Supplementary Information -

Finding least-cost net-zero CO_{2e} strategies for the European cement industry using geospatial techno-economic modelling

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SUPPLEMENTRAY NOTES

Note S1: Biofuels

The use of alternative to fossil fuels in the cement industry has been introduced over five decades ago with the European cement industry currently deriving approximately 52 % of their heating demand from alternative fuels[1]. While these measures were introduced gradually to reduce emissions or as cost reduction measures, they carry the caveat, that the majority of alternative fuels currently being waste and industrial by-products in gaseous (e.g., landfill gas, pyrolysis gas), liquid (e.g., pasty wastes, solvents, waste oils, greases) or solid (e.g., animal powder, bark, paper, tyres, rubber wastes, plastics, fluff) form[2]. As the vast majority of these industrial wastes (84%[3]) contain fossil carbon (e.g., waste oils are often derived from crude oil) they cannot reduce the cement industry's emissions significantly because fossil carbon will be released as CO_2 during combustion. Thus, the use of biofuels (e.g., wood pallets) has been suggested to reduce the energy-related emissions (approx. 40% of cement CO_{2e} emissions)[4]. A review of biomass availability alongside the availability of sewage sludge and waste tyres (which could partially be produced from biogenic carbon) revealed most European countries will not have enough biomass production capacity to be used in the cement industry except for some Nordic countries (Table S1) and wastes such as sludge could only be used as partial replacements for the energy needs. Hence, for deep decarbonisation of energy-related emissions biomass would have to be used which would have to be acquired outside of Europe with the primary import considered locations being in North America[5]. In this study we consider wood pellets from Canada as one of the means to decarbonize the cement industry.

Note S2 Carbon capture and storage

Carbon capture and storage has emerged among critical technologies in the cement industry's journey towards achieving net-zero emissions. Here, a multitude of different capture technologies have been suggested (i.a., monoethanolamine (MEA) capture, oxyfuel combustion capture and calcium looping)[6] to capture the CO_2 directly from flue gas which then is liquefied and transported via truck, train, ship, or pipeline to geological storage sites[7-9]. Previous studies have found pipeline transport to be most economical while simultaneously the lowest emissions[10]. CCS concepts often face acceptance issues from laypeople due to concerns about risks such as induction of earthquakes. Thus, offshore CO_2 storage should be chosen over onshore storage concepts (e.g., larger distances lead to lower risk perception)[11].

In this study we consider MEA capture, pipeline transport and offshore CO_2 storage as one of the strategies to decarbonize the cement industry.

Note S3: CO_2 mineralisation

Carbon dioxide (CO_2) mineralisation pathways have gained significant attention as promising avenues within the realm of Carbon Capture and Utilization (CCU) technologies[12,13]. In CO_2 mineralisation approaches, captured CO_2 is reacted with minerals to form stable carbonates (e.g., $MgCO_3$, $CaCO_3$). A multitude of feedstocks has been suggested for CO_2 mineralisation among them are secondary feedstocks (e.g., steel slag, waste incineration ash, coal fly ash) containing alkaline earth metals oxides (e.g., CaO, MgO, FeO)[14,15] or primary feedstock such as rocks containing magnesium- or calcium-rich silicate minerals[12,16,17]. As primary feedstock for instance, minerals like forsterite (Mg_2SiO_4) found in olivine-bearing rocks, lizardite ($Mg_3Si_2O_5(OH)_4$) present in serpentine-bearing rocks, and wollastonite ($CaSiO_3$) have been highlighted. The composition of rocks can vary significantly, containing anywhere between 50% to 100% of these minerals, contingent upon the geological makeup of the extraction site[17,18]. Equations 1 to 3 delineate the fundamental CO_2 mineralisation reactions applicable to these aforementioned minerals[19] (Eq. 1 to Eq. 3).

$$Mg_2SiO_4 + 2CO_2 \rightarrow 2MgCO_3 + SiO_2 + heat \uparrow \quad \text{Eq. 1}$$

$$Mg_3Si_2O_5(OH)_4 + 3CO_2 \rightarrow 3MgCO_3 + 2SiO_2 + heat \uparrow \quad \text{Eq. 2}$$

$$CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2 + heat \uparrow \quad \text{Eq. 3}$$

The by-product silica (SiO2) resulting from mineralisation reactions using the aforementioned primary feedstocks has an amorphous structure [18,20,21]. Amorphous silica is a well-established pozzolanic additive in cement blends. It reacts with calcium hydroxide CaOH in cement, generating supplementary binding compounds (such as calcium silicate hydrates) that enhance the strength of the cement, either matching or surpassing the strength achieved solely by cement usage [22,23]. Hence, the products can be used as cement replacements (supplementary cementitious materials, SCMs)[20,24]. We previously showed that emission reductions of up to 33% compared to conventional ordinary Portland cement can be achieved using CO_2 mineralisation for SCM production. But for favourable economics the transport must be limited[19] (e.g., in Europe, olivine-bearing rocks can be found only in Norway, Italy, Greece or Spain[18]).

We here selected a direct aqueous CO_2 mineralisation approach based on Eikeland*, et al.*[25], Ostovari*, et al.*[26] and Kremer and Wotruba[27] which we further developed in Strunge*, et al.*[19] to produce suitable SCMs for cement production. We only consider olivine-bearing rocks as feedstocks as they are available in multiple regions in Europe, do not require heat treatment and subsequently showed the best economic potential[19].

Note S4: Calcined clay cements

Commonly the cement industry used SCMs containing amorphous silica which reacts with calcium hydroxide in cement allowing to decrease clinker content and thus reduce emissions. In recent years interest has been growing to use clays (in particular kaolinite ($Al_4[(OH)_8|Si_4O_{10}]$) clays) which not only contain comparably high concentrations of silica, but also Aluminium oxide (alumina, Al_2O_3), which become reactive in cement blends after calcination (600- 800 °C)[28]. Here, in cement blends limestone reacting with alumina in the presence of calcium hydroxide exhibits amplified reactions in the company of additional alumina from calcined clays[29,30]. This interaction yields carboaluminate hydrates, filling pore spaces and enhancing the strength of the mortar (Eq. 4).

$$Al_2O_{3_{(from calcined\ clay)}} + CaCO_3 + 3Ca(OH)_2 \rightarrow [3CaO \cdot \mathrm{Al_2O_3}] \cdot CaCO_3 \cdot 11(H_2O) \qquad \text{Eq. 4}$$

Hence, cement blends comprising of limestone, calcined clay, and clinker, referred to as LC_3 (Limestone Calcined Clay Cement), have been demonstrated [31] and suggested as a strategy to significantly reduce emissions of the cement industry (due to clinker replacement and low calcination temperature of clays)[28,32,33]. Previous studies suggest emission reductions of approximately 30% contingent on technology maturity and transport distance of feedstocks could be achieved using LC_3 blends[28].
We here consider the use of calcined clays in LC_3 cements as one potential intervention as means for emission reduction in the cement industry using kaolinite clays as feedstock.

Note S5: Direct air capture and storage

Removing CO_2 from the air will become imperative during the upcoming decades. On the one hand, hard to abate sectors might still be responsible for 1.5 to 3.1 G $t^{-1}CO_{2eq}$ of greenhouse gas (GHG) emissions which will have to be captured to reach GHG net neutrality[34]. Moreover, climate models suggest the need for net-negative CO_2 emissions in the next decades[35]. This can be achieved using carbon dioxide removal (CDR) technologies, which are concepts in which CO_2 is captured from the atmosphere and then stored permanently[36]. As NETs are a multitude of different concepts currently suggested including enhanced weathering, ocean alkalinity projects or afforestation. The most prevalent technology currently discussed (mainly due to high accountability of captured and stored CO_2) are direct air capture (DAC) and direct air capture and storage (DACS) technologies[37].
DAC technologies can be built remotely to capture CO_2 from the atmosphere using solid sorbents or liquid solvents (e.g., MgO, KOH solutions) to temporarily capture CO_2. After immobilisation of CO_2 for example in K2CO3, energy in form of low-grade heat or electricity is used to regenerate the solvent/sorbent and release CO_2 which then is liquified. In DACS concepts the CO_2 is then transported to geological storage sites where it is stored underground (e.g., in aquifers)[37,38].
For this study we consider direct air capture via liquid sorbents based on an assessment from Young*, et al.*[37], which has to be connected to a CO_2 storage site via pipeline and can be used to decarbonise the cement industry.

Note S6: Selection of Storage locations and other grid point locations.

CO_2 storage locations. Currently not all storage sites in Europe have been investigated and there are regional differences in the depth of research conducted to determine suitable storage sites. Currently, sites that have been determined have been determined through modelling and theoretical work. Only few field tests for CO_2 injections have been conducted to this day. For potential injection sites in the North Sea and the Irish Sea used in the UK&IRE case study we used data from European Comission - Joint Research Centre[39] which were published a decade ago and to this day provides the most comprehensive survey of potential storage sites within Europe. The data provided us with a storage site location as well as the mean capacity. We here assume an injection plant lifetime of 30 years (Table S6: General assumptions) to calculate annual storage capacity. We used the same dataset[39] to determine CO_2 storage sites in the Atlantic for the PT&ESP case study. For Spain the dataset only offered potential onshore storage sites, which we here consider out of scope and thus did not include in the analysis. For Germany the dataset[39] was incomplete. We hence used the provided geographic data of potential storage areas and manually placed potential injection locations in each presented suitable rock formation providing us with 19 storage sites in German North Sea. Due to lack of information for storage in the German North Sea, we used the estimation of Knopf and May[40] which estimated a mean offshore storage capacity for Germany of 9.5Gt, leading to 500Mt per storage site. While these uniformly distributed storage capacities are likely to be overestimated for most storage sites a study of Höller and Viebahn[41] concluded that at least 13 offshore storage sites in Germany could have a capacity larger than 100Mt. For the Germany case study we additionally added storage sites and capacities from Netherland's North Sea territories, which we derived from Neele*, et al.*[42].

Terminal locations. To connect onshore and offshore pipelines, we here define Terminal locations. To reduce computational efforts (increase number of potential options), we selected a few terminal locations for each case study. For Germany and the United Kingdom & Ireland, we selected terminals based on existing natural gas pipeline terminal locations in these countries taken from European Comission[43]. For the Portugal and Spain we assigned terminal locations based on harbour locations as currently no natural gas pipeline into the Atlantic ocean exist [43].

Feedstock locations. We used potential kaolinite clay sites from Dill[44] who reviewed mineral deposits in central Europe. To this dataset we added data from Galán*, et al.*[45] and British Geological Survey[46] for Spain and England respectively. For olivine-bearing rocks locations we used data from Kremer*, et al.*[18] who mapped active olivine-bearing rock locations in Europe. We must acknowledge that there might be more potential feedstock locations both for all feedstock which first must be developed / investigated[47].

Harbour locations and transport route data. The transport model uses shapefiles of European railways obtained from Mapcruzin[48], offshore shipping routes based on automatic identification system data obtained from NCEAS [49] and ports taken from Novikov Novikov[50].

SUPPLEMENTRAY FIGURES

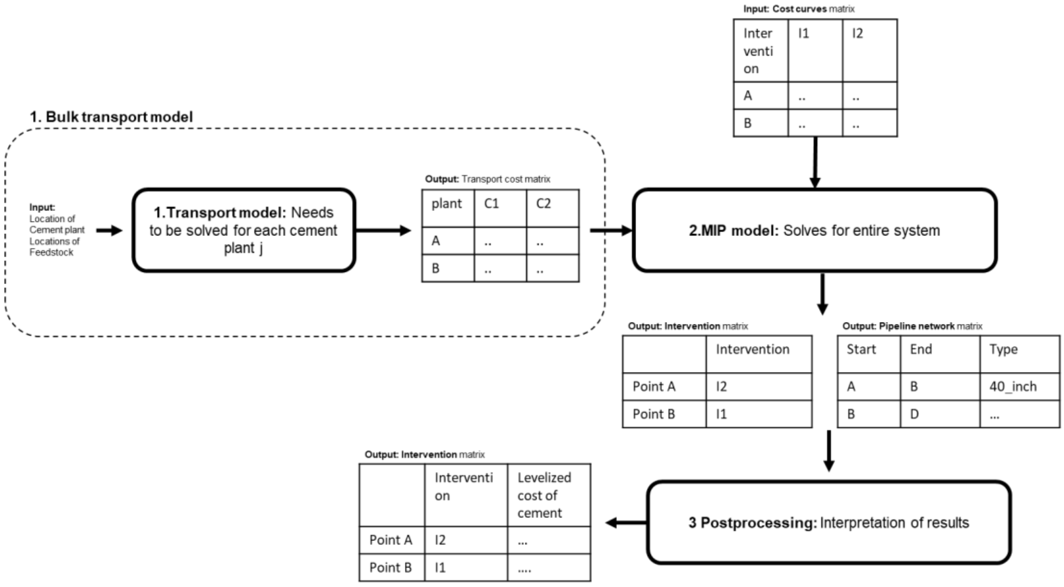

Figure S1: Flowchart techno-economic model.

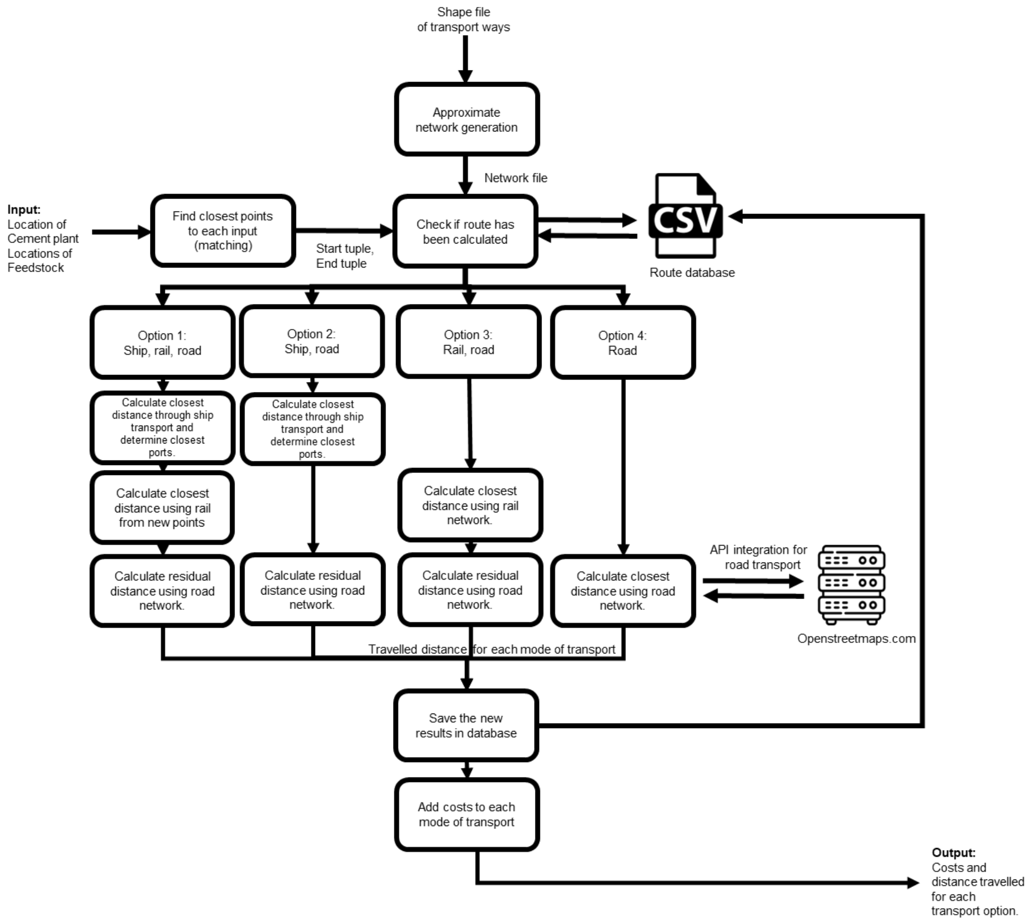

Figure S2: Flowchart of bulk transport model. Previously published in Strunge, et al.[51].

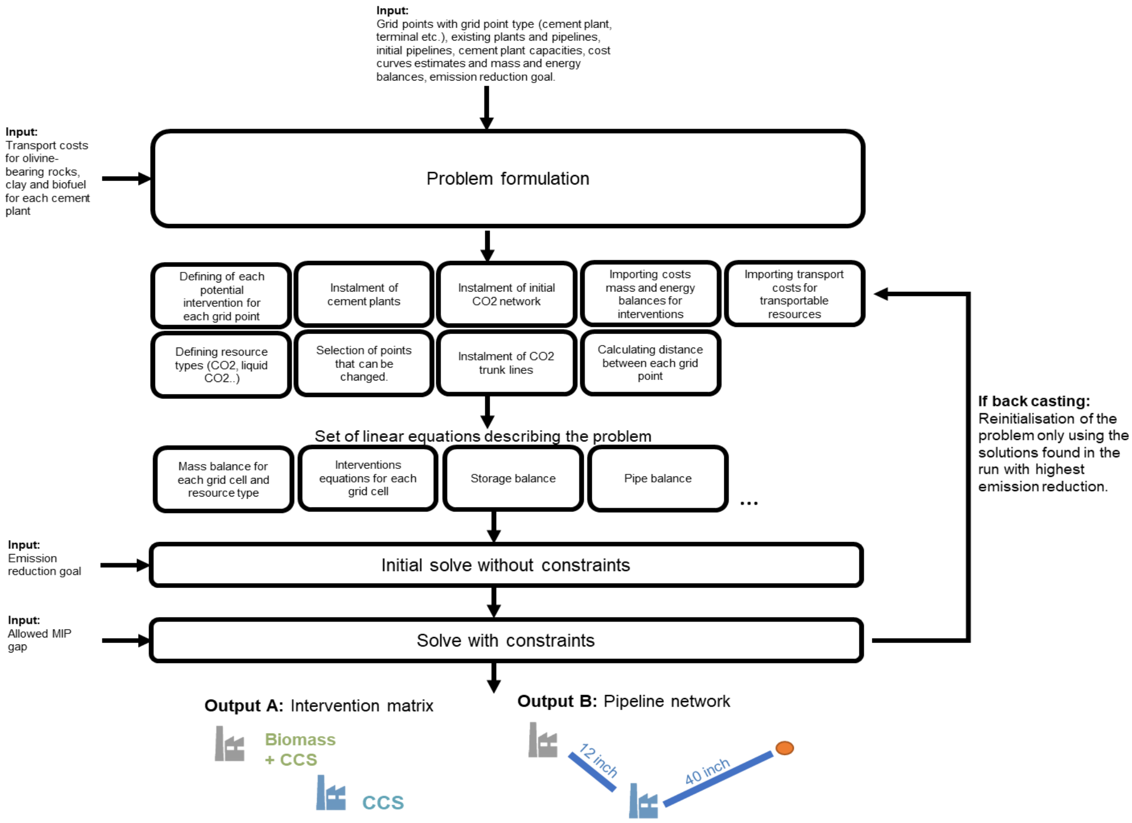

Figure S3: Flowchart of MIP model.

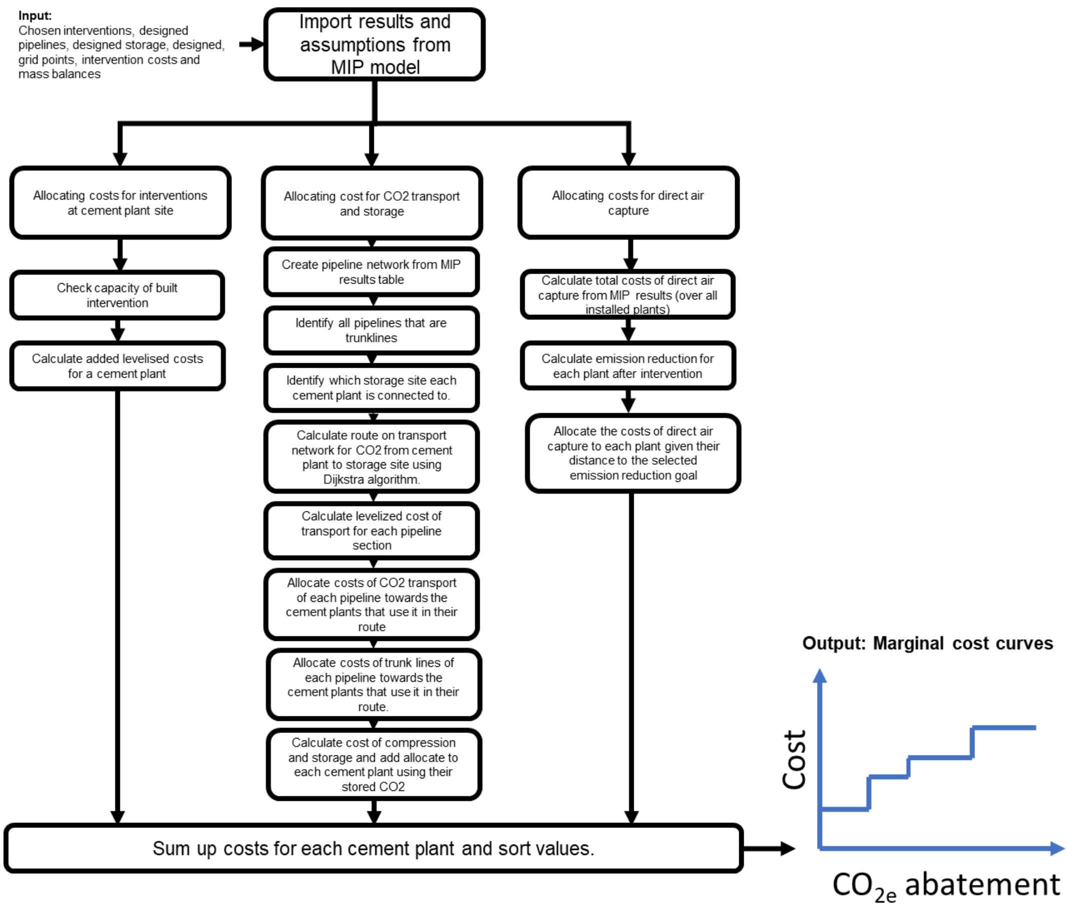

Figure S4: Flowchart of post-processing model.

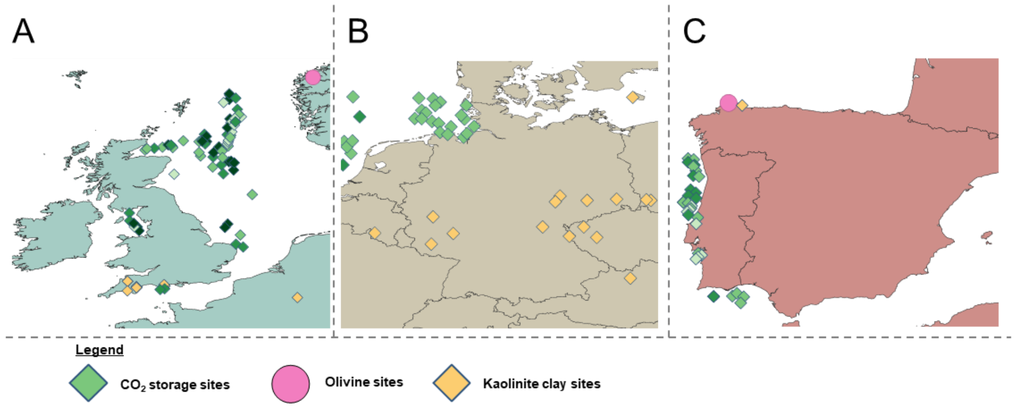

Figure S5: Depiction of case study regions A) UK and Ireland, B Germany and C) Portugal and Spain with relevant resource locations.

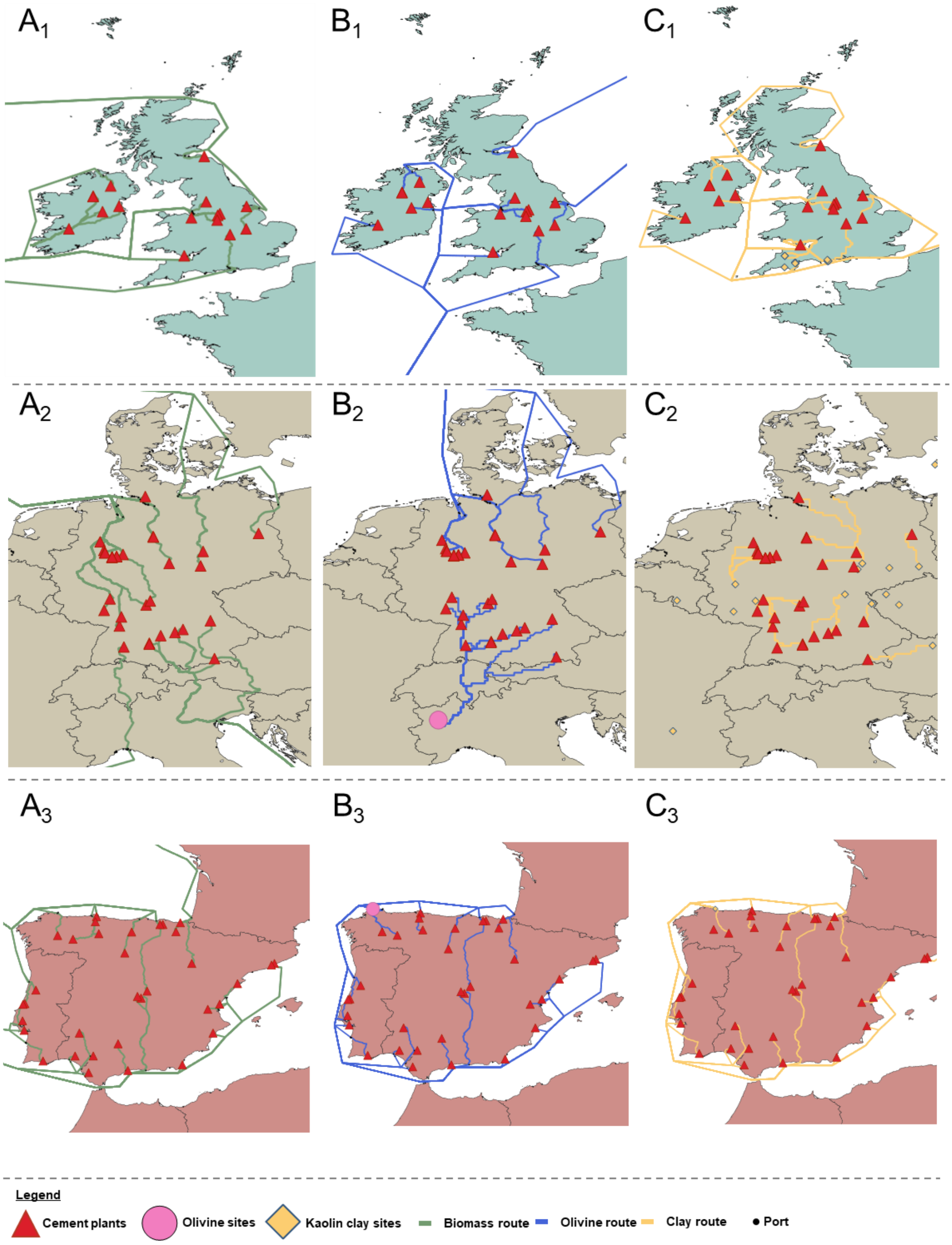

Figure S6: Bulk transport routes for the bulk feedstocks a) biofuel, b) olivine-bearing rocks and c) kaolinite clay in 1) United Kingdom and Ireland, 2) Germany and 3) Portugal and Spain.

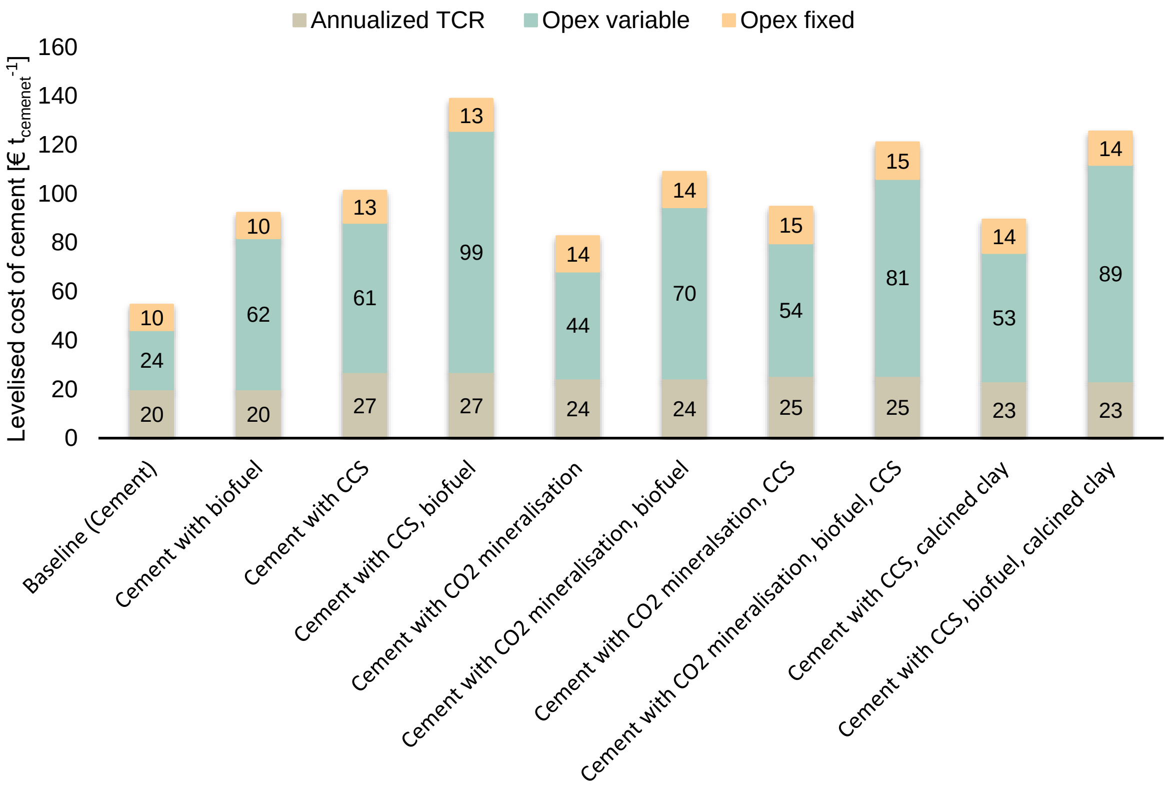

***Figure S7:** Comparison of calculated levelised costs of cement for the baseline (an average European cement plant) and with introducing interventions, excluding transport of feedstocks, CO_2 transport infrastructure or CO_2 storage. Here, ordinary Portland cement (OPC) with a clinker factor of 1 is considered.*

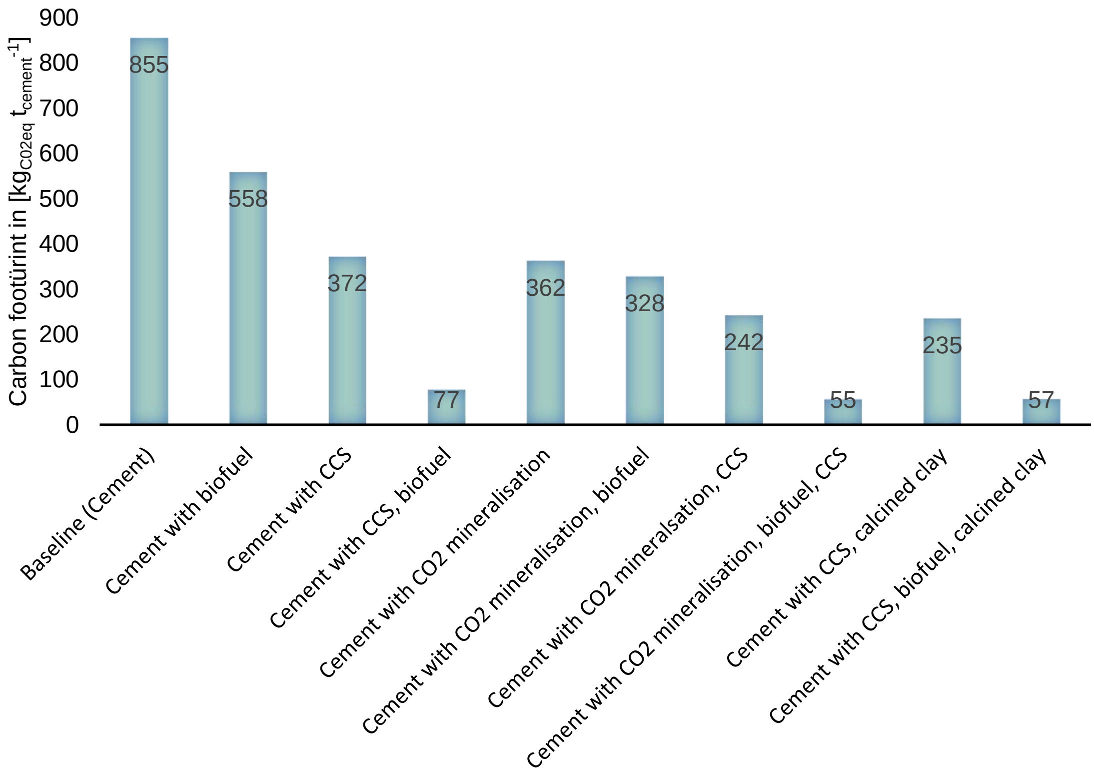

***Figure S8:** Comparison of calculated carbon footprint of cement for the baseline (an average European cement plant) and with introducing interventions excluding transport of feedstocks, CO_2 transport infrastructure or CO_2 storage. Here, ordinary Portland cement (OPC) with a clinker factor of 1 is considered.*

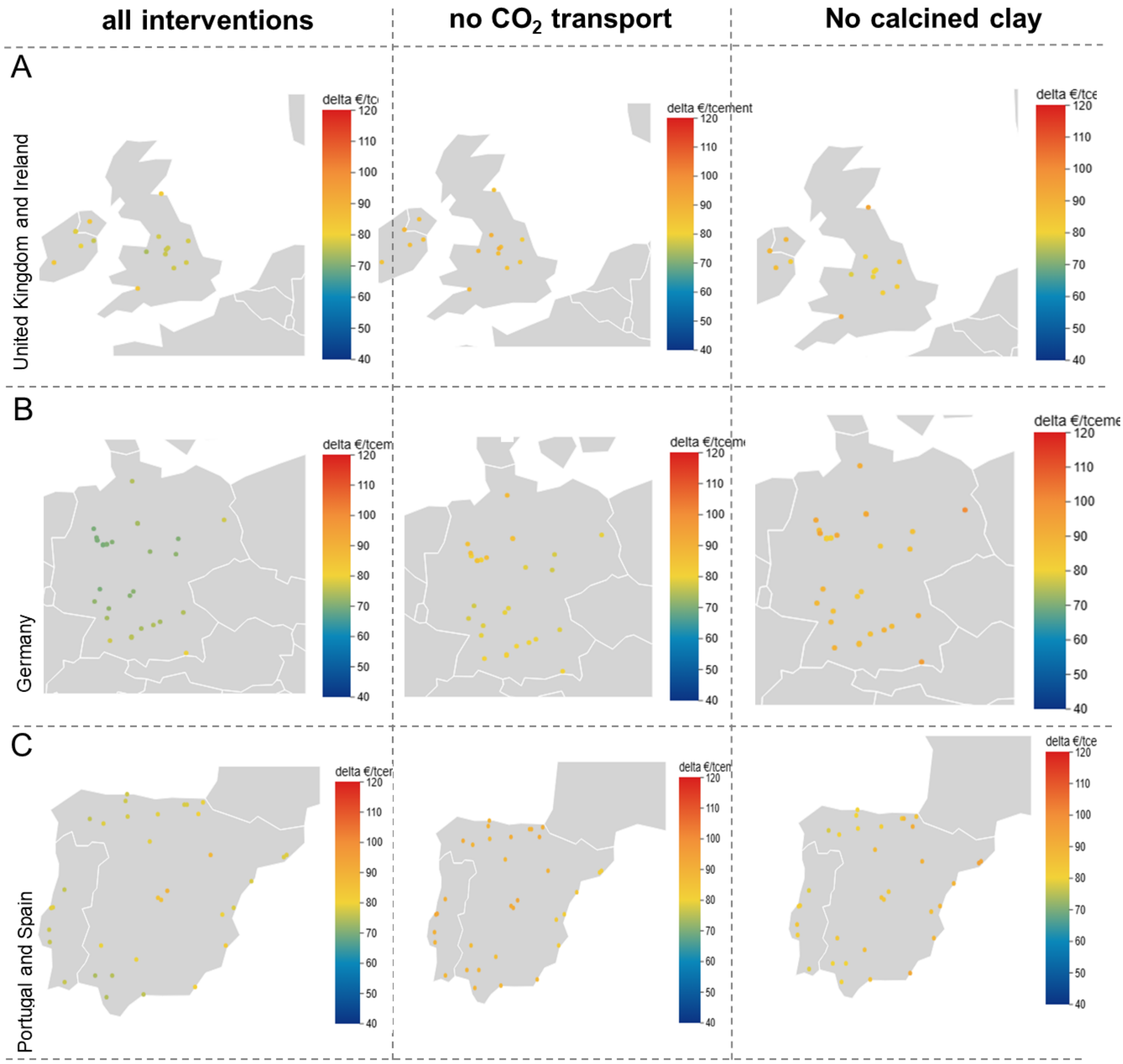

Figure S9: Comparison of calculated added costs of cement by location for cement plants in United Kingdom and Ireland (A), Germany (B) and Portugal and Spain (C).

A

B

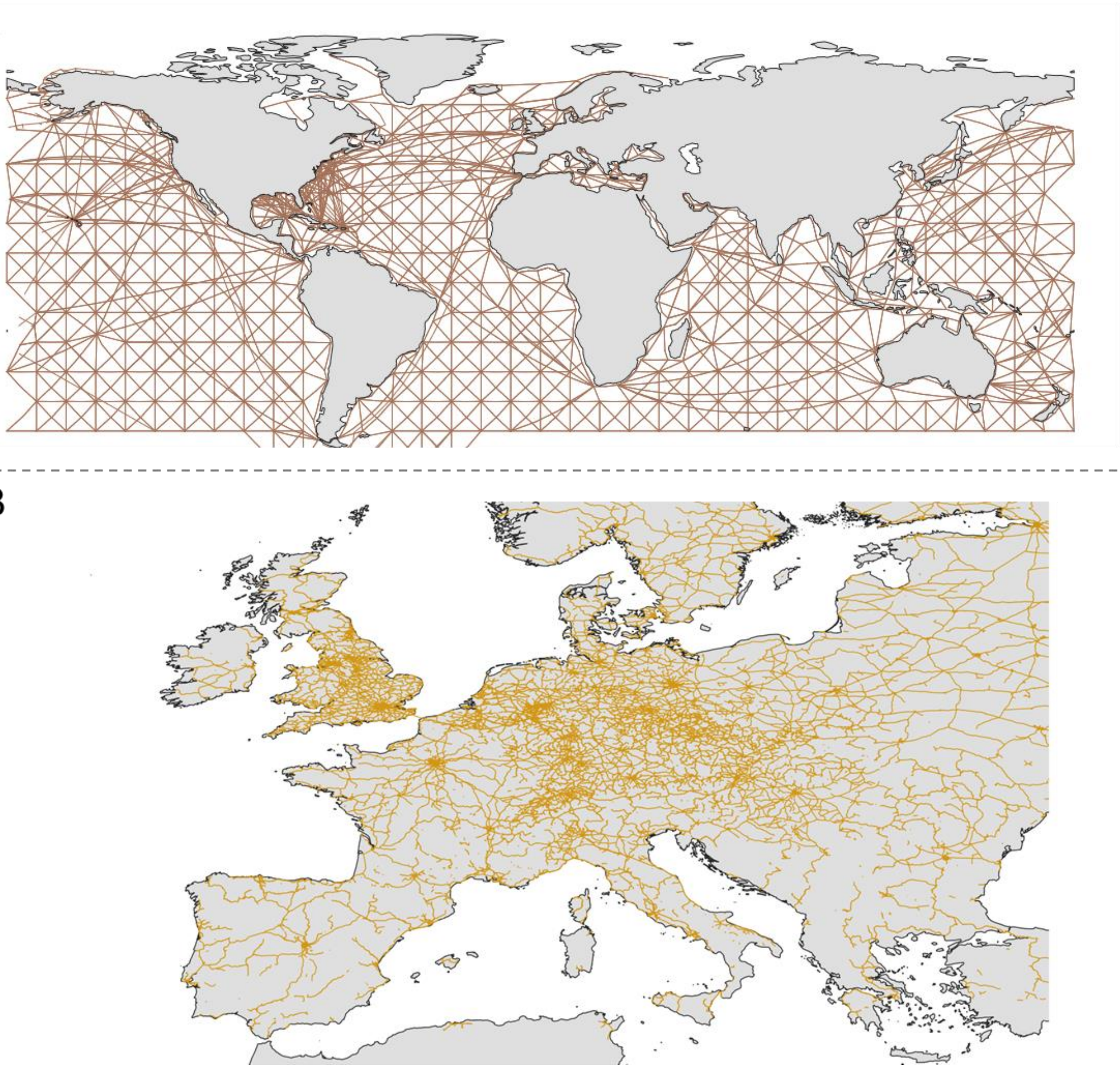

Figure S10: Depiction of transport networks. (A) Ship transport networks, (B) Railway networks.

SUPPLEMENTRAY TABLES

Table S1: Comparison of different demand and supplies for different fuels in the European cement industry. Underlined values show regions where a potential supply would be higher than the potential supply.

		Potential demand for different heating sources				Supply for different heating sources			
	Heating demand for cement production in [TJ a^{-1}]*	Coal [Mt a^{-1}]	Wood pellets [Mt a^{-1}]	Dried sludge [Mt a^{-1}]	Waste tyres [Mt a^{-1}]	Coal [Mt a^{-1}]**,52	Wood pellets [Mt a^{-1}]**	Dried sludge [Mt a^{-1}]**	Waste tyres [Mt a^{-1}]**
Germany	81929	3.0	4.98	8.2	2.7	**189.5**	1.70	1.92	0.14
United Kingdom	18577	0.7	1.13	1.9	0.6	**18.1**	0.13	no data	0.00
Turkey	166926	6.2	10.15	16.7	5.5	**76.9**	0.00	no data	0.07
Italy	45757	1.7	2.78	4.6	1.5	0.1	0.00	no data	0.17
Poland	43980	1.6	2.67	4.4	1.4	**130.5**	0.66	0.77	0.08
France	39250	1.5	2.39	3.9	1.3	no data	0.46	1.34	0.22
Spain	37327	1.4	2.27	3.7	1.2	**10.2**	0.15	1.26	0.08
Romania	24333	0.9	1.48	2.4	0.8	**35.2**	0.00	0.27	0.05
Belgium	15700	0.6	0.95	1.6	0.5	no data	0.54	0.21	0.00
Croatia	12596	0.5	0.77	1.3	0.4	no data	0.00	no data	0.00
Greece	12172	0.5	0.74	1.2	0.4	**65.7**	0.00	0.15	0.01
Czech Republic	10421	0.4	0.63	1.0	0.3	**57.9**	0.04	0.29	0.03
Austria	10409	0.4	0.63	1.0	0.3	no data	**8.50**	0.31	0.03
Portugal	10386	0.4	0.63	1.0	0.3	no data	0.50	0.46	0.03
Switzerland	9582	0.4	0.58	1.0	0.3	no data	0.00	no data	0.05
Slovakia	9401	0.3	0.57	0.9	0.3	**4.0**	0.00	0.10	0.00
Sweden	5807	0.2	0.35	0.6	0.2	no data	**1.65**	0.26	0.07
Denmark	5767	0.2	0.35	0.6	0.2	no data	0.14	0.16	0.00
Serbia	5458	0.2	0.33	0.5	0.2	**40.7**	0.00	no data	0.01
Bulgaria	5022	0.2	0.31	0.5	0.2	**37.2**	0.00	0.09	0.00
Netherlands	4946	0.2	0.30	0.5	0.2	no data	0.80	0.37	0.01
Ireland	4156	0.2	0.25	0.4	0.1	no data	0.00	no data	0.00
Norway	4010	0.1	0.24	0.4	0.1	**3.4**	0.00	no data	0.05
Cyprus	3455	0.1	0.21	0.3	0.1	no data	0.00	0.04	0.01
Finland	3232	0.1	0.20	0.3	0.1	no data	0.00	0.19	0.01
Lithuania	2819	0.1	0.17	0.3	0.1	no data	0.00	no data	0.00
Hungary	2309	0.1	0.14	0.2	0.1	**9.4**	0.07	0.22	0.01
Latvia	2309	0.1	0.14	0.2	0.1	no data	0.00	0.03	0.00
Luxembourg	2309	0.1	0.14	0.2	0.1	no data	0.00	no data	0.00
Republic of North Macedonia	2142	0.1	0.13	0.2	0.1	**7.3**	0.00	no data	0.00
Slovenia	1616	0.1	0.10	0.2	0.1	**4.5**	0.00	no data	0.01
Estonia	597	0.0	0.04	0.1	0.0	0.0	0.00	no data	0.00
	Sum	22.4	36.8	60.5	19.8	690.6	15.3	8.4	1.2
					Potential share of local supply	**2983%**	**41%**	**14%**	**6%**

* Approximated from cement production data taken from Statista[53].
** Approximated using a lower heating value of 27 GJ t^{-1} (coal)[54], 16.45 GJ t^{-1} (wood pallets)[55], 30.5 GJ t^{-1} (end of life tyres)[56], 10 GJ t^{-1} (dried sewage sludge)[56].

Table S2: Overview of suggested measures to reach CO_2 neutrality in the cement industry with references. Previously published in Strunge, et al.[51].

Overarching Theme	Intervention	Measure	Type*	Ref.
Efficiency & substitution	Improve clinker production	Energy efficiency	E	3,57,58
		Alternative fuels / Biofuels	E	3,30,57-60
		Process electrification	E	3,61
	Improve cement production	Supplementary cementitious materials (SCM)	PO&E	57-60
		Improved grinding	E	57
	Improve usage of cement	Improved estimation of cement needs	O	3,57
		Improving structural elements	O	57
Recycling & circular economy	Cement & concrete recycling		PO&E	57,62
	Reuse of concrete elements		O	3,57
New technologies	Alternative clinkers		PO&E	3,57,58,60,63-66
	Carbon capture and storage		PO&E	3,57,60,67
	Carbon capture and utilisation	CO_2 mineralisation	PO&E	3,47,58,67,68
		CO_2 to chemicals	PO&E	3,67
		CO_2 to fuels	PO&E	3,67
		CO_2 usage without transformation	PO&E	3,67
	Alternative building materials		O	59,69

*The measure's type describes which type of emissions they can tackle: **E**, means the measure can tackle **energy**-related emissions. **PO** means it can tackle **process**-inherent emissions and **O** means it lowers overall emissions of the cement sector by **other** means (i.e., via lowering the usage of cement overall).

Table S3: Description of grid point types.

Type	Description	Type of interventions that can be built here.	Type of CO_2 infrastructure connections
CEMENT	On a cement plant grid point a cement plant can be specified as an existing plant and a capacity (i.e., demand for cement can be set).	All cement intervention and direct air capture plants.	Onshore
TERMINAL	A terminal connects onshore and offshore points. Here CO_2 compressors can be built to compress CO_2 for offshore pipelines.	CO_2 compressors and direct air capture plants.	Onshore and offshore
STORAGE	A storage site for this model is specified as offshore points, where CO_2 injection sites can be built.	CO_2 injection site.	Offshore
TRUNKLINE	Trunkline points are points, where trunklines can be connected to. Trunkline points can be specified with or without actual connections to trunklines.	Direct air capture.	Onshore

Table S4 : Estimated pipeline sizes for currently planned pipeline projects in United Kingdom and Germany.

Country	Project Title	Estimated pipe size	Estimated total capacity [MtCO_2 a^{-1}]	Load factor
United Kingdom	Acorn Project	32INCH Onshore	16	0.5
United Kingdom	Viking CCS	28INCH Onshore	10	0.5
United Kingdom	Hynet	28INCH Onshore	10	0.5
United Kingdom	Humber	28INCH Onshore	12.1	0.5
Germany	OGS starter	32INCH Onshore	18.8	0.5
Germany	OGS full	32INCH Onshore	/	0.5

Table S5: Defined ranges for feedstock costs.

Description	Min	Max	Assumption used in case studies	Unit	Reference
Biofuel costs	7	25	15	€ GJ^{-1}	[70]
Clay costs	20	150	30	€ t^{-1}	Own estimation, [71]
Olivine costs	3.5	23	5	€ t^{-1}	[72-74]
Electricity price (2030)	38*	200**	62	€ MWh^{-1}	[75]
Price natural gas (2030)	16.2*	41**	32	€ MWh^{-1}	[76]
Price coal (2030)	2.1*	6.3**	3	€ GJ^{-1}	[77]

All energy costs have been bundled into a low-cost scenario marked as * and a high-cost scenario marked as **.

Table S6: General assumptions

General model assumptions	
Variable	**Assumption**
Clinker factor	For all cement plants and cost of cement we consider a clinker factor of 100%.
Cement plant capacity	As CO_2 networks need to be designed for a full capacity. We took each cement plant's capacity from Tkachenko*, et al.*[78] and applied the clinker factor of 0.737[54] to reach a plants capacity. When clinker is replaced by an innovation we consider further replacement of clinker.
European cement market	A key assumption here is that the currently existing cement plants can and will continue to produce at the capacity they are currently, i.e., European cement demand will remain constant until 2050 and is not further replaced by imports. This assumption appears commensurate with current EU and UK policy, which attempts to shield domestic production (thus jobs) from 'cheap, possibly higher CO2 intensive imports', e.g., via carbon border adjustment mechanisms[79,80].
Fuel conventional cement production	As fuel in conventional cement production we consider coal to be used. As alternative fuel usage differs between plants and might itself lead to emissions, current use of alternative fuels (such as municipal waste) was not considered.
Free allowances CO2 certificates	As our model uses a net-zero approach, we do not consider free allowanced of CO_2 certificates in the model.

General economic assumptions		
Variable	**Value**	**Reference**
Working hours	8000h a^{-1}	[60]
Lifetime*	30 years	Own estimation
Overall interest* (Including interest on equity and dept)	7.69%	[81-84]
Extraction Costs Mineral*	12€ t^{-1}	[72]
Transport costs	0.04€ $t^{-1}km^{-1}$ truck 0.032€ $t^{-1}km^{-1}$ train 0.0032€ $t^{-1}km^{-1}$ ship	[72]
Electricity price*	62€ MWh^{-1}	[75]
Natural gas price*	32€ MWh^{-1}	[76]
Price $NaHCO_3$*	209€ t^{-1}	Comparison of vendor prices [85]
Price NaCl*	61.6€ t^{-1}	Comparison of vendor prices [85]
Price MEA*	1320€ t^{-1}	Comparison of vendor prices [85]

Capital expenditure assumptions for interventions		
Technology	**Value**	**Reference**
MEA capture for 765kt_{CO2} a^{-1}	TDC = €47.6 M	[6]
CO_2 mineralisation plant with a capacity of 750kt_{SCM} a^{-1}	TDC = €93.4 M	[19]
Calciner for calcined clay with capacity of 300kt_{clay} a^{-1}	TDC = €24 M	[28]

*We considered the same lifetime for plants and storage sites. The solver would only choose a storage site, if it can be used for this amount of years, given the calculated flow of liquified CO_2 in the pipeline.

Table S7: Factors used for TCR calculation.

Description	Value	Reference
Indirect costs	14%	[54]
Process contingencies	40%	[86,87]
Project contingencies	30%	[86]
Owner's costs	7%	[88]
Learning rate	10.5%*	[89]
Number of plants	20	[90]

* For baseline cement plants, as well as for CO_2 infrastructure (i.e., pipelines, recompression stations between onshore and offshore pipelines) as well as CO_2 injection sites, we do not consider technological learning and learning rate is set to 0%.

Table S7: Factors used for OPEX calculations.

Description	Value	Reference
Insurance and local tax	2% of TPC	[54]
Maintenance	2.5% of TPC	[54]
Administration and support	30% of operating and maintenance	[54]

Table S8: Process assumptions

Process	Variable	Value	Unit	Reference
Clinker production	Electricity needs	0.132	MWh $t^{-1}_{clinker}$	[6]
	Heating	3	GJ $t^{-1}_{clinker}$	[6]
	Energy density Coal (LHV)	27150	kJ kg^{-1}	[6]
	Raw meal/clinker	1.6	t $t^{-1}_{clinker}$	[6]
	Ammonia for SNCR	0.005	t $t^{-1}_{clinker}$	[6]
	other variable costs	1.1	€ $t^{-1}_{clinker}$	[6]
	Electricity needs	0.132	MWh $t^{-1}_{clinker}$	[6]
	Heating	3	GJ $t^{-1}_{clinker}$	[6]
CO_2 capture	Electricity needs (capture & compression)	0.32	MWh $t^{-1}CO_2$	[91]
	Heating (capture)	3.6	GJ $t^{-1}CO_2$	[91]
	Cooling water (capture)	3.39	m3 $t^{-1}CO_2$	[6]
	MEA makeup (capture)	0.0015	t $t^{-1}CO_2$	[92]
	Capture rate	0.9	t $t^{-1}CO_2$	[6]
CO_2 mineralisation	Electricity needs	426.45	kWh t^{-1}_{SCM}	[19]
	Heating	124.952	kWh t^{-1}_{SCM}	[19]
	Mineral (Olivine)	2.1988	t $t^{-1}CO_2$	[19]
	NaHCO3	0.0324	t $t^{-1}CO_2$	[19]
	NaCL	0.0338	t $t^{-1}CO_2$	[19]
	Process water	0.775	m^3 $t^{-1}CO_2$	[19]
	Electricity needs	426.445	kWh t^{-1}_{SCM}	[19]
Calcined clay	Electricity needs	0.016	MWh $t^{-1}_{LC3\ cment}$	[28]
	Electricity needs grinding	0.024	MWh $t^{-1}_{LC3\ cement}$	[28]
	Heating	2.775	GJ $t^{-1}_{calcined\ clay}$	[28]
	Clay requirements	1.16	t $t^{-1}_{calcined\ clay}$	* derived from Stoichiometry
	Calcined clay in LC3	0.3	t $t^{-1}_{LC3\ cement}$	[28]
	Clinker in LC3	0.5	t $t^{-1}_{LC3\ cement}$	[28]
	Gypsum in LC3	0.05	t $t^{-1}_{LC3\ cement}$	[28]
	Limestone in LC3	0.15	t $t^{-1}_{LC3\ cement}$	[28]
	Electricity needs	0.016	MWh $t^{-1}_{LC3\ cement}$	[28]
	Electricity needs grinding	0.024	MWh $t^{-1}_{LC3\ cement}$	[28]
	Heating	2.775	GJ $t^{-1}_{calcined\ clay}$	[28]
Biofuel	Energy density hardwood pallets	16.45	GJ t^{-1}_{pellet}	[55]

Table S9: Assumptions carbon footprint reduction assessment. The assessment was adapted from Ostovari et al. 25. Multiple values are not displayed, as they belong to propriety datasets. Some propriety data shown here has before been published in Ostovari et al. 25 with the approval of the GaBi.

Description	Name of data set	Database / Reference	Year	Value	Unit
Electricity grid emission	Electricity grid mix [EU-28]	GaBi ts[93]GaBi ts[93]	2016	417	$kgCO_{2e}$ MWh^{-1}
Natural gas emission	Thermal energy from natural gas [EU-28]	GaBi ts[93]GaBi ts[93]	2016	241.0	$kgCO_{2e}$ MWh^{-1}
Transport train	Rail transport, average train, gross tonne weight 1000t / 726t payload capacity [EU-28]	GaBi ts[93]GaBi ts[93]	2016	0.0258	$kgCO_{2e}$ km^{-1} t^{-1}
Transport truck	Transport, small truck (up to 14 t total cap., 9.3t payload) [EU-28]	GaBi ts[93]GaBi ts[93]	2016	0.0791	$kgCO_{2e}$ km^{-1} t^{-1}
Transport ship	/	Psaraftis and Kontovas[94]	/	0.033	$kgCO_{2e}$ km^{-1} t^{-1}
Water	Process water [EU-28]	GaBi ts[93]GaBi ts[93]	2016	/	$kgCO_{2e}$ t^{-1}
$NaHCO_3$	Sodium bicarbonate	GaBi ts[93]GaBi ts[93]	2017	/	$kgCO_{2e}$ t^{-1}
NaCl	Sodium chloride (rock salt) [EU-28]	GaBi ts[93]GaBi ts[93]	2016	/	$kgCO_{2e}$ t^{-1}
$(NH_4)_2SO_4$	Ammonium sulfate production [RoW]	Ecoinvent 3.71[95] Ecoinvent 3.71[95]	2019	/	$kgCO_{2e}$ t^{-1}
Monoethanolamine	/	Pehnt and Henkel[92]	/	/	$kgCO_{2e}$ t^{-1}
Mining Mineral	/	Ostovari, *et al.*[26]	/	5.23	kWh t^{-1}
Wood chips	/	Eco Invent 3.10	/	/	$kgCO_{2e}$ t^{-1}

Table S10: Summary of costs for each cement intervention.

Nr	Type of intervention	Where can this be installed?	Process	Capacity [Mt a^{-1}]	TCR [M€]	$OPEX_{fixed}$ [€ a^{-1}]	$OPEX_{var.}$ [€ t^{-1}_{cement}]
1	Baseline	Incumbent	Integrated cement plant	1	219	10	24
2	Intervention	for Cement plant	Carbon capture	1	53	3	32
3	Intervention	for Cement plant	Biofuels	1	0	0	38
4	Intervention	for Cement plant	Carbon capture and biofuels	1	53	3	70
5	Intervention	for Cement plant	CO_2 Mineralisation	1	64	4	15
6	Intervention	for Cement plant	Biofuels and CO_2 Mineralisation	1	64	4	42
7	Intervention	for Cement plant	Carbon capture, biofuels and CO_2 Mineralisation	1	77	5	52

Table S11: Summary of costs for Direct Air Capture plants.

Nr	**Type of interven-tion**	**Where can this be in-stalled?**	**Process**	**Capacity [Mt a^{-1}]**	**TCR [M€]**	**$OPEX_{fixed}$ [€ a^{-1}]**	**$OPEX_{var.}$ [€ $t^{-1}CO_2$]**	**Refer-ence**
1	New plant	Every-where	Solvent-based DAC (FOAK)	0.98	1663	66.8	2	[96]
2	New plant	Every-where	Solvent-based DAC (NOAK)	0.98	571	37.6	2	[96]
3	New plant	Every-where	Solid sorbent DAC (FOAK)	0.000959 9*	11	3	115	[96]
4	New plant	Every-where	Solid sorbent DAC (NOAK)	0.000959 9*	1	0.4	69	[96]

Table S12: Summary of costs for CO_2 Transport

Type of intervention	Where can this be installed?	Type	Capacity [tCO_2 $30min^{-1}$]	TCR d^{-1}* [M€ km^{-1}]	$OPEX_{fixed}$ [M€ a^{-1}]	$OPEX_{var}$ [€ $t^{-1}CO_2$]	Reference
New pipe	Onshore	12INCH	114.2	0.52	/	2.9E-09	[97,98]
New pipe	Onshore	16INCH	285.4	0.93	/	2.9E-09	[97,98]
New pipe	Onshore	24INCH	570.8	1.30	/	2.9E-09	[97,98]
New pipe	Onshore	28INCH	856.2	1.46	/	2.9E-09	[97,98]
New pipe	Onshore	32INCH	1426.9	1.62	/	2.9E-09	[97,98]
New pipe	Onshore	40INCH	2397.3	2.18	/	2.9E-09	[97,98]
New pipe	Offshore	12INCH	114.2	1.02	/	7.6E-09	[97,98]
New pipe	Offshore	16INCH	285.4	1.21	/	7.6E-09	[97,98]
New pipe	Offshore	24INCH	570.8	1.69	/	7.6E-09	[97,98]
New pipe	Offshore	28INCH	856.2	1.90	/	7.6E-09	[97,98]
New pipe	Offshore	32INCH	1426.9	2.11	/	7.6E-09	[97,98]
Type of intervention	**Where can this be installed?**	**Type**	**Capacity [tCO_2 $30min^{-1}$]**	**TCR [M€]**	**$OPEX_{fixed}$ [M€ a^{-1}]**	**$OPEX_{var}$ [€ $t^{-1}CO_2$]**	**Reference**
New unit	/	Small CO_2 compressor*	63.5	2.20	0.09	4.06E-04	[97]
New unit	/	Large CO_2 compressor*	635.4	22.0	0.88	4.06E-03	[97]

*The capital costs are reported in TCR in M€ per distance (d) in km.
**A compressor needs to be placed between onshore and offshore pipelines.

Table S13: Changes in $OPEX_{variable}$ for different feedstock and fuel price scenarios in € t^{-1}_{cement}.

Intervention	Min biofuel	Max biofuel	Min olivine	Max olivine	Min clay	Max clay	Min energy	Max energy
Integrated cement plant	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-4.98 €	34.06 €
Carbon capture	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-16.50 €	25.23 €
Biofuels	-25.04 €	31.38 €	0.00 €	0.00 €	0.00 €	0.00 €	3.19 €	-11.69 €
Carbon capture, biomass	-25.04 €	31.38 €	0.00 €	0.00 €	0.00 €	0.00 €	-13.31 €	13.54 €
CO_2 Mineralisation	0.00 €	0.00 €	-0.58 €	6.96 €	0.00 €	0.00 €	-4.43 €	14.22 €
Biofuels and CO_2 Mineralisation	-17.53 €	21.97 €	-0.58 €	6.96 €	0.00 €	0.00 €	-2.20 €	6.04 €
Carbon capture, biomass and CO_2 Mineralisation	-17.53 €	21.97 €	-0.58 €	6.96 €	0.00 €	0.00 €	-9.40 €	10.90 €
Carbon Capture and CO_2 Mineralisation	0.00 €	0.00 €	-0.58 €	6.96 €	0.00 €	0.00 €	-11.63 €	19.08 €
Calcined clay	0.00 €	0.00 €	0.00 €	0.00 €	-3.49 €	41.84 €	1.95 €	-10.25 €
Calcined clay, biomass	-19.17 €	24.03 €	0.00 €	0.00 €	-3.49 €	41.84 €	3.54 €	-16.10 €
CCS, calcined clay	0.00 €	0.00 €	0.00 €	0.00 €	-3.49 €	41.84 €	-6.56 €	-1.98 €
CCS, calcined clay, biomass	-19.17 €	24.03 €	0.00 €	0.00 €	-3.49 €	41.84 €	-5.71 €	8.96 €

Table S14: Breakdown of costs for baseline cement plant. Excluding transport of feedstock or CO_2. Calculations based on Voldsund, et al.[6].

	Baseline cement plant	Unit
Capacity	1000000	$t_{clinker}$ a^{-1}
	1000000	t_{cement} a^{-1}
	Capital costs	
TDC (with project contingencies)	149.80	M€
EPC	170.77	M€
TPC	193.24	M€
TPC Nth of a kind	193.24	M€
TCR Nth of a kind	218.59	M€
annualized TCR	19.94	M€ a^{-1}
	Fixed Opex	
Insurance and loc. Tax	3.86	M€ a^{-1}
Maintenance	4.83	M€ a^{-1}
Labour Operating	0.78	M€ a^{-1}
Labour Admin	0.82	M€ a^{-1}
Fixed Opex	10.30	M€ a^{-1}
	Variable Opex	
Electricity	8.18	M€ a^{-1}
Coal	9.40	M€ a^{-1}
Raw Meal	5.00	M€ a^{-1}
Ammonia for SNR	0.65	M€ a^{-1}
Other	1.10	M€ a^{-1}

Variable Opex	24.33	M€ a^{-1}
Specific variable opex	24.33	€ t^{-1}_{cement}
Levelised costs of cement		
Levelised Costs	54.57	€ t^{-1}_{cement}

Table S15: Breakdown of costs for cement plant with CCS. Excluding transport of feedstock or CO_2. Calculations based on Voldsund, et al.[6].

Cement plant with CCS		Unit
Capacity	1000000	tclinker
	1000000	t cement
Capacity	765000	tCO_2 a^{-1}
Capital costs		
$TDC_{capture}$	47.60	M€
$EPC_{capture}$	50.93	M€
$TPC_{capture}$	91.39	M€
TPC Nth of a kind capture	56.45	M€
TPC Nth of a kind cement	193.24	M€
TPC Nth of a kind Total	249.69	M€
TCR Nth of a kind Total	271.51	M€
annualized TCR	27.02	M€ a^{-1}
Fixed Opex		
Insurance and loc. Tax	4.99	M€ a^{-1}
Maintenance	6.24	M€ a^{-1}
Labour Operating	0.78	M€ a^{-1}
Labour Admin	0.98	M€ a^{-1}
Fixed Opex	13.00	M€ a^{-1}
Variable Opex		
electricity	23.35	M€ a^{-1}
Steam	19.13	M€ a^{-1}
Coal	9.40	M€ a^{-1}
Raw Meal	5.00	M€ a^{-1}
Ammonia for SNR	0.65	M€ a^{-1}
Other	1.10	M€ a^{-1}
Cooling water	1.01	M€ a^{-1}
MEA makeup	1.51	M€ a^{-1}
Variable Opex	61.15	M€ a^{-1}
Specific variable opex	61.15	€ t^{-1}_{cement}
Specific variable opex w/o electricity and natgas	18.68	€ t^{-1}_{cement}
Levelised costs of cement		
Levelised Costs of cement	101.18	€ t^{-1}_{cement}

Table S16: Breakdown of costs for cement plant with biofuel. Excluding transport of feedstock or CO_2. Calculations based on Voldsund, et al.[6] and Telmo and Lousada[55].

Cement plant with biofuel		Unit
Capacity	1000000	tclinker
	1000000	t cement
Capital costs		
TDC (with project contingencies)	149.80	M€
EPC	170.77	M€
TPC	193.24	M€
TPC Nth of a kind	193.24	M€
TCR Nth of a kind	218.59	M€
annualized TCR	19.94	M€ a^{-1}
Fixed Opex		
Insurance and loc. Tax	3.86	M€ a^{-1}
Maintenance	4.83	M€ a^{-1}
Labour Operating	0.78	M€ a^{-1}
Labour Admin	0.82	M€ a^{-1}
Fixed Opex	10.30	M€ a^{-1}
Variable Opex		
Electricity	8.18	M€ a^{-1}
Wood pellets	46.98	M€ a^{-1}
Raw Meal	5.00	M€ a^{-1}
Ammonia for SNR	0.65	M€ a^{-1}
Other	1.10	M€ a^{-1}
Variable Opex	61.91	M€ a^{-1}
Specific variable opex	61.91	€ t^{-1}_{cement}
Specific variable opex w/o electricity and natgas	53.73	€ t^{-1}_{cement}
Levelised costs of cement		
Levelised Costs	92.15	€ t^{-1}_{cement}

Table S17: Breakdown of costs for cement plant with CCS, biofuel. Excluding transport of feedstock or CO_2. Calculations based on Voldsund, et al.[6] and Telmo and Lousada[55].

Cement plant with CCS, biofuel		Unit
Capacity	1000000	tclinker
	1000000	tcement
Capacity	765000	tCO_2 a^{-1}
Capital costs		
$TDC_{capture}$	47.60	M€
$EPC_{capture}$	50.93	M€
$TPC_{capture}$	91.39	M€
TPC Nth of a kind **capture**	56.45	M€
TPC Nth of a kind **cement**	193.24	M€
TPC Nth of a kind **Total**	249.69	M€
TCR Nth of a kind **Total**	271.51	M€
annualized TCR	27.02	M€ a^{-1}
Fixed Opex		
Insurance and loc. Tax	4.99	M€ a^{-1}
Maintenance	6.24	M€ a^{-1}
Labour Operating	0.78	M€ a^{-1}
Labour Admin	0.98	M€ a^{-1}
Fixed Opex	13.00	M€ a^{-1}
Variable Opex		
electricity	23.35	M€ a^{-1}
Steam	19.13	M€ a^{-1}
Biomass	46.98	M€ a^{-1}
Raw Meal	5.00	M€ a^{-1}
Ammonia for SNR	0.65	M€ a^{-1}
Other	1.10	M€ a^{-1}
Cooling water	1.01	M€ a^{-1}
MEA makeup	1.51	M€ a^{-1}
Variable Opex	98.73	M€ a^{-1}
Specific variable opex	98.73	€ t^{-1}_{cement}
Specific variable opex w/o electricity and natgas	56.26	€ t^{-1}_{cement}
Levelised costs of cement		
Levelised Costs of cement	138.76	€ t^{-1}_{cement}

Table S18: Breakdown of costs for cement plant with CO_2 mineralisation. Excluding transport of feedstock or CO_2. Calculations based on Voldsund, et al.[6] and Strunge, et al.[19].

Cement plant with CO_2 mineralisation		Unit
Capacity cement	1000000	tcement a^{-1}
Capacity CO_2	175806	tCO_2 stored a-1
Capacity CO_2	175806	tCO_2 captured a-1
Capacity SCM	300000	tscm produced a-1
Capacity SCM	700000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Mineralisation plant	45.18	M€
TDC (incl. installation) Capture plant	19.70	M€
TDC total (mineralisation & capture)	64.88	M€
EPC (mineralisation & capture)	71.20	M€
TPC (mineralisation & capture)	96.96	M€
TPC Nth of a kind (mineralisation & capture)	59.88	M€
TCR Nth of a kind (mineralisation & capture)	64.15	M€
TCR Nth of a kind (clinker)	218.59	M€
TCR Nth of a kind total	282.74	M€
annualized TCR	24.38	M€ a^{-1}
Fixed Opex		
Insurance and loc. Tax	5.65	
Maintenance	7.07	M€ a^{-1}
Labour Operating	0.58	M€ a^{-1}
Labour Admin	1.02	M€ a^{-1}
Fixed Opex	14.33	M€ a^{-1}
Variable Opex		

electricity (mineralisation)	7.93	M€ a^{-1}
heat (mineralisation)	1.20	M€ a^{-1}
Mineral (mineralisation)	1.93	M€ a^{-1}
Additives (mineralisation)	1.56	M€ a^{-1}
Process water (mineralisation)	0.91	M€ a^{-1}
electricity (capture)	8.33	M€ a^{-1}
Steam (capture)	4.40	M€ a^{-1}
Cooling water (capture)	0.23	M€ a^{-1}
MEA makeup (capture)	0.35	M€ a^{-1}
Electricity (clinker)	5.73	M€ a^{-1}
Coal (clinker)	6.58	M€ a^{-1}
Raw Meal (clinker)	3.50	M€ a^{-1}
Ammonia for SNR (clinker)	0.45	M€ a^{-1}
Other (clinker)	0.77	M€ a^{-1}
Variable Opex	43.86	M€ a^{-1}
Specific	43.86	€ t^{-1}_{cement}
Specific variable opex w/o electricity and natgas	22.01	€ t^{-1}_{cement}
Levelised costs of cement		
Levelised Costs of cement	82.57	€ t^{-1}_{cement}

Table S19: Breakdown of costs for cement plant with CO_2 mineralisation, biofuel. Excluding transport of feed-stock or CO_2. Calculations based on Voldsund, et al.[6], Strunge, et al.[19] and Telmo and Lousada[55].

Cement plant with CO_2 mineralisation, biofuel		Unit
Capacity cement	1000000	tcement a^{-1}
Capacity CO_2	175806	tCO_2 stored a-1
Capacity CO_2	175806	tCO_2 captured a-1
Capacity SCM	300000	tscm produced a-1
Capacity SCM	700000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Mineralisation plant	45	M€
TDC (incl. installation) Capture plant	20	M€
TDC total (mineralisation & capture)	65	M€
EPC (mineralisation & capture)	71	M€
TPC (mineralisation & capture)	97	M€
TPC Nth of a kind (mineralisation & capture)	60	M€
TCR Nth of a kind (mineralisation & capture)	64	M€
TCR Nth of a kind (clinker)	219	M€
TCR Nth of a kind total	283	M€
annualized TCR	24	M€ a^{-1}
Fixed Opex		
Insurance and loc. Tax	5.65	M€ a^{-1}
Maintenance	7.07	M€ a^{-1}
Labour Operating	0.58	M€ a^{-1}
Labour Admin	1.02	M€ a^{-1}
Fixed Opex	14.33	M€ a^{-1}
Variable Opex		
electricity (mineralisation)	7.93	M€ a^{-1}
heat (mineralisation)	1.20	M€ a^{-1}
Mineral (mineralisation)	1.93	M€ a^{-1}
Additives (mineralisation)	1.56	M€ a^{-1}
Process water (mineralisation)	0.91	M€ a^{-1}
electricity (capture)	8.33	M€ a^{-1}
Steam (capture)	4.40	M€ a^{-1}
Cooling water (capture)	0.23	M€ a^{-1}
MEA makeup (capture)	0.35	M€ a^{-1}
Electricity (clinker)	5.73	M€ a^{-1}

Coal (clinker)	32.89	M€ a^{-1}
Raw Meal (clinker)	3.50	M€ a^{-1}
Ammonia for SNR (clinker)	0.45	M€ a^{-1}
Other (clinker)	0.77	M€ a^{-1}
Variable Opex	70.17	M€ a^{-1}
Specific	70.17	€ $t^{-1}{}_{cement}$
Specific variable opex w/o electricity and natgas	48.32	€ $t^{-1}{}_{cement}$
Levelised Costs of mineralisation		
Levelised Costs of cement	108.88	€ $t^{-1}{}_{cement}$

Table S20: Breakdown of costs for cement plant with CO_2 mineralisation, CCS. Excluding transport of feed-stock or CO_2. Calculations based on Voldsund, et al.[6] and Strunge, et al.[19].

Cement plant with CO_2 mineralisation, CCS		Unit
Capacity cement	1000000	tcement a-1
Capacity CO_2	175806	tCO_2 stored a-1
Capacity CO_2	535500	tCO_2 captured a-1
Capacity SCM	300000	tscm produced a-1
Capacity SCM	700000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Mineralisation plant	45	M€
TDC (incl. installation) Capture plant	38	M€
TDC total (mineralisation & capture)	84	M€
EPC (mineralisation & capture)	90	M€
TPC (mineralisation & capture)	116	M€
TPC Nth of a kind (mineralisation & capture)	71	M€
TCR Nth of a kind (mineralisation & capture)	77	M€
TCR Nth of a kind (clinker)	219	M€
TCR Nth of a kind total	295	M€
annualized TCR	25	M€ a-1
Fixed Opex		
Insurance and loc. Tax	6	M€ a-1
Maintenance	7	M€ a-1
Labour Operating	1	M€ a-1
Labour Admin	1	M€ a-1
Fixed Opex	15	M€ a-1
Variable Opex		
electricity (mineralisation)	8	M€ a-1
heat (mineralisation)	1	M€ a-1
Mineral (mineralisation)	2	M€ a-1
Additives (mineralisation)	2	M€ a-1
Process water (mineralisation)	1	M€ a-1
electricity (capture)	9	M€ a-1
Steam (capture)	13	M€ a-1
Cooling water (capture)	1	M€ a-1
MEA makeup (capture)	1	M€ a-1
Electricity (clinker)	6	M€ a-1
Coal (clinker)	7	M€ a-1
Raw Meal (clinker)	4	M€ a-1
Ammonia for SNR (clinker)	0	M€ a-1
Other (clinker)	1	M€ a-1
Variable Opex	54	M€ a-1
Specific	54	€ $t^{-1}{}_{cement}$
Specific variable opex w/o electricity and natgas	23	€ $t^{-1}{}_{cement}$
Levelised costs of cement		
Levelised Costs of cement	95	€ $t^{-1}{}_{cement}$

Table S21: Breakdown of costs for cement plant with CO_2 mineralisation, biofuel, CCS. Excluding transport of feedstock or CO_2***. Calculations based on Voldsund, et al.[6], Strunge, et al.[19] and Telmo and Lousada[55].***

Cement plant with CO_2 mineralisation, biofuel, CCS		Unit
Capacity cement	1000000	tcement a-1
Capacity CO_2 Mineralisation	175806	tCO_2 stored a-1
Capacity CO_2 Capture	535500	tCO_2 captured a-1
Capacity SCM	300000	tscm produced a-1
Capacity SCM	700000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Mineralisation plant	45.18	M€
TDC (incl. installation) Capture plant	38.43	M€
TDC total (mineralisation & capture)	83.61	M€
EPC (mineralisation & capture)	89.93	M€
TPC (mineralisation & capture)	115.69	M€
TPC Nth of a kind (mineralisation & capture)	71.45	M€
TCR Nth of a kind (mineralisation & capture)	76.53	M€
TCR Nth of a kind (clinker)	218.59	M€

TCR Nth of a kind total	295.12	M€
annualized TCR	25.45	M€ a-1
Fixed Opex		
Insurance and loc. Tax	5.90	M€ a-1
Maintenance	7.38	M€ a-1
Labour Operating	0.58	M€ a-1
Labour Admin	1.06	M€ a-1
Fixed Opex	14.92	M€ a-1
Variable Opex		
electricity (mineralisation)	7.93	M€ a-1
heat (mineralisation)	1.20	M€ a-1
Mineral (mineralisation)	1.93	M€ a-1
Additives (mineralisation)	1.56	M€ a-1
Process water (mineralisation)	0.91	M€ a-1
electricity (capture)	8.62	M€ a-1
Steam (capture)	13.39	M€ a-1
Cooling water (capture)	0.71	M€ a-1
MEA makeup (capture)	1.06	M€ a-1
Electricity (clinker)	5.73	M€ a-1
Coal (clinker)	32.89	M€ a-1
Raw Meal (clinker)	3.50	M€ a-1
Ammonia for SNR (clinker)	0.45	M€ a-1
Other (clinker)	0.77	M€ a-1
Variable Opex	80.64	M€ a-1
Specific	80.64	€ $t^{-1}{}_{cement}$
Specific variable opex w/o electricity and natgas	49.50	€ $t^{-1}{}_{cement}$
Levelised Costs of mineralisation		
Levelised Costs of cement	121.01	€ $t^{-1}{}_{cement}$

Table S22: Breakdown of costs for cement plant with calcined clay. Excluding transport of feedstock or CO_2***. Calculations based on Voldsund, et al.[6] and Sánchez Berriel, et al.[28].***

Cement plant with calcined clay		Unit
Capacity cement	1000000	tcement a-1
Capacity CO_2 storage (in cement product)	0	tCO_2 stored a-1
Capacity CO_2 capture	0	tCO_2 captured a-1
Capacity Calcined clay	300000	tscm produced a-1
Capacity Clinker	500000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Calcination plant	24.00	M€
EPC (calcination)	3.36	M€
TPC (calcination)	17.04	M€
TPC Nth of a kind (calcination)	10.52	M€
TCR Nth of a kind (calcination)	13.11	M€
TCR Nth of a kind (clinker)	218.59	M€
TCR Nth of a kind total	231.70	M€
annualized TCR	19.98	M€ a-1
Fixed Opex		
Insurance and loc. Tax	4.63	M€ a-1
Maintenance	5.79	M€ a-1
Labour Operating	0.58	M€ a-1
Labour Admin	0.87	M€ a-1
Fixed Opex	11.88	M€ a-1
Variable Opex		
Electricity (calcined clay)	2.48	M€ a-1
Heat (calcined clay)	2.50	M€ a-1
Clay	10.46	M€ a-1
Gypsum	1.00	M€ a-1
Limestone (as additive)	4.69	M€ a-1
Electricity (clinker)	4.09	M€ a-1
Coal (clinker)	4.70	M€ a-1
Raw Meal (clinker)	2.50	M€ a-1
Ammonia for SNR (clinker)	0.32	M€ a-1
Other (clinker)	0.55	M€ a-1
Variable Opex	33.29	M€ a-1
Specific	33.29	€ $t^{-1}{}_{cement}$

Specific variable opex w/o electricity and natgas	28.31	€ t^{-1}_{cement}
Levelised Costs of mineralisation		
Levelised Costs of cement	65.15	€ t^{-1}_{cement}

Table S23: Breakdown of costs for cement plant with calcined clay, biofuel. Excluding transport of feedstock or CO_2***. Calculations based on Voldsund, et al.[6], Sánchez Berriel, et al.[28] and Telmo and Lousada[55].***

Cement plant with calcined clay, biofuel		Unit
Capacity cement	1000000	tcement a-1
Capacity CO_2 storage (in cement product)	0	tCO_2 stored a-1
Capacity CO_2 capture	0	tCO_2 captured a-1
Capacity Calcined clay	300000	tscm produced a-1
Capacity Clinker	500000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Calcination plant	24.00	M€
EPC (calcination)	3.36	M€
TPC (calcination)	17.04	M€
TPC Nth of a kind (calcination)	10.52	M€
TCR Nth of a kind (calcination)	13.11	M€
TCR Nth of a kind (clinker)	218.59	M€
TCR Nth of a kind total	231.70	M€
annualized TCR	19.98	M€ a-1
Fixed Opex		
Insurance and loc. Tax	4.63	M€ a-1
Maintenance	5.79	M€ a-1
Labour Operating	0.58	M€ a-1
Labour Admin	0.87	M€ a-1
Fixed Opex	11.88	M€ a-1
Variable Opex		
Electricity (calcined clay)	2.48	M€ a-1
Biomass (calcined clay)	12.49	M€ a-1
Clay	10.46	M€ a-1
Gypsum	1.00	M€ a-1
Limestone (as additive)	4.69	M€ a-1
Electricity (clinker)	4.09	M€ a-1
Biomass (clinker)	23.51	M€ a-1
Raw Meal (clinker)	2.50	M€ a-1
Ammonia for SNR (clinker)	0.32	M€ a-1
Other (clinker)	0.55	M€ a-1
Variable Opex	62.09	M€ a-1
Specific	62.09	€ t^{-1}_{cement}
Specific variable opex w/o electricity and natgas	47.12	€ t^{-1}_{cement}
Levelised Costs of mineralisation		
Levelised Costs of cement	93.95	€ t^{-1}_{cement}

Table S24: Breakdown of costs for cement plant with calcined clay, CCS. Excluding transport of feedstock or CO_2***. Calculations based on Voldsund, et al.[6] and Sánchez Berriel, et al.[28].***

Cement plant with calcined clay, CCS		Unit
Capacity cement	1000000	tcement a-1
Capacity CO_2 storage (in cement product)	0	tCO_2 stored a-1
Capacity CO_2 capture	382500	tCO_2 captured a-1
Capacity Calcined clay	300000	tscm produced a-1
Capacity Clinker	500000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Calcination plant	24.00	M€
TDC (incl. installation) Capture plant	31.40	M€
TDC total (calcination & capture)	55.40	M€

EPC (calcination & capture)	58.76	M€
TPC (calcination & capture)	72.44	M€
TPC Nth of a kind (calcination & capture)	44.74	M€
TCR Nth of a kind (calcination & capture)	50.29	M€
TCR Nth of a kind (clinker)	218.59	M€
TCR Nth of a kind total	268.88	M€
annualized TCR	23.19	M€ a-1
Fixed Opex		
Insurance and loc. Tax	5.38	M€ a-1
Maintenance	6.72	M€ a-1
Labour Operating	0.58	M€ a-1
Labour Admin	0.98	M€ a-1
Fixed Opex	13.66	M€ a-1
Variable Opex		
Electricity (calcined clay)	2.48	M€ a-1
Heat (calcined clay)	2.50	M€ a-1
Clay	10.46	M€ a-1
Gypsum	1.00	M€ a-1
Limestone (as additive)	4.69	M€ a-1
electricity (capture)	8.49	M€ a-1
Steam (capture)	9.56	M€ a-1
Cooling water (capture)	0.51	M€ a-1
MEA makeup (capture)	0.76	M€ a-1
Electricity (clinker)	4.09	M€ a-1
Coal (clinker)	4.70	M€ a-1
Raw Meal (clinker)	2.50	M€ a-1
Ammonia for SNR (clinker)	0.32	M€ a-1
Other (clinker)	0.55	M€ a-1
Variable Opex	52.61	M€ a-1
Specific	52.61	€ $t^{-1}{}_{cement}$
Specific variable opex w/o electricity and natgas	29.58	€ $t^{-1}{}_{cement}$
Levelised Costs of mineralisation		
Levelised Costs of cement	89.46	€ $t^{-1}{}_{cement}$

Table S25: Breakdown of costs for cement plant with calcined clay, biofuel, CCS. Excluding transport of feed-stock or CO_2. ***Calculations based on Voldsund, et al.[6], Sánchez Berriel, et al.[28] and Telmo and Lousada[55].***

Cement plant with calcined clay, biofuel, CCS		Unit
Capacity cement	1000000	tcement a-1
Capacity CO_2 storage (in cement product)	0	tCO_2 stored a-1
Capacity CO_2 capture	382500	tCO_2 captured a-1
Capacity Calcined clay	300000	tscm produced a-1
Capacity Clinker	500000	tclinker produced a-1
Capital costs		
TDC (incl. installation) Calcination plant	24.00	M€
TDC (incl. installation) Capture plant	31.40	M€
TDC total (calcination & capture)	55.40	M€
EPC (calcination & capture)	58.76	M€
TPC (calcination & capture)	72.44	M€
TPC Nth of a kind (calcination & capture)	44.74	M€
TCR Nth of a kind (calcination & capture)	50.29	M€
TCR Nth of a kind (clinker)	218.59	M€
TCR Nth of a kind total	268.88	M€
annualized TCR	23.19	M€ a-1
Fixed Opex		
Insurance and loc. Tax	5.38	M€ a-1
Maintenance	6.72	M€ a-1
Labour Operating	0.58	M€ a-1
Labour Admin	0.98	M€ a-1
Fixed Opex	13.66	M€ a-1
Variable Opex		
Electricity (calcined clay)	2.48	M€ a-1
Biomass (calcined clay)	12.48	M€ a-1
Clay	10.46	M€ a-1
Gypsum	1.00	M€ a-1
Limestone (as additive)	4.69	M€ a-1
electricity (capture)	15.77	M€ a-1
Steam (capture)	9.56	M€ a-1
Cooling water (capture)	0.51	M€ a-1
MEA makeup (capture)	0.76	M€ a-1
Electricity (clinker)	4.09	M€ a-1
Biomass (clinker)	23.49	M€ a-1
Raw Meal (clinker)	2.50	M€ a-1
Ammonia for SNR (clinker)	0.32	M€ a-1
Other (clinker)	0.55	M€ a-1

Variable Opex	88.66	M€ a-1
Specific	88.66	€ $t^{-1}{}_{cement}$
Specific variable opex w/o electricity and natgas	48.37	€ $t^{-1}{}_{cement}$
Levelised Costs of mineralisation		
Levelised Costs of cement	125.51	€ $t^{-1}{}_{cement}$

Table S26: Results of non-collaborative analysis. For a cement plant assuming full capacity and a clinker factor of 1.

Germany

Cement plant OID	Parent Company	Chosen intervention	Added cost in € t_{cement}^{-1}	Added costs in M€ a^{-1}
CID4	Buzzi Unicem SpA	CCS_CALCINED_CLAY_CEMENT	1.5	1.5
CID5	Buzzi Unicem SpA	CCS_CALCINED_CLAY_CEMENT	2.2	4
CID2	Buzzi Unicem SpA	CCS_CALCINED_CLAY_CEMENT	2.1	2.1
CID3	Buzzi Unicem SpA	CCS_CALCINED_CLAY_CEMENT	2.2	2.2
CID1	Buzzi Unicem SpA	CCS_CALCINED_CLAY_CEMENT	2.6	5.1
CID13	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	4.7	6.2
CID10	CRH PLC	CCS_CALCINED_CLAY_CEMENT	0.7	1.3
CID11	CRH PLC	CCS_CALCINED_CLAY_CEMENT	9.1	9.1
CID20	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	1.7	1.7
CID23	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	2.3	2.3
CID17	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.5	3.5
CID22	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.0	3
CID19	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.4	3.4
CID18	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.1	2.1
CID16	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.6	3.6
CID21	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	5.8	8.1
CID26	Hugo Miebach GmbH	CCS_CALCINED_CLAY_CEMENT	9.1	8.2
CID29	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	3.2	3.2
CID30	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	6.8	6.8
CID28	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	2.7	2.5
CID27	LafargeHolcim Ltd	CALCINED_CLAY_CEMENT	4.9	5.7
CID35	Maerker Zement GmbH	CCS_CALCINED_CLAY_CEMENT	11.9	11.9
CID37	Phoenix Zementwerke Krogbeumker GmbH & Co KG	CCS_CALCINED_CLAY_CEMENT	7.1	7.1
CID39	Rohrdorfer Zementwerke	CALCINED_CLAY_CEMENT	1.9	1.3
CID43	SCHWENK Zement KG	CCS_CALCINED_CLAY_CEMENT	3.7	3.5
CID40	SCHWENK Zement KG	CCS_CALCINED_CLAY_CEMENT	4.6	7.7
CID42	SCHWENK Zement KG	CCS_CALCINED_CLAY_CEMENT	5.1	4.8
CID41	SCHWENK Zement KG	CCS_CALCINED_CLAY_CEMENT	5.6	9.5
CID45	Solnhofer Portland-Zementwerke GmbH & Co KG	CCS_CALCINED_CLAY_CEMENT	12.4	12.4
CID46	Spenner & GmbH Co KG	CCS_CALCINED_CLAY_CEMENT	7.4	7.4
CID9	thomas Beteiligungen GmbH	CCS_CALCINED_CLAY_CEMENT	7.4	7.5
			Sum:	158.7

United Kingdom and Ireland

Cement plant OID	Parent Company	Chosen intervention	Added cost in € t_{cement}^{-1}	Added costs in M€ a^{-1}
CID53	Breedon Group PLC	CCS_CALCINED_CLAY_CEMENT	10.2	11.3
CID71	Breedon Group PLC	CALCINED_CLAY_BIOMASS_CEMENT	7.8	4
CID58	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	0.2	0.1
CID59	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	12.0	15.9
CID55	CRH PLC	CCS_CALCINED_CLAY_CEMENT	8.5	6.2
CID73	CRH PLC	CCS_CALCINED_CLAY_CEMENT	4.2	8.8
CID54	CRH PLC	CALCINED_CLAY_CEMENT	5.5	2
CID72	CRH PLC	CALCINED_CLAY_BIOMASS_CEMENT	1.0	0.6
CID56	CRH PLC	CCS_CALCINED_CLAY_CEMENT	4.6	3.4
CID62	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.2	2.2
CID61	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	8.0	7.7
CID63	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	3.8	6
CID68	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	14.8	10.5
CID67	LafargeHolcim Ltd	CALCINED_CLAY_CEMENT	2.4	0.9

CID74	Mannok Build Ltd	CCS_CALCINED_CLAY_CEMENT	2.1	4.9
CID70	Mannok Build Ltd	CCS_CEMENT	11.0	9.5
			Sum:	94

Portugal and Spain

Cement plant OID	Parent Company	Chosen intervention	Added cost in € tcement-1	Added costs in M€ a-1
CID75	AG Cementos Balboa SA	CCS_CALCINED_CLAY_CEMENT	4.9	6.4
CID81	Cementos Portland Valderrivas SA	CCS_CALCINED_CLAY_CEMENT	2.0	3.8
CID77	Cementos Portland Valderrivas SA	CCS_CALCINED_CLAY_CEMENT	3.7	7.7
CID80	Cementos Portland Valderrivas SA	CCS_CALCINED_CLAY_CEMENT	-1.2	-1.7
CID79	Cementos Portland Valderrivas SA	CCS_CALCINED_CLAY_CEMENT	5.5	4.5
CID78	Cementos Portland Valderrivas SA	CCS_CALCINED_CLAY_CEMENT	3.0	3.1
CID82	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	-0.9	-1.1
CID84	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	0.1	0.2
CID85	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	4.3	9.1
CID86	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	0.4	0.4
CID83	CEMEX SAB de CV	CCS_CALCINED_CLAY_CEMENT	9.0	15.1
CID89	Corporacion Masaveu SA	CCS_CALCINED_CLAY_CEMENT	3.1	4.1
CID87	Corporacion Masaveu SA	CCS_CALCINED_CLAY_CEMENT	3.1	4.5
CID88	Corporacion Masaveu SA	CCS_CALCINED_CLAY_CEMENT	3.1	5.9
CID76	CRH PLC	CALCINED_CLAY_CEMENT	8.0	6.7
CID90	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	5.8	7.5
CID92	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	5.8	12.2
CID91	HeidelbergCement AG	CCS_CALCINED_CLAY_CEMENT	5.6	7.3
CID104	InterCement Participacoes SA	CCS_CALCINED_CLAY_CEMENT	0.3	0.4
CID103	InterCement Participacoes SA	CCS_CALCINED_CLAY_CEMENT	0.8	1
CID105	InterCement Participacoes SA	CCS_CALCINED_CLAY_CEMENT	2.1	3.1
CID94	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	0.0	-0.1
CID97	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	3.2	2.8
CID93	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	-3.2	-4.5
CID95	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	-1.0	-1.4
CID96	LafargeHolcim Ltd	CCS_CALCINED_CLAY_CEMENT	6.9	16
CID108	Secil Companhia Geral de Cal e Cimento SA	CCS_CALCINED_CLAY_CEMENT	1.0	1.3
CID106	Secil Companhia Geral de Cal e Cimento SA	CCS_CALCINED_CLAY_CEMENT	0.6	0.4
CID107	Secil Companhia Geral de Cal e Cimento SA	CCS_CALCINED_CLAY_CEMENT	0.6	1.2
CID102		CALCINED_CLAY_CEMENT	3.2	4.2
CID100	Votorantim SA	CCS_CALCINED_CLAY_CEMENT	3.9	5.4
CID99	Votorantim SA	CCS_CALCINED_CLAY_CEMENT	3.1	4.1
CID101	Votorantim SA	CCS_CALCINED_CLAY_CEMENT	3.9	3.8
CID98	Votorantim SA	CCS_CALCINED_CLAY_CEMENT	3.9	3.8
			Sum:	116.5

Table S27: Results Sensitivity Analysis: selected interventions for cement plants in United Kingdom and Ireland.

Plant ID	Min bio	Max bio	Min olivine	Max olivine	Min clay	Max clay	Min energy	Max energy
CID74	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID73	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID72	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID71	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID70	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID68	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID67	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID63	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID62	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID61	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID59	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID58	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID56	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID55	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID54	CALCINED_CLAY_CEMENT	CALCINED_CLAY_CEMENT	CALCINED_CLAY_CEMENT	CALCINED_CLAY_CEMENT	CALCINED_CLAY_CEMENT	CCS_CEMENT	CALCINED_CLAY_CEMENT	CALCINED_CLAY_CEMENT
CID53	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT

Table S28: Results Sensitivity Analysis: selected interventions for cement plants in United Kingdom and Ireland without calcined clay.

Plant ID	Min bio	Max bio	Min olivine	Max olivine	Min energy	Max energy
CID74	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT
CID73	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID72	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT
CID71	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT
CID70	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT
CID68	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID67	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID63	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID62	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID61	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID59	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID58	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID56	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID55	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID54	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID53	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT

Table S29: Results Sensitivity Analysis: selected interventions for cement plants in Germany.

Plant ID	Min bio	Max bio	Min olivine	Max olivine	Min clay	Max clay	Min energy	Max energy
CID1	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID10	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID11	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID13	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID16	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID17	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID18	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID19	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID2	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID20	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID21	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID22	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID23	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID26	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID27	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID28	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID29	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID3	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID30	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID35	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID37	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID39	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID4	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID40	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID41	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID42	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID43	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID45	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID46	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID5	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID9	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT

Table S30: Results Sensitivity Analysis: selected interventions for cement plants in Germany without calcined clay.

Plant ID	Min bio	Max bio	Min olivine	Max olivine	Min energy	Max energy
CID46	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID45	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID43	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID42	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID41	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID40	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID39	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID37	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT
CID35	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID30	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID29	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID28	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID27	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID26	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID23	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID22	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID21	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID20	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT	CCS_BIOMASS_CEMENT
CID19	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID18	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID17	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID16	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID13	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID11	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID10	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID9	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID5	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID4	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID3	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID2	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID1	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT

Table S31: Results Sensitivity Analysis: selected interventions for cement plants in Portugal and Spain.

Plant ID	Min bio	Max bio	Min olivine	Max olivine	Min clay	Max clay	Min energy	Max energy
CID108	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID107	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID106	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID105	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID104	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID103	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID102	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID101	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID100	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID99	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID98	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID97	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID96	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID95	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID94	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID93	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID92	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID91	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID90	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID89	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID88	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID87	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID86	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID85	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID84	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID83	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID82	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID81	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID80	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID79	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID78	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID77	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_MINERAL_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID76	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT
CID75	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CEMENT	CCS_CALCINED_CLAY_CEMENT	CCS_CALCINED_CLAY_CEMENT

Table S32: Results Sensitivity Analysis: selected interventions for cement plants in Portugal and Spain without calcined clay.

Plant ID	Min bio	Max bio	Min olivine	Max olivine	Min energy	Max energy
CID108	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID107	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID106	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID105	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID104	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID103	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID102	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID101	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID100	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID99	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID98	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID97	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID96	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID95	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID94	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID93	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID92	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID91	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID90	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID89	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID88	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID87	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID86	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID85	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID84	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID83	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID82	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID81	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID80	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID79	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID78	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT
CID77	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT	CCS_MINERAL_CEMENT
CID76	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT	CCS_BIOMASS_MINERAL_CEMENT
CID75	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT	CCS_CEMENT

Table S33: List of all considered grid points. *Note Ports have been excluded from this table due to the large amount of points. Cement plant capacities and locations taken from Tkachenko, et al.*[78]*.Tkachenko, et al.*[78]*. *no capacity data was available. Here an average European cement plant was assumed. Storage sites taken from European Comission - Joint Research Centre*[39] *and Neele, et al.*[42]*. ** storage capacity assumed due to lack of data. Olivine-bearing rock locations taken from* **Kremer, *et al.*[18]. Kaolinite clay site locations taken from Dill[44], Galán, *et al.*[45] and British Geological Survey[46].**

Type	Country	VID	Latitude	Longitude	Capacity Mt_{cement} a^{-1}
Cement plant	GER	CID1	51.364109	10.48	2.61
Cement plant	GER	CID2	51.62267	8.50	1.3*
Cement plant	GER	CID3	49.602402	8.04	1.3*
Cement plant	GER	CID4	52.17459	7.89	1.41
Cement plant	GER	CID5	50.032201	8.26	2.43
Cement plant	GER	CID9	51.599521	8.34	1.3*
Cement plant	GER	CID10	51.270124	11.66	2.30
Cement plant	GER	CID11	49.016926	8.61	1.3*
Cement plant	GER	CID13	52.489222	13.84	1.79
Cement plant	GER	CID16	49.213555	12.03	1.3*
Cement plant	GER	CID17	51.857225	8.03	1.3*
Cement plant	GER	CID18	52.374756	9.88	0.90
Cement plant	GER	CID19	49.357624	8.69	1.3*
Cement plant	GER	CID20	51.698479	8.75	1.3*
Cement plant	GER	CID21	48.368982	9.74	1.90
Cement plant	GER	CID22	49.808084	9.62	1.3*
Cement plant	GER	CID23	51.618256	8.51	1.3*
Cement plant	GER	CID26	51.595161	8.34	1.21
Cement plant	GER	CID27	48.227348	8.78	1.60
Cement plant	GER	CID28	53.875099	9.58	1.29
Cement plant	GER	CID29	52.353363	9.89	1.3*
Cement plant	GER	CID30	51.765425	8.06	1.3*
Cement plant	GER	CID35	48.774206	10.70	1.3*
Cement plant	GER	CID37	51.759234	8.07	1.3*
Cement plant	GER	CID39	47.791873	12.18	0.97
Cement plant	GER	CID40	51.813271	11.75	2.26
Cement plant	GER	CID41	48.333264	9.73	2.29

Cement plant	GER	CID42	48.652954	10.16	1.28
Cement plant	GER	CID43	49.954669	9.77	1.31
Cement plant	GER	CID45	48.884764	11.00	1.3*
Cement plant	GER	CID46	51.602063	8.34	1.3*
Cement plant	UK	CID53	53.337916	-1.75	1.50
Cement plant	UK	CID54	51.397546	-3.39	0.50
Cement plant	UK	CID55	53.265267	-1.85	1.00
Cement plant	UK	CID56	55.979125	-2.47	1.00
Cement plant	UK	CID58	53.675822	-0.53	0.70
Cement plant	UK	CID59	52.377293	-1.29	1.80
Cement plant	UK	CID61	53.888913	-2.38	1.30
Cement plant	UK	CID62	53.152678	-3.06	0.91
Cement plant	UK	CID63	52.640356	-0.55	2.16
Cement plant	UK	CID67	54.618105	-6.77	0.48
Cement plant	UK	CID68	53.044003	-1.88	0.96
Cement plant	UK	CID70	54.143487	-7.57	1.17
Cement plant	IRE	CID71	53.432118	-7.14	0.70
Cement plant	IRE	CID72	52.641364	-8.69	0.80
Cement plant	IRE	CID73	53.684307	-6.39	2.80
Cement plant	IRE	CID74	54.130891	-7.58	1.13
Cement plant	ESP	CID75	38.3792	-6.48	1.3*
Cement plant	ESP	CID76	43.206524	-2.77	0.83
Cement plant	ESP	CID77	42.874825	-4.16	2.90
Cement plant	ESP	CID78	40.244961	-3.47	1.06
Cement plant	ESP	CID79	42.882983	-2.19	0.82
Cement plant	ESP	CID80	41.941676	-4.47	1.45
Cement plant	ESP	CID81	37.359736	-5.87	1.87
Cement plant	ESP	CID82	39.436556	-0.78	1.3*
Cement plant	ESP	CID83	41.475476	-1.49	1.68
Cement plant	ESP	CID84	38.378014	-0.54	1.53
Cement plant	ESP	CID85	40.576824	0.54	2.87
Cement plant	ESP	CID86	39.934332	-3.74	0.94
Cement plant	ESP	CID87	43.560582	-5.72	1.43
Cement plant	ESP	CID88	42.798654	-5.62	1.87
Cement plant	ESP	CID89	43.33011	-5.78	1.3*
Cement plant	ESP	CID90	43.204824	-2.90	1.3*
Cement plant	ESP	CID91	36.714681	-4.33	1.3*
Cement plant	ESP	CID92	43.285684	-2.00	2.87
Cement plant	ESP	CID93	36.966885	-1.90	1.39
Cement plant	ESP	CID94	36.618249	-6.07	2.92
Cement plant	ESP	CID95	40.009935	-3.90	1.3*
Cement plant	ESP	CID96	41.474698	2.18	2.31
Cement plant	ESP	CID97	39.663613	-0.25	0.88
Cement plant	ESP	CID98	37.902032	-4.76	0.98
Cement plant	ESP	CID99	37.359766	-6.67	1.3*
Cement plant	ESP	CID100	42.717483	-7.45	1.37
Cement plant	ESP	CID101	42.553519	-6.77	0.97
Cement plant	ESP	CID102	41.402821	2.05	1.3*
Cement plant	PT	CID103	38.922169	-9.01	1.18
Cement plant	PT	CID104	37.135933	-8.10	1.3*
Cement plant	PT	CID105	40.289074	-8.42	1.50
Cement plant	PT	CID106	39.685773	-8.91	0.62
Cement plant	PT	CID107	39.655677	-8.99	2.00
Cement plant	PT	CID108	38.501466	-8.94	1.3*
Type	Country	VID	Latitude	Longitude	Mean capacity MtCO_2
Storage sites	UK	SID1	54.01255983	1.27	13293.91
Storage sites	UK	SID2	53.41040519	1.66	0.00
Storage sites	UK	SID3	60.26116908	1.79	370.44
Storage sites	UK	SID4	59.74385612	1.39	12220.08
Storage sites	UK	SID5	57.23100117	0.93	339.07
Storage sites	UK	SID6	57.40650906	1.33	26132.05
Storage sites	UK	SID7	57.65877357	0.48	372.18
Storage sites	UK	SID8	58.50572514	0.13	14613.75
Storage sites	UK	SID9	58.88268013	1.24	427.28

Storage sites	UK	SID10	59.86255188	2.00	25.27
Storage sites	UK	SID11	58.84081626	1.43	66.15
Storage sites	UK	SID12	59.98601885	1.86	221.29
Storage sites	UK	SID13	58.44588928	1.33	0.00
Storage sites	UK	SID14	58.75345896	1.36	0.00
Storage sites	UK	SID15	59.03576844	1.49	6.17
Storage sites	UK	SID16	53.84996599	-3.59	1775.02
Storage sites	UK	SID17	54.61267195	-4.02	339.42
Storage sites	UK	SID18	53.97813606	-4.32	0.00
Storage sites	UK	SID19	58.21578367	0.80	4753.13
Storage sites	UK	SID20	58.25739527	1.30	30.49
Storage sites	UK	SID21	53.64289201	-3.50	2141.46
Storage sites	UK	SID22	54.18761158	-4.00	1220.52
Storage sites	UK	SID23	53.86033527	-3.75	0.76
Storage sites	UK	SID24	50.48018176	-2.12	1265.95
Storage sites	UK	SID25	54.04912548	-3.78	11099.42
Storage sites	UK	SID26	53.82349023	1.12	5466.79
Storage sites	UK	SID27	50.43990603	-2.36	393.79
Storage sites	UK	SID28	55.61560804	2.59	101.75
Storage sites	UK	SID29	59.54083262	1.44	27.36
Storage sites	UK	SID30	59.76576328	1.65	17.52
Storage sites	UK	SID31	58.2773108	-2.09	0.00
Storage sites	UK	SID32	58.17111368	-2.21	0.00
Storage sites	UK	SID33	59.57500693	1.68	102.53
Storage sites	UK	SID34	61.02533292	1.38	592.23
Storage sites	UK	SID35	52.90913671	1.71	435.46
Storage sites	UK	SID36	58.02051318	-2.88	0.00
Storage sites	UK	SID37	58.71720687	1.37	0.00
Storage sites	UK	SID38	56.99690677	1.33	0.00
Storage sites	UK	SID39	59.46596161	1.45	0.00
Storage sites	UK	SID40	58.23877412	-2.19	0.00
Storage sites	UK	SID41	56.67399802	-1.62	0.00
Storage sites	UK	SID42	58.59035816	1.47	0.00
Storage sites	UK	SID43	59.57469003	1.72	0.00
Storage sites	UK	SID44	61.04513353	-0.04	0.00
Storage sites	UK	SID45	58.20706176	-2.66	0.00
Storage sites	UK	SID46	56.95215819	1.58	13693.05
Storage sites	UK	SID47	58.37359571	1.26	8.67
Storage sites	UK	SID48	58.48189735	1.29	18.02
Storage sites	UK	SID49	57.68460262	0.28	0.00
Storage sites	UK	SID50	56.72668691	-1.61	12.50
Storage sites	UK	SID51	53.83690733	1.10	0.00
Storage sites	UK	SID52	54.96733408	-1.26	0.00
Storage sites	UK	SID53	54.38312363	-0.11	0.00
Storage sites	UK	SID54	58.90608782	0.02	604.04
Storage sites	UK	SID55	57.71737166	-0.19	79.02
Storage sites	UK	SID56	58.5050536	-0.27	233.24
Storage sites	UK	SID57	56.75116877	1.03	277.51
Storage sites	UK	SID58	57.11599256	0.46	206.11
Storage sites	UK	SID59	52.52674352	1.95	0.00
Storage sites	UK	SID60	58.58919791	-0.11	27.65
Storage sites	UK	SID61	53.21527443	1.01	0.00
Storage sites	UK	SID62	52.98999616	2.97	0.00
Storage sites	UK	SID63	52.50611395	2.84	0.00
Storage sites	UK	SID64	52.7563253	2.10	431.23
Storage sites	UK	SID65	53.41221502	1.95	193.11
Storage sites	UK	SID66	53.91525654	1.28	0.00
Storage sites	UK	SID67	54.02117059	2.29	0.00
Storage sites	UK	SID68	57.90680972	0.51	21852.40
Storage sites	UK	SID69	58.78460253	0.12	8036.79
Storage sites	UK	SID70	59.26360488	1.26	1389.15
Storage sites	UK	SID71	60.80170559	1.35	16360.99
Storage sites	UK	SID72	61.65806026	1.37	0.00
Storage sites	UK	SID73	58.19647436	-2.24	209.13

Storage sites	UK	SID74	57.43753242	1.45	8845.39
Storage sites	UK	SID75	58.13984376	-2.68	736.10
Storage sites	UK	SID76	58.57685962	1.31	15.54
Storage sites	UK	SID77	58.73056033	1.40	132.05
Storage sites	UK	SID78	61.11119113	1.35	2183.78
Storage sites	UK	SID79	57.98727857	0.96	193.25
Storage sites	UK	SID80	58.04728858	-3.17	76.86
Storage sites	UK	SID81	59.40810414	1.62	4.56
Storage sites	UK	SID82	57.62933157	0.99	105.00
Storage sites	UK	SID83	58.24446101	-1.71	1109.52
Storage sites	UK	SID84	58.37975968	0.06	507.60
Storage sites	UK	SID85	60.63316236	1.05	22.02
Storage sites	UK	SID86	58.32562071	-1.92	4741.74
Storage sites	UK	SID87	58.46002611	0.19	0.00
Storage sites	UK	SID88	58.5480616	-1.12	228.31
Storage sites	UK	SID89	58.11731044	-3.07	88.46
Storage sites	UK	SID90	58.52309137	-0.10	2138.84
Storage sites	UK	SID91	57.34975132	1.62	5265.99
Storage sites	UK	SID92	58.17504062	-1.69	55.84
Storage sites	UK	SID93	57.91356974	-0.27	60.83
Storage sites	UK	SID94	59.57640082	1.69	390.45
Storage sites	UK	SID95	60.87246079	1.70	254.43
Storage sites	UK	SID96	58.31936376	-1.78	805.73
Storage sites	GER	SID97	55.07066178	6.67	500.00**
Storage sites	GER	SID98	55.04193579	7.21	500.00**
Storage sites	GER	SID99	54.91985035	7.48	500.00**
Storage sites	GER	SID100	54.7905834	7.29	500.00**
Storage sites	GER	SID101	54.61104599	6.78	500.00**
Storage sites	GER	SID102	54.51768653	6.94	500.00**
Storage sites	GER	SID103	54.30224163	6.52	500.00**
Storage sites	GER	SID104	54.29506013	6.78	500.00**
Storage sites	GER	SID105	54.19451918	7.17	500.00**
Storage sites	GER	SID106	54.12270421	7.42	500.00**
Storage sites	GER	SID107	53.99343727	7.88	500.00**
Storage sites	GER	SID108	53.78517386	7.47	500.00**
Storage sites	GER	SID109	53.7061774	7.76	500.00**
Storage sites	GER	SID110	53.59845495	8.36	500.00**
Storage sites	GER	SID111	53.74208488	8.48	500.00**
Storage sites	GER	SID112	54.00780026	8.75	500.00**
Storage sites	GER	SID113	54.28069714	8.39	500.00**
Storage sites	GER	SID114	54.42432707	8.27	500.00**
Storage sites	GER	SID115	54.7977649	8.46	500.00**
Storage sites	NL	SID116	52.99269476	4.13	168.00
Storage sites	NL	SID117	52.56102532	3.83	360.00
Storage sites	NL	SID118	54.37006107	4.46	650.00
Storage sites	NL	SID119	53.44140379	3.87	60.00
Storage sites	NL	SID120	55.1169628	4.20	190.00
Storage sites	NL	SID121	53.24260865	3.98	165.00
Storage sites	NL	SID122	53.75379614	3.27	140.00
Storage sites	NL	SID123	53.50956212	3.35	195.00
Storage sites	NL	SID124	53.46412323	4.18	175.00
Storage sites	PT	SID125	41.74543596	-9.31	47.00
Storage sites	PT	SID126	41.70771411	-9.11	82.00
Storage sites	PT	SID127	41.61267248	-9.31	512.00
Storage sites	PT	SID128	41.50837801	-9.09	421.00
Storage sites	PT	SID129	41.30790522	-9.04	172.00
Storage sites	PT	SID130	41.45862027	-9.13	166.00
Storage sites	PT	SID131	41.12663299	-9.13	378.00
Storage sites	PT	SID132	41.09598137	-8.92	134.00
Storage sites	PT	SID133	40.62447075	-9.22	603.00
Storage sites	PT	SID134	40.51187346	-9.04	240.00
Storage sites	PT	SID135	40.4087355	-9.31	323.00
Storage sites	PT	SID136	40.32061279	-9.03	335.00
Storage sites	PT	SID137	40.17655026	-9.49	211.00

Storage sites	PT	SID138	40.16902891	-9.49	68.00
Storage sites	PT	SID139	40.14488738	-9.31	157.00
Storage sites	PT	SID140	40.03689421	-9.19	10.00
Storage sites	PT	SID141	39.94828841	-9.21	106.00
Storage sites	PT	SID142	39.8999413	-9.26	10.00
Storage sites	PT	SID143	39.82818359	-9.35	5.00
Storage sites	PT	SID144	39.71735804	-9.30	1024.00
Storage sites	PT	SID145	39.62591193	-8.97	182.00
Storage sites	PT	SID146	39.39648525	-9.02	27.00
Storage sites	PT	SID147	38.34034365	-8.95	29.00
Storage sites	PT	SID148	38.27197658	-8.83	15.00
Storage sites	PT	SID149	38.20444252	-8.95	19.00
Storage sites	PT	SID150	38.13253649	-9.03	22.00
Storage sites	PT	SID151	36.78875451	-8.40	183.00
Storage sites	PT	SID152	36.78875451	-8.40	662.00
Storage sites	PT	SID153	36.79973559	-7.73	86.00
Storage sites	PT	SID154	36.90185608	-7.57	38.00
Storage sites	PT	SID155	36.7747261	-7.32	210.00
Storage sites	PT	SID156	36.55563772	-7.43	68.00
Type	Country	VID	Latitude	Longitude	
Terminal	GER	TID4	53.556378	8.16	
Terminal	NL	TID8	51.98936213	4.16	
Terminal	UK	TID12	57.55512209	-1.84	
Terminal	UK	TID16	53.19136044	-3.06	
Terminal	UK	TID21	53.26012071	0.28	
Terminal	UK	TID22	53.68945314	0.04	
Terminal	IR	TID25	54.82315909	-5.76	
Terminal	IR	TID26	53.63410951	-6.24	
Terminal	PT	TID29	41.13424079	-8.66	
Terminal	PT	TID30	42.22657922	-8.73	
Terminal	PT	TID31	38.65399112	-9.23	
Terminal	PT	TID32	37.13771839	-6.84	
Terminal	PT	TID33	37.0911769	-8.67	
Terminal	PT	TID34	36.59514261	-6.26	
Type	Country	VID	Latitude	Longitude	Name of site
Olivine	NOR	OID1	62.004513	5.85	Steinsvick
Olivine	ESP	OID2	43.73912	-7.87	Spasek Minerals
Olivine	IT	OID3	45.420761	7.75	Nuova Cives S.R.L
Olivine	GR	OID4	40.31253	23.39	Thermolith S.A.
Olivine	GR	OID5	40.318072	23.40	Grecian Magnesite S.A.
Olivine	TUR	OID6	37.739251	29.09	Geomin Madencilik San ve Tic Ltd
Type		VID	Latitude	Longitude	Description
Kaolinite deposit		CLID1	47.88896359	19.20	Felsopeteny (Hungary)
Kaolinite deposit		CLID2	47.92295888	19.26	Romhany (Hungary)
Kaolinite deposit		CLID3	48.65259777	18.91	Bartosova Lehotka (Slovakia)
Kaolinite deposit		CLID4	48.3654678	19.60	Halicska (Slovakia)
Kaolinite deposit		CLID5	48.42309979	19.73	Breznicka (Slovakia)
Kaolinite deposit		CLID6	48.72601481	21.86	Pozdisovce (Slovakia)
Kaolinite deposit		CLID7	50.24421547	21.78	Kolbuszowa (Poland)
Kaolinite deposit		CLID8	50.17472142	20.99	Dabrowa Tarnowska (Poland)
Kaolinite deposit		CLID9	50.7802922	17.16	Wyszonowice (Poland)
Kaolinite deposit		CLID10	50.94088791	16.49	Zarow (Poland)
Kaolinite deposit		CLID11	51.2301887	15.39	Zebrzydowa (Poland)
Kaolinite deposit		CLID12	51.254947	15.22	Czerwona Woda (Poland)
Kaolinite deposit		CLID13	48.85589875	16.05	Znaim (Czech Republic)
Kaolinite deposit		CLID14	48.30894796	14.62	Kriechbaum (Austria)
Kaolinite deposit		CLID15	50.23425202	12.87	Karlsbad (Czech Republic)
Kaolinite deposit		CLID16	49.83993915	13.36	Horni Briza (Czech Republic)

Kaolinite deposit	CLID17	49.88209993	12.33	Tirschenreuth (Germany)
Kaolinite deposit	CLID18	51.27575883	14.10	Kamenz (Germany)
Kaolinite deposit	CLID19	50.23381122	11.33	Kronach (Germany)
Kaolinite deposit	CLID20	51.22761392	12.99	Kemmlitz (Germany)
Kaolinite deposit	CLID21	51.39328755	11.98	Merseburg (Germany)
Kaolinite deposit	CLID22	51.17641883	11.80	Saale (Germany)
Kaolinite deposit	CLID23	55.10113359	14.71	Rönne (Denmark)
Kaolinite deposit	CLID24	50.61131736	7.21	Oberwinter (Germany)
Kaolinite deposit	CLID25	50.00150758	5.02	Haut-Fays(Beglium)
Kaolinite deposit	CLID26	49.58795719	7.14	Nohfelden (Germany)
Kaolinite deposit	CLID27	49.986148	7.97	Geisenheim (Germany)
Kaolinite deposit	CLID28	45.10051816	4.87	Larnage (France)
Kaolinite deposit	CLID29	50.551808	-3.61	Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID30	50.579888	-3.63	Chudleigh Knighton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID31	50.58286	-3.64	Chudleigh Knighton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID32	50.885728	-4.11	TORRINGTON, Devon (UK)
Kaolinite deposit	CLID33	50.556344	-3.61	Chudleigh Road, Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID34	50.562782	-3.61	Chudleigh Road, Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID35	50.575948	-3.63	Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID36	50.887367	-4.11	TORRINGTON, Devon (UK)
Kaolinite deposit	CLID37	50.567934	-3.62	Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID38	50.552935	-3.63	Teigngrace, Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID39	50.889194	-4.12	TORRINGTON, Devon (UK)
Kaolinite deposit	CLID40	50.645981	-2.10	WAREHAM, Dorset (UK)
Kaolinite deposit	CLID41	50.364569	-4.13	Coxside, PLYMOUTH, Devon (UK)
Kaolinite deposit	CLID42	50.573448	-3.63	Heathfield, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID43	50.642542	-2.15	Povington, WAREHAM, Dorset (UK)
Kaolinite deposit	CLID44	50.581467	-3.63	Chudleigh Knighton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID45	50.570072	-3.61	Chudleigh Road, Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID46	50.650407	-2.11	Furzebrook, WAREHAM, Dorset (UK)
Kaolinite deposit	CLID47	50.544147	-3.64	Kingsteignton, NEWTON ABBOT, Devon (UK)
Kaolinite deposit	CLID48	50.708544	-2.15	WAREHAM, Dorset (UK)
Kaolinite deposit	CLID49	43.650291	-7.38	Burela kaolin deposit (Spain)

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