WP7: Transport, utilization and storage of CO_2 emissions produced by cement industry

CLEAN clinKER by calcium looping for low-CO_2 cement

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Objectives

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

- techno-economic modelling of CO_2 transport, storage, and utilization scenarios for Vernasca Cement Plant in Italy, Kunda cement plant in Estonia and Slantsy cement plant in Russia
- gaps in CCUS regulations analyzed for Italy, Estonia, Latvia, Lithuania and Russia involved in the planned CCUS scenarios
- 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.

During first year of the project we have found:

- Russia is one of the largest CO_2emitters and has not yet ratified the Paris Climate Agreement
- Estonia has one of the highest emissions per capita in the world
- Latvia, Lithuania and Russia are not parties of the London Protocol, regulating transboundary offshore CO_2 storage
- CO_2 use options in the studied countries include CO_2 use for EOR, Geothermal Energy Recovery and mineral carbonation using waste materials
- 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

We have proposed:

- The onshore CCUS scenario for CO_2 emissions produced by Kunda Nordic Cement plant and Eesti and Balti (Eesti Energia), and Latvenergo TEC-2 power plants (the largest CO_2 emitters in Estonia and Latvia)
- It includes mineral carbonation of 1.26 Mt and transboundary transport and annual storage of 10 Mt of CO_2 emissions into North-Blidene and Blidene structures in the western Latvia during 30 years

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Samples and experimental methods

- Solid wastes from power and cement sectors were utilized to produce aggregates for construction industry by carbonation-based solidification technique
- BOS1, BOS3 and BOS7 are burnt oil shale ashes from Eesti, Balti and Auvere power plants, BOS5 is PF ash sample from SO_2 removal system (Alstom Power), BOS6 is from Enefit280 units that produce shale oil
- Concrete demolition wastes (CDW) samples are from I.L.C. s.r.l (Rondissone, TO) and Isoltrasporti (Isola Sant'Antonio, AL)
- CDW1 and CDW3 are fine fractions of recycled demolition waste
- CDW2 is demolition waste selectively derived from concrete
- CDW4 is recycled demolition waste submitted to washing process
- Quantitative X-ray diffraction and chemical analysis were used to determine contents of free lime and total carbon

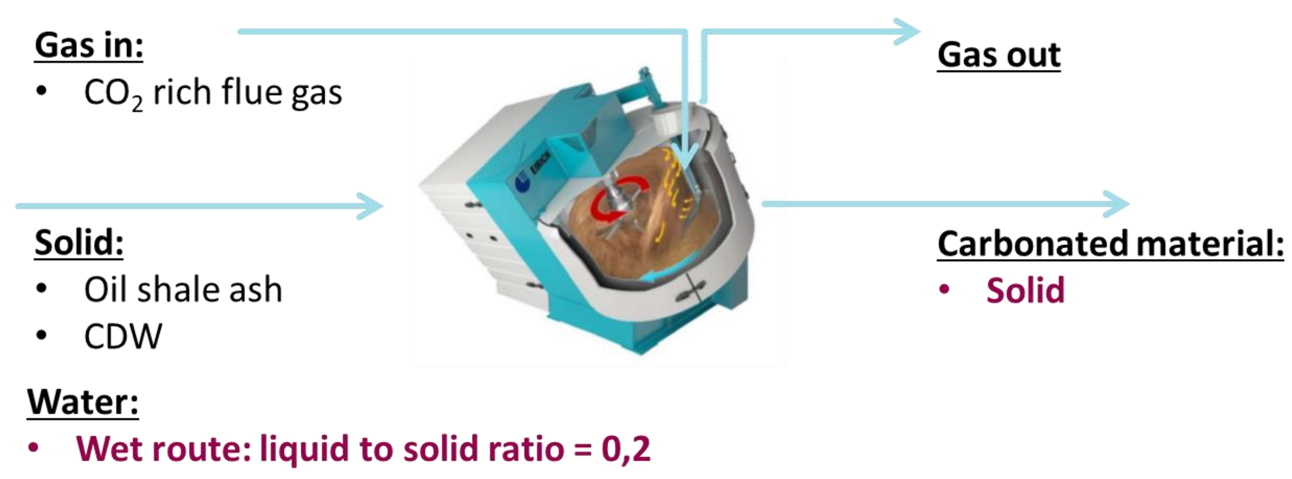

Fig. 1. Experimental setup

Results on mineral carbonation

- The main objective of this task is the construction and operation of a large (100L to 1000L) device for mineralization of CO_2 from the Vernasca demonstration plant
- The laboratory tests on BOS and CDW carbonation determined the most promising materials for CO_2 capture
- The burnt oil shale could be used as effective sorbents in the proposed CO_2-mineralization process, binding up to 0.18 kg CO_2 per kg of waste
- Theoretical annual binding ability of 7 Mt of Estonian oil shale ash is about 1.26 Mt CO_2
- Utilizing 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.

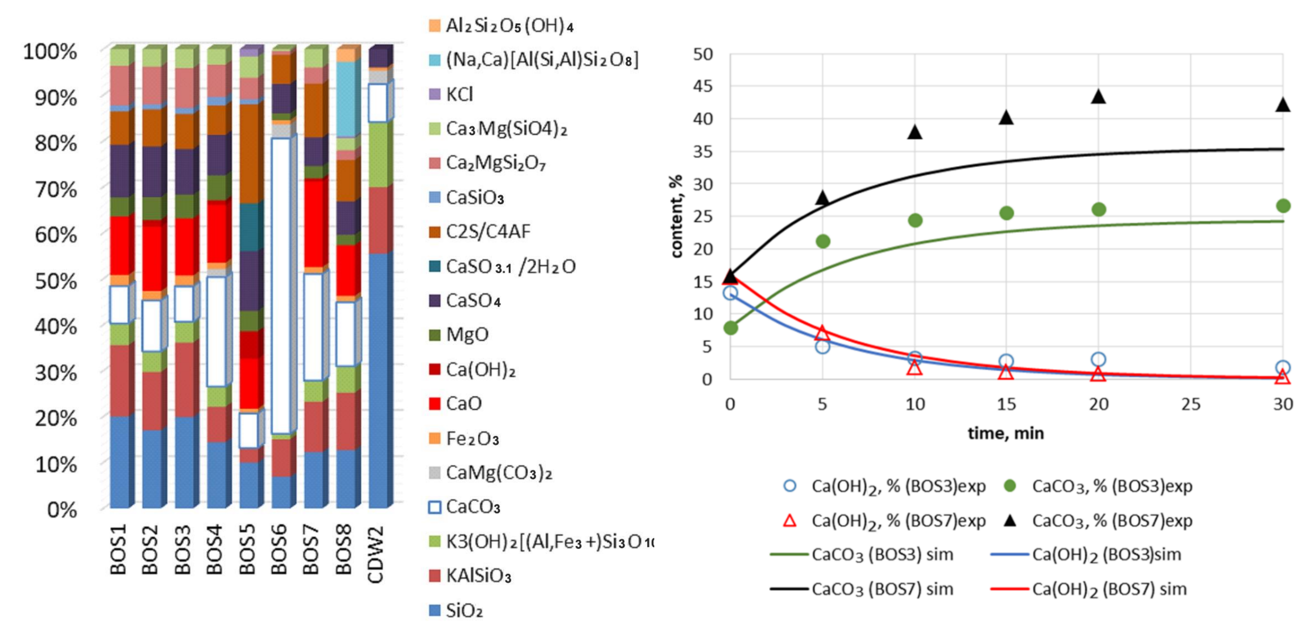

Fig. 2. (a) The phase composition of initial samples and (b) carbonation results of BOS3 and BOS7 model vs experiment (process parameters: gas mixture 400 L/h, 70% CO_2, 600 g initial sample, rotation speed 300 rpm)

Industrial and Fossil CO_2 emissions

- Kunda Nordic Cement Plant (KNC) produces constructional cements and covers nearly all cement consumption in Estonia
- KNC operates a wet cement production process, using oil shale for energy production and clay, limestone and oil shale ash as raw materials
- About 60% of CO_2 emissions from the cement production come from the calcining process, while 40% of CO_2 emissions come from the combustion of fuels
- KNC has formulated a zero vision for CO_2 emissions over the product's life cycle, including energy efficiency, using biomass as energy, new cement types, carbon capture and storage and CO_2 mineral carbonation
- According to EU ETS the CO_2 emissions have increased for 69.7% in 2017, as a result of the increased production (Table 1)

Table 1. Key figures for KNC in 2013 – 2016

Production	2013	2014	2015	2016	2017
Clinker, t	691 443	720 480	356 287	318 500	NA
Cement, t	456 070	447 350	390 430	422 800	NA
Fuel					
Oil shale, t	155 750	150 120	70 201	48 313	NA
Coal, t	58 900	63 850	22 913	19 176	NA
Alternative fuels, t	71 600	78 740	51 640	51 558	NA
Emissions					
CO_2, t	748 123	785 695	379 310	331 299	559 629
Environmental investments, M €	0.98	0.49	0.91	1.89	NA

Estonian-Latvian onshore CCUS scenario

Fig. 3 Estonian-Latvian onshore CCUS scenario includes CO_2 emissions produced and captured by KNC, Eesti and Balti power plants (Eesti Energia) and Latvenergo TEC-2 (the largest CO_2 emission sources in Estonia and Latvia) into the North-Blidene and the Blidene structures

- The North Blidene and Blidene structures are the largest in the western Latvia prospective for CO_2 storage (Fig.4)
- CO_2 storage capacity of the structures were recalculated using improved estimations of all parameters
- Their total optimistic capacity (min-max/mean) is 186-380/297 Mt, while the conservative capacity was estimated as 33.6-68.0/53.4 Mt

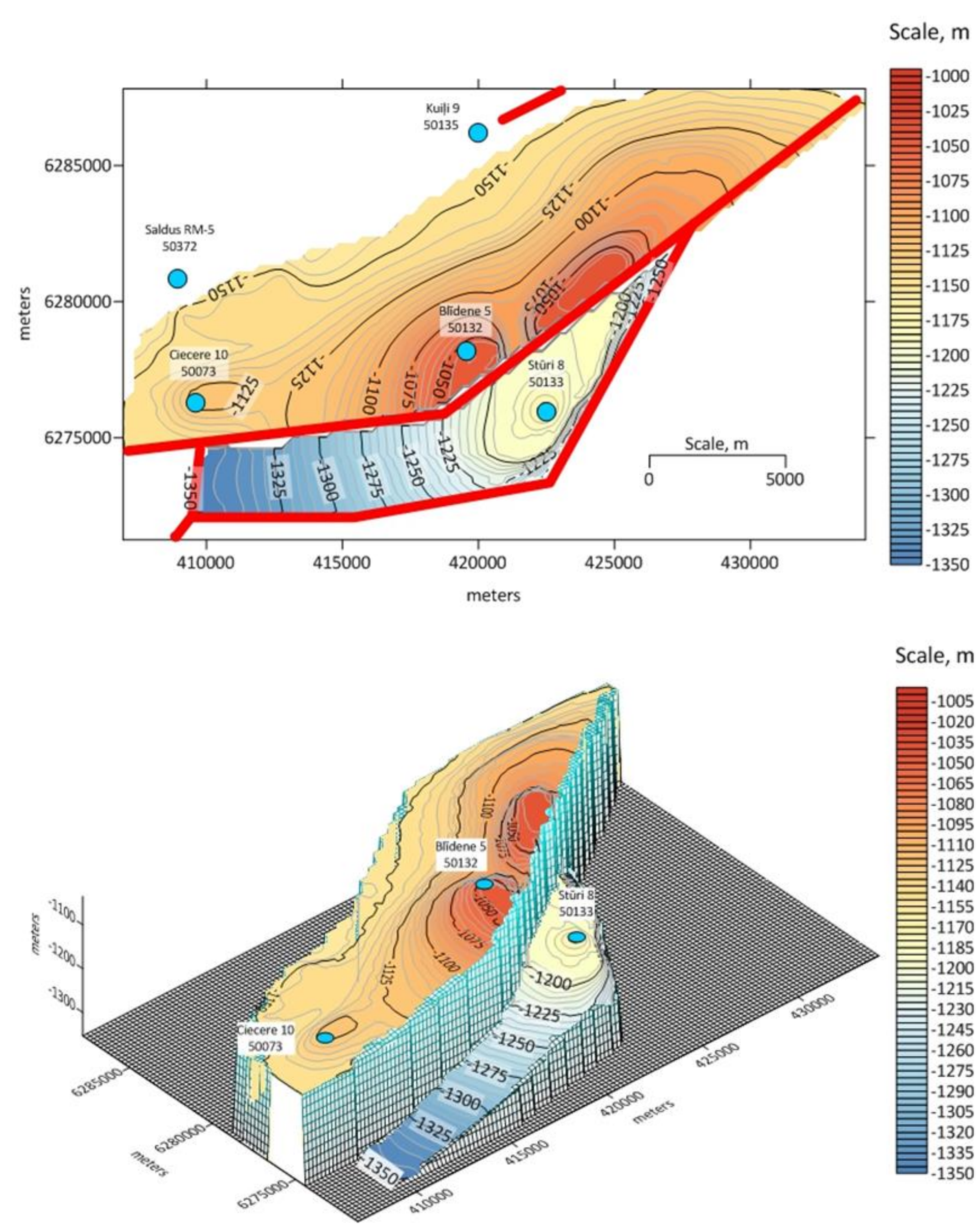

Fig. 4. (a) Contour maps and (b) 3D structure maps of the Cambrian Deimena Formation in the North Blidene (above) and the Blidene (below) structures composed using Golden Software Surfer 15 software. Fault line is indicated with red polyline

Table 2. Planned parameters of Estonian-Latvian CCUS scenario

Technical parameters	Estonian plants				Total Estonian share	Latvian share	Estonian-Latvian CCUS
Emissions sources	KNC	Eesti	Balti	CO_2 use	3 plants	Latvenergo, TEC2	4 plants
CO_2 emissions per year, Mt	0.56	8.36	1.6	-1.26	9.26	0.74	10
Total CO_2 emissions during 29.7 years, Mt	16.6	248.3	47.5	-37.4	275	22	297
Total CO_2 emissions during 29.7 years, %	5.6	83.6	16	-12.6	92.6	7.4	100
Number of wells	1	6		-	7	1	8
Transport, km	750	800	800	-	800	70	800
Pipeline diameter, mm	800	800	800	800	800	300	800

- Four selected plants produced in 2017 together 11.26 Mt CO_2 Considering 1.26 Mt CO_2 to be utilized by mineral carbonation of oil shale ash, the total annual amount for storage will be only 10 Mt
- The average optimistic capacity of the structures (297 Mt CO_2) will allow the storage of emissions produced by these four enterprises for at least 29.7 years (Table 2)
- This scenario will need drilling of eight injection boreholes and construction of about 800 km of CO_2 transport pipelines
- The share of Estonian CO_2 emissions stored in this scenario will be 92.6%, including 5.6% by KNC. Latvian emissions will compose 7.4% of the stored in the structures