BUMN UNTUK INDONESIA

PERTAMINA

CCU-CCUS Innitiatives in Pertamina

Presented in CCUS Technical Workshop – ERIA
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October 7, 2021

Pertamina's ESG Strategy to Ensure Environment Sustainability

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Priority for Pertamina to define a long term climate ambition and long term energy transition strategy

Top Material Issues and Ambitions

- Addressing Climate Change
- Reducing Environment Footprint
- Protecting Biodiversity

Deep dive

- Health & Safety
- Prevention of Major Accidents
- Community Engagement & Impact
- Employee Recruiting, Development & Retention

- Corporate Ethics
- Cyber Security

ESG Strategy across Material Issues

Initiatives	Initiatives to meet the ambitions
Policies	Align policies to achieve and embed ESG practice
Management System	Integrated system to track performance
Disclosures	Sharing achievements with stakeholders

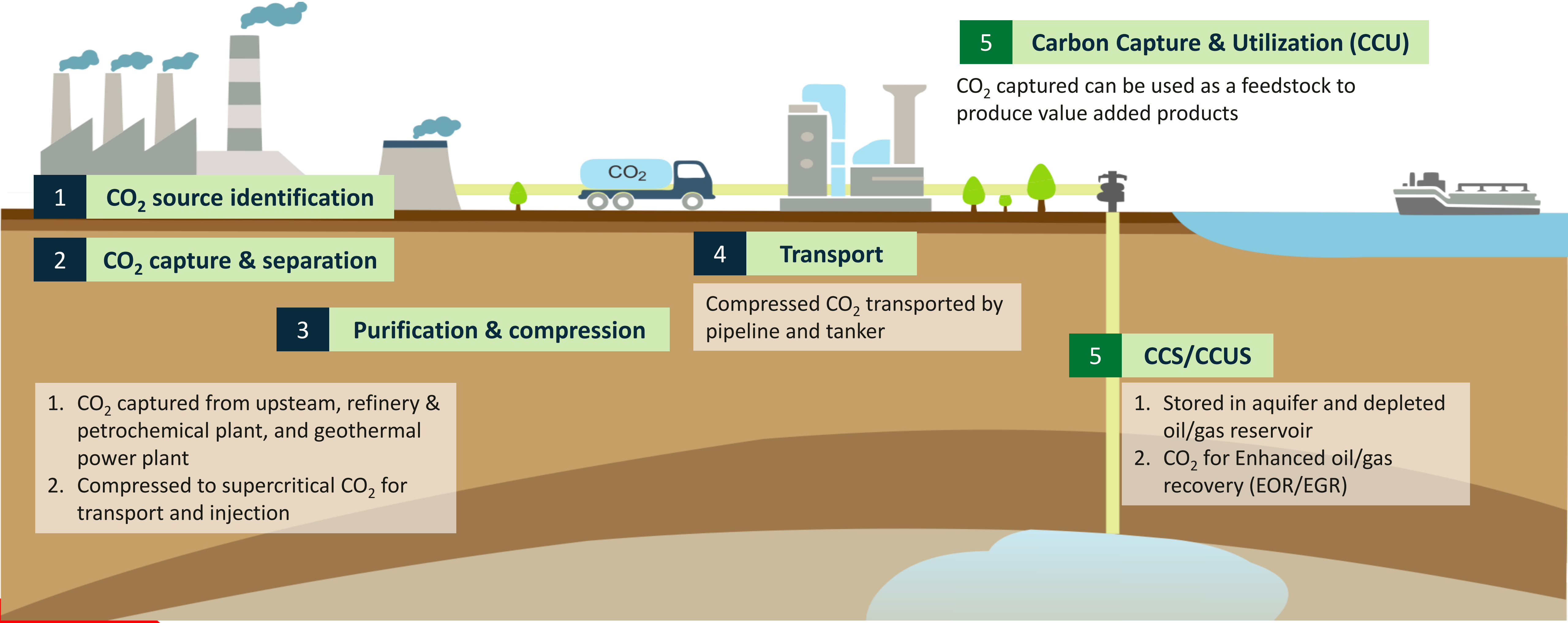
Performance and Results

- Better Business Performance
- Access to more competitive financing
- Competitive positioning among peers
- Improved ESG scoring by rating agencies

PERTAMINA CALL CENTER 135

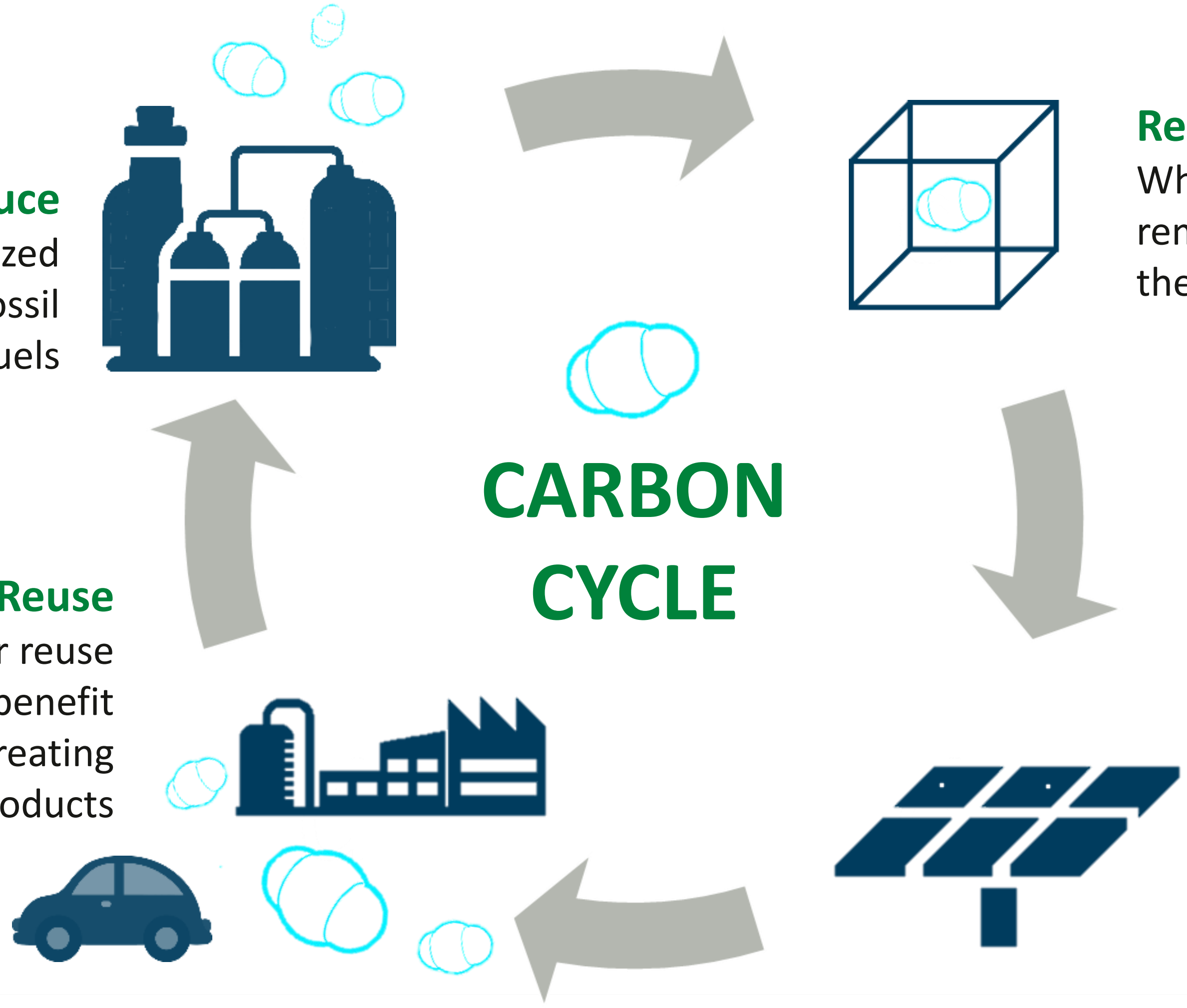
CCS/CCUS Value Chain Development

CCUS is essential to unlock the full potential of decarbonization



Circular Carbon Economy

A circular carbon economy is a framework for managing and reducing emissions. Pertamina have adopted the circular carbon economy framework as a way to reduce their carbon footprints



Reduce
Cleaner burning fuels in optimized engines can reduce the use of fossil fuels

Remove
When fossil fuels are burned, removing the pollutants reduces the impact on the environment

Renew
The integration of renewable energies reduces the use of fossil fuels

Recycle and Reuse
Opportunities to recycle or reuse the carbon produced can benefit the environment while creating valuable products

Pertamina's CCUS Technology Development

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Potential Project Development

1. CCUS CO_2 Enhanced Gas Recovery (EGR)
2. CCUS CO_2 Enhanced Oil Recovery (EOR)
3. CO_2 Direct Hydrogenation to Methanol
4. CO_2 Reforming to Methanol
5. CO_2 Mineralization to Precipitated Calcium Carbonate (PCC)
6. Blue Hydrogen Production with CCS/CCUS

Research & Development

1. CO_2 Mineralization to Prec. Calc. Carbonate (PCC)
2. CO_2 Biocapture and Utilization Using Microalgae
3. CO_2 Direct Electrolysis to Renewable Methanol
4. Catalyst Development for CO_2 Reforming and DME
5. Catalyst Development for CO_2 based Polyurethane

Future Potential Breakthrough Project

Large Industrial CCS / CCUS Technology Hubs & Clusters

1. In Situ CO_2 Source and CO_2 Storage Location
2. Cross – boundaries CO_2 Source and CO_2 Storage Location

** Required multi stakeholder collaboration and storage location can be in offshore or onshore*

CCS/CCUS Study and Implementation

Joint Crediting Mechanisme (JCM) scheme covered by Government to Government (G2G) between Indonesia and Japan Government

Gundih Field, Central Java

CO_2 from CPP Gundih will be injected in Kujung formation with potential EGR benefit

Sukowati Field, East Java

CO_2 from Jambaran Tiung Biru (JTB) will be injected in Tuban layer with EOR benefit

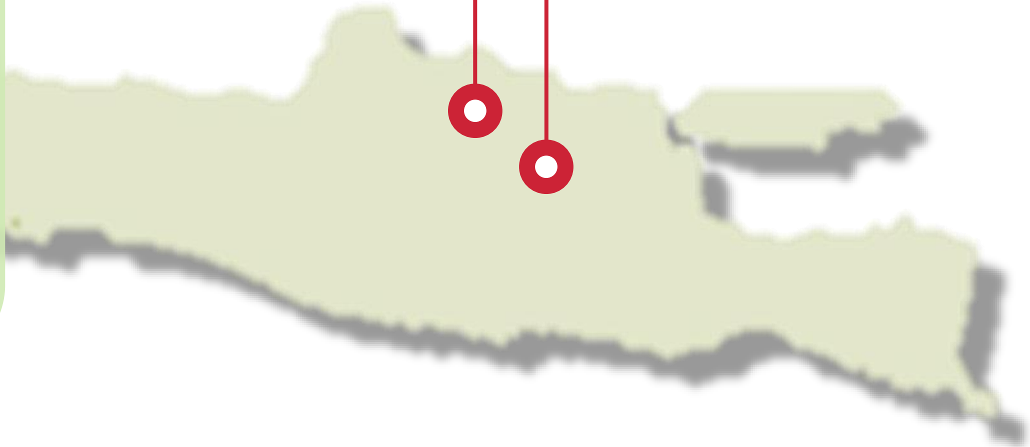
Potential of CO_2 Reduction from CCUS Process in Upstream Field:

18 Million ton CO_2

Gundih: 3 Million ton CO_2 for 10 years

&

Sukowati: 15 Million ton CO_2 for 25 years



The utilization of CO_2 has the potential to benefit carbon reduction

- Potential enhanced hydrocarbon production
- Stored CO_2 will be monetized in Carbon market, after fulfill NDC contribution

CO_2 Utilization

Carbon utilization is the use of CO_2 to create products with economic value

Chemicals

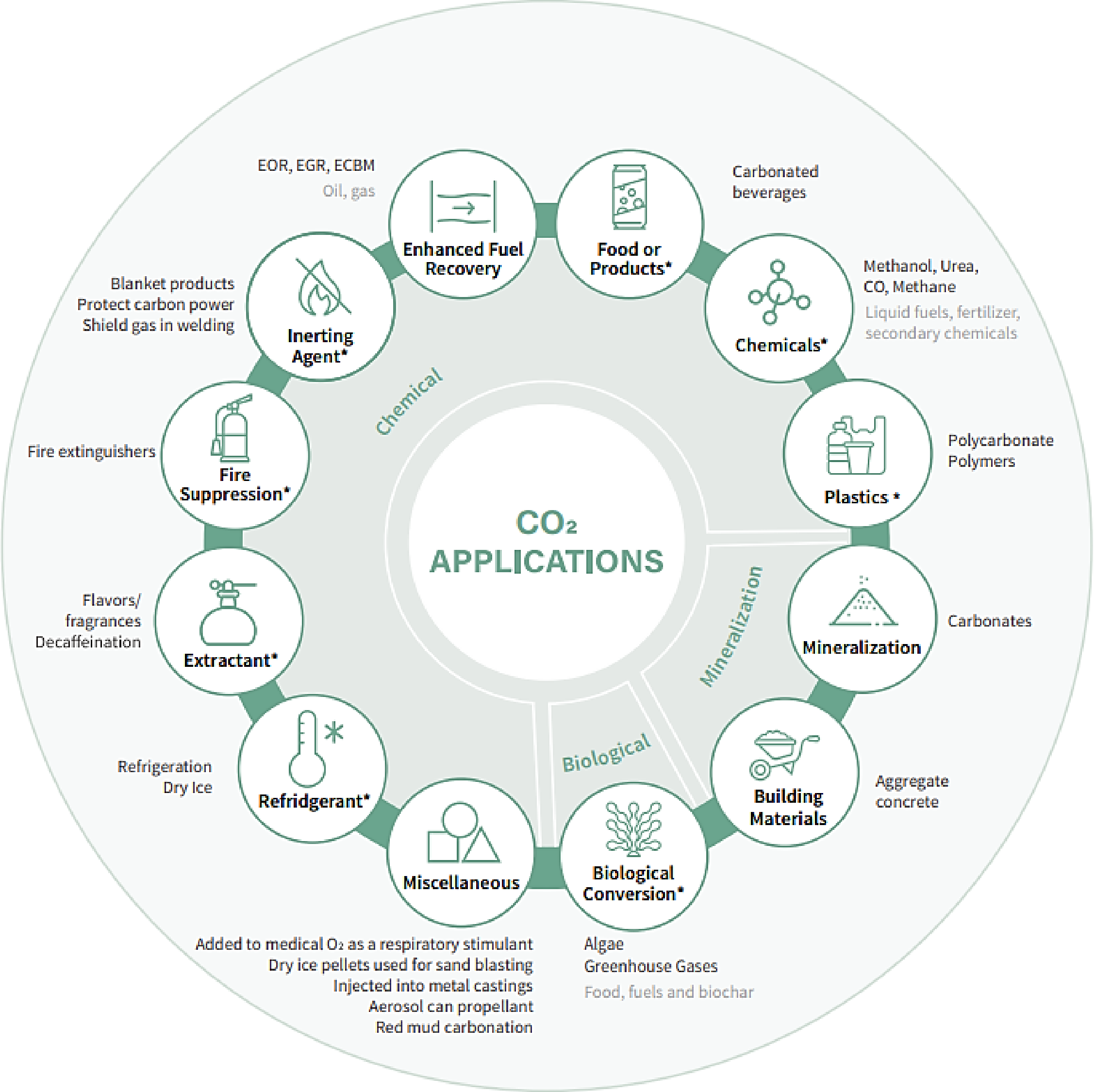
CO_2 is currently used in small quantities to make urea fertiliser and some special polymers. In a future hydrogen economy, CO_2 could be combined with H_2 to make synthetic fuels, syngas and methanol. Syngas and methanol are basic chemical feedstock from which many chemicals and polymers can be made

Biological

CO_2 is used to promote plant growth and can be captured in soils by using biochar to increase soil quality

Mineralization

Incorporating CO_2 into concrete has the most potential to become a large market for CO_2 in the near term. This process is energy efficient using minimal external energy

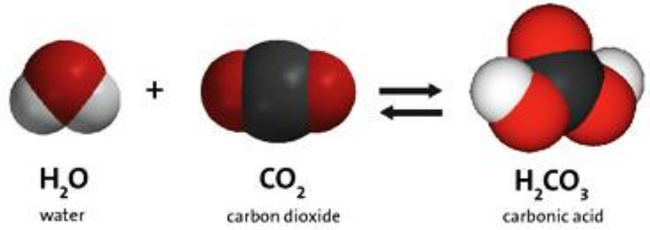


Source:
UNECE Carbon Capture Use and Storage

Conventional CO_2 Utilization

Carbonate Drinks

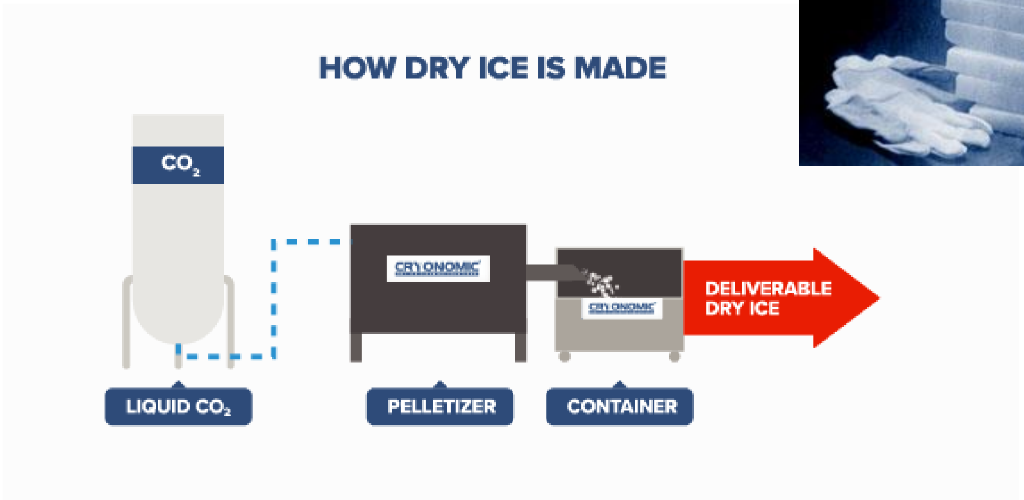
The water will have absorbed as much CO_2 as it can. Chemists call this an equilibrium. Fizzy drinks do release carbon dioxide (CO_2), a can of pop contains 2-3 g of CO_2



Carbonic acid (H_2CO_3) also has a mild antibiotic effect that prevents bacteria from growing in the water

Dry Ice (CO_2) as cooling agent

The carbon dioxide-rich gas is pressurized and refrigerated until it liquefies. Next, the pressure is reduced. As a result, the extreme cold causes the liquid to solidify into a snow-like consistency. Finally, the snow-like solid carbon dioxide is compressed into small pellets or larger blocks of dry ice [a]



Source:
[a] https://www.cryonomic.com/en/dry-ice-process

CO_2 to Mineralization

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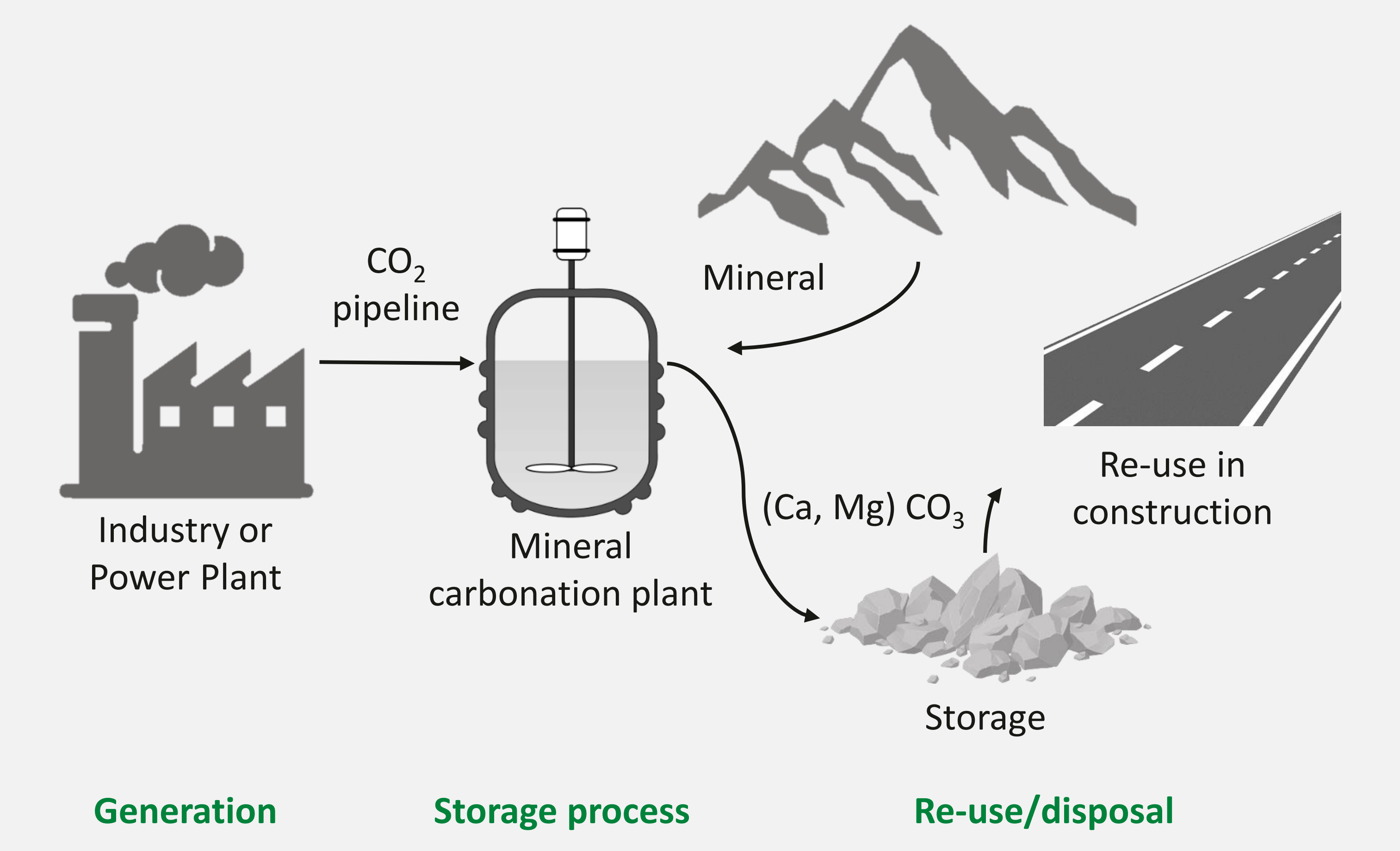
Mineralization of carbon dioxide (CO_2), or mineral carbonation, involves the reaction of CO_2 with materials containing alkaline-earth oxides like magnesium oxide (MgO) and calcium oxide (CaO)



Mineral Carbonation Reaction:

$$MO + CO_2 \rightarrow MCO_3 + \text{Heat}$$

(Where M is a divalent metal, e.g. calcium, magnesium, or iron)

Mineral Carbonation Uses

Precipitated Calcium Carbonate (PCC):

- Paper Industry
- Paint Industry
- Tire Industry
- Pharmacy Industry
- Cosmetics Industry
- Food Industry
- Potential as a PCC technology licensor

CO_2 Capture and Utilization to Precipitated Calcium Carbonate (PCC)

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- **Background :** CO_2 utilization through mineralization route requires much lower energy compare to other method
- **Research Objective :** Reducing CO_2 emission while utilizing it and creating efficient PCC production process

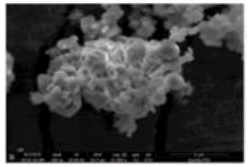
[Lab. Scale Reactor]

[Pilot Plant with Capacity 2 Kg/H]

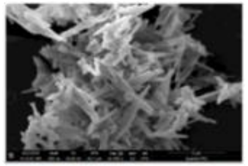
Field Test in Subang Field,
Demo Plant Development 20 kg/h (2022-2024)

PCC Production Process: $CaO + NH_4Cl + CO_2 \rightarrow CaCO_3 + NH_4Cl$

Precipitated Calcium Carbonate (PCC)



PCC with Calcite Structure



PCC with Aragonite Structure

Achievements:

- High purity $CaCO_3$ >99%
- CO_2 conversion up to 70%
- NH_4Cl as a solvent to increase CaO solubility
- Aragonite structure PCC product for high grade

Uses of Methanol

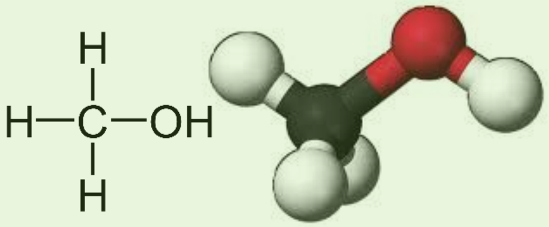
Methanol occupies a critical position in the chemical industry, as a highly versatile building block for the manufacture of countless everyday products

Gasoline blending
15% - 85% Methanol

DME
Dimethyl ether

Polymers
Formaldehyde, acetic acid

MTO
Methanol-to-olefins



Methanol

MTG
Methanol-to-gasoline

Biodiesel
FAME making

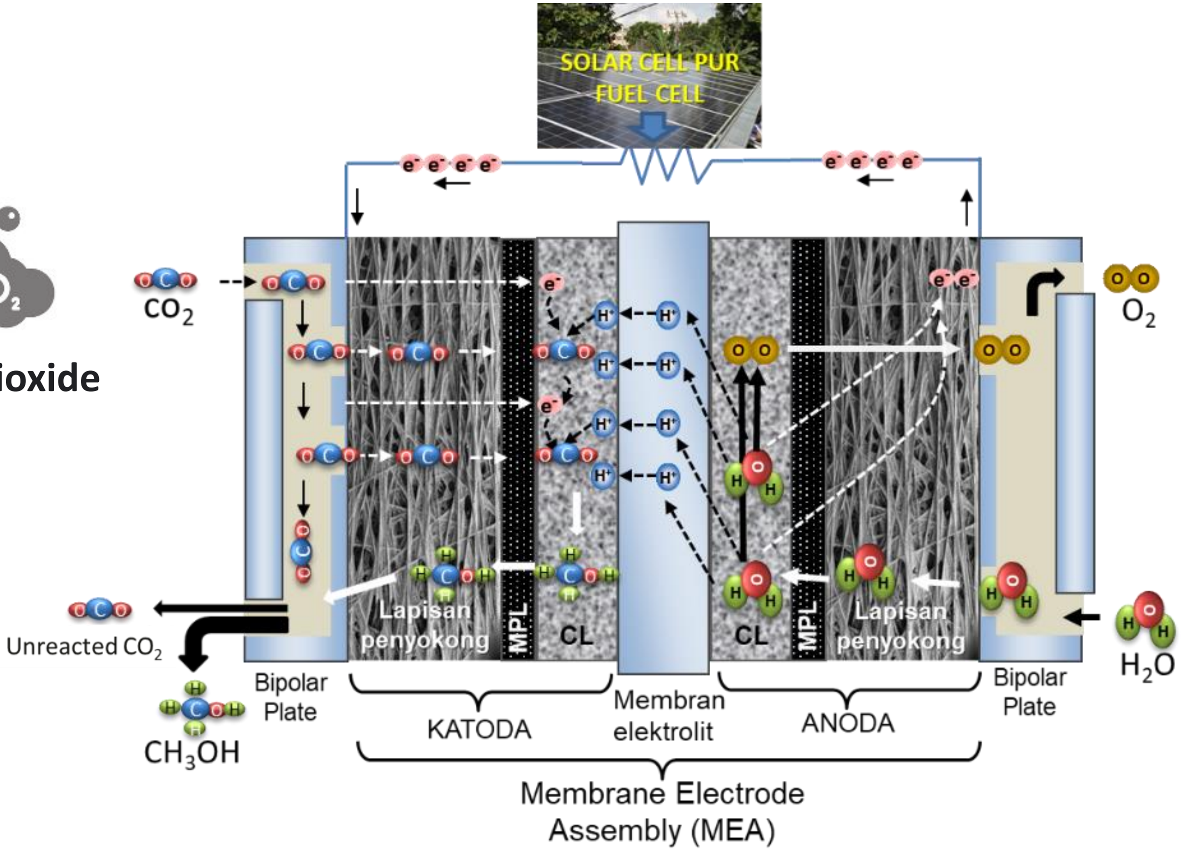
Solvents

Methanol is one of the four critical basic chemicals – alongside ethylene, propylene and ammonia – used to produce all other chemical products

CO_2 Capture and Utilization to Renewable Methanol

Power to Liquid (PtL) to convert renewable energy to liquid fuels and chemicals using Membrane Electrode Assembly (MEA)

Carbon dioxide



Renewable Methanol
> 30% concentration

Renewable Energy source for electrolysis

Electricity from renewable sources is available, hydrogen is produced from water electrolysis

Hydrogen combined with carbon dioxide then converted into renewable methanol

CO_2 Capture and Utilization to Methanol

Pertamina Business Initiative in developing CO_2 based chemicals and fuels through applied technology implementation

Geothermal Field

Green Methanol

- **CO_2 sourced** from non-condensable gas as a content of steam
- **H_2 produced** by electrolysis of water using renewable electricity

$$CO_2 + 3\,H_2 \rightarrow CH_3OH + H_2O$$

Upstream & Refinery

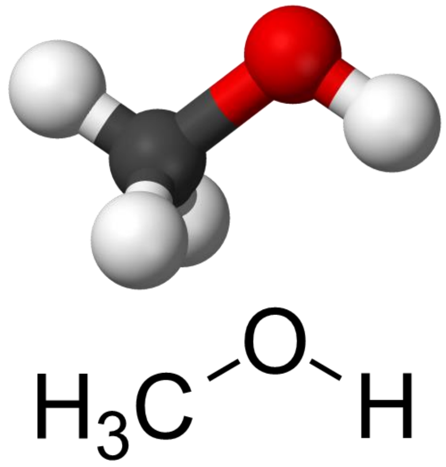
Blue Methanol

1. **CO_2 reforming of methane**
   CO_2 and CH_4 sourced from upstream

   $$CO_2 + CH_4 + \text{low steam} \rightarrow \text{Syngas} \rightarrow CH_3OH$$

2. **CO_2 from refinery field and H_2 produced by electrolysis of water** using renewable electricity or hydrogen recovery

Methanol



Methanol for gasoline blending (Up to 15% methanol) & Support FAME Industry

Natural gas with High CO_2 Utilization

CO_2 as feedstock integrated with NG conversion process (NG-CO_2 reforming) to produce high value-added products

Steam reforming of methane combined with CO_2 or commonly referred to as **CO_2 reforming of methane**

Steam reforming $CH_4 + H_2O \rightarrow 3\ H_2 + CO$	CO_2 reforming (with Less Steam) $CH_4 + CO_2 \rightarrow 2\ H_2 + 2\ CO$		
$H_2 : CO = 3 : 1$	$H_2 : CO = 2 : 1$	$H_2 : CO = 1 : 1$	$H_2 : CO =$ Less 1
Hydrogen	FT Synthesis (Jet/Diesel Fuel)	Oxo Alcohol	Acetic acid
	Ethylene glycol	Other chemicals	Dimethyl ether (DME)

METHANOL

More CO_2 utilized →

Catalyst Development for CO_2 Reforming & Direct DME

Catalyst development based of Cobalt – Nickel (Co-Ni) and Copper (Cu) to produce DME from natural gas

UPSTREAM GAS FIELD

Carbon dioxide up to 30% of CO_2 content in Natural Gas

Additional Steam

Direct Dimethyl Ether (DME) Synthesis from Syngas

Syngas Synthesis
$CO_2 + CH_4 + H_2O \rightarrow CO + H_2$

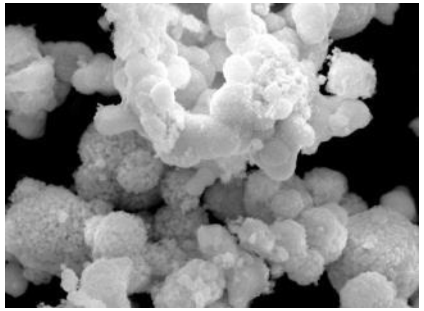
Natural Gas – CO_2 Reforming

Methanol Synthesis
$CO + 2 H_2 \rightarrow CH_3OH$

Low Emission Methanol Production

DME Synthesis
$3 CO + 3 H_2 \rightarrow CH_3OCH_3 + CO_2$

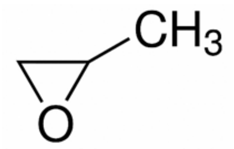
Low Emission DME Production



- Gasoline Blending (A20 program)
- LPG Blending
- Chemical Industry
- FAME Industry
- RTI Internal Research Usage (DMFC Fuel Cell, Direct Methanol Fuel)

CO_2 based Polyols for Polyurethane Synthesis

Polyurethane made from CO_2-based polyol and di-isocyanate



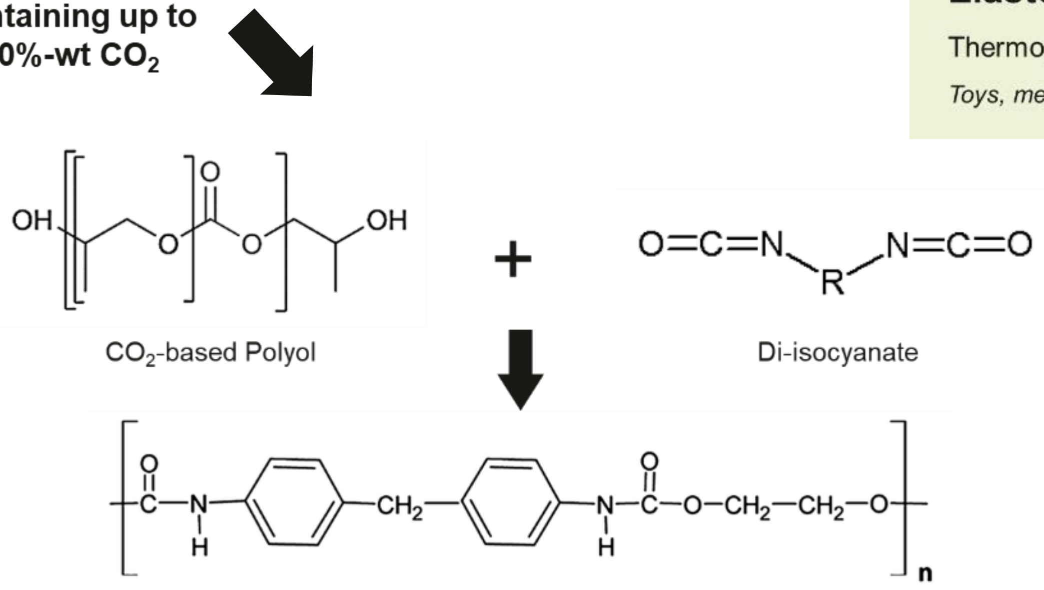
Propylene oxide (PO)

&

Ethylene oxide (EO)

+ CO_2

Containing up to 40%-wt CO_2



CO_2-based Polyol

Di-isocyanate

Polyurethane

CO_2-based Polyol as an intermediate product for Polyurethane synthesis

Coatings – a high degree of hardness while maintaining sufficient flexibility

Coil, can, automotive, plastic, wood, textile or leather coatings

Adhesives & sealants

Flexible packaging adhesives, reactive hot melts, structural adhesives, and used in many applications

Elastomers

Thermoplastic polyurethane

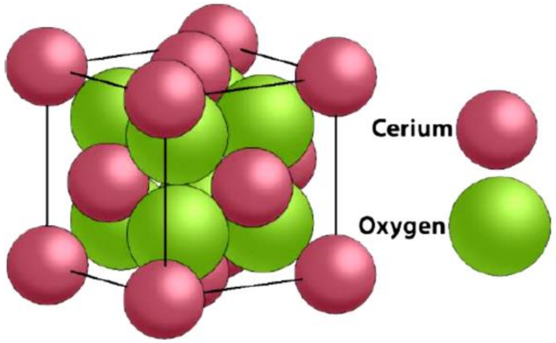
Toys, medical application, automotive, etc.

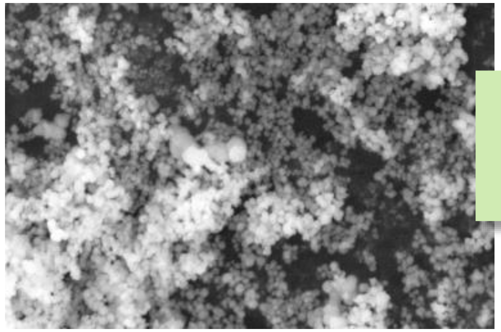
Polyols synthesis by reaction of CO_2 with epoxides (ethylene oxide and propylene oxide)

Catalyst Development for CO_2 Utilization to Polymer

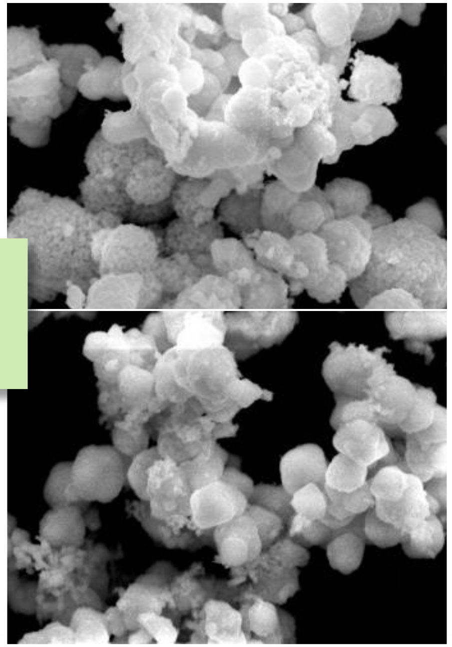
By reaction of non-isocyanate polyurethane (NIPU) using CO_2 and alcohol as feedstock

Catalyst CeO_2 with other transition metals doping to enhance the activity of the catalyst





Catalyst CeO_2 without metal doping



Catalyst CeO_2 with metal doping

The particle catalyst size increases 2 - 5 times with addition of other transition metals

CO_2 Biocapture

Algae and forests have great potential in the reduction of CO_2 emissions

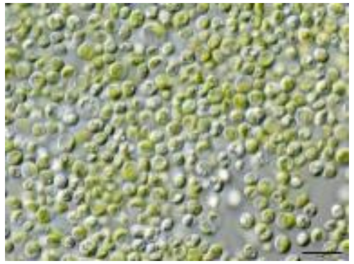
Planted species	Removal rate
Forest (*Eucalyptus*)	**38.0 – 40.7** t CO_2 /ha/year
Forest (*Pine*)	**10.2 – 21.1** t CO_2 /ha/year
Mangrove tree restoration	**Up to 23.1** t CO_2 /ha/year [a]
Algae dry material (*C. vulgaris*)	**1.6 – 2** kg CO_2 /kg/year [b]

For forest during the first 20 years of growth

Planting woodland to remove CO_2 from the atmosphere, known as woodland carbon capture, **is a cost-effective way of compensating for emissions** while also providing many other social and environmental benefits

Growth Parameters for Microalgae

Species	CO_2 (%)	Features [c]
Chlorococcum sp	8	High CO_2 fixation rate Densely culturable
Chorella sp	Up to 60	High growth ability, High temperature tolerance
Euglena gracilis	Up to 100	High amino acid content, Good digestibility (effective fodder) Grows well under acidic conditions, not easily contaminated
Galdieria sp	Up to 100	High CO_2 tolerance
Synechococcus lividus	Up to 70	High pH tolerance



Source:
[a] Bernal et al. (2018): Global carbon dioxide removal rates from forest landscape restoration activities
[b] Carlsson et al. : Micro-and Macro-Algae: Utility for Industrial Applications
[c] The Comprehensive Guide for Algae – based Carbon Capture (www.oigae.com)

CO_2 Biocapture and Utilization using Microalgae

Specific algae strains will be tested in CO_2 concentrated carbon source

Carbon dioxide

Carbon Source | **Nutrient Source** | **Solvent**

Microalgae Cultivation Process
$6CO_2 + 6H_2O + Light \rightarrow C_6H_{12}O_6 + 6O_2$

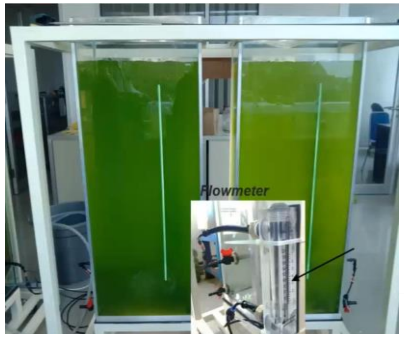
Extraction Process and Product Development

- Pharmacy Industry
- Fertilizer Industry
- Chemical Industry
- FAME Industry
- Food Industry

Biodiesel **Biofuel** **Biomass**

Laboratory and Pilot test
Development for Field Test

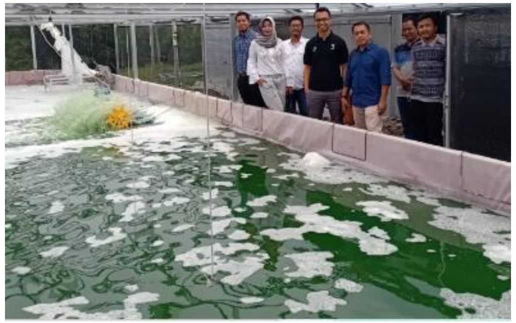
[Lab. Scale PBR – 100 L]



[Pilot Vertical PBR Reactor – 1,000 L]

Economic commercial development with Open Pond cultivation

[Commercial Open Pond – 20,000 L]



Key Takeaways Development for Decarbonization

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Robust legal and regulatory frameworks are needed to facilitate the development of CCUS to provide project developers and financiers with certainty and confidence to invest in green and low carbon projects. They will also play a key role in ensuring the protection of public health and the environment

Support from the government

EXISTING

- **Research funding/grant** by Indonesia Endowment Fund for Education (LPDP) and Ministry of Education and Culture
- **Super tax deduction** for decarbonization research by Ministry of Finance

FUTURE

- **Carbon Economy Value (NEK)** by Ministry of Environment and Forestry
- **Regulations for implementing CCS/CCUS** by Ministry of Energy and Mineral Resources

Collaboration and partnership opportunity

- **Green financing and softloan**
- **Partnership** to share project cost and benefit, sharing risk and to build required technology capability
- **Carbon trading program**
- **Technology improvement and optimization** to reduce Capex & Opex
- **Creating CCUS market and stakeholders acceptance**

The appropriate policy mix will depend on local market conditions and institutional factors, as well as the stage of technology development in the sector or application

THANK YOU

"Mewujudkan Ketahanan, Kemandirian, & Kedaulatan Energi untuk Indonesia"

Ketulusan untuk Melayani