Solving Industry's CO₂ Problem by Storing it in the Seabed?

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The Topic: Storage of CO₂ in the Soil

IPCC (Intergovernmental Panel on Climate Change): **«The international climate goals will only be achieved if CO₂ is also removed from the atmosphere *) and stored in the soil.»** *) Note JW: or captured in the emissions and not released into the atmosphere

The Swiss Federal Council decided in November 2023:

- Switzerland will be allowed from 2024 on to export CO₂ and store it in the seabed.
- Storage is essential from a climate policy perspective in order to achieve international and national climate goals.



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Unavoidable CO₂-Emissions

- CO₂-Emissions of Switzerland (2021): 35 Mio. [t] globalcarbonatlas.org 2021
- Switzerland will not be able to reduce CO₂ emissions to zero by 2050.
- The Federal Office for the Environment estimates that around 12 million tons of CO₂, or around a quarter of today's emissions, are unavoidable.
- Of these twelve million tons, seven million must be filtered directly from the air. Five million tons can be separated from industrial exhaust gases (cement plants and waste incineration plants).







Why are CO₂ Emissions from Cement Production so high?



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Note: Published figures vary slightly depending on the source

Cement Worldwide



CIS = Russia and Post-Soviet States





Swiss cement industry (2021) 2.45 million [t/year] or 78 kilograms per second

CO₂ Formation from the Raw Material (Calcination)



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CO₂ Reduction between 1990 und 2020



Reduction through:

- Closing factories with outdated production methods
 + improvement of existing processes
- Using "alternative fuels"
- Reducing the clinker content in cement





CO₂-Reduction; Closing of Plants

- Between 1992 and 2013, 7 of 13 cement plants in Switzerland were closed; mostly outdated production processes (Examples: Olten, Roche, Brunnen, Thayngen, ...)
- Today (2024) the following plants still exist
 - 1: Holcim (Suisse) SA, Eclépens
 - 2: Juracime SA, Cornaux
 - 3: Vigier Cement AG, Péry
 - 4: Jura-Cement, Werk Wildegg
 - 5: Holcim (Schweiz) AG, Siggenthal
 - 6: Holcim (Schweiz) AG, Untervaz





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Hürlimann Zement, Brunnen

CO₂ Reduction via "Alternative" Fuels





Waste Oil



Used Tires



Plastic



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Solvents



Animal Meal



Sewage Sludge



Waste Wood

CO₂ can be reduced by alternative fuels ("Waste")

- Alternative fuels («waste») generally have a lower C content and therefore emit less CO₂
 C + O₂ → CO₂
- b. Alternative fuels contain parts of so-called biogenic carbon. The CO2 emissions from this part are not counted.

Biogenic substances are those that are created by living organisms in natural processes and do not come from fossil resources. Biogenic CO_2 is created when biomass (e.g. wood) or parts of biomass are burned.

Remember:

Fuels in TOTAL affects ~1/3 of CO₂ emissions!

Reduction of Clinker Content in Cement



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Success of these measures between 1990 and 2020



Reduction: 39.2 [%]

1990: 4.03 Mio. [t CO_2 /year] (Reference year of the agreements) 2021: 2.45 Mio. [t CO_2 /year]



Planned CO₂ Reductions in the Swiss Cement Industry 2020 – 2050

- Various industries have published "roadmaps", etc. or have entered agreements
- Examples

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- Swiss cement industry (cemsuisse)
- Swiss industry association of waste incineration plants

Similar Processes in other European Countries





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Roadmap cemsuisse 2020 - 2050

	CO ₂ Reduction					
Reduction according to Roadmap	[t CO ₂ /t Cement]	Million tons per year *)		cem		
1. Fuels	-125.8	-0.53	1 26 Mio	Association		
2. New types of cement and concrete	-101.9	-0.43				
Transport	-21.0	-0.09	[
Electricity	-15.1	-0.06		Swiss Cement Industry		
Recarbonation	-58.6	-0.25				
3. CCU / CCS	-423.7	-1.79				
			· · ·			

*) Based on the 2019 production of 4.214 million tons of cement





Planned Reduction Measures 2020 – 2050



1. Fuels:

Increase in alternatives from today's 79 to 100 [%] and increase in biogenic fuels

→ Very difficult to achieve

- There are already problems increasing this share
- Radio Argovia report from June 28, 2024, 08:00: New fuel plant at Holcim in Siggenthal in operation in 2028 (according to Würgerbauer); 70 - 100 million CHF Reduction of CO₂ from 450,000 to 420,000 [t/year] (reduction ~ 6.7 [%])
- 2. New types of cement and concrete The following applies to all "new" types of cement: As long as the at least equivalent performance of these so-called eco-cements cannot be demonstrated, today's cements will continue to be the main building material. It is difficult to estimate the importance of the new cements (eco-cements) by 2050 and what CO2 reductions can be expected.



Planned Reduction Measures 2020 – 2050



3. CCS und CCU:

- 423.7 [kg CO₂/t Cement] or -1.79 Million tons per year

CCU: Carbon Capture and Utilization CCS: Carbon Capture and Storage

New measure:

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- Around 60 70 [%] of the CO2 emissions from the six Swiss cement plants must be captured and used or stored!
 N.B. Worldwide, this would be in the order of magnitude one billion [t] (cement industry only)
- Other industries will also have to go down this path.
 Example: The Swiss Waste Incineration Plants Association has committed itself to capturing the CO₂ produced in the future and storing it underground.



CCU/CCS





CC: CO₂ – Capture/Separation

Capture from the Atmosphere

Swiss start-up company Climeworks has developed the world's first industrial plant for capturing CO_2 from the atmosphere.

(Direct Air Capture, DAC)





The CO₂ content in the atmosphere today (Sept. 2024) is 422.03 [ppm] or 0.0422 [%]

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 Average month September 2024

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 https://gml.noaa.gov/ccgg/trends/mlo.html

Separation from exhaust gases from large emitters (cement plants)

The CO₂ content in the exhaust gases from cement plants is relatively high (approx. 17 to 22 [vol-%]).



With appropriate systems (here is an example), CO₂ can be extracted directly from the exhaust gas.

CO₂ Capture and Utilization





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CCU : CO₂ Capture and Utilization

KOHLENDIOXID ALS WERTVOLLER ROHSTOFF

Rohrdorfer baut als erstes deutsches Zementwerk eine CO2-Abscheideanlage OVB-online

(Oberbayerisches Volksblatt)

veröffentlicht: 17.03.2022 - 08:41



Translation: "Rohrdorfer" is the first German cement plant to build a CO_2 capture plant

End of June 2022: Commissioning of the prototype with a separation capacity of two tons of CO_2 per day O_1 (without formic acid plant)

Separated CO_2 is used directly in the plant to produce formic acid. (1800 liters per day)

Later expansion is planned. Example 80 [%] separation \rightarrow approx. 100,000 liters per day Problem: what to do with the formic acid?



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This is no more than a small prototype 2 [t CO_2/day] \rightarrow approx. 1.5 [%] of daily CO_2 emissions

CCU: Project in North Germany

- Separation of CO_2 in the cement plant
- Electrolysis of water with "green electricity": $H_2O \rightarrow H_2 + \frac{1}{2}O_2$
- H₂ and CO₂ \rightarrow Production of Methanol: 3 H₂ + CO₂ \rightarrow CH₃OH + H₂O
- $O_2 \rightarrow$ Enrichment of the combustion air in the cement plant



CCU: Project in North Germany

The C emissions from the cement plant replace C from the oil

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- Fuel is produced from the fuel (refinery). When it is burned, CO_2 is produced again \rightarrow partial elimination of CO₂
- Energy supply from an external source (here "green" electricity from wind power)



CCU: Methanol as a Chemical Raw Material



- Formaldehyde HCHO Glues and plastics, wood preservatives, disinfectants
 - Acetic acid C₂H₄O₂ Acetic acid esters, cellulose acetate (artificial silk). Solvents (varnishes, resins), additives in the textile industry
- Solvents

MMA (methyl methacrylate)

 \rightarrow acrylic glass

DMT (dimethyl terephthalate) \rightarrow PET Solvents based on methanol

 \rightarrow insecticides, pharmaceuticals

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CO₂-Storage under Land Masses (Onshore)





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Example: CCS – Test Facility in Ketzin



- Porous, dome-shaped sandstone layers at a depth of 630 to 650 [m] were used, which can absorb the CO₂ in their pores.
- The storage rocks are sealed by overlying claystone's more than 165 m thick. This sealing, together with the arching structure, ensures a controlled and limited spread of the CO₂.
- The injection of 67,271 [t] of CO₂ began in June 2008 and ended in August 2013.

RESULT:



The geological storage of CO₂ at the Ketzin pilot site is safe!

CCS – Resistance against CO₂ Storage Facilities

Arguments of the Opposition

- No long-term experience: e.g. about the tightness of the storage facilities
- Danger to drinking water
- Huge land consumption destruction of natural landscapes
- CCS is the "opposite of climate protection" it prevents the phase-out of fossil fuels
- Burden on future generations

Association of German Cement Works (VDZ) "Today, the legal situation in Germany is such that CO₂ storage on land (onshore) is de facto not possible."

Minister of Economic Affairs Habeck Germany (2024):



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Storage on land, for example in former gas and oil deposits, should be ruled out for the time being.



CCS – Where does Switzerland stand?

Switzerland is currently only conducting basic research Investigations in the Swisstopo rock laboratory in Mont Terri in the canton of Jura Possibility of using Opalinus Clay as a covering layer. This Clay is very dense and has very little permeability for liquids and gases. It would be an excellent covering rock for sealing a CO₂ repository deep down.

CCS in the Swiss Soil

- Opposition is to be expected --> years of delays (analogy: nuclear waste?)
- Perhaps the realization that storage in the ground is not possible at all (technically, politically, ...)





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New: Switzerland is examining Onshore Storage



- September 2024: The federal government wants to examine the feasibility of storing CO₂ in Switzerland.
- swisstopo takes over the borehole of Nagra (National Cooperative for the Storage of Radioactive Waste) to initiate a pilot test for feeding CO2 underground.
- Immediately: In-depth investigations into the suitability of the borehole. If necessary, the feed-in test would probably be carried out from 2025 and would last until 2030 at the latest.
- Regardless of the findings, the pilot project does not constitute a preliminary decision as to whether Switzerland will store CO2 in geological layers in the future and where this would happen if necessary.



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The disused drilling site in Trüllikon in the Zurich Unterland

Storage in Seabed (Offshore)





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CCS – Storage under the Seabed

- The CO₂ is brought to deep sandstone layers under the seabed. These are the same layers from which oil and gas were extracted.
- Technologies for geological storage are available from oil or gas extraction.
 Examples:
 - Sleipner-field/Norway: 1 million tons of CO₂ annually since 1996
 - Snow White field/Norway: approx. 700,000 tons of CO₂ annually since 2007
- Monitoring programs show that there is no CO₂ release!







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World's First CO₂ Capture Plant



- Norcem Cement Factory (HeidelbergCement) in Brevik, Norway, installs capture plant in an industrial-scale cement plant; commissioning in summer 2024; Reported status: Final assembly
- Planned: Capture of 400,000 [t/year] CO₂, about 50 [%] of total emissions
- CO₂ is captured, compressed and liquefied (Aker Carbon Capture and MAN Energy Solution) and transported by ship to an underground storage location.







Town of Zurich: Vote September 22nd, 2024



Template 5: CO₂ Capture Plant on the Werdhölzli Site (Waste Incinerator, Town of Zurich)

- one-off expenditure of 35.747Mio. CHF (41.37 Mio. \$) and 14.212 Mio. CHF (16.45 Mio. \$) annually
- When cleaning wastewater, sewage sludge remains This is burned on the Werdhölzli site.
- With a capture plant, the city wants to remove a large part of the CO₂ from the exhaust gas and store it permanently.

Planned capture

- The CO₂ capture plant can process a total of 25,000 tons of CO₂ per year. Around 94% of this is to be stored permanently.
 - \rightarrow up to 23,575 tons per year
- Between 5 and 7 truck journeys are expected per day. Half of the CO₂ goes by truck (3 trucks), rail and ship to a storage facility abroad (North Sea) specially developed for this purpose. The rest goes to the concrete industry.
- Duration of the contract for acceptance or storage: 10 years (annual costs)



Town of Zurich: Vote September 22nd, 2024

Instructions from the city council to the municipal council

dated January 17, 2024 - GR No. 2024/12

Around 50 percent of the annual amount of CO₂ is bound in recycled concrete from various Swiss concrete plants.



- The remaining 50 percent of CO₂ is to be brought into a storage facility abroad, probably in the Danish North Sea, with the help of "Project Greensand", a consortium of 23 international organizations. The CO₂ is compressed around 2000 m below the seabed under a layer of cover rock that prevents the CO₂ from rising to the surface. A geological CO₂ storage license from the Danish government has been issued for the offshore transport and storage project.
- For the capture and storage of a maximum of 25,000 t of CO₂ from the Werdhölzli wastewater treatment plant, the costs, excluding reserves but including capital follow-up costs, are CHF 614 per ton of CO₂



CCS in Seabed – Where does Switzerland stand?



- First plant in Werdhölzli around 2026 \rightarrow partly to the North Sea
- CCS abroad (in the seabed)
 - Possible disposal sites are far away (e.g. North Sea)

Transport Problem!!!

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- Transporting 1 million tons of CO₂ means for Switzerland:
 - 1 pipeline or
 - 250 inland vessels (Rhine) or
 - 1,000 freight trains or
 - or 50,000 tank trucks

According actech (Deutsche Akademie der Technikwissenschaften)





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CCS – Risk of Final Storage?





CCS – Risk of Final Storage



Danger of such storages - Scaremongering or reality?

- Salah / Central Algeria: oil and gas extraction and CCS plant
 - Between 2004 and 2011, 3.8 million tons of CO₂ were injected into a reservoir at a depth of 1,800 meters.
 - Cover layer: approx. 1,000 m thick; impermeable to the CO₂ gas.

June 2011:

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- Significant uplifts were discovered in all sectors of the plant
- Increased pore pressure in the lower 200 meters of the 1,000-meter-thick cover layer
- Conclusions from the uplifts: Pumping in the CO₂ has led to cracks and other changes in both the reservoir and the cover rock.
- Conclusion: In Salah, the cover layer is thick enough to rule out leaks.



A residual risk remains with every CCS plant!!!



Realized and planned CCU/CCS applications worldwide



Holcim in Europe: GO4ZERO Projects

The Swiss cement company Holcim has planned various CCU and CCS applications



Country	Plant	Reduction Million [t]	Process		1)	
Poland	Kujawy	1.2	CCS	2027	EU	$^{2)}$ by the
Croatia	Koromacno	0.4	CCS	2028	EU	
Greece	Milaki	1.0	CCS	2029	EU	
Belgium	Obourg	1.1	CCS	2028	EU	3) 5 Ca
France	Le Teil	0.2	CCU	2028	EU	4)
Germany	Lägerdorf	1.2	CCU	2029	EU	4)

France	Martres	0.7	CCS		
Romania	Campulung	1.0	CCS		
Bulgaria	Beli Izvor	0.7	CCS		
Germany	Höver	0.7	CCU	Projects	
Austria	Mannersdorf	0.7	CCU	after 2030	
Great Britain	Cauldon	0.7	CCU		
France	Saint-Pierre-la-Cour	1.0	CCU		
Spain	Carboneras	0.8	CCU		



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- 1) EU = Selected for funding from the EU Innovation Fund 4) Methanol production
- 2) Transported to the North Sea; how?
- 3) CO₂ pipeline from Obourg (near Mons) to Antwerp (approx. 120 [km])

Feasibility study of the pipeline (Fluxys) completed

4) Methanol production

GO4ZERO North-America





- Exshaw Cement Plant (ehemals Lafarge)
 Exshaw, Alberta/Kanada
 CCS, 1.0 Mio. tons CO₂; 2030
- Ste. Geneviveve Bloomsdale, Missouri/USA CCS, 2.75 Mio. tons, 2028/9
- Holcim Portland Cement Plant Florence, Colorado/USA CCS, 1.3 Mio. tons, 2032



-lolcim

CCS in Europe



- Carbon capture is a crucial cornerstone for achieving climate goals in Europe.
- The capture and storage of CO₂ (CCS) is a crucial method to significantly and immediately reduce these emissions from the cement and other industries.
- Bilateral agreements are the basic prerequisite for the transport and storage of carbon dioxide across national borders.
- There must be a common European market (including Switzerland!!!) for the transport and storage of CO₂ so that the goal of a "climate-neutral Europe" can be achieved.



CCS worldwide





(Production Gap Report; UN Environmental Program and Stockholm Environment Institute)

- Currently (2023), only 49 million tons of CO₂ are captured annually. That is only around 0.13 percent of global CO₂ emissions.
- The current speed of plant construction is also far from sufficient for the International Energy Agency's (IEA) netzero scenario, which envisages global climate neutrality by 2050.
- New CCS projects have been announced for years but are then often postponed or canceled altogether. In 2021, around 80 percent of all CCS projects in the USA have failed so far due to technical problems or because they are not economically viable.



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The cement industry says: "We want to be climate neutral by 2050!"

(World Cement and Concrete Association)

"I have been in the cement business for more than 40 years and I doubt that we can do this!"



Doubts are an indication of things that are important to us

Closing Words from the "Climate Icon"



"The only thing that will help is the abolition of capitalism and a state that dictates people's lives down to the last detail!"

Quote from Greta Thumberg from her book "The Climate Book"



No Greta, definitely not!!!

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