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Marine Carbon Removal in Integrated Assessment Models

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Lago d’Orta in Italy

OptimESM
Optimal high resolution Earth System Models for exploring future climate change

RESCUE

RETAKE

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The technoeconomics of OAE via Ocean Liming

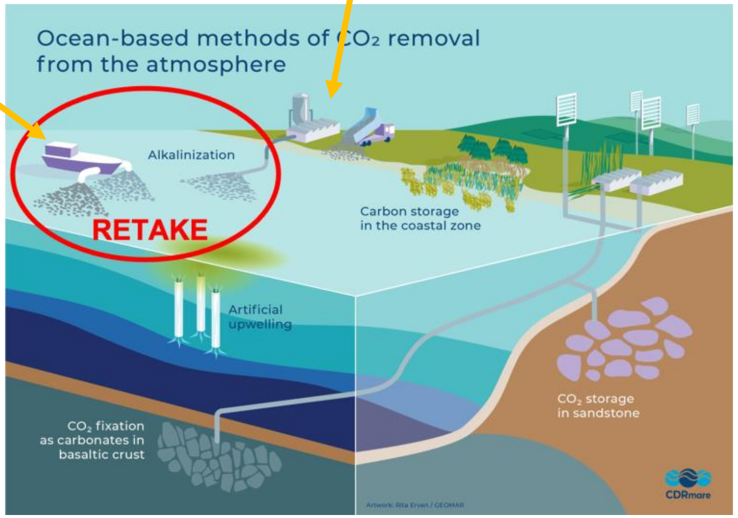
https://iopscience.iop.org/article/10.1088/1748-9326/ad5192

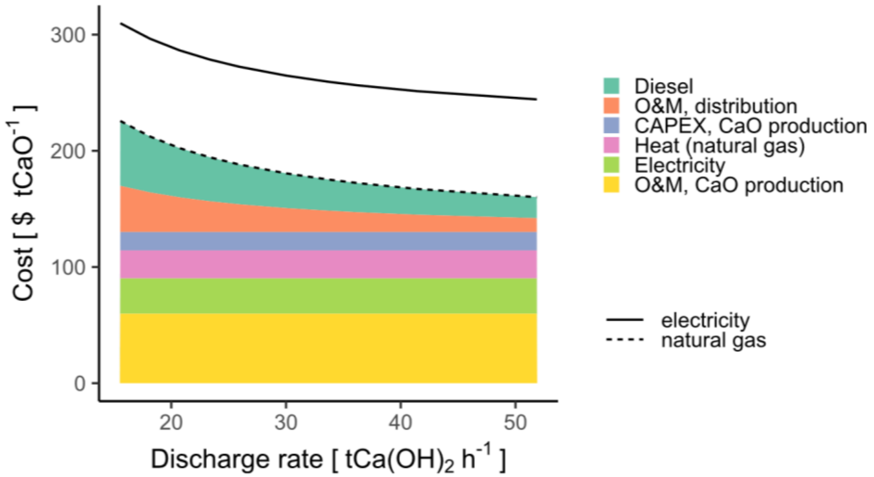
Table 1. Energy requirements, levelized capital cost per unit of CaO produced (CAPEX), operation and maintenance costs (OPEX), energy cost assumptions, and material demand of the production of hydrated lime, excluding the distribution of alkalinity. Step-specific data can be found in note S7 (SI).

Energy demand		
Heat (high-temperature) [MJ $tCaO^{-1}$]	3100 (2910–3492)	[20]
Electricity [MJ $tCaO^{-1}$]	995 (992–1188)	[20, 25–27]
Diesel [MJ $tCaO^{-1}$]	103 (73–943)	[20]
Costs w/o energy		
CAPEX [$ $tCaO^{-1}$]	15.8 (31 if electric calciner)	[20, 25, 28]
OPEX [$ $tCaO^{-1}$]	58.1	[20, 26]
Energy costs		
Natural gas [$ GJ^{-1}]	8	[29]
Electricity [$ GJ^{-1}]	31	[29]
Diesel [$ L^{-1}]	0.7	[29]
Materials		
Limestone demand [$tCaCO_3$ $tCaO^{-1}$]	1.82	
Hydrated lime output [$tCa(OH)_2$ $tCaO^{-1}$]	1.32	

Table 3. Distribution of alkalinity via ships.

Parameter/Assumption		Comment
Hiring a ship [$ day^{-1}]	11 250	Market report [39]
Fuel consumption [t h^{-1}]	1.41	[40]
Fuel cost [$ t^{-1}]	450	Market report [41]
Average speed [km h^{-1}]	25	[24]
Ship's tonnage [t]	75 000	[24]
DWCC usable for alkaline material [%]	85	[24]
Concentration limit [$gCa(OH)_2$ m^{-3}]	20	[22]; calculations in Note S4, SI





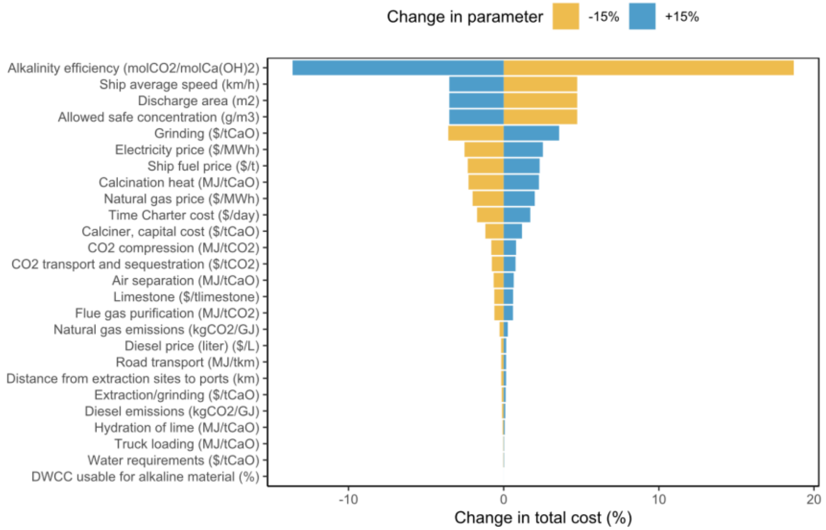


Table 2. Carbon intensity factors and efficiency-related assumptions.

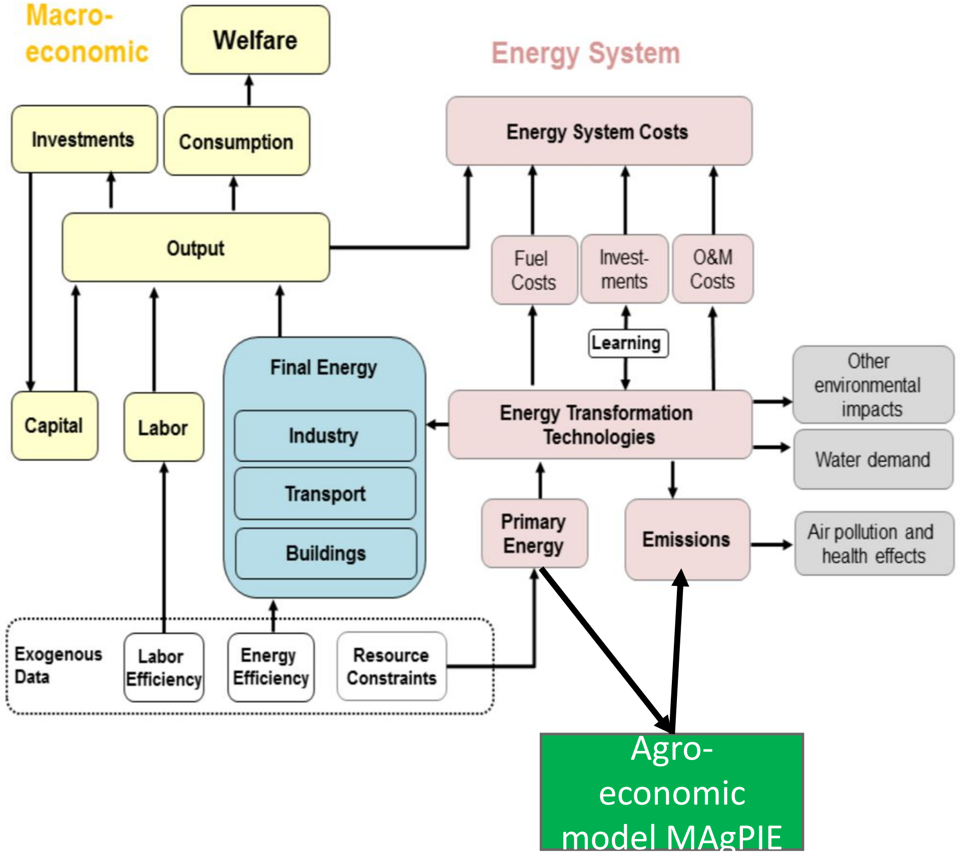
Parameter/Assumption	Value	Comment
Electricity emissions [$kgCO_2$ GJ^{-1}]	0	In line with deep decarbonization assumptions [2]
Heat emissions [$kgCO_2$ GJ^{-1}]	3 (59)	[35]; assuming geological storage; used for the natural gas calciner scenario (numbers without CCS in parenthesis)
Fuel emissions [$kgCO_2$ GJ^{-1}]	76 (0)	[20]; fully decarbonized scenario in parenthesis
Process emissions [tCO_2 $tCaO^{-1}$]	0.04 (0.78)	Assuming geological storage, numbers without CCS in parenthesis
CCS capture rate	95%	Typically between 90%–98% [38]
Uptake efficiency [$molCO_2$ $molCaO^{-1}$]	1.2–1.8	[13]; note S6, SI

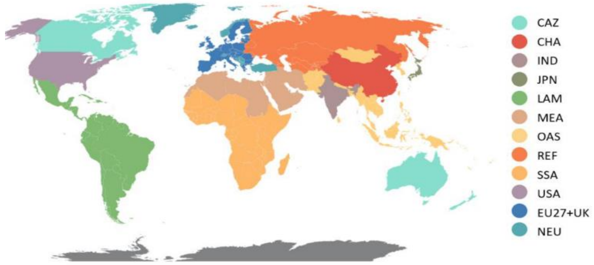
The REMIND-MAgPIE integrated assessment modeling framework

Shared Socioeconomic Pathways

Drivers:
- Population
- Economic development

Narratives:
- Technological development
- Food and energy demand
- Non-climate policies
- Trade liberalization
- ….





Climate policy scenarios

Emission/temperature target

Assumptions about overshoot

Assumptions about carbon prices

http://link.springer.com/10.1007/s10584-020-02895-z

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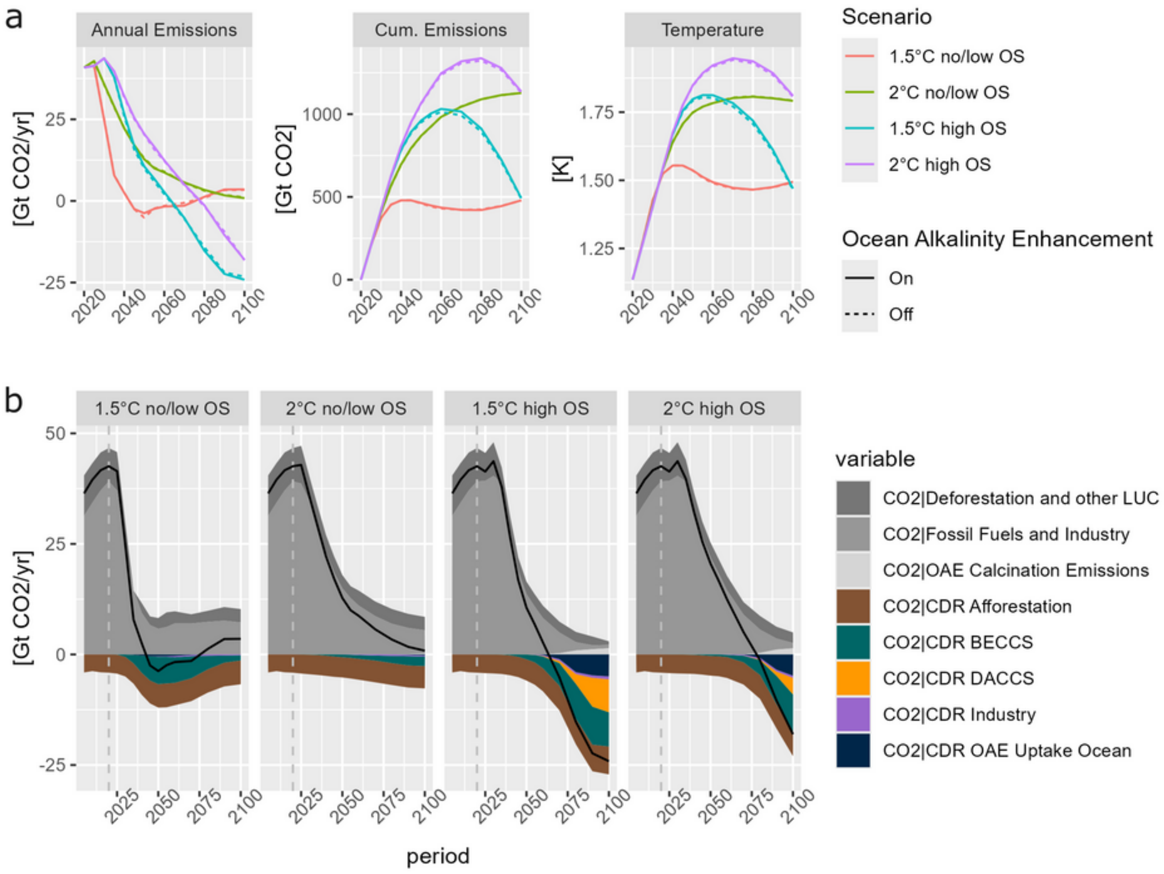
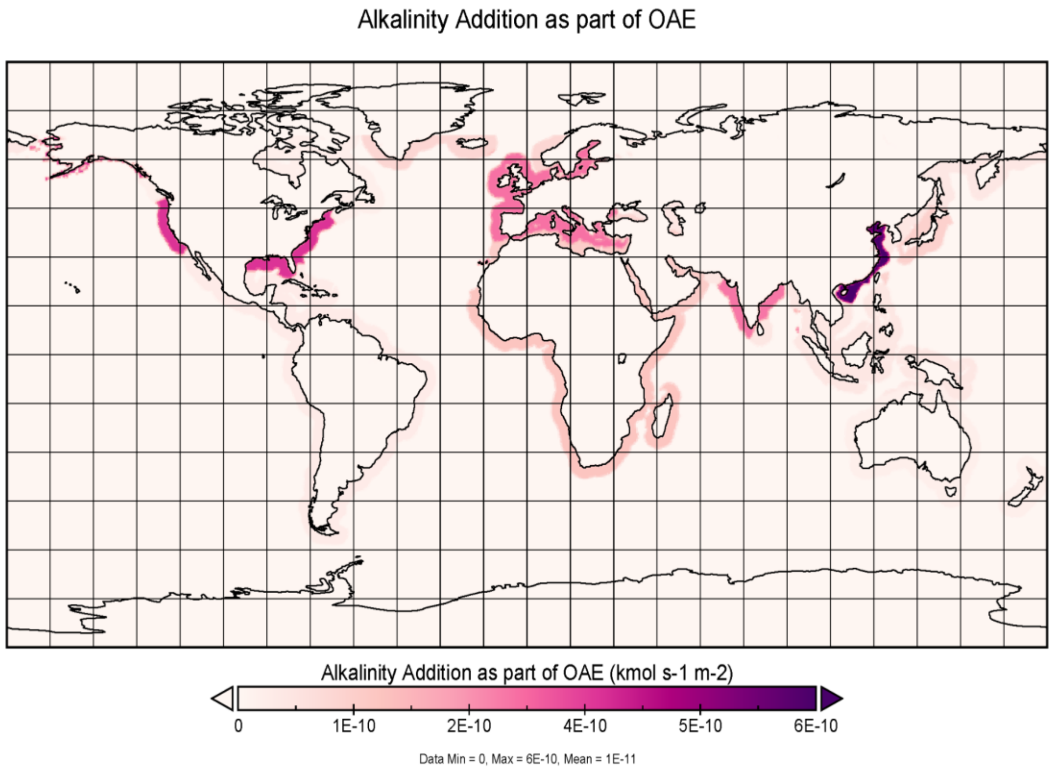
OAE in climate change stabilization scenarios





https://www.rescue-climate.eu/resources/resource-library/policy-brief

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Many open questions remain

› Factors that would suggest early deployment

› Industry scale-up (quicklime production, extending the carrier fleet, …)

› Monitoring, reporting, verification

› Physical limitations (e.g. precipitation, geological concentration of activity)

› Governance

› Marine ecosystems (acidification, etc.)

Two things good to know about Lago d'Orta

Min. pH-value in 1985 was 3.9

1989-90: "A total of 10,900 t of pure calcium carbonate was sprayed on the lake's surface and pumped under the thermocline during the summer months."

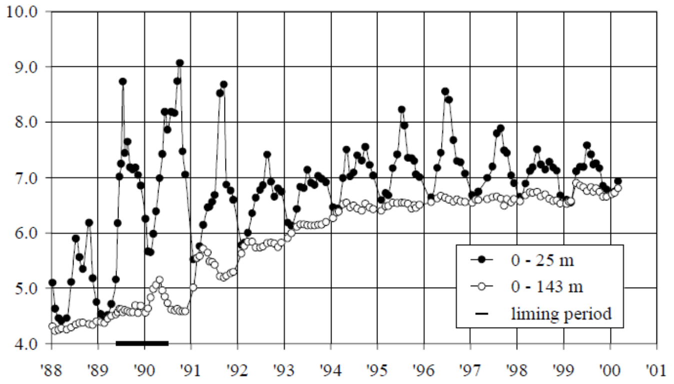

Fig. 2. pH in the epilimnetic layer (0-25 m) and in the whole lake (0-143 m) from January 1988 to March 2000 (volume weighted mean values).

https://doi.org/10.4081/jlimnol.2001.69