SHORT COURSE ON RECENT DEVELOPMENTS IN CCUS IMPLEMENTATION AND RESEARCH:

LESSONS LEARNED

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Course Content

- A) Developments in strategic, political and regulatory issues
- Strategic (Climate strategies and revenue systems)
- Political and Regulatory (National strategies and regulations)
- Geological 1: Negative and positive lessons
- B) Geological 2: Site characterization and modelling (Prof. Auli Niemi)
- **Coffee break: 15 min**
- C) Techno-economic aspects of CCUS clusters and hubs
- CCUS clusters and hubs: Carbon Neutral Scenario for the Baltic States
- **Conclusions and integration of the learned lessons**

Part A

Developments and lessons learned in strategic, political and regulatory issues

Strategic (Climate strategies and revenue systems)

Political and Regulatory (National strategies and regulations)

Geological 1: Negative and positive lessons

Strategic lessons

Climate strategies

The UN Climate Agreements

Kyoto Protocol & Paris Agreement

Kyoto Protocol	Paris Agreement
Was created in 1997 and ratified in 2005. Had two periods from 1997-2020.	Signed in November of 2016. New commitments are due every 5 years
Legally binding agreement to decrease GHG	Not legally binding commitment to reduce emissions, increase accountability
Original commitment to decrease overall emissions by 5% from 1990 levels	Overall goal to limit global temperatures to 1.5 degrees celcius above pre-industrial levels
Only required developed nations to reduce emissions	Asked all nations to reduce emissions
Targets are set but no determined time frame	New set of targets declared after 5 years (these are now due in 2020)

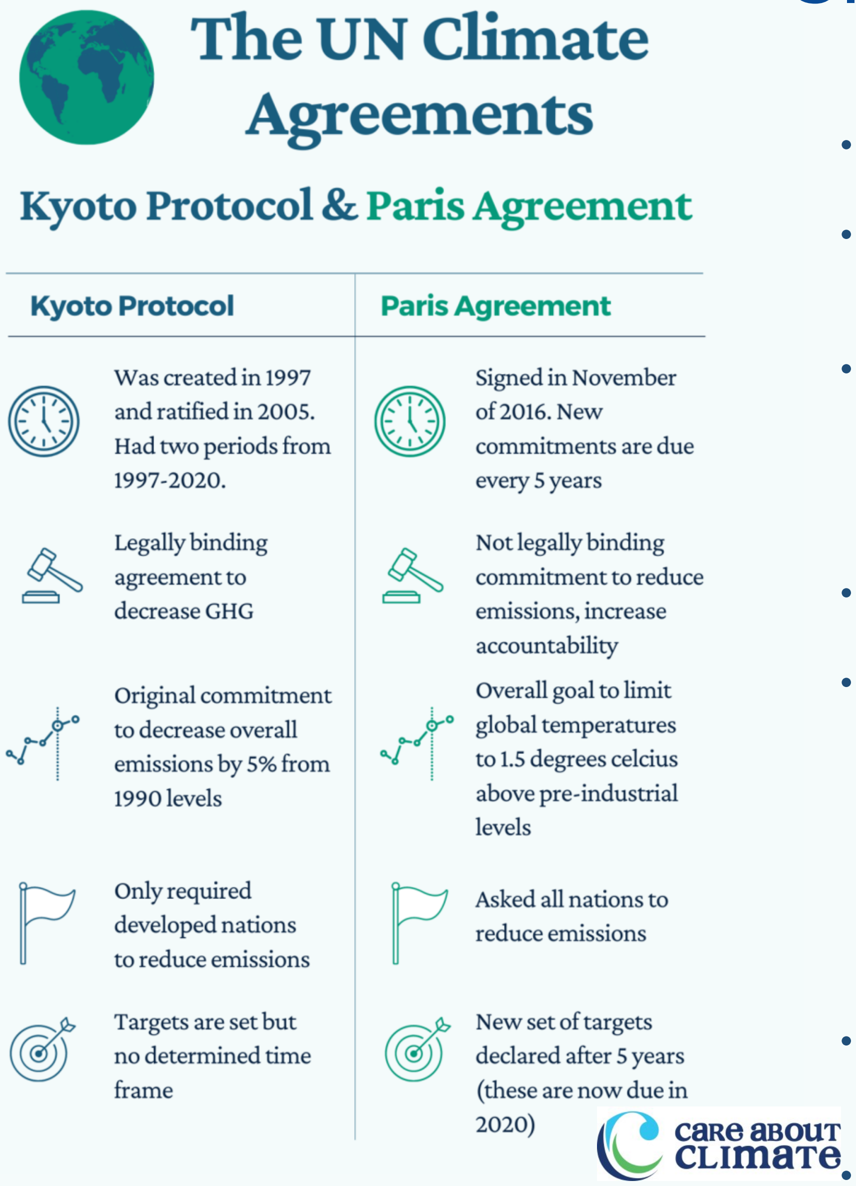
Credit: Karsten Würth/Unsplash

- The **Kyoto Protoco**l was the first major step toward climate change mitigation created in **1997.**
- But due to the complex endorsement process, this document **came into force** from February **2005**. It currently has **192** signatory parties.
- Kyoto Protocol sets **binding emission** reduction targets for only **37 industrialized** countries (**developed nations**) and economies in transition and the European Union.
- The targets were an average 5% emission reduction compared to **1990** levels over the five-year period **2008–2012** (the first commitment period).
- In December **2012**, some changes were added to the Kyoto Protocol, known as the Doha Amendment.
- Some new GHG emission reduction goals were added for the second commitment period (**2013 to 2020**). In this period, participating countries committed to an **18%** GHG reduction in comparison to the **1990** levels.
- Targets were set, but they were not enough strong! The whole burden was put on the **developed** countries, which made it lack ratification from various countries like the US.

CARE ABOUT CLIMATE

Strategic

Climate strategies



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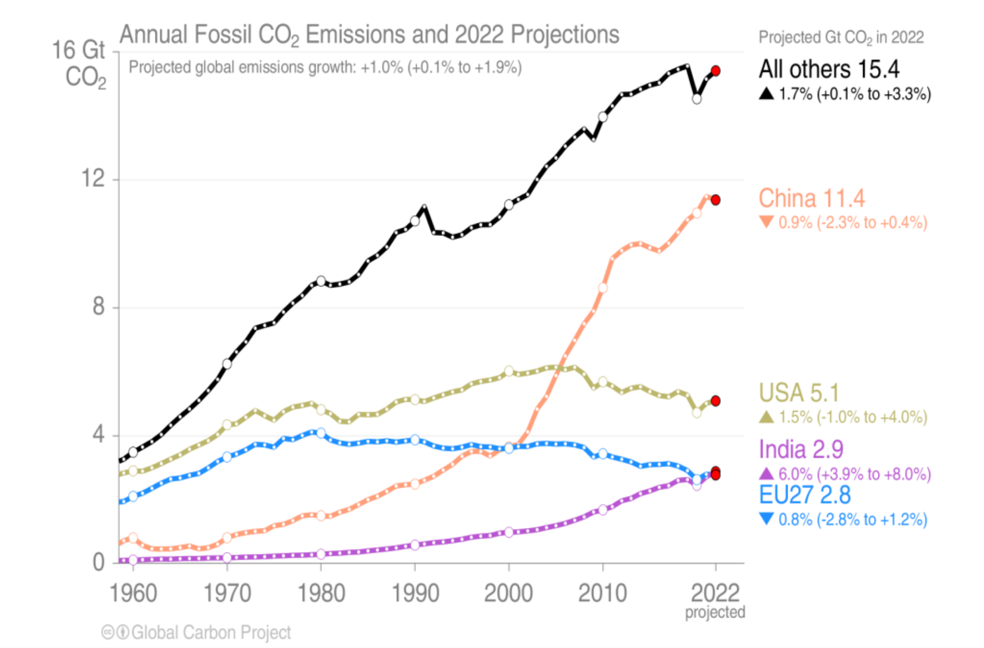
care about CLIMATE

- **2015 Paris Climate Agreement** was a breakthrough in the development of the climate change mitigation program.
- Very strong targets - TO LIMIT GLOBAL TEMPERATURES 1,5 DEGREES CELSIUS ABOVE PRE-INDUSTRIAL LEVELS! Almost all nations participated this time and were asked to reduce CO2 emissions significantly by **2030** and drastically by **2050**.
- Paris Agreement was drafted with every nation on the planet in mind. It requires every nation (whether developed or developing), to take part in saving our environment. This made **195** countries to endorse the document right from the beginning. At the present time 195 countries ratified and only 3 countries signed, but not ratified (Iran, Libya and Jemen), responsible for 1.38% of the world CO2 emisssions.
- Implementation of the Paris Agreement requires **economic and social transformation**, based on the best available science.
- The Paris Agreement works on a **five-year cycle** of increasingly ambitious climate action -- or, ratcheting up -- carried out by countries. Since 2020, countries have been submitting their national climate action plans, known as **nationally determined contributions (NDCs)**. Each successive NDC is meant to reflect an increasingly higher degree of ambition compared to the previous version. Recognizing that accelerated action is required to limit global warming to 1.5°C, the COP27 cover decision requests Parties to revisit and strengthen the 2030 targets in their NDCs to align with the Paris Agreement temperature goal by the end of 2023, taking into account different national circumstances.
- In June 2021, the EU adopted a European Climate Law, establishing the aim of reaching **net zero greenhouse gas emissions (GHG) in the EU by 2050**. The law sets an intermediate target of reducing GHG by at least 55% by 2030 compared to 1990 levels.

Strategic lessons

Climate agreements and US



The 2022 projections are based on preliminary data and modelling.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

NB! According to international standards, China is still a developing country! Its population is more than 1.42 Billion, while in USA is about 340 Mln.

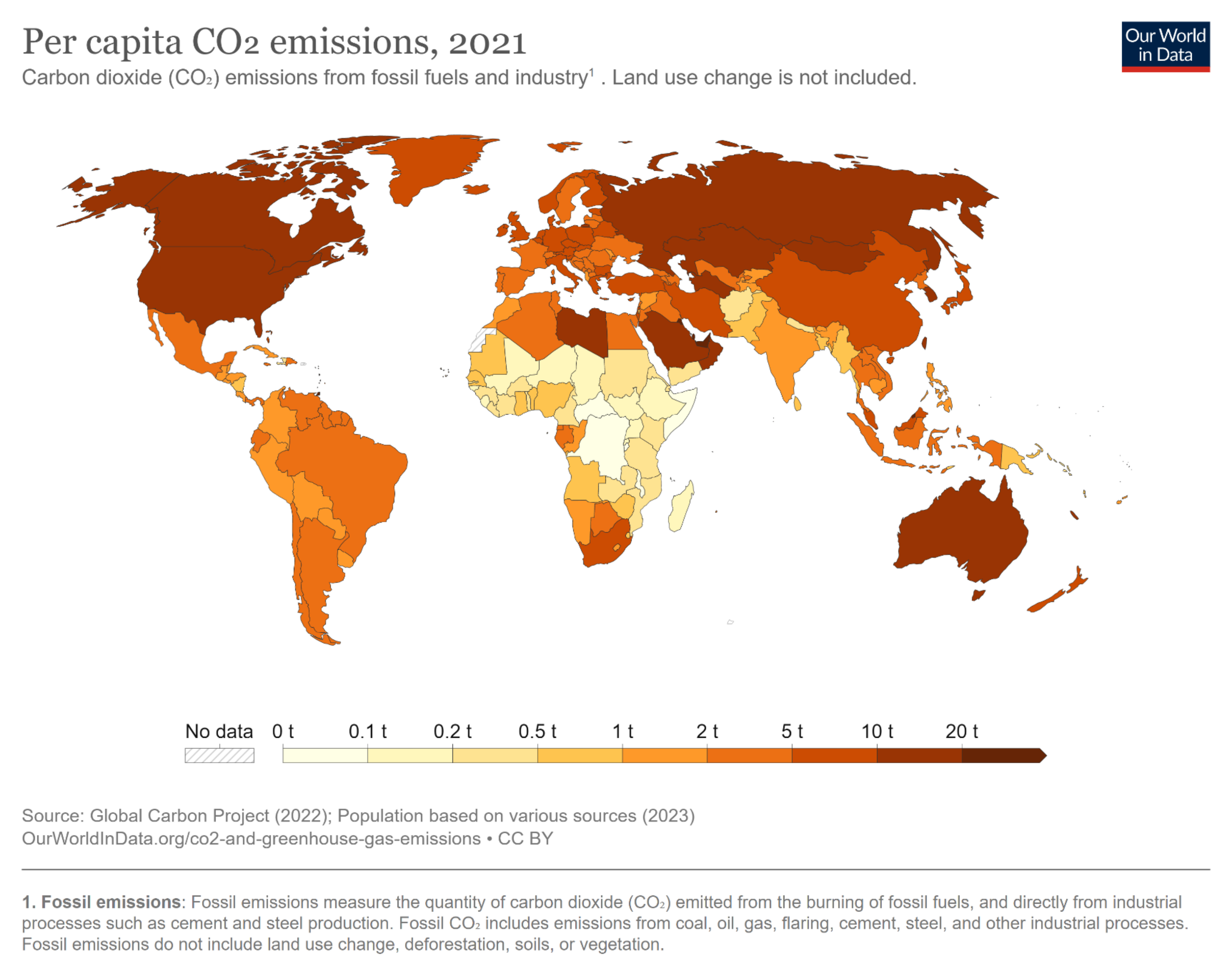
- US is responsible for 17.9% of the world's CO2 emissions and it was the largest CO2 emitter in the world until 2015 and became the second one after China since 2015 (20% of CO2 world emissions).
- US did not ratify **Kyoto Protocol**. Why? They had not any chance, because in July **1997**, five months before the Kyoto meeting, the Senate passed the Byrd–Hagel resolution:
- "the United States should not be a signatory to any protocol … which would (A) mandate new commitments to limit or reduce greenhouse gas emissions for the Annex I Parties, unless the protocol … **also mandates new specific scheduled commitments … for Developing Country Parties within the same compliance period**, or (B) result in serious harm to the economy of the United States" (passed with 95–0 vote).

Paris Agreement. Climate-election races of US presidents

- 2015 – President Obama signed the Paris Agreement without going to the Senate. The **treaty only came into force on 4 November 2016**, 30 days after at least 55 countries representing 55% of global emissions had ratified it.
- 2016 – Donald **Trump** promised to withdraw from the Paris Agreement – it was his main president-electing promise.
- 2017 – US officially announced this withdrawal.
- On 4 November 2019, the United States notified the depositary of its withdrawal from the agreement, to be effective exactly one year from that date.
- 2021 - On January 20, on his first day in office, **President Biden** signed the instrument to bring the United States back into the Paris Agreement.

CARE ABOUT CLIMATE

Strategic lessons

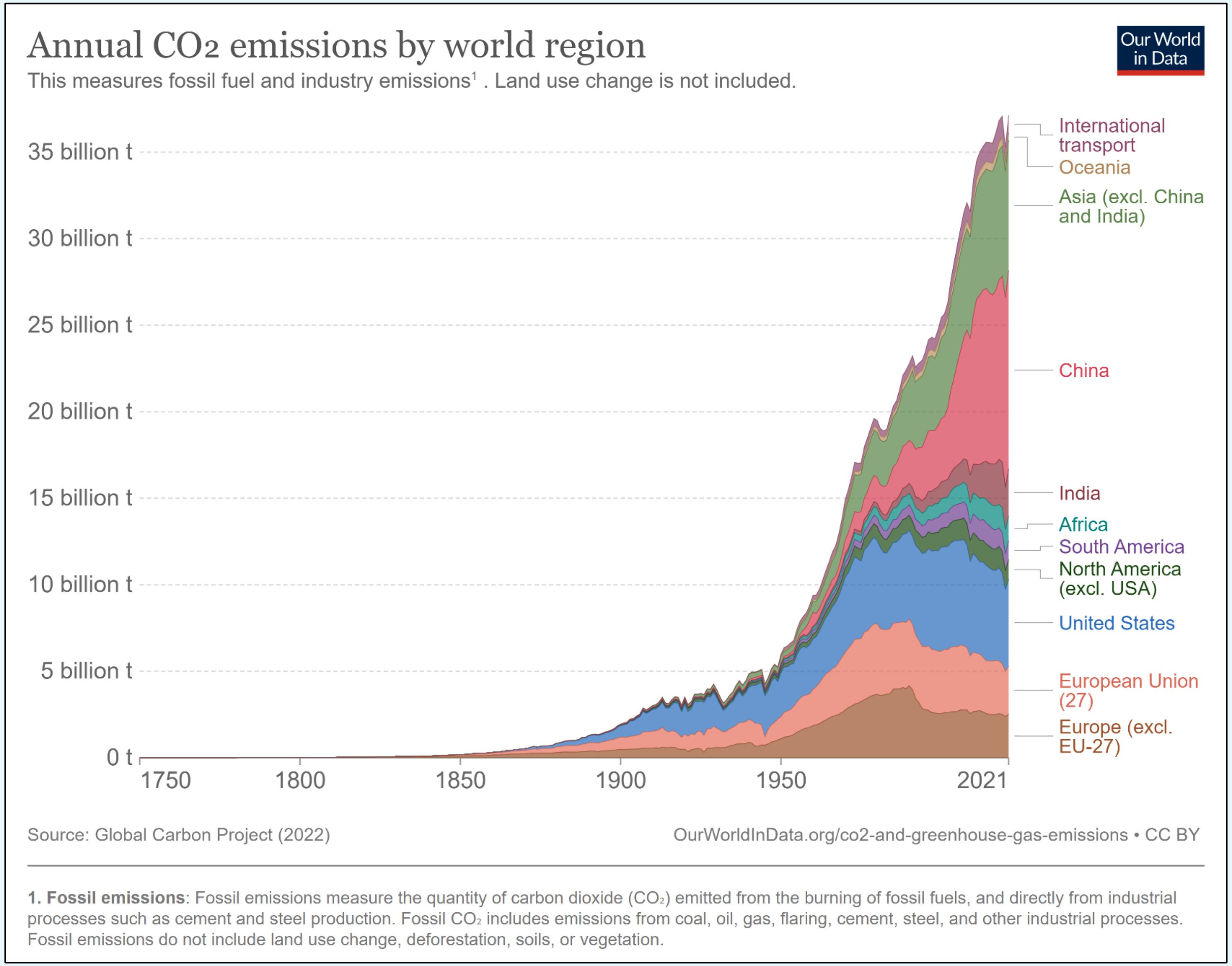


China is only 8 t CO2 per capita!

The largest CO_2 emitters per capita > 10 t CO_2 per capita

	2021
Qatar	35.6 t
Bahrain	26.7 t
Kuwait	25.0 t
Trinidad and Tobago	23.7 t
Brunei	23.5 t
United Arab Emirates	21.8 t
New Caledonia	19.1 t
Saudi Arabia	18.7 t
Oman	17.9 t
Australia	15.1 t
Mongolia	15.0 t
United States	14.9 t
Sint Maarten (Dutch part)	14.7 t
Kazakhstan	14.4 t
Canada	14.3 t
Palau	13.2 t
Faroe Islands	13.2 t
Turkmenistan	13.1 t
Luxembourg	13.1 t
Russia	12.1 t
South Korea	11.9 t
Taiwan	11.9 t
Libya	11.1 t
Saint Pierre and Miquelon	10.5 t

Strategic lessons



10 largest CO_2 emitters in the world

Country	2021
China	11,472,369,000.00 t
United States	5,007,336,000.00 t
India	2,709,683,700.00 t
Russia	1,755,547,400.00 t
Japan	1,067,398,460.00 t
Iran	748,878,700.00 t
Germany	674,753,540.00 t
Saudi Arabia	672,379,900.00 t
Indonesia	619,277,500.00 t
South Korea	616,075,000.00 t

Conclusion: among 10 largest CO2 emitters in the world, only 6 are developed and 4 are developing countries.

Lesson learned: it was a mistake of the Kyoto Protocol (1 stage) and Doha Amendment (2nd stage) to include commitments only for developed countries!

Strategic: Revenue systems

Revenue sources

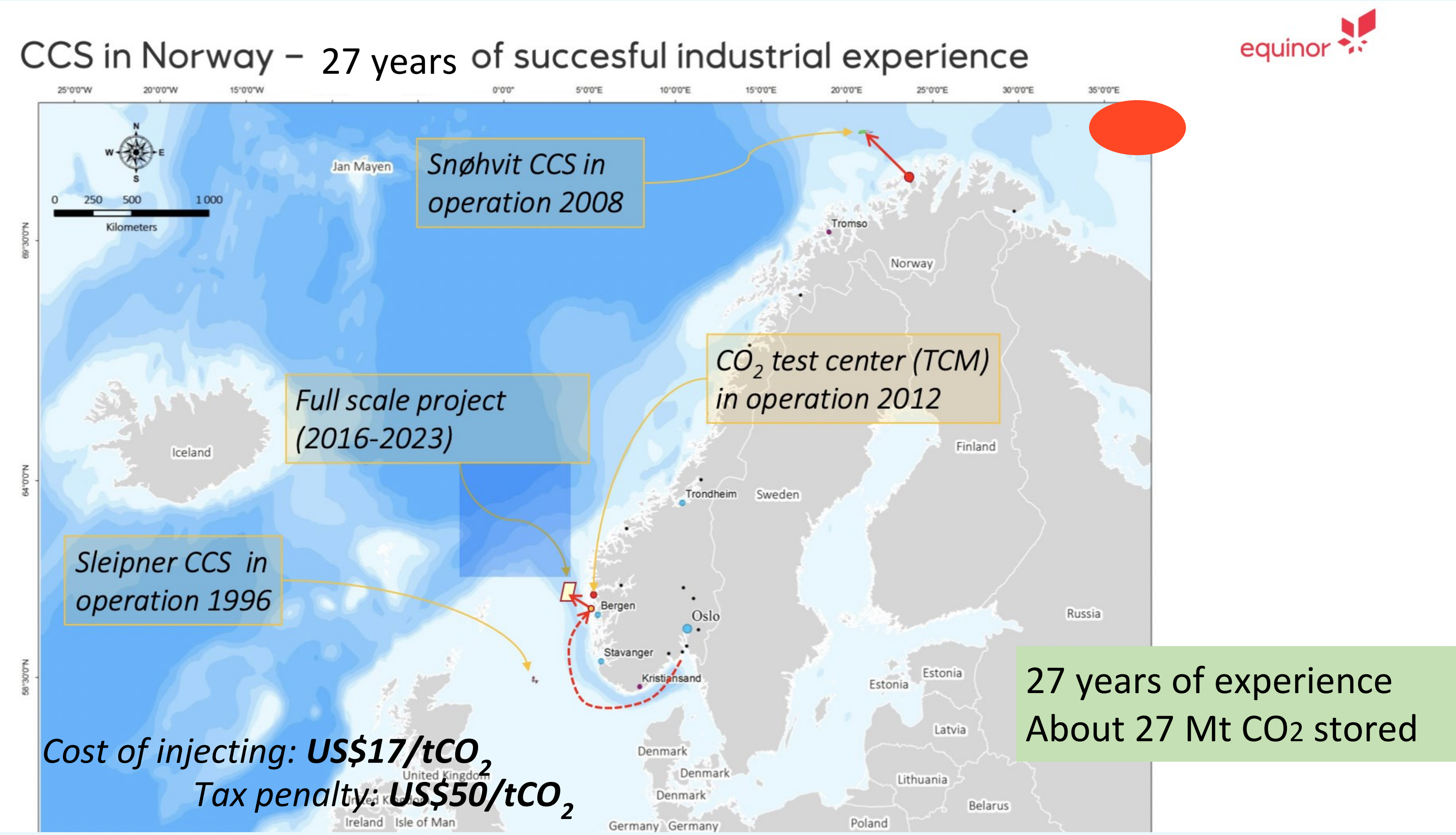
- Carbon Tax Revenues:
  - National Carbon Tax
  - Emission Trading Systems
- Revenues from CO2 use:
  - CO2 use for EOR and enhanced recovery of other resources
  - CO2 use for Carbon Based Products

European Emissions Allowance Price

- Can we get a negative price for CCUS?

Strategic lessons Revenue systems

National CO_2 tax as a driver of CCS technology



Updated after: https://bcforum.net/presentations2019/07-01-Northern-Lights-BCF-23.10.2019-Shared%20version.pdf

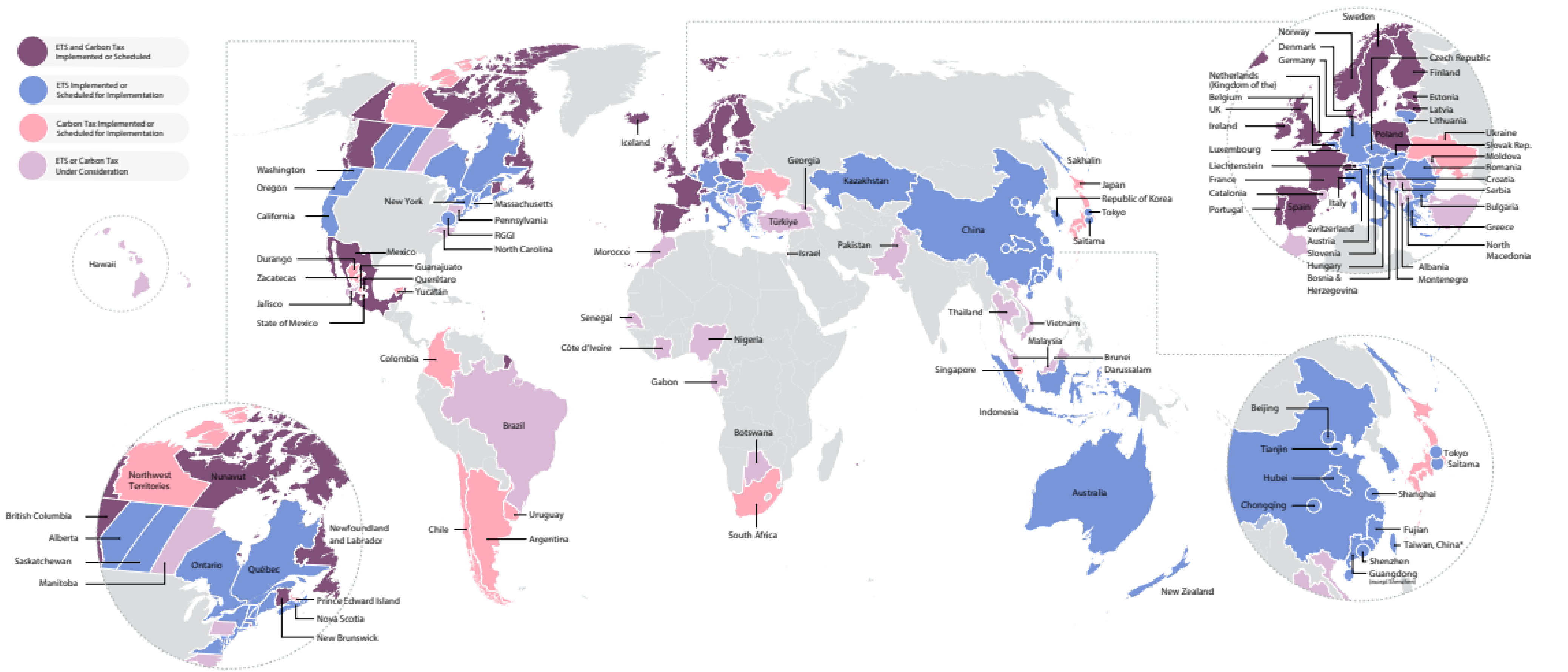
Lessons learned since 1996:

- **CCS technology** was started in **1996** in **Norway** with **Sleipner Project**
- The driver for technology was the high national CO_2 tax in Norway
- The first carbon tax ever introduced was in **Finland**, in **1990**
- Norway, Sweden (both in **1991**) and Denmark (**1994**) followed
- A carbon tax introduced in Norway in 1991 has been successful in incentivizing the development of the Sleipner and SnØhvit CCS projects
- At **US$17/t$CO_2$**, the cost of injecting and storing CO_2 for the Sleipner project was much less than the **US$50/t$CO_2$** tax penalty at the time for CO_2 vented to the atmosphere
- This was complemented by a commercial need to separate CO_2 from natural gas to meet market requirements and provided a clear business case to invest in CCS
- The current level of the tax is higher than the level when it was introduced, making the business case for CCS in Norway even stronger

Strategic

National Carbon tax & Emission Trading Systems (2023)

MAP OF CARBON TAXES AND ETSs



Source: The World Bank. 2023. "State and Trends of Carbon Pricing 2023" (May), World Bank, Washington, DC. Doi: http://dx.doi.org/10.1596/39796. License: Creative Commons Attribution CC BY 3.0 IGO

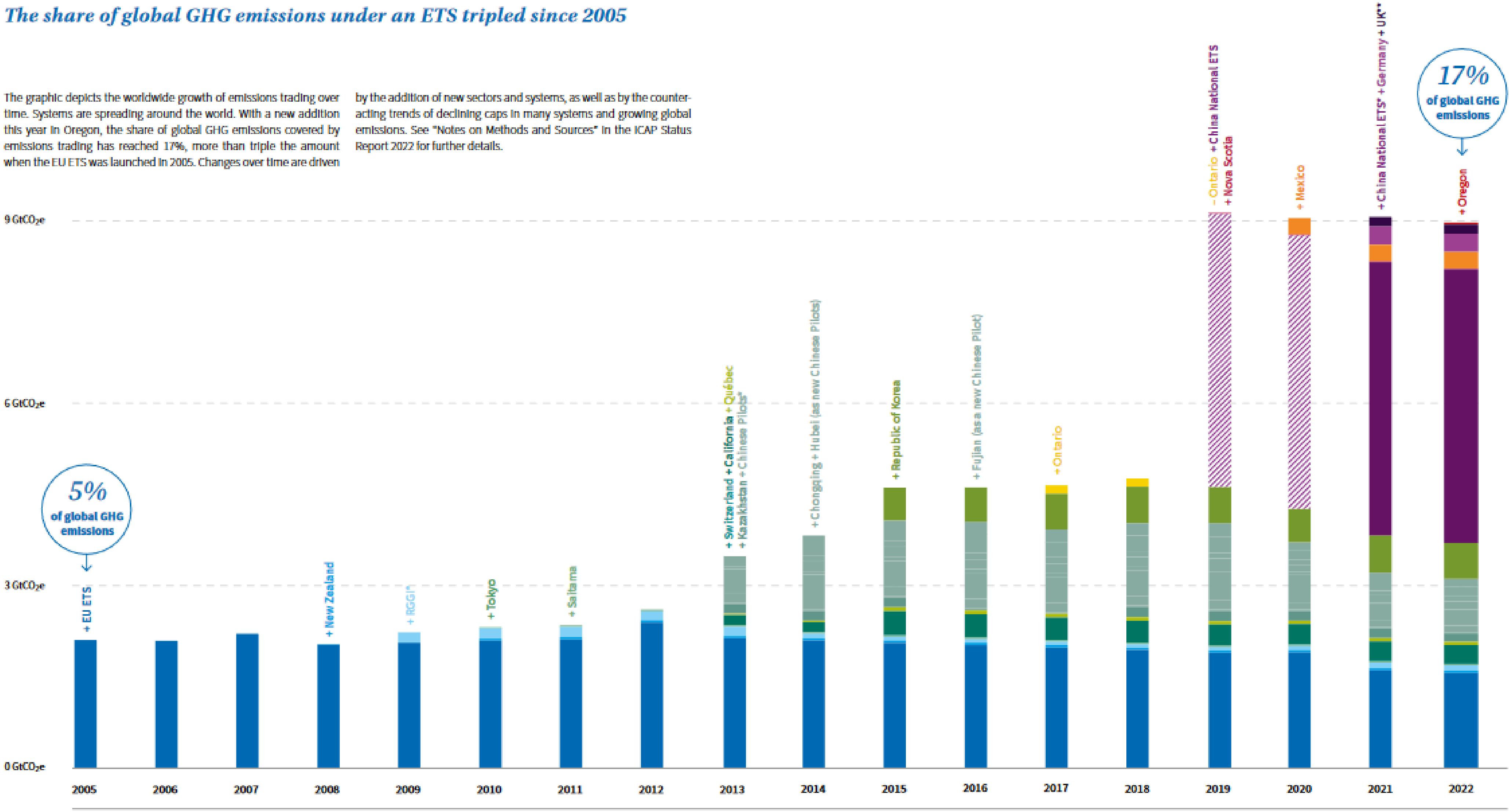
Emission Trading Systems

- Several ETSs are now in place, most notably the EU ETS in which 31 countries participate .
- Additionally, a national-level ETS is slated for introduction in China in 2020.
- ETSs have been applied downstream to power generators and large industry, which, however, typically misses around 50 percent of emissions (from vehicles, buildings, and small enterprises).
- Moreover, the administrative costs of monitoring emissions and allowance markets may be prohibitive for a small jurisdiction or a capacity constrained developing country (while much of the legal and administrative infrastructure for taxes would typically exist).
- Prices in ETSs are uncertain and sometimes depressed by overlapping instruments—recent prices have been around US$5-25 per ton of CO2.
- Furthermore, prospects for large budget revenues can be diminished by:
- (i) the much narrower base for emissions pricing
- (ii) the possibility of free allowance allocations
- (iii) earmarking of revenues from allowance auctions—in striking contrast with taxes

Global Expansion of ETS

The share of global GHG emissions under an ETS tripled since 2005

The graphic depicts the worldwide growth of emissions trading over time. Systems are spreading around the world. With a new addition this year in Oregon, the share of global GHG emissions covered by emissions trading has reached 17%, more than triple the amount when the EU ETS was launched in 2005. Changes over time are driven by the addition of new sectors and systems, as well as by the counter-acting trends of declining caps in many systems and growing global emissions. See "Notes on Methods and Sources" in the ICAP Status Report 2022 for further details.



* RGGI includes New Jersey (as of 2020) and Virginia (as of 2021).

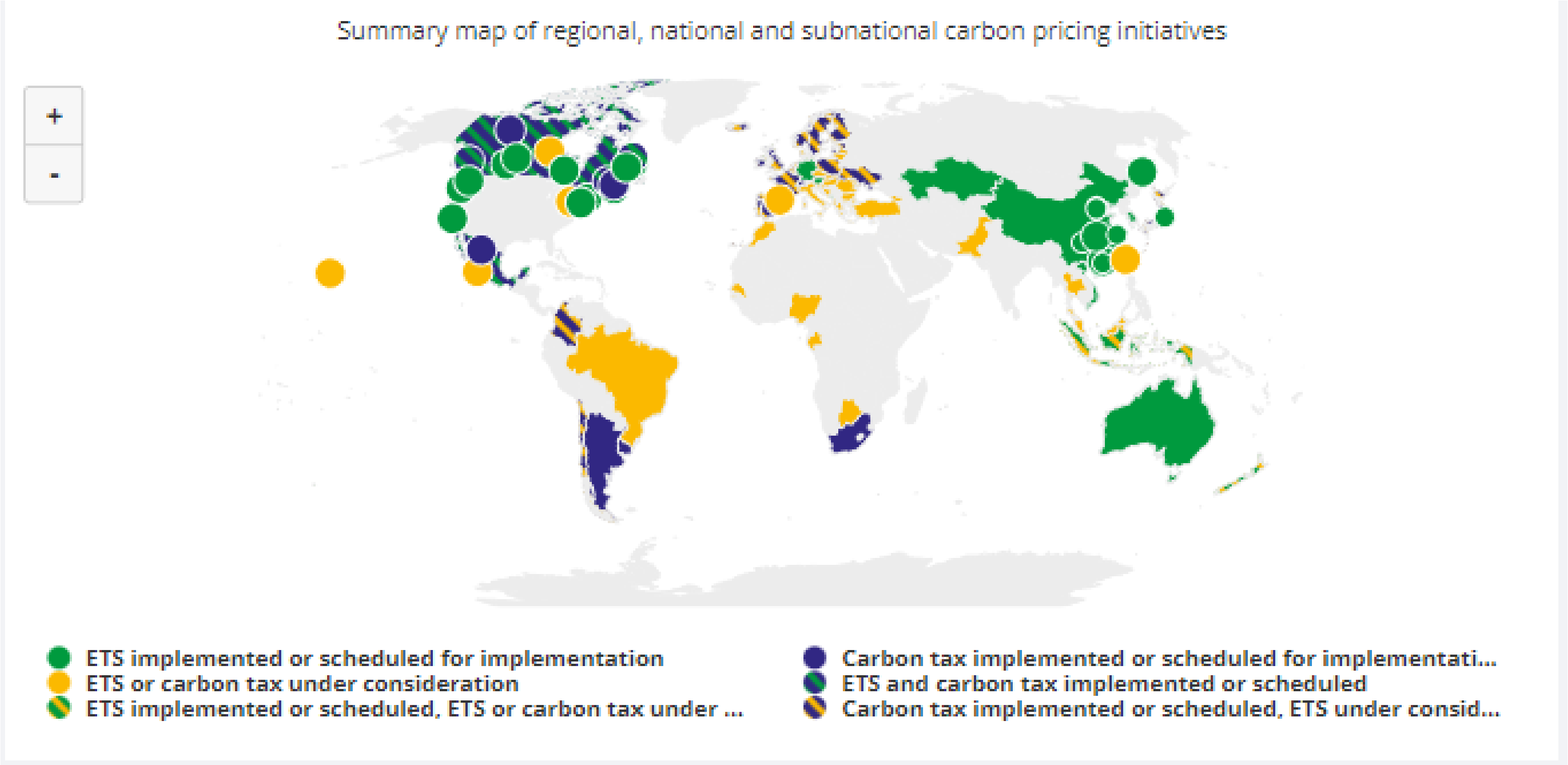
* Beijing, Guangdong, Shanghai, Shenzhen, Tianjin

* The Chinese National ETS came into force in 2021 but has retroactive compliance obligations in 2019 and 2020, indicated above by the striped bar

** In 2021, the UK launched its own ETS which required an adjustment in the EU ETS cap.

Emissions Trading Worldwide
International Carbon Action Partnership (ICAP)
Status Report 2022

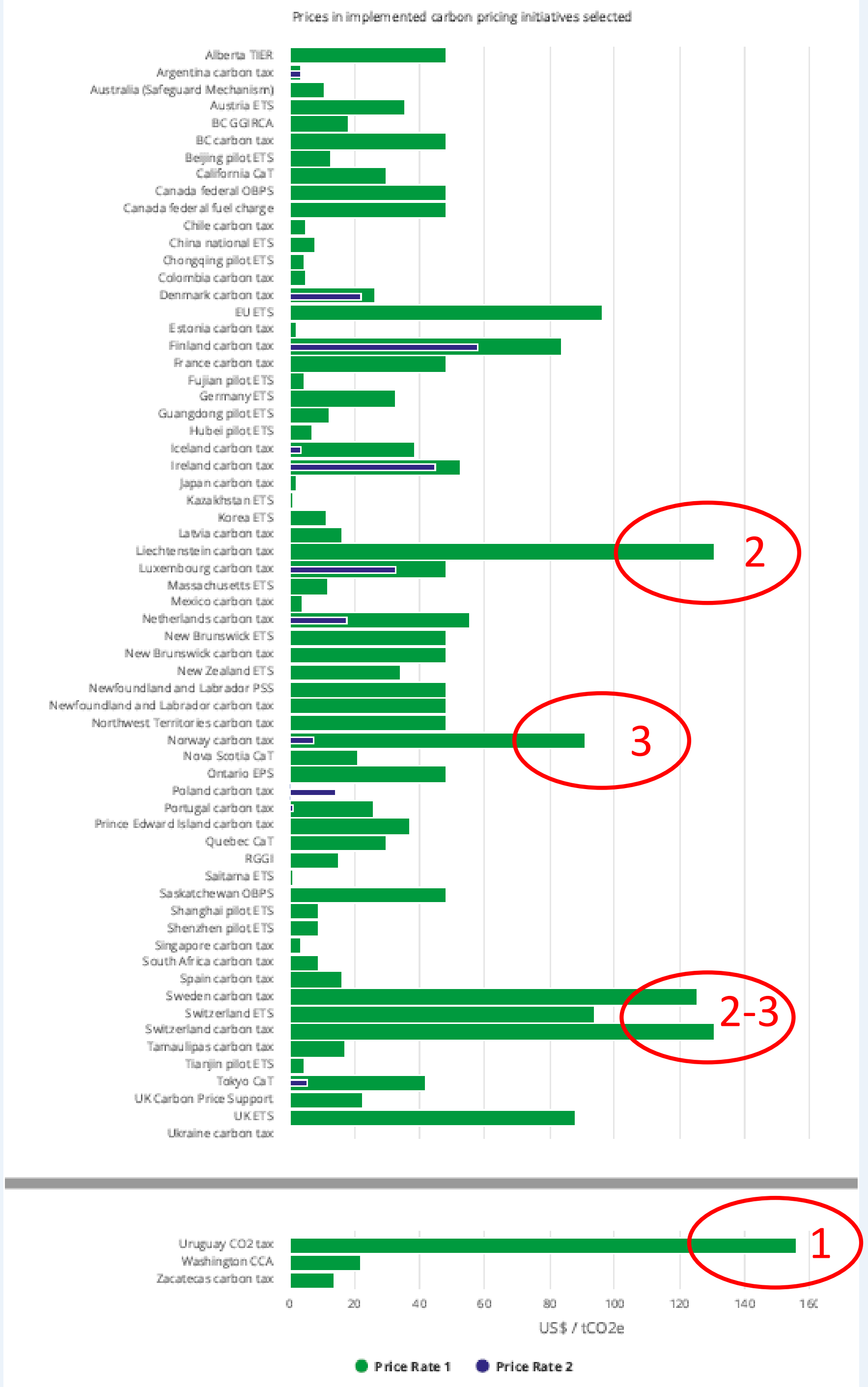
National, regional and subnational Carbon Taxes



https://carbonpricingdashboard.worldbank.org/map_data

KEY STATISTICS ON REGIONAL, NATIONAL AND SUBNATIONAL CARBON PRICING INITIATIVE(S)

- 73 Carbon Pricing initiatives implemented
- 39 National Jurisdictions are covered by the initiatives selected
- 33 Subnational Jurisdictions are covered by the initiatives selected
- In 2023, these initiatives would cover **11.66 $GtCO_2e$**, representing **23%** of global GHG emissions



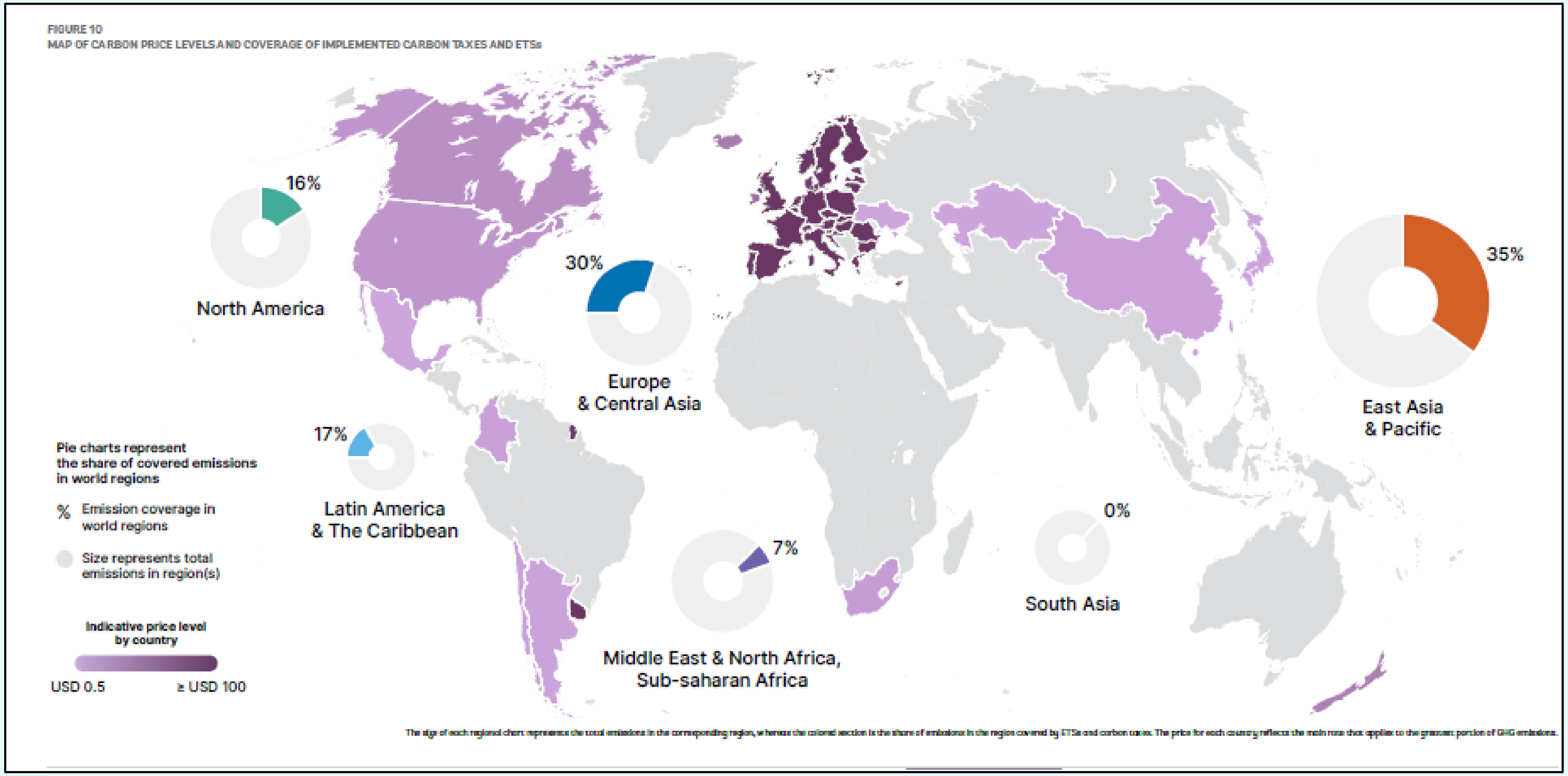
Prices in implemented carbon prices initiatives for the YEAR **2023**, for multiple STATUSES, for multiple INSTRUMENTS, for multiple JURISDICTIONS

- Note: Nominal prices on March, 31 2023
  Prices are not necessarily comparable between carbon pricing initiatives because of differences in the number of sectors covered and allocation methods applied, specific exemptions, and different compensation methods.
- Due to the dynamic approach to continuously improve data quality and fluctuating exchange rates, data of different years may not always be comparable and could be amended following new information from official government sources.
- In addition, data for a limited number of initiatives may be incomplete as they are in the process of being validated and will be updated following confirmation from official government sources.

- The highest national Carbon taxes in the world are marked by red ovals

https://carbonpricingdashboard.worldbank.org/map_data

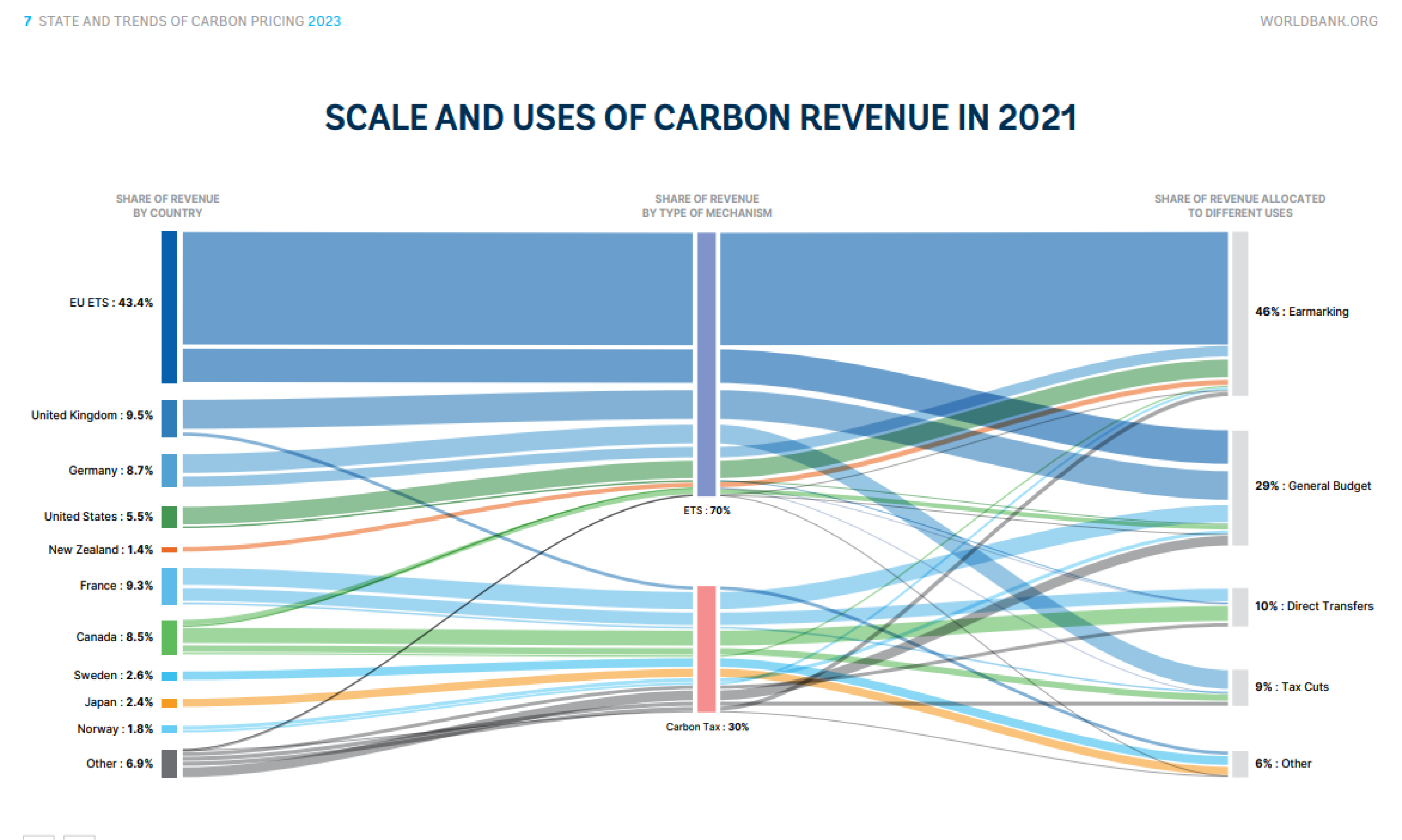
Implemented Carbon Taxes and ETSs



- ➢ Carbon tax rates and ETS prices in high-income countries tend to be higher than those in middle-income countries (Figure 10).
- ➢ Most instruments in high-income countries have prices above USD 50, and nearly all above USD 15.
- ➢ In middle-income countries most instruments have prices below USD 10.
- ➢ There are, though, several examples of instruments in middle-income countries with prices above USD 10, such as in:
- the Beijing and Guangdong ETS Pilots (in China),
- the carbon tax of Latvia,
- and the subnational carbon taxes in Mexico (Querétaro, Yucatán, and Zacatecas

https://carbonpricingdashboard.worldbank.org/map_data

RECORD HIGH REVENUES FROM ETSs AND CARBON TAXES APPROACHED USD 100 BILLION

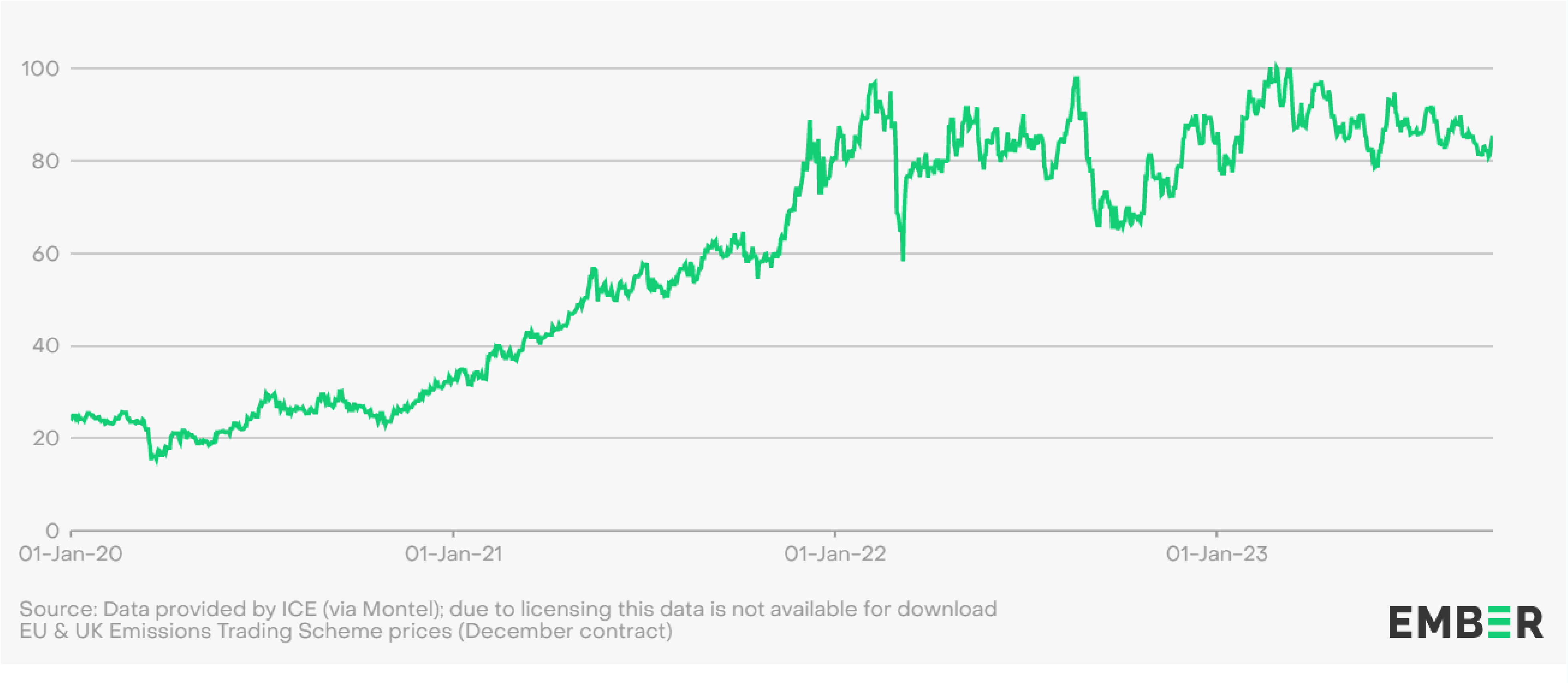


- Governments continue to face trade-offs between different objectives, such as increasing revenue, promoting community acceptance, and managing international competitiveness.
- Revenues from ETSs and carbon taxes are often used for specific purposes:
  - almost 40% of the revenue is earmarked for green spending,
  - and 10% is used to compensate households or businesses.
  - Both are seen as ways to increase support for these policies.
- The revenue potential of ETSs and carbon taxes has become more relevant in light of increasing pressures on public budgets

Source: The World Bank. 2023. “State and Trends of Carbon Pricing 2023” (May), World Bank, Washington, DC. Doi: http://dx.doi.org/10.1596/39796. License: Creative Commons Attribution CC BY 3.0 IGO

1. Strategic – Revenue sources

CO_2 allowance price in Emission Trading Systems (2023)



CO_2 emission price in EU ETS is already crossed 100€ in February 2023 but was only 85 Euro in September 2023
https://ember-climate.org/data/carbon-price-viewer/

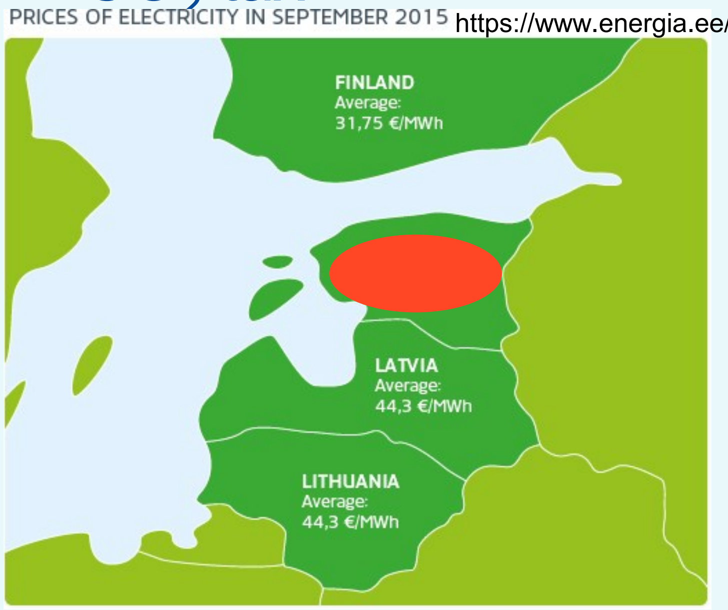
Lessons learned

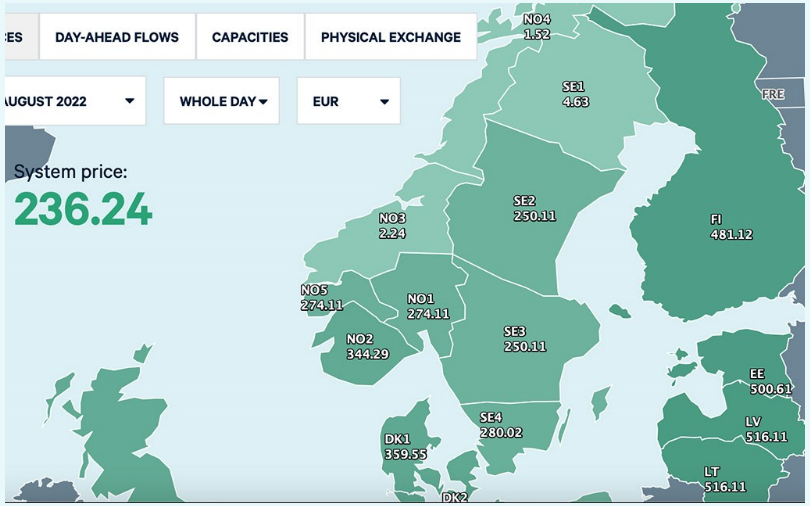
- Carbon pricing is a necessary, but not sufficient policy.
- Carbon pricing can play a role in stimulating low-carbon action by adopting the cost of greenhouse gas emissions
- However, for it to work, several things are needed:
- It must be sufficiently AMBITIOUS
- Experts say prices of USD 40-80€/tCO_2 are needed to meet the 2°C goal
- It must be WELL DESIGNED AND ADAPTED to the jurisdictional context.
- It must FORM PART OF A SUPPORTIVE POLICY PACKAGE – other policies are needed to drive research and development, unlock non-economic barriers to mitigation, and to target emissions reductions with very high abatement costs
- CO2 prices in EU ETS increased much faster than predicted! “Most analytics have reviewed their figures and estimate the carbon price will reach 35 to 40 euros per ton in 2023 (Roig-Ramos, 2018).”
- It means that CCS cost per ton of CO2 is started to be feasible from the end of 2021!

Political and Regulatory: Estonian case

Carbon leakage – one of the consequences of wrong national policy connected to CO_2 tax

https://www.energia.ee/





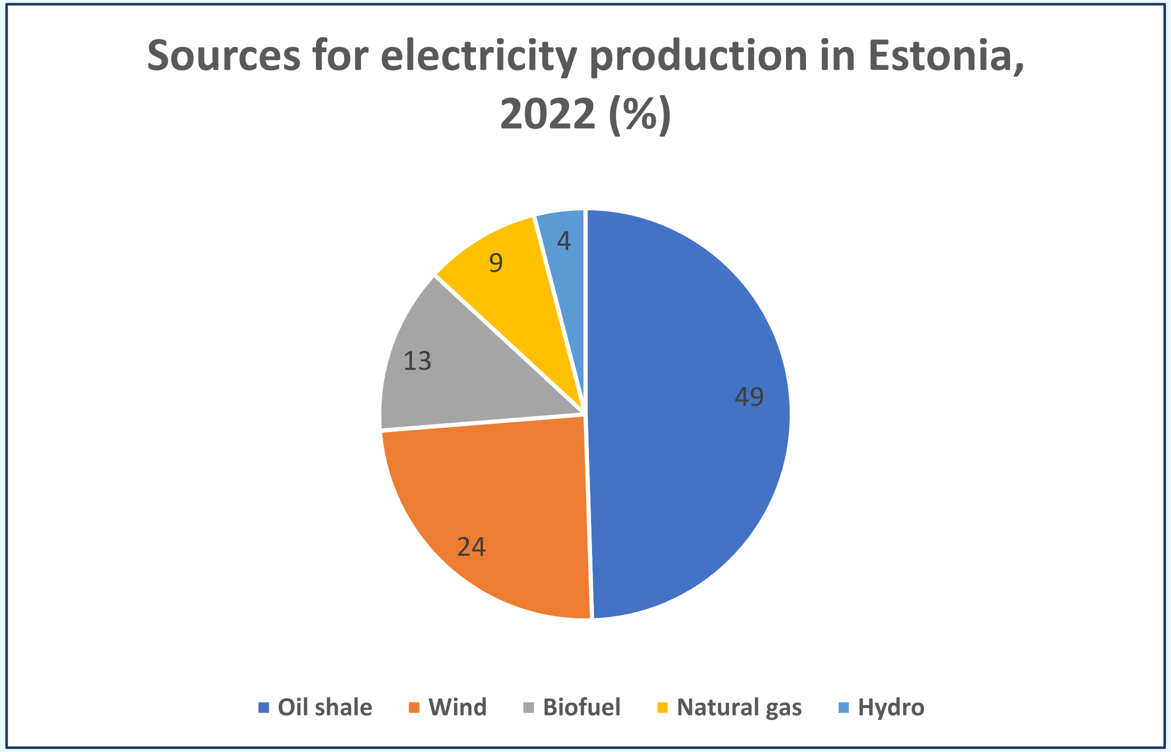
- Carbon leakage happens, when carbon tax causes an increase in emissions in other jurisdictions that do not have equivalent emission-reduction policies (e.g. through relocating production)
- Such a case happened in 2020 in Estonia when the CO_2 tax reached 40€/tCO_2. National energy company Eesti Energia closed more than 50% of its energy-producing power plants (for about 4 Terawatts of energy production) and Estonia became an energy-importing country instead energy-exporting before.
- It was announced that Estonia will get cheaper energy from Russia, which does not have any CO_2 tax.
- In fact, Estonia is producing now CO_2 leakage in various countries from where energy is coming through Nord Pool (including Nordic, Baltic, and some other countries)
- The energy did not become cheaper in Estonia since that time
- Starting from the end of 2021, the price increased from an average 40€/Mw in 2020, up to 500€/Mw on average and reached the world-historical maximum 4000€/Mw on some days in some hours in 2022 (from 10 to 100 times increase)
- Now, Estonia restarted again already closed blocks of the power plants using Estonian oil shale, but the price of energy is still high, because Estonia provides cheaper energy to the Nord Pool, but getting their energy at a higher prices.

https://lounaeestlane.ee/

Political and Regulatory: Estonian case

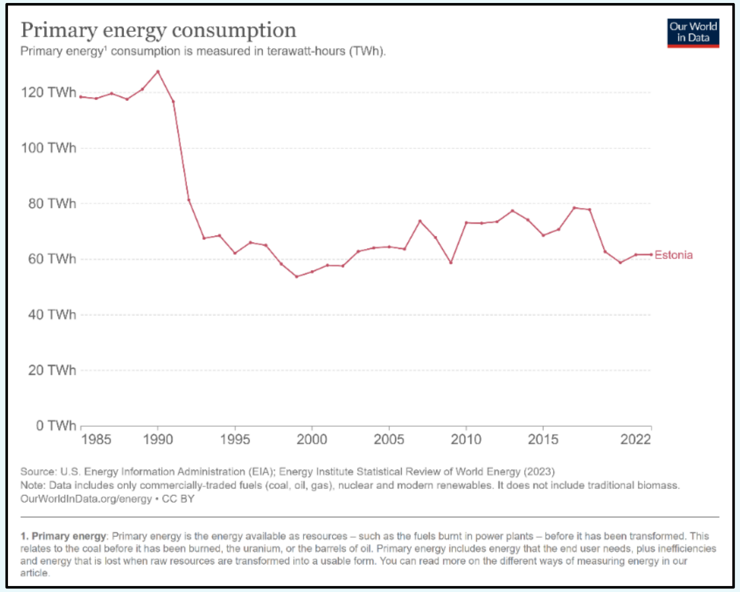
Carbon leakage – one of the consequences of wrong national policy connected to CO_2 tax

- Baltic countries are disconnected from the Russian energy grids in advance after the war started in Ukraine (February, 2022). Before the war, it was planned to disconnect in 2025.
- According to Statistics Estonia, power plants produced **8,910 gigawatt hours** (GWh) of electricity and **5,074 GWh** of heat in 2022.
- In August 2023 energy production decreased for 40%. Energy export was 399 GWh, while import 663 GWh (**difference 264 GWh**).
- Estonia had a plan for renewable energy 42% by 2030. Now the plan is increased by 100% by 2030. It is not clear, if these plans could be reached.
- As we know, Eesti Energia already opened several times the closed in 2019-2020 power plants…
- Estonian companies are developing at least two CO2-use projects, based on the long-term research results.
- The question about CO2 capture and CCUS technology is still an open issue…



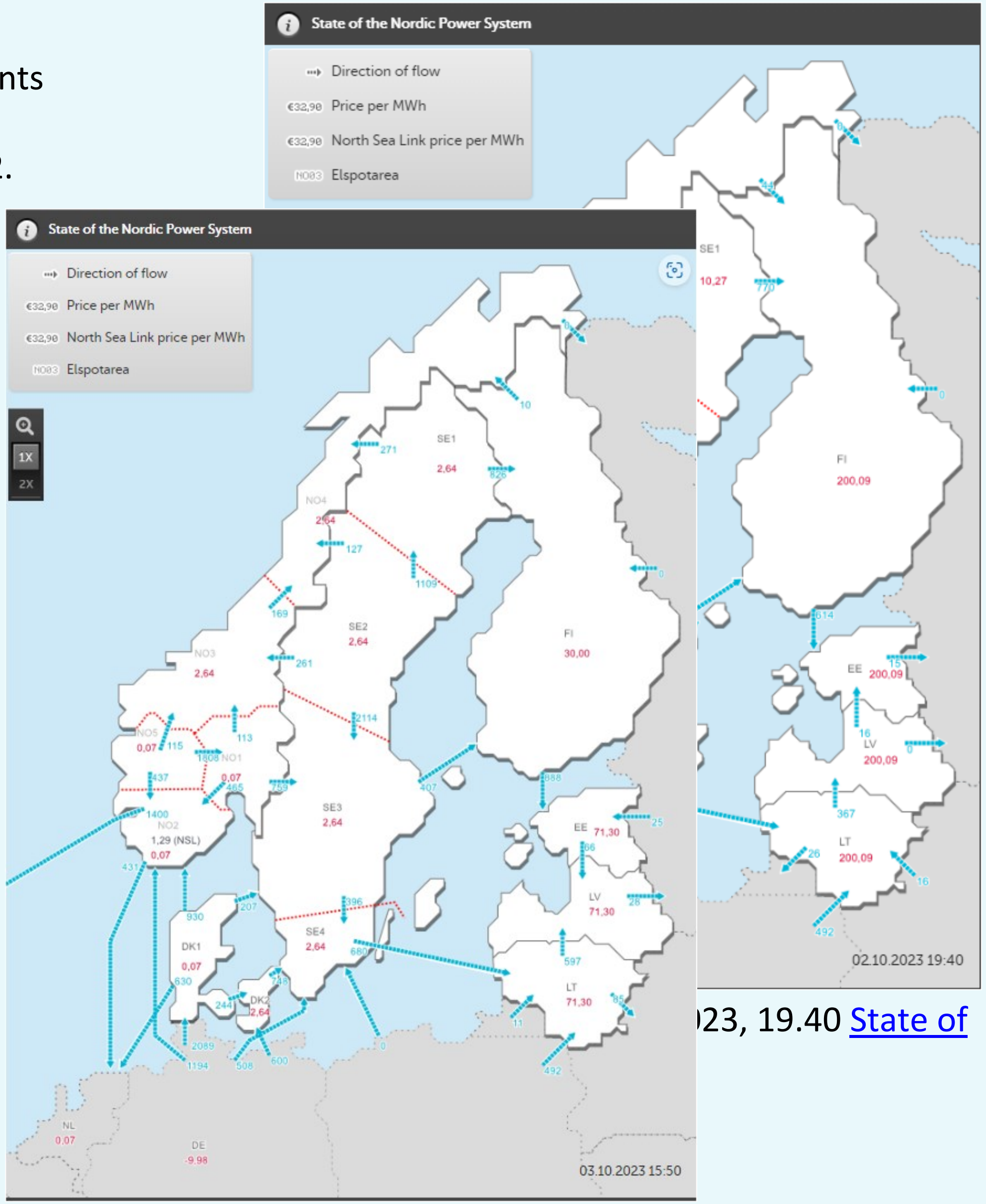
Political and Regulatory: Estonian case

Estonian energy consumption



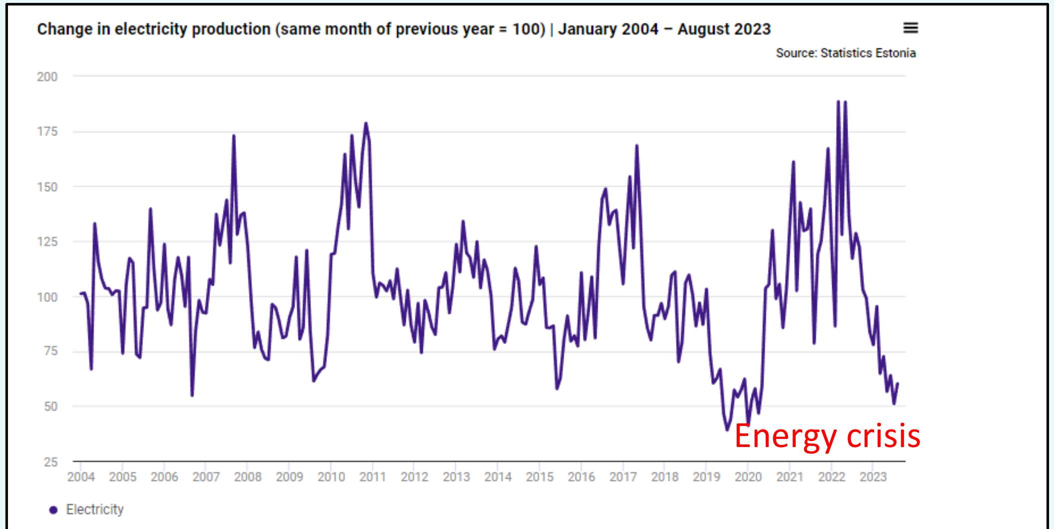
According to Statistics Estonia, power plants produced **8,910 gigawatt hours** (GWh) of electricity and 5,074 GWh of heat in 2022.

- In August 2023 energy production decreased for 40%. Energy export was 399 GWh, while import 663 GWh (difference 264 GWh).
- This clearly means that Estonia produces CO_2 leakage when importing energy from Nord Pool.
- The cost of energy in the Baltic States on the 2nd October 20 times higher than in Sweden and 25 times higher than in some parts of Norway!!!



23, 19.40 State of

versus Estonian energy production



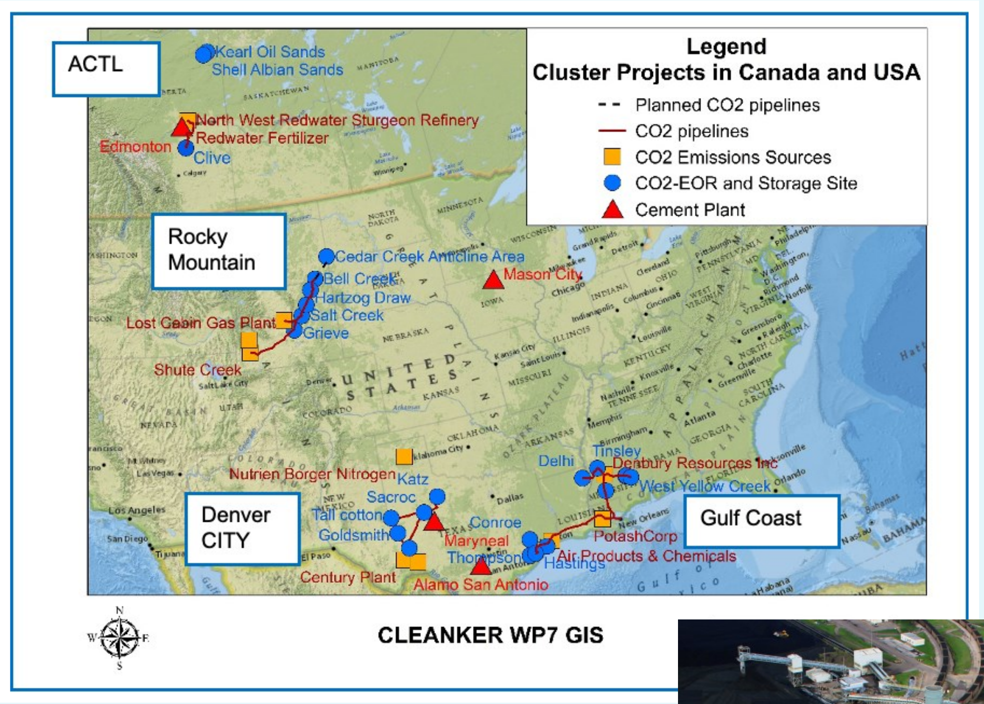
Decrease of local energy production in Estonia caused energy and economic crisis, that in turn pushed government to restart Estonian power plants!

Political and Regulatory: Estonian case

Lessons learned

- Estonia decided to force energy transition without CCS and called it Rohepööre (Green turn)
- As a result, import of energy became higher than export and it caused CO2 leakage to the Nord Pool countries
- The energy price increased from 5 to 100 times compared to 2017 and caused very high inflation and energy and economic crisis.
- From time to time the closed oil shale power plants are reopened, but cheap energy is sold to the Nord Pool and people have to buy much more expensive energy from there.
- As a result, national energy security decreased proportionally to the energy policy in the country and in the region.
- Country increased its ambitions to have 100% of renewable energy by 2030, but it is not clear if Estonia will be able to reach these targets without CCUS and how CO2 use projects will be implemented efficiently without captured CO2.

Political and Regulatory: Lithuanian case versus North-America experience




Texas, USA, CO2-EOR facilities, https://rbnenergy.com/

CLEAN clinKER by calcium looping for low-CO_2 cement

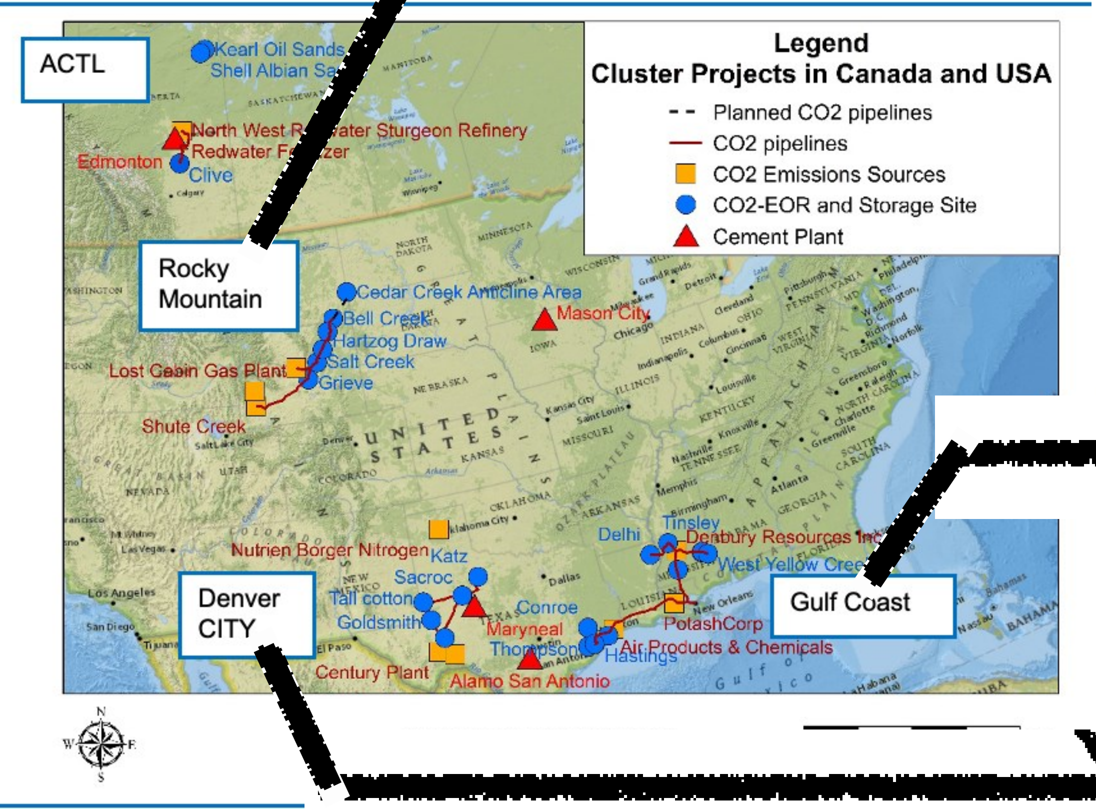
CLEANKER

CO_2-EOR

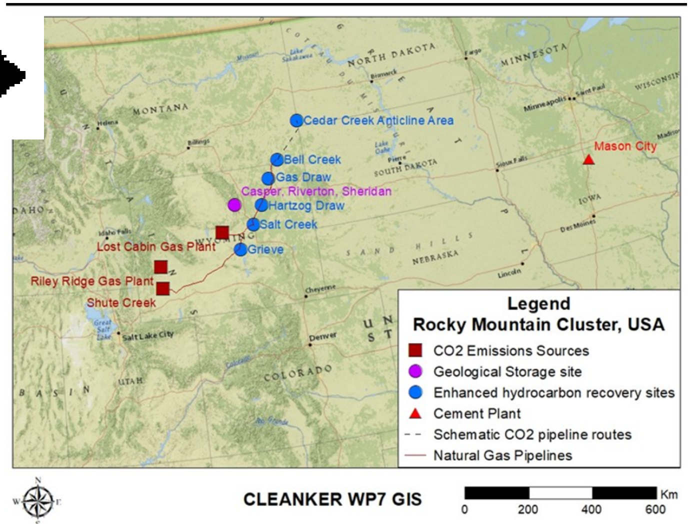
- Injecting CO2 into oil reservoirs to enhance oil recovery has been practiced on a commercial scale for nearly 50 years, with the first successful pilot tests conducted in the early 1960s in the state of Texas (Holm, 1987).
- Experience in the United States shows that CO2-EOR can boost recovery by 5% to 15% of the original oil in place (IEA, 2013).
- **In Lithuania, Baltic country, these numbers are even higher - 10 to 20%!**
- In Texas, CO2 is commercially bought for Enhanced Oil Recovery.
- The price paid for the CO2 is in this case dependent on the price of oil:
- For example, the cost of CO2 is around US$30/tCO2 at oil prices of US$70 per barrel (Bliss, et al., 2010).
- At these prices, the revenue from the sale of CO2 for EOR alone may be sufficient to cover the costs of capturing and transporting CO2 in sectors where the cost of capturing CO2 is relatively low, such as natural gas processing, fertilizer, and bioethanol production.
- This combination of favourable project costs and revenues from the sale of CO2 for EOR has been the main driver of early CCS projects in the US.

Political and Regulatory: North-America 50 years experience – CLUSTER projects in operation

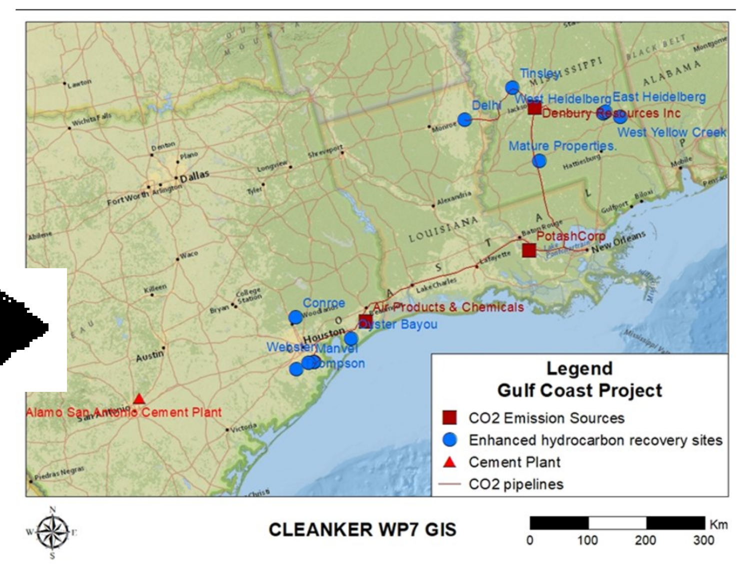
North-America cluster projects



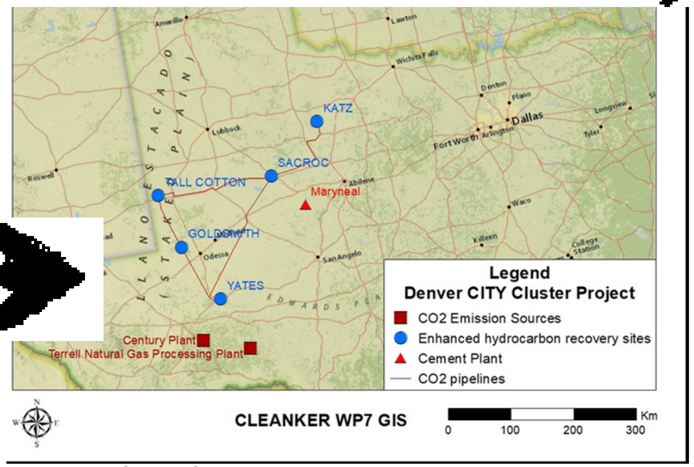
North American Clus... CP included; 2) Rocky Mountain project with HCG Mason City Lehigh Portland CP proposed; 3) Denver CITY Cluster project in Texas with BU Maryneal CP; 4) The Gulf Coast cluster with BU Alamo San Antonio CP



Rocky Mountain project with Mason City (Heidelberg)



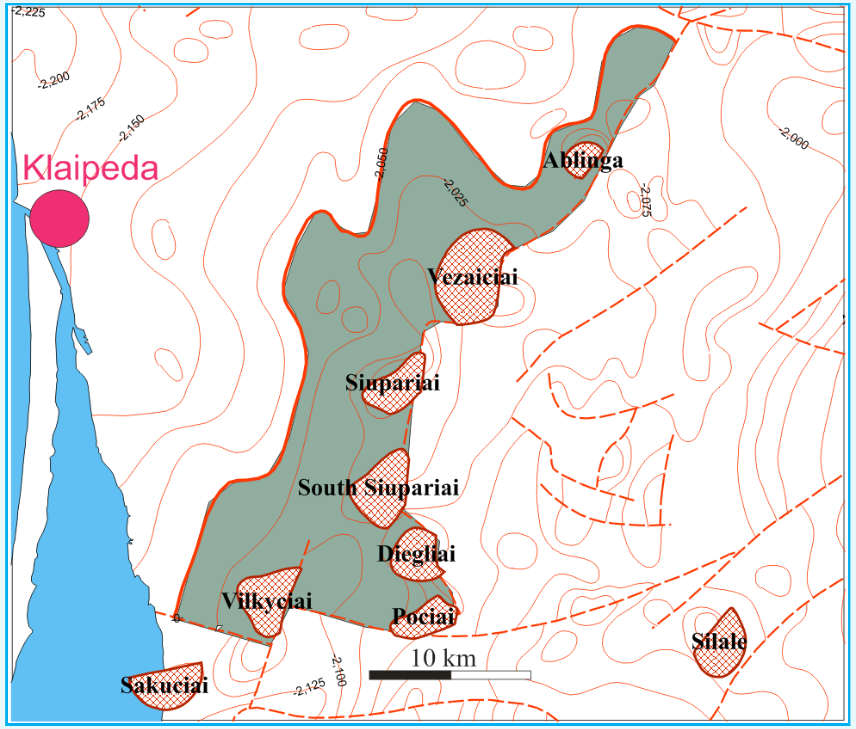
The Gulf Coast cluster in located in Texas, Lousiana and Mississipi states with Alamo San Antonio Buzzi Unicem Cement Plant as a possible candidate for exploitation study



Denver CITY Cluster project in Texas with Maryneal Buzzi Unicem Cement Plant included

Political and Regulatory: Lithuanian case

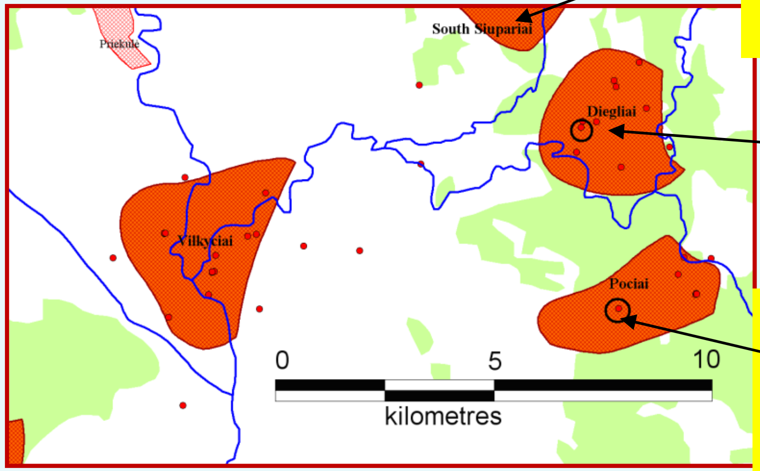
CO_2-EOR AND CO_2 STORAGE OPTIONS IN GARGZDAI ZONE



- CO_2 experiments were performed in Diegliai and Pociai and South Siupariai fields. From 1300 t of CO2 injected, only 330 t CO2 was recovered together with oil. **Other stayed underground!**
- 1000, 300 and 46 tons of CO_2 were injected in three wells to investigate the effectiveness of CO_2-EOR technology in the producing and residual oil zones

- Gargzdai uplift zone (green-grey polygon) and oil fields (named) in western Lithuania.
- Depths of top of the Cambrian reservoir are indicated. Hatched lines are faults cutting the Cambrian reservoir.
- The area of the Gargzdai uplift zone is 380 km^2.
- Seven oil fields were identified and exploited in the zone.

2015:
- 260 t CO_2 injected
- 30 t CO_2 recovered



2013:
- 1000 t CO_2 injected
- 300 t CO_2 recovered

2013:
- 40 t CO_2 injected
- ? CO_2 recovered

Data provided by Prof. S. Sliaupa and by Minijos Nafta company

Political and Regulatory: Lithuanian case – negative political case versus first and unique pilot CO2 injection experience in the BSR

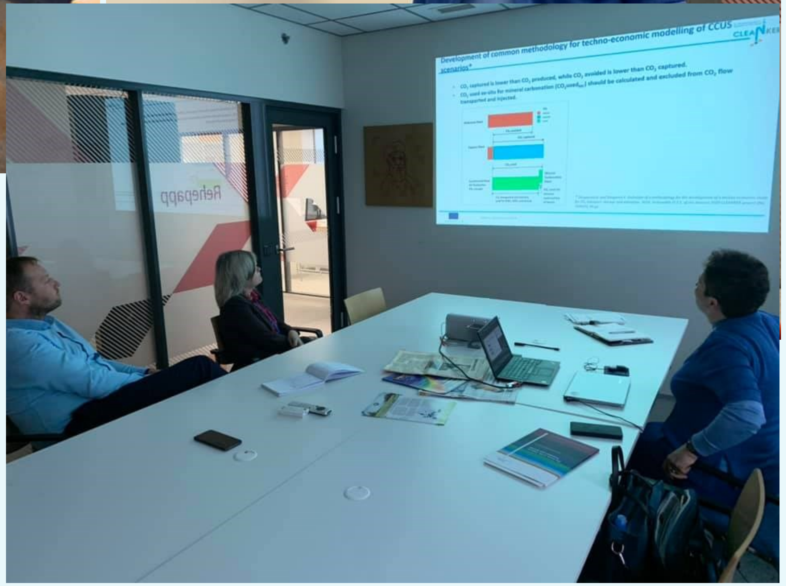
- Lithuania was only one Baltic country where EU CCS Directive was fully implemented and CO2 storage was permitted.
- A negative example of an unpredicted political decision in Europe: in 2019 the new Lithuanian government fully prohibited any CO2 injection underground and
- Minijos Nafta- a Lithuanian Oil producer had to stop this CO2-EOR project after several years of pilot implementation.
- The reason is a very low public awareness and no lobby in the Lithuanian political system.

Lithuania, CO2-EOR facilities, https://bcforum.net/

Political and Regulatory

National climate policies

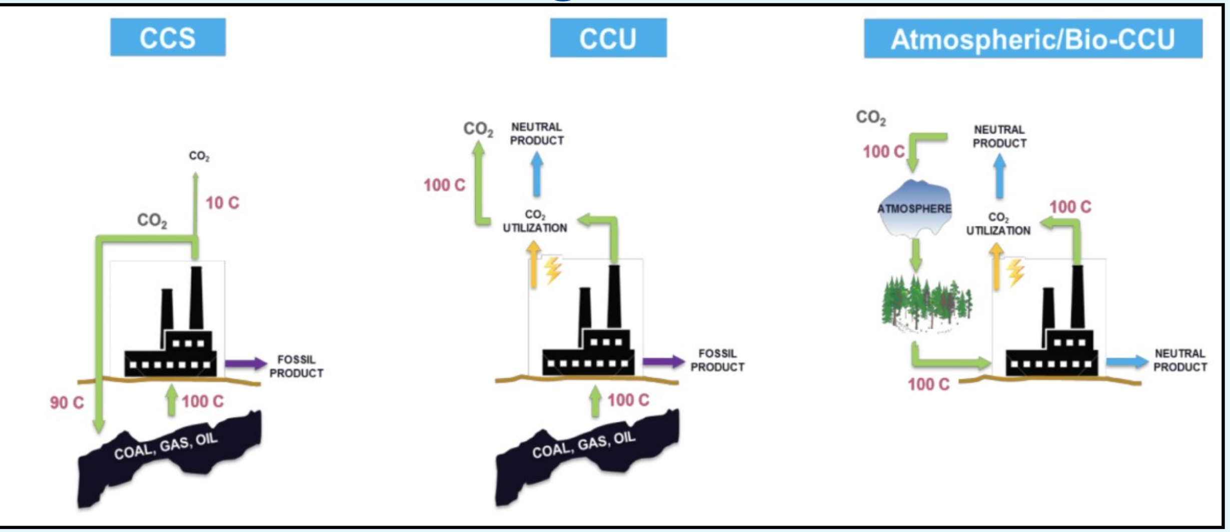
Presentations of CCUS to Estonian Parliament members–Viktoria Ladõnskaja & future minister of environment (2021-2022) Erki Savisaar



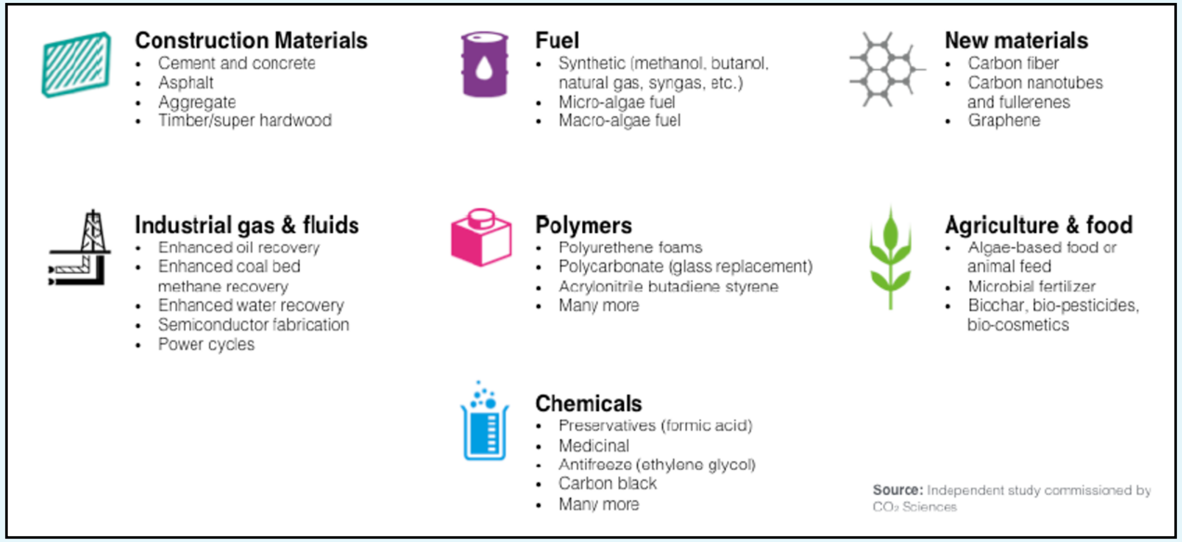
Presentation at the Estonian Ministry of Economic Affairs and Communications, Timo Tatar - Deputy Secretary General

Political and Regulatory – gaps in EU regulations

CCS regulations VS CCUS regulations

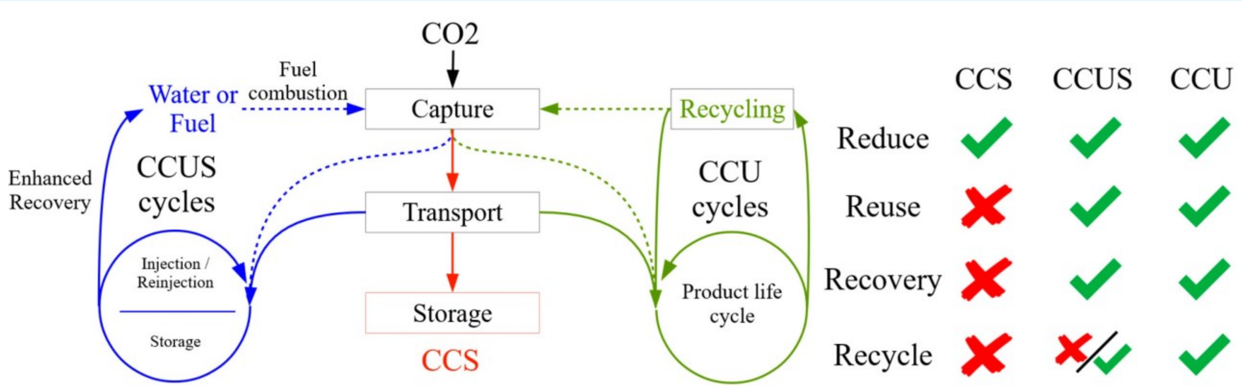


Carbon capture and storage vs. carbon capture and utilization (https://task41project5.ieabioenergy.com)



The 26 products span seven categories.
CO2 Sciences and The Global CO2 Initiative, 2016

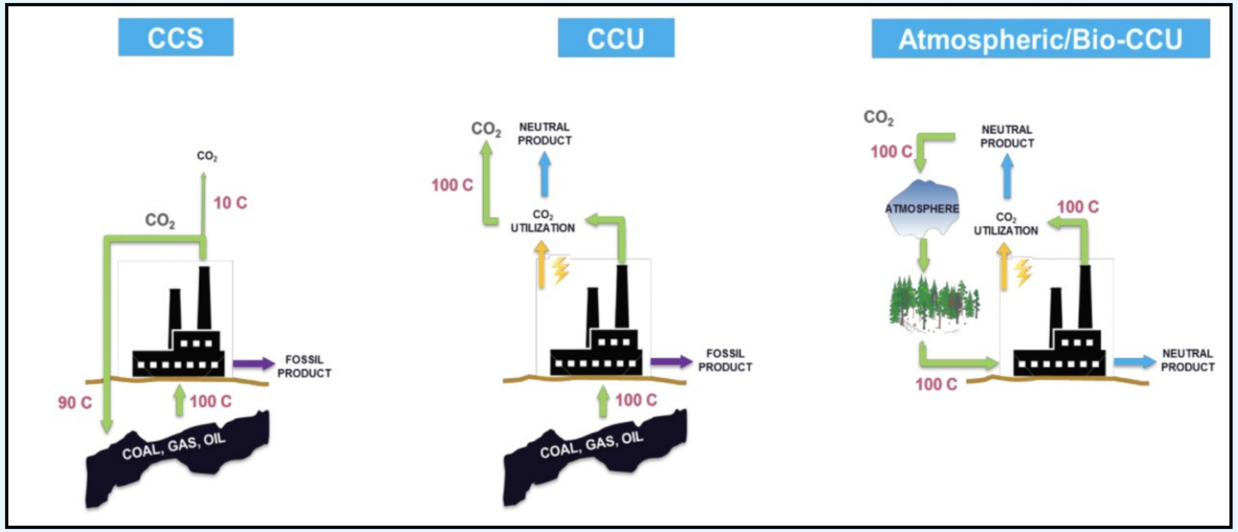
- CCUS - is a driver for CCS.
- Here you can see examples of products and ways to use CO2 that can be made from captured CO2.
- The problem is that EC started to use this abbreviation (CCUS and CCU) after EU CCS Directive was prepared, published and implemented.
- In the draft of EU CCS Directive (2009) was Annex about CO2 mineral carbonation. It was not included in the final version! Regulations for CO2 mineral carbonation are still not available in EU!
- There are also no regulations for other targeted CO2 use options in Europe!



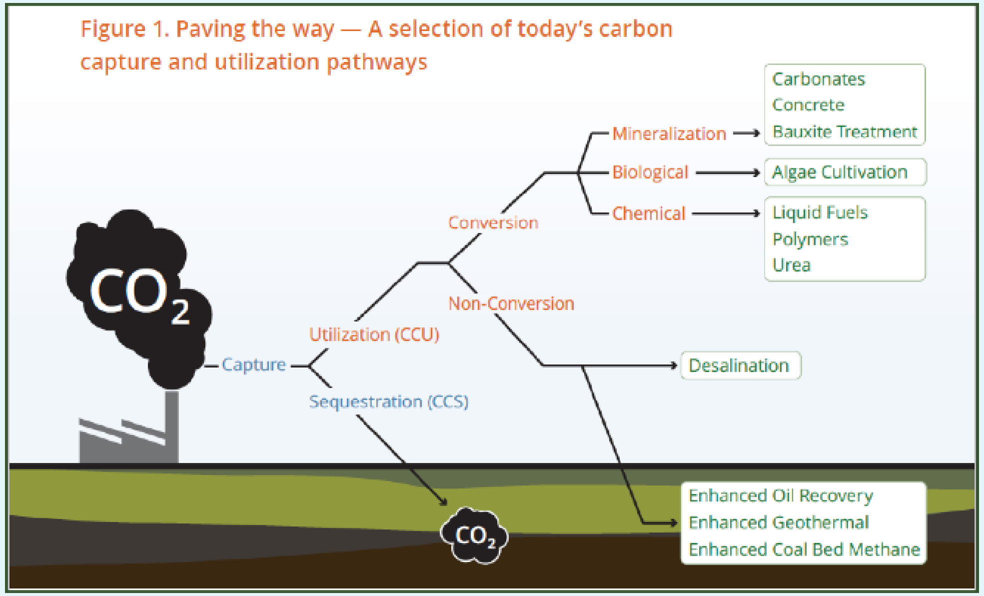
Compliance of CO_2 sequestration options with the principles of a circular economy (Tcvetkov, P, et.al, 2019)

Political and Regulatory

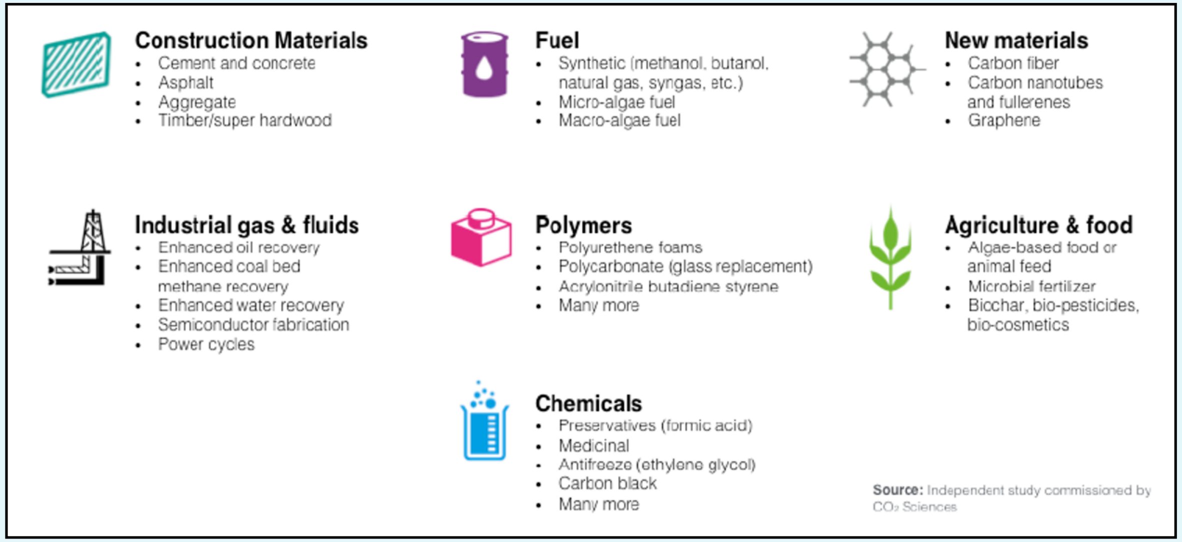
CCS regulations VS CCUS regulations



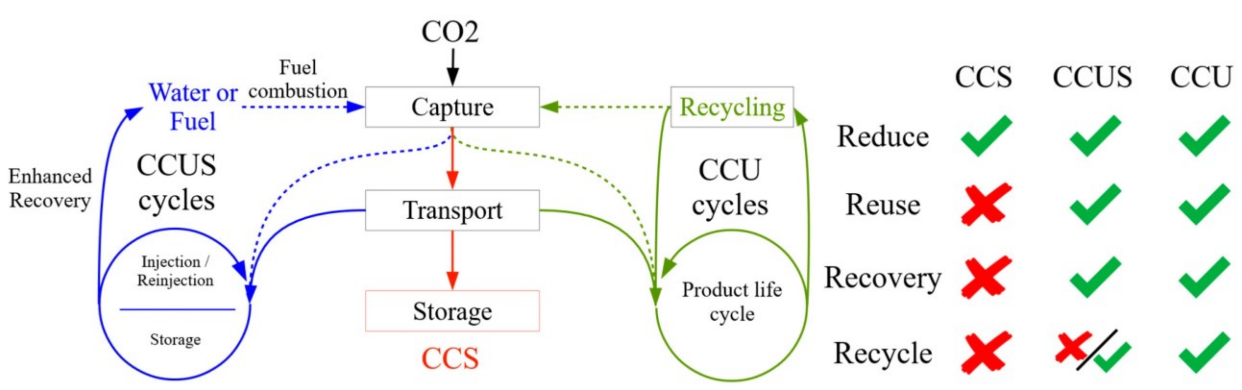
Carbon capture and storage vs. carbon capture and utilization (https://task41project5.ieabioenergy.com)



Pembina and ICO2N



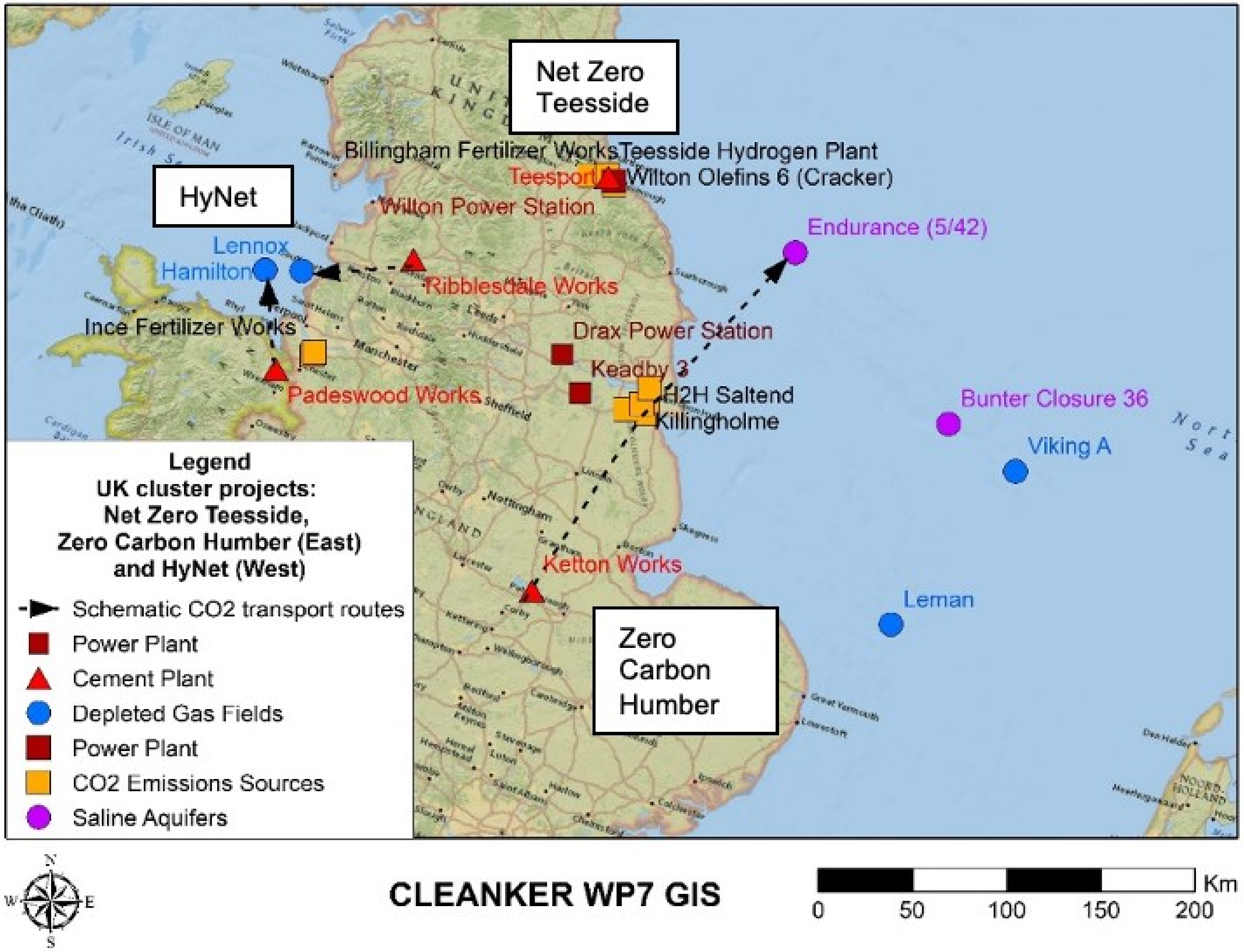
The 26 products span seven categories.
CO2 Sciences and The Global CO2 Initiative, 2016



Compliance of CO_2 sequestration options with the principles of a circular economy (Tcvetkov, P, et.al, 2019)

Political and Regulatory – gaps in EU regulations

Example from European Projects – UK cluster projects



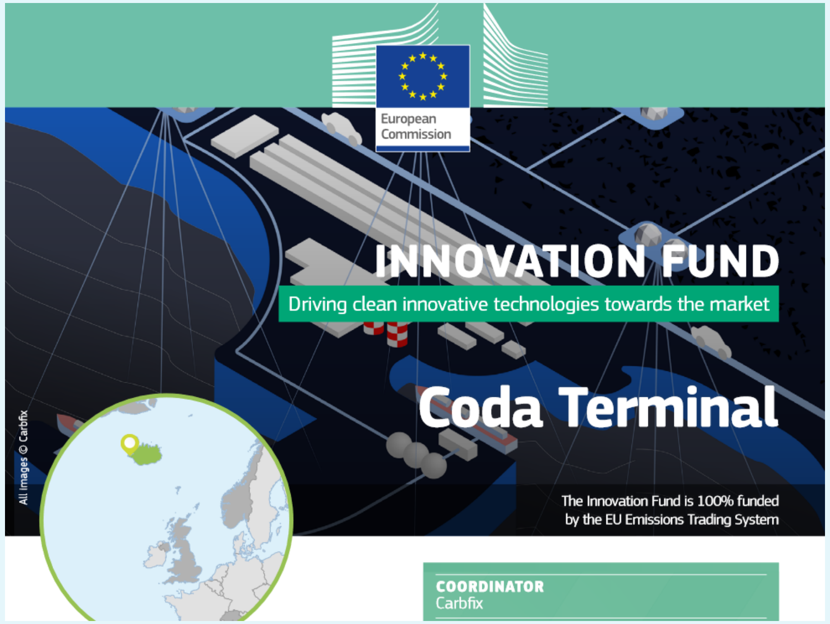
- The EU CCS Directive was initiated and prepared by members of EU Parliament from UK.
- In 2009 they could not expect that after one decade, all the projects in UK and most of European projects will be developed offshore.
- As a result, the ship transport was not included neither in CCS Directive nor in EU ETS.
- It was a great mistake, but several years later, after the implementation of CCS Directive, EC organized open public debates about needs to update CCS Directive and concluded, that no significant changes were needed!!!
- EU regulations still have this gap (until 2025!)

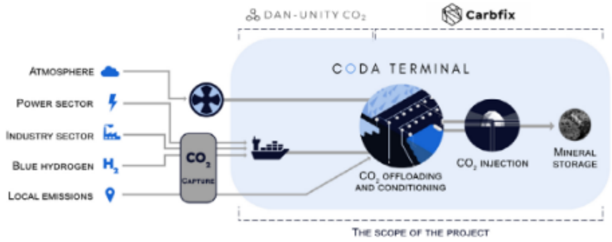
In the CLEANKER project we recommended to Heidelberg Cement: Three CCUS cluster projects in the UK. HyNet North West cluster can integrate two CPs: Padeswood Works and Ribblesdale Works, Hanson UK.
Zero Carbon Humber can include HCG Ketton Works, Hanson UK CP with CO2 storage in Endurance SA (in cooperation with Teesside cluster).
Padeswood was included in the HyNet cluster after our recommendations!

Political and Regulatory

CCS regulations VS CCUS regulatio

Silverstone Project





The world's first CO_2 mineral storage terminal

The Coda Terminal will substantially alter the costs associated with CO_2 transport and storage, by building a highly scalable onshore carbon mineral storage terminal. While CCS projects have traditionally overlooked basaltic formations, these rocks have been proven as reliable reservoirs for permanent CO_2 storage. With an estimated storage cost of 13 €/tCO_2, Coda will drastically reduce the cost of CO_2 storage.

Coda relies on the Carbfix technology, in which captured CO_2 is dissolved in water and injected into basalts. Robust monitoring and verification methods will be used to validate the rapid mineralisation of CO_2. Dan-Unity CO_2 (a specific shipping entity) will manage maritime transportation to the Coda Terminal. Innovative solutions in low-pressure tank design and ship propulsion will be used to minimise the carbon footprint of CO_2 transport.

The port and storage site will be located in Straumsvik, SW Iceland, where there are geologically young basaltic rock formations and ample supply of renewable energy and water. Coda will geologically store, and thereby avoid, 21 Mt of CO_2 equivalent emissions over the first ten years of operation. This annually equates to over half of Iceland's yearly emissions and approximately 2.5% of reductions required across the EU by 2030.

Key policy contributions

For the EU to meet its 2050 climate neutrality ambition, large-scale deployment of CCS is needed. The Coda Terminal offers a scalable, cross-border CO_2 transport and onshore mineral storage solution that mainly requires water and favourable rock formations for operations. Coda will offer the most cost-efficient European CO_2 transport and storage service on the market. The project will also directly contribute to policy targets in energy efficiency, circular economy, and renewable electricity.

Scaling up a new climate-friendly industry

The Coda Terminal provides the foundation for a new climate-friendly industry. During the project's lifetime, Coda will create between 130 and 260 local jobs on site, and 85 (crew) and 5 (ashore) for transportation. In addition, indirectly 400 (shipyard) jobs will be created.

Coda has an exceptional scale-up potential. Local opportunities include expansion of the terminal, replication sites and coupling with local sectors, such as geothermal, heavy industry, waste management and direct air capture. In this respect, it should be noted that the project, during its lifetime, will use a mere 3% of the estimated capacity of the site to mineralise CO_2, which highlights the technology's scalability.

Globally, mineral storage terminals can be built in strategic locations favourable for mineral storage, receiving CO_2 regardless of sector or origin. Planned capture projects in Europe far outnumber storage sites currently in development, meaning demand for reliable storage is high.

- The Coda Terminal in SW-Iceland is a cross-border hub for CO_2 transport and mineral storage, the first of its kind in the world.
- The CO_2 will be transported to Iceland and permanently stored underground as solid carbonate minerals via the Carbfix technology.
- The Coda Terminal will accommodate the storage of CO_2 from local industrial emitters.
- The onshore infrastructure needed for the Coda Terminal are temporary storage tanks, pipelines and injection wells that will be built in steps from 2022 to 2031.
- An industrial harbour is already in place in Straumsvík and is equipped to receive large CO_2 carriers.
- At full scale, the Coda Terminal will have the capacity to annually inject about 3 million tonnes of CO_2 for permanent mineral storage.
- Once the process is confirmed, further monitoring is not required.

Political and Regulatory

CCS regulations VS CCUS regulations – example from Iceland

Silverstone Project


European Commission

INNOVATION FUND

Driving clean innovative technologies towards the market

Carbfix

Silverstone: Full-scale CO_2 capture and mineral storage

© Benjamin Hardman

Project summary

The Silverstone project will deploy commercial scale CO_2 capture and mineral storage of the emissions of the Hellisheidi geothermal power plant in Iceland, one of the largest geothermal power plants in the world. The project will bring an innovative technology to full commercial scale, demonstrating its competitiveness and enabling the power plant to reach a near-zero carbon footprint.

COORDINATOR
CARBFIX OHF

LOCATION
Hellisheidi Geothermal Power Plant in South-West, Iceland

SECTOR
CO_2 Transport and Storage

AMOUNT OF INNOVATION FUND GRANT
EUR 3 867 988

RELEVANT COSTS
EUR 6 446 646

Phase 1
500 thousand tonnes of CO_2 per year. One ship in operation. 2026-2028

Phase 2
One million tonnes of CO_2 per year. Two ships in operation. 2028-2030

Phase 3
Three million tonnes of CO_2 per year. Five ships in operation. 2031 - and onwardsc

- However, regulatory basis for CO2 mineral carbonation was not available in any country.
- Iceland has to create its own national regulations for CO2 mineral carbonation and not only. It is a great challenge. They are working on it.
- The Annex of 2009 on CO2 mineral carbonation was not applied for the EU CCS Directive (11). At least 12 years ago these regulations could be available in Europe!
- Another regulatory challenge for Silverstone Project is the same that we have for all European offshore projects (absent ship transport in EU ETS and not yet ratified 2009 Amendment to article 6 of London Protocol, permitting CO2 export for sub-seabed geological storage).

Political and Regulatory

CCS regulations versus bio-CCS regulations – example from Iceland

Carbfix and Waste Management

- Carbfix and Sorpa, the waste management centre in Reykjavík, will start capturing and storing CO_2 from the landfill site in Álfsnes, near Reykjavík.
- CO_2 is sourced from organic waste forming as a byproduct along with methane, which is sold on the domestic market.
- **The CO_2 will be captured in a water scrubbing unit at the waste management facilities of Sorpa and injected for permanent mineral storage underground.**
- The pilot phase in 2022 will store 3,500 tonnes of CO_2 and build up to 7,500 tonnes. This project aims to reduce the carbon footprint associated with domestic waste disposal. Additionally, the feasibility of issuing certified carbon credits based on the project will be assessed.

Carbfix iCert GeoEnergy SORPA ÁRANGUR Í UMHVERFISMÁLUM Technology Development Fund

- **Carbon credits**
- As part of this project, a standard and technical framework for climate mitigation solutions will be developed.
- The goal is to make certified and verified carbon credits commercially available on international carbon markets.
- A technological solution, in adherence to the standard, will be developed to capture CO_2 emitted from organic waste at the facilities of Sorpa in Álfsnes and inject it for permanent mineralisation underground via the Carbfix method.
- The project will reduce the emission of greenhouse gases by thousands of tonnes per year and form the basis of a carbon offset program that is both permanent and measurable in real time.
- **Lessons learned:**
- There is no European and International regulations on CO2 mineral carbonation and bio-CO2 emissions.
- They are no in EU ETS, nor in CCS Directive!

Political and Regulatory

National CCS regulations – examples of mistakes and ways to avoid them

https://www.energyintel.com/

https://www.zdnet.com/

Political and Regulatory

National CCS regulations and permitting processes – history of mistakes and ways to avoid them

- Planned **Beáchatów (Poland) and Jänschwalde (Germany)** demoprojects were challenged by the inadequate regulatory response at national level.
- Poland transposed the CCS Directive in April 2013 – about two years after the deadline. Germany transposed the Directive in August 2012.
- By that time, the proponents had already terminated the project (February 2012) partially because of the delays by the German authorities in transposing the EU directive on CCS
- Even implemented and available laws could not guarantee the smooth implementation of CO_2 storage projects, even CO_2 storage pilots:
- At a national level, it is particularly important to have a clear and
- efficient permitting process in place.
- For example, the **Compostilla project (Spain)** faced serious delays due to the lack of CO_2 permitting regulation.
- Spain fully implemented the CCS directive by December 2010 (Ley 40/2010), however, it did not develop a system for storage licence application. It also did not transpose the amendments from the EIA directive that was addressing CO_2 transportation legislation.
- **Lessons learned: Timely transposition and alignment of legislation on the EU and national level is essential to overcome delays and avoid project cancelations.**

Source: Kapetaki et al, 2017

Ansicht des Kraftwerks Jänschwalde vom Aussichtsturm Teichland, 2018, Wikipedia (left),
Belchatow Power Plant (right), the most polluting PP in europe. Image cortesy of Morgre, https://www.nsenergybusiness.com/projects/belchatow-power-plant/

Political and Regulatory

National CCS regulations and permitting processes – history of mistakes and ways to avoid them

- The **Porto Tolle project** also faced regulatory challenges – the project was aiming to finalise the permit in 2014 but was delayed because of the decision from the Italian State Council to annul the plant’s initial Environmental Impact Assessment.
- The change from oil to coal combustion required a new EIA. The project was terminated in August 2013 at the request of the developer due to delays in project execution caused by these permitting issues.

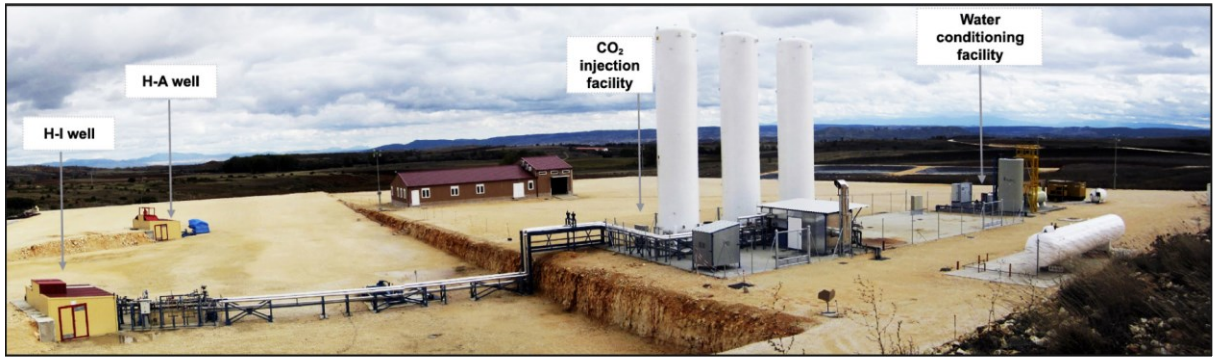
- **Lessons learned:**
- **Timely transposition and alignment of legislation on the EU and national level is essential to overcome delays and avoid project cancelations.**
- **At a national level, it is particularly important to have a clear and efficient permitting process in place.**

https://www.incide.it/en/project/porto-tolle-power-plant/

Source: Kapetaki et al, 2017

Political and Regulatory lessons coupled with public opposition

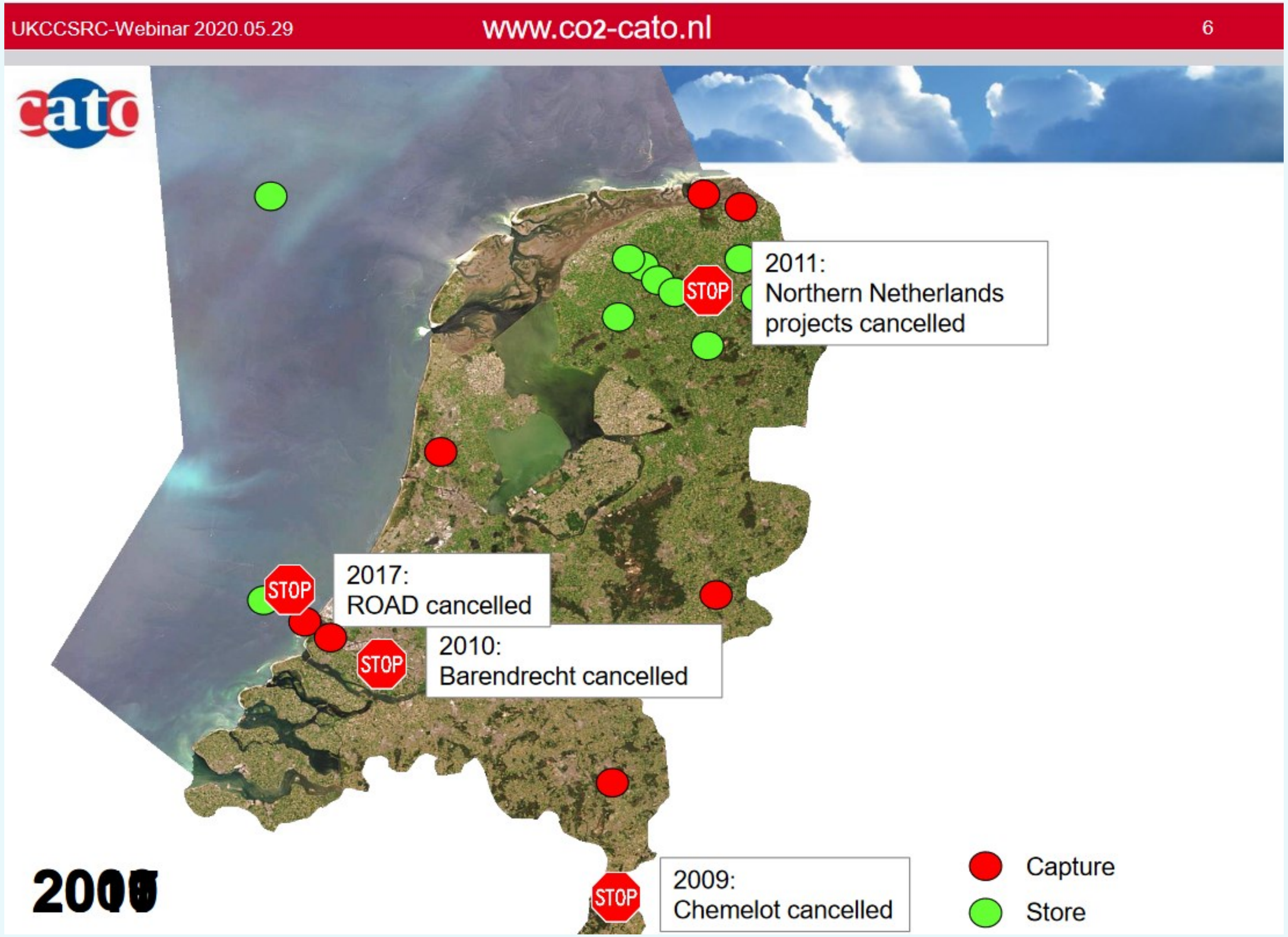
- Even implemented and available laws could not guarantee the smooth implementation of CO2 storage projects, even CO2 storage pilots:
- Absent public awareness and public resistance coupled with regulatory problems can ban the already planned and well-advanced projects (we have negative examples in Minjos Nafta project in Lithuania, ENOS storage pilot in Hontomin, Spain, Jänschwalde project)
- With regards to CO2 storage, number of projects that decided to opt for onshore formations were cancelled.
- Onshore transport and storage could be challenging for project progress.
- In the case of **Jänschwalde** project, it can even be considered one of the reasons for cancellation due to public opposition on the initiative.
- While there have not been significant concerns regarding technology and technology implementation, a valuable lesson is that public support proved to be essential for projects to progress with onshore activities.



Hontomin Technology Development Plant (http://www.enos-project.eu)


Minjos Nafta project in Lithuania, CO2-EOR facilities (https://bcforum.net)

LESSONS LEARNED FROM THE NETHERLAND



- These Carbon Capture and Storage (CCS) projects in the Netherlands were abandoned during the last decade because of social resistance and lack of a business case.
- It was coneceted with low CO2 price in EU ETS during this time (2009-2017).

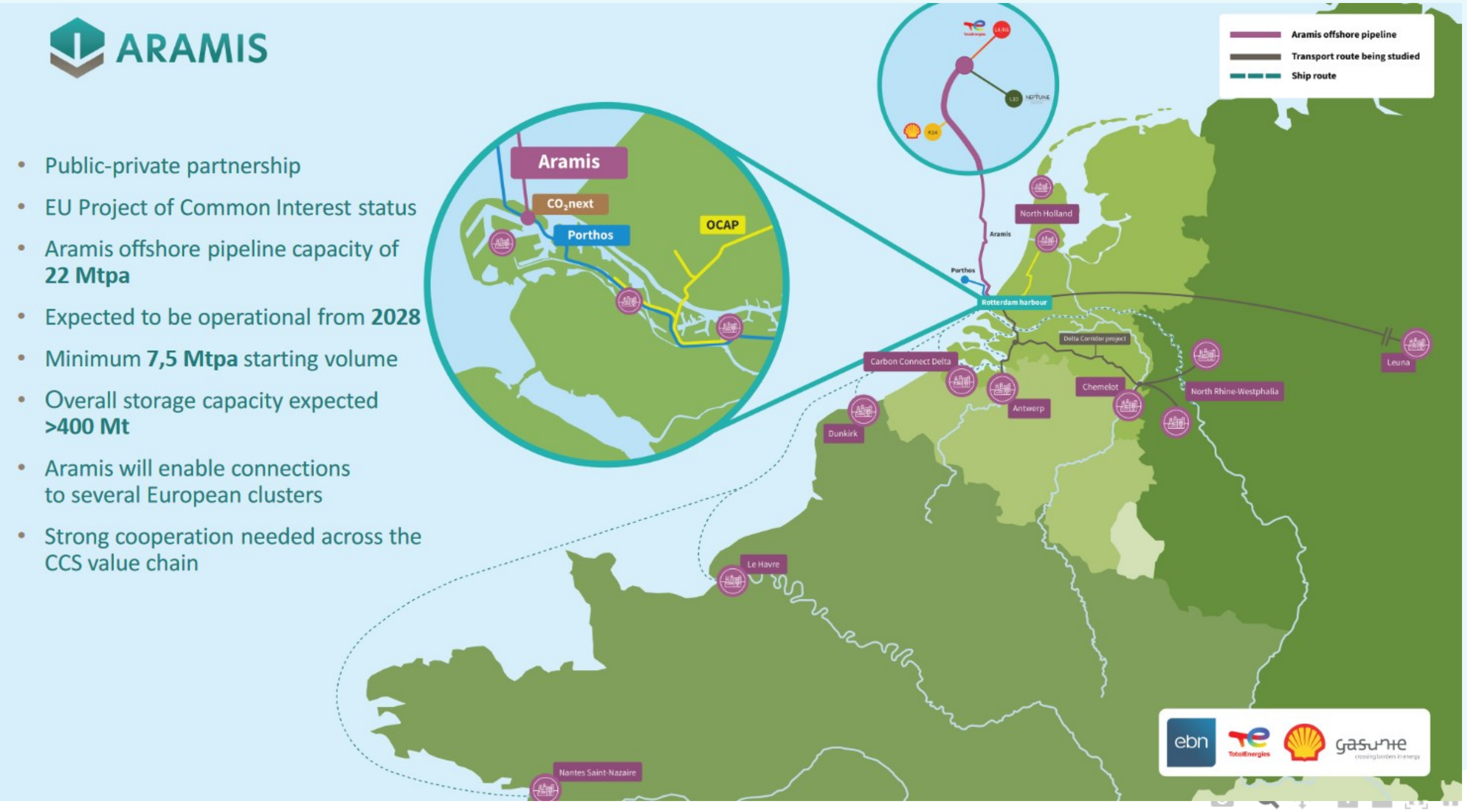
2021: ATOS project cancelled: The Athos carbon capture and storage project in the Netherlands has been cancelled following project partner Tata Steel's decision to develop a direct reduced iron process using hydrogen, Athos said Sept. 20, 2021

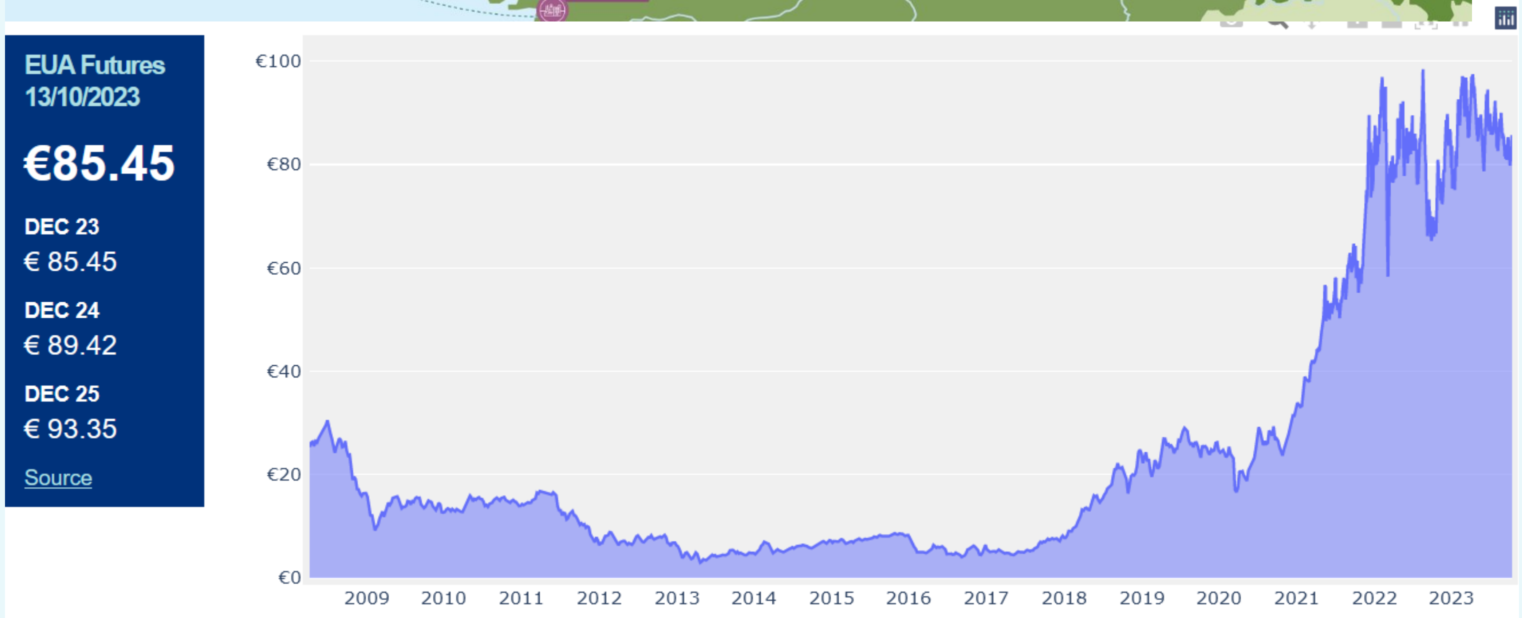
Good news:

- Ongoing projects in the Netherland:
- Porthos
- Aramis (PCI project)
- C 4 U https://c4u-project.eu/ (iron and steel industry)
- CO2 next

LESSONS LEARNED:

- From the end 2022 the CO2 Price in EU ETS is high enough for the business case to be demonstrated!
- Public acceptance should be developed by increasing public awareness about social and financial benefits of CCUS projects!
- Additionally, EC is supporting projects using innovation fund, and infrastructure projects using PCI calls (50% support).





Political and Regulatory

National CCS regulations – positive lessons

https://theconversation.com/

- Nevertheless, we have also positive lessons:
- Ambitious political measures and initiatives of the European Union and support of research and innovation projects finally influenced the CCUS developments, and much more CCUS projects and cluster projects are under development now in a number of European countries.
- Increased activity of the oil and gas companies towards CO2 storage projects is caused by the recent changes in regulations including tax credits for CO2 storage in the USA (Section 45Q, 2022) and in Canada.
- New national regulations in Denmark supported very fast development of CCUS activities in the country during just two-three years (Greensand project and others).
- New CCS regulations are ready in Poland, which will permit industrial scale CO2 storage and CO2 use for EOR (https://www.energy.gov/sites/default/files/2023-07/5.%20Piotr%20Dziadzio_CCUS%20activities%20in%20Poland-final.pdf).

UNITED STATES OF AMERICA

- Section 45Q of the Internal Revenue Code establishes tax credits for storage of CO_2.

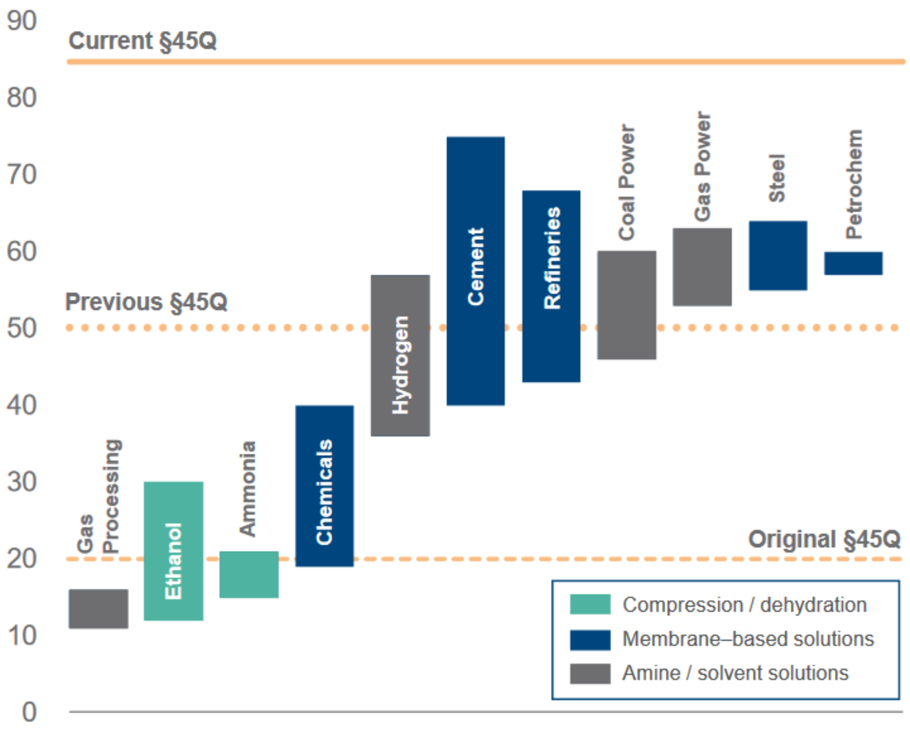
Country United States	Section 45Q
Year 2008	First introduced in 2008, Section 45Q of the Unites States Internal Revenue Code provides a tax credit for CO_2 storage. The policy is intended to incentivize deployment of carbon capture, utilisation and storage (CCUS), and a variety of project types are eligible.
Status: in force	• In 2022, the US introduced a significant stimulus for CCUS investment with the passage of legislation (the Inflation Reduction Act) to expand and extend the 45Q tax credit. • The 2022 changes to 45Q provide up to **USD 85** per tonne of CO_2 permanently stored • **and USD 60** per tonne of CO_2 used for enhanced oil recovery (EOR) or other industrial uses of CO_2, provided emissions reductions can be clearly demonstrated. • The credit amount significantly increases for direct air capture (DAC) projects to **USD 180** per tonne of CO_2 permanently stored • and **USD 130** per tonne for used CO_2.
Jurisdiction National	In addition, the 2022 changes reduce the capacity requirements for eligible projects: 18,750 tonnes per year for power plants (provided at least 75% of the CO_2 is captured), 12,000 tonnes per year for other facilities and 1,000 tonnes per year for DAC facilities.
	Finally, the 2022 changes include a seven-year extension to qualify for the tax credit, meaning that projects have until January **2033** to begin construction.

Example from US – Denbury oil company is is encouraged with new 45Q regulation

Increasing CCUS Scale With IRA and Technology

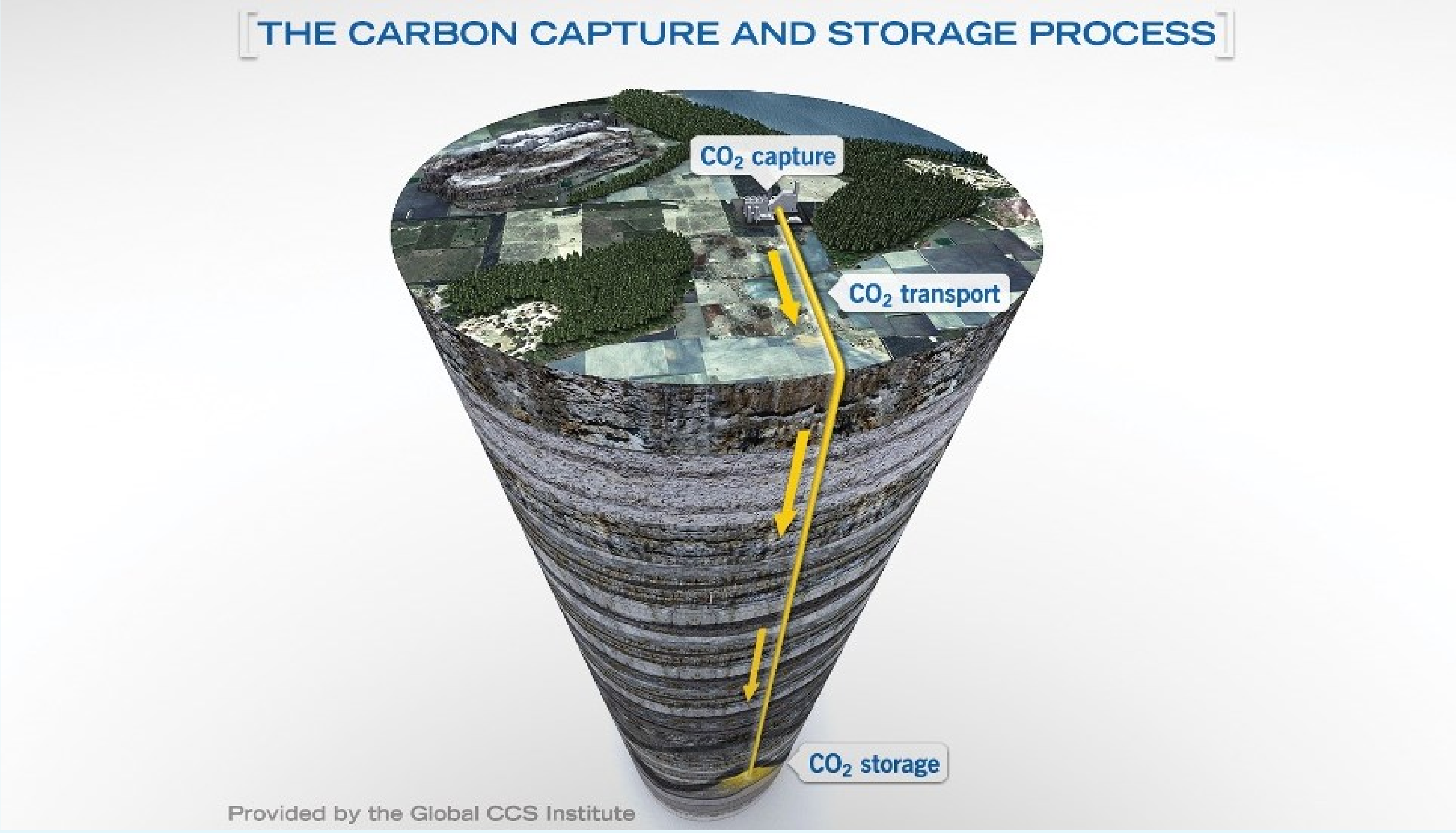
- **New technologies and enhanced §45Q levels ($35 / $50 to $60 / $85 per tonne) bring post-combustion emissions into economic capture window**
- **Emerging technologies driving down the cost of CO_2 capture by up to 40%**
  - Membrane-based technologies offer lower cost of capture for lower volume levels
  - Liquid technologies (solvent-based) offer lower cost of capture at higher volumes; benefit from economies of scale
- **DEN assessing equity investments / partnerships with multiple CO_2 capture technology companies**
  - Insights into capture technology innovation
  - Increases potential transportation and storage opportunities

Industry Capture Cost per Metric Ton
$ per metric ton



Source: Great Plains Institute, *Transport Infrastructure for Carbon Capture and Storage*

Geological lessons



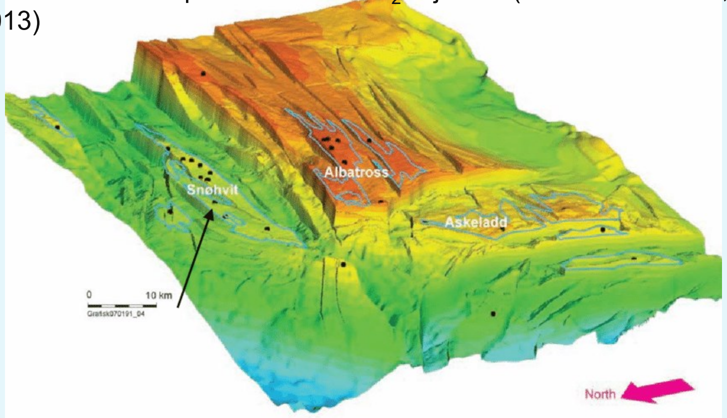
Requirements for CO_2 storage site selection:

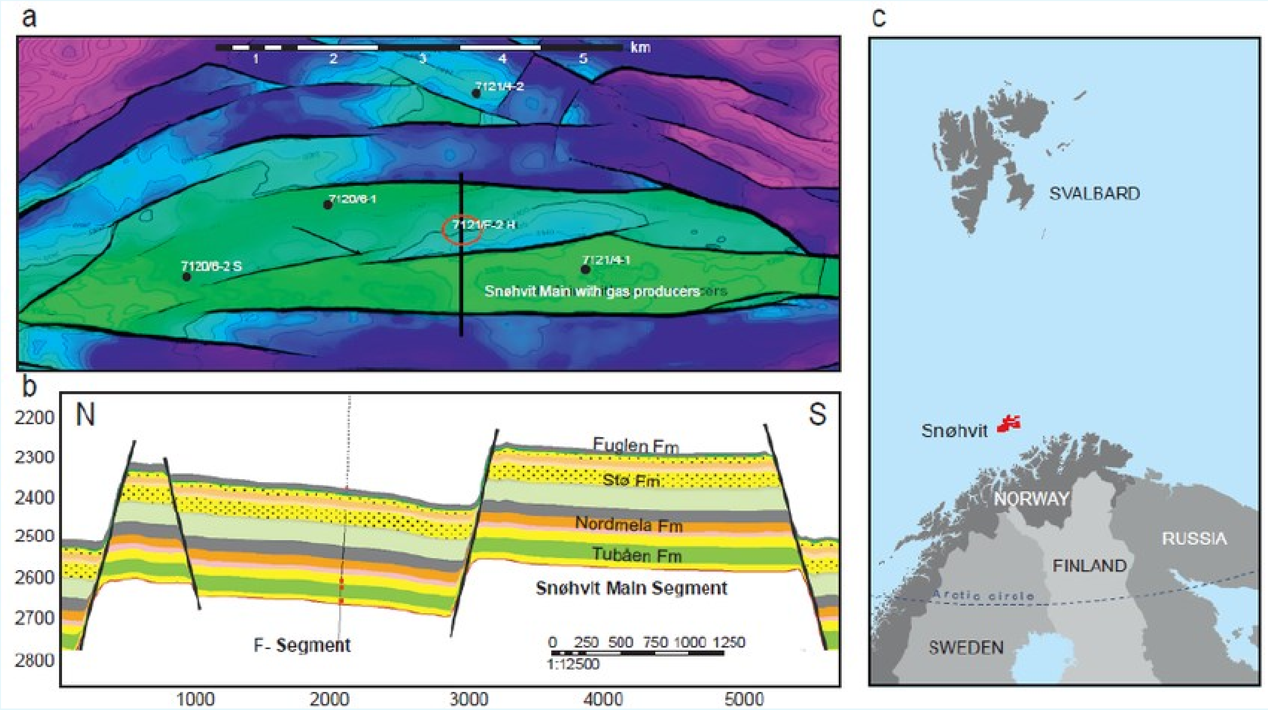
- CO_2 storage capacity
- CO_2 injectivity
- Good and safe cap rocks – Seal capacity
- Good sealing faults bordering your storage structure
- We should consider risks and safety of storage, global and local risks, leakage risks.

Geological lessons

Negative Example: Snohvit, Norway (Problems: injectivity, storage capacity, etc)

Three-dimensional structural map of the Snøhvit Field. The black arrow points to the CO_2 injector (Simmenes et al., 2013)



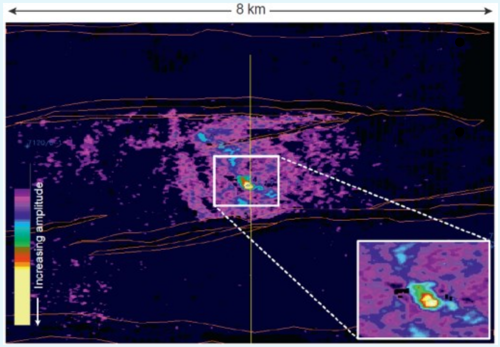


Location of the Snøhvit fields with filed map and vertical cross section over the main field. The red squares point ot the perforated intervals. Adapted from Hansen et al., 2012 (Simmenes et al., 2013)

- The first one projects Snohvit in Norway, operated by Equinor oil company before it was a Statoil – the most experienced operator of CCS projects in Europe and even in the WORLD (they have experience with the world-famous Sleipner storage site in the North Sea).
- Around 0.7 million tonnes per year of CO_2 have been safely injected and stored in the Tubåen sandstone (2,600 meters beneath the seabed and about 45-75 meters thick) since April 2008.
- The maximum injection is planned for 31-40 Mt, with 1.9 Mt injected to date. 2010, when Statoil announced that they had discovered that there was less storage capacity than expected at the Snohvit injection site.
- They estimated incorrect models of injectivity, and as a result wrong storage capacity!

Measures are now being taken to increase Snohvit's capacity - like drilling new wells and/or fracturing the formation.

A monitoring program has also been set up to investigate the behavior of CO_2 underground.



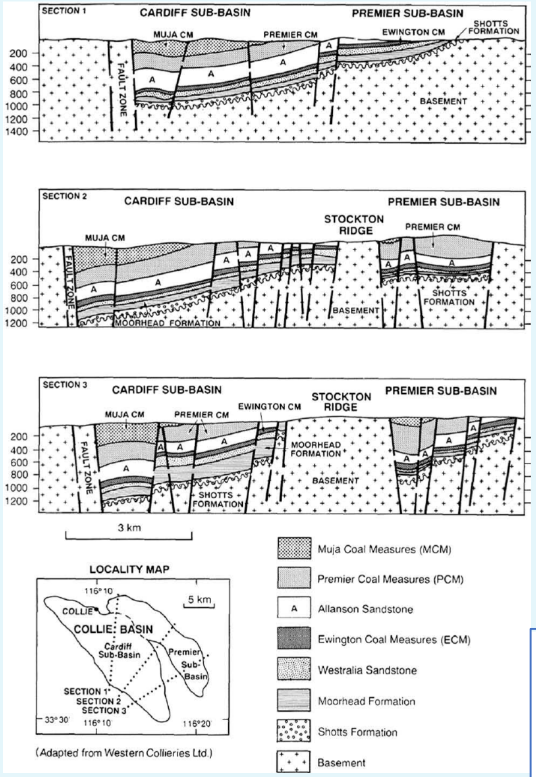
Time lapse (post-injection minus pre-injection) seismic data from the Snøhvit Field. Adapted from Hansen et al., 2011 (Simmenes et al., 2013)

https://sequestration.mit.edu/tools/projects/snohvit.html

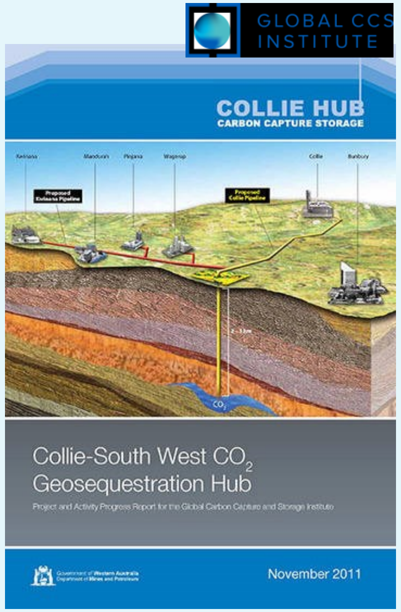
Geological lessons

Negative Example: Collie, Australia (Problem: no ceiling-seal capacity)

Location of Collie and the Collie Basin (Turner, J., 1999)



Schematic structural cross-sections of the Collie Basin (Le Blanc Smith, 1993) Depth is in meters (Varma et. al., 2009)



- (https://phys.org/news/2014-01-prospective-carbon-capture-site-lacks.html) -It was called a "Prospective carbon capture site". But in the end, it was reported, that site lacks a ceiling!
- In 2009 Varma et. al. reported this storage site in Australia as "suitable" to become the main candidate for the CCS project in Australia.
- In November 2011, the South West Hub project was shortlisted as one of the **Australian CCS National Flagship Projects and in June 2011 was awarded AU$52 million** under that Program for its ongoing project development.
- But later in 2014, after deeper research, scientists did not find a cap rock or sealing capacity in the reservoir.
- CCS HUB project was cancelled.
- Lessons: Deeper studies must be provided in the project preparation phase - geological study and estimation of geological properties of storage site candidates are crucial.

PHYS.ORG

Prospective carbon capture site lacks ceiling

31 January 2014, by Geoff Vivian

"That included logging the sedimentology.

"Later on, we did some sampling and with those samples analyse the porosity and the permeability.

"We were trying to essentially figure out how much porous base we have in our reservoir and how impermeable our cap was."

He says the site was chosen because of its proximity to the Collie coal-fired power station: sequestering its CO2 emissions there would minimise transport costs.

Hugo Olierook says the site was chosen because of its

A layer of impermeable cap rock was also thought

"Researchers' early attempts to find a Perth Basin site to sequester carbon have detected a suitable porous aquifer, but they are yet to find a nonporous cap rock to contain it."

Provided by Science Network WA

APA citation: Prospective carbon capture site lacks ceiling (2014, January 31) retrieved 20 September 2022 from https://phys.org/news/2014-01-prospective-carbon-capture-site-lacks.htm

3. Geological

Example of full chain geological study

Example of detailed laboratory study, including laboratory CO2 injection experiment in IFPEN (Paris):

PhD study (K.Shogenov, 2015)
"Petrophysical models of the CO_2 plume at prospective storage sites in the Baltic Basin"

GlobalScientia

Global Science and Technology

PUSHING BEYOND THE BARRIERS

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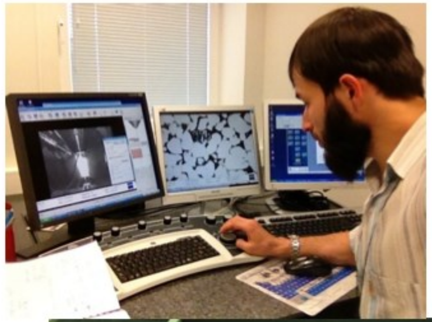
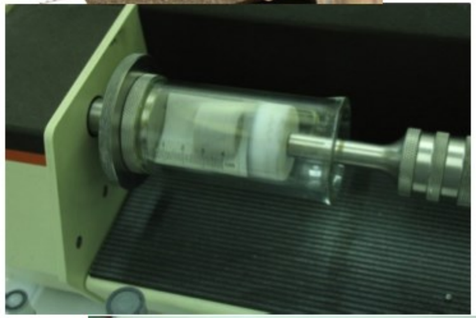
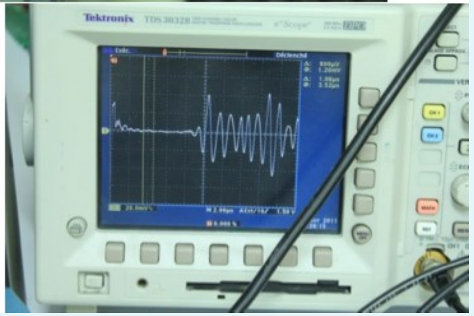
Fig. 4 *"Thanks to my CGS Europe study visit at IFPEN, I was able to perform first-class laboratory experiments on my rock samples that represent an important part of my PhD research." - Kazbulat Shogenov, PhD student of Tallinn University of Technology, Estonia (pictured at IFPEN laboratory in Rueil-Malmaison, France).*

CO_2GeoNet Open Forum – European top event on CO_2 storage research







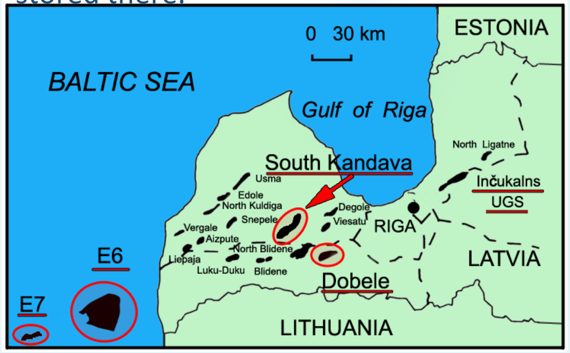
Example of detailed laboratory study, including laboratory CO2 injection experiment in IFPEN (Paris)
A full chain of geological research was made in this study to find, estimate and prove the storage site's quality: from the study of all available data, rock sampling, chemically induced alteration experiments with reservoir and cap rocks, petrophysical, geophysical, mineralogical, geochemical study and (next page)

3. Geological

PhD study (K.Shogenov, 2015)
"Petrophysical models of the CO_2 plume at prospective storage sites in the Baltic Basin"

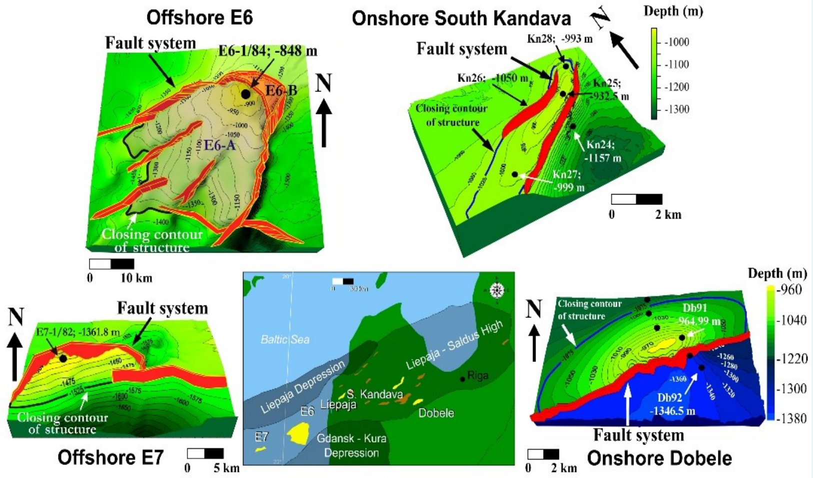
Example of risk study. Seismic numerical modelling

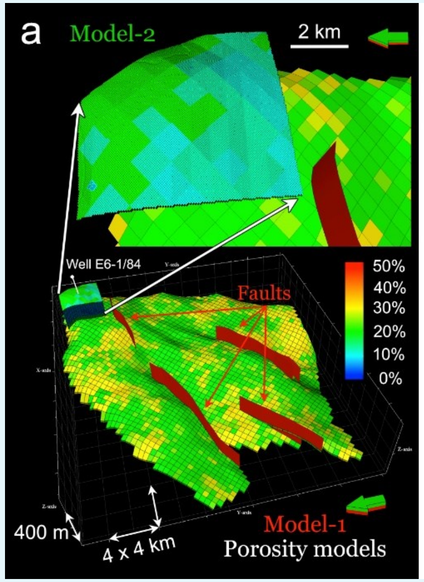
• finishing with reservoir geological modelling and seismic numerical 4d time-lapse modelling and integration of petrophysical alteration effects into the seismic numerical modelling.
•This is an example about risk management, from PhD study and modelling of Kazbulat Shogenov (2015).
•There are risks, but results show that if there are good cap rocks, modelling and projects, that it is safe, - oil and gas exist in the traps for millions of years, gas storages are working for more than 50 years (Incukalns Latvia).
•Even with limited data it is possible to model the storage site and fate of CO2 stored there.

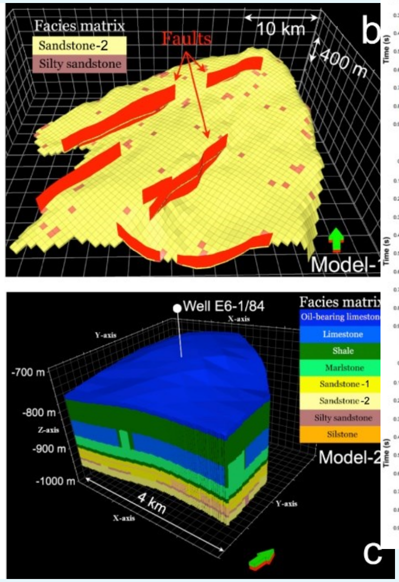


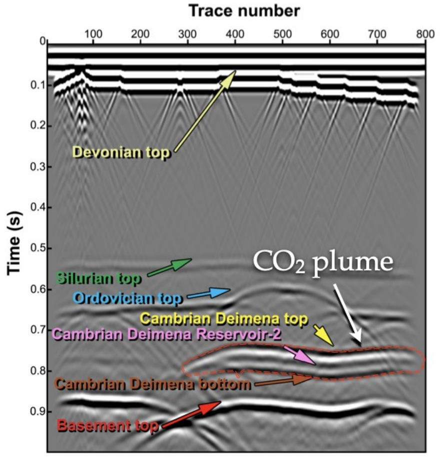
(Shogenov et al, 2013)

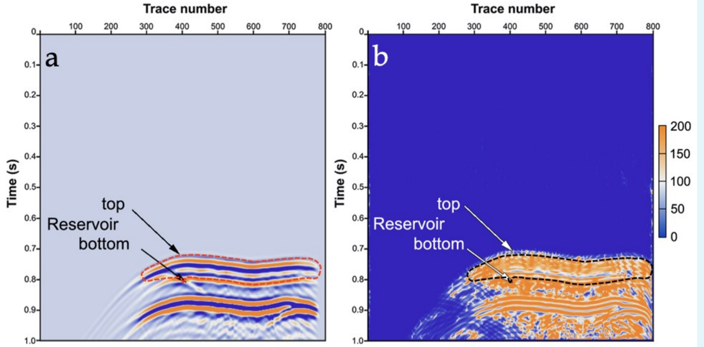
• The novelty of the applied seismic numerical modelling approach was the coupling of the chemically induced petrophysical alteration effect of CO2-hosting rocks measured in the laboratory with time-lapse numerical seismic modelling.



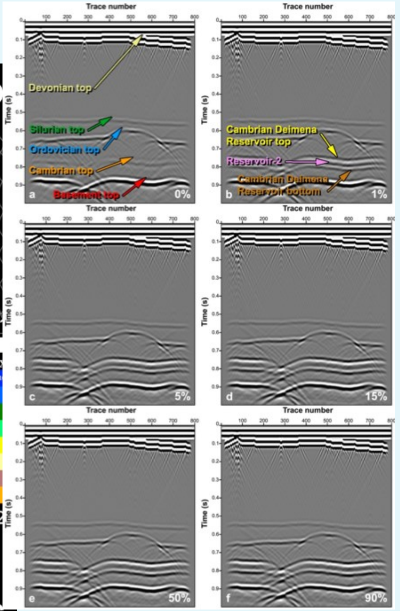


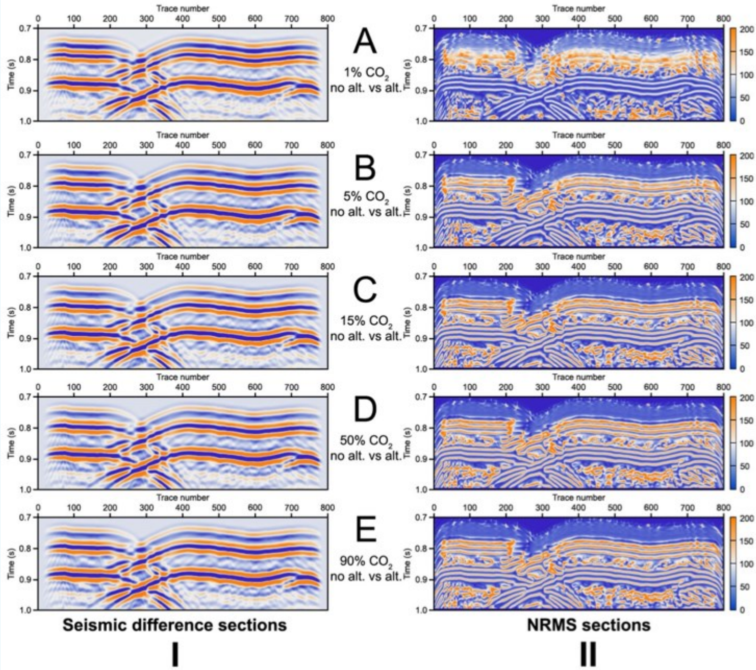






For the first time, seismic time-lapse numerical modelling based on rock physics studies was applied to monitor possible CO 2 storage in the largest geological structure, E6 offshore Latvia in the Baltic Sea.



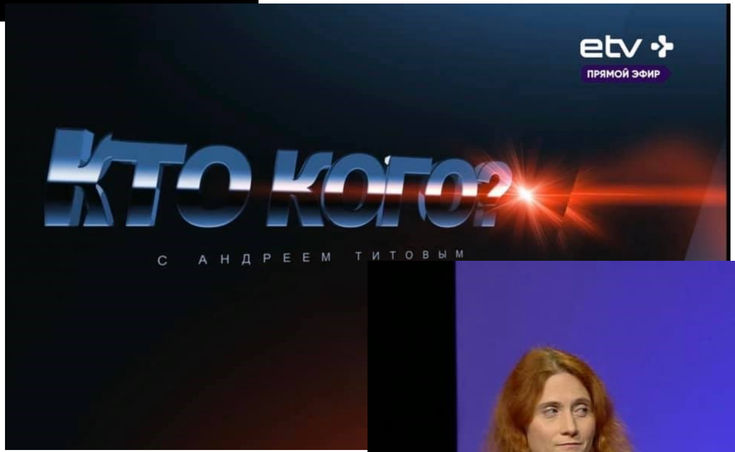


Course Content

- A) Developments in strategic, political and regulatory issues
- Strategic (Climate strategies and revenue systems)
- Political and Regulatory (National strategies and regulations)
- Geological 1: Negative and positive lessons
- **B) Geological 2: Site characterization and modelling (Prof. Auli Niemi)**
- **Coffee break: 15 min**
- C) Techno-economic aspects of CCUS clusters and hubs
- Economic (Cost of technologies)
- CCUS clusters and hubs: Carbon Neutral Scenario for the Baltic States
- **Conclusions and integration of the learned lessons**

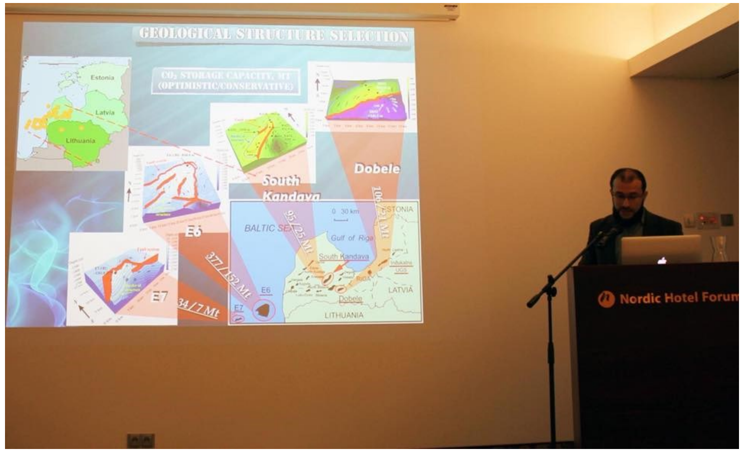
- Part C
  Techno-economic aspects of CCUS clusters and hubs
  Public communication
  CCUS clusters and hubs: Carbon Neutral Scenario for the Baltic States
  Conclusions and integration of the learned lessons

Public communication



Talk show on the National Estonian TV: “Who will win?” about the ecological crisis

Talk show on the National Estonian Radio channel 4: about CCUS technologies



Baltic Forum on Carbon Dioxide Capture and Storage 2018, Tallinn

Baltic Forum on Carbon Dioxide Capture and Storage 2019, Tallinn
And interview for the national newsletter

Public communication

POSTIMEES МНЕНИЕ СПОРТ ВИДЕО К

Rus.Postimees.ee > Экономика > Ученые знают, как сп

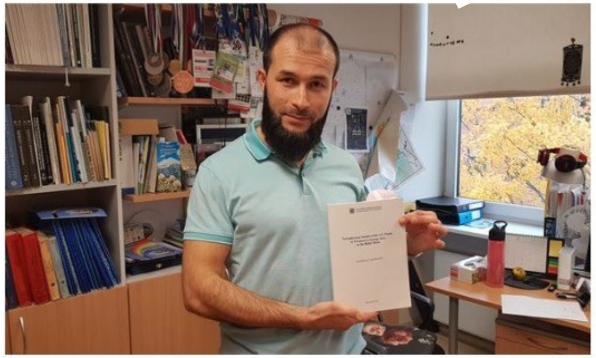
269 1

17 октября 2019, 18:31

Ученые знают, как спасти сланцевую энергетику Эстонии не в ущерб экологии, но их не слышат

Добавлен комментарий Eesti Energia

Олеся Лагашина



Казбулат Шогенов со своей докторской диссертацией, посвященной хранению углекислого газа.

ФОТО: Олеся Лагашина

В ТТУ утверждают, что знают, как решить проблему неэкологичной сланцевой энергетики, не закрывая производство. Однако пока ученым не внемлют ни политики, ни энергетики. О том, почему так происходит и как работает

...агенть • 7 ноября 2019

Только для подписчиков

В США разработаны технологии, позволяющие устранить 90% выбросов CO_2 в атмосферу. Их можно применять и в Эстонии. Но есть проблема: они невероятно дорогие.

Казбулат Шогенов, научный сотрудник Таллиннского технического университета

EestiPäevaleht UUDISED ARVAMUS VÄLISMAA ÄRILE ... LP

KLIIMA 31. OKTOOBER 2019

Teadlane: ka Eesti maapõues saaks ... ladustada ja siis näiteks maasooja toota

23

Maasooja tootmine CO_2 abiga on Alla Šogenova sõnul täiesti võimalik. „Seda pole ma veel kellelegi Eesti rääkinud. Olen juba rääkinud teile rohkem, kui peaks!"

RAIMO POOM
raimo.poom@epl.ee

JAGA 56 KU

Kui süsihappegaas Eestis kinni püüda, siis on Alla Šogenova sõnul olemas väga head ärivõimalused, kuhu ja kellele seda müü

Public communication
CCS Advocates & Green NGOs against CCS

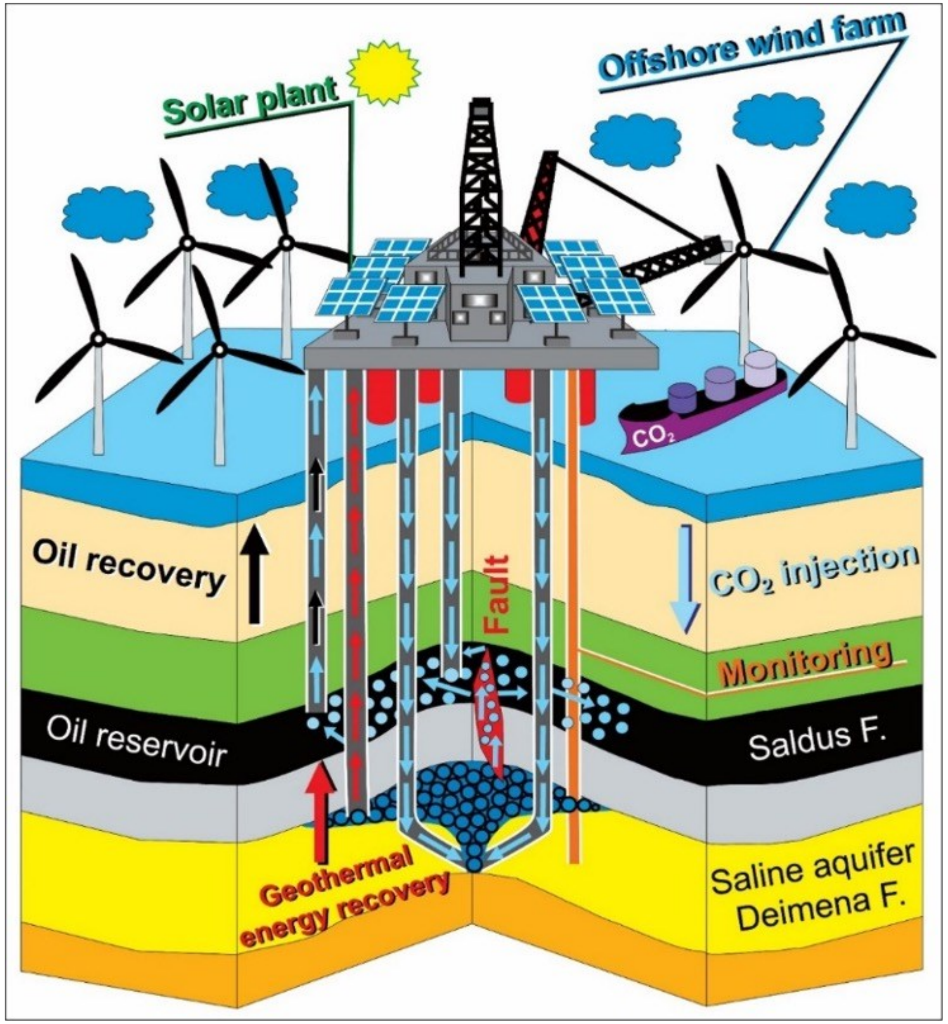
https://bellona.org

BELLONA
EUROPA

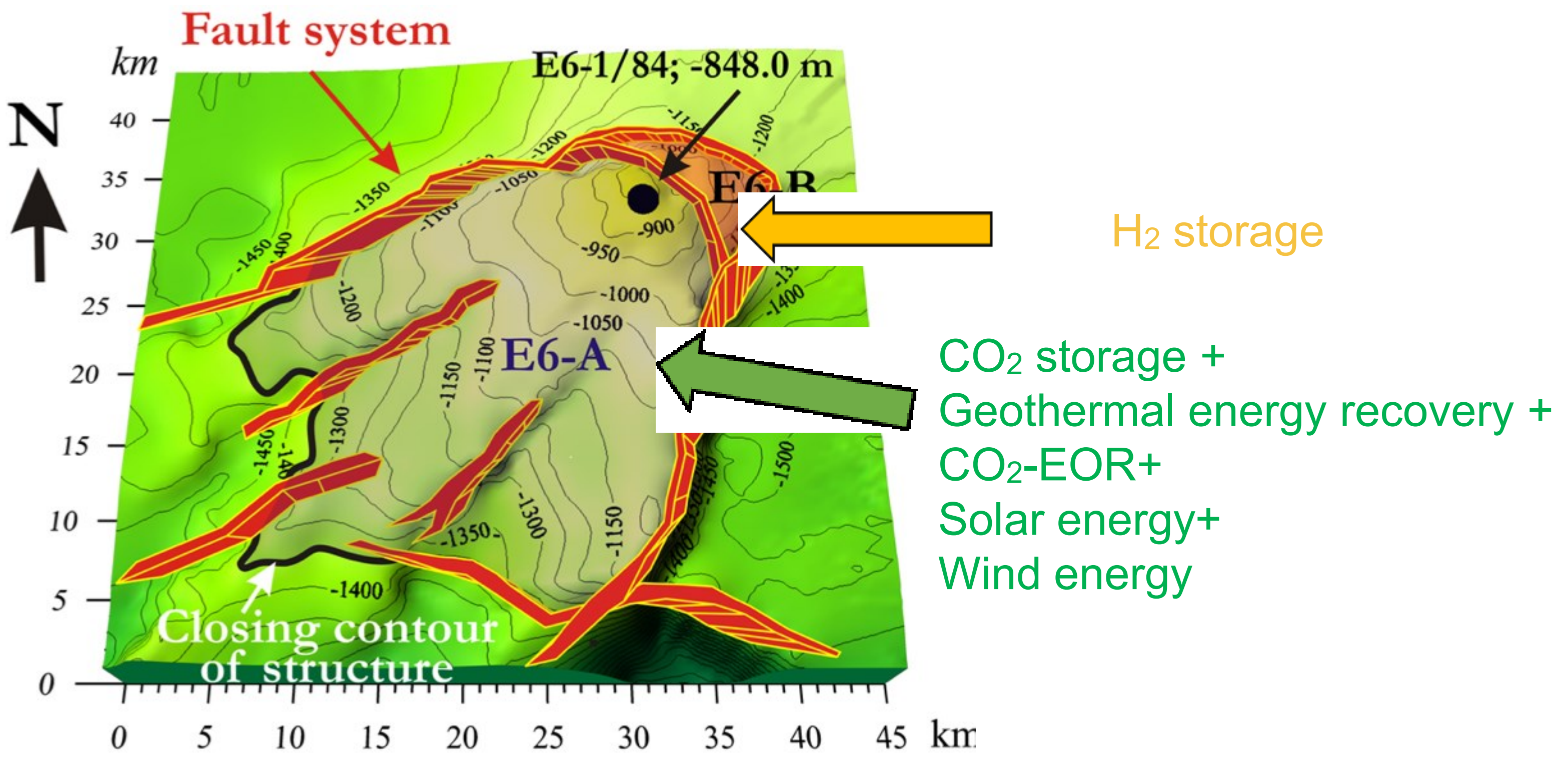
https://www.pxfuel.com/

Public communication

Synergy of CCS with renewable energies



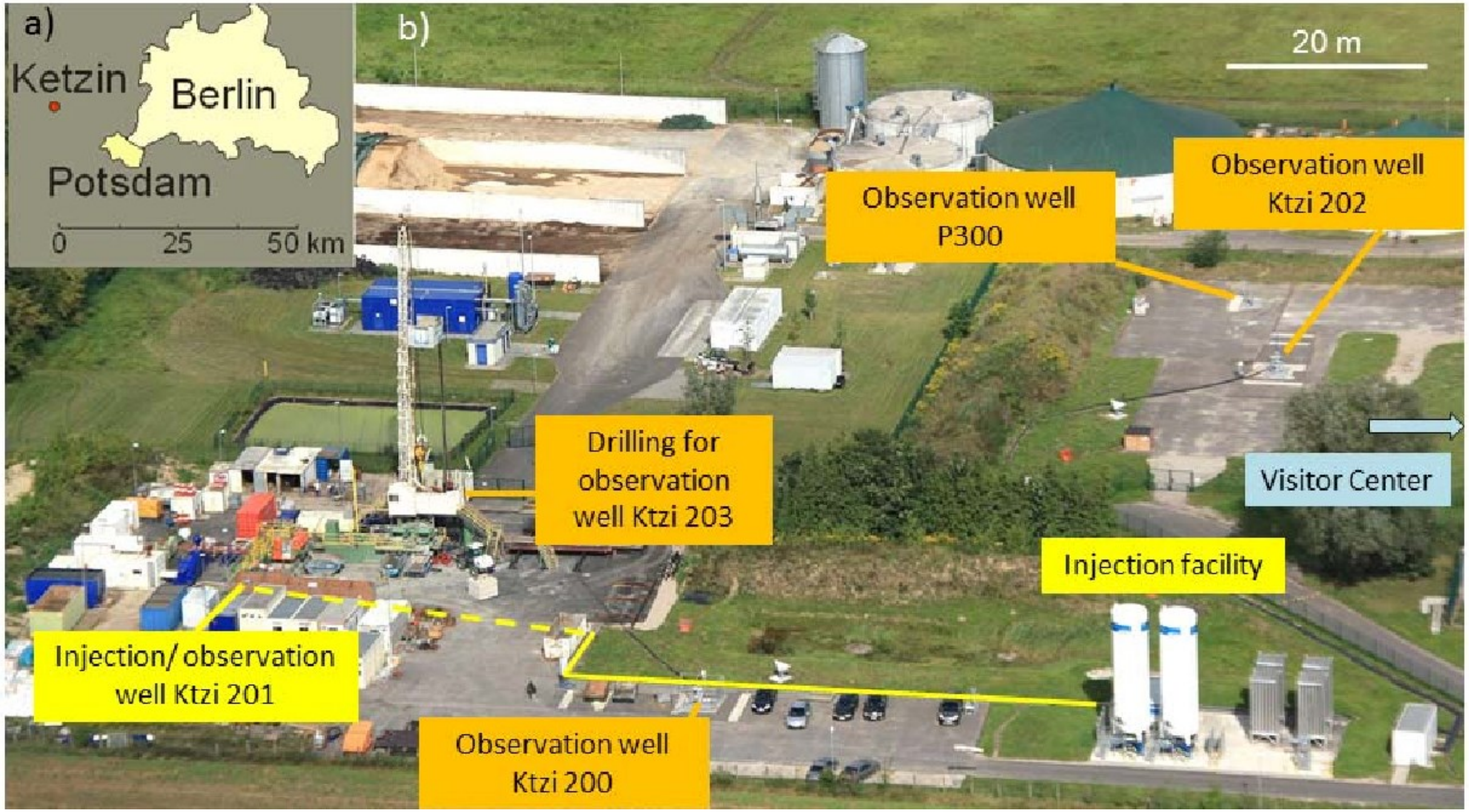
Conceptual techno–ecological schematic model of CCUS project with different green renewable energy recovery technologies in the structure E6 including synergy of (1) CGS, (2) GCS, (3) CO2-EOR/EOR+ in different geological formations in the same storage site and (4) solar energy and (5) wind energy recovery



The synergy concept of CCUS and different renewables energy recovery, including HYDROGEN storage in different compartments of E6 offshore Latvian structure.

Shogenov et. al., 2021, 2022.

Full value chain understanding, CCS hubs and clusters

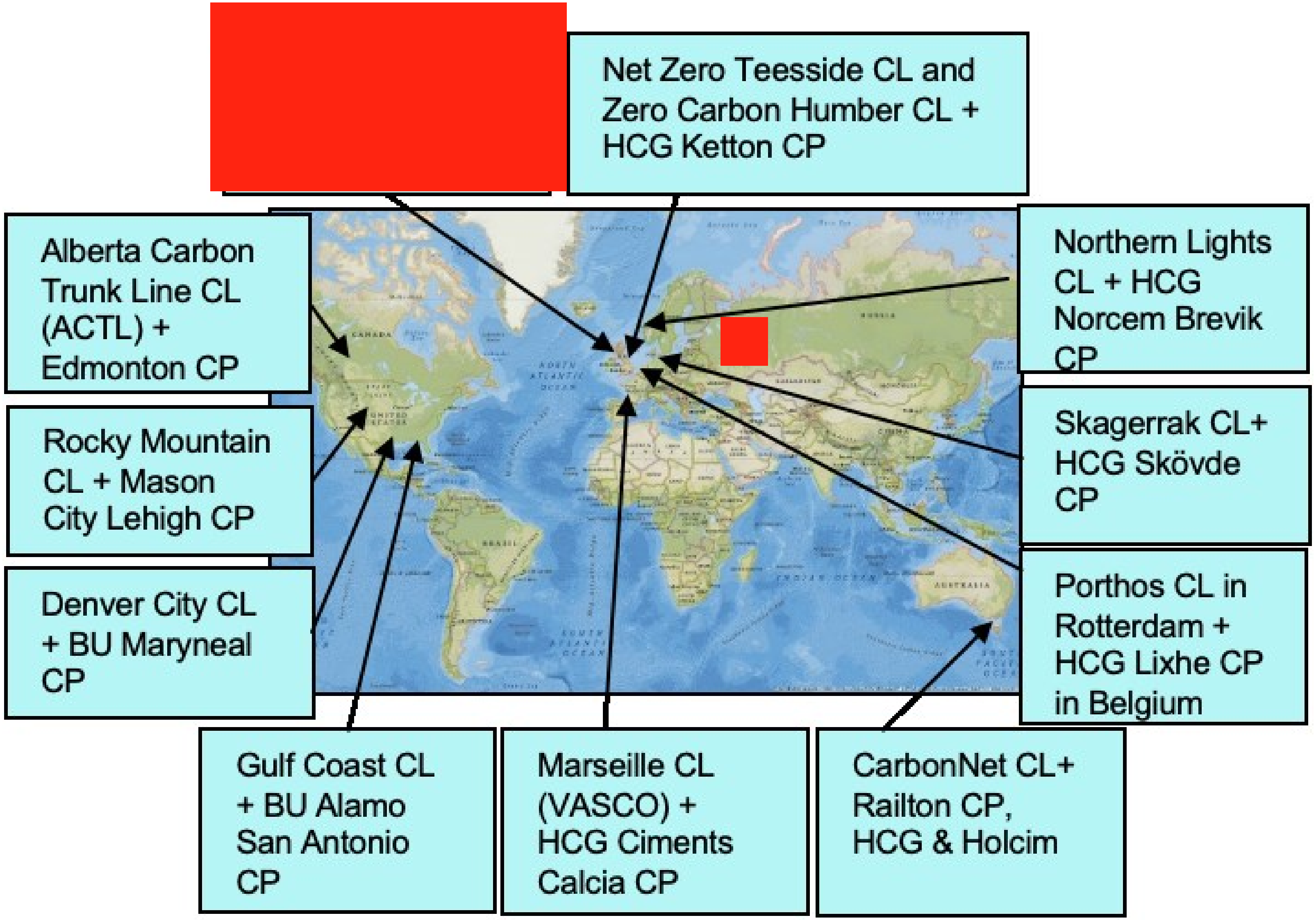


Ketzin pilot site (a) location; (b) aerial photograph with infrastructure and drilling for well Ktzi 203 (Martens, et. al., 2013)

- Germany: at the successful demo CO_2 injection project Ketzin. 30 km from this storage site was CO_2 capture pilot project Schwarze Pumpe.
- One project made the capture, and another made the injection. One bought CO_2 from outside for high prices and another free CO_2 to the atmosphere after the capture. They met each other only once at the mid of Ketzin and end of capture projects close to the end of the Schwarze Pumpe oxyfuel CO_2 capture pilot.
- Lessons learned: We lost time, since EU FP6 and FP7 programmes did not have calls for full chain CCUS projects.

CLEAN clinKER by calcium looping for low-CO_2 cement
CLEANKER

Full value chain understanding, CCS hubs and clusters



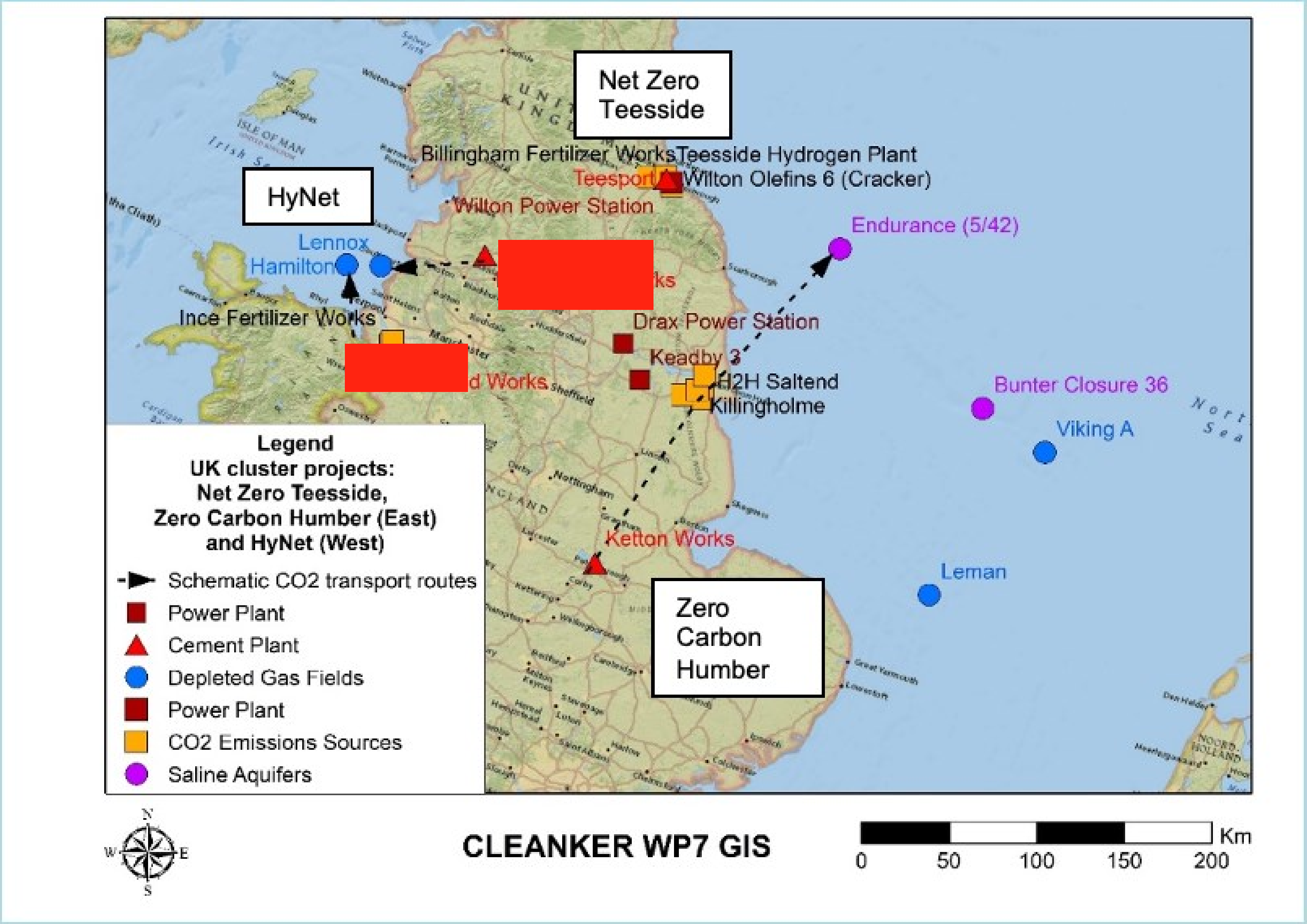
12 CCUS Cluster Projects (CL) with Cement Plants (CP) proposed

- Very important option for UNDERSTANDING OF FULL CHAIN CCUS is implementation of CCUS hubs and clusters.
- Our team have participated in the European Horizon 2020 project Cleanker, initiated by Heidelberg Cement company, the leader in Cement production in the world.
- Here you can see an example of the results. 12 CCUS projects from almost all over the world (USA, Canada, EUROPE, and Australia) with cement plants, as main CO2 emitters, were included in the hub.

Results and recommendations from this study was sent to HeidelbergCement Group in December 2020

Full value chain understanding, CCS hubs and clusters, and reusing of infrastructure

European Projects – UK cluster projects



Three CCUS cluster projects in the UK. HyNet North West cluster can integrate two CPs: Padeswood Works and Ribblesdale Works, Hanson UK.
Zero Carbon Humber can include HCG Ketton Works, Hanson UK CP with CO2 storage in Endurance SA (in cooperation with Teesside cluster).

- Part C
  CCUS clusters and hubs: Carbon Neutral Scenario for the Baltic States
  Conclusions and integration of the learned lessons

TAL TECH

BASRECCS

CCUS ZEN

SHOGENERGY
Consulting & Solutions for future energy sector
CCUS / H_2 / Energy storage / Geothermal energy recovery
SYNERGY CONCEPTS

CLEAN clinKER by calcium looping for low-CO_2 cement
CLEANKER

Nordic Energy Research

TAL TECH
DEPARTMENT OF GEOLOGY

CO_2 net

ENOS
Enabling Onshore CO_2 Storage

SCHWENK

MINIJOS NAFTA

Acknowledgement to CCUS ZEN Project:

CCUS ZEN

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