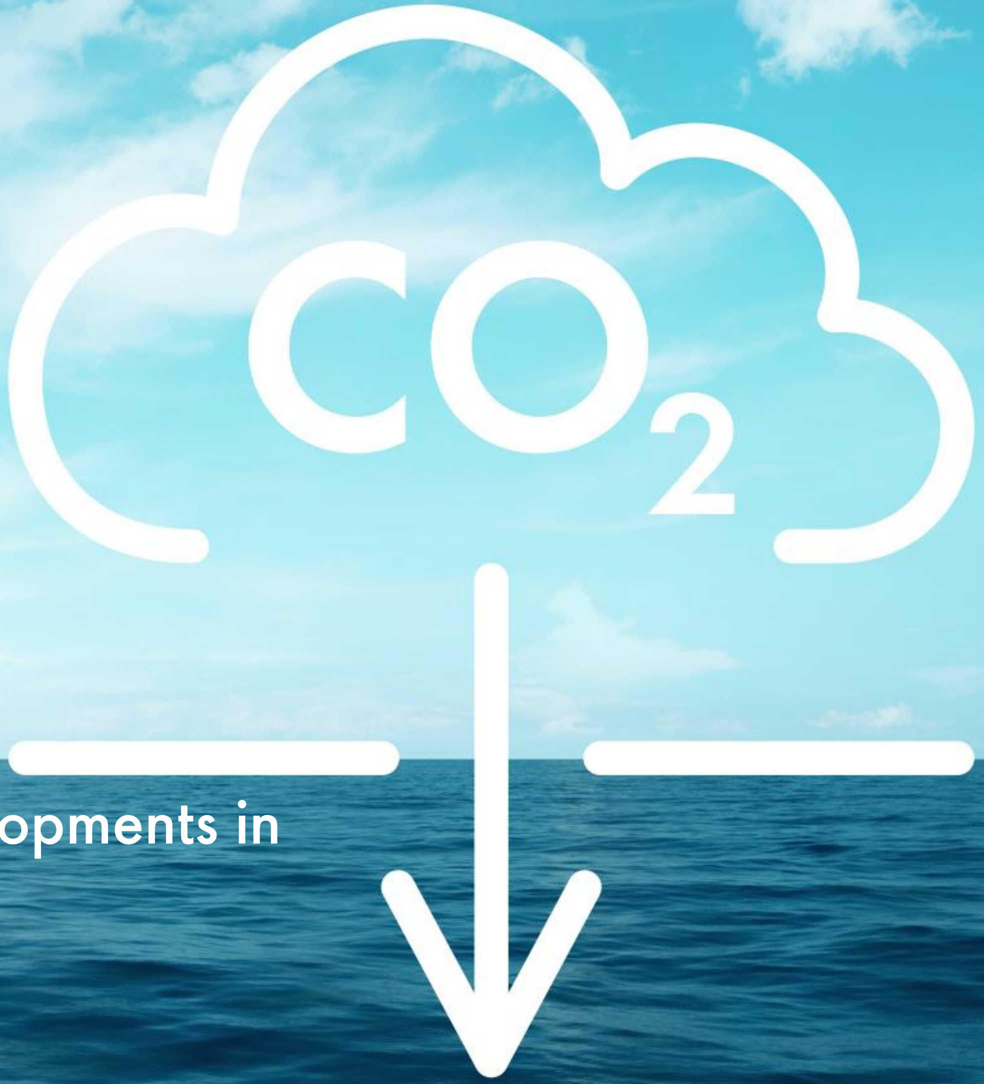
Shell Offshore Carbon Storage NL



Learnings of multi-access phased CCS developments in the Netherlands

Onno van Kessel
General Manager CCUS
Shell Global Solutions International B.V.

Definitions & cautionary note

Agenda

- Shell CCS portfolio
- Aramis, a large scale ‘open access’ transport and storage network offshore the Netherlands
  - Shell NOV partner in trunkline, operator of launch and growth stores
- Challenges with maturing (large scale) CCS projects
- Change from point-to-point to hub CCS developments
- Challenges on CO_2 specifications in a hub CCS project
- Conclusions and recommendations

Shell CCS Project Portfolio

1. Quest

2. Polaris/Atlas

3. Louisiana Hub

4. Acorn

5. Pernis to Porthos

6. Aramis & SOCS NL

7. Northern Lights

- CCS Operations
- Projects in Execution
- Projects in Development
- CCS Projects
- CCS study agreements

8. Daya Bay

9. S-Hub Project

10. Asia-Pacific Hub

11. Gorgon

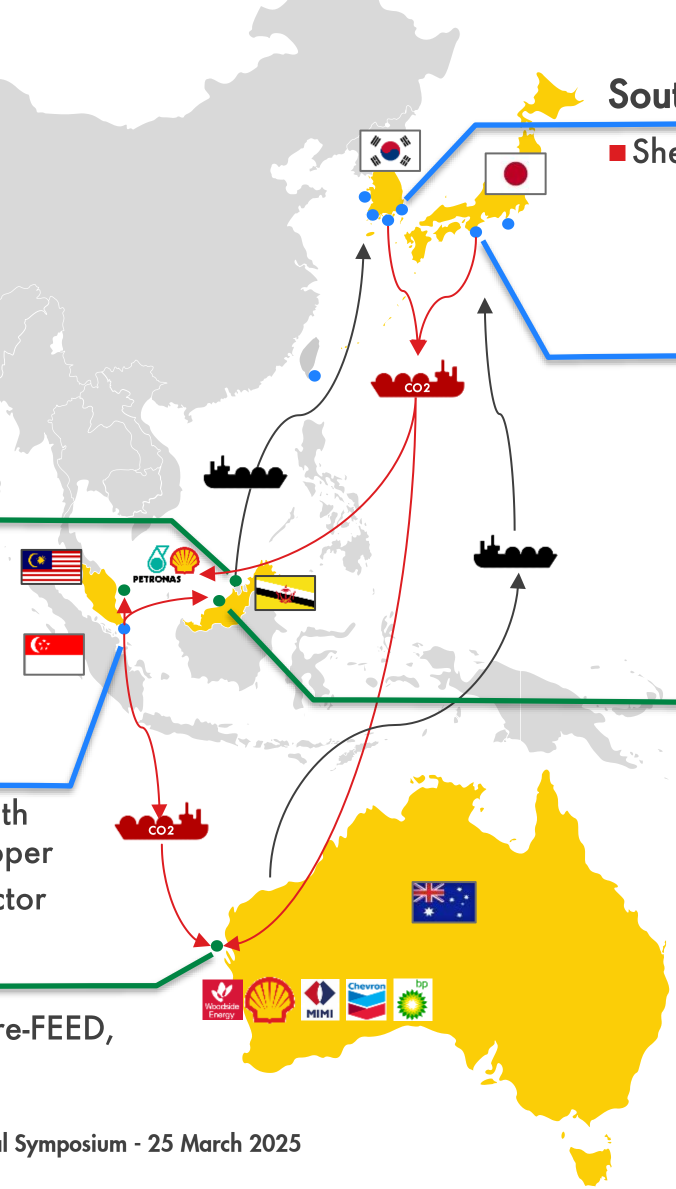
12. Angel CCS

Shell is working to develop multiple stores in Asia-Pacific

together with our existing and future partners.

- Investing $10-15 billion from 2023 to 2025 in low carbon solutions, incl CCS
- Shell's customers in Japan, S. Korea, Singapore and Taiwan emit >70 Mtpa of CO_2
- Attractive reservoir characteristics for world class stores in Australia, Brunei and Malaysia
- Leading in LCO2 shipping design for long distance shipping in APAC
- Recognised industry operator in the region with world-wide CCS capabilities

* China is led by a separate team but Shell is also in collaboration with Exxon in Guangdong



South Korea

- Shepherd Consortia

Hanwha, Air Liquide, KNOC, SK energy, Samsung Engineering, Petronas, Lotte Chemical, Samsung Heavy Industries, SK earthon

Japan

- MOUs with key LNG importers / aggregators
- Joint Study Agreement with Osaka Gas

OSAKA GAS

Brunei

- Depleted fields and aquifers under evaluation

Malaysia

- Sarawak Luconia heartland (RFSU 2030)

Singapore

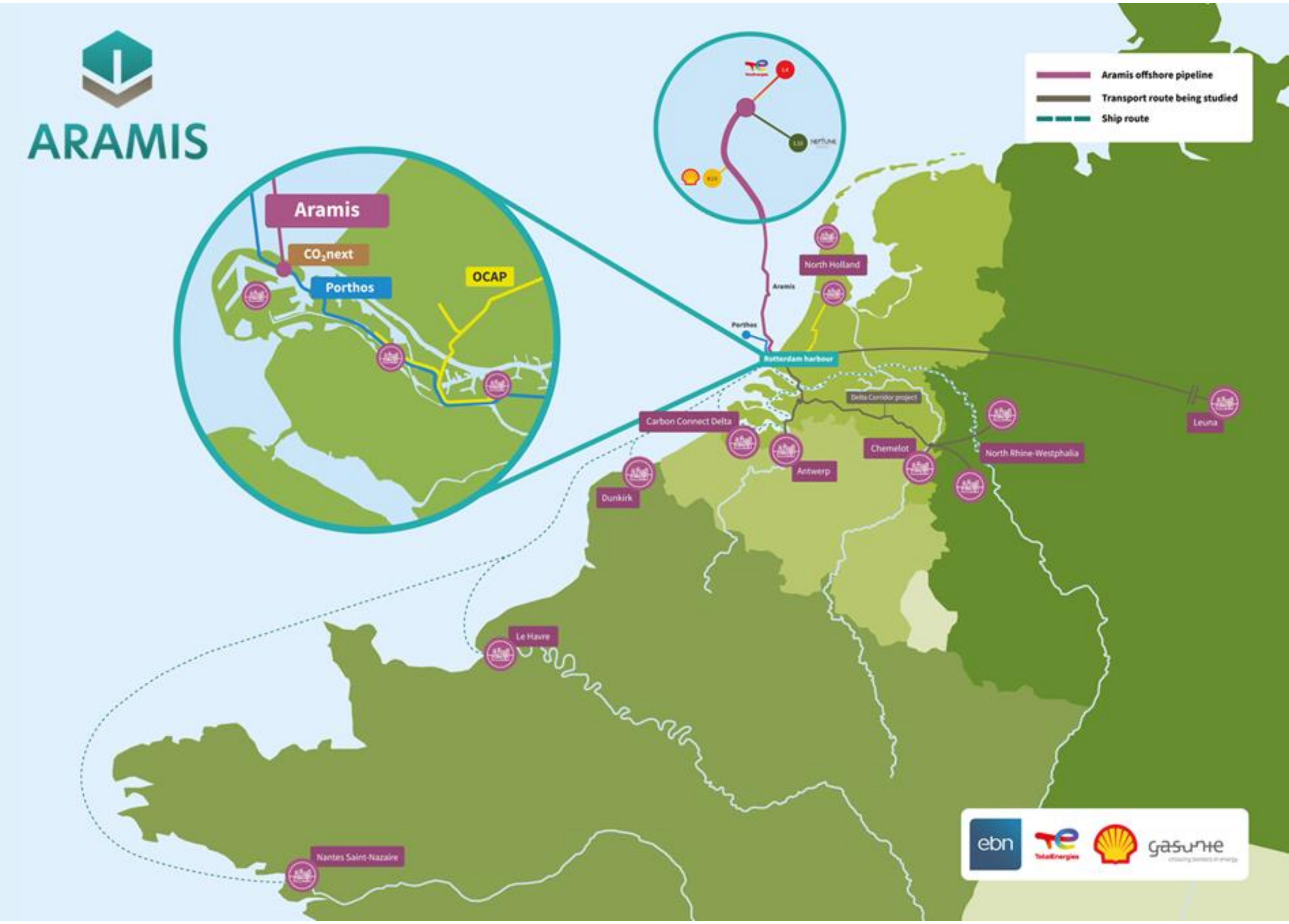
- Shell & Exxon signed MOU with Singapore EDB as lead developer
- Study with EMA for Power Sector

Australia

- Angel CCS project (5 Mtpa, Pre-FEED, RFSU 2030)

Aramis value chain

- Public-private partnership
  - Aramis trunkline Shell, TTE, GasUnie, EBN
- Aramis offshore pipeline capacity of 22 Mtpa
- 8 - 12 Mtpa starting volume
- Design life 30 years, overall storage capacity ~ 600 Mt
- FEED started Nov23, expected to be operational in 2028
- Aramis will enable connections to several European clusters
- Strong cooperation needed across the CCS value chain
  - Shell/TTE/ENI launch stores
  - Emitters (could be as many as 15-20 for Launch)
  - Porthos (compression & onshore pipeline), CO_2next (terminal), OCAP (onshore pipeline), Delta Rhein Corridor (dense phase CO_2 pipeline), ships
  - Dutch government (permits, licenses, regulations, subsidies)



Nine essential enablers for deploying and upscaling CCS

1. Durable policy mechanisms that encourage financing and investment in CCS
2. Dynamic and internationally integrated transportation networks
3. Overcoming significant co-dependency to get a value chain to work
4. Establishing clear carbon accounting for customers to confidently choose
5. Building organizational, institutional and supply chain capability
6. Addressing technical complexities especially in large, diversified hubs
7. Defining industry standards, guidelines and practices specific to CCS
8. Improving cost competitiveness by applying multiple levers
9. Creating an environment where CCS is demystified among the public

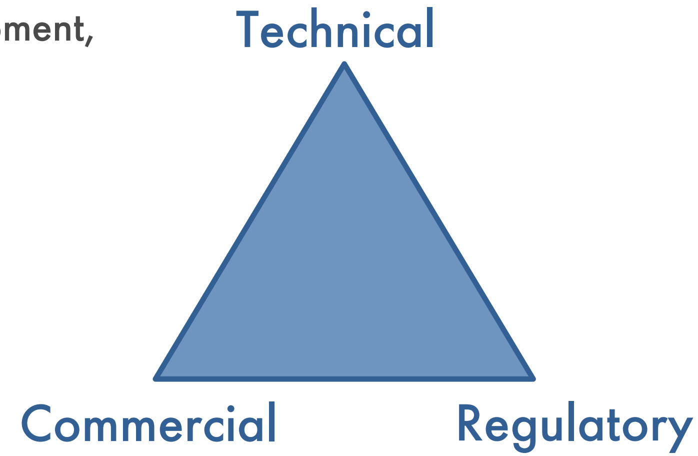
Challenges with maturing CO_2 projects – Novelty Aspects

- Technical – often developing first of a kind – High costs
  - Legacy wells / seismicity / injectivity / availability risks leading to higher scope / costs
  - Technology maturation, no unified standards yet – CO_2 specs, materials, pipeline specs, well equipment, flow meters, analysers

- Commercial / Economical – Affordability
  - Securing customers – no established market yet
  - Developing new business models – with difficult and marginal risk – reward balance
  - Partnership - Type of JV, with whom, when to set up

- Regulatory & Policy – Co-operation with the government to enable the business!
  - Limited experience & lot of work - Close engagement with the regulators developing the pathway
  - Policies supporting CCS are for now required
    - In the Netherlands/EU; SDE++ subsidies for emitters, IF / CEF for transport and stores, NZIA just approved

- Timing - How to mature all parties in parallel (technical & commercial)? Need to take FID together
  - Project technically matured, but more time required to secure customers – e.g. tariffs might be only set before FID – so several open switches might remain on the commercial side



Shell storage Permit - 380pages main body – 780 pages of appendices! More than 20 months for approval!


Aanvraag CO2-opslagvergunning K14-FA

Shell Gas & Power Developments B.V.

SRN-03091

June 2022

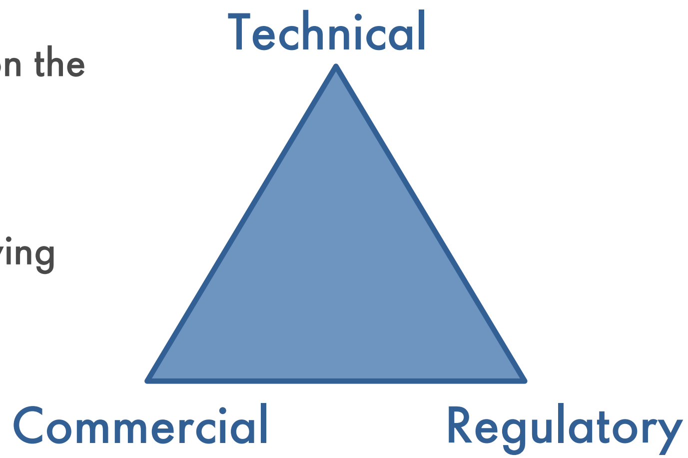
NZIA: Net Zero Industry Act

CCS Projects are moving from point-to-point to multi-client hubs to drive economy of scale ...leading to increased complexity

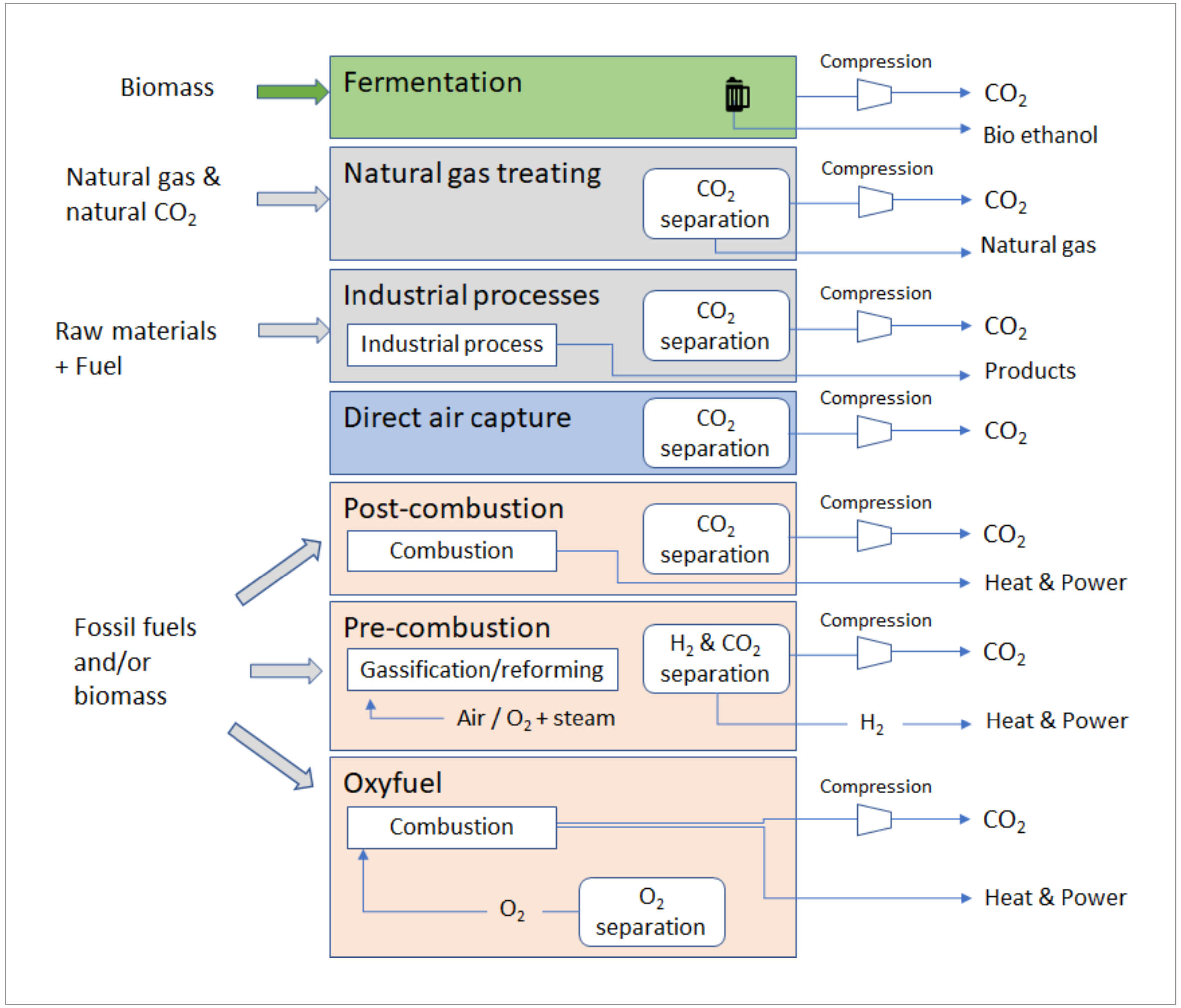
- Technical Complexity – e.g.
  - CO_2 specifications – what is the impact of mixing impurities on corrosion?
  - Interface and integration management, who is leading?
  - High variability in the demand rate from the customers – how to manage the flexibility? Impact on the store operating envelope (esp for depleted fields)?

- Commercial Complexity – complex and long value chains with multiple entities, with not always having same understanding of risks
  - Might have different strategic approach
    - First customers and then we invest or Invest first then the customers will come
  - Different views on cost of capital
  - Different views on the risks and the ability to accept those, how to take those into account in the tariffs, and on how to value the project

- Regulatory Complexity – cross border agreement between countries needs to be in place to allow exporting CO_2 - e.g. London protocol



CO2 quality requirements need to be optimized along the entire chain



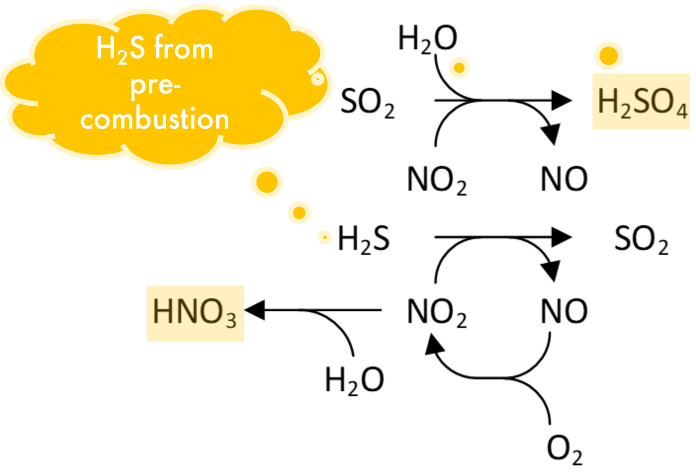
Key impurities by industry source

Power, Waste–to-energy	SO_x, O_2, NO_x, H_2O
Cement	NO_x, SO_x, O_2, H_2O
Fertilizer, Blue hydrogen	CO, H_2, CH_4, H_2O, MeOH
Gas production/EOR	CH_4, H_2, CO, H_2S, H_2O
Refineries (post-comb)	H_2O, O_2, SO_x, NO_x
Refineries (pre-comb.)	H_2S, CO, H_2, CH_4, H_2O, HCN, MeOH
Steel plant (Blast offgas)	CO, H_2, H_2S
Bioethanol	MeOH, CH_4, H_2S
CO_2 treatment	Amines (MEA), Glycol, MeOH

Example of Challenging Chemistry Related to Hub Operation

Examples where impurities impact design

- CO_2 transport and storage infrastructure typically has no CO_2 purification units and is based on non-corrosive fluid in CS pipe
- Mixing CO_2 from different sources in a hub design poses corrosion threats and new challenges for CO_2 specs….
- It is generally more economic to clean up CO_2 stream at capture than to deal with significant downstream effects
- A standardized spec, catering for a broad range of emitters and process conditions, is essential for scale-up of CCS
- Required: knowledge on process interactions – experience, experiments
- Hub Operator needs to test specs at worst conditions (P, T)



- Reaction happens faster in presence of H_2S – subject of experiments
- Temperature effect identified (Offshore Aramis 6C seawater worse than 25C)

Reaction products: H_2SO_4+HNO_3 extremely corrosive

- Removing SO_2 not sufficient, as H_2S can form SO_2
- Tighten spec on total Sulphur or NO_x?

Reference: J. Sonke, B.H. Morland, G. Moulie, M.S. Franke, Corrosion and Chemical Reactions in Impure CO_2, [Int. Journal of Greenhouse Gas Control 133 (2024) 104075]

Conclusions and recommendations

- The development of CCS projects poses new technical – commercial – regulatory challenges, which require timely and strong integration. Strong government support is required via a range of policy instruments.

- The CCS business moves from point-to-point to multi-client hub developments; this poses new challenges like risk-reward expectations, alignment between many partners, and the definition of the CO_2 specifications

- There is no simple single solution for CO_2 specifications; it depends on the capture & transport concepts of the emitters and needs to be tested at the worst P & T conditions in the hub

Central Luconia CCS Project Updates

Technical Feasibility 2024 | Concept Select | Start pre-FEED 01/25 | *now* | Start FEED | FID | On-stream

Feasibility & Concept Select | *Pre-FFED* | *FEED*

TECHNICAL UPDATES

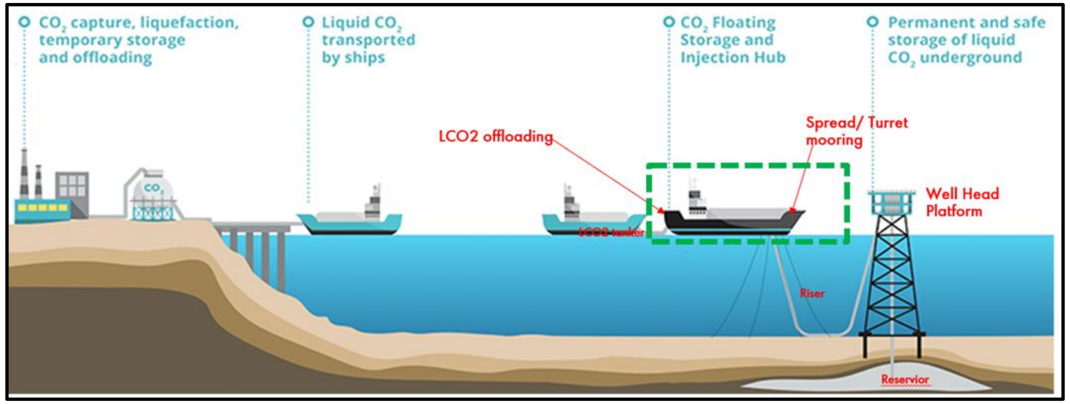
- Passed Technical Feasibility Assessment for Store & Terminal in 2024
- Selected Best Technical Concept of 5Mtpa, WHP & FSIU in Q4'24
- Start of pre-FEED work with selected contractors in Q1'25
- LP LCO2 vessel Concept Design (20-80km3) ongoing
- Pre-FEED and customer termsheet planned to complete in Q2-3'25
- Project on schedule, customer readiness remains biggest uncertainty

COMMERCIAL UPDATES

- **Strategic CCS partnering to start in Q2'25 for cost-/risk-sharing**
- Luconia is shortlisted to participate in S-HUB RFP to bid for Transport & Storage services
- Multiple customers will be required to satisfy 5Mtpa store, need to consider Malaysia/Sarawak CVP
- Start FEED requires a license, supporting policy, customer certainty

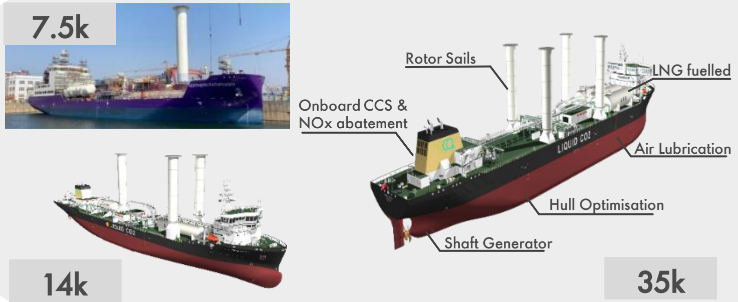
[FSIU (Floating Storage and Injection Unit)]

- Spread moored near WHP and connected via flexible riser
- Within industry tanker size (250 x 55 x 19)
- Loading/Unloading system
- Metering systems
- LCO2 storage system (include buffer Storage)
- Control and monitoring system
- Living quarters
- Fuel Engine
- BOG system
- Injection system
- Heating system



LCO$_2$ SHIPPING

What are we working on?



Medium Pressure LCO$_2$

Vessel sizes with Approval in Principle (AiP) ranging from 7.5km^3 to 35km^3 for Medium Pressure (MP) carriage

LCO$_2$ Barge

6km^3 to 9km^3 design (Inland Waterways)

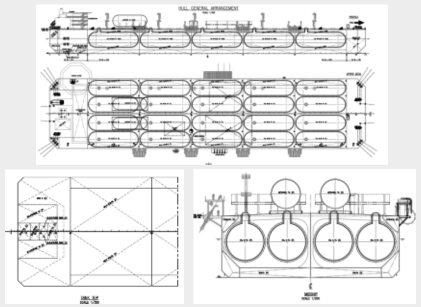
OCCS

Investment in Value Maritime – developer & installer of an Onboard Carbon Capture System

VM Value Maritime

LCO$_2$ FSIU

Floating Storage & Injection Unit Feasibility Study completed



Low Pressure LCO$_2$

Scalable Concept Designs ranging from 22km^3 to 80km^3 with detailed AiP for 74km^3 for Low Pressure (LP) carriage

ISO SIGTTO DNV

Industry Engagement

Chaired ISO LCO$_2$ working group. Key participant in SIGTTO CO$_2$ working group. CETO Low Pressure (LP) Joint Industry Project (JIP) member. Chairing DNV JIP on LCO$_2$ direct injection

Materials Studies & Qualification

Working with several Steel Mills & Classification Society for the development of new materials for LCO$_2$ cargo containment systems at MP and LP carriage condition