment support, there has been a major increase in the use of biofuels. In fact, in 2019, Swedish energy utility Stockholm Exergi AB has inaugurated the country's first BECCS pilot plant at its Värtan biomass-fired CHP plant in Stockholm partnering the Northern Lights project.

CC(U)S could also help to fully decarbonise heavy industry like cement and steel, where CO_2 is produced by industrial processes in addition to using energy from fossil fuels. In Sweden, for example, the cement industry produces 5% of the country’s total CO_2 emissions [9]. Therefore, decarbonization of the cement industry will play a vital role in achieving Sweden's climate goals. One of the main ways in which production of cement can be made more sustainable and emissions deeply cut is through the application of CC(U)S. This has been already recognized by HeidelbergCement in Norway. Their plan to realise the first industrial-scale CCS project at a cement production facility in the world at Brevik involves capturing 400,000 tons of CO_2 annually and transporting it for permanent storage[1].

Currently, the largest industrial use of CO_2 is in enhanced oil recovery (EOR), whereby pressurized CO_2 is injected into existing oil and gas reservoirs to extract more hydrocarbons. Today, EOR is the only industrial use of CO_2 that has reached an appreciable scale. Evaluation of CO_2 injection for EOR has already been performed by oil companies in Lithuania and Russia. In Lithuania, pilot injections have been made in three oil exploitation wells to investigate the potential of CO_2 for EOR. The results showed high oil recovery percentage and about 100-200 Mt CO_2 storage capacity in the Gargzdai oil zone [14, 16]. A comprehensive study on the potential of Russia to implement CO_2-EOR showed that the geological, mining, geographical, and economic conditions of some regions in Russia have a very good potential for the technologically feasible and economically efficient implementation of CO_2-EOR technologies in depleted oil fields [10]. The most promising of the estimated regions are located in the North-Western, Volga, and Ural Federal districts.

In Poland, there are currently two candidate fields for enhanced oil recovery (EOR): the B3 oil field in the north-east part of the Polish sector [13] and Kamień Pomorski in the northwestern coastal region [14]. Another nearby hydrocarbon field, B8, with a good theoretical storage potential and with commercial production running since 2016, could be another potential site in the country for enhanced hydrocarbon recovery (EHR).

---

[1] www.heidelbergcement.com

Captured CO_2 can be also used in processes where underground minerals are utilised to mineralise CO_2, or in enhanced geothermal systems (EGS) where CO_2 would be used, instead of water, as heat transmission fluid, and would achieve geologic storage of CO_2 as an ancillary benefit. Research on CCUS started in many countries, including geothermal-CCS projects in France [11], Germany [12], Poland and Norway[2].

3. The geological storage potential in the BSR

A modelling study conducted in 2014 on the potential CO_2 storage sites in the southern Baltic Sea and surrounding onshore areas has identified a relatively large theoretical CO_2 storage capacity in the subsurface: about 16 Gt in the Middle Cambrian sandstone beneath 900 m of caprock and 1.9 Gt in the Dalders Monocline [13]. It has been also concluded that areas to the northeast of the Dalders Monocline, such as the eastern Swedish sector of the Baltic Sea and offshore part of Latvia where limited data is available, may have better reservoir qualities which would allow a higher injection rate, and thus would be more suitable for regional industrial CO_2 storage.

In addition to that, there is a possibility to use hydrocarbon and saline structures located both onshore and offshore Latvia. The estimated storage capacity of these structures is more than 880 Mt CO_2 [15, 16]. The reservoir rock properties in five onshore and offshore structures were experimentally analyzed and estimated from good to high quality, or from appropriate to very appropriate for CO_2 storage [17].

A number of studies have identified and assessed the storage capacity of reservoirs within the Baltic Basin, which is potentially suitable for CO_2 storage [18, 19, 20, 21, 22, 23]. Four potential test sites located in the BSR have been then identified and described: Southern Gotland (Sweden), South Kandava (Latvia), Vaškai structure (Lithuania) and Kamień Pomorski (Poland) (Figure 1).

There are also many places in Danish subsoil with suitable reservoirs. Anthonsen et al. [5] estimate that the subsoil can probably contain up to 22 GT of CO_2 (both onshore and offshore). This corresponds to between 500 and 1000 years of total Danish emissions at the current level. Furthermore, CO_2 storage could be established both on land and at sea, as the underground reservoirs are the same[3]. A few decades of research on CCS in Denmark have gathered good knowledge about the CCS potential.

In Poland, the latest national studies estimated the country's underground CO_2 storage capacity to be 10-15 Gt (predominantly onshore) [24]. The storage capacity corresponds to 50-75 years of Polish ETS industrial installations emissions at the current level.

A fairly different situation exists in Russia where, based on the data from the former Soviet Union, estimated geological storage capacity is about 560 Gt [10], however, with most of the reservoirs being located far distant from large fossil-based power plants. CO_2 injection would therefore require construction of a gigantic pipeline system.

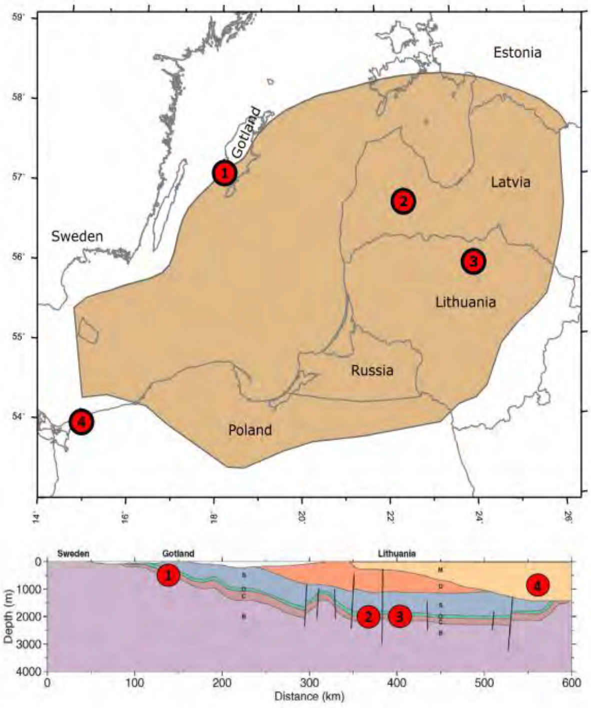

Figure 1: The area marked in brown shows the approximate area where Cambrian sandstones are present below 500 m depth where potential CO_2 storage reservoirs can exist. The locations of the four potential storage sites identified in the study are shown on the map (upper figure). Schematic cross section shows the general stratigraphic placement of the four pilot sites. B, C, O, S, D denote Basement, Cambrian, Ordovician, Silurian and Devonian, respectively. M denotes Strata which is younger than Devonian (lower figure) (Source: Nordbäck, N. et al. [14]).

On the other hand, in countries that lack potential for geological CO_2 storage, such as Finland and Estonia, captured CO_2 would need to be transported to other countries with suitable geology and storage infrastructure options. A study performed by Lauri et al. [25] has shown that the cost for transporting CO_2 from Finland to final geological CO_2 storage sites abroad is higher compared to that from the coastal regions in countries around the North Sea. However, significant cost reductions for CO_2 transport can be reached by joint transport infrastructure projects. For instance, transportation of CO_2 from the Gulf of Finland by ships could be carried out more

---

[2] www.sintef.no/en/projects/2020/energizers-co2-enhanced-geothermal-systems-for-climate-neutral-energy-supply

[3] www.geus.dk/

economically by employing an infrastructure of ship terminals where CO_2 is collected into intermediate storage facilities from several capture units.

4. National CCS regulations

Article 6 of the London Protocol prohibits “export of wastes or other matter to other countries for dumping or incineration at sea” [26]. The article has been interpreted by contracting parties as prohibiting the export of CO_2 from a contracting party for injection into sub-seabed geological formations [27]. In 2009, the article was amended by contracting parties to allow cross-border transportation of CO_2 for sub-seabed storage [28], but the amendment must be ratified by two-thirds of contracting parties to enter into force.

In October 2019, the London Protocol Parties adopted a resolution to allow provisional application of an amendment to article 6 of the Protocol to allow sub-seabed geological formations for sequestration projects to be shared across national boundaries. This provisional application allows countries to agree to export and receive CO_2 for offshore geological storage. It removes the last significant international legal barrier to CCS and means that CO_2 can be transported across international borders to offshore storage.

This may enable CCS deployment in the BSR countries, as it permits countries to transport their captured CO_2 to offshore storage sites in Norway. Poland, Finland, and Germany could see this as an opportunity to decrease their CO_2 emission significantly.

The current situation in the BSR regarding the implementation of the CCS technology varies significantly from country to country. CO_2 storage is currently either permitted with different limitations or prohibited for various reasons, or CCS/CCUS laws are not yet introduced, such as in the case of Russia and Belarus (Table 1).

In Poland, CO_2 storage is prohibited until 2024 except for offshore demonstration projects in the Cambrian reservoir. CO_2 use for Enhanced Oil and Gas Recovery (EOR/EGR) is not restricted, but the status of the associated CO_2 storage possibilities both onshore and offshore is unclear.

In Germany, according to the Carbon Capture and Storage Act (KSpG), the total admissible annual storage volume is limited to four million tons of CO_2 in total, with a maximum annual storage volume of 1.3 million tons of CO_2 per storage site. Applications for storage site authorisations had to be made by the 31st of December 2016, so new storage sites can no longer be permitted as the legislation stands at present. In the evaluation report, which was presented and discussed in the parliament in December 2018, the German federal government stated that there was no need to modify these regulations. As a result, CO_2 storage is still not permitted in Germany on an industrial scale [29, 30]. The federal government is however looking into tapping the sizable carbon storage potential under the North Sea[4].

Table 1: National CCS regulations in the BSR countries.

	CO_2 permitted for industrial scale	
Country	**Onshore**	**Offshore**
Denmark	No	Yes - for EOR
Estonia	No	No
Finland	No	No
Germany	No	No
Latvia	No	No
Lithuania	No	No
Poland	Not permitted, except for demo-projects	
Sweden	No	Yes
Norway	No	Yes
Russia	NE	NE
Belarus	NE	NE

In Estonia, Finland and Latvia, CO_2 storage is prohibited except for research and development, although underground CO_2 storage potential in Finland and Estonia is almost non-existent.

In Sweden and Norway, industrial-scale CO_2 storage is permitted only offshore. Sweden has also recently accepted the Amendment to article 6 of the London Protocol[5]. Previously, only Estonia, Finland, Norway, The Netherlands, UK and Iran have done that. A number of capture pilot projects have started or are in preparation to start in several places in the country with the aim to transport CO_2 to Norway from Swedish power plants,

---

[4] www.cleanenergywire.org

[5] shippingregs.org/Reference/IMO-Regulations/IMO-Circulars/2020

since an offshore CO_2 storage site in Sweden has not yet been established.

Significant changes have happened in Lithuania recently, where CO_2 geological storage was allowed both onshore and offshore until October 2019, when the new government of Lithuania adopted the new Subsurface Law. Since then, injection and storage of CO_2 in natural or artificial underground cavities or aquifers have been prohibited. This ban came into force in July 2020 [31].

In contrast, positive changes have been observed in Denmark. In the Danish Council on Climate Change report on Denmark's climate action towards 2030, CCS is presented as one of the main tools in order to reach CO_2 neutrality[6]. Although it is not possible at present to obtain permits for CO_2 storage in the Danish subsoil, the Danish Government works towards uncovering the regulatory obstacles to CC(U)S within the sectors in which the technology may be of relevance [32]. Also, based on the assessments of the Global CCS Institute undertaken in 2015[7], Denmark has the most developed framework for CCS among the BSR countries, while the rest of the region demonstrates limited or very few CCS-specific existing laws applicable to all aspects of the CCS project lifecycle.

The enabling legislation for CCS in the BSR is regulated by national laws and international conventions. Since several BSR countries are not yet parties of the London Protocol (Finland, Poland, Latvia, Lithuania and Russia), bilateral and international agreements and local permits will be needed for transboundary offshore CO_2 storage.

Furthermore, several challenges still remain for the large-scale implementation of CCS projects in Europe. These include high investment costs and lack of public and consequently political support for onshore storage.

As concluded in the study by Shogenova et al. [30], the implementation of the CCUS technology requires regional and national incentives to be further developed in the BSR. For the realization of transboundary CCUS scenarios and construction of regional networks, both international and national legislation should be updated and implemented in a way that enables CCUS projects on an industrial scale. Furthermore, cooperation through clustering of CO_2 emitters and CO_2 storage sites and using common infrastructure could decrease costs, improve the communication with governments and local residents and create new opportunities in the BSR.

5. Politics and social aspects of CCS in the region

Advancing CC(U)S deployment is a multi-dimensional question including technological, socio-political, legal, economic and environmental dimensions. Although the BSR has a unique potential for joint efforts on climate change mitigation, the level of CCS knowledge and understanding varies significantly between the countries. Various perceptions, concerns and values among stakeholders hamper the process of development and deployment of CC(U)S in the region. Furthermore, these diverse perceptions have led to fragmented governance, not least on the regional level. Strong sentiment against CCS exists among various stakeholders such as NGOs and the public in Germany [33], and to some extent, in Poland [34]. However, an exception is Norway's case where NGOs support CCS as a measure for combating climate change. This highlights different CCS perceptions in various countries attributable to various values, economic and political settings of the countries (for instance, see [33] and [34]).

In stark contrast to the development of CCS in Finland, there is fairly positive to neutral perceptions of and opinions about the technology among the public and industrial stakeholders, not least about BECCS [35], [36], [37].

In sum, the current state of stakeholders' acceptance in the BSR countries is the following: significant lack of acceptance in Germany; neutral to moderate lack of acceptance in the Baltic States and Poland; neutral to moderate acceptance in Finland, Sweden and Denmark; and acceptance and support in Norway.

Perceptions, reactions, and acceptance significantly affect the development of sustainable energy technology and the energy transition at local [37], regional, and global levels [38], [39]. Sovacool and Ratan [40] argue that social acceptance will emerge among stakeholders in the presence of the following: robust institutions, political commitment, supportive laws and regulations, competitive costs, a sophisticated communication system, and comprehensive financing.

Finally, we recommend that a comprehensive BSR campaign for social outreach would be worthwhile, including effective and transparent communication with the public concerning the cost, economic benefit and (dis-) advantages of CC(U)S. To pursue this successfully, consideration of the differences in cross-cultural and social settings between the countries is important.

6. Conclusion

International cooperation both within a region, such as the BSR, and outside the region borders is crucial to expedite CCUS development given the costly infrastructure and limited geologically suitable storage sites. Issues such as environmental concerns, safe transport and storage, public perceptions, and acceptability are of common regional interest. Therefore, it is vital to start processes which would enable such

---

[6] www.klimaraadet.dk/da/nyheder/klimaraadet-ny-rapport-om-vejen-til-70-procentsmaalet-i-2030

[7] www.globalccsinstitute.com/resources/publications-reports-research/global-ccs-institute-ccs-legal-and-regulatory-indicator/

cooperation, such as creating an EU Project of Common Interest (PCI) where all interested parties and countries could be involved, signing the London Protocol and ratifying the 2009 amendment by those countries that have not done yet, and reconsidering the current ban for CO_2 storage in Latvia and Lithuania.

The CC(U)S challenges in the various BSR countries are different. CO_2 storage capacity, for instance, is abundant in Norway but not available in Finland. This means that combining challenges, competence and possibilities in the different countries would lead towards creating more possibilities for establishing complete and optimal CC(U)S value chains in the region. Therefore, addressing the issues related to the current unfavorable national regulations that prevent full deployment of CC(U)S at an industrial scale in most of the countries in the BSR is urgently needed.

In sum, despite having relatively a shared vision in the BSR countries for expediting tackling climate change based on the EU goals and the Paris Agreement, this region is not homogenous, particularly when it comes to challenges of deployment of technologies such as CC(U)S. Also, various risk and benefit perceptions exist among the stakeholders. When it comes to the policy and politics of CC(U)S, one notable challenge is the need to deal with the existing fragmented governance concerning the deployment of the CC(U)S in the region.

Acknowledgements

This work was supported by the RouteCCS project funded by the Swedish Institute (01199/2020).

References

[1] IEA (2016). 20 Years of Carbon Capture and Storage. Paris: International Energy Agency.

[2] IEA report, 'Five Keys to Unlock CCS Investment, 2018, www.iea.org.

[3] Thomassen, J., 2019. Fortum's CCUS initiatives in the Baltic Sea Region. Baltic Carbon Forum – BASRECCS Conference 22-23.10.2019, Tallinn, Estonia, https://bcforum.net/presentations2019/02-05-Fortums-Initiatives-in-the-Baltic-Sea-Region.pdf

[4] Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J.G.J., Vignati, E., Fossil CO_2 emissions of all world countries - 2020 Report, EUR 30358 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21515-8, doi:10.2760/143674, JRC121460.

[5] Anthonsen KL, Frykman P., Nielsen CM, 2016. Mapping of the CO_2 storage potential in the Nordic region. Geological Survey of Denmark and Greenland 35:87-90, doi: 10.34194/geusb.v35.4946

[6] Vangkilde-Pedersen, T. et al. 2009. Assessing European capacity for geological storage of carbon dioxide – the EU GeoCapacity project. Energy Procedia 1, 2663–2670.

[7] Shogenova, A., 2020. Carbon Neutral Baltic States: Do We Have CCUS Among Accepted Options? Baltic Carbon Forum 2020.

[8] Teir S. et al., 2013. CCSP Carbon Capture and Storage Program, Mid-term report 2011–2013, (Eds.). Espoo 2013. VTT Technology 125. 76 p.

[9] Tillväxtanalys. (2016). Klimatneutral cementindustri – Koldioxidavskiljning och lagring i Sverige? Retrieved from: https://www.tillvaxtanalys.se/in-english/publications/direct-response/direct-response/2016-11-10-a-climateneutral-cement-industry----carbon-capture-and-storage-in-sweden.html

[10] Cherepovitsyn, A. Fedoseev, S., Tcvetkov, P., Sidorova, K., Kraslawski A. (2018). Potential of Russian Regions to Implement CO2-Enhanced Oil Recovery. Energies 2018, 11, 1528; doi:10.3390/en11061528.

[11] Galièguea, X., Laudeb, A. (2017). Combining Geothermal Energy and CCS: From the Transformation to the Reconfiguration of a Socio-Technical Regime? Energy Procedia 114 (2017), 7528 – 7539.

[12] McDonnell, K., Molnár, L.,Harty, M., Murphy, F. (2020) Feasibility Study of Carbon Dioxide Plume Geothermal Systems in Germany - Utilising Carbon Dioxide for Energy. Energies 2020, 13, 2416; doi:10.3390/en13102416

[13] Final report on prospective sites for the geological storage of CO_2 in the southern Baltic Sea, 2014, www.globalccsinstitute.com

[14] Nordbäck, N., Sopher, D., Niemi, A., Juhlin, C., et al. (2017). CGS Baltic seed project (S81). Project substance report. 1−84., https://bcforum.net/storage.php.

[15] Šliaupa S, Lojka R, Tasáryová Z, Kolejka V, Hladík V, Kotulová J, Shogenov K, et al. 2013. CO_2 storage potential of sedimentary basins of Slovakia, the Czech Republic, Poland and the Baltic States. Geological Quarterly; 219 - 232.

[16] Shogenov K, Shogenova A, Forlin E, Gei D., 2017. Synergy of CO_2 storage and oil recovery in different geological formations: case study in the Baltic Sea. Energy Procedia, 114: GHGT-13, Lausanne, Switzerland, 14-18 November 2016. The Netherlands: Elsevier: 7047−7054. /doi.org/10.1016/j.egypro.2017.03.1846.

[17] Shogenov, K.,, Shogenova, A., Vizika-Kavvadias, O., Nauroy, J. F. 2015. Reservoir quality and petrophysical properties of Cambrian sandstones and their changes during the experimental modelling of CO_2 storage in the Baltic Basin. Journal of Earth Sciences, 64 (3), 199−217.

[18] Shogenova, A., Sliaupa, S., Vaher, R., Shogenov, K., Pomeranceva, R., 2009. The Baltic Basin: structure, properties of reservoir rocks and capacity for geological storage of CO_2. Estonian Journal of Earth Sciences, 58(4), 259 - 267.

[19] Erlström, M., Fredriksson, D., Juhojuntti, N., Sivhed, U., Wickström, L., 2011. Lagring av koldioxid i berggrunden - krav, förutsättningar och möjligheter. Sveriges Geologiska Undersökning Rapporter och meddelanden 131, 7–94.

[20] Vernon R., O'Neil N., Pasquali R. Nieminen M., 2013. Screening of prospective sites for geological storage of CO_2 in the Southern Baltic Sea. Espoo 2013. VTT Technology 101, 58 p. + app. 1 p. (final report of the BASTOR project).

[21] Sopher, D., Juhlin, C., Erlstrom, M., 2014. A probabilistic assessment of the effective CO_2 storage capacity within the Swedish sector of the Baltic Basin. International Journal of Greenhouse Gas Control, 30, 148-170.

[22] Lothe, A., Emmel, B., Bergmo, P., Mortensen, G. M., Frykman, P., 2015. Updated estimate of storage capacity and evaluation of Seal for selected Aquifers (D26). NORDICCS Technical Report D 6.3.1401 (D26). 80 pp.

[23] Yang Z, Tian L., Jung B, Joodaki S, Fagerlund F, Pasquali R., 2015. Assessing CO_2 storage capacity in the Dalders Monocline of the Baltic Sea Basin using dynamic models of varying complexity. International Journal of Greenhouse Gas Control. 2015; 43:149-60.

[24] Wójcicki A., Nagy S., Lubaś J., Chećko J., Tarkowski R., 2014. Assessment of formations and structures suitable for safe CO_2 storage (in Poland) including the monitoring plans (summary). PGI-NRI, Warsaw (report available at PGI website; skladowanie.pgi.gov.pl).

[25] Lauri, K., Jouko, R., Nicklas, N. and Sebastian, T., 2014. Scenarios and new technologies for a North-European CO2 transport infrastructure in 2050. Energy Procedia 3 (2014) 2738 – 2756.

[26] Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (London Convention 1972). London Protocol (1996) – protocol thereto. www.imo.org

[27] IMO. Report of the Thirtieth Consultative Meeting and the Third Meeting of Contracting Parties, LC 30/16. London: IMO; 2008.

[28] IMO. Report of the Thirty-First Consultative Meeting and the Fourth Meeting of Contracting Parties, LC 31/15. London: IMO; 2009.

[29] Bals, C., Bellmann, E., Bode, A., Edenhofer, O., et al. (2019). CCU and CCS – Building Blocks for Climate Protection in Industry. Analysis, Options and Recommendations (acatech – Deutsche Akademie der Technikwissenschaften e.V., Ed.). München: utzverlag GmbH.

[30] Shogenova, A., Nordback, N., Sopher, D., Shogenov, K. et al. (2021). Carbon Neutral Baltic Sea Region by 2050: Myth or Reality? 15th International Conference on Greenhouse Gas Control Technologies, GHGT-15, 15-18 March 2021, Abu Dhabi, UAE. Elsevier, SSRN, 1−12. DOI: 10.2139/ssrn.3817722.

[31] Pakeisti Lietuvos Respublikos žemės gelmių įstatymą Nr. I-1034 ir jį išdėstyti taip, www.infolex.lt/ta/556859:str1

[32] Danish Ministry of Climate, Energy and Utilities. The ugly duckling – *CCS* and CCU in Denmark. Baltic Carbon Forum 2020. 14. October.

[33] Karimi, F., Komendantova, N., 2017. Understanding experts' views and risk perceptions on carbon capture and storage in three European countries, Geojournal 82 (1), 185–200.

[34] Karimi, F., and Toikka A., 2018. 'General Public Reactions to Carbon Capture and Storage: Does Culture Matter?' International Journal of Greenhouse Gas Control 70 : 193–201. https://doi.org/10.1016/j.ijggc.2018.01.012.

[35] Rodriguez, Emily, Adrian Lefvert, Mathias Fridahl, Stefan Grönkvist, Simon Haikola, and Anders Hansson. 2021. 'Tensions in the Energy Transition: Swedish and Finnish Company Perspectives on Bioenergy with Carbon Capture and Storage'. Journal of Cleaner Production 280 (January): 124527. https://doi.org/10.1016/j.jclepro.2020.124527.

[36] Kojo, Matti, and Eeva Innola. 2017. 'Carbon Capture and Storage in the Finnish Print Media'. Risk, Hazards & Crisis in Public Policy 8 (2): 113–46. https://doi.org/10.1002/rhc3.12111.

[37] Karimi, F. and Rodi, M., 2021. Energy-Transition Challenges in the Baltic Sea Region: An Overview of Socio-Political and Legal Gaps. From Economic to Energy Transition, pp.457-487.

[38] Wolsink, M. 2018. Social Acceptance Revisited: Gaps, Questionable Trends, and an Auspicious Perspective. Energy Research & Social Science, 46, 287– 295.

[39] Sütterlin, B., & Siegrist, M. 2017. Public Acceptance of Renewable Energy Technologies from an Abstract Versus Concrete Perspective and the Positive Imagery of Solar Power. Energy Policy, 106, 356–366.

[40] Sovacool, B. K., & Lakshmi Ratan, P. 2012. Conceptualizing the Acceptance of Wind and Solar Electricity. Renewable and Sustainable Energy Reviews, 16 (7), 5268–5279.