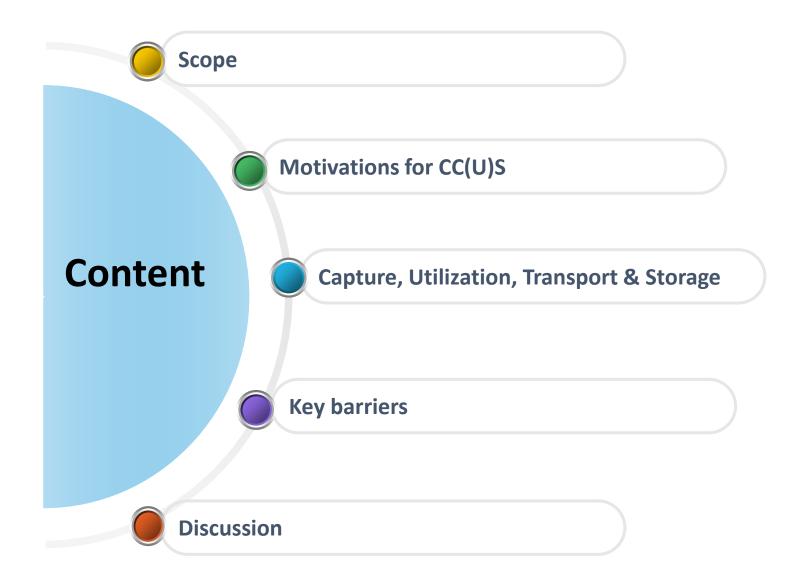


# **Integration of CCS with Gas Turbines**

**Mohammad Mansouri & Peter Breuhaus** 







# **Scope of this presentation**

To provide an overview of the CCS system & technologies

To provide the basis for the discussion in the 2<sup>nd</sup> day of the workshop

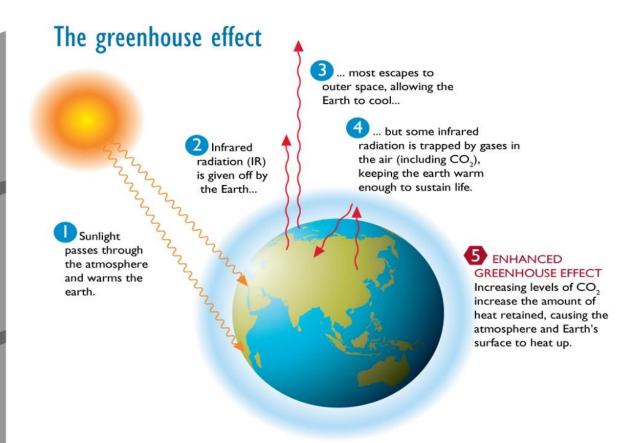


# How to supply energy in the transition time?

Kyoto Protocol in 1997

Several years of efforts

Paris Agreement in 2015



Source: Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)



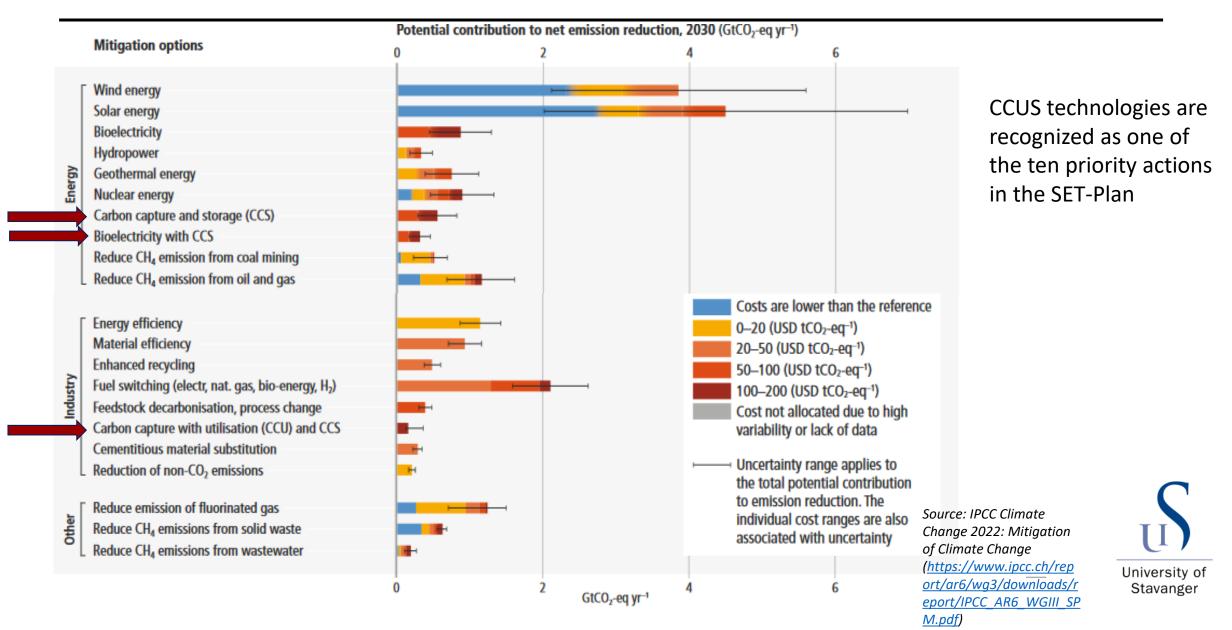






GT-CCS / Mansouri & Breuhaus

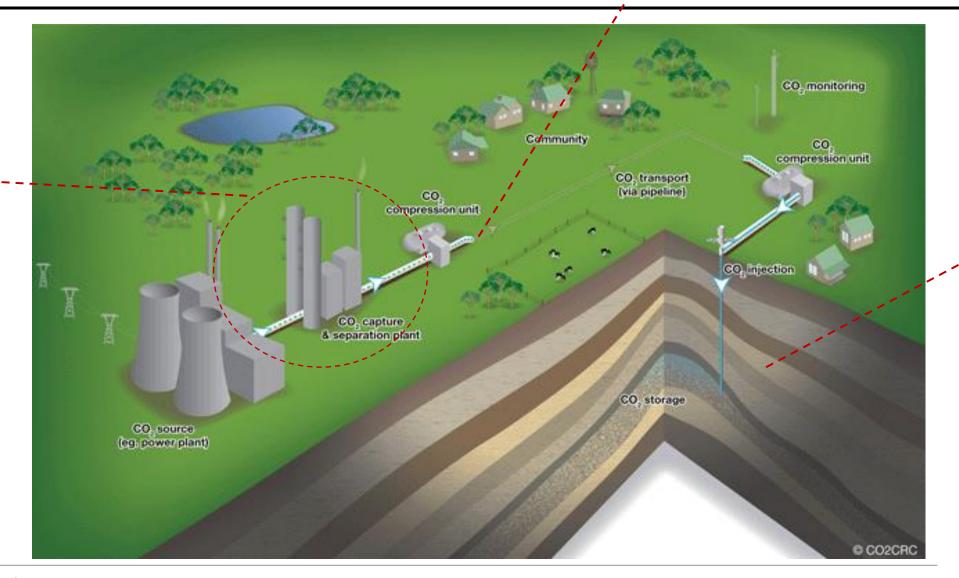
#### **CCS** importance in GHG mitigation scenarios



What is CCS?

Capture -

Transport



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Storage

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# CCS – A chain of processes/technologies that enable

**1.** Capture of CO<sub>2</sub> from large points sources

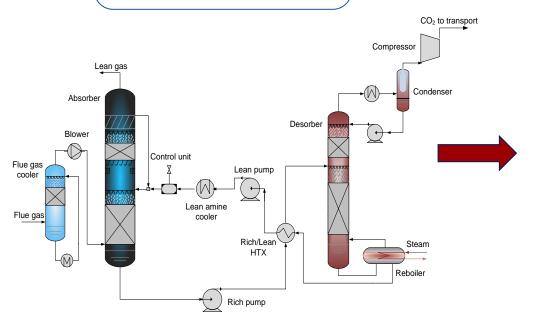
2. Transport

**3.** Storage of CO<sub>2</sub> in geological formations

Power plants, steel, cement, refineries, gas processing, etc.

Trucks, ships, pipelines

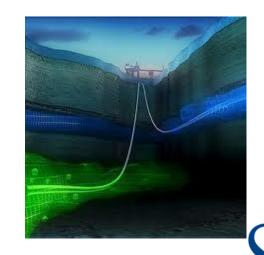
Depleted oil and gas fields, saline aquifers, etc.











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#### **Utilization in CCUS**

**Fuels** Food ·Algae Greenhouse Gases Carbonated Beverages ·Flavors/Fragrances Decaffeination Conversion Biological Carbonates Liquid Fuels Methanol •EOR Captured Enhanced ·Oil Chemicals •Urea •EGR Fertilizer ·CO •Gas **Fuel Recovery** CO2 •ECBM Methane Source: Secondary https://www.netl.doe.gov/research/c Chemicals oal/carbon-storage/research-and-Polycarbonate development/co2-utilization Refrigeration Inerting Polymers Agent ·Dry Ice Fire Extinguishers ·Injected into metal castings Blanket Products ·Added to medical O2 as a respiratory stimulant •Protect Carbon Powder Aerosol can propellant ·Shield Gas in Welding ·Dry ice pellets used for sand blasting •Red mud carbonation University of

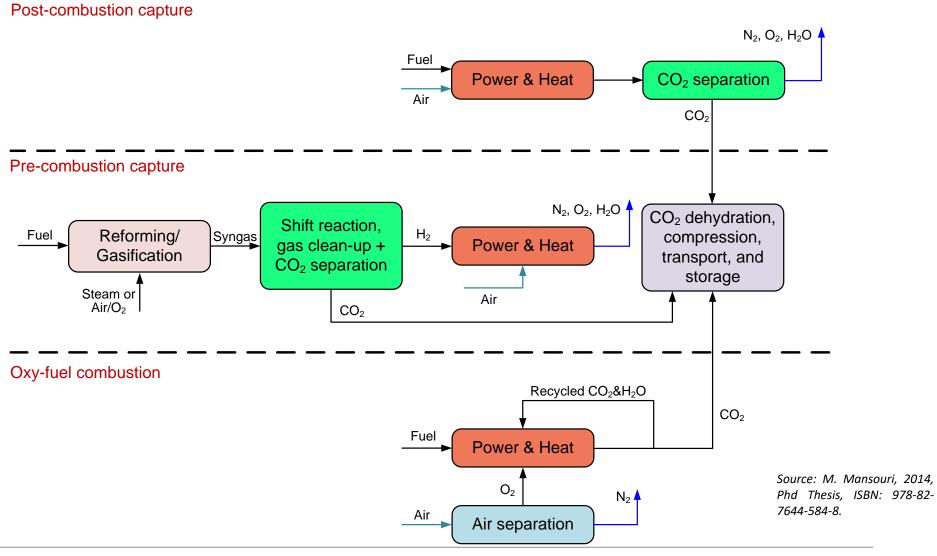
The current and potential uses of CO<sub>2</sub>

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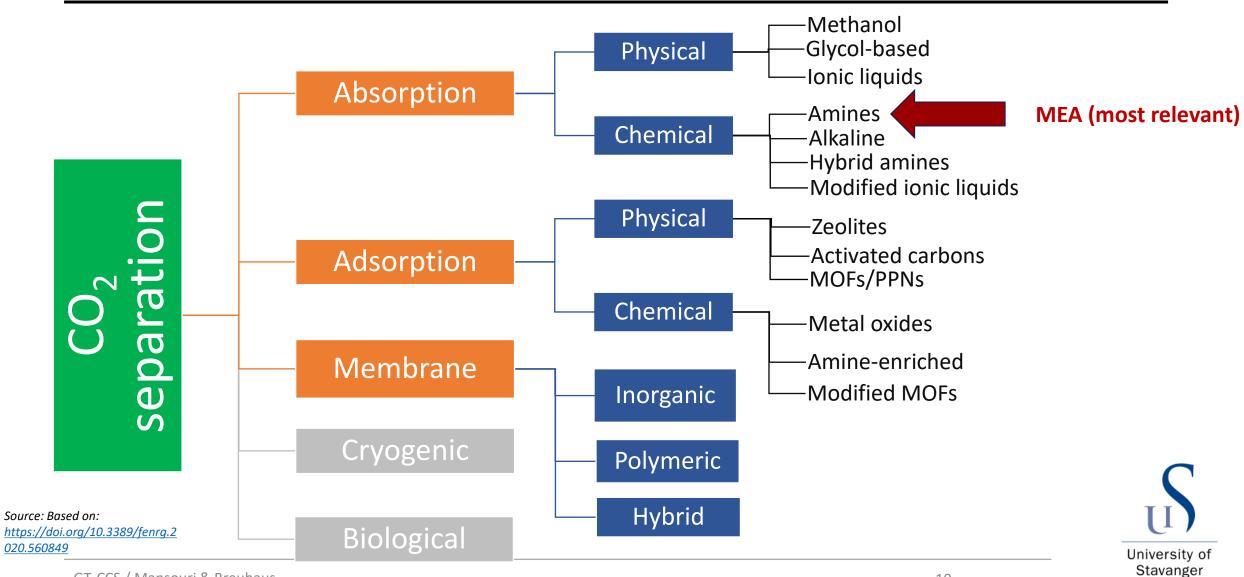
## **Capture techniques – Heat & power sector**



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9

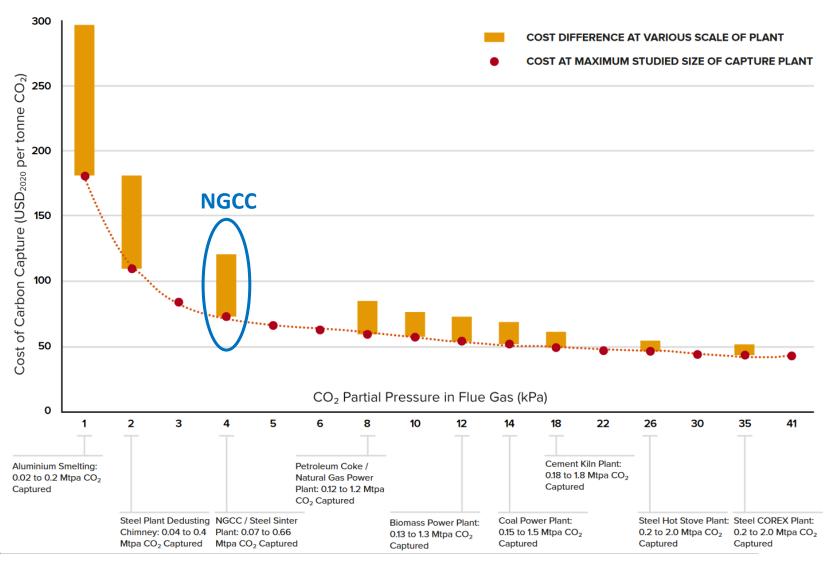
# CO<sub>2</sub> separation technologies



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### CO<sub>2</sub> capture cost – Sensitive to scale & application 1

Cost is very high at low CO<sub>2</sub> partial pressure and reduces significantly at higher partial pressures



Source: GCCSI,

https://www.globalccsinstitute.com/wpcontent/uploads/2021/03/Technology-Readiness-and-Costs-for-CCS-2021-1.pdf

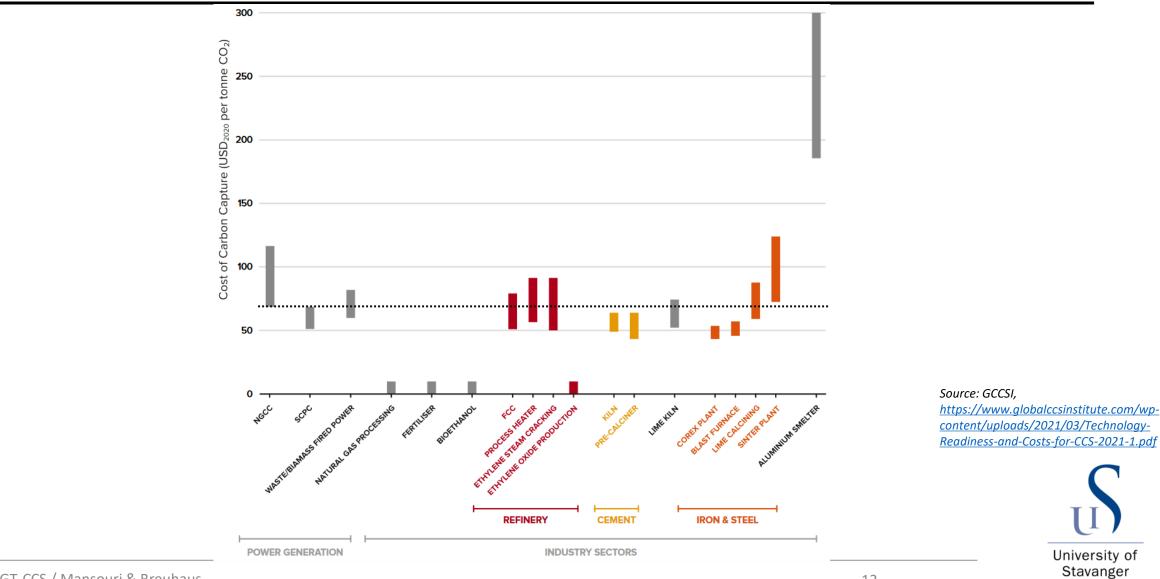
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11

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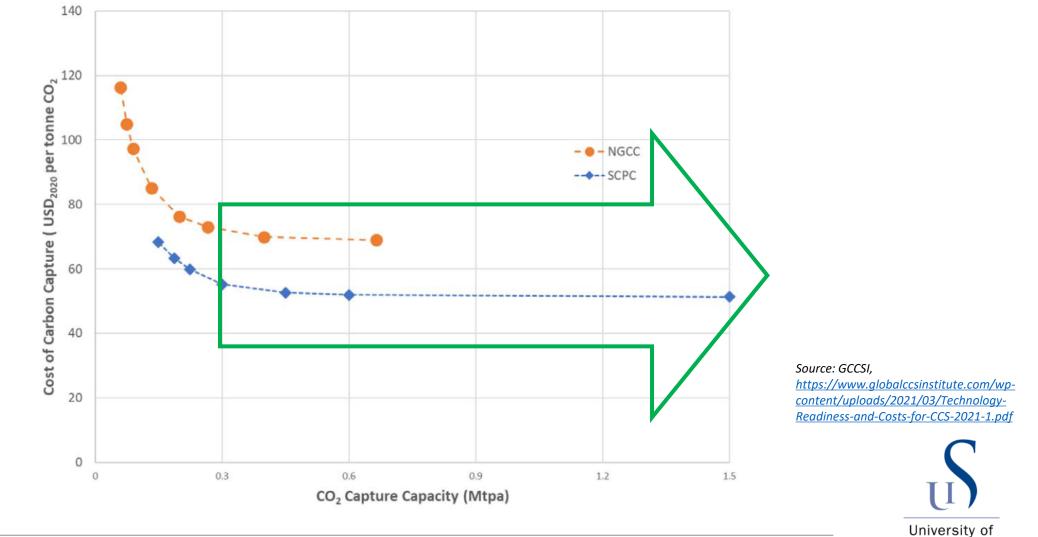
Chain Motivation Capture

# CO<sub>2</sub> capture cost – Sensitive to scale & application 2



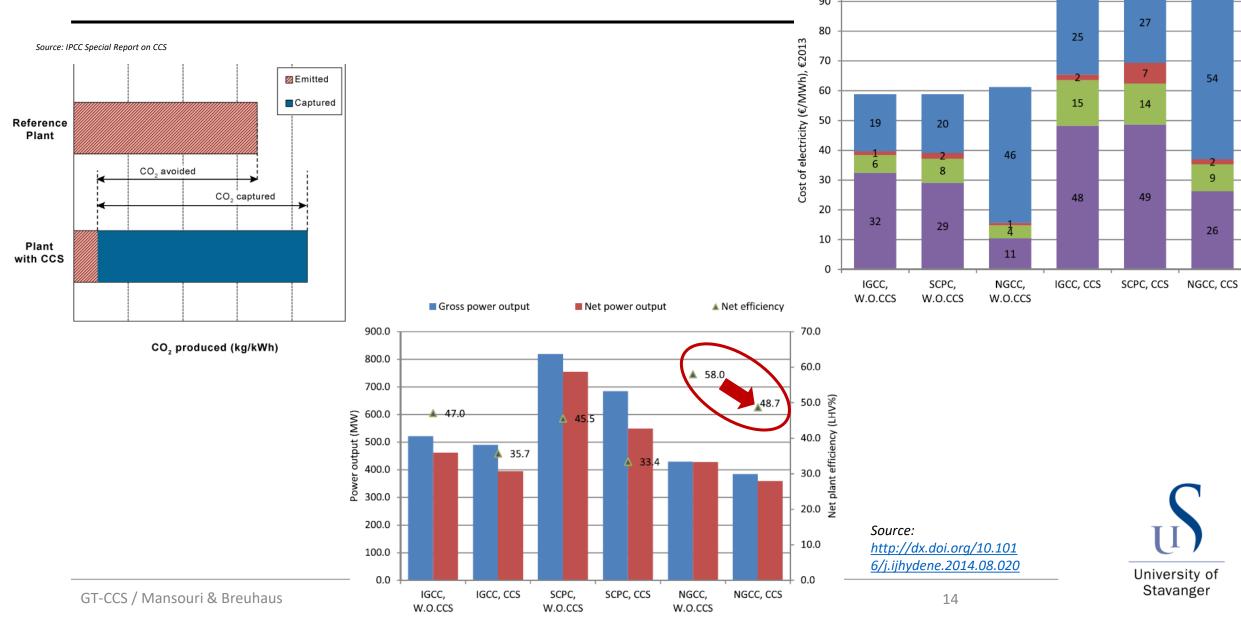
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# **CO<sub>2</sub>** capture cost – Sensitive to capacity of capture unit



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# **Consequences on the performance**



100

Fuel costs

Fixed O&M costs

■ Variable O&M costs

■ Capital costs

**Motivation** Chain **Capture** 

#### **Post-combustion capture dynamics**

Source: PhD Thesis of Nina Enaasen Flø, NTNU, <u>https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/301562</u>	Residence time [min]	Volumetric flow solvent [m³/min]	Hold-up [m³]
Absorber sump	5	32.9	164.6
Buffer tank	16	68.8	1100.5
Reboiler	5		353.2
Desorber sump	5	70.7	353.3
Desorber sump and reboiler	10	70.7	706.6
Cross heat exchanger and piping	26	66.8	1736.7
Reboiler steam side	1	5.9	5.9

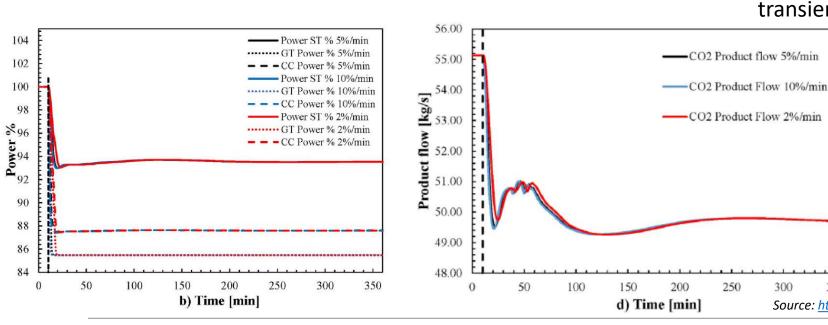
Acc. to a simulation study by Montañés et al. (100-85% load change):

300

- 1. The capture addition to the NGCC plant should not impose any problem for stable power plant operation under scheduled load changes
- 2. Inefficient transient operation of the PCC unit can be expected in the long timescales
- 3. The control parameter is also affecting the transient performance of both GT and PCC sides

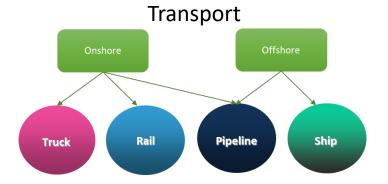
Source: http://dx.doi.org/10.1016/j.ijggc.2017.05.011

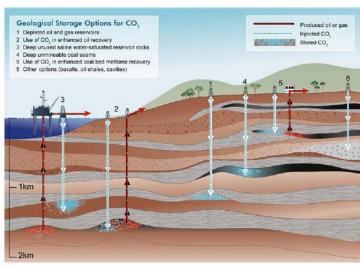
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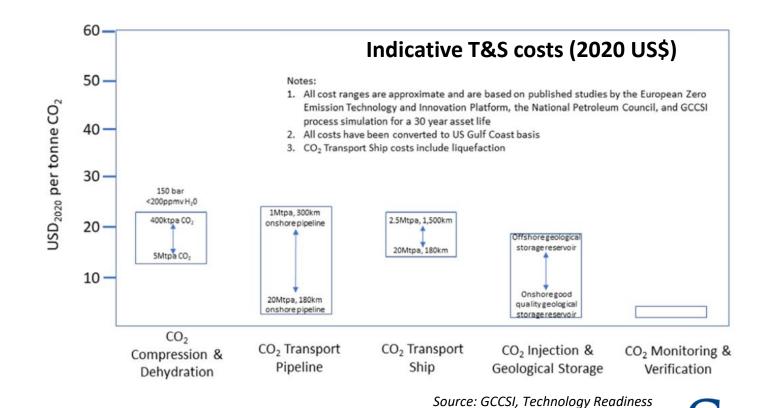




#### **Transport & Storage**







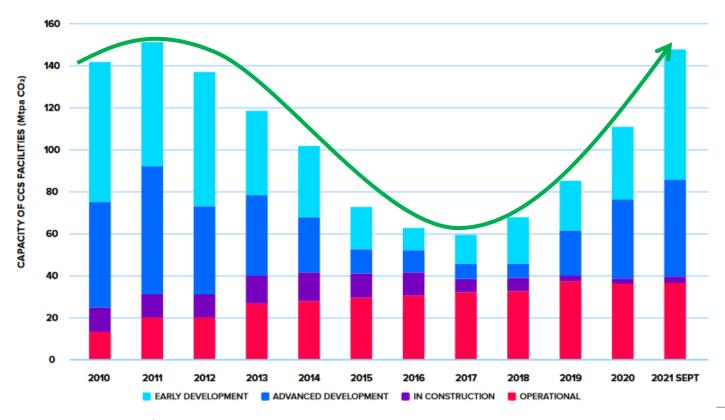
and costs for CCS, 2021.

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Different geological storage (Source: IPCC & CO2CRC)

#### **CCS** projects status

	OPERATIONAL	IN CONSTRUCTION	ADVANCED DEVELOPMENT	EARLY DEVELOPMENT	OPERATION SUSPENDED	TOTAL
Number of facilities	27	4	58	44	2	135
Capture capacity (Mtpa)	36.6	3.1	46.7	60.9	2.1	149.3



In Europe (acc. to GCCSI):

- 35 projects under development (as of Sep. 2021)
- Mostly around the North Sea region, but also in other locations

Source: GCCSI, Global Status of CCS 2021



3. K6 Program

#### **CCS** projects in Europe

#### **POLAND AUSTRIA GERMANY** . Vienna Green CO2\* Poland EU CCS Interconnector 1. H2morrow\* 2. Leilac 2 **BELGIUM** 3. Wilhelmshaven REPUBLIC OF IRELAND GREECE 1. Leilac (pilot capture only) 1. ERVIA 2. Antwerp@C (Port of Antwerp)\* 1. Energean Carbon Storage 3. Carbon Connect Delta<sup>†</sup> **ROMANIA** 4. Flite\* **ICELAND** 1. Onshore storage project 5. C4U 6. North-CCU-Hub 1. Orca **SPAIN** 7. Power-to-Methanol Antwerp BV 2. Hellisheidi 8. Kairos@C 3. Silverstone 1. CCU Lighthouse Carboneras **ITALY CROATIA SWEDEN** 1. iCORD\* 1. CCS Ravenna Hub\* 1. Preem CCS\* 2. Bio-Refinery Project\* 2. Cleankerk 2. Cementa Slite Plant 3. Vattenfall Uppsala **CZECHIA** THE NETHERLANDS 4. CinfraCap 1. Onshore storage project 1. Porthos (Port of Rotterdam)\* 5. BECCS@STHLM 2. Aramis (Den Helder)\* 3. Magnum (Eemshaven)\* UK **DENMARK** 4. H-Vision\* 1. Greensand\* 1. Acorn\* 5. Twence 2. Caledonia Clean Energy 2. C4: Carbon Capture Cluster Copenhagen 6. AVR-Duiven 3. Copenhill 3. Zero Carbon Humber\* 7. Project Everest\* 4. HyNet\* 8. Vlissingen Cryocap FG 5. Netzero Teesside\* **FINLAND NORWAY** 6. South Wales Industrial Cluster 1. SHARC 7. STEMM-CCS\* 1. Sleipner CO<sub>2</sub> Storage\* 8. CO<sub>2</sub> Sapling Transport Infrastructure 2. Longship (including Northern Lights)\* **FRANCE** 3. Polaris CCS\* 9. Northern Endurance Partnership\* 4. Norsk e-fuel 10. H2Teeside\* 1. DMX Demonstration in Dunkirk\* 5. Borg CO2\* 11. H2H Saltend\* 2. Pycasso\*

6. Fortum Oslo Varne

7. Barents Blue\*

Norcem Brevik
Pilot CCS project

University of

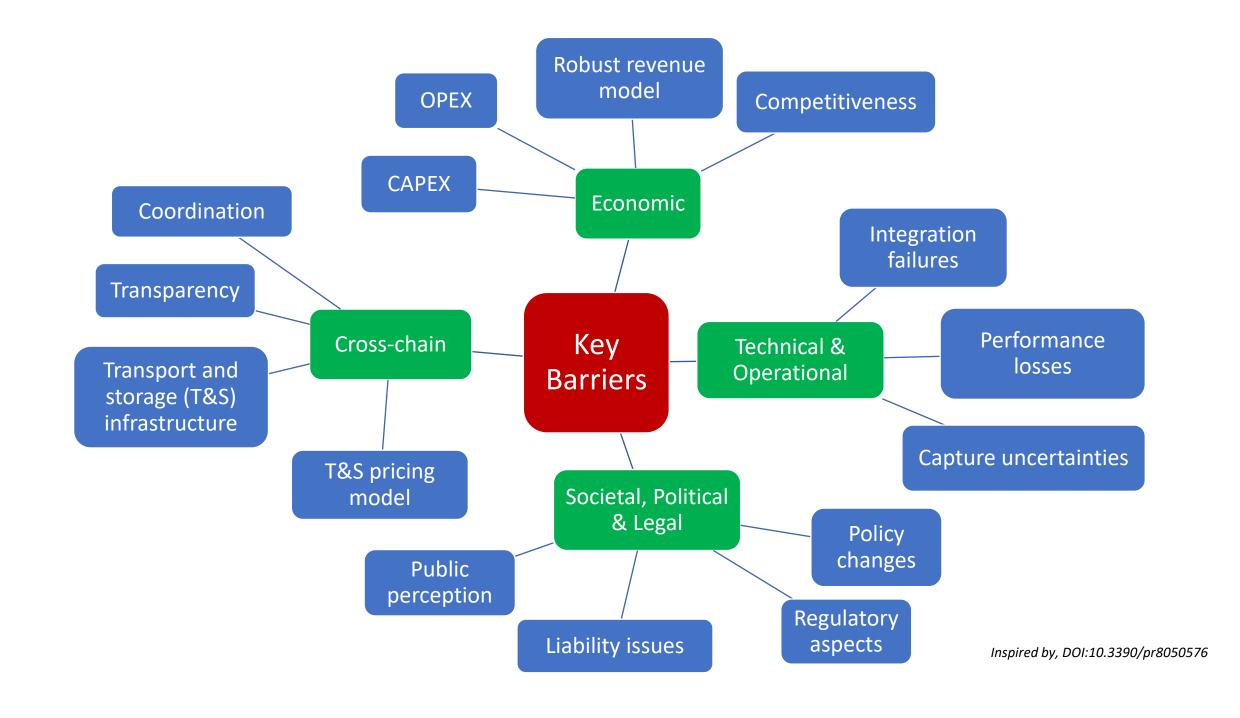
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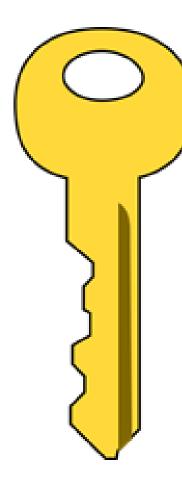
Source: IOGP, https://iogpeurope.org/wp-

Projects-January-2022.pdf

content/uploads/2022/01/Map-of-EU-CCS-



# **Key takeaways & discussion points**



There are several challenges when considering CC(U)S as a mitigation option more specifically for the GT users

Costs, performance losses, CO<sub>2</sub> partial pressure, immaturity of technologies etc.

Does it make sense to invest in such a cost intensive integration:

When operated only a couple of hundreds of hours annually?

What about other users than the utility sector?

Short-term implementation targeted or a long-term vision?



