Tallinn, 22 October 2019

CLEAN clinKER by calcium looping for low-CO_2 cement

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Baltic CCUS Scenario for the Cement Industry

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Introduction

The EU Horizon 2020 project CLEANKER is aimed on Ca-looping capture of CO_2 emissions produced by cement industry

- **For the first time capture-focused EU project includes the full CCUS value chain study**
- **This study includes:**

➢ **techno-economic modelling of CO_2 transport, storage, and utilization scenarios**

➢ **CCUS regulatory issues**

➢ **definition of BUZZI and ITC-HCG cement plants suitable for first-of-a-kind CCS plant based on transport and storage opportunities**

➢ **mineral trapping of CO_2 from the demo system and testing the carbonated materials for reuse in concrete**

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Introduction

- The main objectives of the CLEANKER CCUS study is to explore local and regional transport, utilization and storage needs, options and solutions in the vicinity of the Vernasca cement plant in Italy, the Kunda cement plant in Estonia and Cesla cement plant in Russia (Slantsy town).
- Integration of the local and regional transport networks, infrastructure and synergy with other large CO_2 emission sources were planned by modelling of one local and one regional CCUS scenarios.
- One possible Estonian-Latvian transboundary CCUS scenario proposed for further development and modelling will be presented today.
- Italian local scenario, which can include CO_2 use for EOR and Geothermal Energy Recovery and storage in depleted oil fields and saline aquifers in Lombardy Region, will be developed also in the CLEANKER project.
- Such scenarios are the first step towards creation of national and regional CCUS networks and infrastructure involving cement plants operated by the end-users of the project.

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Development of common methodology for techno-economic modelling of CCUS scenarios*

- To collect data for techno-economic modelling data base structure was developed including Excel datasheets and using of **Geographic information System ArcGIS Pro, version 10.6,** permitting to create and working with spatial data on the desktop.
- MS Excel datasheets are used for easy database collection by project partners .
- All collected data to be integrated into ArcGIS platform as multi-layered maps supported by multiple parameters for every map location, and to be available online for projects partners when ready.

Datasheets are developed for several GIS layers:

- CO_2 emission sources
- CO_2 mineral carbonation experimental data
- Geological storage sites
- Enhanced hydrocarbon recovery site (EHR)
- Enhanced geothermal energy recovery site (CO2-GER)
- Cluster projects for exploitation study

** Shogenova A. and Shogenov K. Definition of a methodology for the development of a techno-economic study for CO_2 transport, storage and utilization. 2018. Deliverable D 7.1. of the Horizon 2020 CLEANKER project (No. 764816), 56 pp.*

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Development of common methodology for techno-economic modelling of CCUS scenarios*

Techno-economic modelling of CO_2 transport, storage, utilization scenarios including database collection

- Steps to be done :
- Select storage sites, optionally select additional CO2 emission sources to decrease transport and storage costs
- Fill datasets for CO2 emission sources, storage sites, CO2 use options (If any)
- Integrate data into the ArcGIS platform, including data for natural gas pipelines (transport routes)
- Compose geological models of the storage sites and estimate their storage capacity
- Calculate and select technical parameters for scenarios
- Estimate/calculate economic parameters of scenarios

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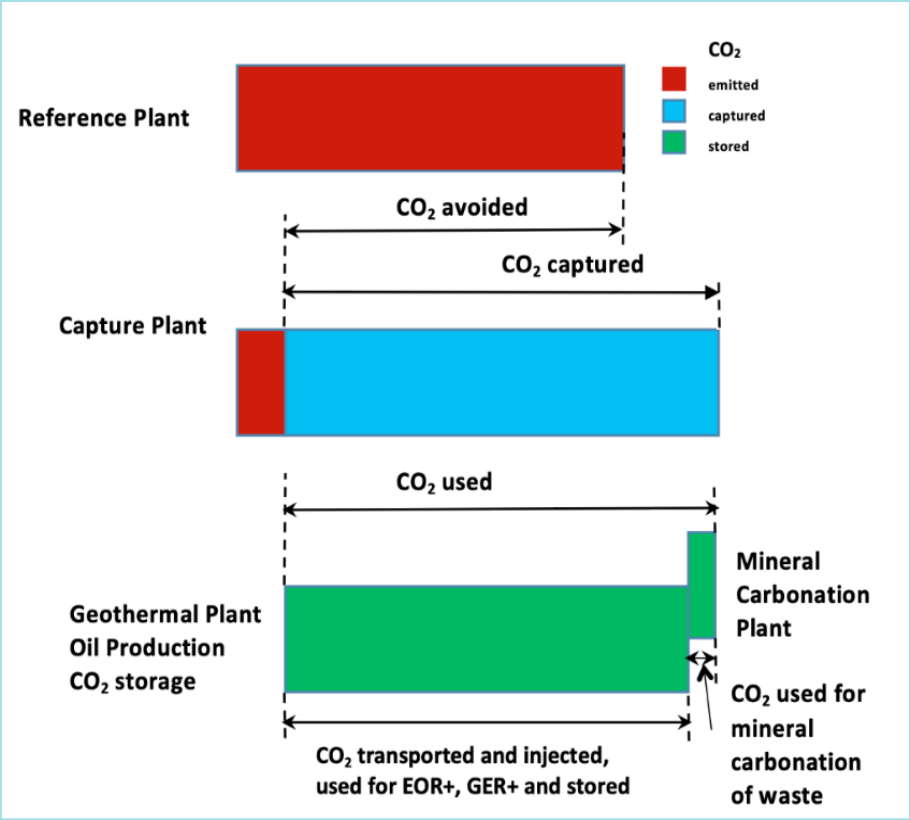
Development of common methodology for techno-economic modelling of CCUS scenarios*

- CO_2 captured is lower than CO_2 produced, while CO_2 avoided is lower than CO_2 captured.
- CO_2 used ex-situ for mineral carbonation (CO_2used_{MC}) should be calculated and excluded from CO_2 flow transported and injected.



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Development of common methodology for techno-economic modelling of CCUS scenarios

- The cost of CO_2 supplied for CO_2 use is assumed for simplicity according to the approach used in (IEA, 2015)*.
- The cost of CO_2 supplied (CO_2SP) is equal to the difference between CO_2 capture cost (NPVcapture) and the European Emission Allowance Price (EEAP) from EU ETS and National Carbon Tax (NCT) for CO_2 emissions already set up in some EU countries.
- $$CO_2SP = NPVcapture - EEAP - NCT$$
- A positive CO_2SP indicates that it costs more to capture CO_2 than to pay for the emissions allowance through EU ETS and paying NCT. In this case the CO_2 emitter would sell CO_2 to the operator of CO_2 use activity, as is commonly the case today for CO_2-EOR.
- A negative CO_2SP means that the CO_2 emission allowance price together with NCT are higher than the cost to capture CO_2. This creates incentive for the CO_2 emitter to pay for the CO_2 to be verifiably stored.
- Economic parameters and equations were developed for CO_2 use processes including CO_2 mineral carbonation process and CO_2 use for geothermal energy recovery.
- Economic modelling of scenarios includes CO_2 transport, injection, monitoring and verification costs.
- Methodology includes equations for calculation of capital, operation and monitoring costs.

**IEA, 2015. Storing CO2 through Enhanced Oil Recovery, 48 pp.*

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Development of common methodology for techno-economic modelling of CCUS scenarios”

Table 1. Shared and specific costs and revenues of CO_2 use options

	Ex-situ Mineral Carbonation/MC	CO_2-EOR	CO_2-GER
COSTS			
CO_2 capture & compression	Should be added to the cost of the carbonated product	Shared cost for CCUS storage project	
CO_2 transport (pipelines and boosters)	Not needed at the Cement capture plant/ short distance to MC plant	Shared cost for CCUS storage project (from medium to long distance)	
Capital	Mineral Carbonation Reactor/ Mineral Carbonation Plant	Shared with CCUS storage project injection well and injection facility	
		Additional oil recovery wells	Additional energy recovery wells
		Oil-gas-brine separation CO_2 separation and cleaning	CO_2 small-scale geothermal plant CO_2 -brine separation
		Shared CO_2 recycling and compression unit and brine reinjection well	
Operation	Fixed operation costs (2% of CAPEX)	Fixed operation costs (4% of CAPEX)	Fixed operation costs (4% of CAPEX)
	Transport of waste material could be needed (from short to medium distance)	On-site operation cost	On-site operation cost
Storage site monitoring	Not needed	Shared cost for storage project	Not needed
Monitoring in wells		Shared cost for CCUS storage project	
REVENUES			
Specific	Carbonated product National waste tax (OST)	Recovered Oil	Recovered energy and heat
Common	CO_2 allowance price in EU ETS (EEAP)		
Common	National Carbon Tax*		

”Shogenova A. and Shogenov K. Definition of a methodology for the development of a techno-economic study for CO_2 transport, storage and utilization. 2018. Deliverable D 7.1. of the Horizon 2020 CLEANKER project (No. 764816), 56 pp.

*In Estonia only from CO2 from heat production

*In Latvia National Carbon Tax is not overlapping with EEAP

*Not yet introduced in Italy, Lithuania and Russia

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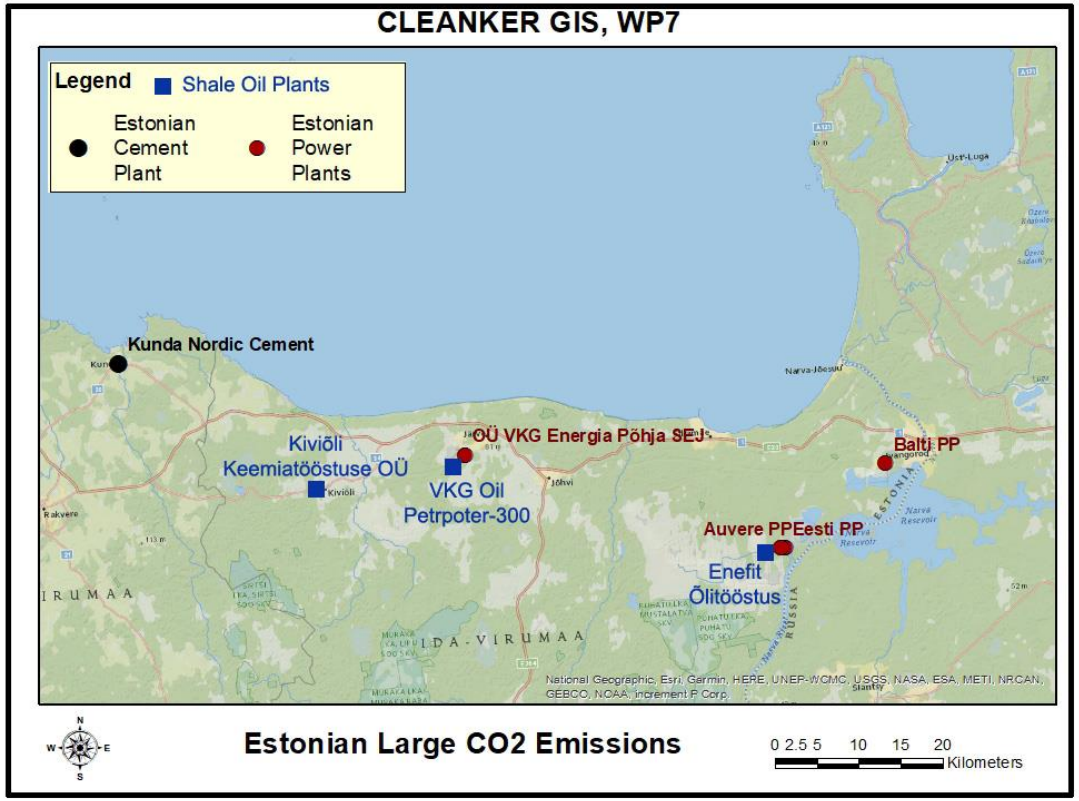
Large industrial CO_2 emissions in Estonia



Name of the Plant	Company owner/owners	CO_2 total emissions (Mt/yr)			
		2016	2017	2018	Average
Eesti Power Plant	Eesti Energia	7.94	8.357	7.759	8.019
Auvere Power Plant	Eesti Energia	1.63	1.360	1.519	1.503
Balti Power Plant	Eesti Energia	1.05	1.603	1.125	1.259
Enefit Õlitööstus (shale oil production)	Eesti Energia	0.65	0.815	0.838	0.767
VKG Oil Petrpoter-300 (shale oil production)	VKG Oil, Viru Keemia Grupp	0.57	0.594	0.667	0.610
OÜ VKG Energia Põhja SEJ (Thermal Power Plant)	OÜ VKG Energia	0.45	0.600	0.589	0.546
Kunda Nordic Cement	Heidelberg Cement Group	0.33	0.560	0.548	0.479
Kiviõli Keemiatööstuse OÜ (shale oil production)	Alexela Group	0.15	0.146	0.147	0.148
	Total for Estonia	**12.76**	**14.033**	**13.191**	**13.332**

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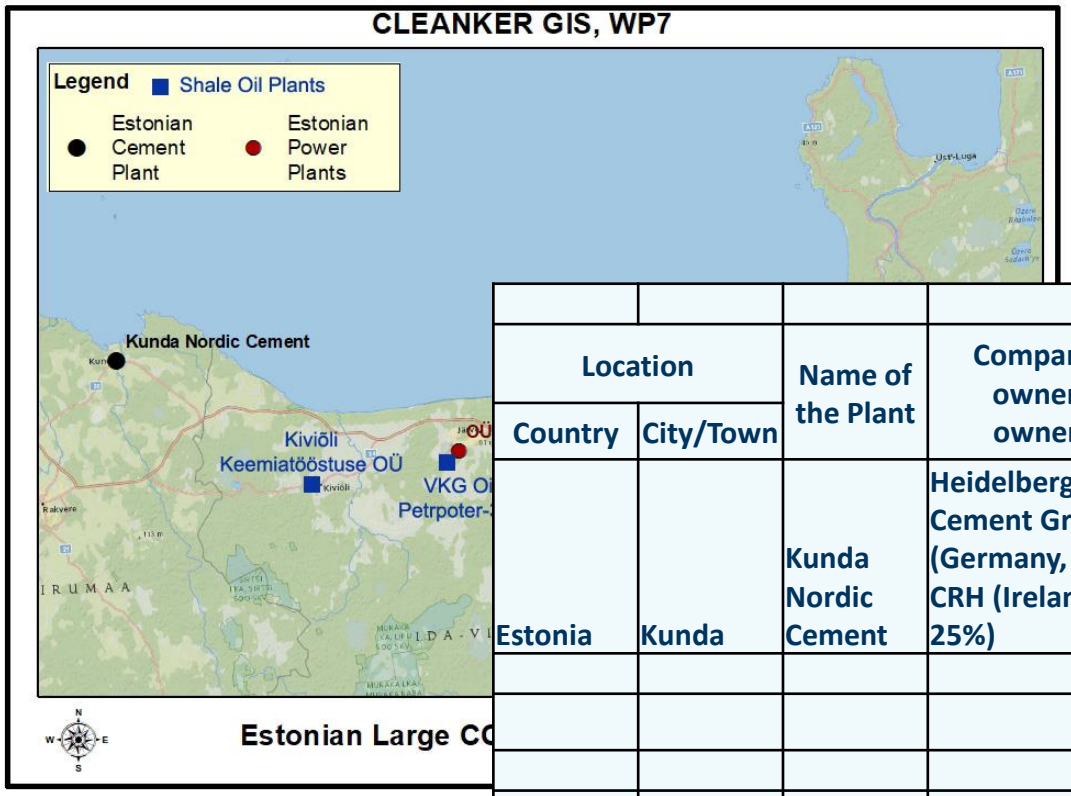
Kunda Nordic Cement Plant - Estonia



							Production					
Location		Name of the Plant	Company/ owner/ owners	CO_2 total emissions (Kt/yr)			Clinker (Kt)			Cement (Kt)		
Country	City/Town			2017	2018	Average	2017	2018	Average	2017	2018	Average
Estonia	Kunda	Kunda Nordic Cement	Heidelberg Cement Group (Germany, 75%); CRH (Ireland, 25%)	559,629	547,647	553,638	517,916	505,349	511,633	502,920	526,920	514,920
				Raw material used				Consumption				
				Limestone (Kt)		Other materials (kt)		Type of fuel	Fuel (t)			
				2017	2018	2017	2018		2017	2018	Average	
				770,900	763,069	141,000	85,550	oil shale	97,350	106,338	101,844	
								coal	32,883	44,068	38,476	
								Remarks				
								Tsemendiwabrik, Kevad 2018, https://www.knc.ee/et/node/12370				
								Tsemendiwabrik, Kevad 2019, https://www.knc.ee/et/node/12370				

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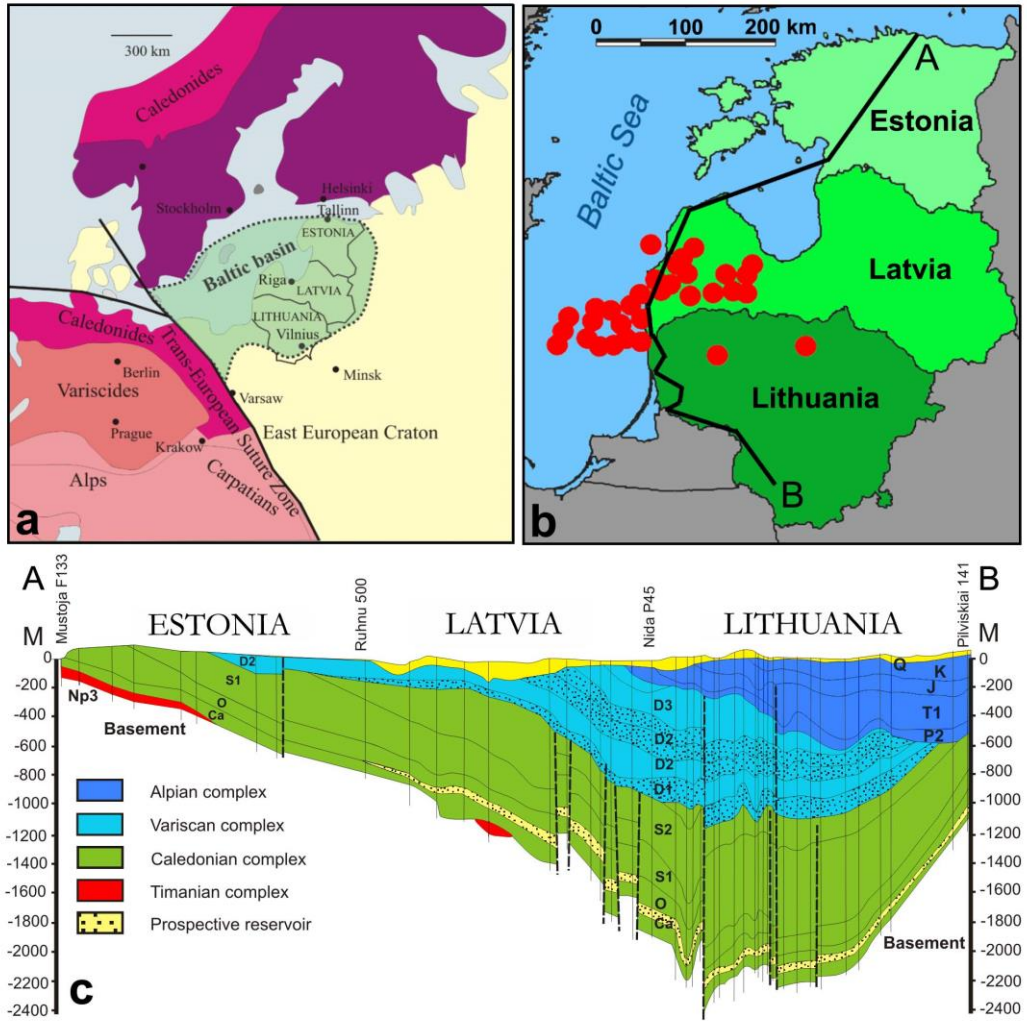
CO_2 storage capacity in the Baltic Basin



Physical parameters of the Latvian structural traps (Shogenova, et al., 2009a)

Structure	Depth, m	Thickness, m	Area, km^2	CO_2 storage capacity, Mt
Aizpute	1096	65	51	14
Blidene	1050	66	43	58
Degole	1015	52	41	21
Dobele	950	52	67	56
Edole	945	71	19	7
Kalvene	1063	45	19	14
Liepaja	1072	62	40	6
Luku-Duku	937	45	50	40
N. Kuldiga	925	69	18	13
N. Ligatne	750	50	30	23
N. Blidene	920	40	95	74
S.Kandava	983	25-30	69	44
Snepele	970	30	26	17
Usma	975	50	20	2
Vergale	981	65	10	5
Viesatu	1020	50	19	10
Total				404

Figure 1. (a) Structure map of the Baltic Basin. (b) Approximate location of onshore and offshore Latvian and Lithuanian structures in the Cambrian aquifer prospective for CGS (CO_2 storage potential exceeding 2 Mt), shown by red circles. The black line A–B represents the geological cross section shown in Fig. 1c. (c) Geological cross section across Estonia, Latvia and Lithuania. The cross section line A–B is shown in Fig. 1b. Major aquifers are indicated by dots. Dotted vertical lines mark faults. Np3 – Ediacaran; Ca – Cambrian; O – Ordovician; S1 – Lower Silurian (Llandovery and Wenlock series); S2 – Upper Silurian (Ludlow and Pridoli series); D1, D2 and D3 – Lower, Middle and Upper Devonian, respectively; P2 – Middle Permian; T1 – Lower Triassic; J – Jurassic; K – Cretaceous; Q – Quaternary (updated after Shogenov et. al, 2013).

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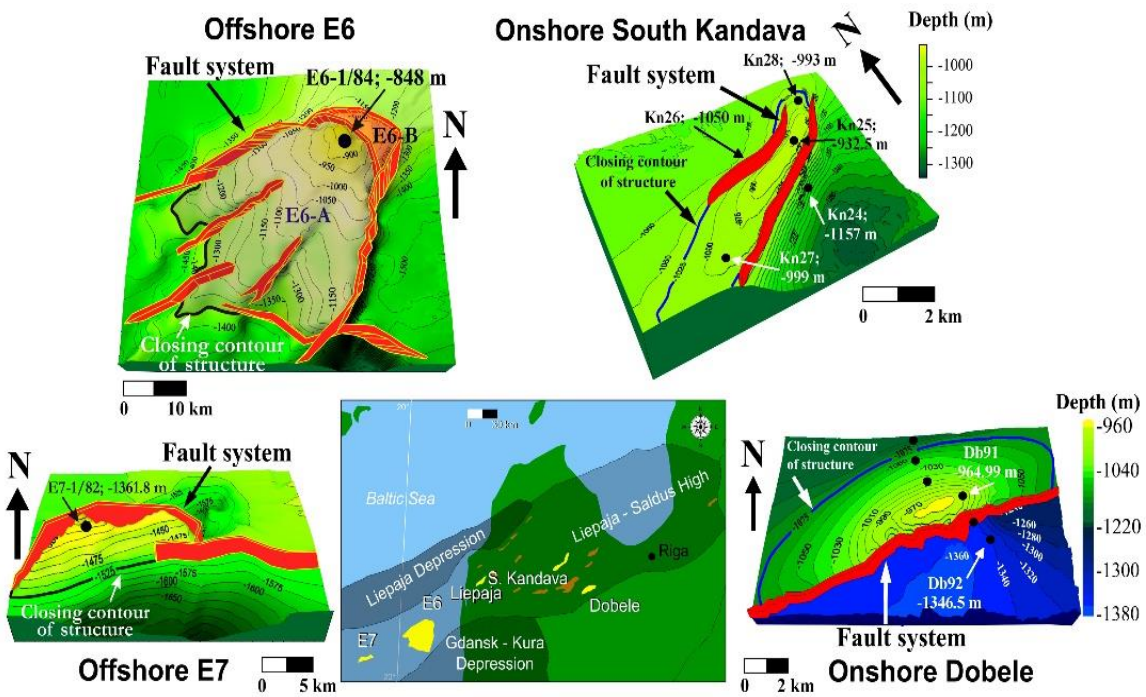
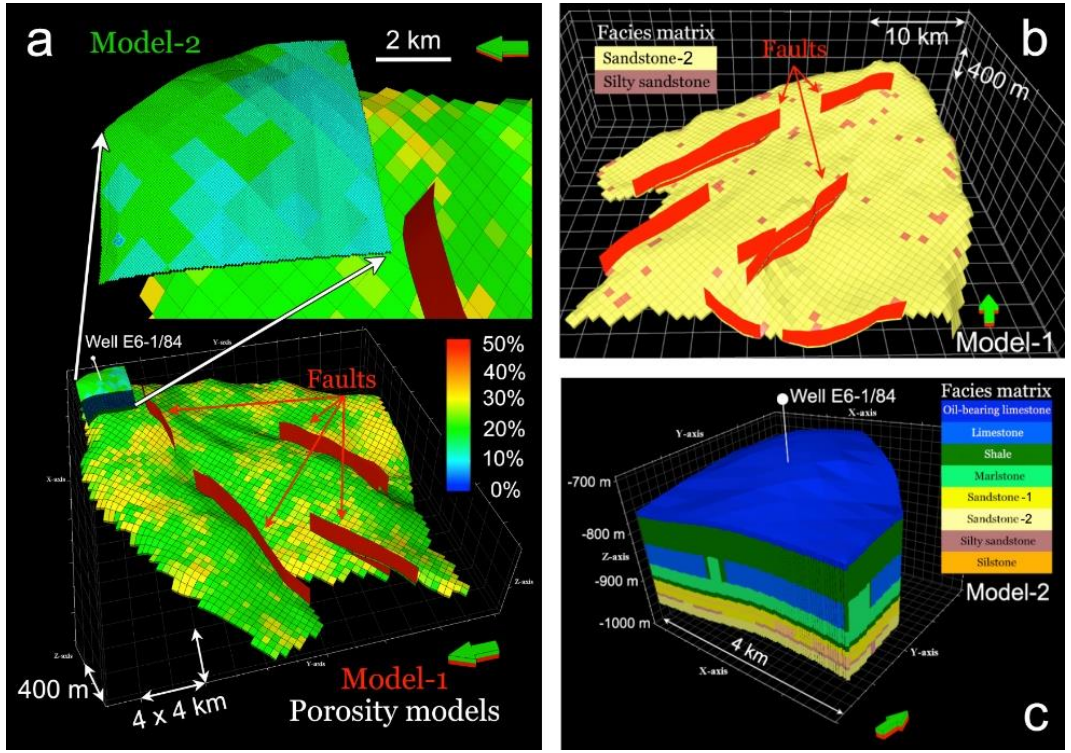
CO_2 storage capacity in the Baltic Basin



Some prospective recently studied structures (Shogenov & Shogenova et al, 2013, a, b, 2015)



3-D geological and petrophysical static models of E6 structure offshore Latvia (Shogenov et al, 2017).

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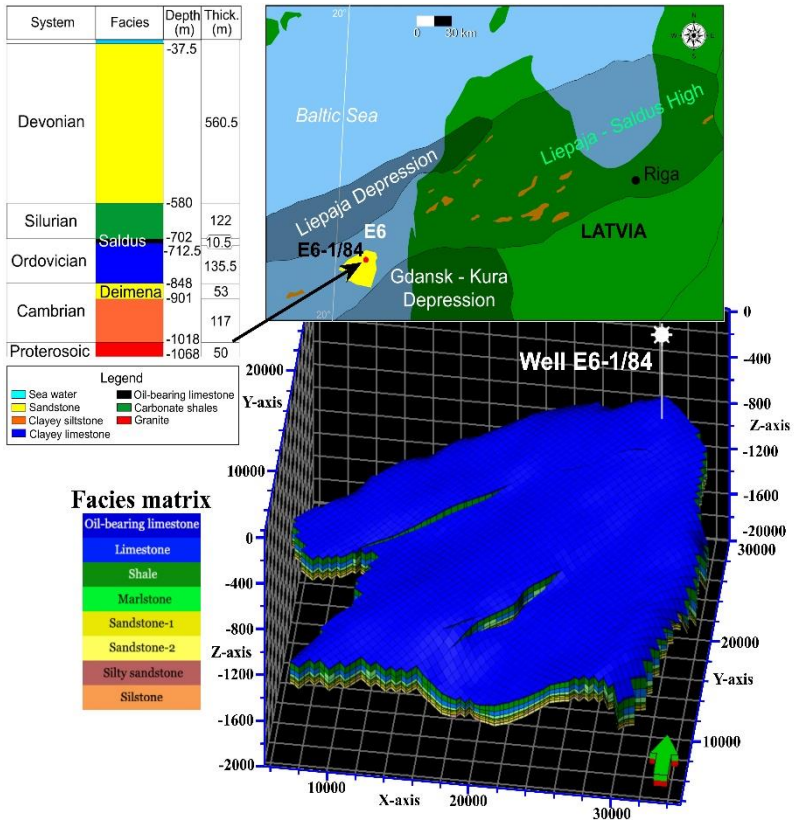
CO_2 storage capacity in the Baltic Basin – offshore E6 structure



- For the first time, we estimated theoretical storage capacity of the **Upper Ordovician Saldus Formation** with different levels of reliability at the end of CO_2-EOR cycle:
- 65–144 Mt, average: 110 Mt
- Total capacity of the E6 structure in two different formations
- **(Saldus and Deimena**) at the end of CO_2-EOR cycle;
- by optimistic: **320–745 Mt,** average: **490 Mt**
- and conservative approaches: **170–385 Mt,** average: **265 Mt**
- (Shogenov & Shogenova, 2017)

Country	CO_2 storage capacity reported (Mt)			Reference
	Onshore	Offshore	EOR (onshore + offshore)	
Latvia	400	300	-	Šliaupa, et al., 2013
Latvia, E6 structure		370	110 offshore	Shogenov & Shogenova, 2017
Lithuania	29	0	5.7 /100 onshore	Šliaupa, et al., 2013; CGS Baltic seed project (S81), 2017
Sweden	0	145	-	Sopher, et al., 2014
The Russian Federation (Kaliningrad)	-	-	33	Šliaupa, et al., 2013

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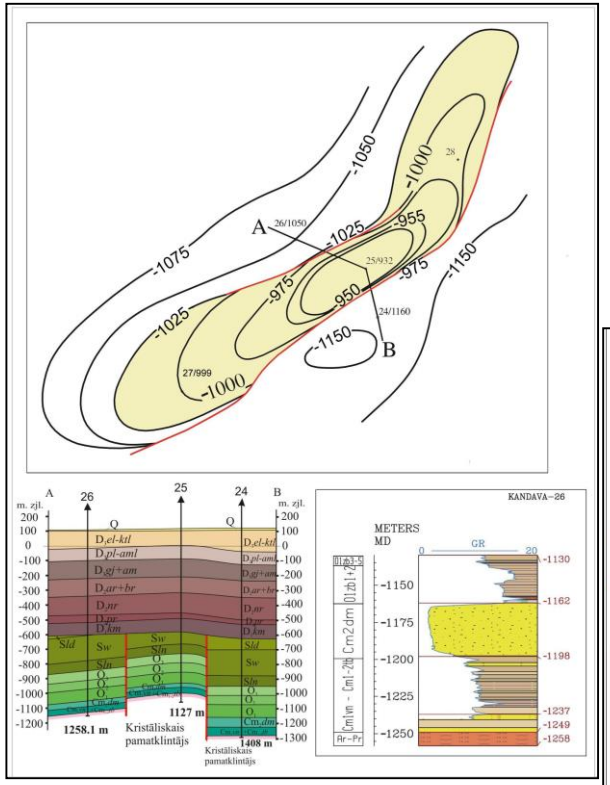
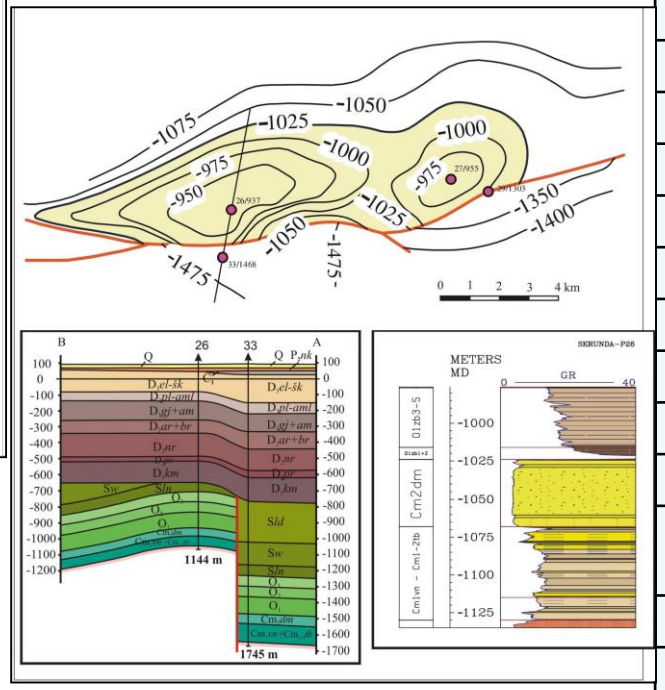
State of the art: **Economic modelling of the capture–transport–sink scenario of industrial CO2 emissions: the Estonian–Latvian cross-border case study, 2011**





Summary of the input parameters for storage in the GeoCapacity Model

Sink Name	Luku-Duku	South Kandava
Sink type	aquifer	aquifer
Depth (m) (from the earth surface)	1024	1053
Current reservoir pressure (bar)	93.7	98.3
Maximum reservoir pressure (bar)	107.8	113
Reservoir radius (km)	8	5
Trap radius (km)	8	5
Reservoir thickness (m)	45	28
Porosity (%)	22	20
Connate water fraction	0.25	0.25
Net to gross ratio	0.8	0.8
Reservoir temperature (°C)	19	11
Permeability (mD)	300	300
Well radius (m)	0.15	0.15
Storage capacity ($MtCO_2$)	40.2	44
Well injection rate (Mt/yr)	2	2
Storage efficiency factor in trap (%)	40	40
Number of wells	3	4
CO_2 concentration	20	20

Source: Shogenova, A., Shogenov, K., Pomeranceva, R., Nulle, I., Neele, F. and Hendriks, C. 2011. Economic modelling of the capture–transport–sink scenario of industrial CO2 emissions: the Estonian–Latvian cross-border case study. Elsevier, The Netherlands. *Energy Procedia* **4**, 2385-2392. | DOI |

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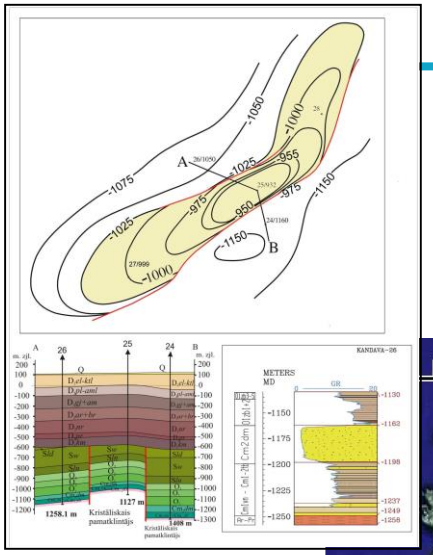

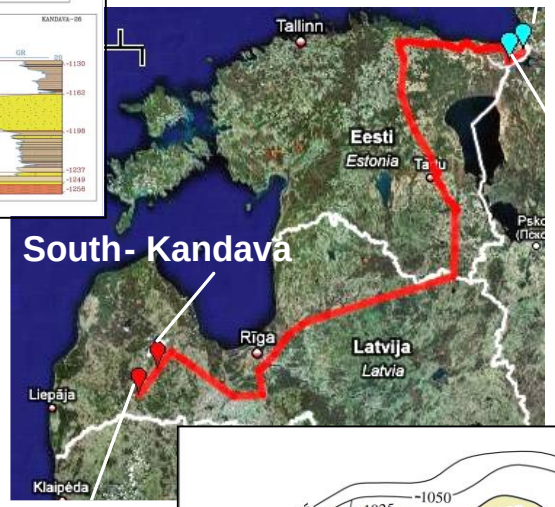

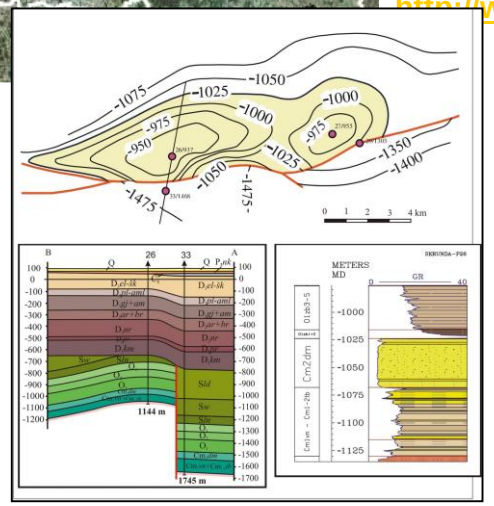

http://www.powerplant.ee/

Summary of the output parameters for Estonian–Latvian cross-border case study

(NPV is a net present value, SRC NPV is a net present value for capture costs).

NPV	2835	€ million	NPV storage normalised	3.0	€/tCO_2injected
NPV capture	1928	€ million	Unit technical cost	37.4	€/tCO_2avoided
NPV compression	210	€ million	Pay out time	30	Yr
NPV transport	447	€ million	SRC NPV capture 0	1103	€ million
NPV storage	250	€ million	SRC NPV compression 0	162	€ million
NPV normalised	37.4	€/tCO_2avoided	SRC NPV capture 1	825	€ million
NPV capture normalised	25.5	€/tCO_2avoided	SRC NPV compression 1	48	€ million
NPV compression normalised	2.8	€/tCO_2avoided	SINK NPV storage 0	129	€ million
NPV transport normalised	5.3	€/tCO_2injected	SINK NPV storage 1	121	€ million

Reference

Shogenova, A., Shogenov, K., Pomeranceva, R., Nulle, I., Neele, F. and Hendriks, C. 2011. Economic modelling of the capture–transport–sink scenario of industrial CO2 emissions: the Estonian–Latvian cross-border case study. Elsevier, The Netherlands. *Energy Procedia* 4, 2385-2392. | DOI |

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Summary of results of 2011 economic modelling

- Two power plants close to the city of Narva, with annual CO_2 emissions of 8.0 and 2.7 Mt were chosen for the economic modelling of the capture–transport–sink scenario using the GeoCapacity Decision Support System (DSS) based on the GeoCapacity GIS database.
- Two anticlinal structures of Latvia, Luku-Duku and South Kandava with the area of 50–70 km^2 were selected for the CO_2 storage. The depth of the top of the Cambrian reservoir is 1020–1050 m, the thickness 28–45 m; permeability of sandstone is more than 300 mD, and the trap storage efficiency factor 40%.
- The conservative storage capacity of these structures 40 and 44 Mt of CO_2 respectively will be enough for 8 years. The estimated pipeline length required for CO_2 transportation is about 800 km.
- The oxyfuel capture technology is applied in this scenario. With a conservative storage capacity for 8 years of emissions, avoidance costs are rated at €37.4 per tonne of CO_2.
- The total cost of the project estimated by the Decision Support System using the GeoCapacity GIS is about €2.8 billion for 30 years of payment period.

Reference

Shogenova, A., Shogenov, K., Pomeranceva, R., Nulle, I., Neele, F. and Hendriks, C. 2011. Economic modelling of the capture–transport–sink scenario of industrial CO2 emissions: the Estonian–Latvian cross-border case study. Elsevier, The Netherlands. *Energy Procedia* 4, 2385-2392. | DOI |

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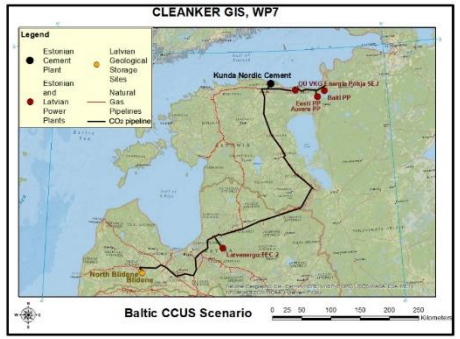
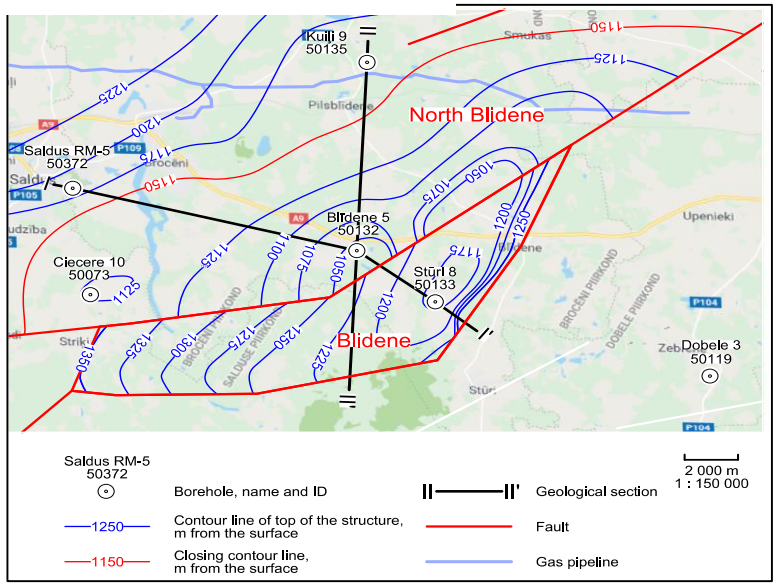
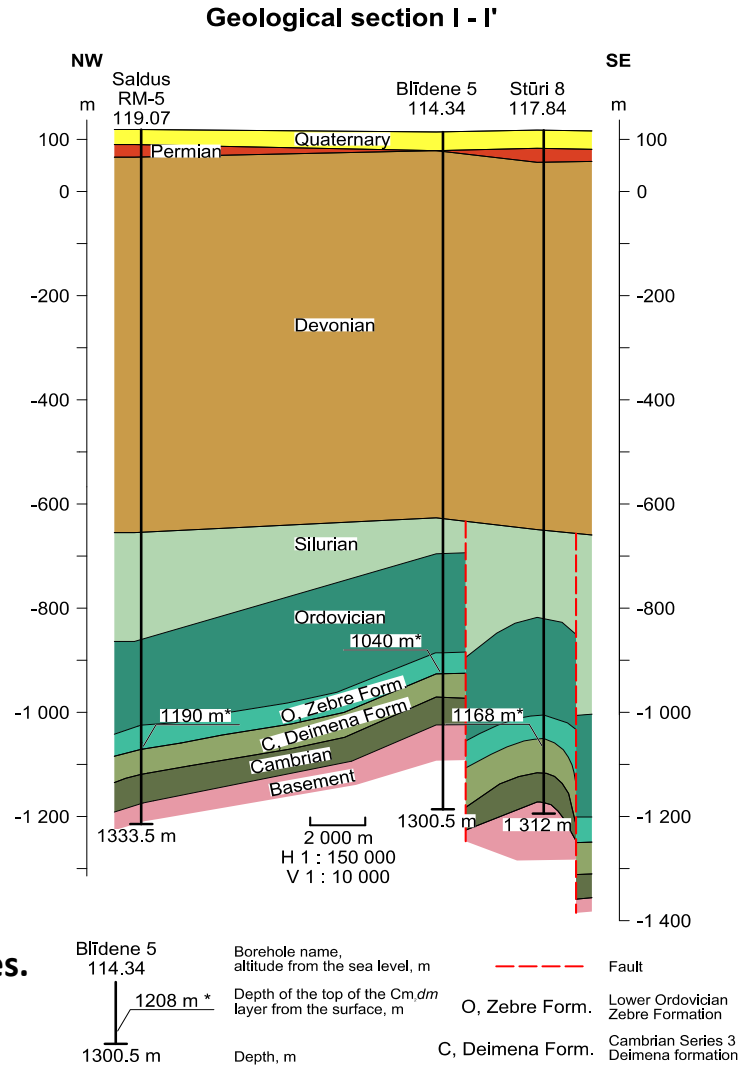
Baltic CCUS Scenario for the Cement Industry: **North Blidene and Blidene structures**

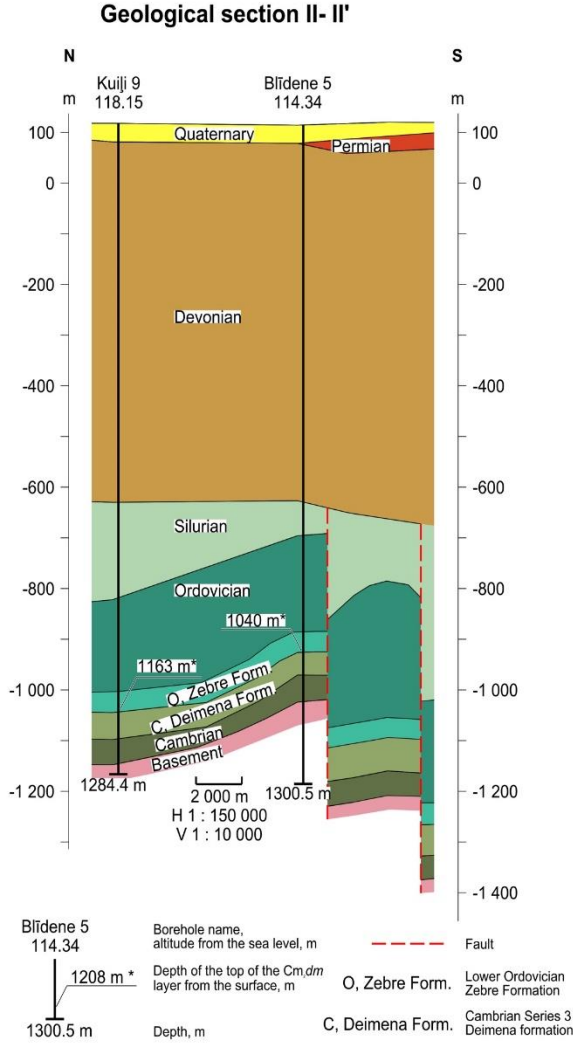




Structure map of the North Blidene and the Blidene structures. Lines of geological cross sections are shown.

The map and geological sections are composed using Bentley PowerCivil for Baltics V8i (SELECTseries 2) software. Base map is from the Google Maps, 2018. (Simmer K., 2018).





Two geological sections) were composed using available borehole and seismic interpretation data. The borehole data from (Popovs, 2015) were used to compose nine layers of geological sections. **(Simmer K., 2018).**

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Baltic CCUS Scenario for the Cement Industry: **North Blidene and Blidene structures**

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Studied parameters of the North Blidene and Blidene structures (Šliaupa, et al., 2008; Vangkilde-Pedersen, et al., 2009a; Shogenova, et al., 2009a)

Structure	North Blidene	Blidene
Reservoir parameters		
Trap area, km^2	95	43
Depth of the top, m	1 070 - 1 170	1 170 - 1 270
Thickness, m	45 - 53	66
Effective thickness, m	37 - 41	60
Porosity, %	21	20
Permeability, mD	370 - 400	860
Mineralization of groundwater, g/l	100 - 114	
Well yield, m^3/day	100	
Hydrostatic reservoir pressure, atm	100 - 115	
Water temperature, °C	18 - 20	
Density of the rocks, kg/m^3	2 300	
CO_2 density, kg/m^3	750	
Storage efficiency, %	35 - 40	
Chemical composition		
SiO_2, %	89.3	
Al_2O_3, %	3.6	
CaO, %	0.6	
CO_2 storage capacity		
Conservative estimates, Mt	74	58

Studied parameters of the North Blidene and Blidene structures (Simmer K., 2018, Shogenova et al, 2019)

Structure	North Blidene	Blidene
Depth of reservoir top, m	1035-1150	1168-1357
Reservoir thickness, m	48	66
Trap area, km^2	141	62
CO_2 density, kg/m^3	881	866
Net to gross ratio, %	75	80
Salinity, g/l	100-114	100-114
T, ºC	18	22.9
Storage efficiency factor (S_{eff}) Optimistic/Conservative (%)	30/4	5/3
Porosity (min-max/avg), %	12.5-25.6/20	13.5-26.6/21
Optimistic CO_2 storage capacity (min-max/avg), Mt	167-342/267	19-37.5/29.6
Conservative CO_2 storage capacity (min-max/avg), Mt	22.2-45.5/35.6	11.4-22.5/17.8

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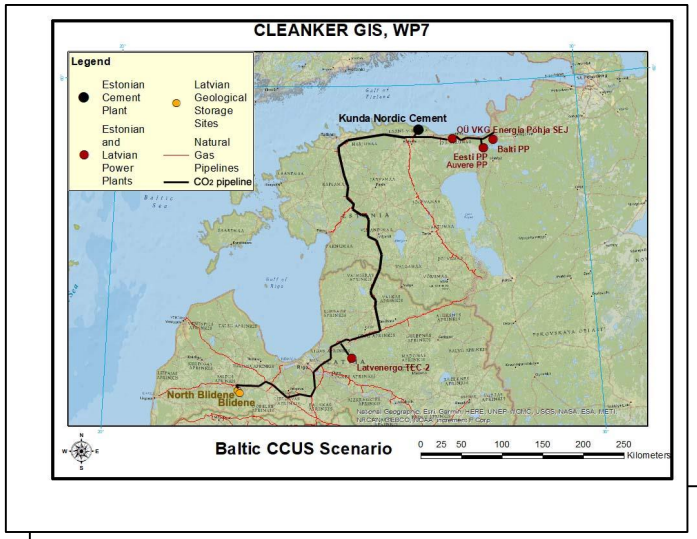
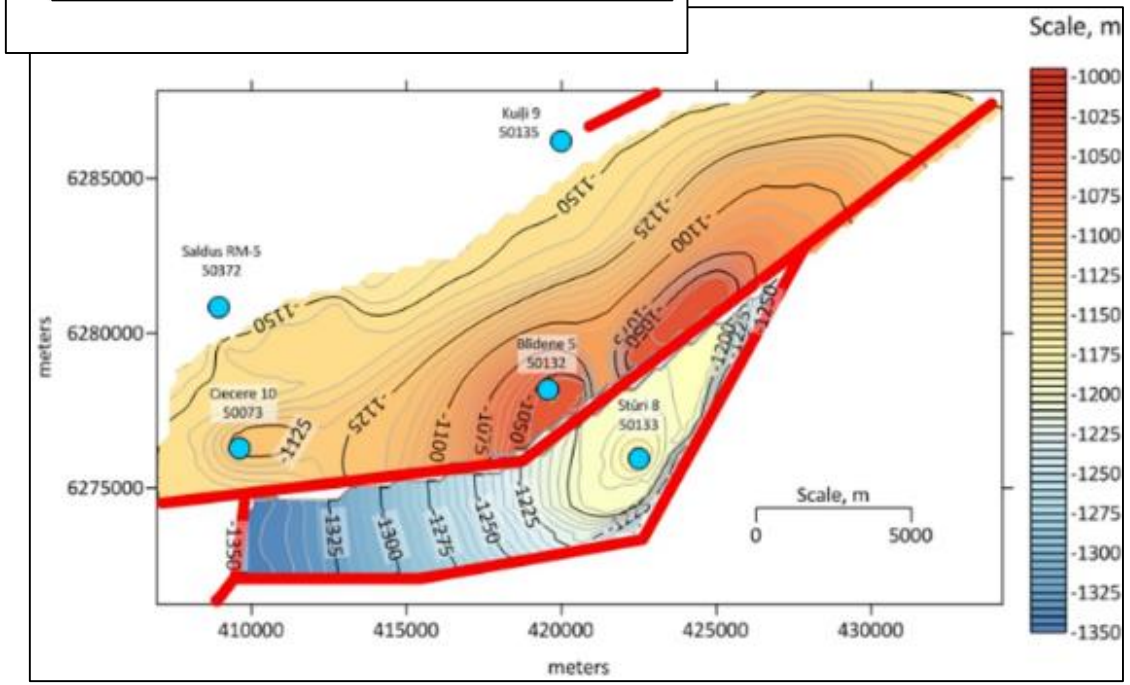
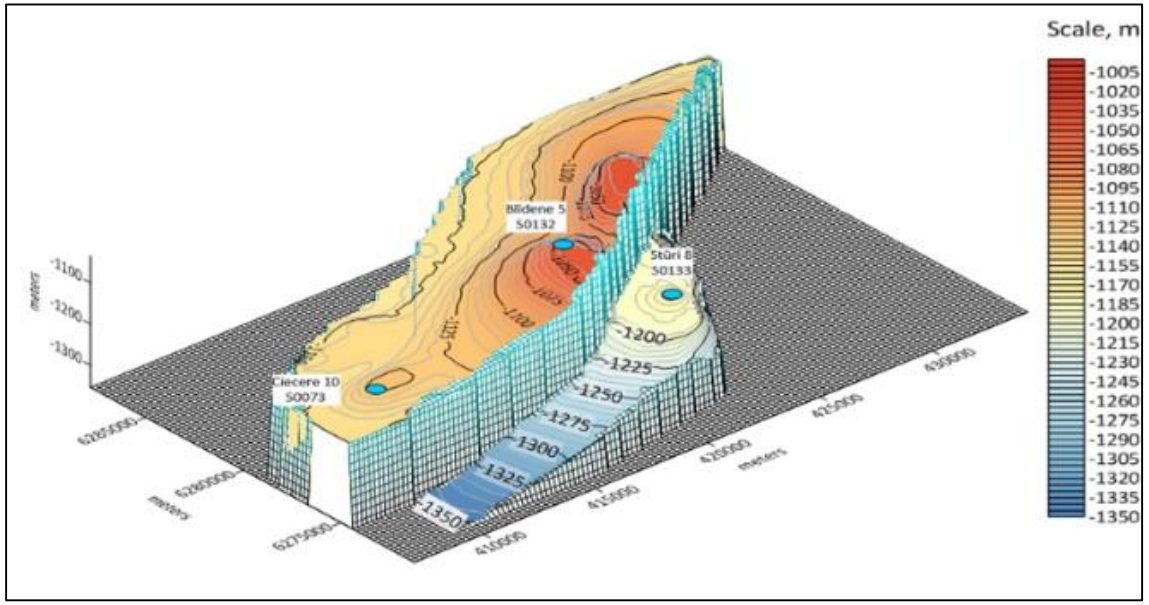
North Blidene and Blidene structures



- **The North Blidene and Blidene structures, the largest prospective for CO_2 storage structures located in the western Latvia, were chosen for the Estonian-Latvian onshore CCUS scenario.**
- **In the present study new contour and 3D structure maps were composed and CO_2 storage capacity of the Blidene and the North Blidene structures were calculated using improved estimations of all needed parameters.**





(a) Contour maps and (b) 3D structure maps of the Deimena Formation in the North Blidene (above) and the Blidene (below) structures composed using Golden Software Surfer 15 software. Fault line is indicated with red polyline. (Simmer, 2018; Shogenova et al, 2019)

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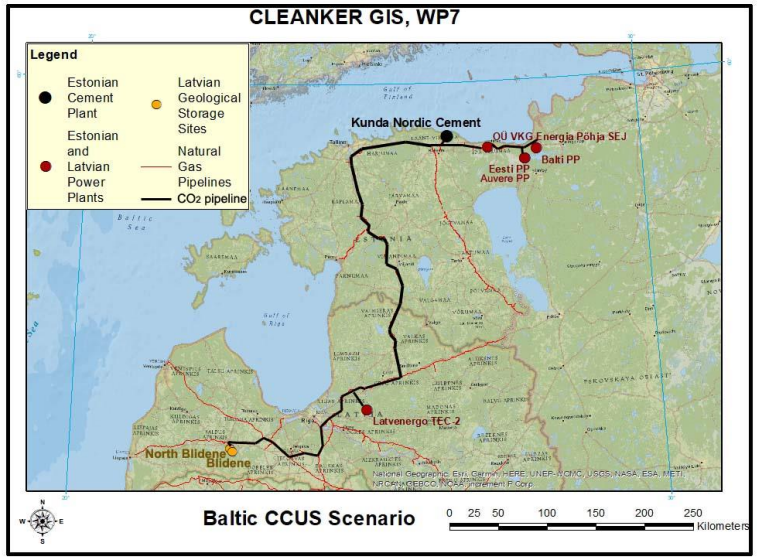
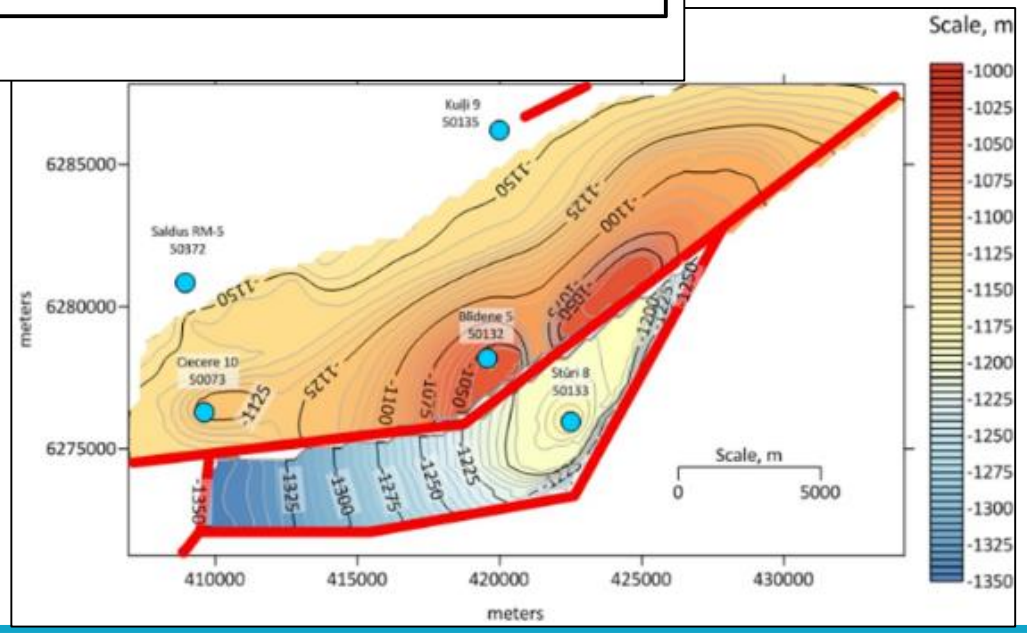
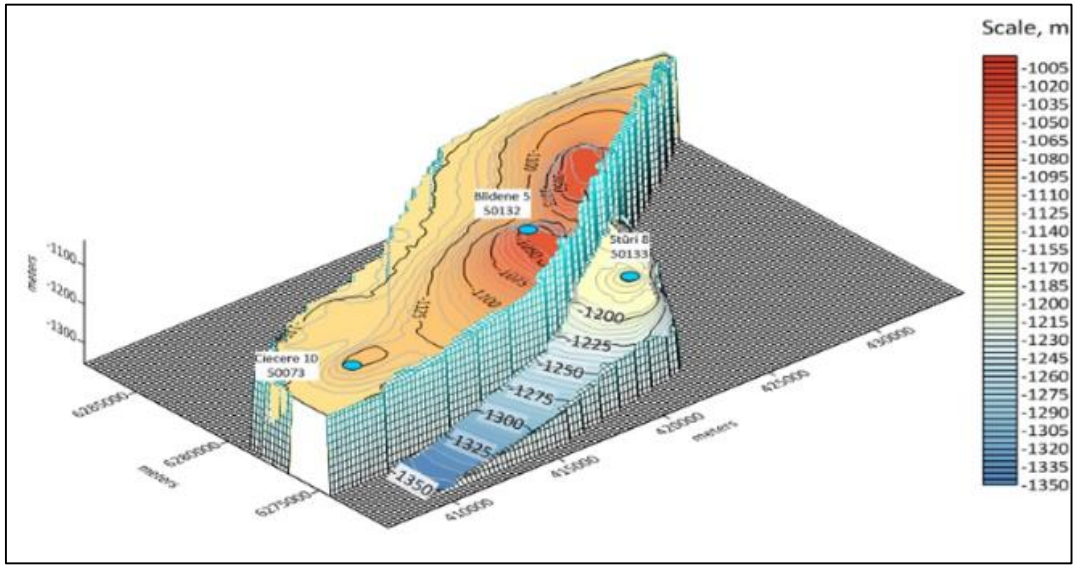
North Blidene and Blidene structures



- The total optimistic capacity (min-max/mean) is 186-380/297 Mt.
- The conservative capacity was estimated as 33.6-68.0/53.4 Mt.
- The average optimistic capacity is more than two times higher than the capacity estimated in the previous reports (132 Mt), explained by a larger estimated area and a higher CO_2 density in this study.
- The average conservative capacity in this study is lower by 2.5 times, explained by the lower storage efficiency applied.





(a) Contour maps and (b) 3D structure maps of the Deimena Formation in the North Blidene (above) and the Blidene (below) structures composed using Golden Software Surfer 15 software. Fault line is indicated with red polyline. (Simmer, 2018; Shogenova et al, 2019)

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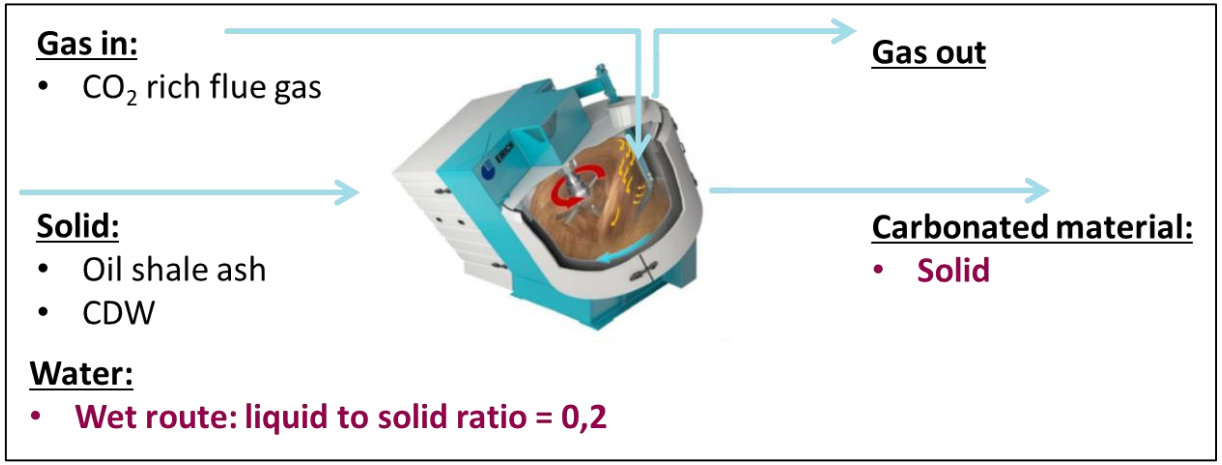
CO_2 use option for the Baltic CCUS Scenario

Mineral Carbonation of waste material

- **Estonian burnt oil shale (oil shale ash) could be used as an effective sorbent in the proposed CO_2-mineralization process, binding up to 0.18 kg CO_2 per kg of waste.**



Experimental setup: The experiments were carried out in a semi-batch Eirich EL1 type intensive mixer (Fig. 1). The wastes were treated under different operating regimes (by varying rotation speed from 300 to 3000 rpm, CO_2 content in model gas from 20 to 70%, gas flow from 30 to 400 L/h and the mass of initial sample from 150 to 600 g). The CO_2 content in gas phase was detected by Doutec infrared analyzer and the carbonated samples were dried in thermostat for 3h at 105°C and analyzed for TC and free lime content as the main indicators for the carbonation process (Shogenova et al, 2019).

Location of the studied Estonian samples

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CO_2 use option for the Baltic CCUS Scenario

CO_2 mineral Carbonation of waste material : studied samples from NE Estonia

			Annual production of waste (kilotonnes)			Annually used/sold at the market (tonnes)			Average market price per Eur/kg	Number of studied samples	Reaction T (C°)	Reaction P (MPa)	Amount of CO_2 bound per kg of material (kg)			Mineral carbonation product	Amount of the product per kg of material (waste) bound (kg)
			2016	2017	Average	2016	2017	Average					Min	Max	Average		
Eesti PP	Waste	Electrostatic precipitator ash				128257.0	147256.0	137756.5	0.006	1	25.00	0.10133			**0.0713**	calcite	0.162
Eesti PP	Waste	Total ash	4321997	4440412	4381205				0.006	1	25.00	0.10133			**0.076**	calcite	0.090
Balti PP	Waste	Electrostatic precipitator ash							0.006	1	25.00	0.10133	0.075	0.132	**0.077**	calcite	0.175
Balti PP	Waste	Total ash	866603	865401	866002				0.006	1	25.00	0.10133			**0.113**	calcite	0.257
Eesti PP	Waste	DeSOx ash							0.006	1	25.00	0.10133			**0.043**	calcite	0.098
Enefit 280	Waste	Total ash	454907	645575	550241				0.006	1	25.00	0.10133			**0**	calcite	0
Auvere PP	Waste	Electrostatic precipitator ash	369692	466014	417853				0.006	1	25.00	0.10133	0.091	0.18	**0.13**	calcite	0.295
Auvere PP	Waste	Total ash	2368757	716964	1542861				0.006	1	25.00	0.10133			**0.131**	calcite	0.298
		Total ash produced:	**8381956**	**7134366**	**7758161**												

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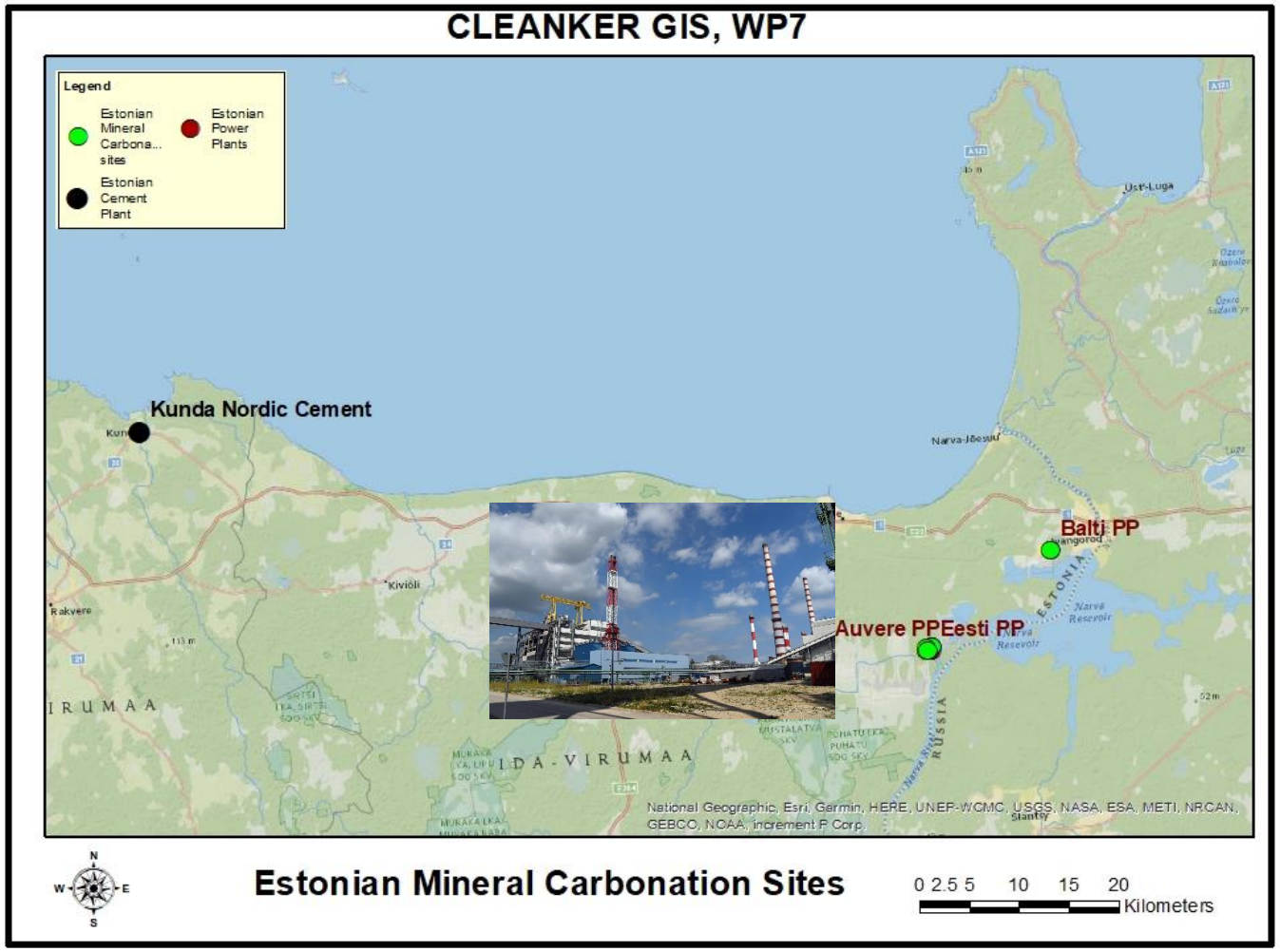
Mineral carbonation samples and emission sources from Estonia. Example of the most prospective material from Auvere Power Plant

Data for Electrostatic precipitator ash from Auvere Power Plant

Country	Estonia
City/Town	Auvere
Brand (name of plant)	Auvere PP
Number of studied samples	1
Name of material	**Electrostatic precipitator ash**
Reaction P (MPa) 0.101325	
Product mineral formula	CaCO3
Mineral carbonation product	calcite
MgO content (%, total MgO) - min	2.43
MgO content (%, total MgO) - max	5.22
MgO content (%, total MgO) – average	3.9125
Average market price per Eur/tonne	6
Annually used/sold at the market (tonnes) in 2017	147256
Annually used/sold at the market (tonnes) in 2016	128257
Annually used/sold at the market (tonnes) average	137756.5
Annual production of waste (kilotonnes) in average	**417.853**
Annual production of waste (kilotonnes) in 2017	466.014
Annual production of waste (kilotonnes) in 2016	369.692
Amount of the product per kg of material (waste) bound (kg)	0.295455
Amount of CO2 bound per kg of material (kg) - min	**0.091**
Amount of CO2 bound per kg of material (kg) - max	**0.18**
Amount of CO2 bound per kg of material (kg) – average	**0.13**



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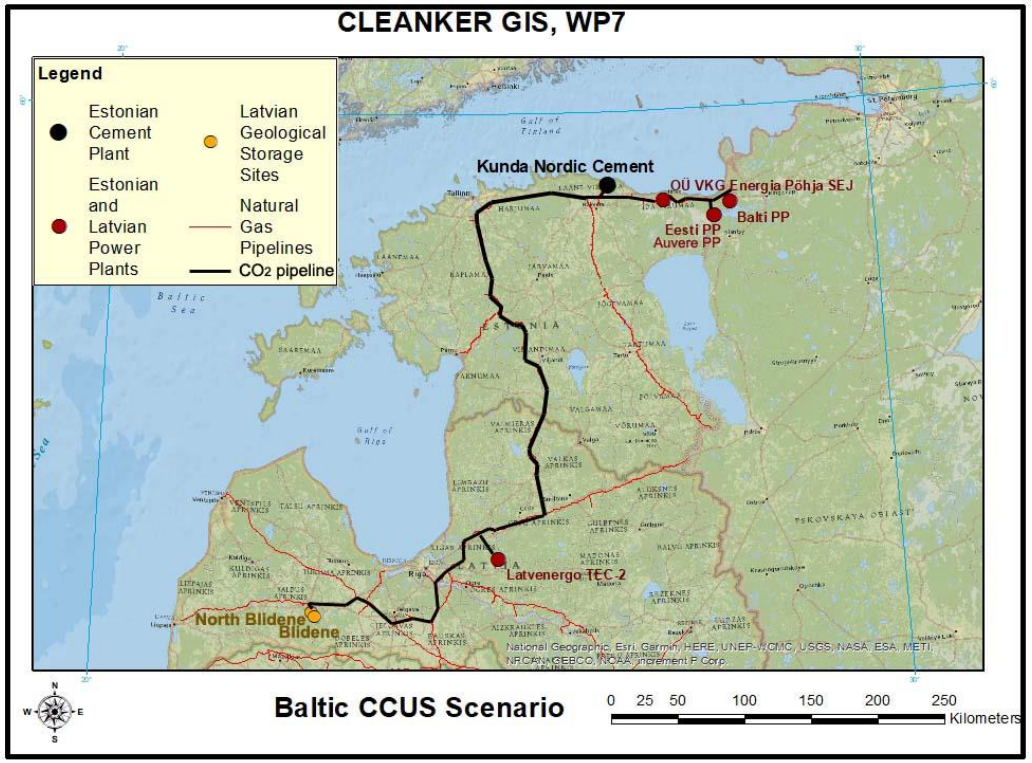
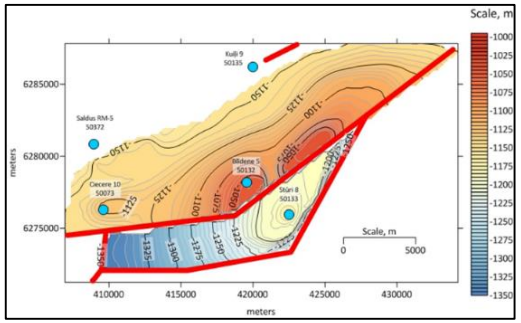
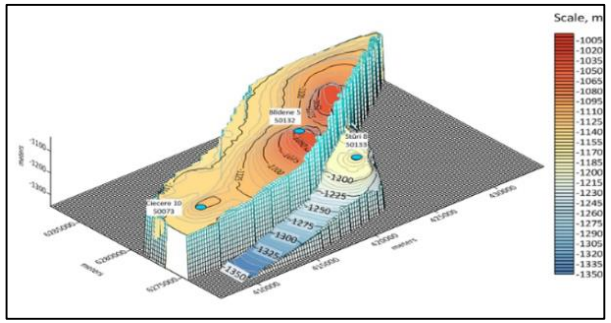
Task 7.2. Baltic Scenario – new draft version, recalculated parameters







Recalculated parameters of Estonian-Latvian CCUS scenario (6 sources, 25 years)

Technical parameters	Estonian Power Plants						Total Estonian share	Latvian share	Estonian-Latvian CCUS
Emissions sources	Kunda Nordic Cement	Eesti Energia			VKG Energia	CO_2 use for mineral carbonation	5 plants and CO_2 use	Latvenergo, TEC2	6 plants and CO_2 use
		Eesti	Balti	Auvere	North				
CO_2 emissions per year, Mt	0.554	8.06	1.364	1.44	0.595	-0.7	11.313	0.653	11.966
Total CO_2 emissions during 25 years, Mt	13.85	201.50	34.10	36.00	14.88	-17.50	282.83	16.33	299.15
Total CO_2 emissions during 26 years, %	4.63	67.36	11.4	12.03	4.97	-5.85	94.54	5.46	100
Number of wells	0.5	7			0.5	-	8	0.5	8
Total transport, km	700	795	800	795	750	-	800	30+150	830
Transport share, km	32.4	535.5	91.2	95.64	37.3		792	38.2	830.2
Pipeline diameter, mm	800	800	800	800	800		800	300	800

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Summary of the Baltic CCUS Scenario

- Six emission sources were included in the presented version of the Baltic CCUS scenario in order to decrease costs for the industrial project partners.
- Kunda Nordic Cement Plant will share infrastructure and monitoring costs with four Estonian and one Latvian Power Plant.
- Ca-Looping capture is expected for KNC (Cost from the CLEANKER) and Oxyfuel capture for the PPs (COST from the Shogenova et al, 2011).
- Methodology for economic modelling is developed as Deliverable of the CLEANKER project
- Technical parameters will include CO2 storage monitoring programme during and after CO2 storage
- Cost sharing will be proportional to the CO2 emissions share
- The storage capacity is enough for 25 years of emissions for the 2018 rate. For the present rate of emissions it could be enough for the longer time.
- This BALTIC CCUS Scenario could be easily modified into Estonian CCUS scenario, which could include all interested Estonian stakeholders and Estonian Storage Site (to be developed – proposal is submitted to ETAG).
- This scenario could be also modified into the Baltic offshore synergy CCUS scenario with storage and CO2-EOR in Latvian E6 structure and other CO2 use options.
- Political decisions and regulatory changes are needed to implement these scenarios.
- Regulatory framework is analysed in CLEANKER Deliverable D7.3, was presented last year at the BASRECCS-ENOS workshop in Tallinn and available online at the ENOS project website:

http://www.enos-project.eu/media/15322/7-shogenova-baltic-regulations.pdf

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Publications in Conference Proceedings, related to this scenario

CLEANKER clinKER by calcium looping for low-CO_2 cement

14th International Conference on Greenhouse Gas Control Technologies, GHGT-14

21st -25th October 2018, Melbourne, Australia

Transport, utilization and storage of CO_2 emissions produced by cement industry: CCUS study of the CLEANKER project

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Abstract

The EU Horizon 2020 project CLEANKER is aimed on Ca-looping capture of CO_2 emissions produced by cement industry. For the first time capture-focused EU project includes the full CCUS value chain study. This study includes techno-economic modelling of CO_2 transport, storage, and utilization scenarios; CCUS regulatory issues; definition of BUZZI and ITC-HCG cement plants suitable for first-of-a-kind CCS plant based on transport and storage opportunities; mineral trapping of CO_2 from the demo system and testing the carbonated materials for reuse in concrete.

Gaps in national regulations were analysed for Italy, Estonia, Latvia, Lithuania and Russia involved in two planned CCUS scenarios (Italian and Baltic). Russia is one of the largest emitters and Estonia has one of the highest CO_2 emissions per capita in the world. Russia has not ratified yet Paris Climate Agreement. Latvia, Lithuania and Russia are not parties of the London Protocol. CO_2 use options in these countries include CO_2 use for EOR, Geothermal Energy Recovery and mineral carbonation using waste materials. Additional CCUS regulations and political incentives are needed in these countries. Estonian burnt oil shale could be used as an effective sorbent in the proposed CO_2-mineralization process, binding up to 0.18 kg CO_2 per kg of waste. The onshore CCUS scenario was proposed for CO_2 emissions produced and captured by Kunda Nordic Cement plant (KNC), Eesti and Balti power plants, and Latvenergo TEC-2, the largest CO_2 emitters in Estonia and Latvia. CCUS scenario includes mineral carbonation of 1.2 mln tonnes CO_2 and transport and storage of about 10 mln tonnes annually into North-Blidene and Blidene structures in the western Latvia. The average optimistic capacity of the structures (297 Mt CO_2) will allow to store these emissions for at least 29.5 years. The share of the Estonian emissions stored in Latvia will be about 92.6%, including 5.6% by KNC. Latvian stored emissions will compose 7.4%. Such scenario will support Estonia and Latvia to reach their climate strategic targets. Techno-economic modelling of this scenario will be the next step of this study. Utilizing of the re-carbonated wastes in concrete application supports closing the CO_2 cycle of Vernasca cement plant by trapping the carbon dioxide into a concrete that contains the cement of the same plant.

Keywords: CO_2 emissions; Cement plant, CCUS regulations; CO_2 mineral carbonation; oil shale ash; CCUS scenario; CO_2 storage

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https://ssrn.com/abstract=3378578

14th International Conference on Greenhouse Gas Control Technologies, GHGT-14

21st -25th October 2018, Melbourne, Australia

Mineral trapping of CO_2 for cement industry de-carbonization

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Abstract

Mineralization of carbon dioxide by alkaline industrial wastes is a promising carbon capture and storage method. The Estonian oil shale based energy sector is the source of substantial CO_2 emissions as well as the formation of huge amounts of burnt oil shale (7.2 Mt annually). Retention capacity of these wastes is about 0.1 t of CO_2 per t of ash. In addition, concrete demolition wastes, specifically the fine fractions rich in calcium hydroxide and calcium silicate hydrate, are also considered to be good sorbents for CO_2 sequestration, forming thermodynamically stable calcium carbonate.

The objective of current research is to study burnt oil shale and concrete demolition wastes as sorbents in CO_2 mineralization process in order to identify the most promising materials for CO_2 capture as well as to specify reaction kinetics and operating parameters for a scale up. Results indicated that selected types of burnt oil shale could be used as effective binders in the proposed CO_2-mineralization system. The CO_2 uptake was mainly attributed by the free lime content, which is relatively high (10-15%) in burnt oil shale, but nonexistent in concrete demolition wastes. A kinetic model was built to predict the composition of solid and gas phase at given operating conditions. The re-carbonated materials could in turn be used in concrete application, so the CO_2 captured from the Ca-looping installation in Vernasca Cement Plant could be trapped and utilized in the same plant.

Keywords: burnt oil shale; CO_2 mineralization; concrete demolition waste

1. Introduction

Mineralization of gaseous CO_2 into thermodynamically stable carbonates is one of the carbon capture and storage methods of interest. In particular, using solid wastes generated from large scale industrial processes has a number of advantages, as these materials are forming often in vicinity of CO_2 point source emissions, supply a readily available source of CaO and/or Ca-silicates without the need for mining, they are usually fine-grained with high surface areas, and the end product may be reusable in construction materials [1]. The Republic of Estonia is in a unique position due to its oil shale based energy sector. About 7.2 Mt of burnt oil shale (BOS) [2-4], consisting 5-20% of free lime [5, 6], is formed annually in the heat and power production.

Another type of waste, concrete demolition waste (CDW), contains considerable amount (10-15%) of cement hydrate that could bind CO_2 improving also the quality of the concrete slurry waste for concrete application [7]. Specifically, fine fractions of CDW are generally characterized by a higher amount of the cement hydrate (25-30%) enabling a high trapping potential for CO_2 [8]. Considering that around 0.87 ton of CO_2 is emitted for every ton of

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https://ssrn.com/abstract=3365766

Co-funded by the Horizon 2020 Framework Programme of the European Union

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FP7: CGS Europe, CO2 Stop

Horizon 2020: ENOS project

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