

INTRODUCTION CARBON CAPTURE

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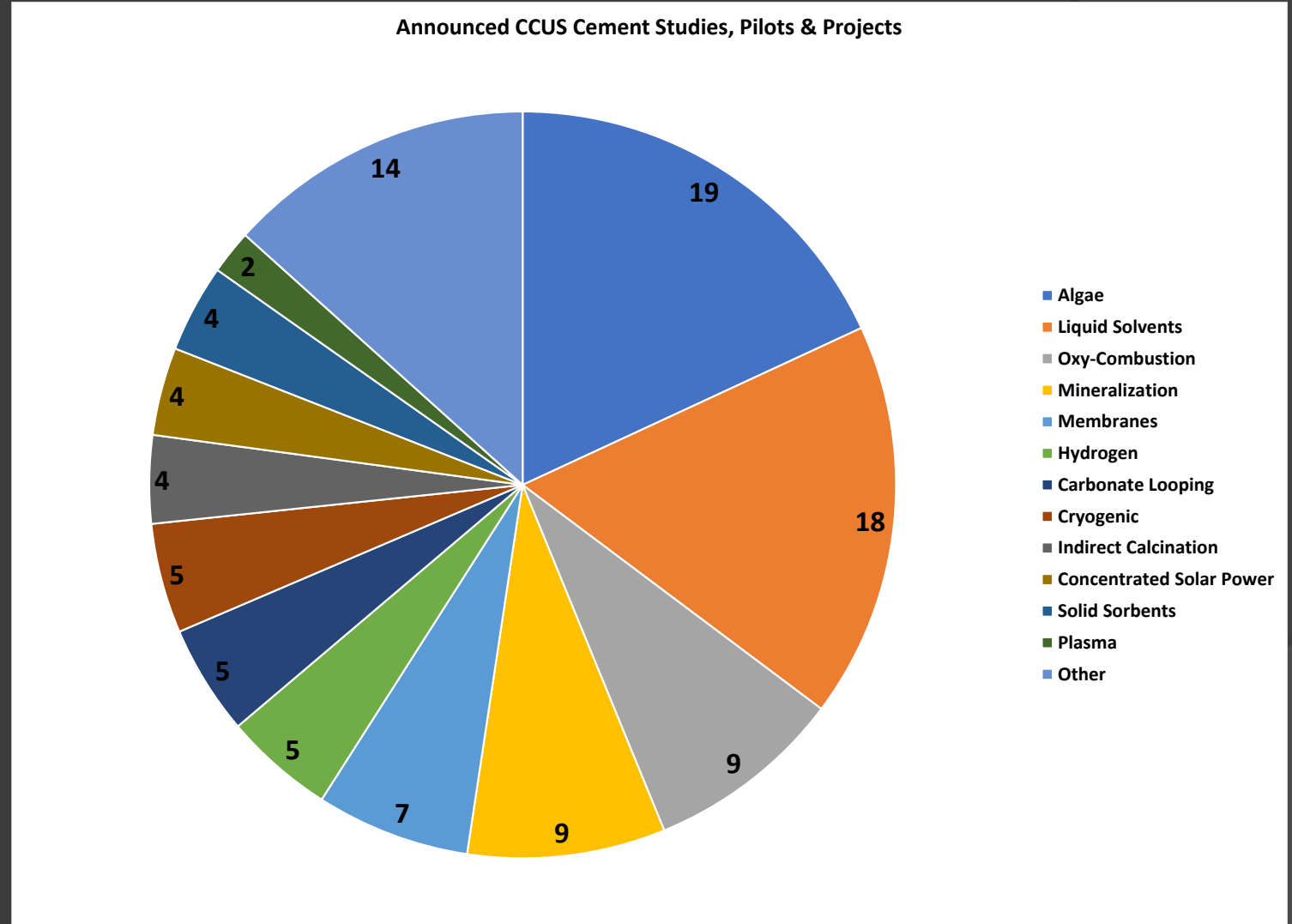
Performance Indicators from Selected Sustainability Reports

| Cement Roadmap Indicators (CSI) | Sustainability Report Year | Thermal energy consumption per tonne of clinker GJ / tonne | Electricity intensity of cement (kWh/t cement) | Alternative Raw Materials in Cement | Alternative fuels total % (1) | Biomass fuel usage % | Clinker to cement ratio | Tonne CO2 emissions net per tonne cement | 2030 Pledge |
|---------------------------------|----------------------------|--|--|-------------------------------------|-------------------------------|----------------------|-------------------------|--|-------------|
| 2DS Targets | 2050 | 3.1 | 79 | | NA | 30% | 60.0% | 0.370 | |
| LafargeHolcim | 2021 | 3.520 | - | 13.0% | 13.0% | 8.0% | 70.1% | 0.553 | 0.475 |
| Heidelberg | 2021 | 3.590 | - | 11.8% | 26.4% | 11.2% | 72.9% | 0.565 | 0.400 |
| Cemex | 2021 | 4.023 | 122 | 11.0% | 29.2% | 10.7% | 75.2% | 0.591 | 20% |
| Ultratech | 2020/2021 | 3.034 | 78.5 | 18.4% | 3.1% | 0.5% | 72.3% | 0.597 | 0.557 |
| Votorantim | 2021 | 3.000 | 109 | 9.2% | 22.4% | 12.1% | 74.9% | 0.597 | 0.520 |
| CRH | 2021 | 3.782 | - | 11.9% | 25.3% | 7.3% | 78.4% | 0.586 | 0.520 |
| Buzzi | 2021 | 4.106 | 122 | 9.0% | 27.8% | 7.1% | 80.2% | 0.633 | - |
| Siam cement | 2021 | 3.466 | - | 8.4% | 7.7% | 12.2% | 74.2% | 0.623 | 20% |
| Taiheyo | 2021 | 3.321 | 106.4 | 15.8% | 12.2% | 2.0% | 82.4% | 0.675 | >20% |

| Area | Cembureau | VDZ | PCA | CA-NV |
|----------------------------|---------------------------------------|---|------------------------------|----------------|
| | 2017 Baseline | 2017 Baseline | | |
| Decarbonized Raw Materials | 8% Decarbonized RM | | 10% Decarbonized RM | 10 ~ 20% |
| Biomass Fuels | 90% AF & 50% Biomass | 90% AF & 35% Biomass | 50% AF & 18% Biomass | 10 ~ 20% |
| Thermal Efficiency | 14% Thermal Eff. Improvement | 13% Improvement | 25% Thermal Eff. Improvement | |
| Low Carbon Clinker | | 5% Low Carbon Clinker | | <10% |
| Hydrogen | | 10% Hydrogen | | |
| Clean Electrification | | | | <10% (Onsite) |
| Clinker Substitution | 65% Clinker Content | 53% Clinker Factor | 75% Clinker Factor | ~10% (PLC) |
| Electrical Efficiency | 100% Renewable Electrical Energy | | | <10% (WHR) |
| CCU/S | 42% of Total Reductions | 52% of Total Reductions | | >50% |
| CO2 Capture (Carbonation) | | 20% Carbonation | 20% Carbonation | |
| Transportation | (Not in Cement Scope) (+10% CCU/S) | (Not in Cement Scope) (+10.5% CCU/S) | | |

Technologies, Studies, Pilots, and Projects (JK's List)

- Algae – 19
- Liquid Solvents – 16
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- Solid Sorbents – 4
- Plasma - 2



Known Algae & Microbe Projects in the Cement Industry

| Company | Plant | Country | Partner | Comments |
|---------------|----------------|-----------|--------------------------|-----------------|
| Cemex | Alicante | Spain | BFS | Closed |
| Lafarge | Val d’Azergues | France | Salata | Closed |
| Heidelberg | Degerhamn | Sweden | Linnaeus Univ. | |
| Heidelberg | Cupertino | US | Oakbio | Microbes |
| Heidelberg | Buda | US | Sunrise Ridge Algae | Closed |
| Heidelberg | | US | Joule Energy | Out of Business |
| Italcementi | Gargenville | France | Algosource | Heidelberg |
| Heidelberg | Safi | Morocco | Omega Green | 2019 |
| Heidelberg | Canakkle | Turkey | Tubitak Insititute | Announced |
| Votorantim | St. Marys | Canada | Pond Technologies | |
| Argos | | Columbia | Eafit Univ. | |
| Cemex | | UK | Algaecat Consortium | Closed |
| Holcim (sold) | Lanka | Sri Lanka | Algae-Tec | Not started |
| Secil | Cibra-Pataias | Portugal | A4F – Algafuel | |
| Intercement | | Brazil | Various Universities | |
| Taiwan Cement | Hoping | Taiwan | ITRI | |
| Calcia | | France ? | Algo Source Technologies | Pilot |
| Cemex | | Croatia | Yodfat Engineers | Study ? |



Heidelberg



Cemex



Votorantim

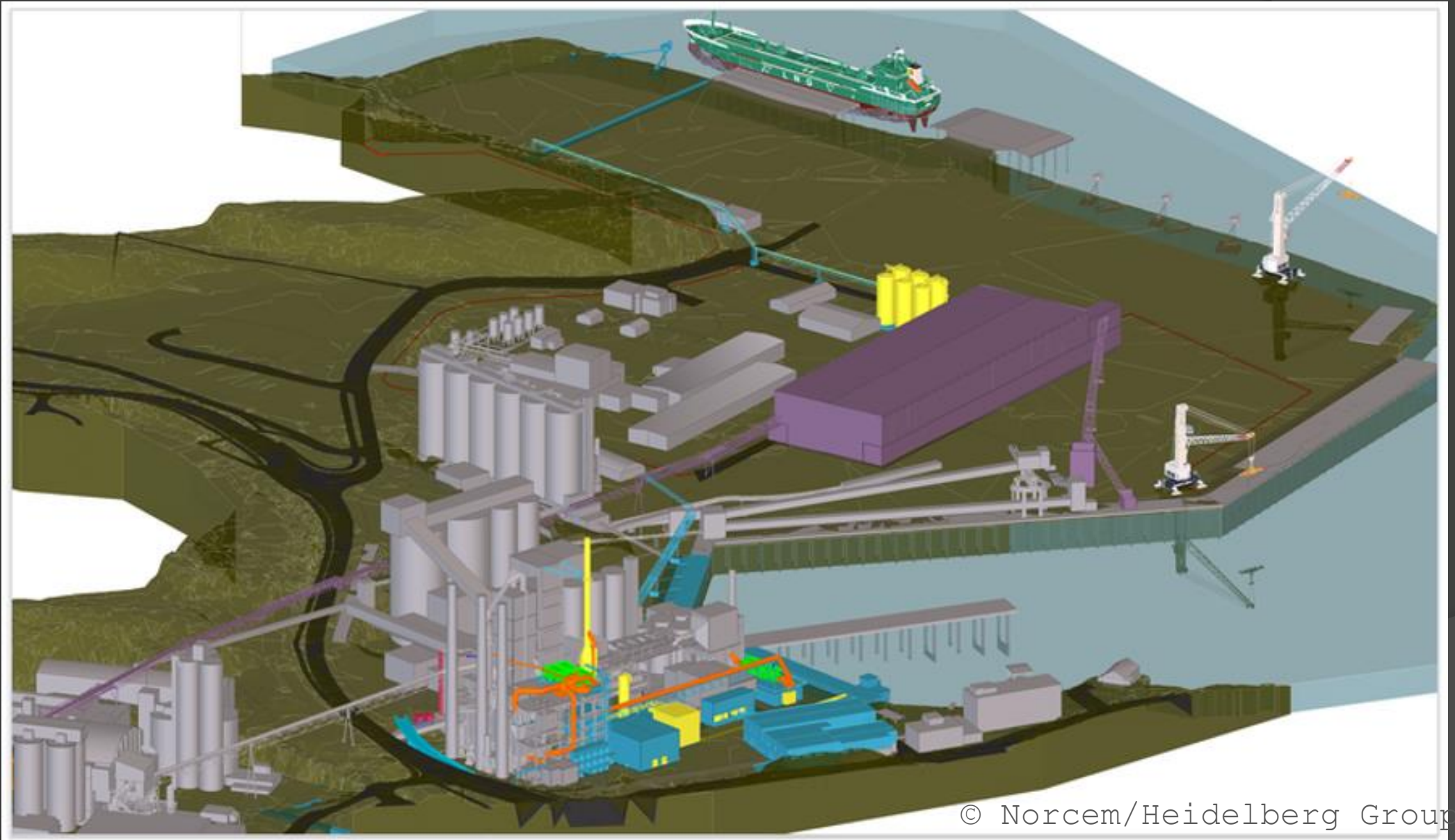


Argos

Liquid Solvents

| Company | Plant | Country | Partner | Capacity | Comments |
|-------------|-------------|----------------|--------------|------------|---------------|
| Anhui Conch | Baimasham | China | | 50k TPY | Operating |
| Heidelberg | Brevik | Norway | Aker | 400k TPY | Permitting |
| Dalmia | Tamil Nadu | India | Carbon Clean | 500k TPY | Status ? |
| Holcim | Carboneras | Spain | Carbon Clean | 70k TPY | Status ? |
| Cemex | Victorville | United States | Carbon Clean | 10 TPD | Ongoing study |
| Heidelberg | Edmonton | Canada | | 760k TPY | Ongoing study |
| Heidelberg | Brevik | Norway | | Pilot | Completed |
| Heidelberg | Slite | Sweden | Amines | 1,600k TPY | Announced |
| Taiheyo | Kumagaya | Japan | Carbon Clean | Pilot | Announced |
| Taiheyo | Fujiwari | Japan | | Pilot | Announced |
| Taiheyo | Mojave | United States | CanSolv | Pilot | Completed |
| Rohrdorfer | Rohrdorf | Germany | Andritz | Pilot | Announced |
| Cemex | Rudersdorf | Germany | Carbon Clean | Pilot | Announced |
| Tokuyama | Shunan | Japan | Mitsubishi | Pilot | Announced |
| Holcim | Beckum | Germany | | Pilot | Announced |
| Heidelberg | Ketton | United Kingdom | C-Capture | Study | Announced |

Heidelberg – Norcem Brevik Plant (440k TPY)



© Norcem/Heidelberg Group

Heidelberg – Edmonton Plant (google maps)



Heidelberg – Edmonton Plant ()



Oxy-Combustion Projects

| Company | Plant | Country | Partner | Capacity | Comments |
|------------|-------------------|---------|--------------|----------|-----------|
| Holcim | Laegersdorf | Germany | Consortium | Project | Announced |
| Holcim | Mannersdorf | Austria | Consortium | Project | Announced |
| Cemex | Ruderdorf | Germany | Consortium | Study | Status ? |
| Holcim | Retznei | Austria | | Study | Announced |
| Heidelberg | Colleferro | Italy | | Study | Announced |
| Schwenk | Mergelsstetten | Germany | Consortium | 450 TPD | Announced |
| | | Germany | Consortium | Study | Announced |
| Vicat | Montalieu-Vercieu | France | EDF-Hynamics | 800k TPY | Announced |
| Holcim | Obourg | Belgium | | | Announced |
| Equiom | Lumbres | France | Air Liquide | 600k TPY | Announced |
| Carmeuse | Charleroi | | | | Status ? |

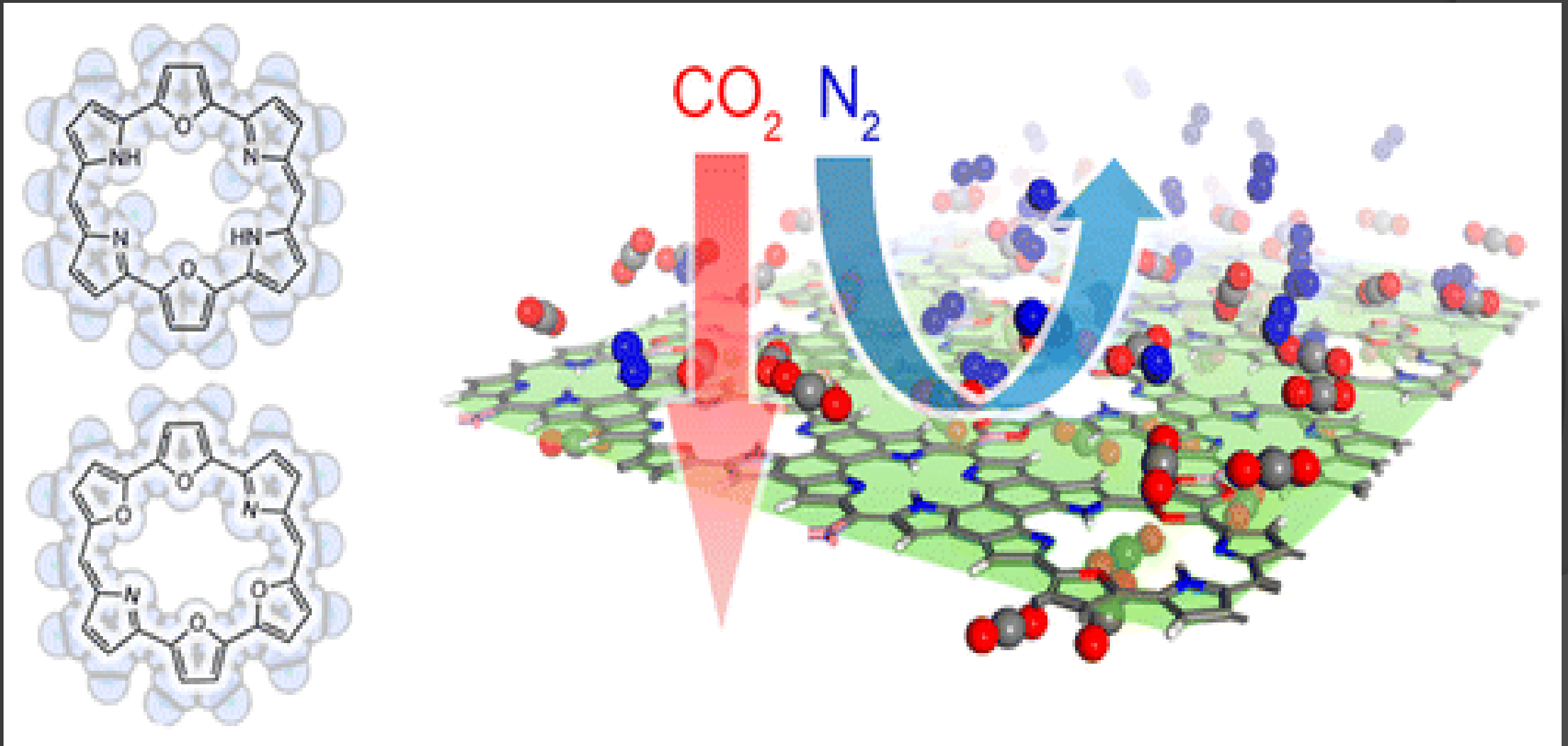
Mineralization Projects

| Company | Plant | Country | Partner | Capacity | Comments |
|-------------|-------------|---------------|------------------|-------------|-----------|
| CRH | Mississagua | Canada | Carbon8 | Pilot | Completed |
| Vicat | Montalieu | France | Carbon8 | Pilot | Ongoing ? |
| | | France | Consortium | Study | Fastcarb |
| Holcim | | United States | Solidia | Large Pilot | Ongoing |
| Cemex | | Canada | Carbon Upcycling | | Announced |
| Holcim | | | Eni | | Announced |
| Holcim | Mons | Belgium | | | Announced |
| CalPortland | Redding | United States | Forterra | Pilot | Announced |
| Titan | Kamari | Greece | | Pilot | Announced |

Membrane Projects

| Company | Plant | Country | Partner | Capacity | Comments |
|------------|----------|---------------|--------------------|----------|-----------|
| Cemex | Balcones | United States | MTR | Pilot | Announced |
| Heidelberg | Brevik | Norway | Consortium | Pilot | Completed |
| Titan | Kamari | Greece | Consortium | Study | Announced |
| Cemex | | | Genesis | Study | Announced |
| Holcim | Hover | Germany | Consortium | Pilot | Announced |
| Cemex | | Croatia | Yodfat Engineering | Study | Announced |
| | | | Agualung | 2 Pilots | Announced |

Membrane technology



Hydrogen Fuel

| Company | Plant | Country | Partner | Capacity | Comments |
|----------------|-------------|----------------|-------------|----------------|-----------|
| Heidelberg | Ribblesdale | United Kingdom | | Pilot / Plasma | Announced |
| Heidelberg | Port Talbot | United Kingdom | | Pilot | Operating |
| Cemex | Alicante | Spain | | Pilot | Announced |
| Cemex | Rugby | United Kingdom | | Project / AF | Announced |
| Secil / Cimpor | | Portugal | Rega Energy | 40 MW | Announced |

Carbonate Looping

| Company | Plant | Country | Partner | Capacity | Comments |
|---------------|----------|---------|-------------|----------|-------------|
| Buzzi Unicem | Vernasca | Italy | Consortium | Pilot | Operating |
| Taiwan Cement | Hoping | Taiwan | TDRI & ITRI | 1 TPD | Operating ? |
| Heidelnerg | Brevik | Norway | Alstom | Pilot | Closed |
| Heidelberg | | Norway | GE | Pilot | Closed |
| Cemex | | | Consortium | Study | Announced |

Cleaner Project, Vernasca, Italy



Cryogenic Capture

| Company | Plant | Country | Partner | Capacity | Comments |
|-----------------------|---------------|---------------|-------------|--------------|-----------|
| Holcim | Devil's Slide | United States | SES | 1 TPD Pilot | Closed |
| Argos | Roberta | United States | SES | 1 TPD Pilot | Closed |
| Central Plains Cement | Sugar Creek | United States | SES | 30 TPD Study | Ongoing |
| Holcim | St Genevieve | United States | Air Liquide | Feed Study | Announced |
| Lhoist | Rety | France | Air Liquide | 600k TPY | Announced |

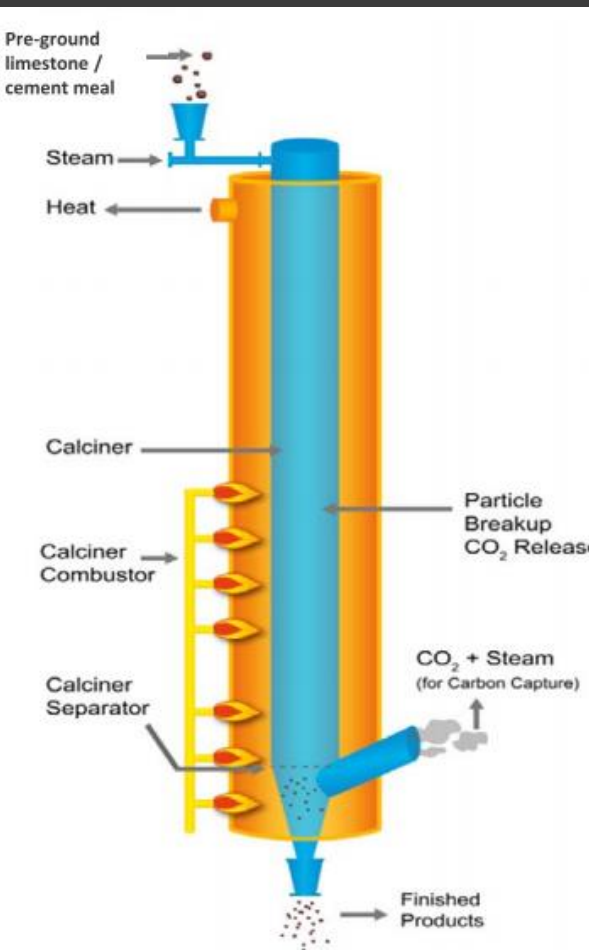
Indirect Calcination

| Company | Plant | Country | Partner | Capacity | Comments |
|------------|--------------------|-----------|------------|----------------|-------------|
| Heidelberg | Lixhe | Belgium | Consortium | Pilot | Operating ? |
| Heidelberg | Hanover | Germany | Consortium | 100k TPY | Announced |
| ANICA | | | Consortium | Study | Announced |
| Boral | Southern Highlands | Australia | Calix | Pre Feed Study | Announced |

Heidelberg Lixhe Pilot

Phase 1 – debugging
Phase 2 – announced

HEIDELBERGCEMENT



Indirect Calcination Tower

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Concentrated Solar Power

| Company | Plant | Country | Partner | Capacity | Comments |
|---------|-------|-------------|------------|----------|-----------|
| Holcim | | Switzerland | ETH Zurich | Study | Closed ? |
| Cemex | | France | Consortium | Pilot | Closed |
| Titan | | Greece | | Study | Announced |
| Cemex | | Mexico | Synhelion | Pilot | Announced |

Cemex & Synhelion
Pilot to be operating by 2022
Site not mentioned



Solid Adsorbents

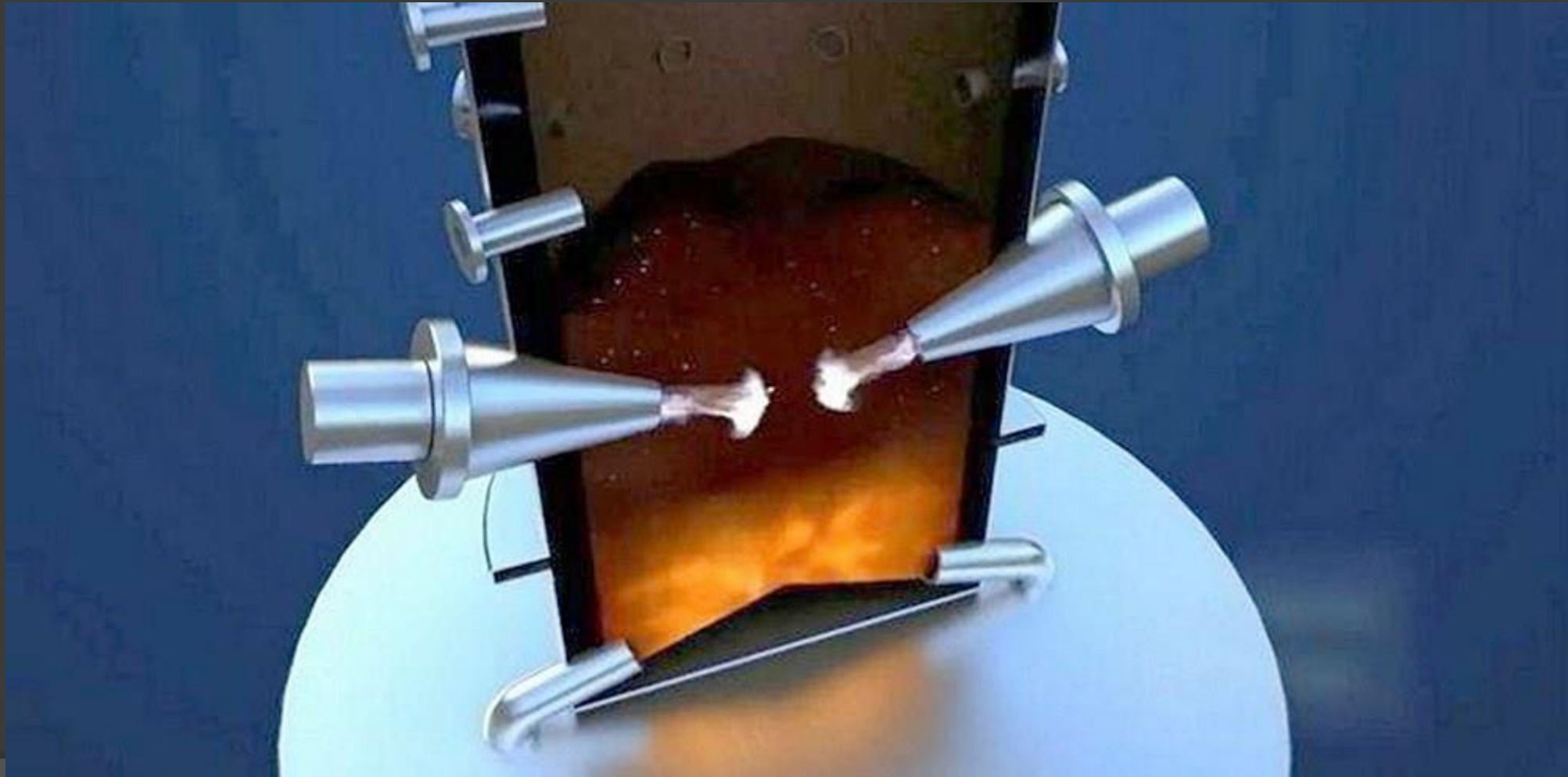
| Company | Plant | Country | Partner | Capacity | Comments |
|------------|----------|---------------|----------------|-----------------------|-------------|
| Heidelberg | Brevik | Norway | RTI | Pilot | Closed |
| Holcim | Richmond | Canada | Svante / Total | 1 TPD Pilot | Operating ? |
| Holcim | Florence | United States | Svante / Total | 1mn TPY FEED study | Announced |
| Titan | Kamari | Greece | Consortium | Pilot | Announced |

Plasma

| Company | Plant | Country | Partner | Capacity | Comments |
|------------|-------------|----------------|------------|----------|-----------|
| Heidelberg | Ribblesdale | United Kingdom | Consortium | Pilot | Announced |
| Cemex | | | | | Closed |

Ribblesdale, UK (H) Zero Carbon Fuel

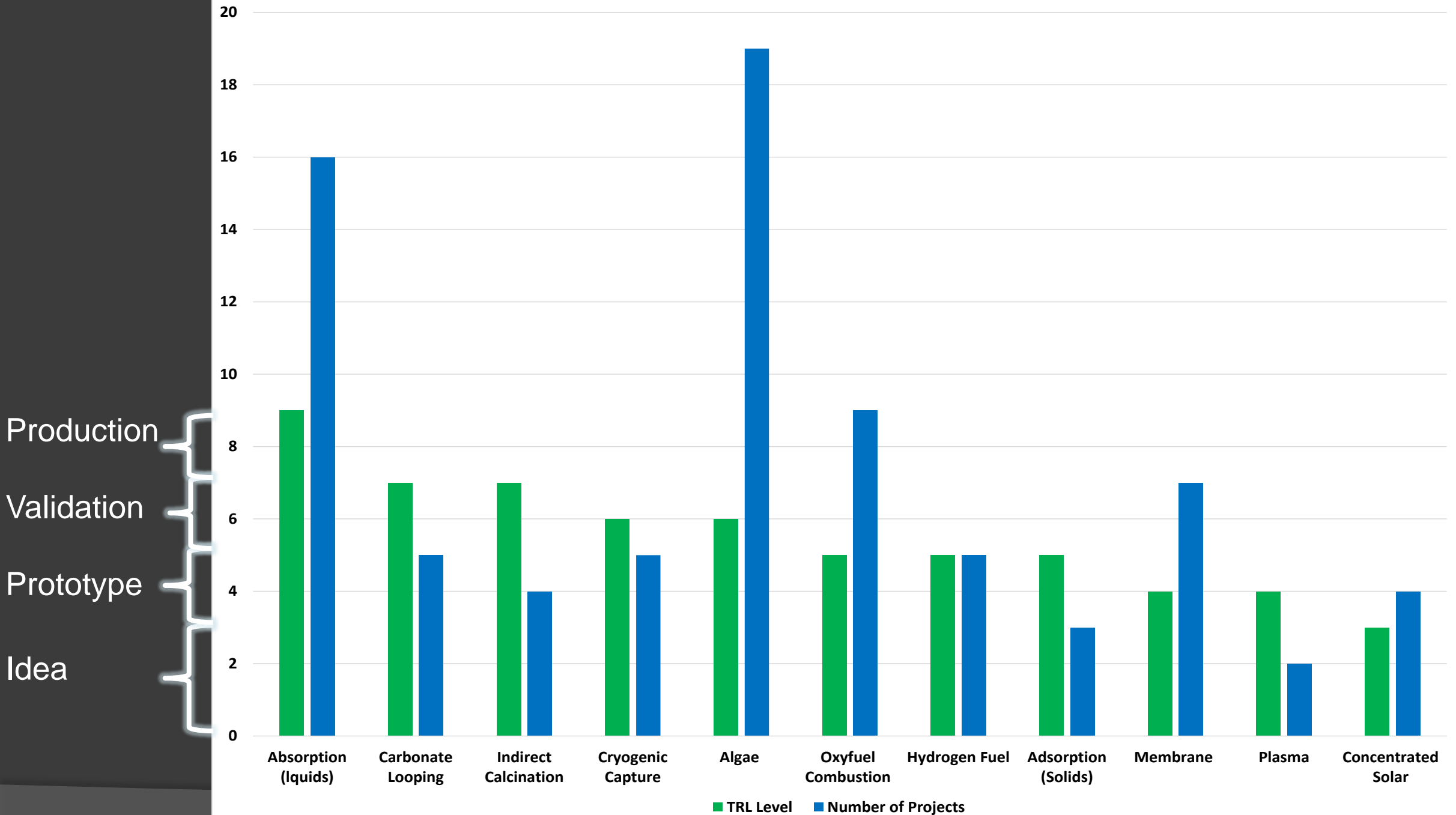
70% biomass,
20% hydrogen and
10% plasma energy



In the US & Canada

- CarbonFree / SkyMine – Chemical Process – Capitol Cement – San Antonio, TX – 50ktpy
- Svante – solid sorbent – LafargeHolcim – Richmond BC – 1tpd pilot
- Svante – solid sorbent – Holcim - Florence, CO – FEED Study
- Carbon Clean – Liquid sorbent – Cemex – Victorville, CA – 10 tpd Pilot study
- MTR – Membranes – Cemex – Balcones, TX
- Air Liquide – Membrane Liquefaction – Holcim – St. Gen, MO – FEED study
- Mitsubishi – Amine – Heidelberg – Edmonton, AB, Canada – FEED
- Carbon8 – Mineralization – CRH – Mississauga, ON, Canada – Pilot
- SES – Cryogenic – Central Plains – Sugar Creek, MO – 30 tpd pilot
- Heliogen – CSP – California Cement Plant – Pilot
- Mitsubishi – Amine - Heidelberg – Mitchel, IN – FEED study
- Hydrogen – Lots of interest

Technology TRL Levels & Number of Studies, Pilots, and Projects



Summary & Conclusions

- ⦿ There are bold commitments for 2030 and 2050
- ⦿ CCUS required for 40-60% of the reduction to zero
- ⦿ There are a lot of ongoing studies, pilots, and projects
- ⦿ Many of which are publicly funded
- ⦿ Move from company specific to consortium approach
- ⦿ Despite all of the announcements, very little “real” investment has been made
- ⦿ Serious CCUS will require serious money and serious real estate
- ⦿ Investments in “Green Energy” are growing, mostly photovoltaic
- ⦿ Meanwhile interest in cement and concrete substitutes is also growing

QUESTIONS & ANSWERS

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