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LEAP
Laboratorio Energia e Ambiente Piacenza

CLUST-ER GREENTECH
ENERGIA E SOSTENIBILITÀ

## Ecomondo - Key Energy

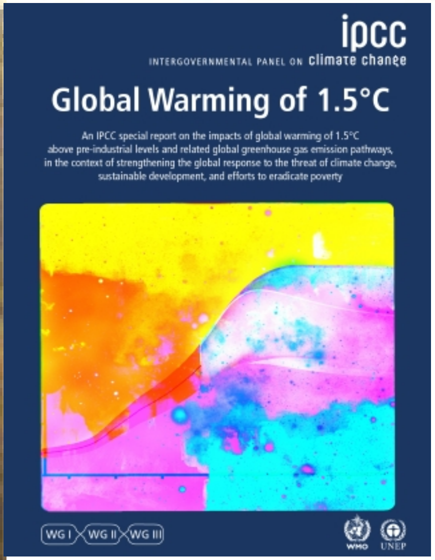
Rimini, 08 novembre 2018

# CCUS - cattura, utilizzo e stoccaggio della CO2 - una sfida tecnologica e una opportunità per il mondo industriale

*Prof. Stefano Consonni*

*Politecnico di Milano / presidente LEAP*

# IPCC - SR15- Special report on 1.5 deg warming




**IPCC - SR15- Special report on 1.5 deg warming**

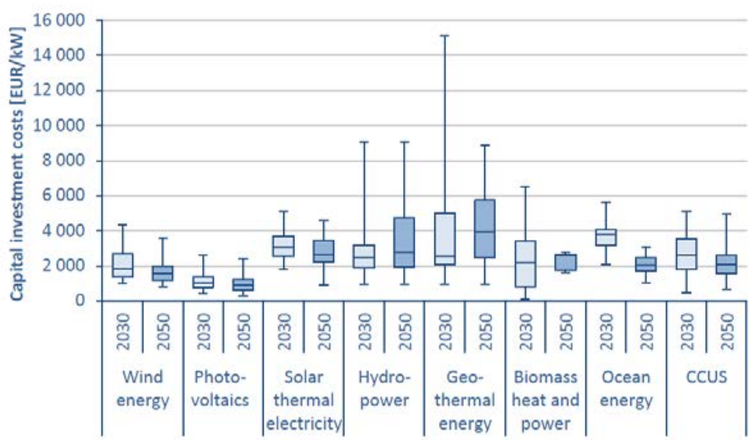
**October 2018**

# The daunting job of the mitigation strategy

**How can we meet the Paris targets ?**

– **There's NO SINGLE solution**

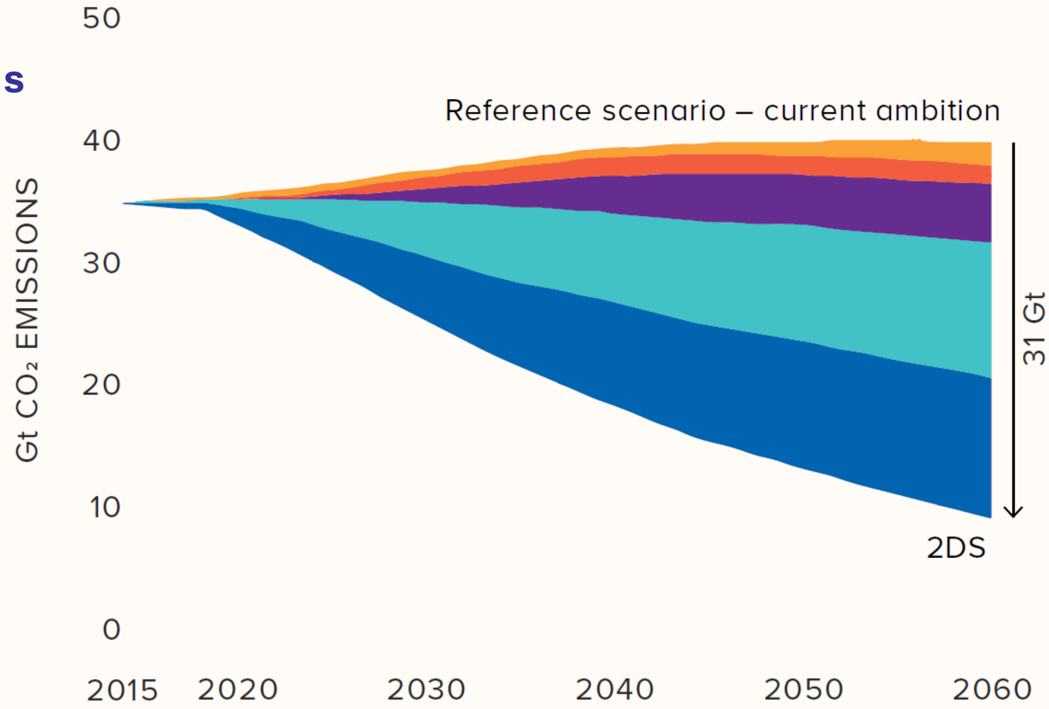
– **Must pursue a portfolio of strategies**
- higher energy efficiency
- more renewables
- fuel switching
- CCS
- nuclear
- etc., etc. ...




Investment costs of low carbon technologies according to literature

JRC Tecnical Report, 2018, "Cost development of low carbon energy technologies"

## CCS in the 2DS



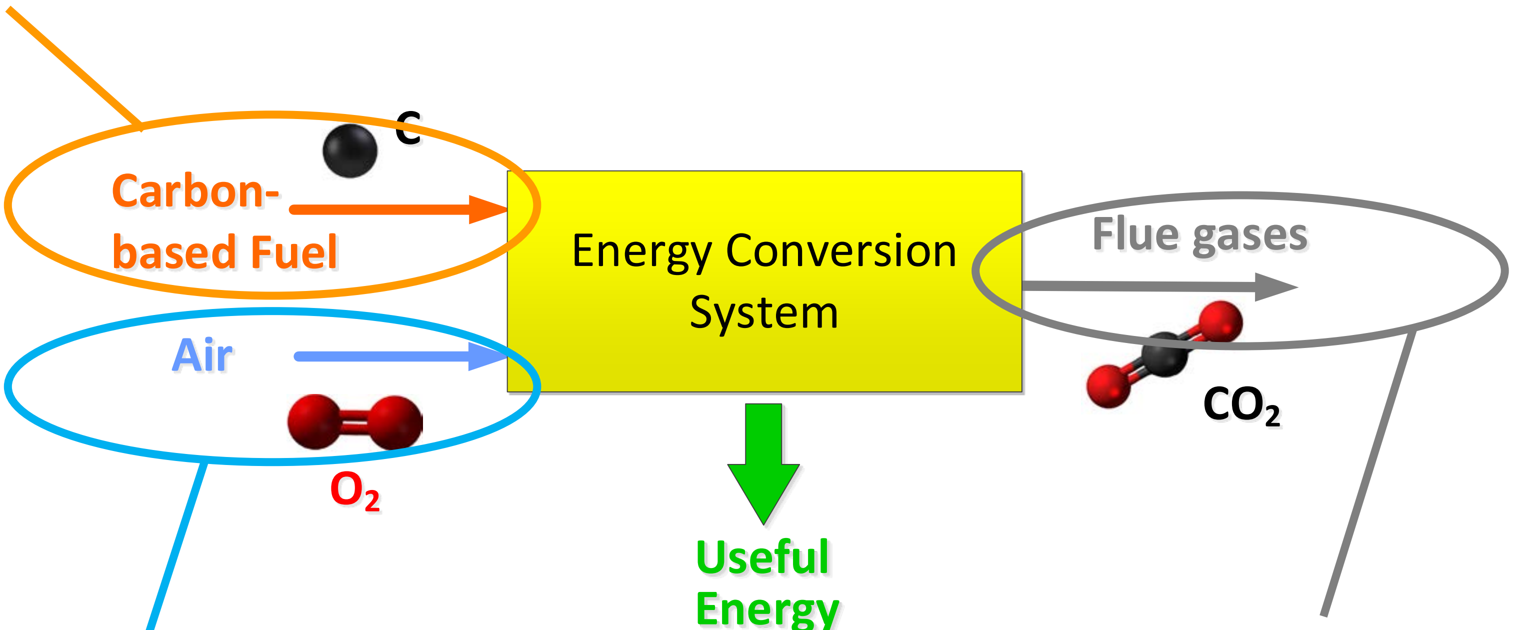

Source: International Energy Agency, "Energy Technology Perspectives 2017", Paris: OECD/IEA, 2017

- Efficiency 40%
- Renewables 35%
- CCS 14%
- Nuclear 6%
- Fuel switching 5%

**CCS: a key strategy to manage the transition toward carbon-free energy sources and carriers**

**In an energy conversion systems fed with fossil fuels, $CO_2$ capture can be pursued according to three basic concepts**

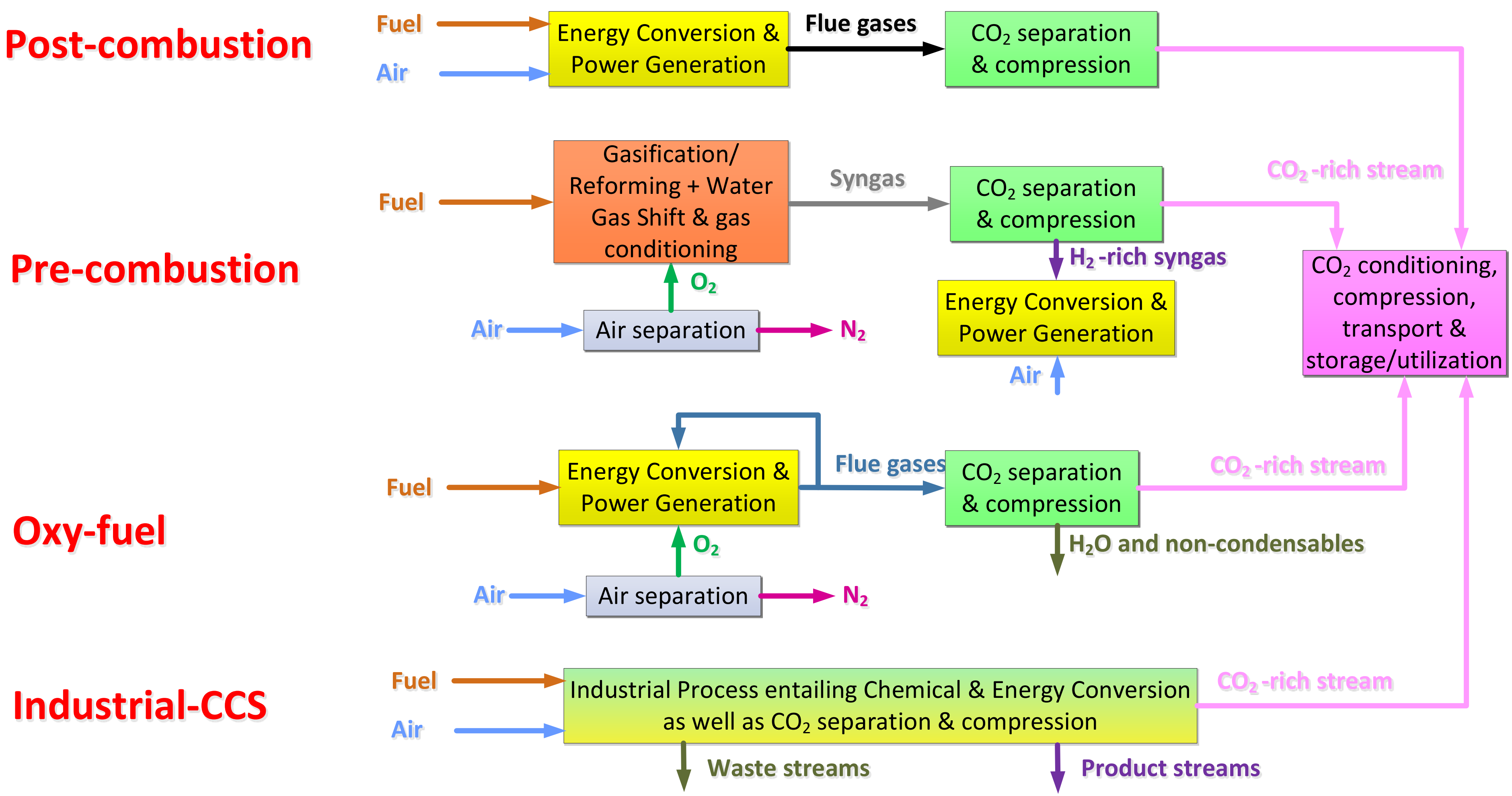
1. Treat the fuel → <u>pre-combustion</u> capture




3. Treat the flue gases → <u>post-combustion</u> capture

2. Treat the oxidizer → <u>oxy-fuel</u>

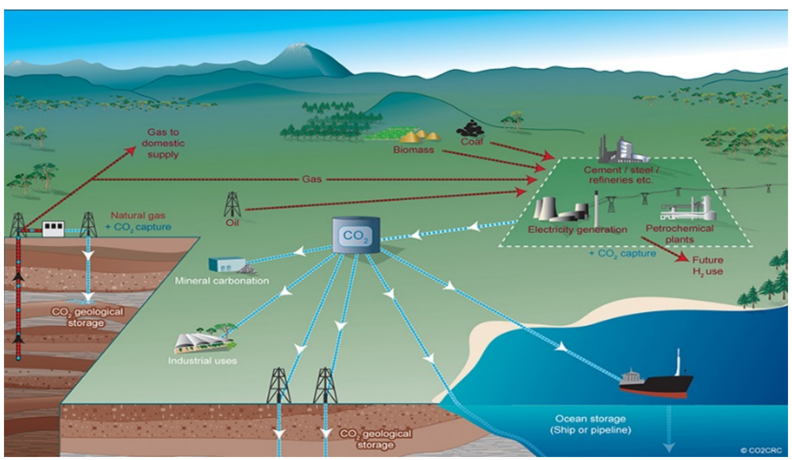
# CO2 capture concepts

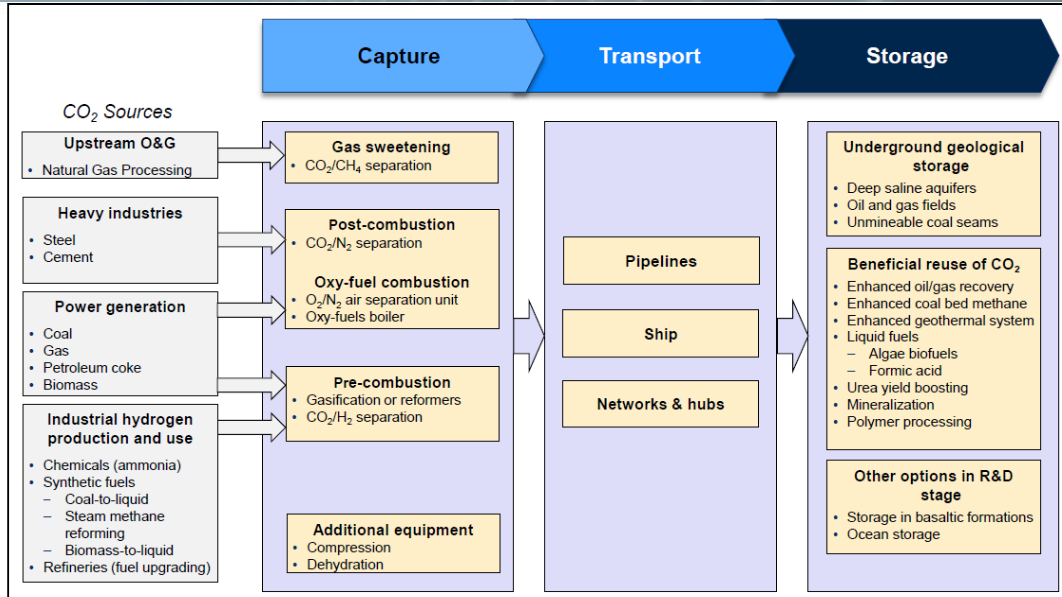


# What is CC(U)S ?

**CCS refers to a set of CO2 capture, transport and storage technologies to abate emissions from stationary CO2 sources**

1. **Capture CO2-rich gas**
2. **Transport (pipeline or shipping)**
3. **Injection (or Utilization)**




**TOP R&D PLAYERS IN TERMS OF PATENTS FILED**

| | $CO_2$ CAPTURE | TRANSPORT | STORAGE |
|---|---|---|---|
| **Key R&D players** | ▪ Praxair<br>▪ Air Liquide<br>▪ Air products<br>▪ Linde<br>▪ Shell<br>▪ Mitsubishi<br>▪ ExxonMobil<br>▪ Arkema<br>▪ General electric<br>▪ IFPEN | ▪ GDF Suez<br>▪ Maersk<br>▪ Wartsila | ▪ Shell<br>▪ IFPEN<br>▪ Terralog<br>▪ ExxonMobil<br>▪ Schlumberger<br>▪ CDX gas<br>▪ Air products<br>▪ Diamond qc technologies<br>▪ Dropscone<br>▪ BHP Billiton |

"LEADING THE ENERGY TRANSITION FACTBOOK - Carbon Capture and Storage Bringing Carbon Capture and Storage to Market - SBC Energy Institute - September 2012"

# CC(U)S: Capture

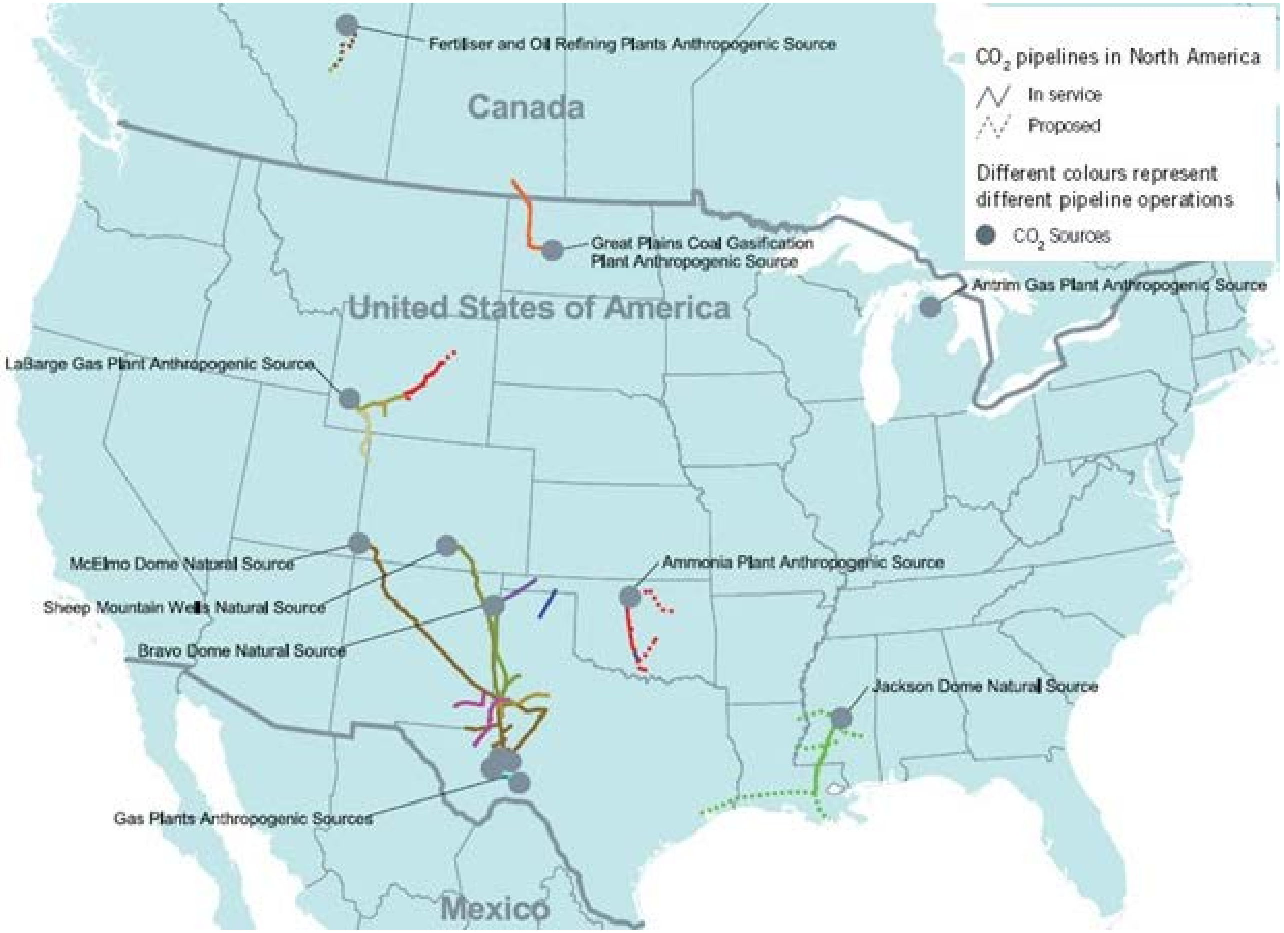

Coal power plant ("Boundary Dam") in Canada:
1.3 Mt / year of $CO_2$ captured (2014).


Coal power plant ("Petra Nova") in Texas:
1.6 Mt / year of $CO_2$ captured (2016).

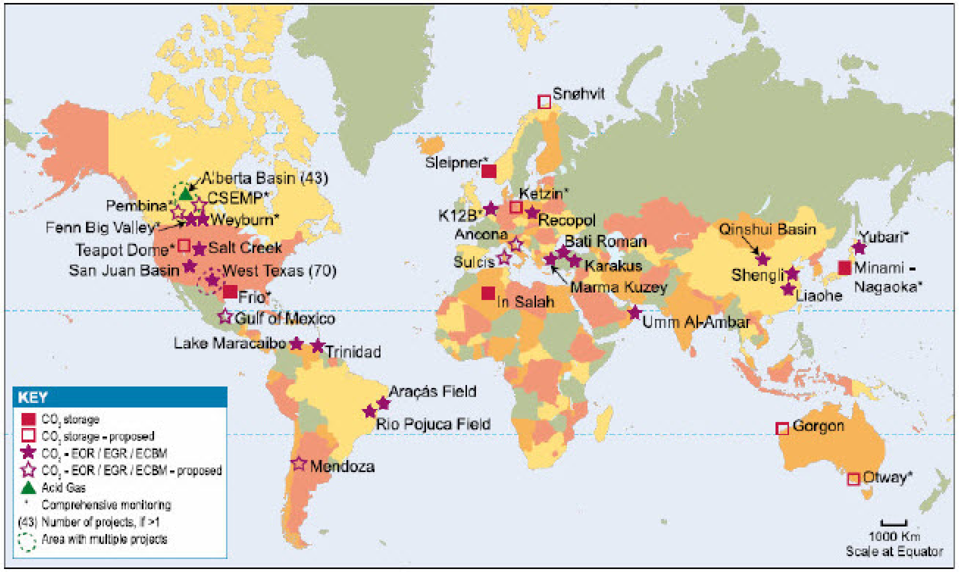
# Petra Nova – July 2018

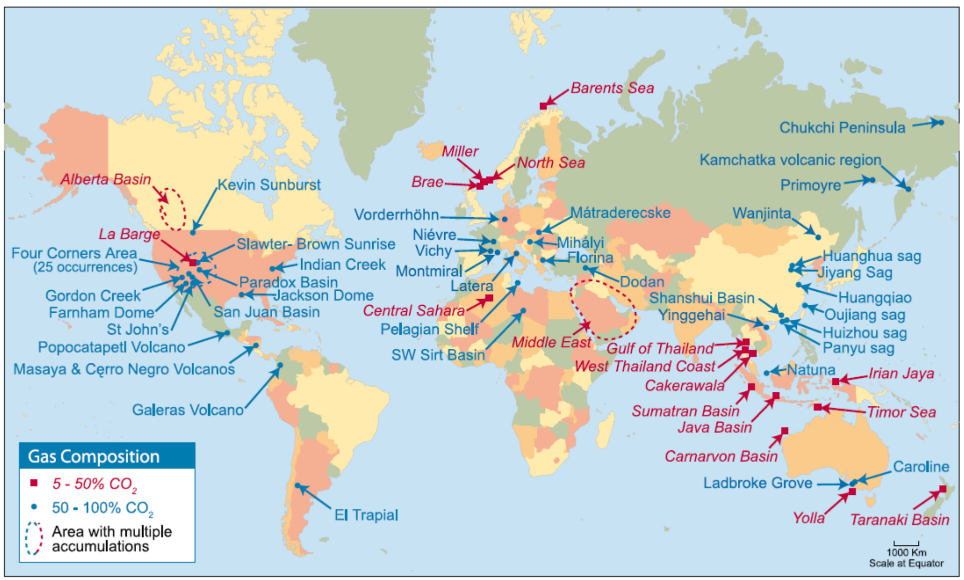
# CC(U)S: Transport

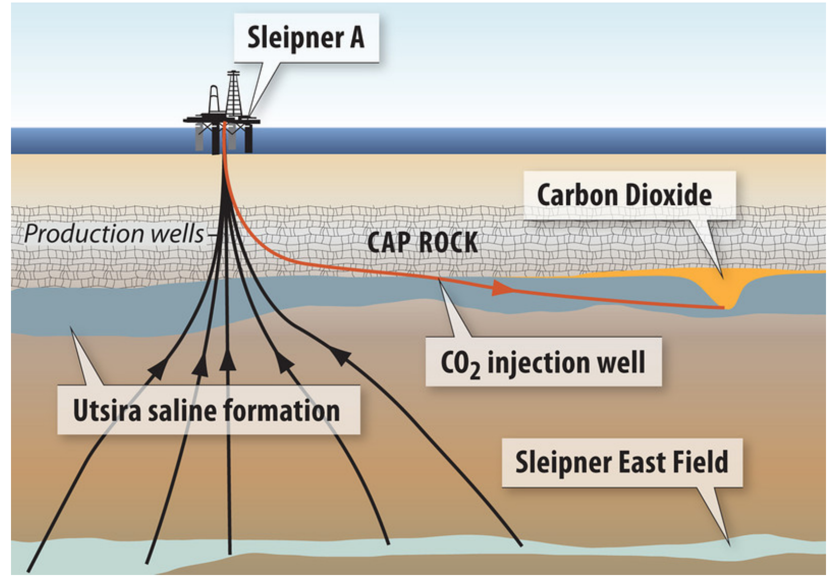
## USA – 6,000 km of pipelines in the last 40 years



# CC(U)S: Storage



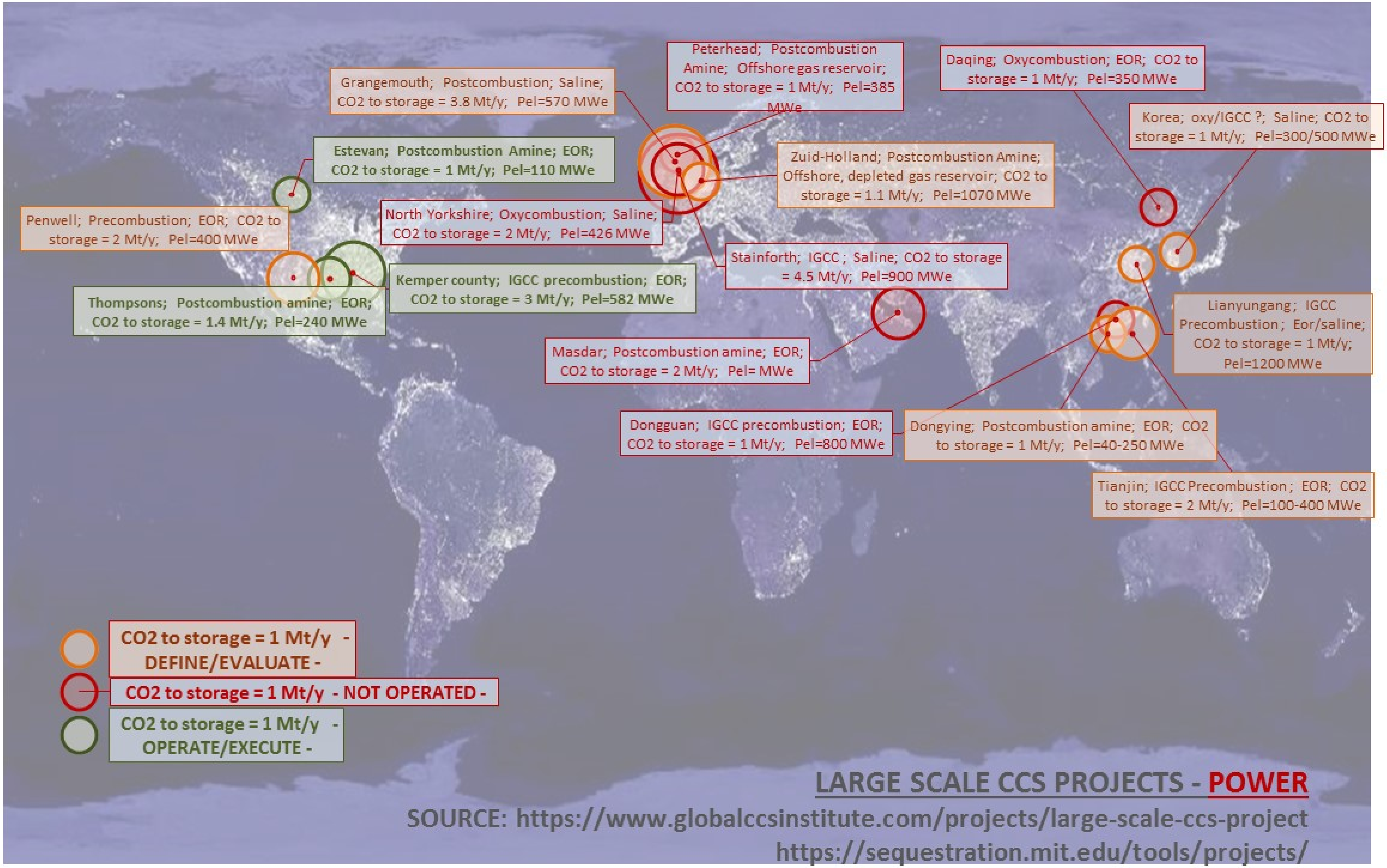



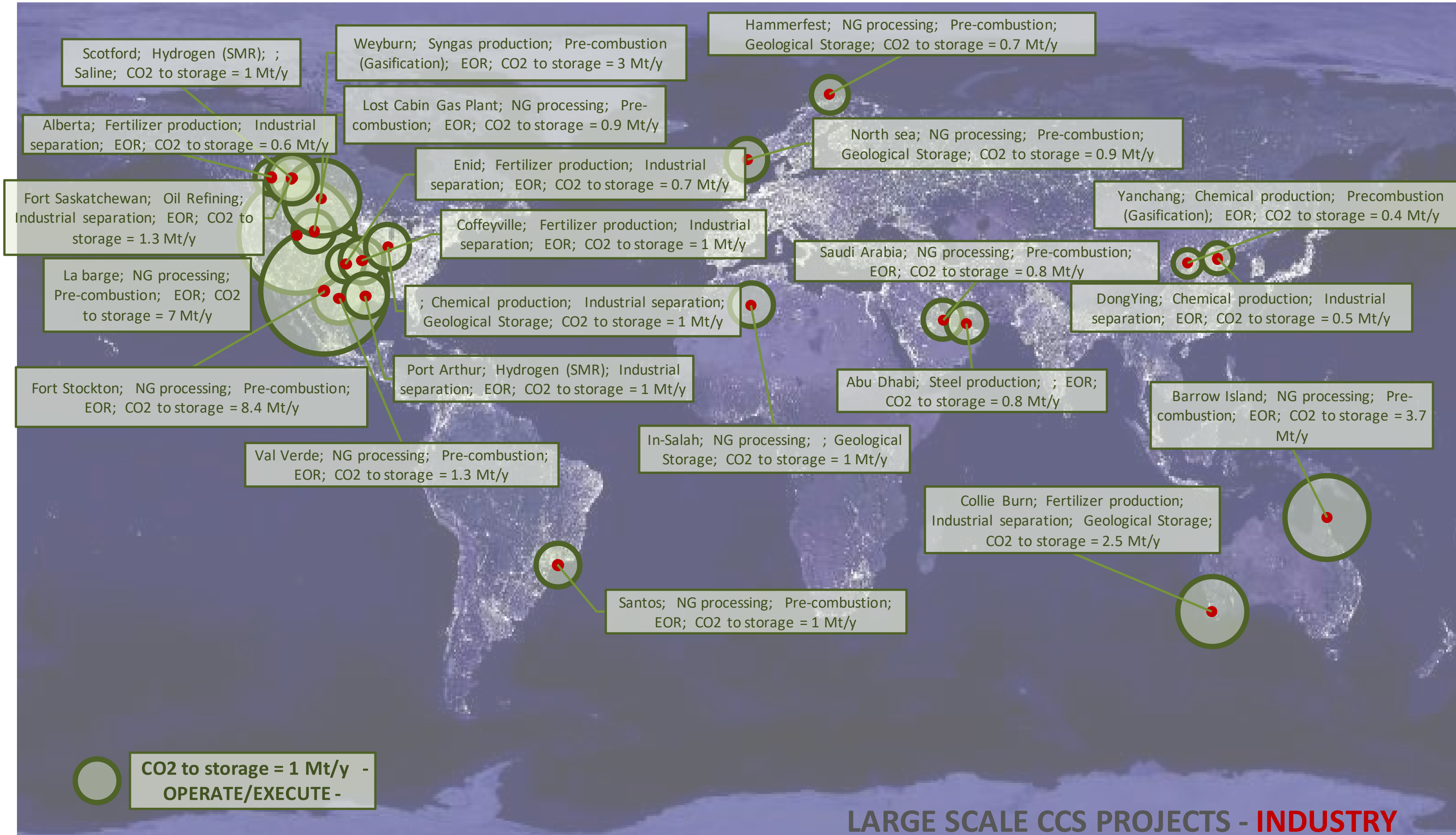


**Sleipner plant:**
**0.85 Mt / year of $CO2$ (1996).**

# Reaserch and demonstration efforts: Power

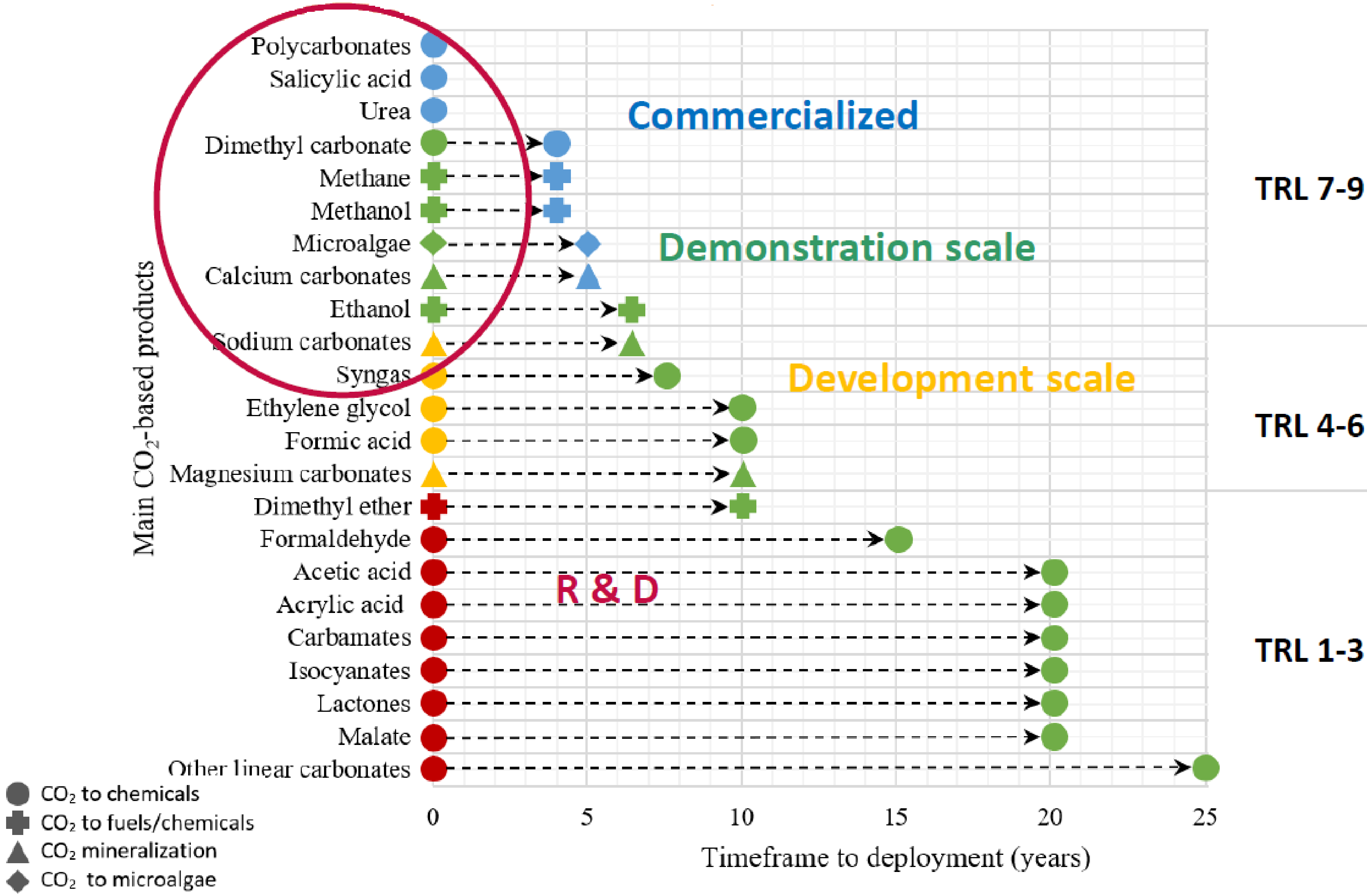


# Reaserch and demonstration efforts: Non-Power




SOURCE:https://www.globalccsinstitute.com/projects/large-scale-ccs-project

## Technology Readiness Level for main CO2-based products



## Novel CCU Technologies, research and climate aspects. A SAPEA Report

- **Under what circumstances CCU for production of fuels, chemicals and materials can deliver climate benefits and what are their total climate mitigation potential in the mid- and long-run?**

- **How can the climate mitigation potential of CO2 incorporated in products such as fuels, chemicals and materials be accounted for considering that the CO2 will remain bound for different periods of time and then may be released in the atmosphere?**

SAPEA

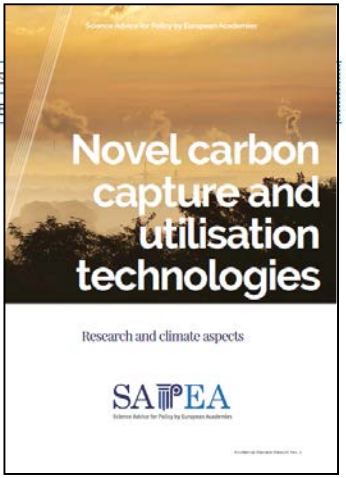
Science Advice for Policy by European Academies

### 10. Working Group members

| | | | |
|---|---|---|---|
| **Schlögl (Chair)** | Robert | Fritz-Haber-Institute | Germany |
| **Abanades** | Carlos | Spanish Research Council | Spain |
| **Aresta** | Michele | CIRCC, University of Bari | Italy |
| **Blekkan** | Edd Anders | Norwegian University of Science and Technology | Norway |
| **Cantat** | Thibault | CEA | France |
| **Centi** | Gabriele | University of Messina | Italy |
| **Duic** | Neven | University of Zagreb | Croatia |
| **El Khamlichi** | Aïcha | ADEME | France |
| **Hutchings** | Graham | Cardiff University | United Kingdom |
| **Mazzotti (Co-chair)** | Marco | ETH Zürich | Switzerland |
| **Olsbye** | Unni | University of Oslo | Norway |
| **Mikulcic (invited member)** | Hrvoje | University of Zagreb | Croatia |

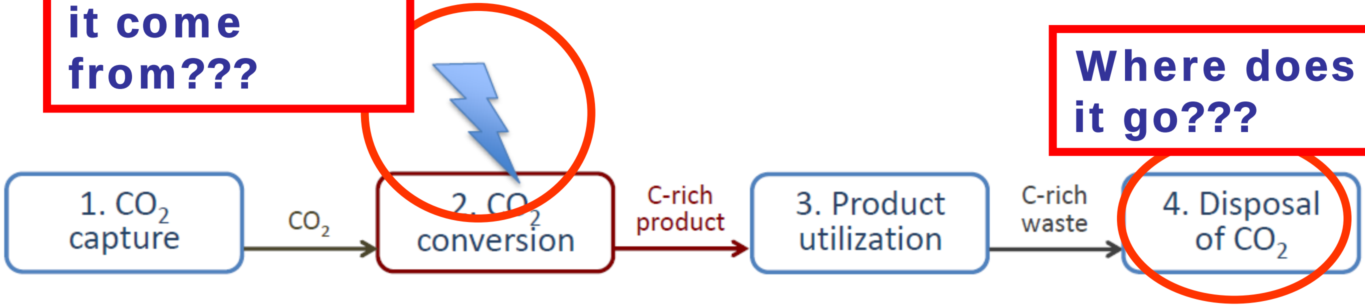
**Sherpa**

| | | |
|---|---|---|
| **Caristan** | Yves | S |
| **Gehrisch** | Wolf | E |



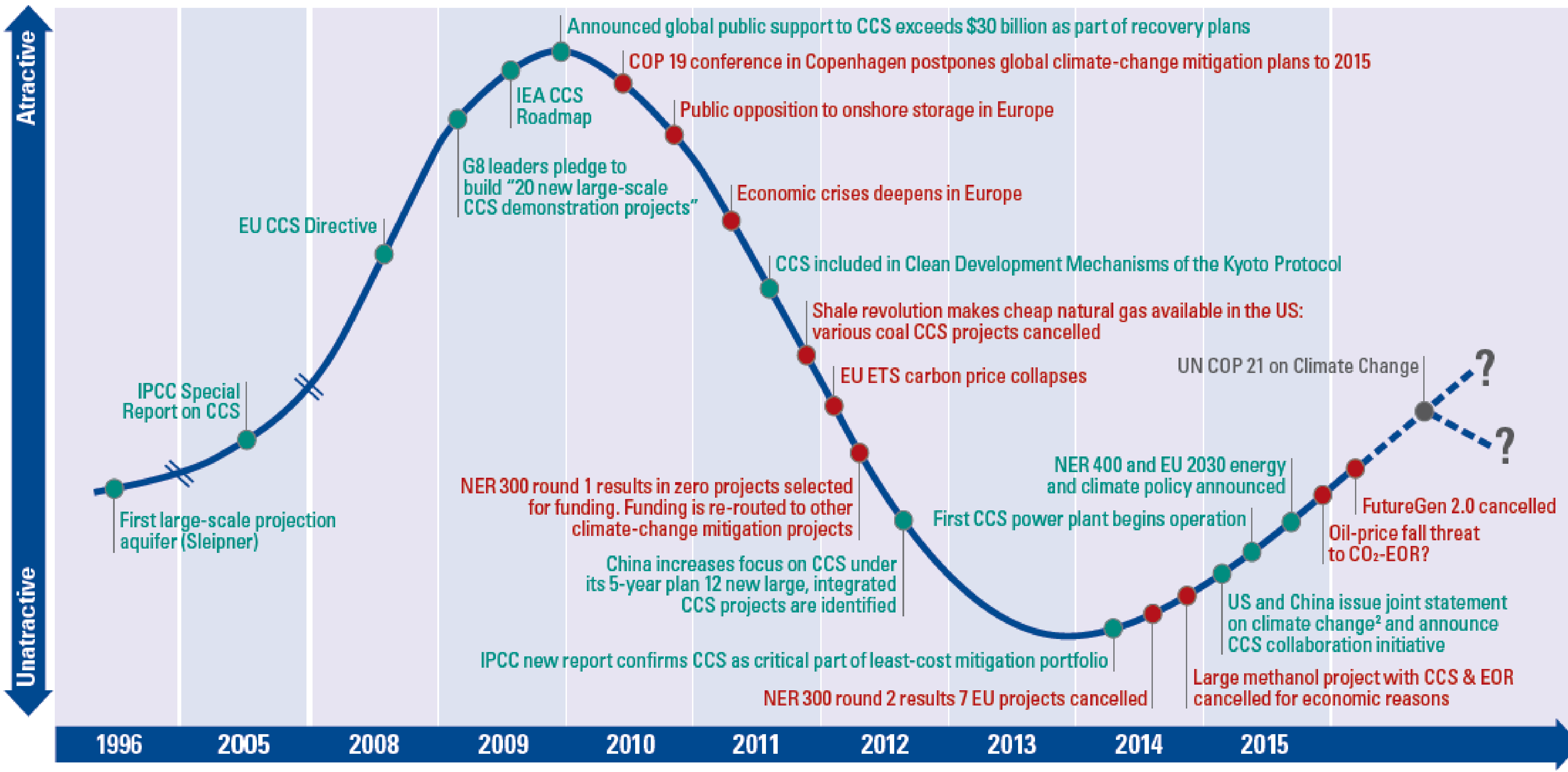

**Where does it come from???**

**Where does it go???**



# CCS policy and political support over time

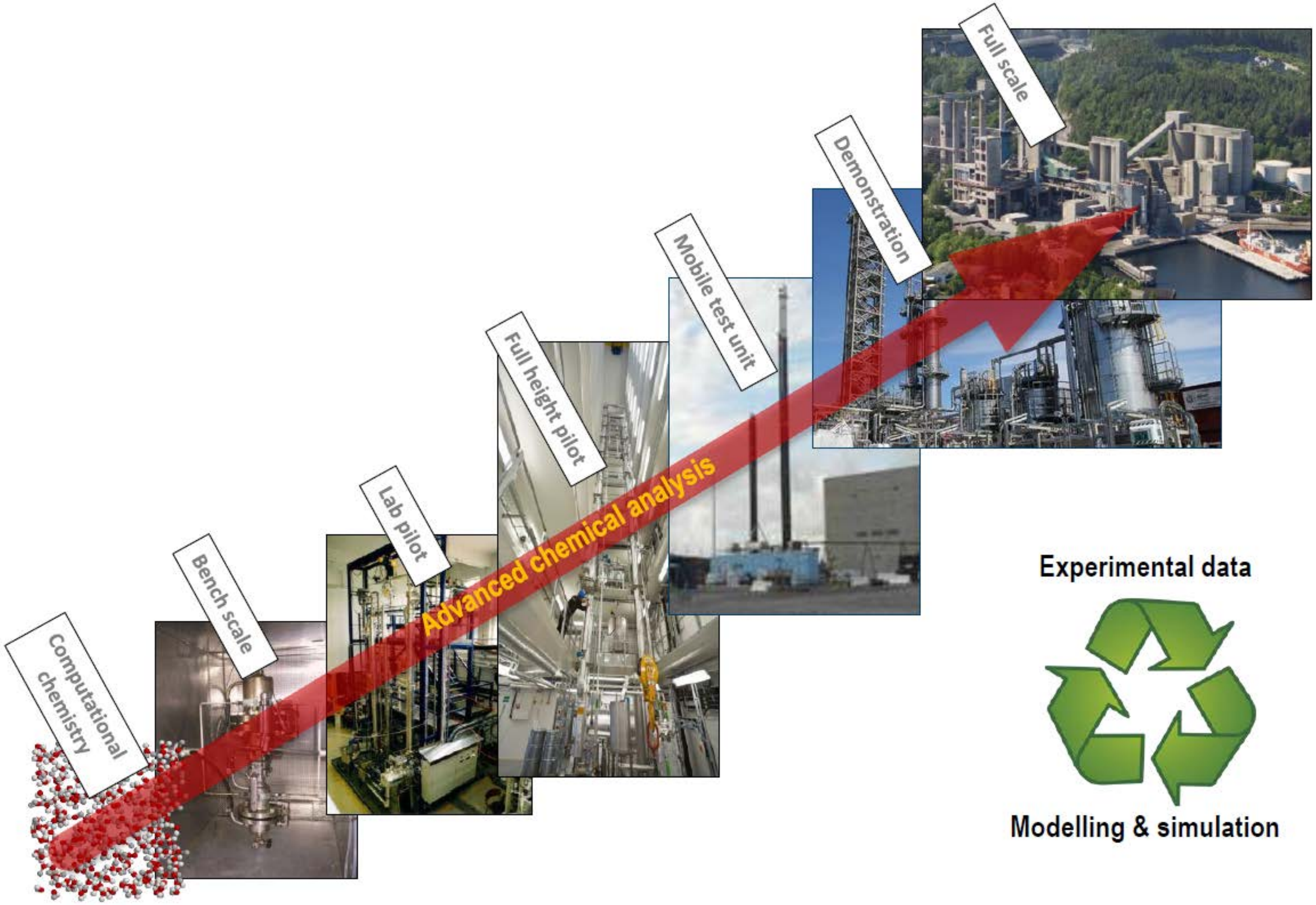
**Committed public funding is a fraction of initially hoped-for levels, due to depressed carbon prices, projects being cancelled and funds not being reallocated**




SBC Energy Institute (2016), Low carbon energy technologies fact book update: carbon capture and storage at a crossroads

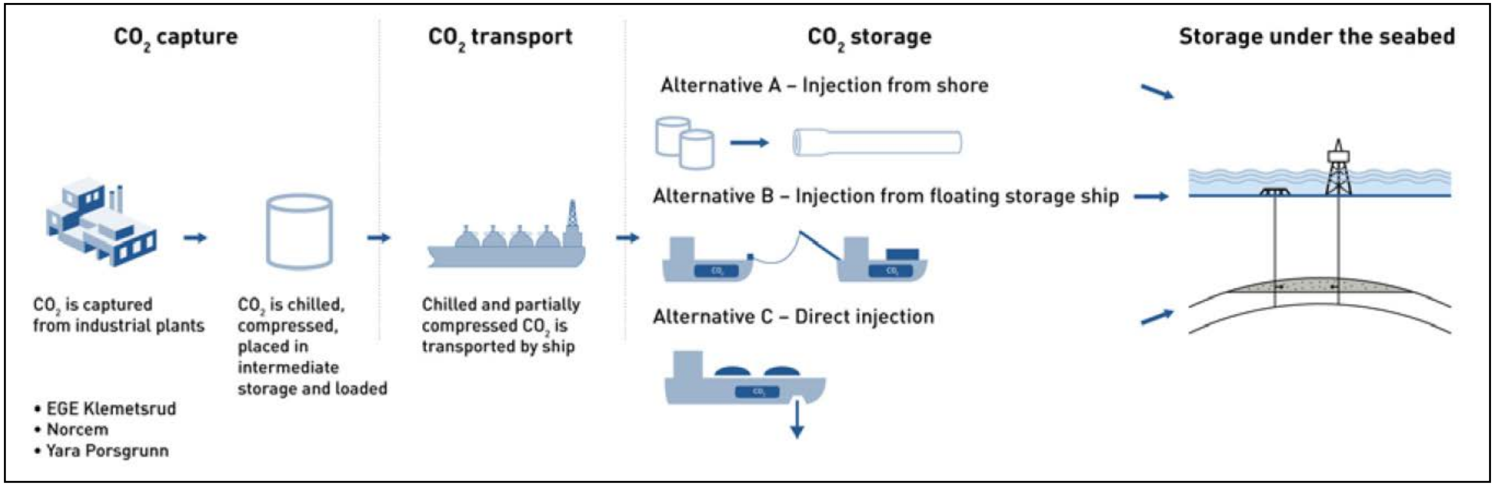
# Multi-scale approach

## to the development of CO2 capture technology

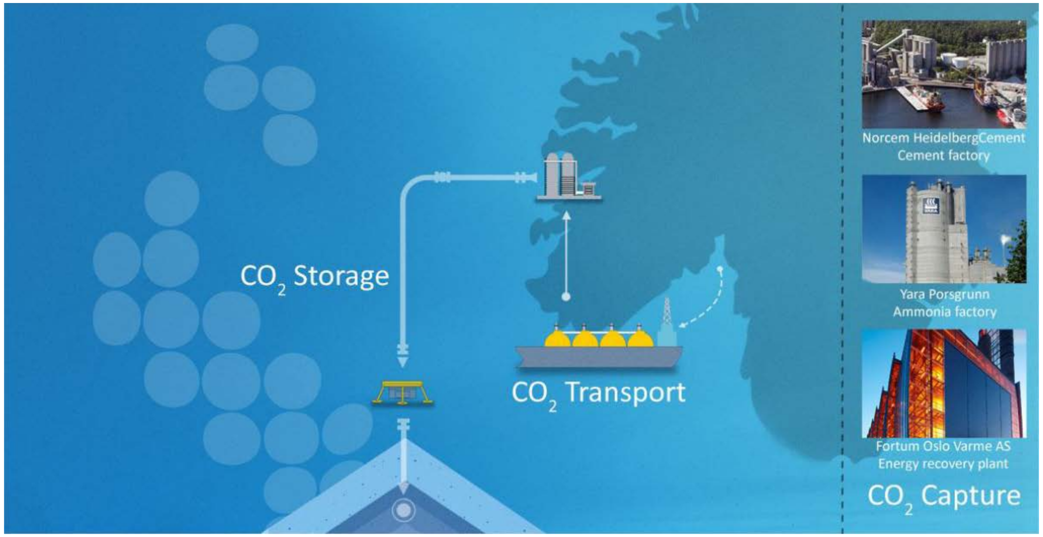



"Presentation: "The role of research in realizing CCS" – Nils A. Rokke – SINTEF – ECRA / CEMCAP / CLEANKER workshop, 2018"

# Non-power: the Norwegian Project




- **1,580,000 tonnes of CO2 / year coming from:**
  - **400,000 t / y from FORTUM OSLO VARME;**
  - **400,000 t / y from NORCEM, HEIDELBERG CEMENT;**
  - **780,000 t / y from YARA'S AMMONIA FACTORY.**
- **Storage: 50 km from the coast;**
- **The cost for planning and investment for such a chain is estimated to be between 0.750 and 1.32 billion euro (exluding VAT)**



# Non-Power: Cement - LEILAC project

- **Consortium**

Calix, Lhoist, HEIDELBERGCEMENT, amec foster wheeler

TARMAC A CRH COMPANY, CEMEX Building a better future, CARBON TRUST, Imperial College London, Quantis Sustainability counts, PSE, ECN

- **Indirect heating raw meal:**
  - Separate process $CO_2$
  - Calix MgO proven process
- **10 tph demonstration plant, Lixhe-Belgium**
  - Cement & Lime applications
  - www.leilac.org.uk

# Non-Power: Cement - CLEANKER project

**The ultimate objective of CLEANKER is <u>advancing the integrated Calcium-looping process for $CO_2$ capture in cement plants</u>.**

CLEAN clinKER by calcium looping for low-$CO_2$ cement

CLEANKER


Kick-off meeting - Piacenza, 18-19 ottobre 2017

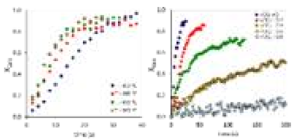
| Objective | Key indexes | Target |
|---|---|---|
| $CO_2$ emissions | $CO_2$ capture efficiency<br>$CO_2$ specific emissions | Cement plant $CO_2$ capture efficiency > 90%<br><br>Negative direct $CO_2$ emissions by biomass co-firing (Bio-CCS) |
| Economics | Cost of cement<br>Cost of $CO_2$ avoided | Increase of cement cost < 25 euro/$t_{cement}$<br><br>Cost of $CO_2$ avoided < 30 euro/$t_{CO_2}$ |

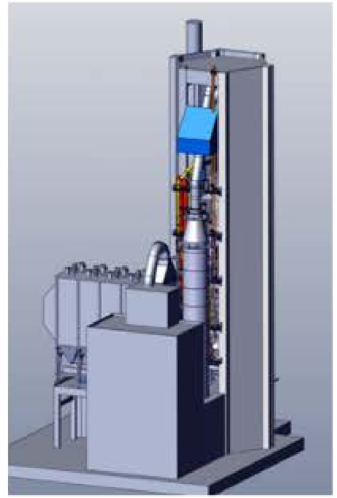
# CLEANKER project

1st October 2017

17-18 October 2017
Kick-off meeting
(Piacenza)

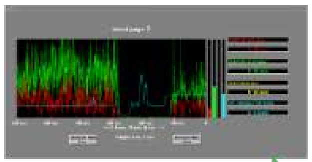
July 2018
Raw meal
characterization





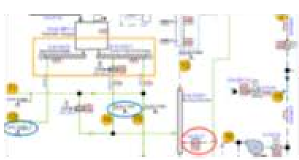
December 2019
Erection

March 2020
Running tests and
data analysis



2017 → 2018 → 2019 → 2020 → 2021

June 2018
Measuring points
and
instrumentation



July 2018
Final Plant layout

January 2020
Inspection

March 2019
Main items fabrication

April 2021
Casting concrete results
and full economic analysis
of cement plant with CaL

September 2021
Strategic conclusions

30th September 2021

# EU Emission Trading System (ETS)

5 - YEARS


1 - YEAR


**"The recent increase in CO2 prices might indicate that this will change in the future, and our analysis shows that prices of €10-30/ton could be sufficient to make low-emission alternatives compete with coal and gas during 2020-2030"**

**ERCST, Wegener Center, Nomisma Energia, I4CE and Ecoact, «2018 State of the EU ETS Report», 2018**

**https://markets.businessinsider.com/commodities/co2-emissionsrechte**

# Revenues from auctions of EUA (EU Allowances)

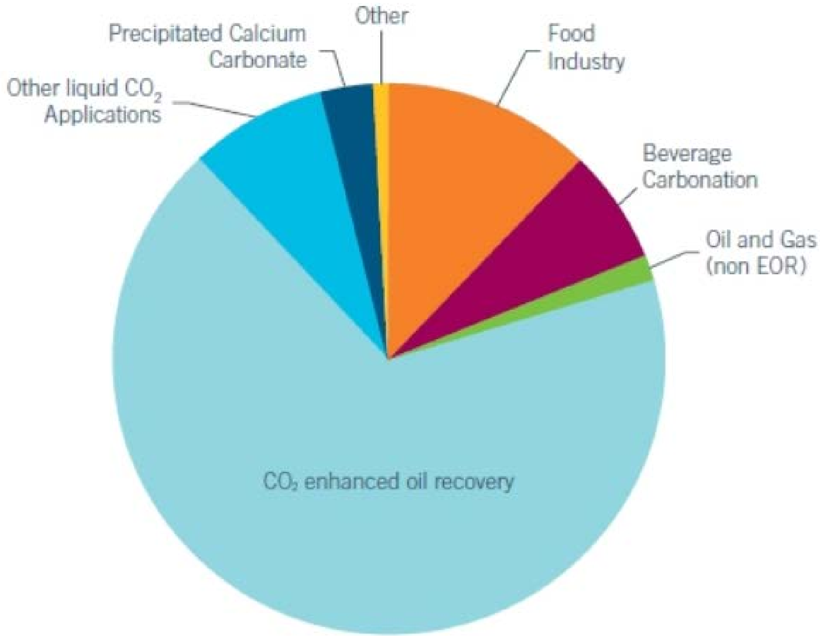
## Italy (GSE data)

| Data | Quote | Prezzo medio ponderato | Ricavi |
|---|---|---|---|
| 2012 | 11.324.000 | € 6,76 | € 76.497.240 |
| Trim. 4 | 11.324.000 | € 6,76 | € 76.497.240 |
| 2013 | 87.873.000 | € 4,39 | € 385.979.650 |
| Trim. 1 | 23.004.000 | € 4,50 | € 103.578.565 |
| Trim. 2 | 23.004.000 | € 3,83 | € 88.028.640 |
| Trim. 3 | 20.767.500 | € 4,61 | € 95.680.665 |
| Trim. 4 | 21.097.500 | € 4,68 | € 98.691.780 |
| 2014 | 61.175.500 | € 5,91 | € 361.249.645 |
| Trim. 1 | 23.281.000 | € 5,91 | € 137.676.580 |
| Trim. 2 | 13.020.000 | € 5,25 | € 68.373.600 |
| Trim. 3 | 12.648.000 | € 6,01 | € 75.990.300 |
| Trim. 4 | 12.226.500 | € 6,48 | € 79.209.165 |
| 2015 | 69.254.000 | € 7,62 | € 527.999.080 |
| Trim. 1 | 18.360.000 | € 6,96 | € 127.755.000 |
| Trim. 2 | 17.340.000 | € 7,30 | € 126.602.400 |
| Trim. 3 | 16.320.000 | € 7,92 | € 129.203.400 |
| Trim. 4 | 17.234.000 | € 8,38 | € 144.438.280 |
| 2016 | 77.376.000 | € 5,26 | € 407.231.650 |
| Trim. 1 | 20.720.000 | € 5,40 | € 111.935.360 |
| Trim. 2 | 20.128.000 | € 5,67 | € 114.184.960 |
| Trim. 3 | 17.024.000 | € 4,47 | € 76.163.040 |
| Trim. 4 | 19.504.000 | € 5,38 | € 104.948.290 |
| 2017 | 94.726.000 | € 5,76 | € 545.443.290 |
| Trim. 1 | 25.848.000 | € 5,10 | € 131.846.340 |
| Trim. 2 | 23.694.000 | € 4,77 | € 112.948.580 |
| Trim. 3 | 22.258.000 | € 5,90 | € 131.261.170 |
| Trim. 4 | 22.926.000 | € 7,39 | € 169.387.200 |
| 2018 | 24.395.000 | € 9,69 | € 236.401.490 |
| Trim. 1 | 24.395.000 | € 9,69 | € 236.401.490 |
| Totale complessivo | 426.123.500 | € 5,96 | € 2.540.802.045 |

## In EU (EU data, 2017)

- 3.7 billion € in 2013
- 3.2 billion € in 2014
- 4.9 billion € in 2015

# $CO_2$ market: practicing $CO_2$ utilization




*https://hub.globalccsinstitute.com/publications/accelerating-uptake-ccs-industrial-use-captured-carbon-dioxide/2-co2-market
**(PRODUCT FACT SHEET FOOD-GRADE CO2 - CEMCAP project)

*__The CO2 market:__

**Demand:** The current global CO2 demand is estimated to be **80 Mtpa**, of which 50Mtpa is used for EOR in North America. The future potential demand for CO2 that could eventuate by 2020 is estimated to be **140Mtpa**, taking into consideration the current development status of the short-listed reuse technologies.

**Current CO2 used for food sector worldwide:** approx. **12 Mt/y**

**Price of CO2: 80 – 150 €/tonnes****

**Possible saving: average 1.4 B€ per year**


**Nogara plant: 100% of CO2 used (99,9% purity), comes from the Nogara quadrigeneration system**

plantbottle

# Summary

- Need to speed up CCS in lieu of the IPCC SR15
- CCS is now a viable technology, although integrated, large-scale projects need further demonstration. Must cover the whole value chain for CCUS
- Innovation needed:
  - Policy perspective – Measures, regulations and incentives for CCUS
  - Systemic perspective –Evaluate energy system and its CCU sub-systems with consistent definitions of system boundaries and reference datasets.
  - Technology perspective – Must overcome a number of scientific and technical challenges
- R&I key for CCS to happen - derisk, optimize, reduce costs. Cost reduction appears to be the first R&D's priority
- Stakeholders of demonstration projects need to secure public support for storage and develop awareness of CCS benefits
- Utilization can accelerate initial penetration into the market

# Thank you for your attention

# Contacts at LEAP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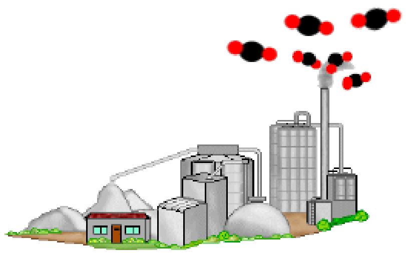
**www.leap.polimi.it**

**www.mater.polimi.it**

**www.cleanker.eu**

## Utilization

**$CO_2$ capture and purification**



Amine scrubbing
Membrane
Pressure Swing
Adsorption etc.

**Capture and Storage (CCS)**

**Sequestration**
Geological storage
Saline aquifers

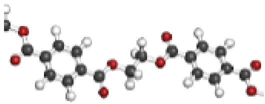
**Capture and Utilization (CCU)**

**Conversion**
Chemicals
Mineralization
Biological
etc.

Fuels

Organic chemicals

Carbonates



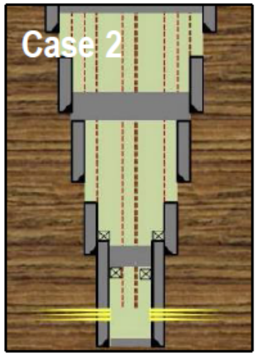
Polymers

Microalgae

# 7 cases showing the effect of R&I


Geophysical methods for monitoring subsurface storage of $CO_2$

Savings:
~€100 million/site




Improved completion of $CO_2$ wells

Savings:
~ €20 million /completion


Capture and liquifaction of $CO_2$ for ship transport

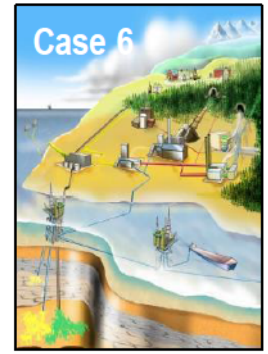
Savings:
~10% cost reduction per ton $CO_2$ captured


Capturing $CO_2$ using CLC

Savings:
Could cut capture costs by 30-40%


Avoiding running ductile cracks in $CO_2$ transport

Savings:
~€25 million for a 500km pipeline




Smart design of $CO_2$ value chains

Savings:
~10-15% of mitigation costs


Efficient capture processes

Savings:
Energy- €10 mill/yr (1Mt/yr)

"Presentation: "The role of research in realizing CCS" – Nils A. Rokke – SINTEF – ECRA / CEMCAP / CLEANKER workshop, 2018"