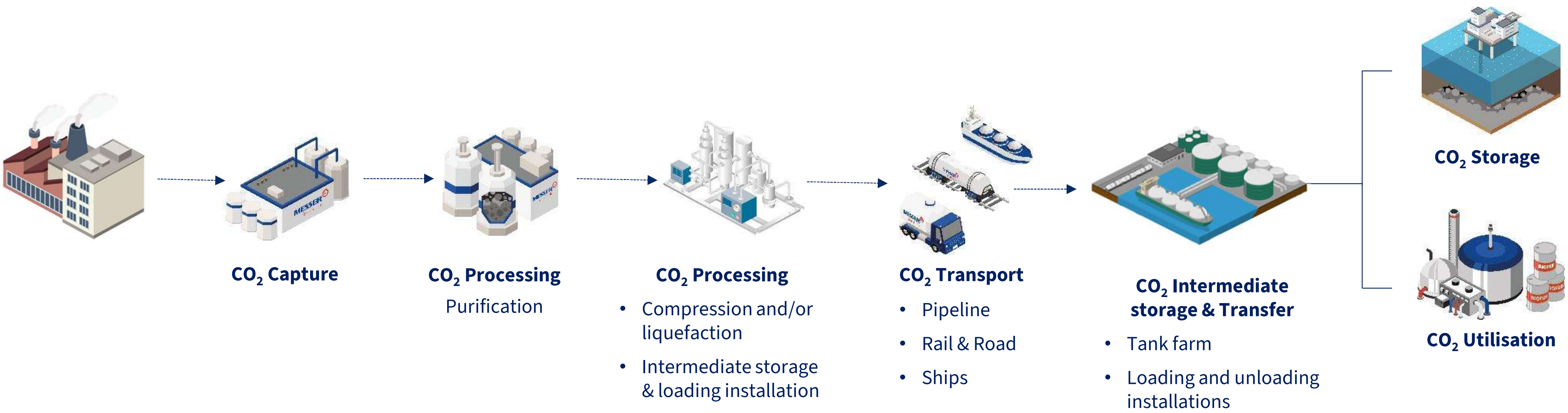

MESSER
Gases for Life
Simplifying carbon neutrality
ZeCARB®

From Capture to Storage, some technical-economic challenges to optimise the value chain

The complexity of the CCUS value chain



Challenges along the value chain

Long term storage assurance

Geological sink availability

Legal complexity

Capture efficiency

High costs and lack of profitability

Permitting facilitation

Regulatory and policy gaps

Public acceptance

Long lead times

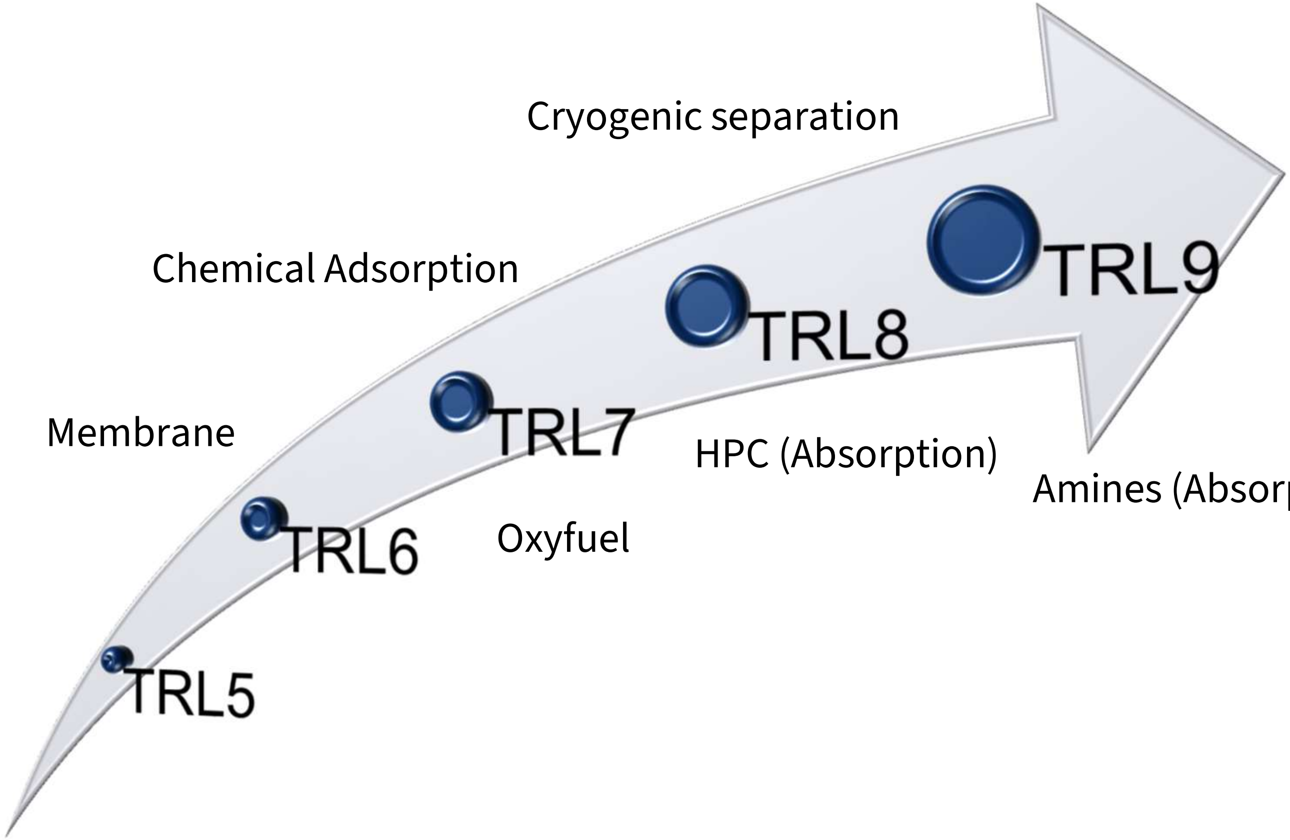
Lack of infrastructure

Energy required

Monitoring and verification

Safety and risk management

Carbon capture technologies ...on progress



CO_2 specifications

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What is the destination of the CO_2 after capture and processing?

Influence:

- Downstream process
- Material compatibility
- Chemical cocktail

Identified challenges:

- Blockages due to solid CO_2, H_2O or hydrate formation
- Corrosion due to H_2O, H_2S, SOx, NOx, MEA, DEA, NH_3
- Predictability related to incondensable such as N_2, H_2, Ar, O_2…
- Interations and contamination

Constituents	Units	Requirements	Note
CO_2	% mol	> 95	(1)
H_2O	ppm mol	< 40	(1)
H_2	% mol	< 0,75	(1)
N_2	% mol	< 2,4	(1)
Ar	% mol	< 0,4	(1)
CH_4	% mol	< 1	(1)
CO	ppm mol	< 750	(1)
O_2	ppm mol	< 40	(1)
$H_2+N_2+Ar+CH_4+CO+O_2$	% mol	< 4	(1)
Total aliphatic hydrocarbons (C2-10)	ppm mol	< 1200	(1)
Total aromatic hydrocarbons (C6-10, incl. BTEX)	ppm mol	< 0,1	(1)
H_2S	ppm mol	< 5	(1)
SO_3	ppm mol	< 0,1	(2)
SO_x	ppm mol	< 10	(1)
S_{tot} (COS, DMS, H_2S, SO_x, Mercaptan)	ppm mol	< 20	(1)
NO_x	ppm mol	< 5	(1)
Dewpoint (for all liquids)	°C on whole operating pressure range	< -10	(1)
NH_3	ppm mol	< 3	(2)
Total volatile organic compounds (excl. methane, total aliphatic, HC C_2 to C_{10}, methanol, ethanol, and aldehydes)	ppm mol	< 10	(2)
Total aldehyde compounds	ppm mol	< 10	(2)
Ethanol	ppm mol	< 20	(2)
Methanol	ppm mol	< 620	(2)
Total carboxylic acid and amide compounds	ppm mol	< 1	(2)
Total phosphorus - contained compounds	ppm mol	< 1	(2)
Hydrogen cyanide (HCN)	ppm mol	< 2	(2)
Mercury (Hg)	ppm mol	< 0,03	(2)
Cadmium (Cd) + Thallium (Tl)	ppm mol	< 0,03	(2)
Total amine compounds	ppm mol	< 1	(2)

(1) Compounds that shall be measured on a continuous basis at entry points
(2) Compounds that do not have to be measured on a continuous basis at entry points. However, the producers need to demonstrate that they respect the requirements in the table :

X A:

ACTERISTICS

IN BEVERAGES FOR SOURCE
ION[3]

tration
/v min.
v/v max
v/v max.
v/v max.
v/v max. each
w/w max.
/w max.

Quality specification for liquifie

omponent	Concentration, ppm (mol)
ater (H_2O)	≤ 30
Oxygen (O_2)	≤ 10
Sulphur oxides (SOx)	≤ 10
Nitric oxide/Nitrogen dioxide (NOx)	≤ 10
Hydrogen sulphide (H_2S)	≤ 9
Carbon monoxide (CO)	≤ 100
Amine	≤ 10
Ammonia (NH_3)	≤ 10
Hydrogen (H_2)	≤ 50
Formaldehyde	≤ 20
Acetaldehyde	≤ 20
Mercury (Hg)	≤ 0.03
Cadmium (Cd), Thallium, (Tl)	Sum ≤ 0.03

Porthos
CO_2 TRANSPORT & STORAGE

CO_2 specifications

Component	Mole Base
CO_2	≥ 95%
H_2O	≤ 70 ppm
Sum [$H_2+N_2+Ar+CH_4+CO+O_2$]	≤ 4%
H_2	≤ 0.75%
N_2	≤ 2.4%
Ar	≤ 0.4%
CH_4	≤ 1%
CO	≤ 750 ppm
O_2	≤ 40 ppm
Total sulfur-contained compounds (COS, DMS, H_2S, SOx, Mercaptan)	≤ 20 ppm Of which H_2S ≤ 5 ppm
Total NOx	≤ 5 ppm
Total aliphatic hydrocarbons (C2 to C10)[i]	≤ 1200 ppm
Total aromatic hydrocarbons (C6 to C10, incl. BTEX)[i]	≤ 0.1 ppm
Total volatile organic compounds[ii] (excl. methane, total aliphatic HC (C2 to C10), methanol, ethanol, and aldehydes)	≤ 10 ppm
Total aldehyde compounds	≤ 10 ppm
Ethanol	≤ 20 ppm
Methanol	≤ 620 ppm
Hydrogen cyanide (HCN)	≤ 2 ppm
Total amine compounds	≤ 1 ppm
Total glycol compounds	Follow dew point specification
Ammonia (NH_3)	≤ 3 ppm
Total carboxylic acid and amide compounds	≤ 1 ppm
Total phosphorus-contained compounds	≤ 1 ppm
Toxic compounds[iii]	
Dew point limit value measurement (for all liquids, i.e. for complete CO_2 composition)	< -10 °C (at 20 bara)

Note I: Specification values are molecular based
Note II: VOC definition according to Dutch policy
Note III: Toxic compounds: although CO_2 and other gases like i.e. H_2 and N_2 can form a risk of asphyxiation, Porthos would like to know other components within the stream which impose a risk on personal safety to be taken into account in Porthos HSE policy

Title: Porthos CO_2 specifications
Date: 30 September 2021

Which CO_2 phase ...

- Liquid
  - Medium pressure 13-18 bar (-20/-40°C)
  - Low pressure 7-9 bar (-50°C)
- Gaseous
- Dense phase (pressure > 70 bar, temperature > 0°C)

Figure 4: Pressure and temperature ranges of the three conditions considered for CO_2 transportation[13]

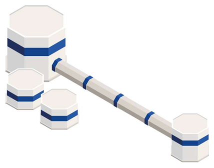
	Low pressure	Medium pressure	High Pressure
Temperature (degC)	-55 to -40	-30 to -20	0 to 15
Pressure (Barg)	5 to 10	15 to 20	35 to 50
Density (kg/m3)	1170 to 1120	1080 to 1030	930 to 820
Tonnes cargo weight per m3	1.2 to 1.1	1.1 to 1.0	0.9 to 0.8

Source: CCSA-ZEP report

Note: There is some rounding in these numbers

Source: What do we need to know to make CO_2 shipping for CCS a reality? – March 2024 – The Oxford Intitute for Energy Studies

… for which transport modal



Pipeline: dense phase or high pressure

Ship: large vessels in liquid - low pressure

Railcar / Trailers: liquid – medium pressure

Sources: ZEP reports - A-Trans-European-CO2-Transportation-Infrastructure-for-CCUS-Opportunities-Challenges-1.pdf (zeroemissionsplatform.eu) & ZEP-CCSA-Report-on-CO2-transport-by-ship-March-2022.pdf (zeroemissionsplatform.eu)

Other challenges along the value chain

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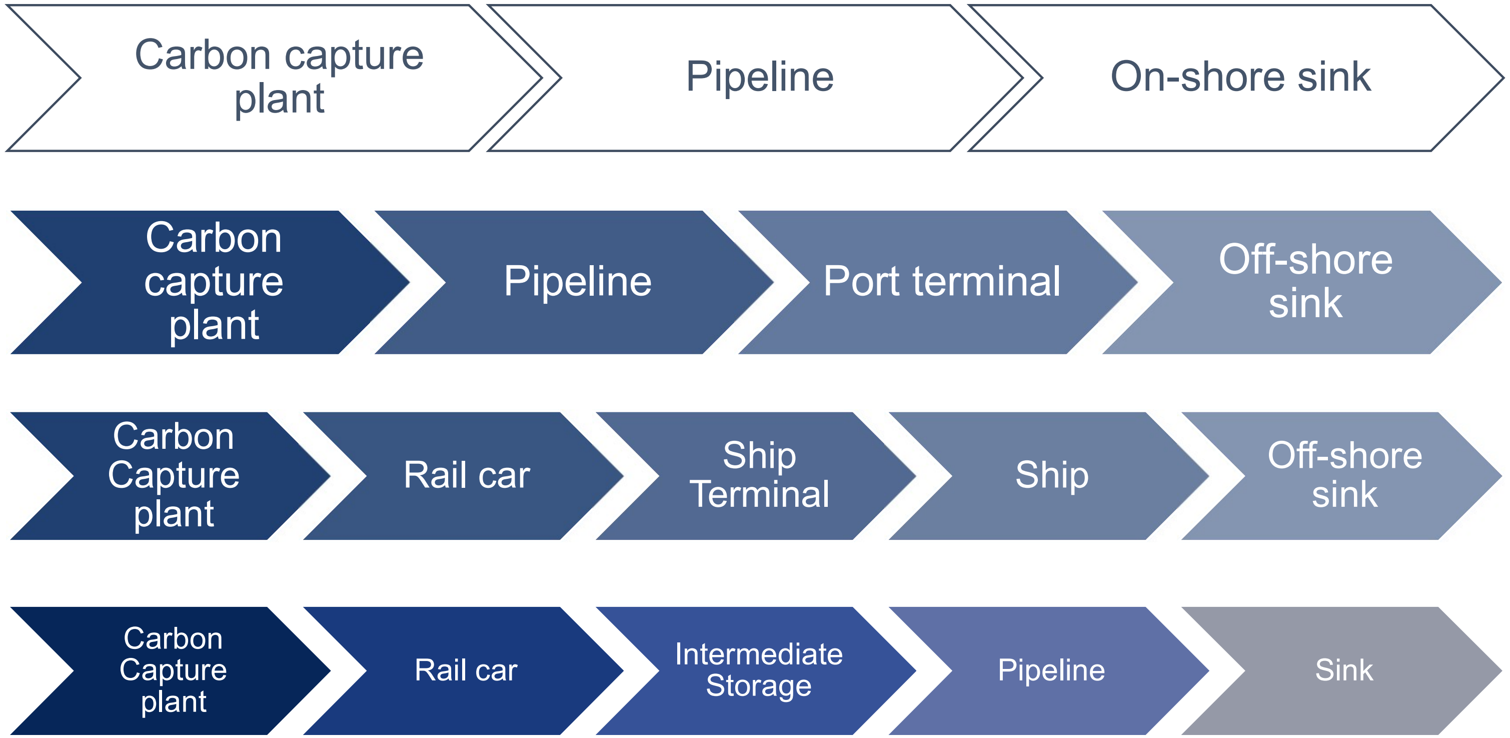
Energy efficiency along the supply chain

Change of CO_2 phase	Energy requested
Liquefaction from non-pressurised gas	~150-200 kWh/t
Boosting from liquid to 130 bar	~5-7 kWh/t
From gaseous 50 bar to liquid 15 bar	~80-120 kWh/t

Losses monitoring

- Losses will occur along the value chain, from the capture to the sink, on each transfer and phase change
- Reasonable estimation of carbon capture rate: 85%
- Monitoring is not easy
- Responsibility of losses

Complexity of the value chain



Split cost in the CCS value chain*

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CO_2 capture	30 -> 100€/t
CO_2 processing	5 -> 50€/t
CO_2 transport	10 -> 100€/t
CO_2 sequestration	10 -> 80€/t

Carbon capture costs represent about 60% of CCS value chain or large emitters
For small or intermediate emitters, the supply chain will represent more than 30% of the costs

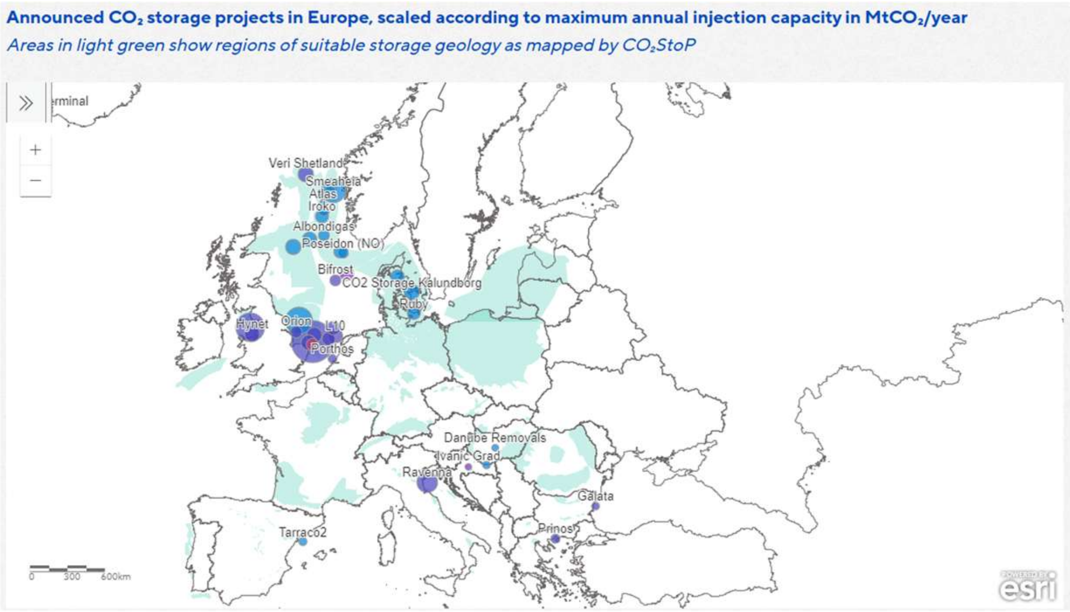
*those values are indicative, based on the various literature and our understanding of the current market.

Multi-modal transport costs

Transportation	Estimated costs*
On-shore pipeline	~ 5 -> 12 €/t
Off-shore pipeline	~ 10 -> 20 €/t
Ships	~ 10 -> 30€/t
Rails	~ 10 -> 60 €/t

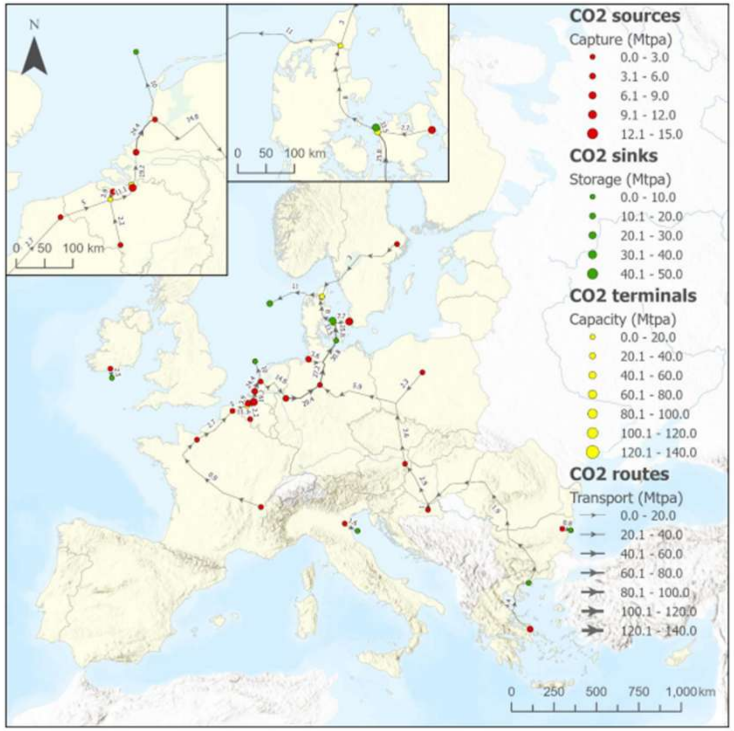
*Those costs are influenced by the volumes of the carrier, the distance to cover.

CO_2 infrastructure is expected



Source: [Tracking CO_2 Storage Project Capacity in Europe – Clean Air Task Force]

Figure 7. Scenario A1 - CTP 2040 (EU), year 2030



Source: JRC, 2024

Source: [Shaping the future CO2 transport network for Europe]

Aggregation in a ship terminal

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- Intermediate storage tank farm
- Railway unloading station
- Future local pipeline connection
- Losses control unit
- Ship loading station
- Monitoring and verification

On-going collaboration with Ambrian Energy in Bremen (Germany)

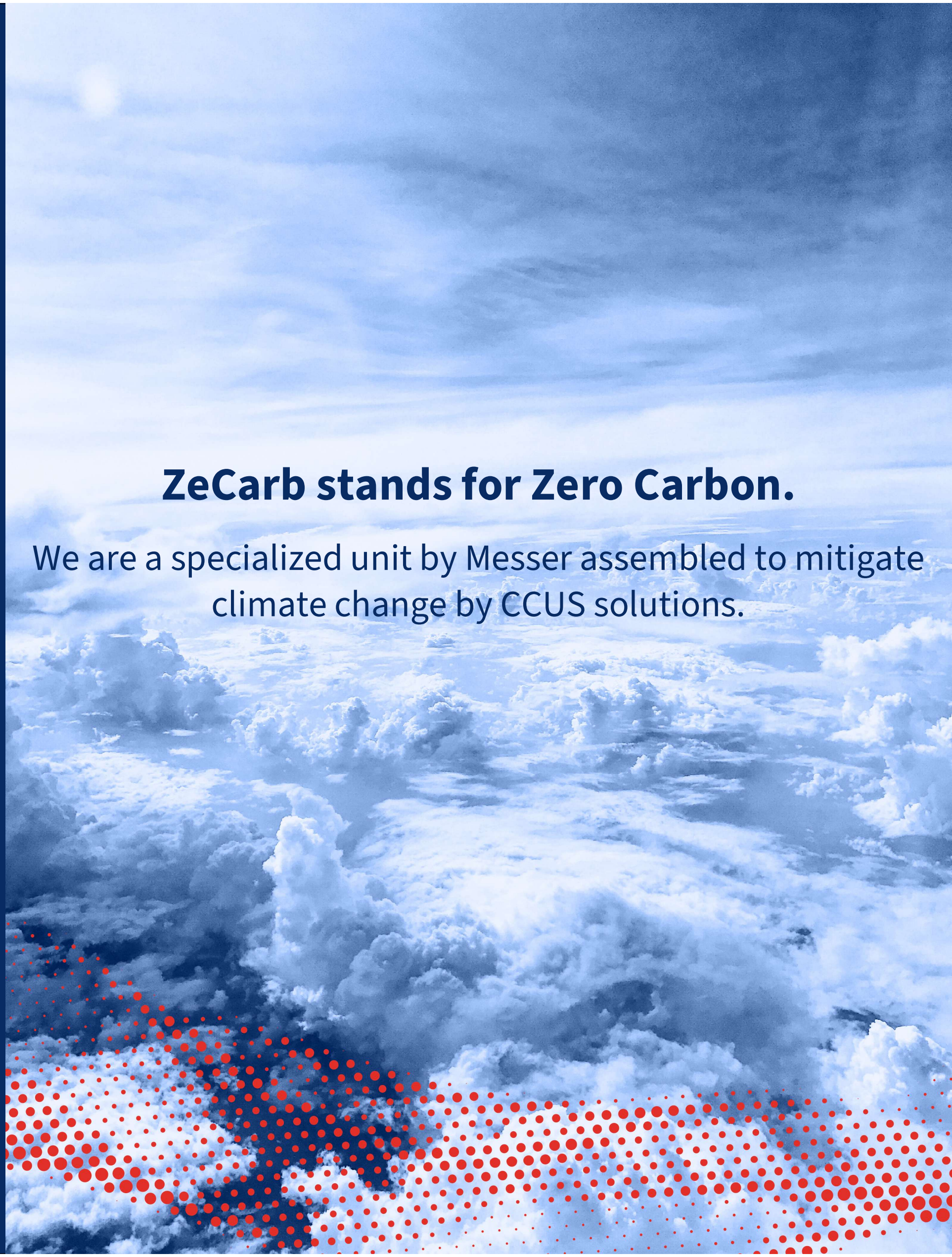
Conclusions

- Many clarifications are still needed in term of regulations, infrastructure, standardization
- Capture technologies are in good progress
- Energy efficiency is vital in CCUS projects
- Let‘s start with trains and ships, and expect pipelines to come later
- Working together to share the risk and move faster

About ZeCarb

Hello, we are ZeCarb.

- 70 years of experience in the CC-Business
- Capable of capturing from different CO_2 sources
- Global reach for CO_2 capturing
- Partner for all questions on CO_2
- Extensive partner network



ZeCarb stands for Zero Carbon.

We are a specialized unit by Messer assembled to mitigate climate change by CCUS solutions.

ZeCarb is a brand by Messer Group

Group sales figures and number of employees 2024:

		Total
Sales	in billion euro	4,5
EBITDA	in billion euro	1,4
Investments	in million euro incl. IFRIC4	878
Employees	Contractual employment relationships in FTE**	> 11,800

** Full Time Equivalent

About Messer:
Messer is the world's largest privately held specialist for industrial, medical, electronic and specialty gases and a highly professional and sustainable global player.

Products
Messer manufactures and supplies oxygen, nitrogen, argon, carbon dioxide, hydrogen, helium, shielding gases for welding, specialty gases, medical gases and food gases as well as many different gas mixtures.

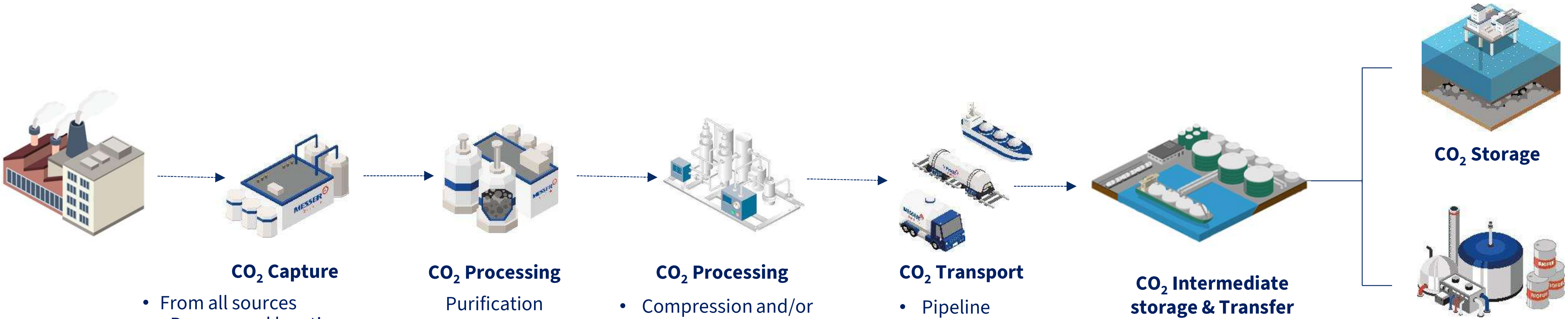
Customers
Our products are used in industry, environmental protection, medicine, the food and beverage sector, welding and cutting technology, 3D printing, construction, and research and science.

ZeCARB Simplifying carbon neutrality.

We simplify carbon neutrality!

MESSER Gases for Life

ZeCarb offers **Carbon Capture as a Service** (CCaaS). Our services can be tailor made to your specific carbon capture needs.



CO_2 Capture

- From all sources
  - Process and location
- Low to high concentrations
- Wide range of capacity/volumes

CO_2 Processing

Purification

CO_2 Processing

- Compression and/or liquefaction
- Intermediate storage & loading installation

CO_2 Transport

- Pipeline
- Rail & Road
- Ships

CO_2 Intermediate storage & Transfer

- Tank farm
- Loading and unloading installations

CO_2 Utilisation

ZeCarb is your single-source solution!

We unify complex CCUS management processes under one roof!

We tackle your emission reduction targets together!

You take care of your business. We take care of the whole CCUS process

Economic stability

- Cost effectiveness
- Market positioning
- Financial security
- Planning security

Strategic forecast

- Sustainability goals
- Risk mitigation
- Stakeholder engagement
- Image benefit

Technological Benefits

- Innovation
- Maintenance and support
- Scaleability

Get in touch!

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