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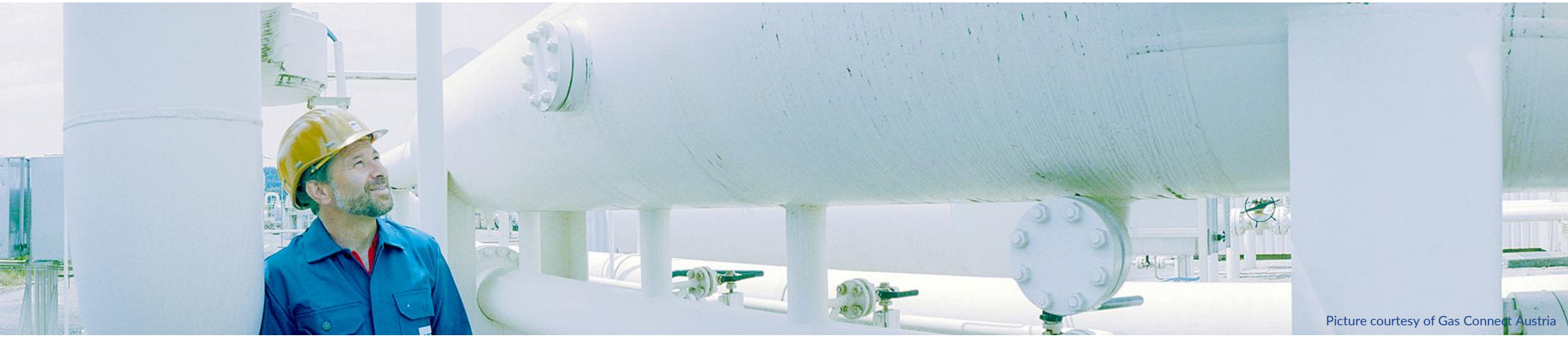


Picture courtesy of Gas Connect Austria

13th Advisory Panel for Future Gas Grids

7 November 2024

MS Teams

Agenda

#	Topic	Presenter	Start
1	Introduction and welcome	Piotr Kuś **ENTSOG**	11:00
2	Panel discussion on Carbon Capture and Storage	Linas Kilda (**KN Energies**) Caterina De Matteis **(IOGP Europe)** John-Henri Van Massenhove (**Fluxys**)	11:05
3	Q&A (10 Minutes)	Piotr Kuś **ENTSOG**	11:50
4	Presentation on Project Prinos CO2	Ioannis Stavrakopoulos **DESFA SA**	12:00
5	Presentation on CCU	Anastasios Perimenis **CO2 Value Europe**	12:25
6	Q&A (15 Minutes)	Piotr Kuś **ENTSOG**	12:50
7	**Conclusions and next meeting**	Piotr Kuś **ENTSOG**	12:55

2. Panel Discussion on Carbon Capture and Storage

13th meeting of Advisory Panel for Future Gas Grids

ENTSOG Offices
7 November 2024

Overview of existing and planned CO_2 storage projects in Europe

BULGARIA
1. ANRAV (IF)

CROATIA
1. Petrokemija Kutina*
2. Bio-Refinery Project*
3. CCGeo (IF)
4. **CO_2 EOR Project Croatia***
5. Geothermal CCS project (PCI)

CZECH REPUBLIC
1. CO2-SPICER

DENMARK
1. **Greensand***
2. Bifrost* (PCI)
3. Stenlille demo CO_2-storage
4. Nome (PCI)
5. Ruby

FRANCE
1. Pycasso* (PCI)

GREECE
1. Prinos CCS (PCI)

HUNGARY
1. MOL-Hungary CCS Project*

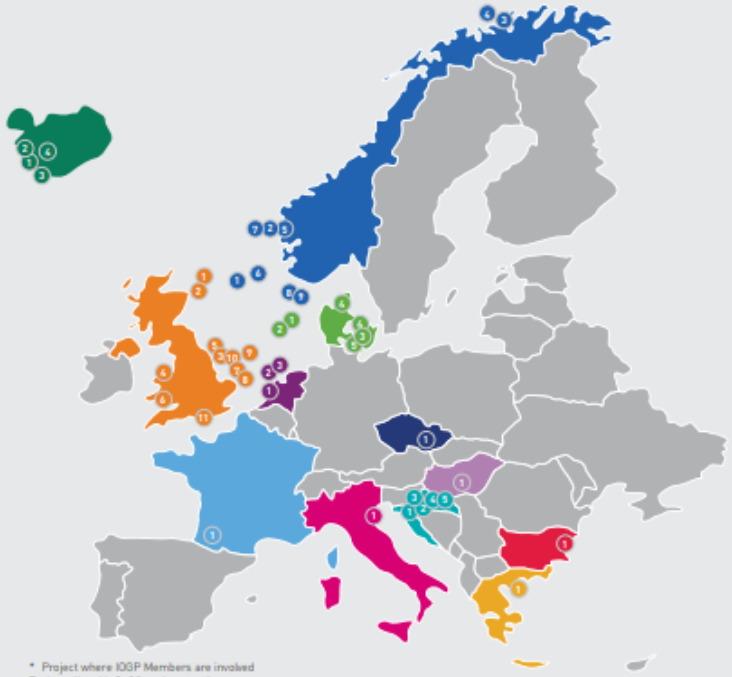
ICELAND
1. **Orca**
2. **Silverstone** (IF)
3. Coda Terminal (IF)
4. Mammoth

ITALY
1. Ravenna CCS (includes Callisto)* (PCI)

THE NETHERLANDS
1. Porthos* (PCI)
2. Aramis* (PCI)
3. L10 CCS*

NORWAY
1. **Sleipner***
2. Longship (includes Northern Lights)* (PMI)
3. Barents Blue (includes Polaris)
4. **Snøhvit***
5. Smeaheia*
6. Trudvang*
7. Luna*
8. Havstjerne*
9. Poseidon (NO)*

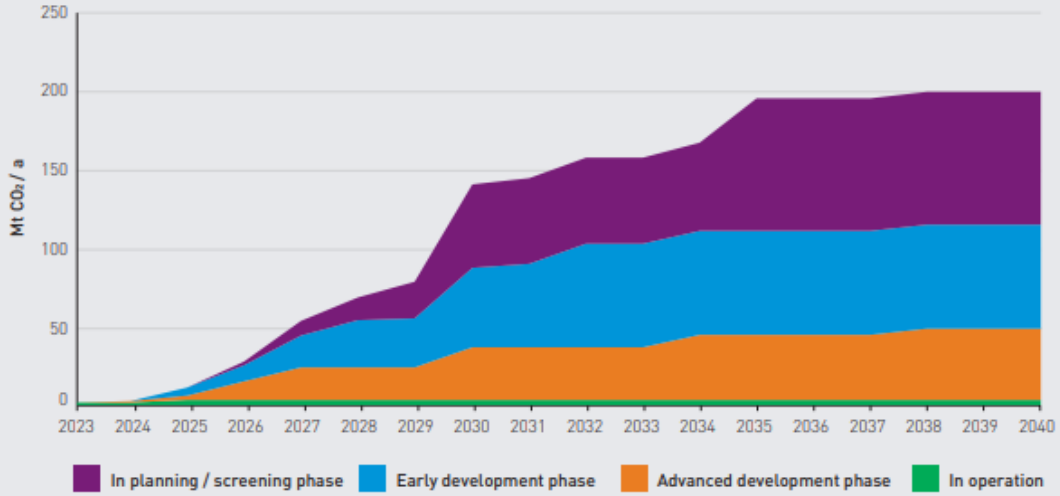
UK
1. Acorn*
2. Caledonia Clean Energy
3. Zero Carbon Humber*
4. HyNet*
5. Net Zero Teesside*
6. South Wales Industrial Cluster
7. Bacton Thames Net Zero initiative*
8. Poseidon (UK)
9. Viking CCS*
10. Orion
11. Solent Cluster*



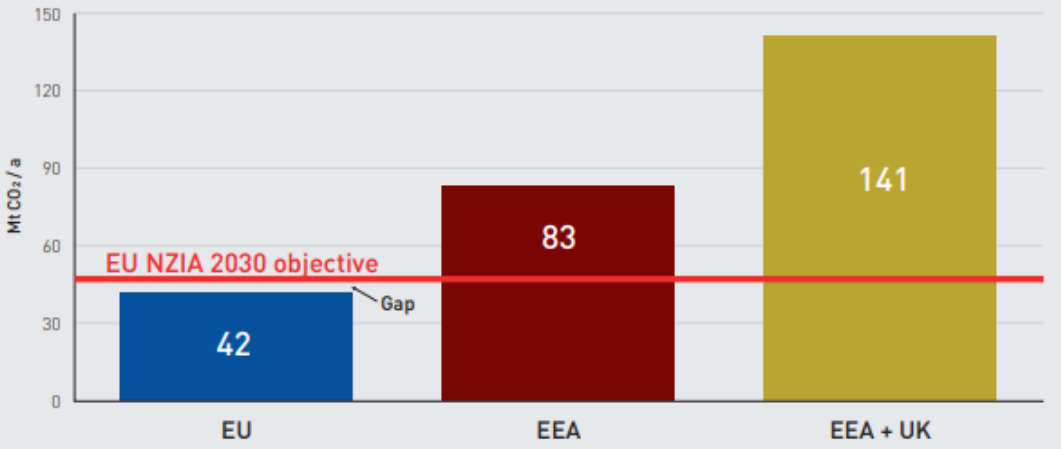
* Project where IOGP Members are involved
Projects listed in **bold** are in operation
(PCI) – Project of Common Interest
(PMI) – Project of Mutual Interest
(IF) – Project supported by the EU Innovation Fund

EU	**19 projects** - 42 MtCO2/yr by 2030
Europe	**43 projects** - 141 MtCO2/yr by 2030

Build-up of CO_2 storage injection capacity in Europe



Regional breakdown of CO_2 storage injection capacity by 2030



Key numbers

EU

19 CO_2 STORAGE PROJECTS

9 COUNTRIES WITH CO_2 STORAGE PROJECTS

42 MT CO_2/YEAR CO_2 storage injection capacity by 2030

Europe

43 CO_2 STORAGE PROJECTS

12 COUNTRIES WITH CO_2 STORAGE PROJECTS

141 MT CO_2/YEAR CO_2 storage injection capacity by 2030

International Association of Oil & Gas Producers

Translating ambition into actions

NZIA (2030) and ICMS (2030+beyond) show ambition, but there is an incomplete enabling framework

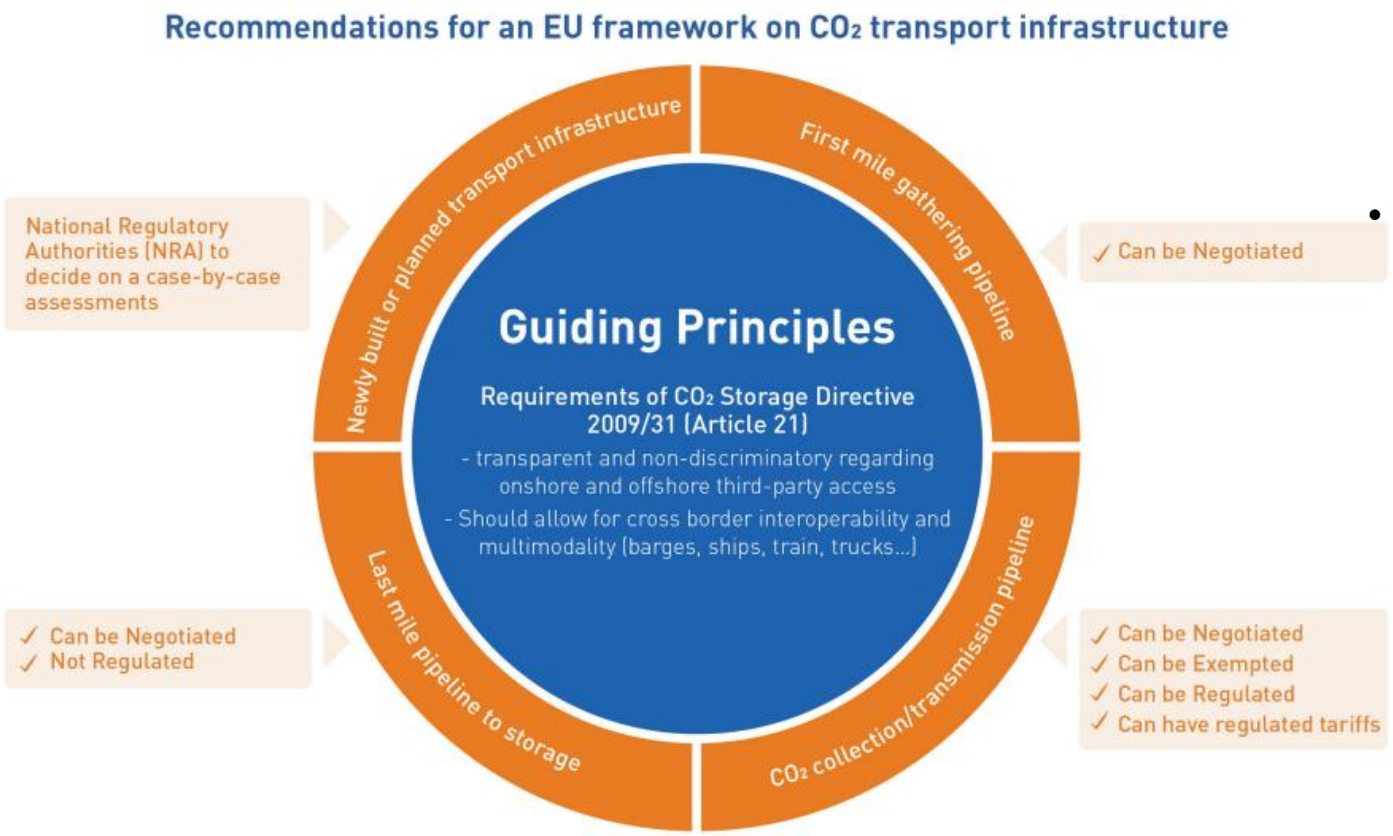
Key areas for actions

1) **CO2 infrastructure:**
   - Proposal for a regulatory framework for CO2 transport (CO2 storage infrastructure should not be regulated)

2) **Cross-border cooperation:**
   - Accelerate harmonized accounting of EU and UK CO2 emissions by setting-up a dedicated EU-UK WG.

3) **Funding and de-risking:**
   - IPCEI for CCUS
   - CCfDs under Innovation Fund
   - Continued research in capture technologies to bring cost down (economies of scale)

IOGP Europe views on CO2 transport regulatory framework



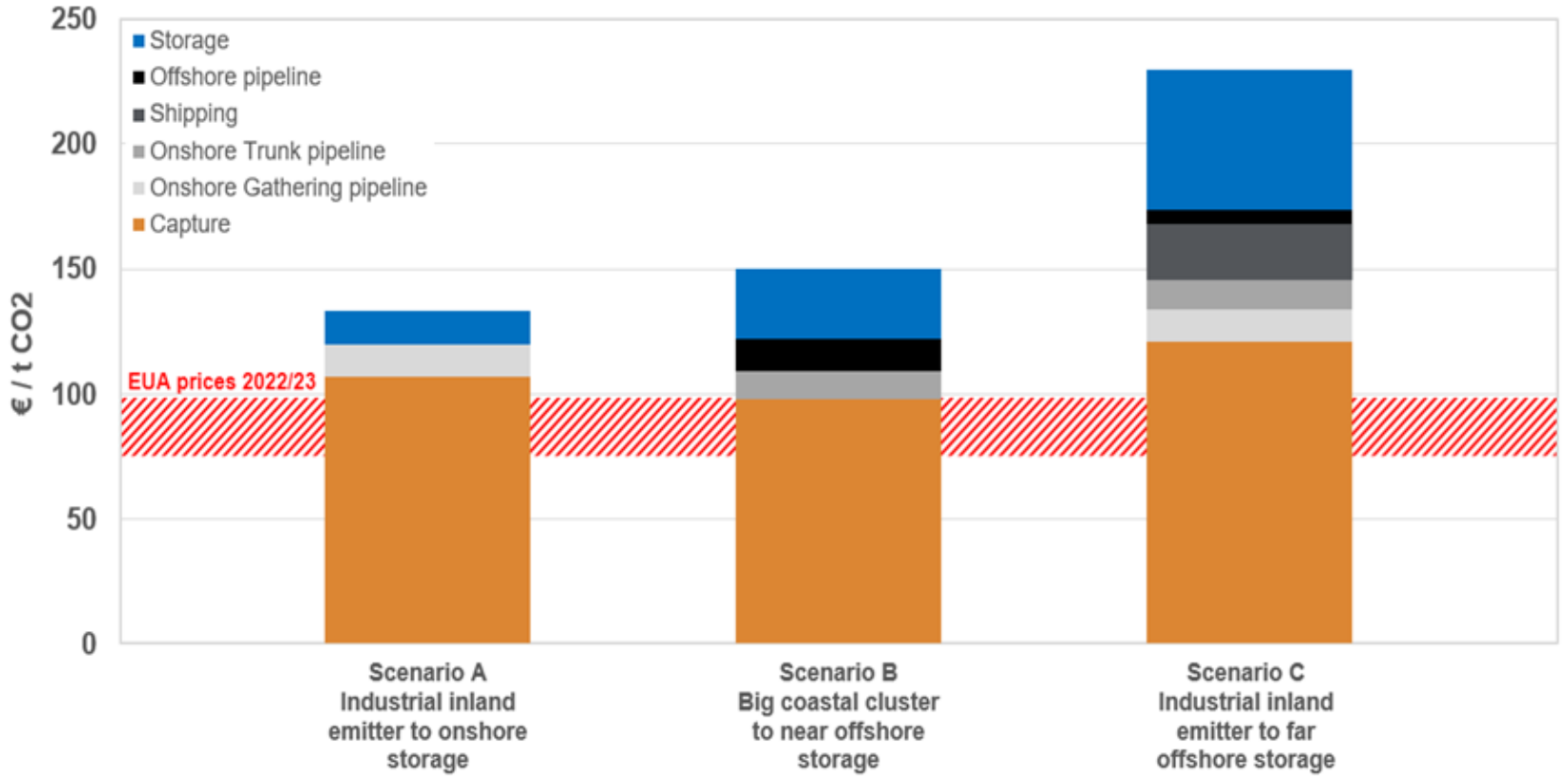
- Need for robust development of CO2 transport infrastructure, with balanced risk and reward mechanisms along the value chain, supported by long-term contracts and dedicated funding
- Flexible regulatory approach → conditions in MSs are different
  - ➢ Access to the CO2 transport network and storage sites guided by CCS Directive principles of transparent and non-discrimination
  - ➢ A one-size-fits-all regulatory approach for CO2 transportation pipelines is not suitable → framework for distinguishing different types of pipelines
  - ➢ Storage operators to compete against each other, leading to cost-efficient market-driven solutions

IOGP Europe paper '*key principles on a future regulatory framework for CO2 transport infrastructure*' HERE

International Association of Oil & Gas Producers

Europe needs a business case

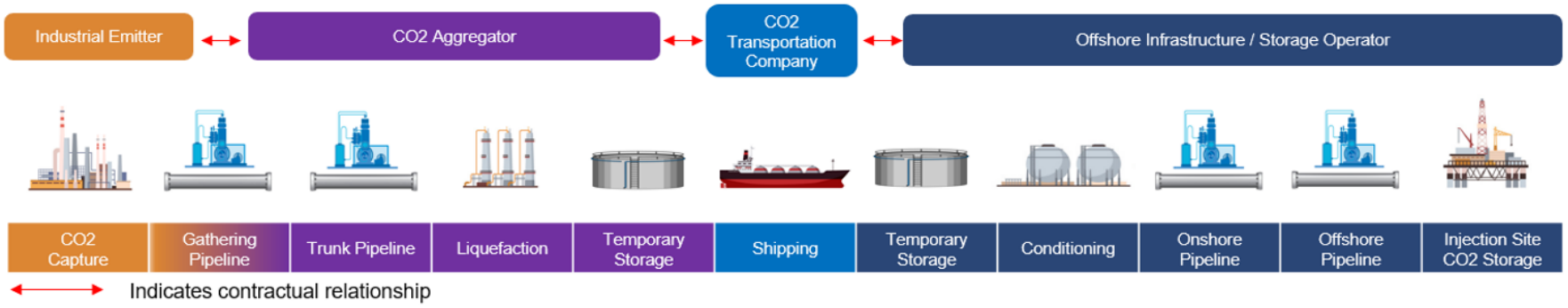
Levelized cost of CCS value chains range from 130 to 230 €/t_{CO2}
3 scenarios based on Rystad Energy data



➢ **Current ETS allowances prices are insufficient for emitters to underpin CCS value chains**

International Association of Oil & Gas Producers

Each segment of CCS value chain needs targeted support



Key de-risking & funding mechanisms along the CCS value chain

Emitter with capture	Transportation infrastructure operators	Storage & offshore infrastructure operators
• CCfDs • Targeted funding • Long term CO2 offtakes contacts • Economic incentives	• Government backed guarantees • CO2 aggregators with public backing • Long term back-to-back • capacity bookings • Regulated tariffs	• Targeted funding • Long term store-or-pay contracts • Financial security optionality • Improving the framework for cross-border carbon accounting and bilateral agreements

Member States need to take necessary measures for entities to reach the target by 2030, however:

- **An enabling framework is still missing**
- **Industrial Carbon Management Strategy sets actions, but actions set (including enabling legislation) will be ready only in 2026!**

International Association of Oil & Gas Producers

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4. Presentation on Prinos CO2 Project

DESFA's CCS PCI Project

13th meeting of Advisory Panel for Future Gas Grids

November 2024

AGENDA

About DESFA

Our CCS project – ApolloCO2

DESFA counts 17 years of successful operation post the liberalization of natural gas market in 2007

About DESFA

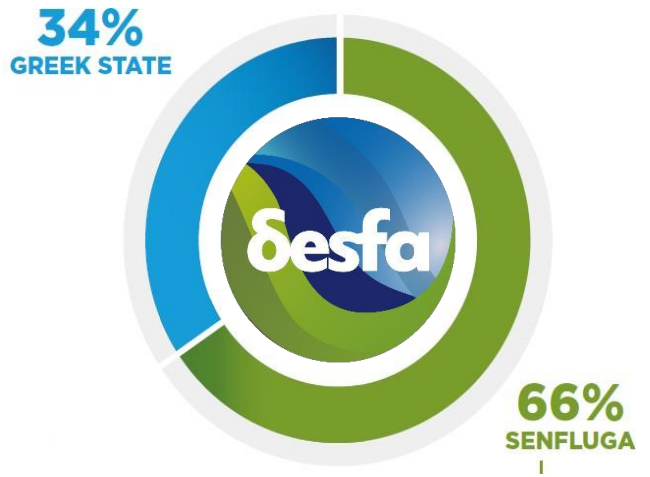
Key Points

- Established in **March 2007**, **DESFA owns & operates the Greek Natural Gas System (NNGS),** consisting of the **National Natural Gas Transmission System** & the **LNG Terminal in the islet of Revithoussa**
- DESFA has been certified as an **Ownership Unbundled Operator** under the **3rd EU Energy Package**, following the **completion of a privatization process on 20th December of 2018**
- **DESFA operates, maintains & develops the Greek Natural Gas System** in a **safe, reliable and economically efficient way**, offering:
  - **Regulated Third Party Access services** in a transparent and non-discriminatory way
  - **A range of non-regulated services** to a number of national & international clients
- DESFA has the **necessary know-how, highly trained staff and the proper equipment** to provide **high-level operation and maintenance services for LNG storage and gasification facilities**

Key Milestones

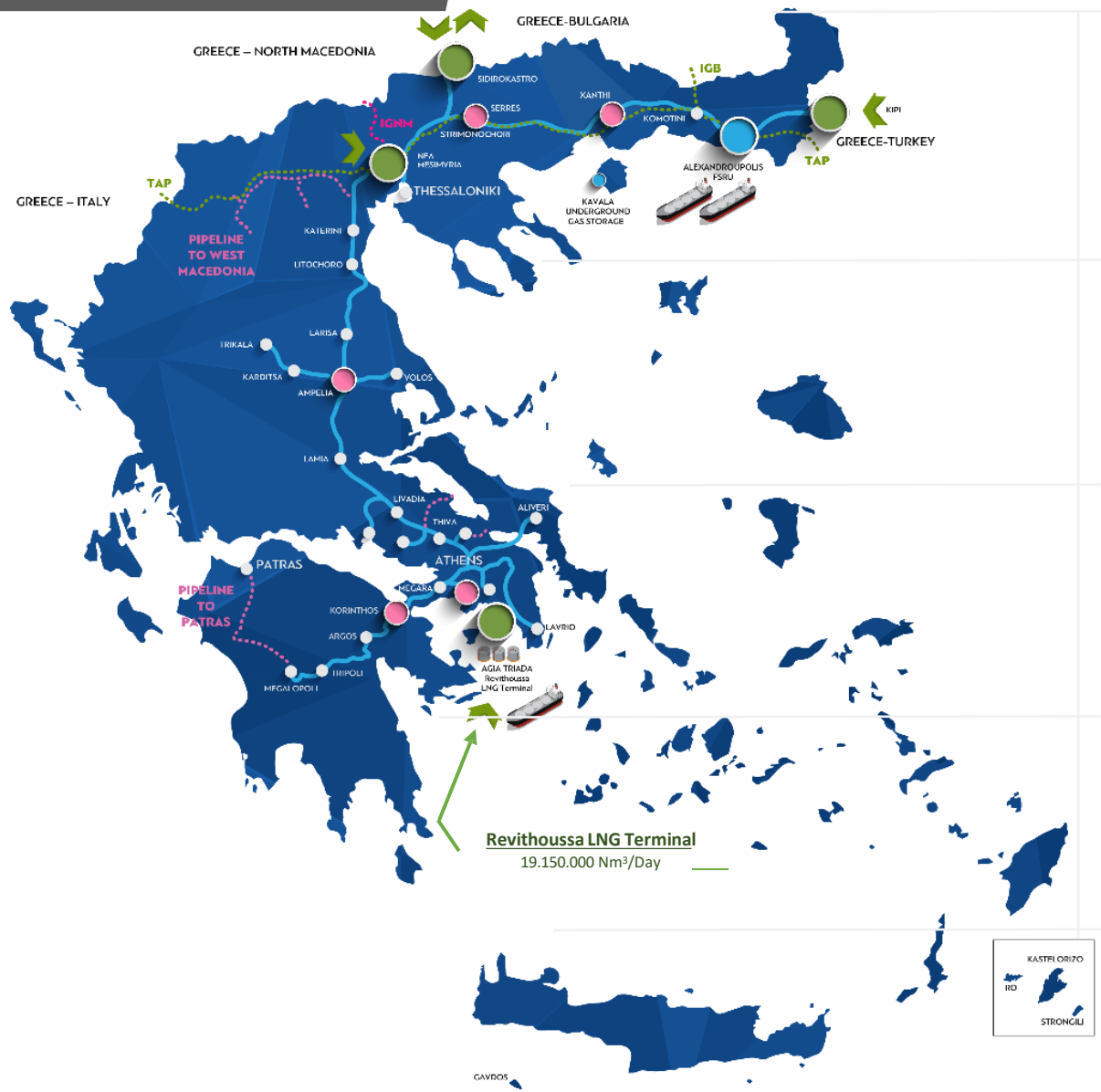
2007	*2014*	*2018*
• Establishment of DESFA	• Certification of DESFA as Independent Transmission Operator under the 3rd EU Energy Package	• Completion of privatization process & certification as Ownership Unbundled Operator • Participation as a shareholder (7%) in the Hellenic Energy Exchange (HEnEx)

Shareholders' Structure



DESFA's network at a glance

About DESFA



1,466 km
High Pressure Pipelines

6
Operation & Maintenance Centers

1
LNG Storage & Regasification Terminal Station in Revithoussa

25
Exit Points to Distribution Systems

4
Interconnection Points

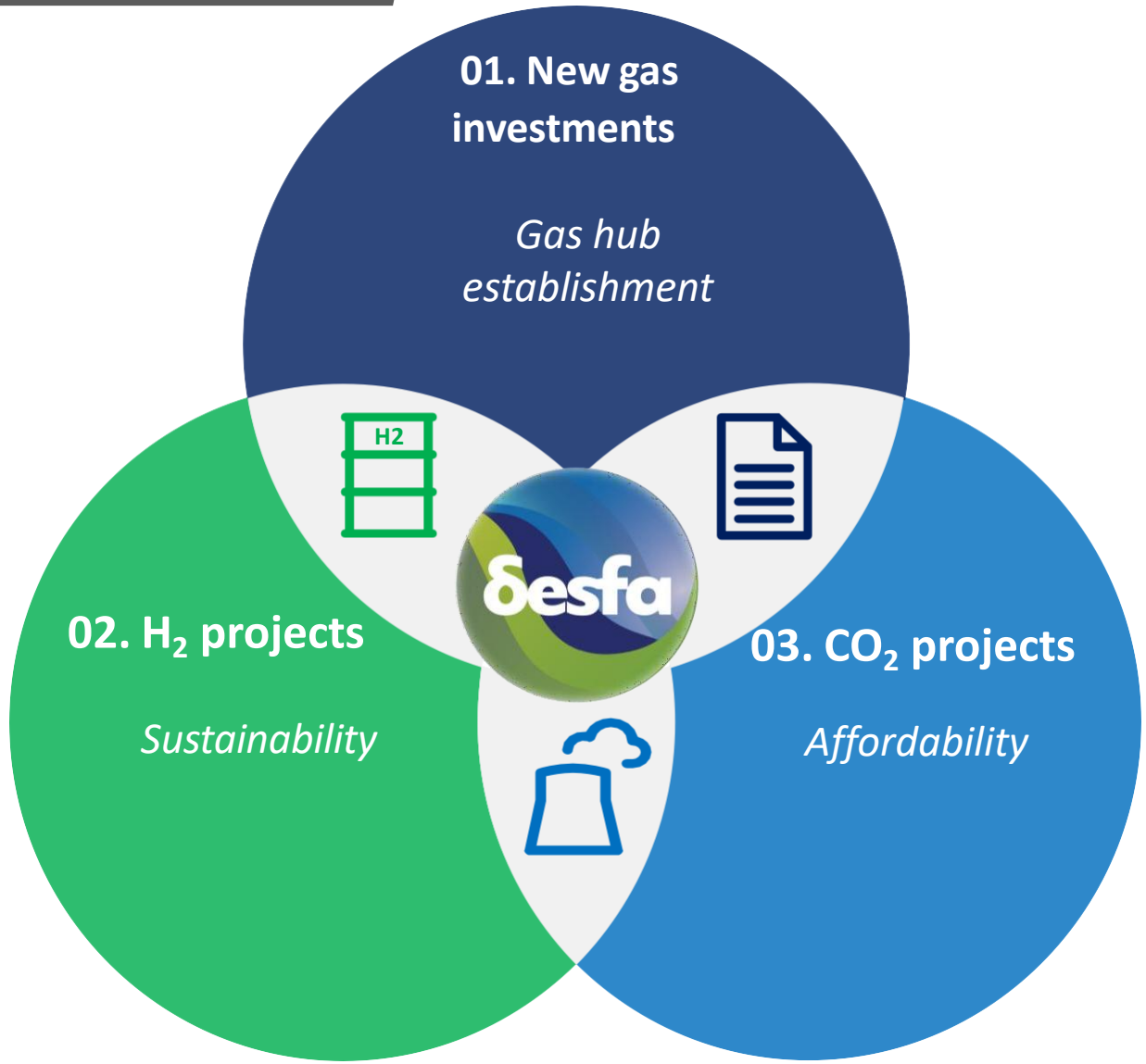
2
Dispatch Centers

53
Metering & Regulating Stations

1
Compression Station

DESFA's focuses on three main pillars to address the energy transition ambition as well as to support EU succeeding in its climate targets

About DESFA



01

Through **new (100% H_2 ready) gas investments** in Greek transmission system and in line with its **extroverted activity**, **DESFA secure the supply of NG in SEE and central EU**

02

Based on **EU targets**, the Greek TSO has set as one of its **main strategic goals** the **development of H2 sector in Greece** through the assessment of **Smart Gas Grid and H2 pipelines projects**

03

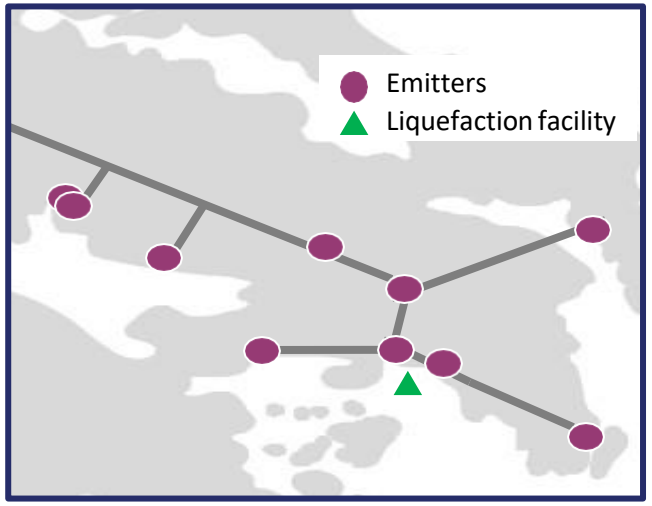
DESFA focuses on being **integral part** and constituting a **vital role in the CCUS business in Greece**, activated in the **midstream** part of the value chain

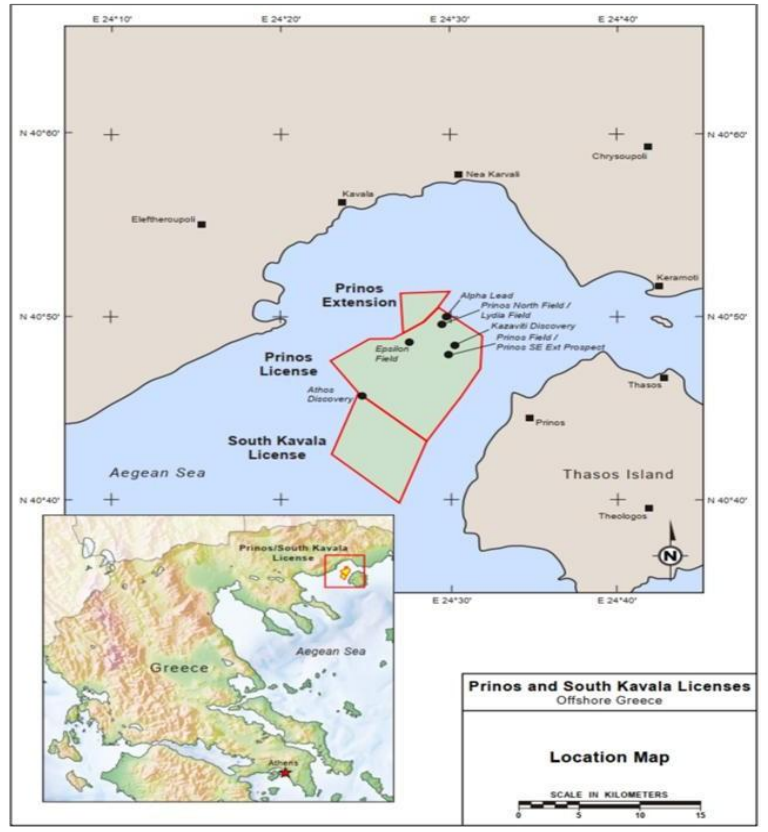
AGENDA

About DESFA

Our CCS project – ApolloCO2

Prinos CCS project developed by DESFA and Energean is part of the latest PCI list



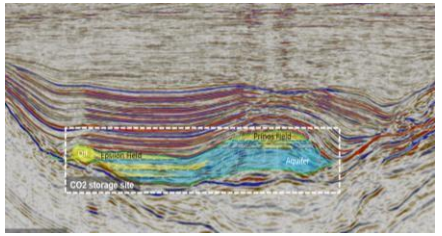


Key Highlights

The **"Prinos CO_2"** project submitted by Energean and DESFA has been included in the latest PCI list of EC

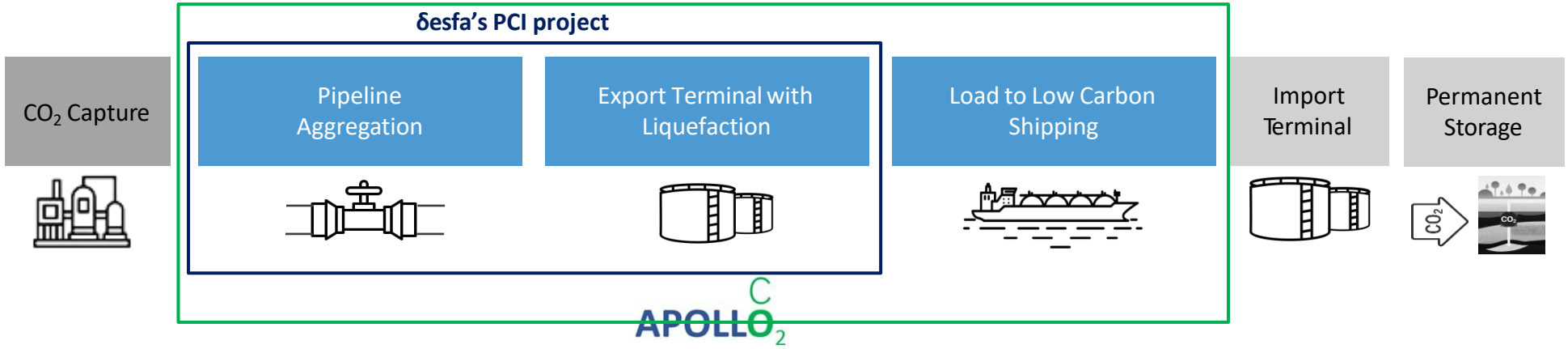
- ✓ **Energean's project** envisages Prinos CO_2 Storage Project to be among the **first CO_2 storage hubs at industrial/commercial scale in the Mediterranean**. **Prinos capacity** is expected to be deployed in Phases; **Phase 1** (2025-2028): **1 MTPA; Phase 2** (12/2027 – onwards): **3 MTPA**
- ✓ **DESFA's project** includes the construction of a **dedicated CO_2 pipeline** collecting CO_2 from emitters, a liquefaction terminal, from where the liquid **CO_2 will be temporarily stored in a dedicated facility** and then loaded to **CO_2 carriers that will transport it by sea** to Prinos Storage facility, **but also to future storage facilities to be developed in the wider European neighborhood**

Mapping of CO2 Storage Site

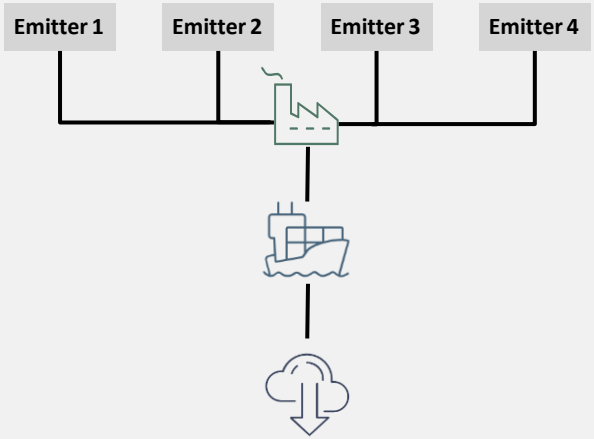


Existing On-Site Infrastructure

APOLLOCO$_2$ will cover the midstream part of the CCS system value chain



Key highlights



- Due to the benefits offeíed by **economies of scale**, DESFA píoposes **an aggíegated scenaíio** of a **single expoít facility** located baíycentíically íegaíding industíial plants
- CCS Hub based on a scalable platfoím-as-a-seívice, with **an open-access system to add potential paítneís and technology** (e.g., smalleí-scale emitteís and cold eneígy usage)
- Acceleíated licensing and peímitting application and píocess

Main benefits from CCUS

Stíengthen the Eneígy l'íansition pathway, decaíbonizing paít of Gíeek industíial emission by 2030

Development of a leading EU Infíastíuctuíe píoject

Suppoít Gíeek Industíy to stay in countíy by enhancing competitiveness in Gíeen Píoducts

Substantial Investment in Gíeek infíastíuctuíe foí expoít teíminal and pipeline

Gíeen Job Cíeation foí constíuction, engineeíing and innovation with oppoítunity foí Local Labouí Upskilling

Significant suppoít foí National Businesses duíing constíuction and opeíation, geneíating wideí Economic Benefits

There is a potential of approximately 9 Mtpa CO2 in Central Greece and Attica region

CO2 market potential

Cluster Size

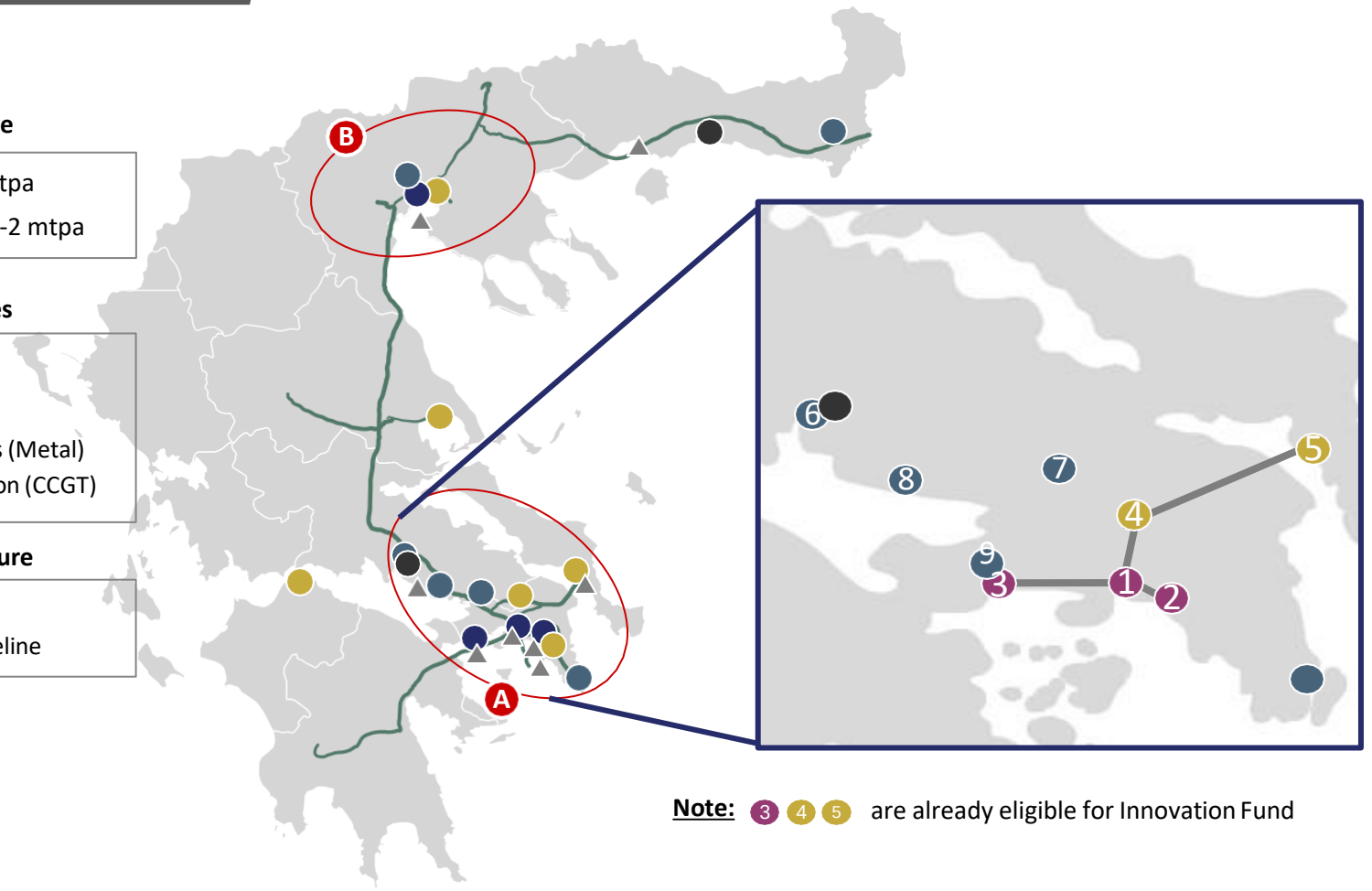
- A. Attica – 5-10 mtpa
- B. N. Greece – 1,5-2 mtpa

Industries

- Refining
- Cement
- Other industries (Metal)
- Power generation (CCGT)

Infrastructure

- Key ports
- Natural Gas Pipeline



Note: 3 4 5 are already eligible for Innovation Fund

South Greece potential in phases

Phase 1: EoI &NDA in place (4,1 mtpa)

Refining

1. **Refinery 1** (date tbc) -> **0,6 mtpa**
2. **Refinery 2** (date tbc) -> **tbd**
3. **Refinery 3** (2028) -> **0,5 mtpa**

Cement

4. **Cement 1** (2028-2029) -> **1,9 mtpa**
5. **Cement 2** (date tbc) -> **1,1 mtpa**

Phase 2: Future emitters (4,7 mtpa)

Power plants

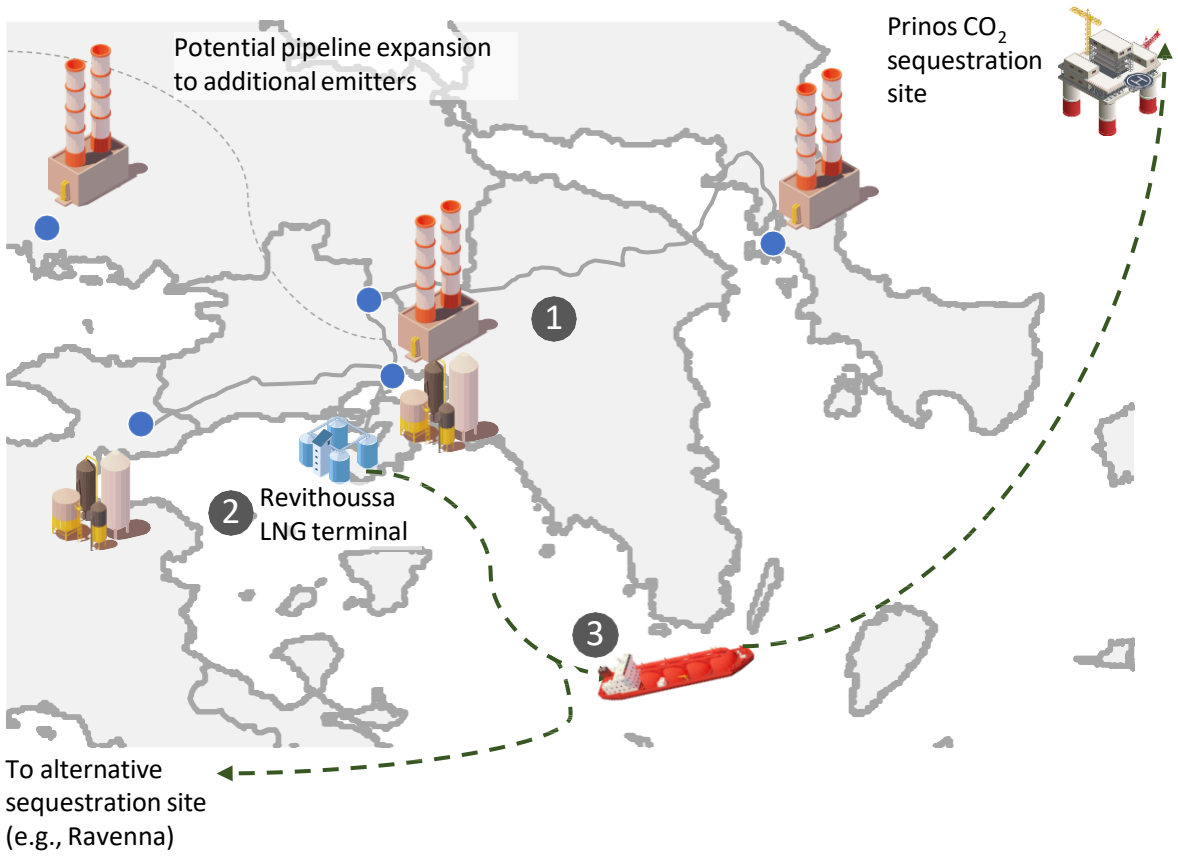
6. **Power producer 1** (date tbc) -> **2,3 mtpa**
7. **Power producer 2** (date tbc) -> **1,6 mtpa**
8. **Power producer 3** (date tbc) -> **0,4 mtpa**
9. **Power producer 4** (date tbc) -> **0,4 mtpa**

Total (Phase 1 & 2)≈ 9 mtpa

The design and techno-economic aspects of the APOLLOCO$_2$ CCS hub in a nutshell

Industrial emitters — CO_2 pipeline -- Potential expansion: CO_2 pipeline → LCO_2 shipping

APOLLOCO$_2$ CCS hub schematic



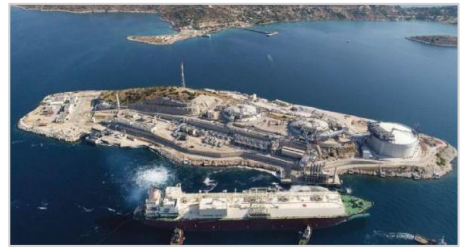
Details of core value-chain assets

1 Pipeline network to integrate key emitters in South Greece

- Aggregates ~50% industrial emissions in Attica with expansion to Viotia
- Feasibility studies finalized, currently at the FEED stage

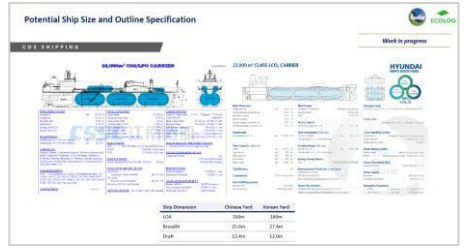
2 CO_2 liquefaction facility with synergies with Revythoussa LNG terminal

- 5 MTPA capacity to accommodate several emitters (expandable to 10 MTPA)
- Cost efficient CO_2 liquefaction, leveraging cold energy with LNG (~65% opex savings)

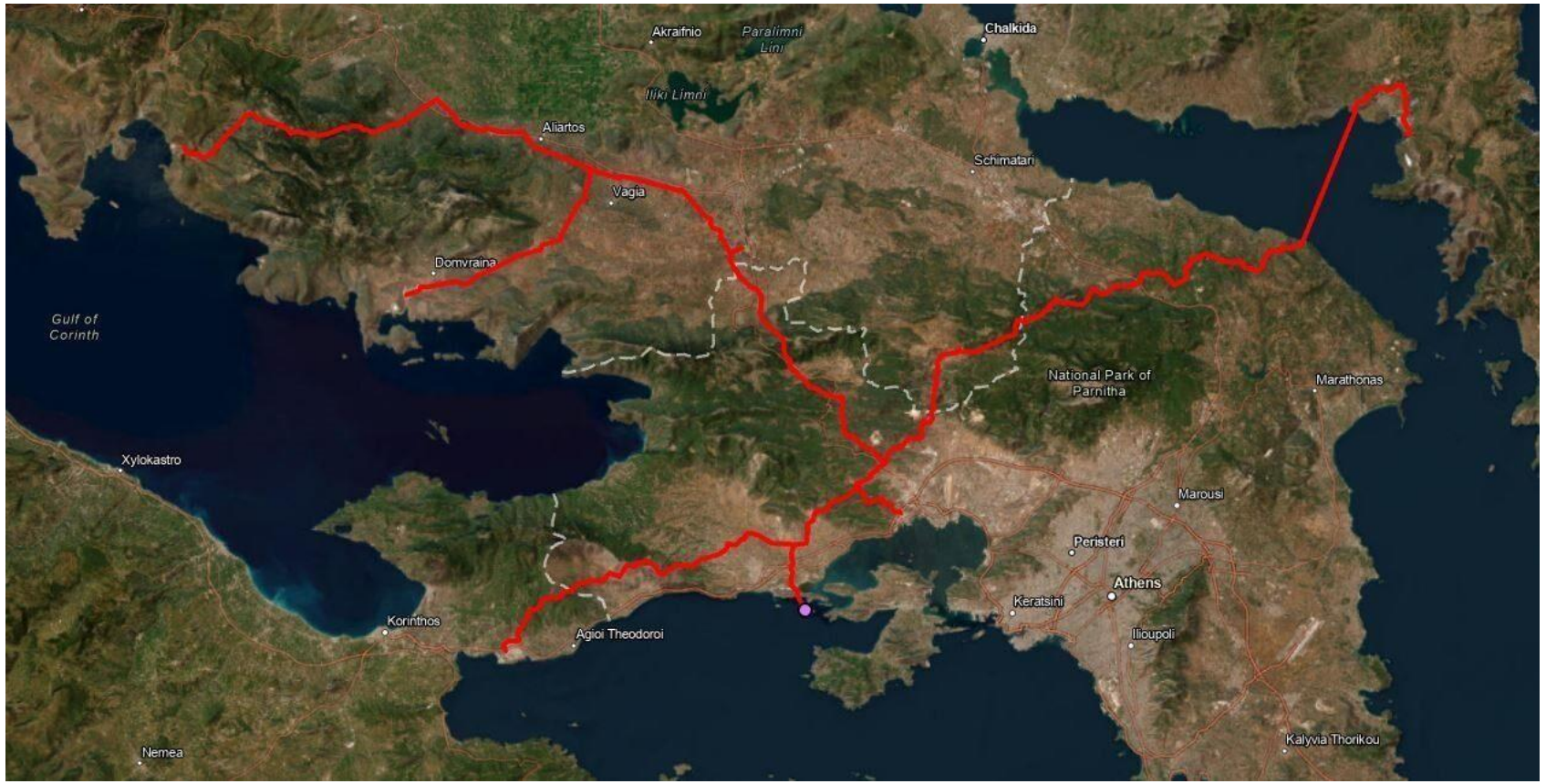


3 Large-scale liquid CO_2 vessel (22-40k cbm)

- Optimised vessel size and routes, considering draft limitations around Attica
- Up to ~60% cost savings from scale and maximising utilisation



Feasibility study for CO2 Pipelines has been executed in 2 phases, resulting in a network of ~300km if all big emitters join ApolloCO2



Pipeline dimensions	
Total length	275 km
Pipeline Diameter	20'' – 24''

Gas composition
Northern Lights specification

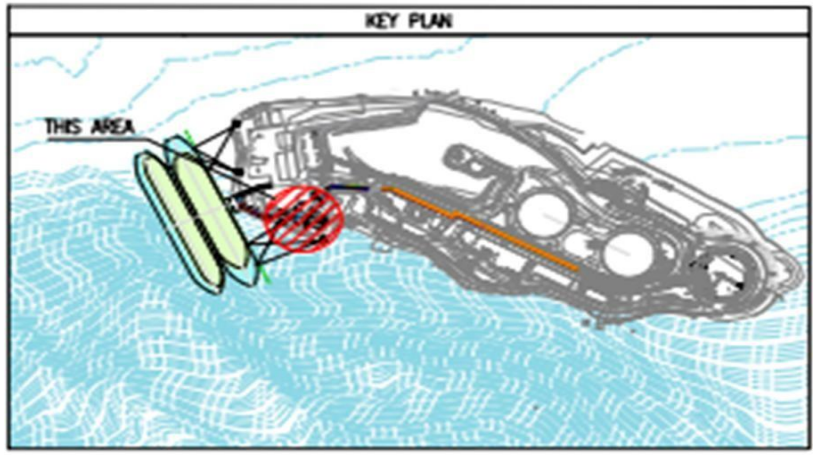
Gas conditions	
Upstream (Inlet of the CO2 pipelines)	
Temperature	40 oC
Maximum pressure	42 barg
Downstream (Inlet of Liquefaction Terminal)	
Delivery pressure	20 barg

Feasibility study for Liquefaction & Export Terminal has proven the benefits of proceeding with Revithoussa as the preferrable terminal location

Liquefaction Terminal

1 Technical solution

- ✓ Carbon dioxide **liquefaction facility located on Revithoussa Island** will comprise of both onshore and offshore parts
- ✓ Gas CO_2 will be delivered through pipelines in Revithoussa and **the cold energy exchange will take place on the island** (onshore part)
- ✓ Due to space constraints on the island, for **Storage, Backup liquefaction system** (in the case of LNG unavailability) **and Offloading** of LCO_2 an **FSU solution** was selected
- ✓ **FLSU Jetty linked** at south – west area of Revithoussa Island



2 Innovative characteristics of the proposal

Cold energy utilisation

Exploitation of the otherwise wasted **cold energy generated from LNG regasification processes** to significantly reduce the energy requirements for the CO_2 liquefaction and LNG regasification at the same time.

Low pressure solution

Implementation of a low pressure/gas phase system for the aggregation of CO_2, **providing scalability, safety in terminal's operation, mitigation of permitting hurdles & a cost-competitive advantage by minimising infrastructure & transportation expenses.**

Floating liquefaction & storage unit

Introduction of a FLSU as a **ground-breaking solution to geographical and physical constraints**, with a primary focus on temporary storage and secondary on liquefaction as a backup option. The depth of Revithoussa island enables the accommodation of larger vessels, which can cover greater distances and enable the feasibility of otherwise much more costly standalone CCS supply chains.

CO2 Sequestration Site Optionality

- APOLLOCO$_2$ through its partners is in advanced discussions with several sequestration providers in Europe, mitigating storage capacity and delay risks to customers
- By aggregating the volume and increasing the ship size, there are more storage options available for emitters with optimised costs

Potential Partner	Distance to Athens (Nm)	Note
ENERGEAN	250	▪ Nearest sequestration site / lowest transportation cost ▪ Limited sequestration capacity
eni	815	▪ Within Mediterranean ▪ Large sequestration capacity (c. 500mt) ▪ Significant emitter cluster in Northern Italy ▪ Restricted depth for shipping
NEPTUNE ENERGY	2,900	▪ Longer distances / higher transportation cost ▪ More mature compared to Med sequestration sites
STOREGGA	3,140	▪ Longer distance/ higher transportation cost / low sequestration cost ▪ More mature compared to Med sequestration sites ▪ Regulatory hurdle to sequestrate outside of EU
EnQuest	3,215	

APOLLOCO$_2$ Timeplan

Launch in Q1 2023

Pre-FEED + FEED + Permitting

FID

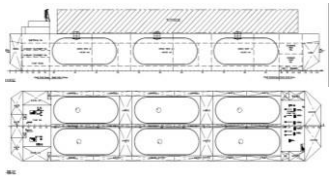
Construction

Operational Start

2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029

Pre-Feasibility Studies

Today



Thank you!

Giannis Stavrakopoulos

Energy Transition & Strategic Planning Specialist

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4. Presentation on CCU

CO2 VALUE EUROPE

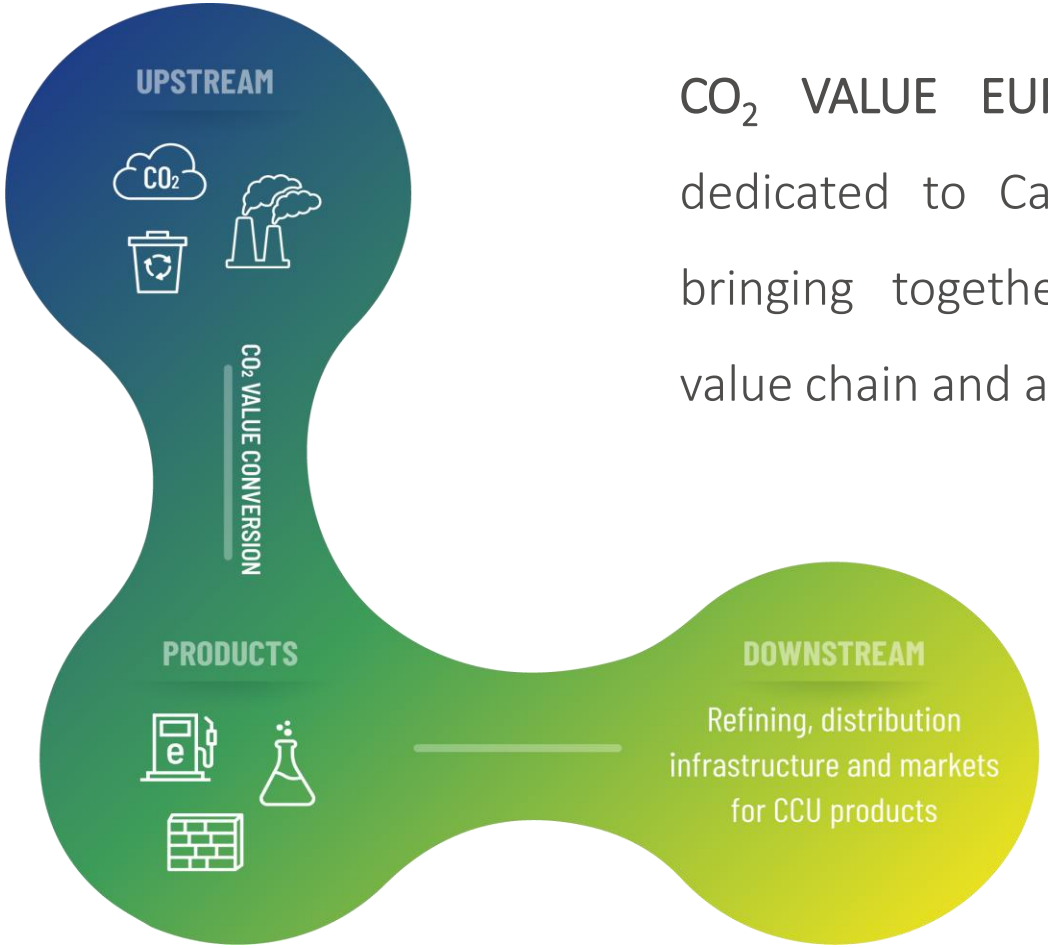
CCU in the current EU context

Anastasios Perimenis, Secretary General

Advisory Panel for Future Gas Grids

07 November 2024

The association



CO_2 VALUE EUROPE is the European association dedicated to Carbon Capture & Utilisation (CCU), bringing together stakeholders from the complete value chain and across industries.

Our priorities

Provide scientific & technical knowledge and evidence-based information on CCU

Raise awareness, engage with stakeholders, communicate about CCU and CVE

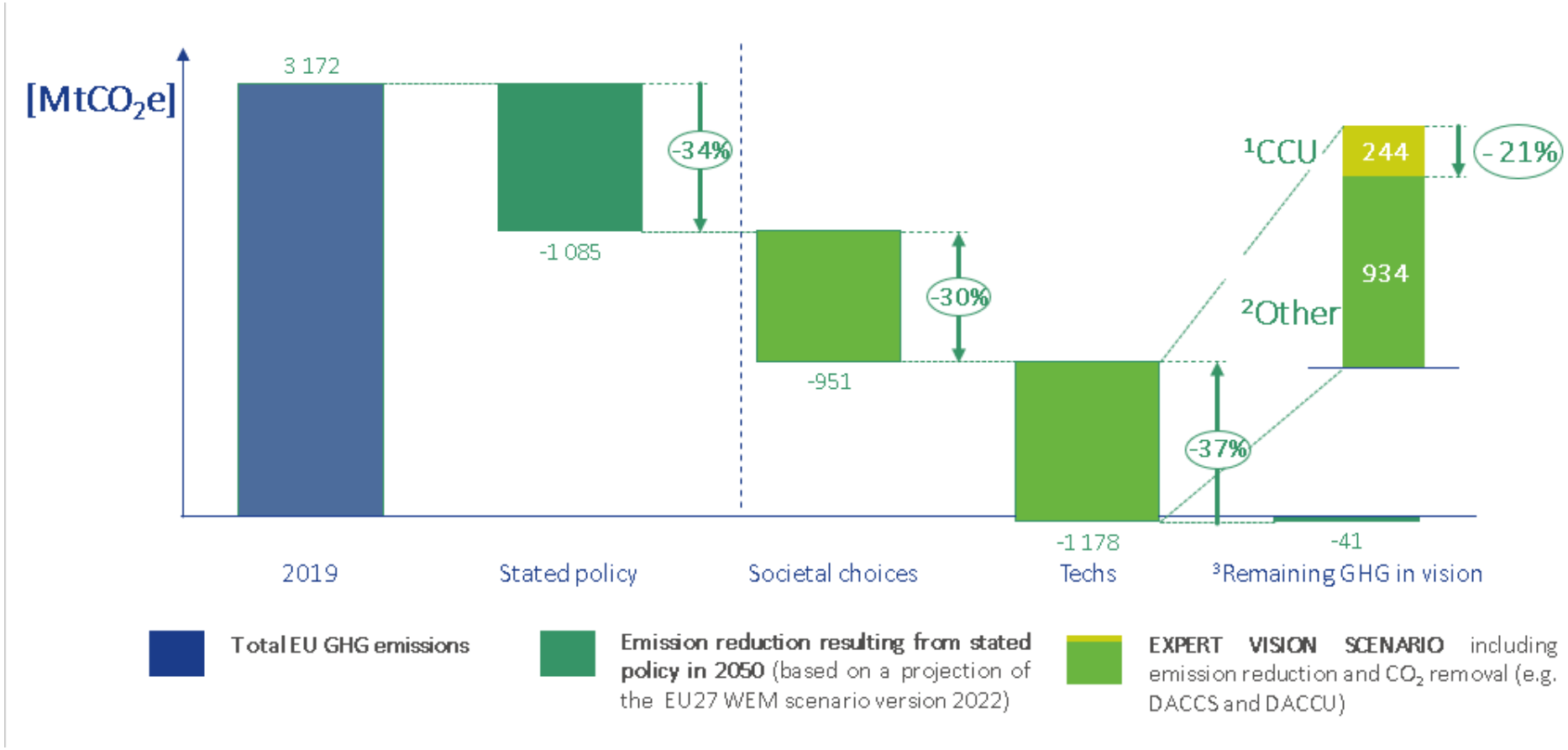
Create a supportive and consistent regulatory framework for large-scale deployment of CCU

Support and accompany innovative and industrial-scale project development

Our members

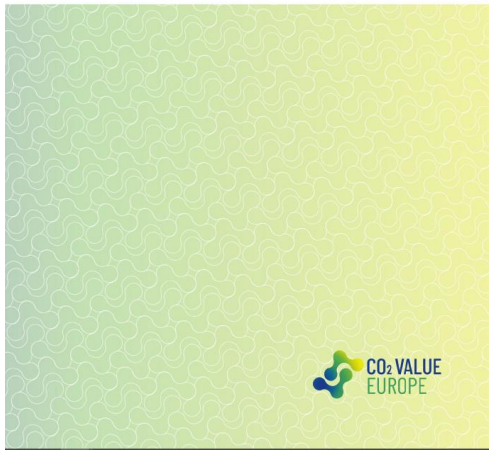
38 Large Companies | **27** Research Organisations | **47** SMEs | **6** Clusters

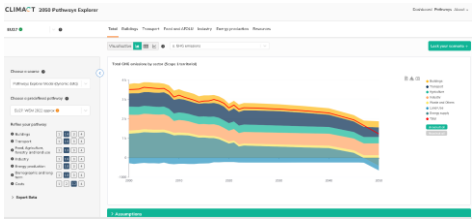
Essential contribution of CCU



THE CONTRIBUTION OF CARBON CAPTURE & UTILISATION TOWARDS CLIMATE NEUTRALITY IN EUROPE

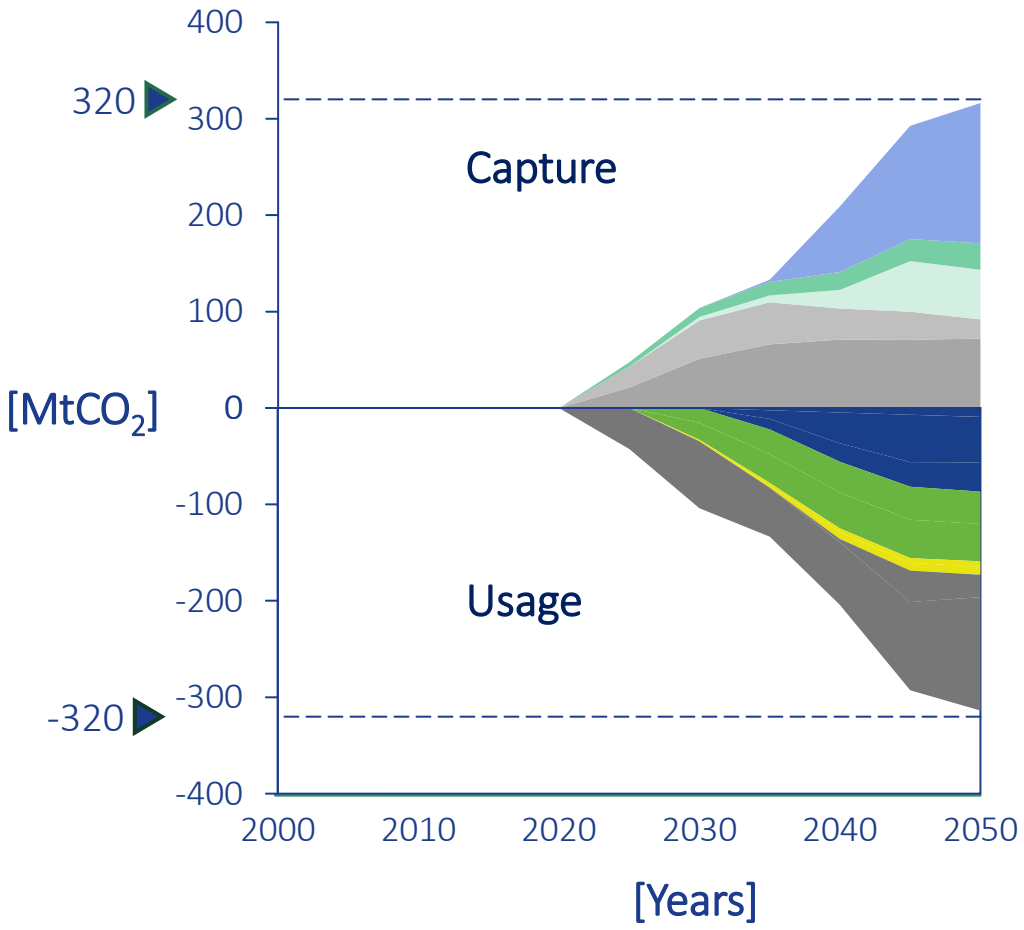
A SCENARIO DEVELOPMENT AND MODELLING EXERCISE

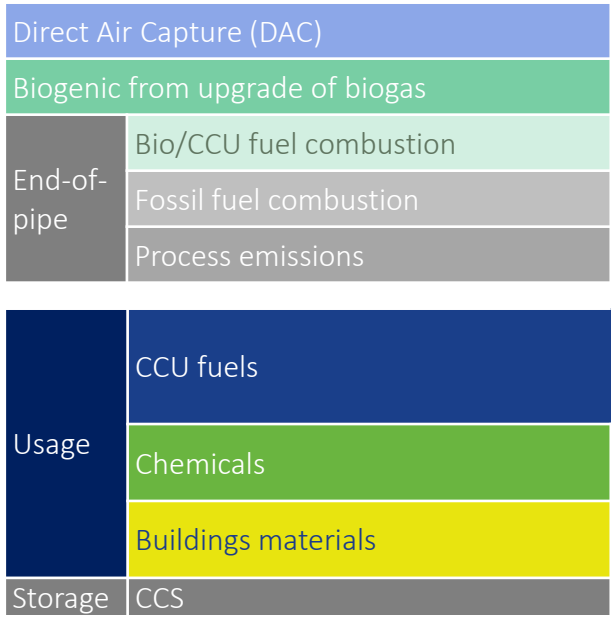




CO2 VALUE EUROPE

Essential contribution of CCU





	Share	Mt CO_2
CO_2 from DAC	46%	147
CO_2 from biogenic sources	23%	72.6
CO_2 from CCU-fuel combustion	2%	6
CO_2 from fossil fuel combustion[1]	6%	20
CO_2 process emissions	23%	72

CO_2 used for CCU-fuels production	28%	87
CO_2 used in chemicals production	23%	72
CO_2 stored in building materials	4%	14
CO_2 stored as CCS	45%	141

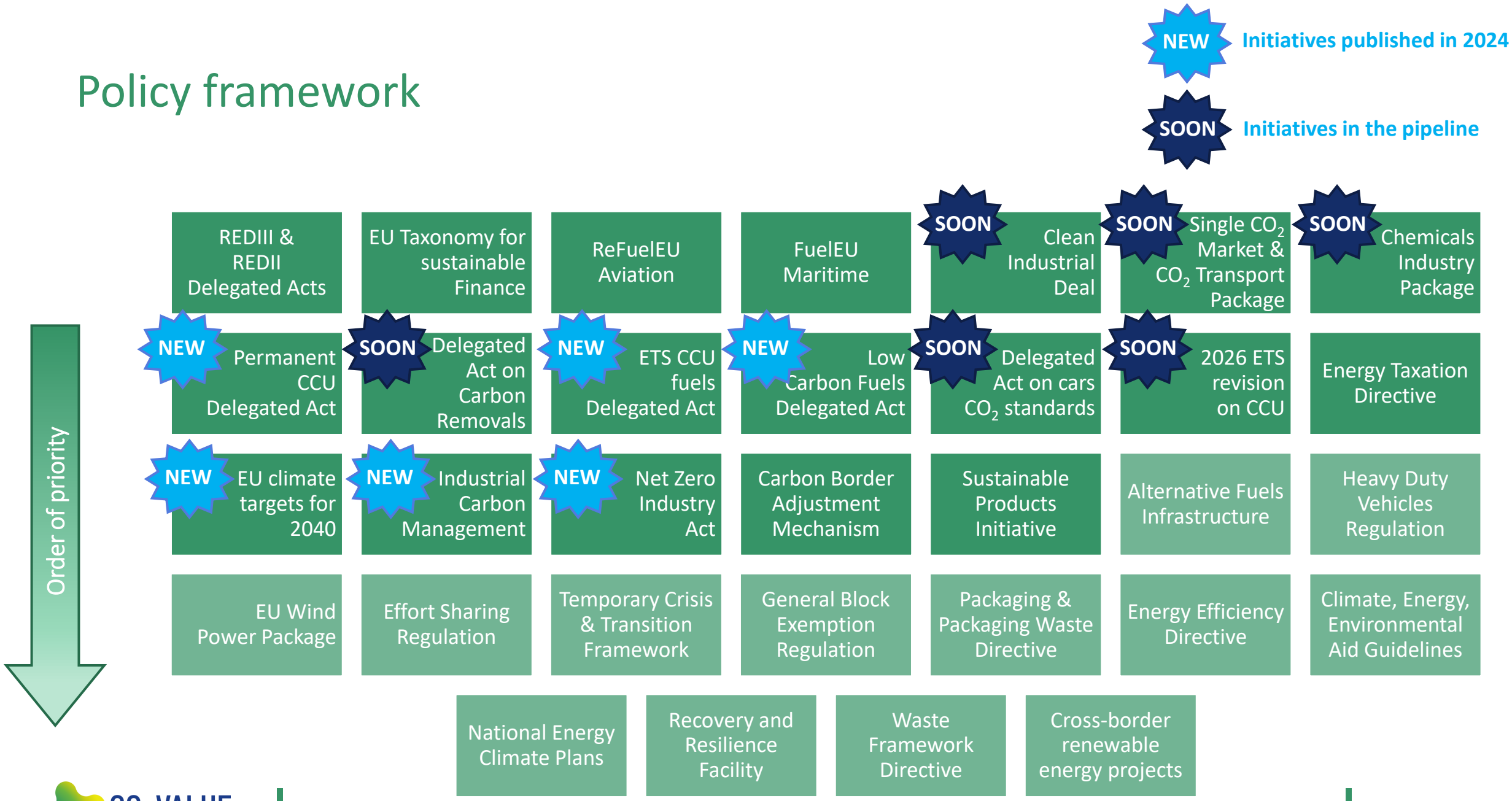
CO2 VALUE EUROPE

Projects

Project	Country	Product	Estimated capacity (t/a)
Carbon2Business	Germany (Lägerdorf)	Fuels & chemicals	350.000
HySkies	Sweden (Forsmark)	Fuels & chemicals	90.000
AIR	Sweden (Stenungsund)	Fuels & chemicals	200.000
eM-Rhône	France (Roussillon)	Fuels & chemicals	150.000
Green MEIGA	Spain (Caldas de Reis)	Fuels & chemicals	100.000
TRISKELION	Spain (Mugardos)	Fuels & chemicals	40.000
Flagship TWO	Sweden (Sundsvall)	Fuels & chemicals	130.000
E-fuel pilot	Norway (Porsgrunn)	Fuels & chemicals	8.000
Green Fuels for Denmark	Denmark (Copenhagen)	Fuels & chemicals	250.000
Norsk e-fuel	Norway (Mosjøen)	Fuels & chemicals	40.000
Power-to-Methanol	Finland (Lappeenranta)	Fuels & chemicals	25.000
Vordingborg	Denmark (Vordingborg)	Fuels & chemicals	80.000
E-fuel	Germany (Frankfurt)	Fuels & chemicals	2.500
AGGRECACO2	Spain (Muskiz)	Materials	56.000
CO2NCREAT	Belgium (Hermaille-sous-Huy)	Materials	130.000
CAP2U	Germany (Lengfurt)	Chemicals & Materials	70.000*
C2PAT	Austria (Mannersdorf)	Chemicals	160.000
Columbus	Belgium (Wallonia)	Fuels & Chemicals	330 GWh/y
REUZE	France (Dunkirk)	Fuels & Chemicals	100.000
HyNetherlands	Netherlands (Delfzijl)	Fuels	100 MW **
Hynovera	France (Meyreuil)	Fuels & Chemicals	100 MW **
LIPOR	Portugal (Meia)	Fuels & chemicals	32.000
Finnfjord	Norway (Finnfjord)	Fuels & chemicals	100.000
eNRG Kotka	Finland (Kotka)	Fuels	35.000
NeoCarb	France (Marseille)	Fuels	50.000
SkyKraft	Sweden (Skellefteå)	Fuels	100.000

**capture capacity, ** electrolytic capacity ;*
Source: CO_2 Value Europe database

Policy framework



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Representation

Representation

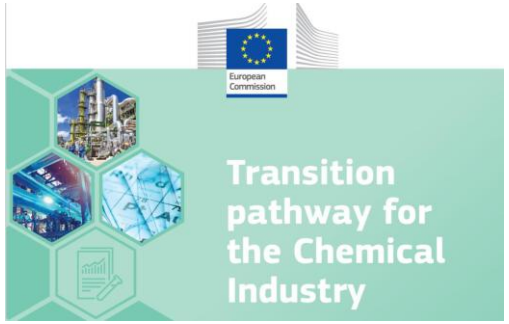
Innovation Fund Expert Group (DG CLIMA)

RLCF Alliance

Renewable & Low Carbon Fuels Alliance (DG MOVE)

TYNDP // 2024
Scenarios Storyline Report

Stakeholder Reference Group TYNDP (ENTSO-E & ENTSO-G)



Chemical Transition Pathway (DG GROW)

ICM Forum - WG CCU co-chair (DG ENER)

CCUS SET-Plan (DG ENER)

ENERGY GASES

Metrology Network (EURAMET)

CLIMATE ACTION

Climate Change Expert Group (DG CLIMA)

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Representation

Industrial Carbon Management Forum – WG on CCU (co-chairs)

- **Mandate:** Describe challenges and provide recommendations to incentivise industrial-scale CCU deployment
- Addressing critical issues like:
  - Definitions (e.g. sustainable carbon, unavoidable emissions, renewable vs. low carbon vs. zero-rated, etc.)
  - Rules around RFNBO/RCF and derivatives (e.g. sunset clause of 2041, energetic vs non-energetic applications, additionality, geographical & temporal correlation)
  - Captured carbon as feedstock (e.g. treatment of captured carbon vs. virgin fossil carbon for chemicals)
  - Incentivising permanent and non-permanent CCU (e.g. ETS revision, Carbon removal certification)
  - Accounting of emissions from CCU value chains (e.g. GHG protocol)
  - Mix of inputs & mass balance,
  - Product and CO_2 certification
  - …

Representation

TYNDP – Stakeholder Reference Group – WG on Carbon Management (chair)

- **Mandate:** Provide advice on the TYNDP scenarios
- WG on Carbon Management addressing issues like:
  - Calculation of carbon budget
  - Including non-energy emissions & more CCU energy carriers (e.g. methanol)
  - Assessing how CCU/CCS can be included in the model and not only as an external assumption → Innovation Roadmap
  - Including CO2 transport infrastructure → Innovation Roadmap
  - …

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Thank you!

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FOLLOW US ON

3. Q&A

Thank you for your attention

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