PTTEP Knowledge Sharing Session

Carbon Capture Utilization and Storage

September 23, 2022

ENERGY SECURITY

DECARBONIZATION

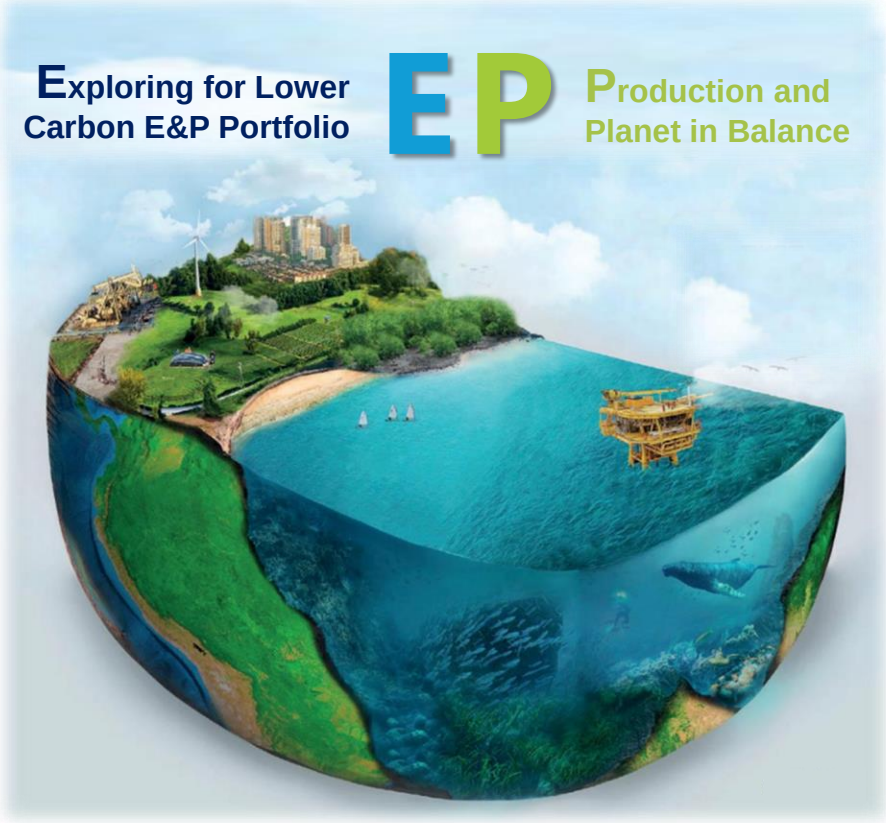
How can we ensure sustainable energy supply ?

How can we mitigate environmental impact ?

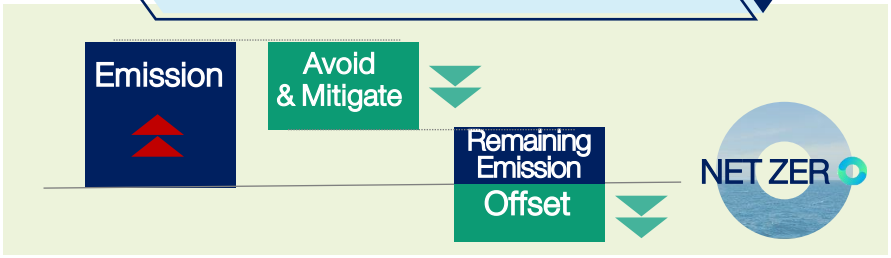
Decarbonization | PTTEP's pathway to net-zero emission

Exploring for Lower Carbon E&P Portfolio

E P Production and Planet in Balance



GHG Management Concept



Net Zero Roadmap & Key Milestones

2021 — 2030 — 2040 — **2050 NET ZER**

Greenhouse Gas Emissions
E&P, Operational Control
SCOPE 1 & 2

Avoid

- Internal Carbon Price
- Lower Carbon E&P Portfolio Management

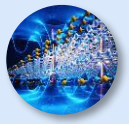
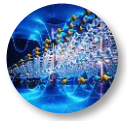
Mitigate

- Flare Gas / Energy Optimization
- Onshore Solar Power Plant
- CCS at Arthit & Lang Lebah
- Methane Emission Reduction via Tech.
- Zero Routine Flare
- Maximize Renewable Energy in Operation
- Apply Other Future Clean Energies

Offset

- Forestation Program and Blue Carbon Project
- Other Offset Program through Ocean for Life

Beyond E&P Business Landscape at PTTEP

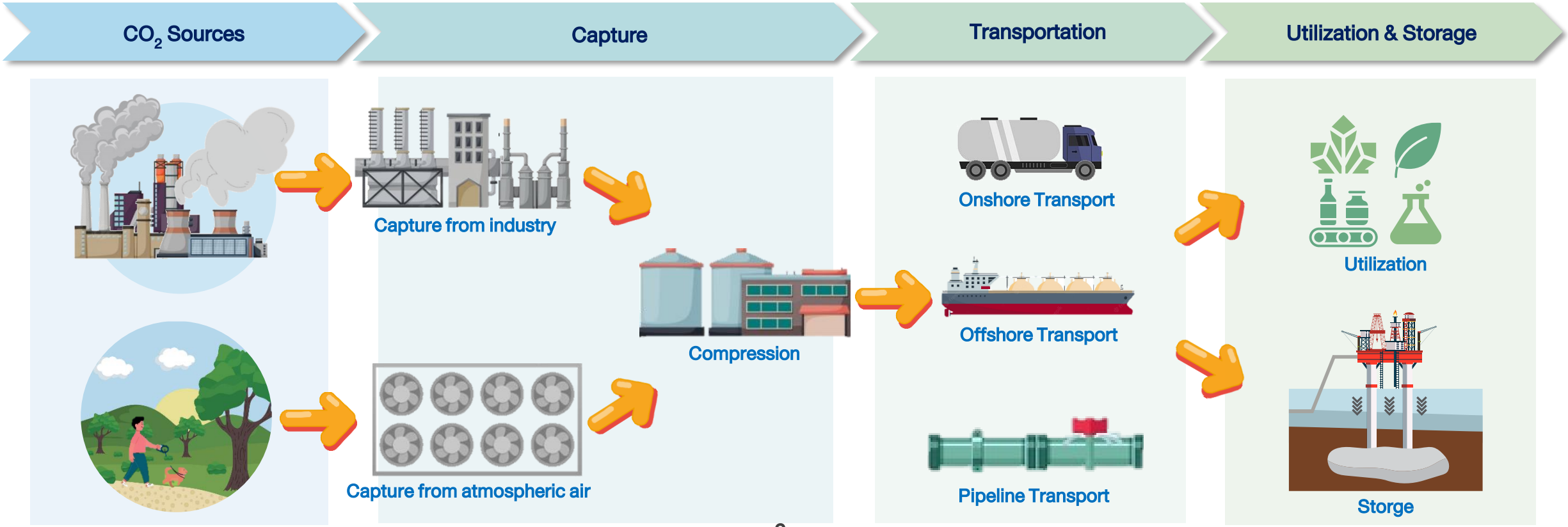
	Advanced Technology	Decarbonization	Future Energy
	Exploring Potential Areas	Capturing Growing Demand from Climate Change	Expanding to Future Energy Business
Market / Tech. Maturity			
Emerging	 **In-house Tech** e.g. carbon nanotube, graphene, etc. • *Advanced Technology* • *Future Energy Infrastructure*	 **CCU** • CO_2-to-Methanol • Others e.g. CNT, cement, aggregate, etc. • *Direct Air Capture*	 **Hydrogen** • *Fusion* • *Biofuels* • *Next-Gen Renew. Technology*
	Develop technology	***Value-added Technology***	***Act now for Future Energy / Fuel***
Growth/ Mature	 **AI & Robotic**  **In-house Tech** pipeline decommissioning	 ***CCS Initiative*** • *Reforestation* • *Carbon credit*	 ***Power Business*** • G2P & L2P • Renewables
	Market Opportunity	***Capture demand***	***Accelerate monetization***

Introduction to CCUS

Introduction to CCUS | Carbon Capture Utilization and Storage

CCUS is the process of capturing CO_2 that would otherwise be released into the atmosphere and either injecting it into deep geologic formations for safe storage such as oil and gas reservoirs, un-mineable coal seams and deep saline reservoirs or utilizing it for various applications.

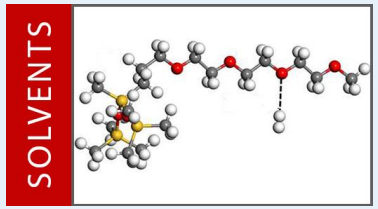
CCUS value chain



How to Capture CO_2? | 3 Main Methods

1 Pre-combustion carbon capture

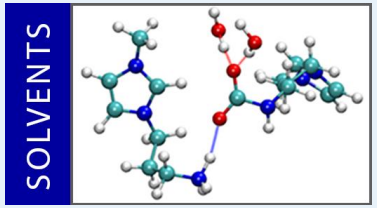
(largely used in industrial & petroleum production process)



Pre-combustion capture is very well known in O&G industry (a.k.a gas sweetening process). PTTEP also does it at ART and GBS.

2 Post-combustion carbon capture

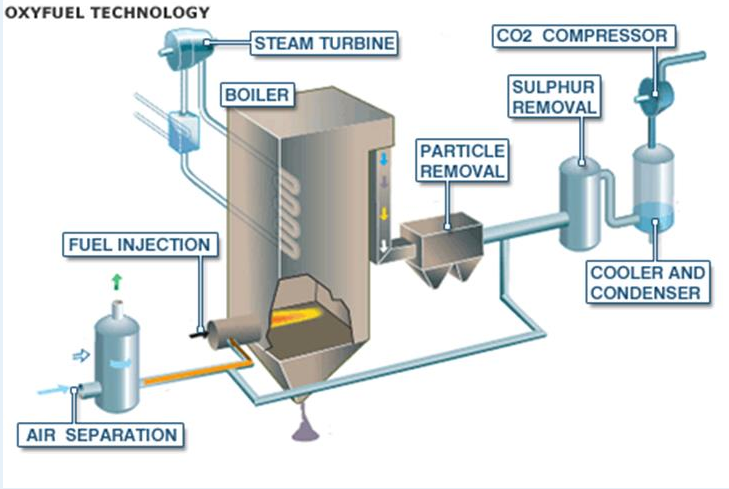
(the primary method used in existing power plants)



For post-combustion carbon capture, CO_2 is separated from the exhaust of a combustion process.

3 Post-combustion carbon capture Oxy-fuel combustion systems

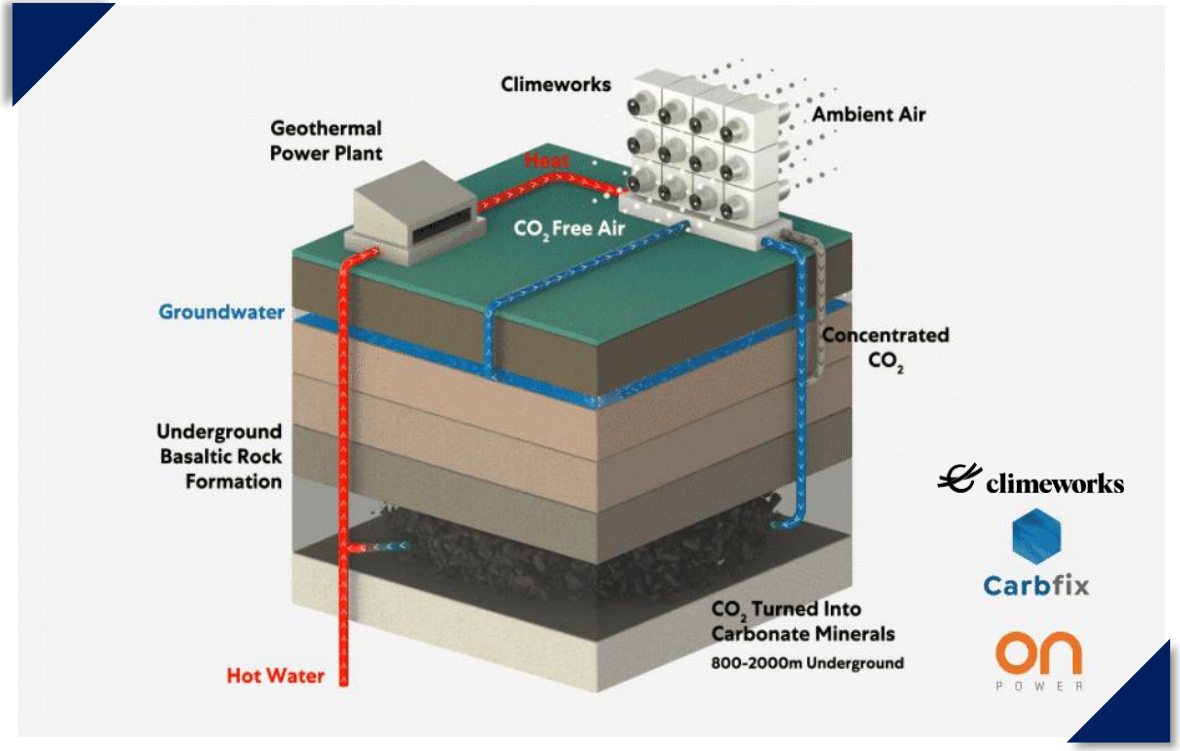
(alternate combustion method)



For oxy-fuel combustion, fuel is burned in a nearly pure-oxygen environment, rather than regular air, which results in a more concentrated stream of CO_2 emissions, which is easier to capture.

How to Capture CO_2? | Direct Air Capture

Direct Air Capture Process



The Orca Plant in Hellisheioi, Iceland

Methods

- **Solid Sorbent System:** CO_2 is captured on the surface of a solid filter material that sits inside the collectors. When the filters are heated, they release the concentrated CO_2, which can be captured for storage or use – the Orca Plant utilizes this method.
- **Liquid Based System:** Liquid systems pass air through chemical solutions (e.g. a hydroxide solution), which removes the CO_2 while returning the rest of the air to the environment.

Source: Climeworks

How to Transport CO_2? | Pipeline Truck and Shipping as the Primary Methods

After carbon dioxide (CO_2) is captured, the next step is transporting it to the storage/utilization site. The usual method of transporting CO_2 is through pipeline, truck or ship.

Pipeline

Truck

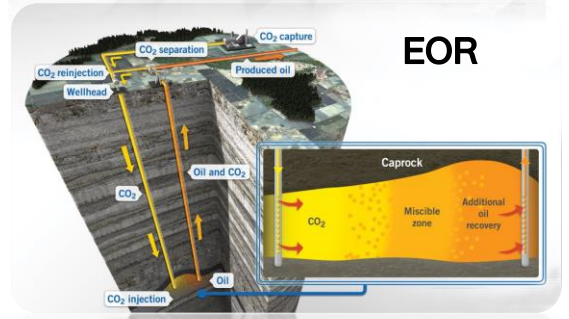
Ship


Carbon Capture and Utilization
CCU

CCU | How to Utilize CO_2?

By conversion into new products and non-conversion as working fluid / solvents

	Categories	Applications (Examples)
Chemical & Biological conversion	Chemical Intermediates	■ Methanol production ■ Syngas production ■ Formic acid production
	Fuels	■ Methane production ■ Liquid fuels
	Building materials	■ Concrete production ■ Aggregates
	Algae	■ Biofuels ■ Food additive
	Polymers	■ Polycarbonates ■ Polyethene ■ PHA (Polyhydroxyalkanoates)
	Novel Materials	■ Carbon fiber ■ Carbon nanotubes (CNT)
Non-conversion	Working fluid	■ Enhanced geothermal systems ■ Supercritical power cycle
	Solvents	■ Enhanced oil recovery (EOR) ■ Enhanced coal bed methane recovery (ECBM)



References: Arthur D Little

CCU | Examples of CCU around the World

Creating building material from CO_2

Produce liquid fuel (methanol) from CO_2 and hydrogen

Accelerated Carbonation Technology (Act)

Vicat cement group (France)

CO_2 directly captured from the plant's flue gas emissions will be used to convert cement bypass dust into lightweight aggregates via Carbon8's CCU technology.

George Olah Renewable Methanol Plant

1st Production of Fuel from CO_2 at Industrial Scale

Location	Iceland
Status	Operational since 2012
Capacity	4,000 tons/year of methanol (recycling of 5,500 tons of CO_2 from powerplant)

Source: Carbon Recycling International (CRI)

FReSMe & MefCO_2

Pilot project for CO_2 utilization

Location	Sweden, Germany
Status	Operational since 2019
Capacity	1 tons/day of methanol (recycling of 1.5 tons of CO_2 a day from steel manufacturing)

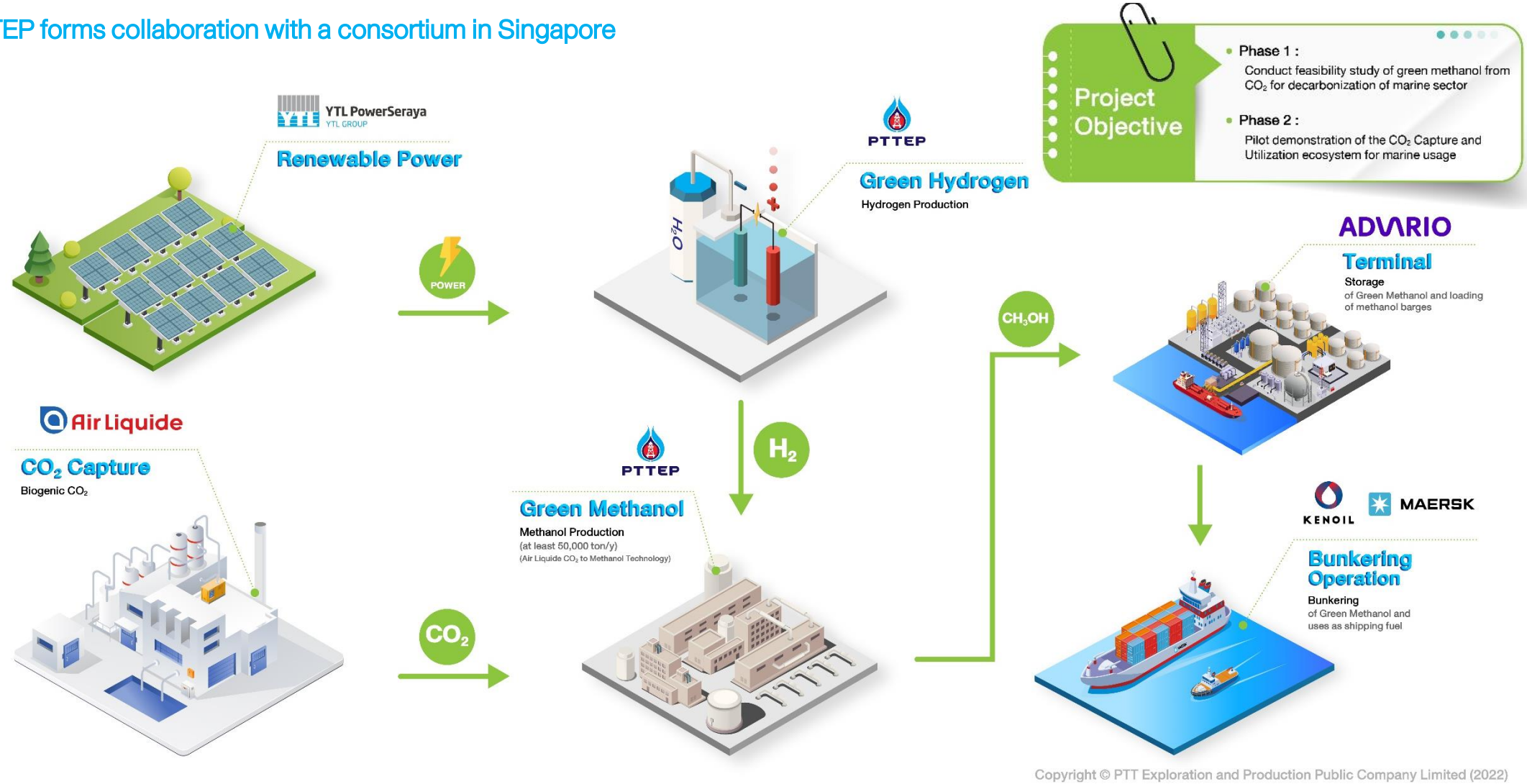
The Shunli CO_2-to-Methanol Plant

World's largest production of fuel from CO2

Location	China
Status	Commissioning in late 2021
Capacity	100,000 tons/year of methanol (recycling 160,000 tons of CO_2 from coke oven gas production)
Investment	USD 90 million (design & equipment)

CCU | Example of CCU at PTTEP

PTTEP forms collaboration with a consortium in Singapore



CCU | Challenges for CCU

1

- CCU technologies are at an early stage of development
- Most of them not yet ready for commercial deployment

2

- High investment for R&D, Scale up and demonstration
- No markets for “Greener” products
- Project uneconomic

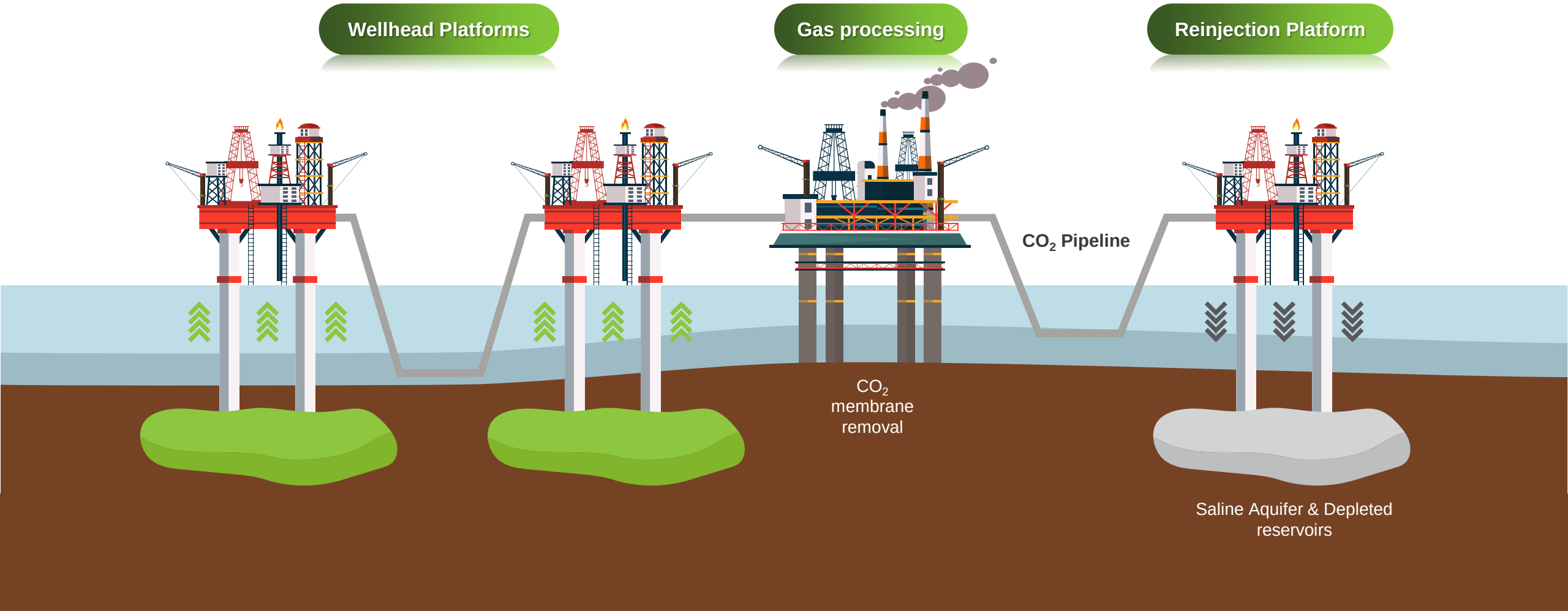
3

- National policy, regulation still to be developed
- To support industry to invest in CCU technology
- To create incentive for shifting to Greener product


PTTEP
Carbon Capture and Storage
CCS

CCS | Definition & Reverse E&P notion

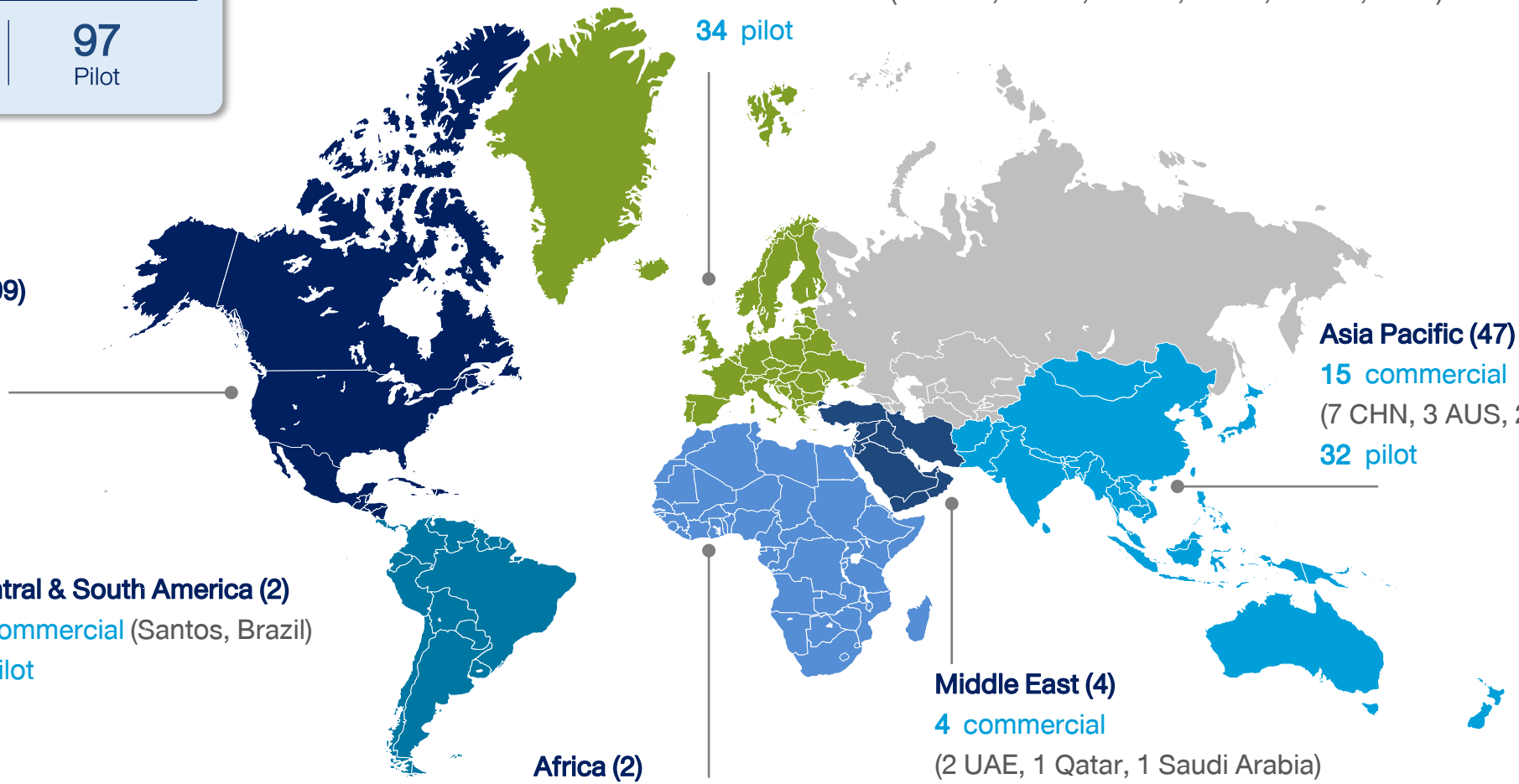
CCS refers to a process to capture CO_2 from industrial activities and inject it into the subsurface for permanent storage – essentially returning carbon molecules to where they came from.



CCS | CCS around the World

242 Ongoing Projects

145	97
Commercial	Pilot



North America (109)
80 commercial
29 pilot

Central & South America (2)
1 commercial (Santos, Brazil)
1 pilot

EU (78)
44 commercial (16 GBR, 8 NLD, 8 NOR, 4 BEL, 3 SWE, ITA 2)
34 pilot

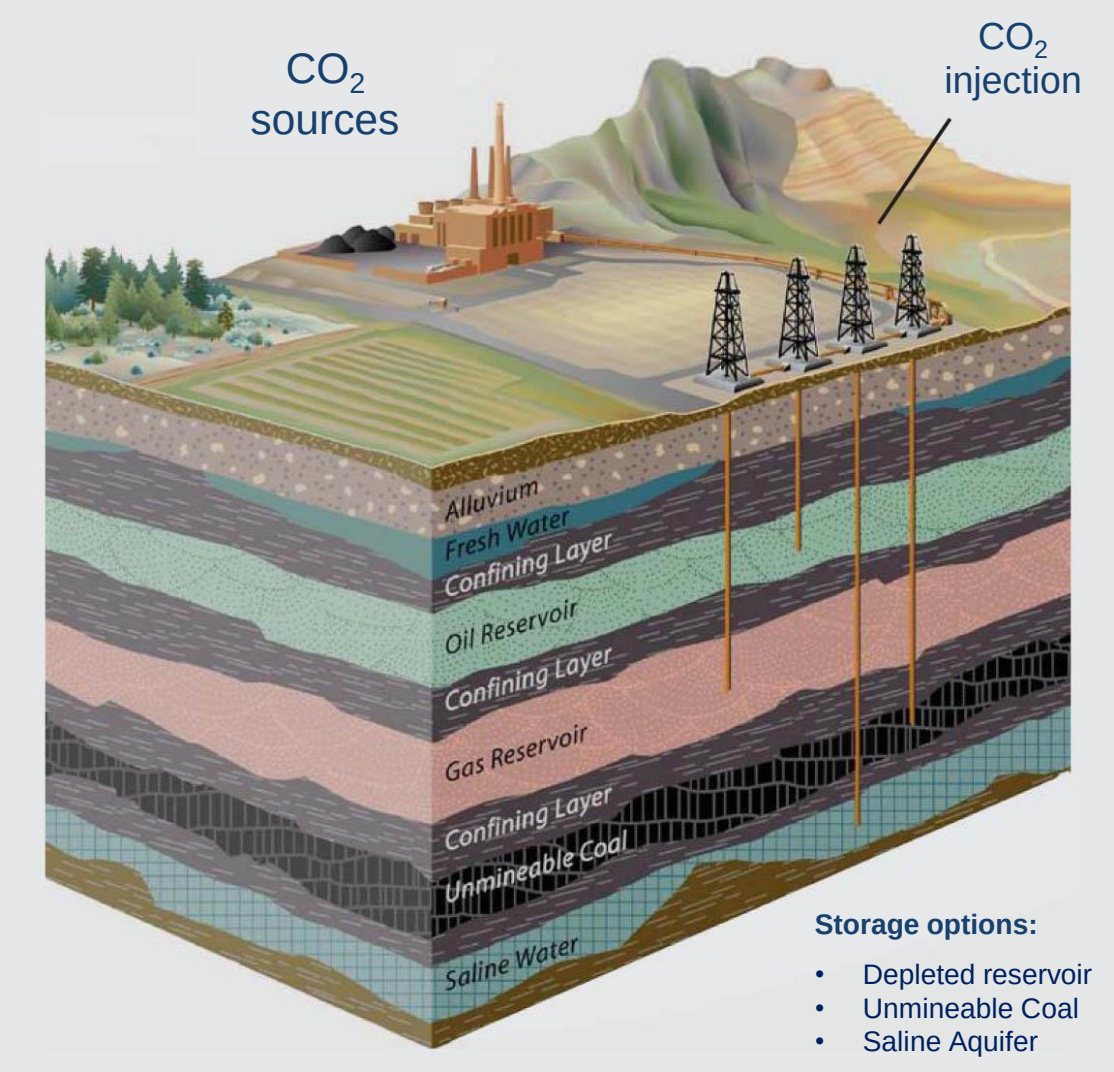
Africa (2)
1 commercial (Salah, Algeria)
1 pilot

Middle East (4)
4 commercial
(2 UAE, 1 Qatar, 1 Saudi Arabia)

Asia Pacific (47)
15 commercial
(7 CHN, 3 AUS, 2 IDN, 1 MYS)
32 pilot

Source: Global CCS Institute - CO2RE (Nov 2021)

How To Store CO_2 ? | 4 aspects to evaluate storage by



1 **Capacity**

2 **Containment**

3 **Injectivity**

4 **MMV**

Measurement, Monitoring, Verification

Source: Picture from University of Utah

CCS | Required information & relative activity time

Data gathering & screening
(*3 years*)
- Site screening
- Subsurface image and analysis
- Concept dev. & Planning for exploration drilling

Expl. Drilling & detailed analysis
(*2 – 3 years*)
- Core analysis
- FEED
- Field development planning

EPCI
(*2 – 3 years*)
- Engineering & construction
- Drilling program development

1st operation
- Injection
- Concurrent MMV activities

CCS | Detailed evaluation & PTTEP's capability

1 Capacity

Seeking sizable storage bodies

Geological Principles
Subsurface expertise for finding CO_2 storage bodies

Subsurface Information
Storage est. from seismic and well information

2 Containment

Verifying holding capability

Integrated Subsurface Analysis
Investigation of CO_2 trapping with reservoir characterization

Reservoir Modelling
Characterization of injected CO_2 under geological constraints

3 Injectivity

Ensuring injection performance

Lab-scale Rock Properties Analysis
Evaluation of rock properties with at fine scale

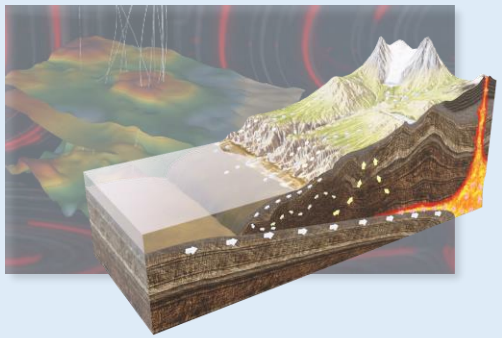
Core Flooding
Lab simulation of CO_2 injection for performance prediction

4 MMV

Monitoring of CO_2 plume

Geophysical Monitoring
Repeated seismic surveys for continuous monitoring of injected CO_2 for storage verification

Leveraging PTTEP's capability



Subsurface Expertise for integrated analysis based on geological principles and subsurface information to evaluate potential CO_2 storage capacity

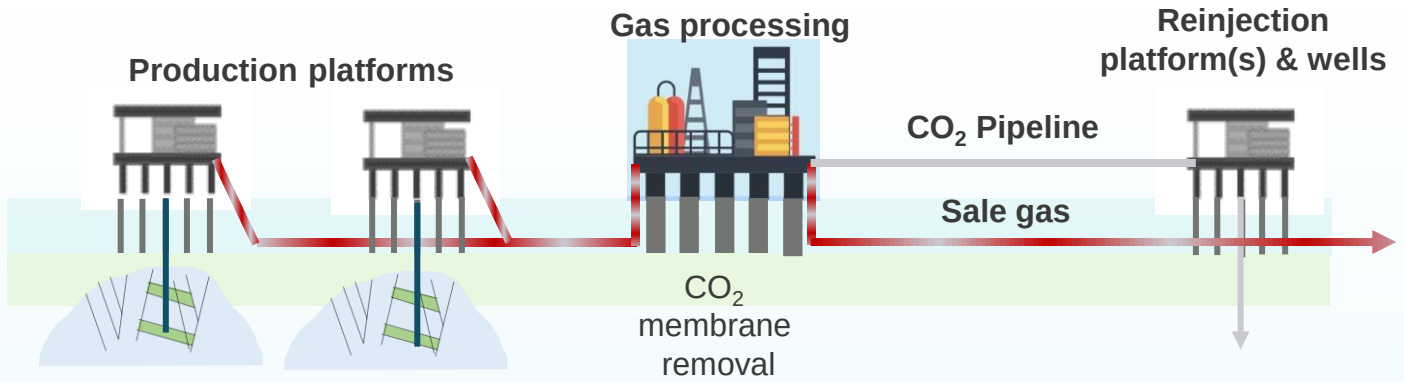
PTTEP Reservoir Simulation Center for comprehensive reservoir characterization to model behavior of CO_2 storage bodies prior, during, and after injection

Subsurface Research Center as a collaborative workspace for R&D studies and cutting-edge laboratory analysis to enable on CO2 injectability

PTTEP Seismic Reprocessing Center (PSPC) for advanced subsurface imaging and in-depth technical analysis to flexibly monitor CO2 plume.

CCS | 1st domestic CCS initiative at Arthit

ART CCS *for* **EP NET ZERO** PTTEP



> 95% **CO_2 (Upto 1 Mtpa)**

Objectives

- *Reduce emissions from upstream*
- *"Pilot" project to initiate dialogue with Gov. & other stakeholders*
- *Showcase PTTEP's commitment & CCS capability*

Highlights

Project development

- *Ongoing Pre-FEED study to support an integrated development plan*
- *Partners interested in CCS & potential METI support via MOECO*

Regulation

- *CCS as part of upstream allowed under Petroleum Act*
- *Required Technical Guidelines under ongoing study with PTIT*

Timeline

2021 Kick-off — **2023** FID — **2026** 1st operation

Study & Development

CCS | Thailand's decarbonization goal

COP26

2021

40% reduction with intl. support

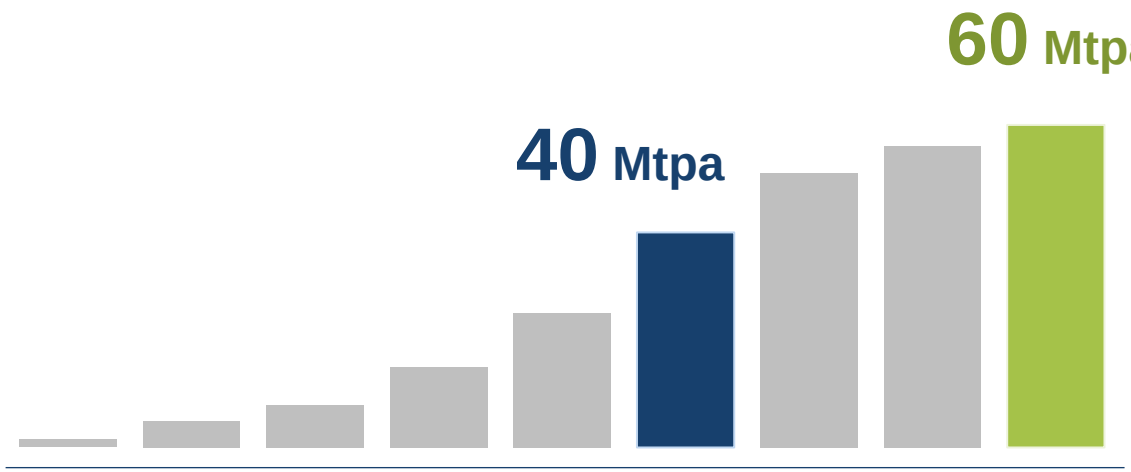
2030

CARBON NEUTRALITY

2050

NET-ZERO GHG Emission

2065



Required CCS contribution

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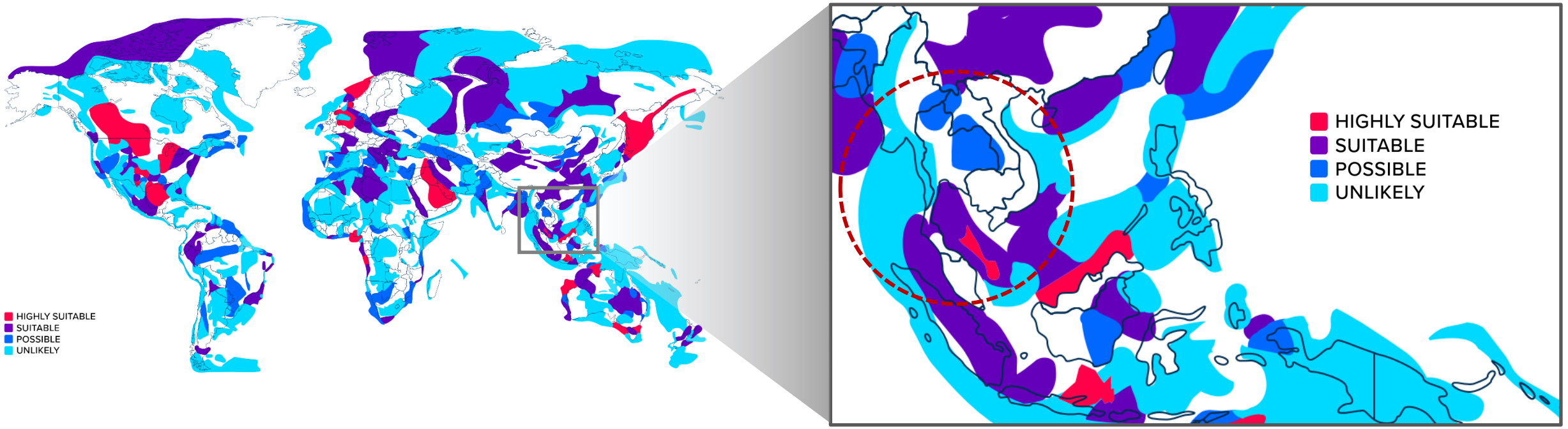
CCS | CO_2 Storage Suitability by Global CCS Institute



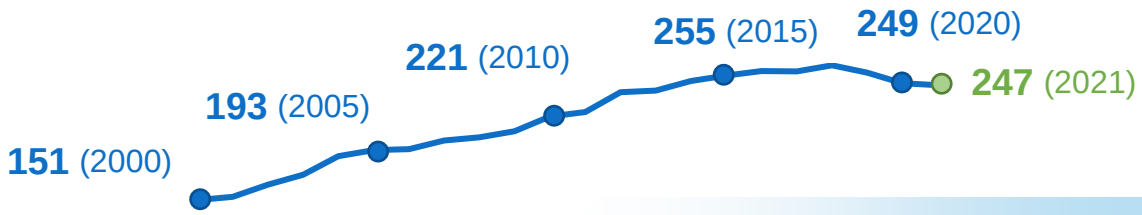
Implications for PTTEP

- **Gulf of Thailand** and certain areas of Thailand appear to be suitable for CO_2 storage, but detailed investigation is still required.
- Regulation, policy, and economics of CCS to be concurrently explored and developed to accelerate its deployment.
- Other SEA areas are also notable targets for CCS development including Malay, Sarawak, and Sabah basins.

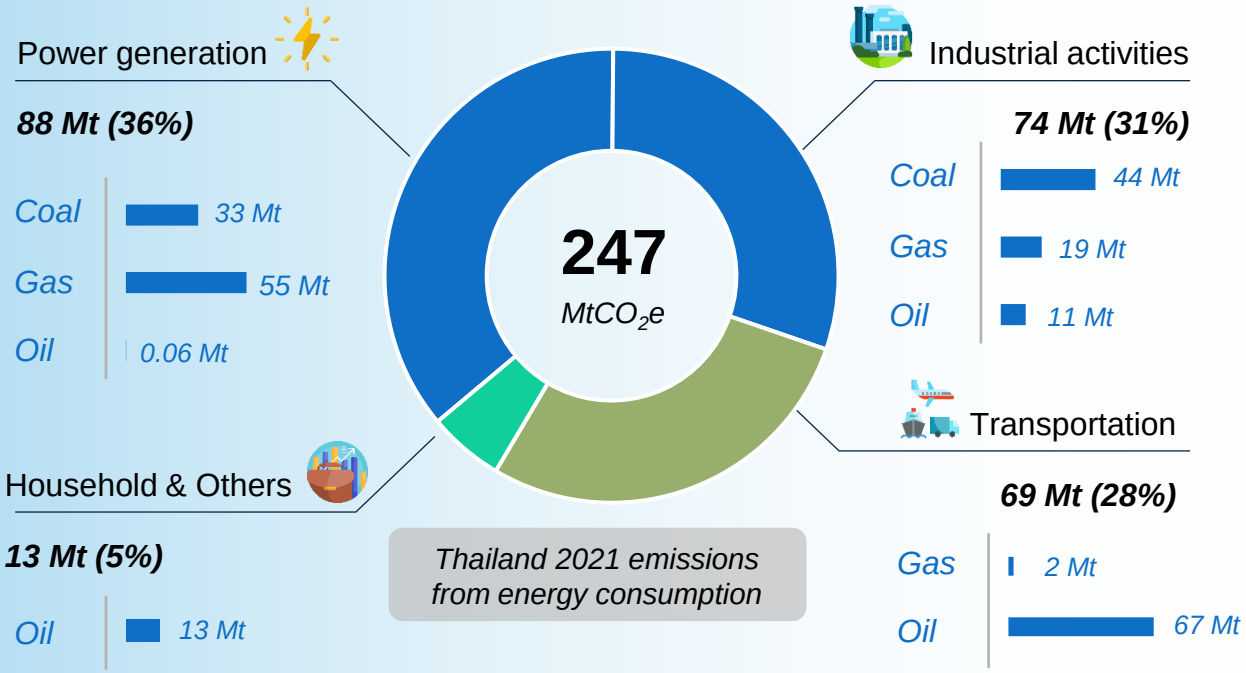
Source: Global CCS Institute Global Report 2021

CCS | Current emission and PTTEP's position

Thailand's historical emissions ($MtCO_2e$)



2021 Emission by sources



Leading CCS effort of PTT Group

PTT Group is committed to reducing GHG emission across the business value chain with key initiatives on CCS that **PTTEP** serves in the leading role.

Source: Energy Policy and Planning Office, Ministry of Energy

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Striving for Key CCUS Enablers

Support from various sectors are needed to accelerate the project.

1 Financial Support / Obligations

- Tax credit/subsidies for CO_2 avoidance
- CCUS R&D grant, government investments, low to zero interest loan
- Low gas and electricity prices
- Emissions trading scheme
- Sector specific carbon tax

2 CCUS Infrastructure

- Government owned or regulated entity to provide transport & storage infrastructure

3 Policy & Regulation

- GHG Strategic targets and commitment
- Consistent carbon capture requirement
- CCUS legal and regulatory framework
- Long-term liabilities provision

4 Others

- **Technical:** Global collaboration on CCUS and standards for low carbon product
- **Human Capital:** workforce training program and talent attractiveness
- **Public awareness** of CCUS

Thank you and Q&A

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+66 2 537 4000

IR@pttep.com

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