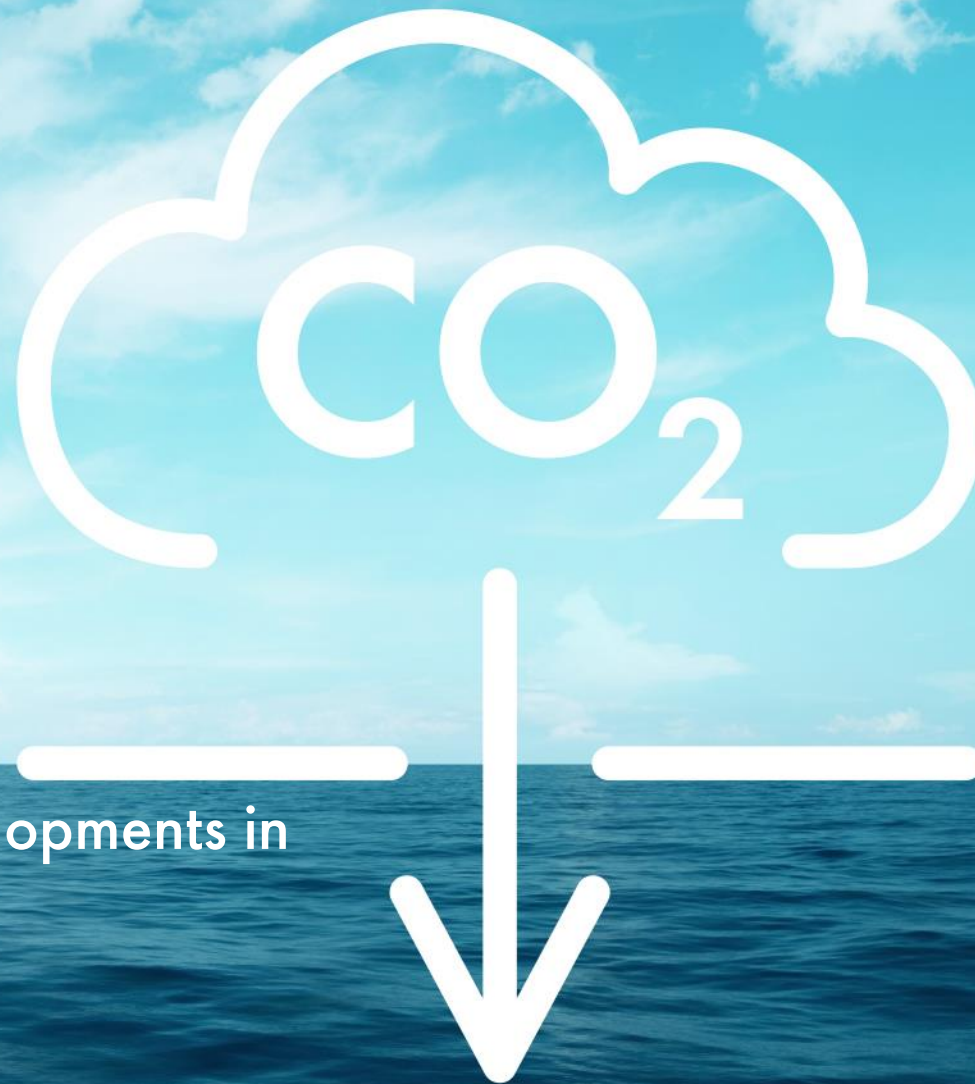




# Shell Offshore Carbon Storage NL

Learnings of multi-access phased CCS developments in  
the Netherlands

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# Definitions & cautionary note

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Also, in this presentation we may refer to Shell’s “Net Carbon Intensity” (NCI), which includes Shell’s carbon emissions from the production of our energy products, our suppliers’ carbon emissions in supplying energy for that production and our customers’ carbon emissions associated with their use of the energy products we sell. Shell’s NCI also includes the emissions associated with the production and use of energy products produced by others which Shell purchases for resale. Shell only controls its own emissions. The use of the terms Shell’s “Net Carbon Intensity” or NCI are for convenience only and not intended to suggest these emissions are those of Shell plc or its subsidiaries.

## Shell’s net-zero emissions target

Shell’s operating plan, outlook and budgets are forecasted for a ten-year period and are updated every year. They reflect the current economic environment and what we can reasonably expect to see over the next ten years. Accordingly, they reflect our Scope 1, Scope 2 and NCI targets over the next ten years. However, Shell’s operating plans cannot reflect our 2050 net-zero emissions target, as this target is currently outside our planning period. In the future, as society moves towards net-zero emissions, we expect Shell’s operating plans to reflect this movement. However, if society is not net zero in 2050, as of today, there would be significant risk that Shell may not meet this target.

## Forward-Looking non-GAAP measures

This presentation may contain certain forward-looking non-GAAP measures such as **cash capital expenditure** and **divestments**. We are unable to provide a reconciliation of these forward-looking non-GAAP measures to the most comparable GAAP financial measures because certain information needed to reconcile those non-GAAP measures to the most comparable GAAP financial measures is dependent on future events some of which are outside the control of Shell, such as oil and gas prices, interest rates and exchange rates. Moreover, estimating such GAAP measures with the required precision necessary to provide a meaningful reconciliation is extremely difficult and could not be accomplished without unreasonable effort. Non-GAAP measures in respect of future periods which cannot be reconciled to the most comparable GAAP financial measure are calculated in a manner which is consistent with the accounting policies applied in Shell plc’s consolidated financial statements.

The contents of websites referred to in this presentation do not form part of this presentation.

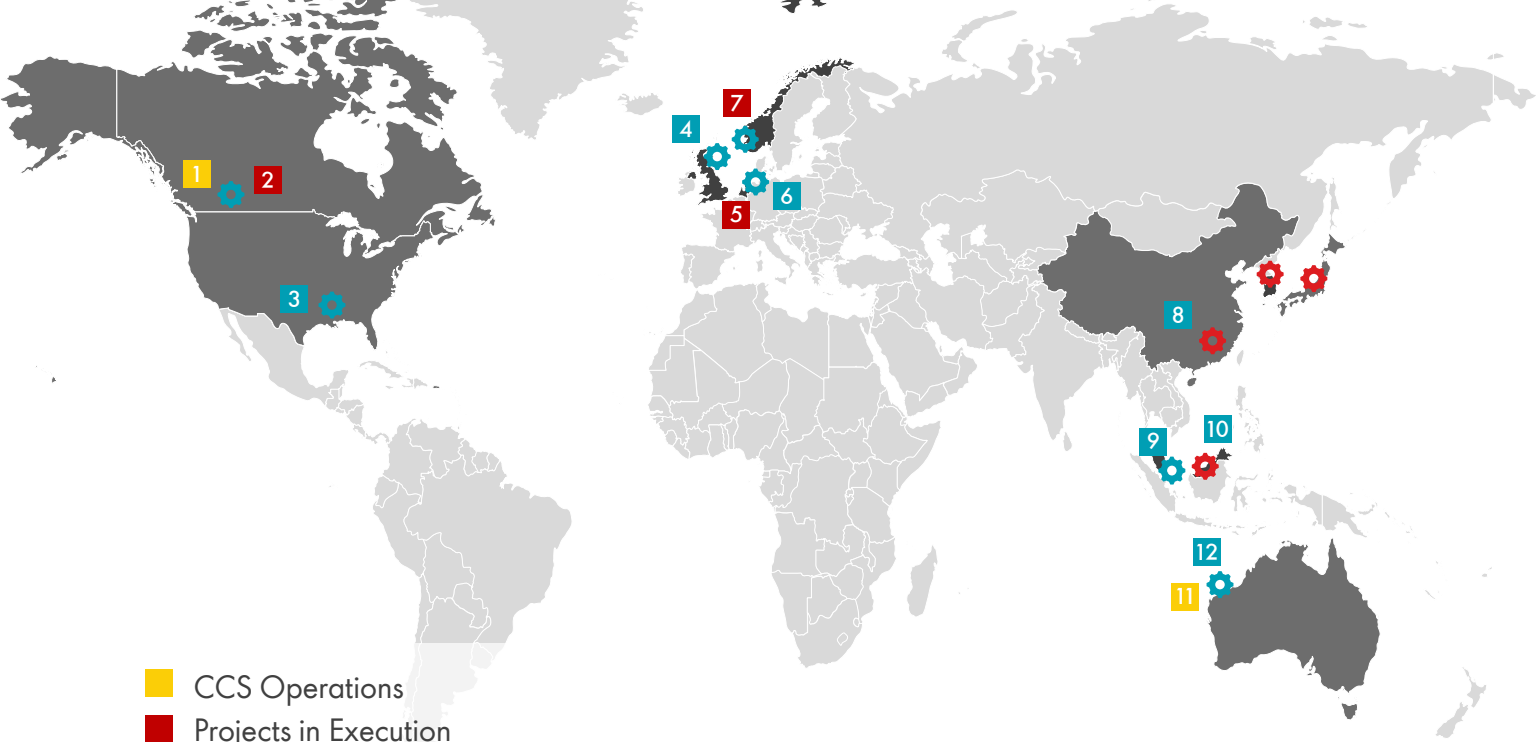
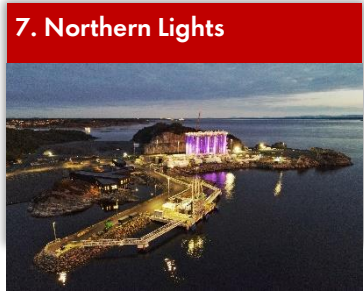
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# Agenda

- 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<sub>2</sub> specifications in a hub CCS project
- Conclusions and recommendations



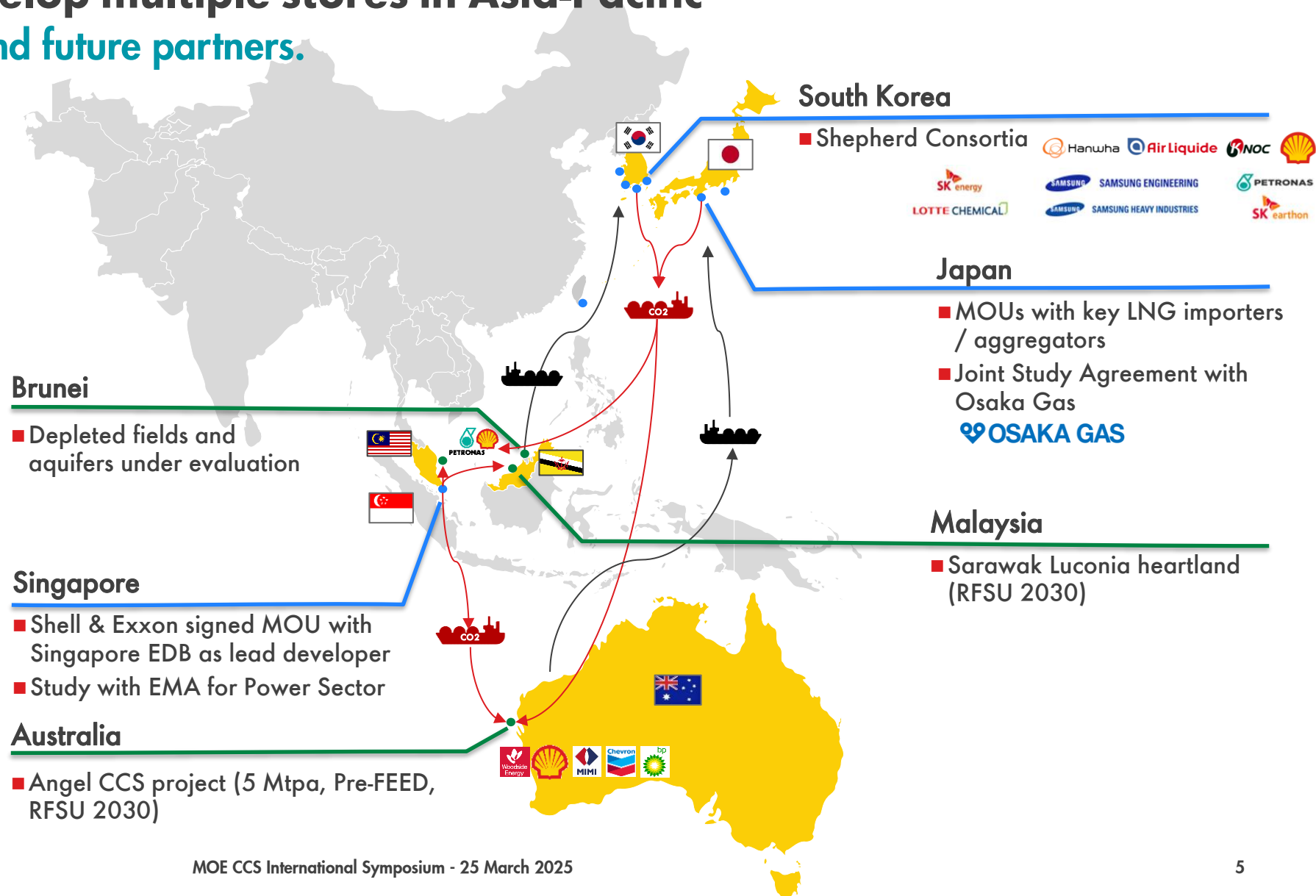
# Shell CCS Project Portfolio



# Shell is working to develop multiple stores in Asia-Pacific together with our existing and future partners.

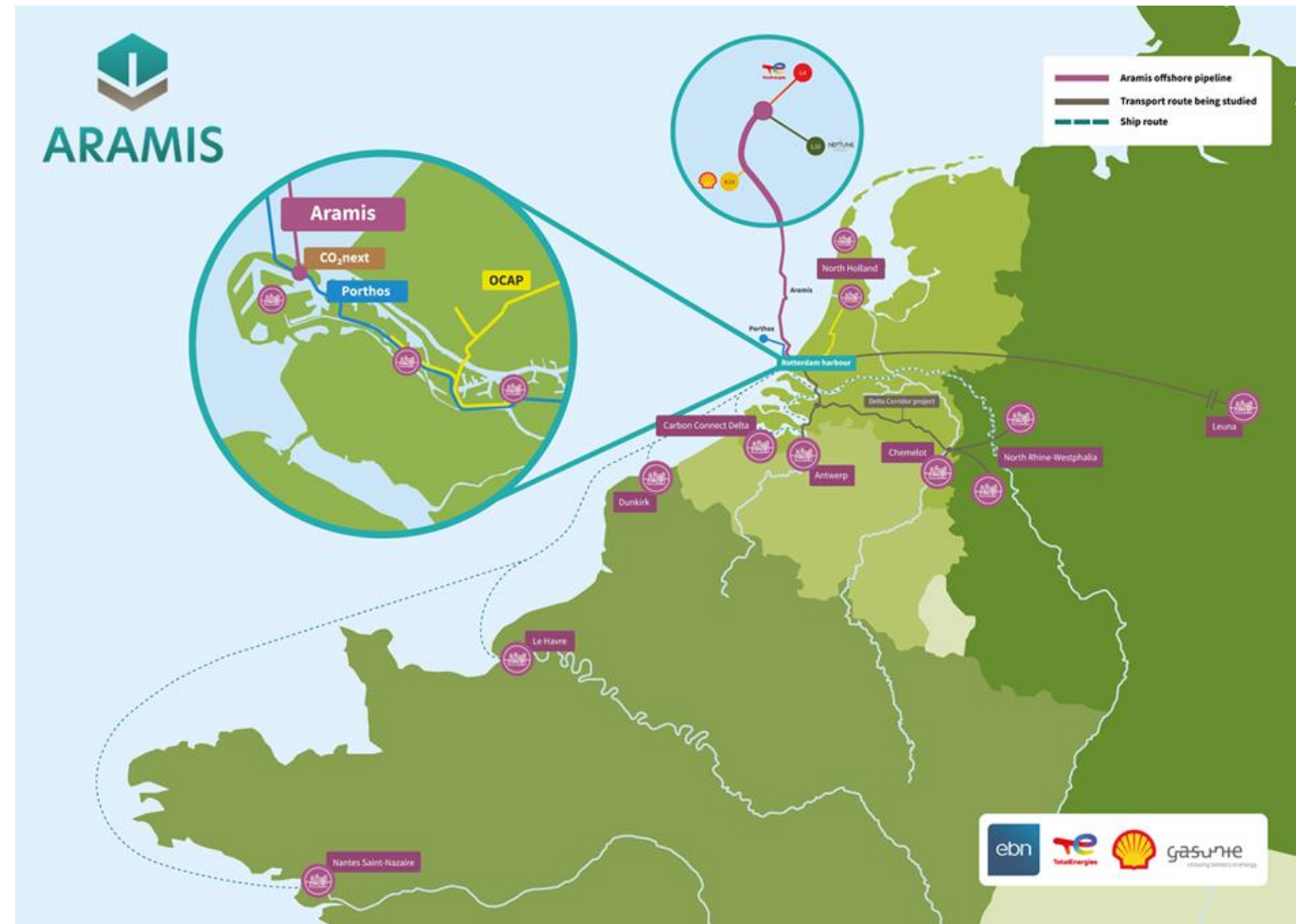
- Investing \$10-15 billion from 2023 to 2025 in low carbon solutions, incl CCS
- Shell's customers in Japan, S. Korea, Singapore and Taiwan emit >70 Mtpa of CO<sub>2</sub>
- Attractive reservoir characteristics for world class stores in Australia, Brunei and Malaysia
- Leading in LCO<sub>2</sub> shipping 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



# 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<sub>2</sub>next (terminal), OCAP (onshore pipeline), Delta Rhein Corridor (dense phase CO<sub>2</sub> pipeline), ships
  - Dutch government (permits, licenses, regulations, subsidies)





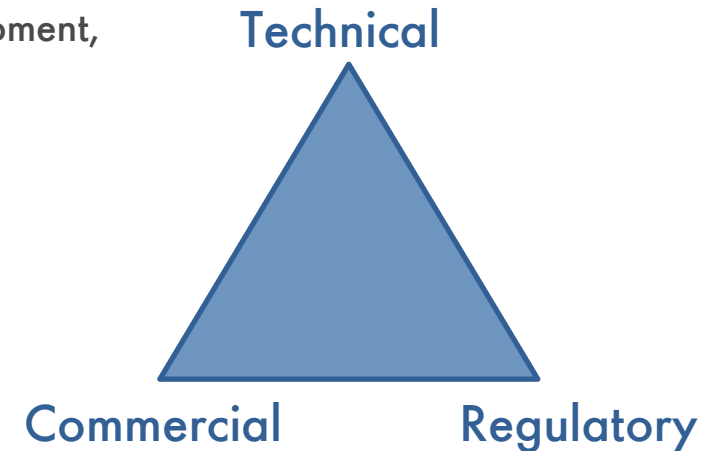
# Nine essential enablers for deploying and upscaling CCS

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<sub>2</sub> 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<sub>2</sub> 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<sup>++</sup> 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



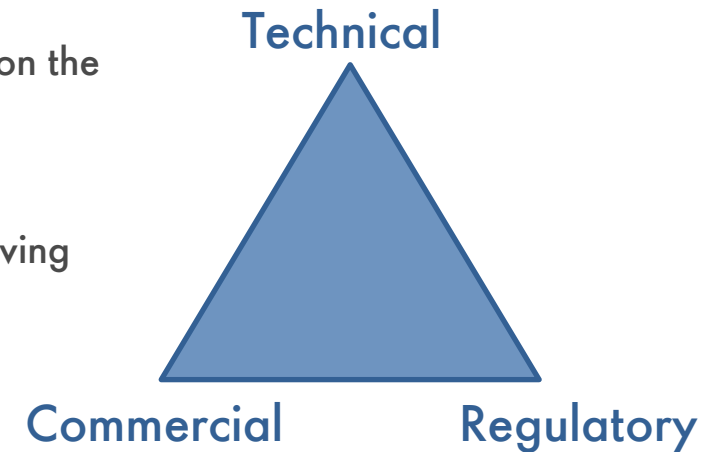
Shell storage Permit - 380pages main body – 780 pages of appendices! More than 20 months for approval!



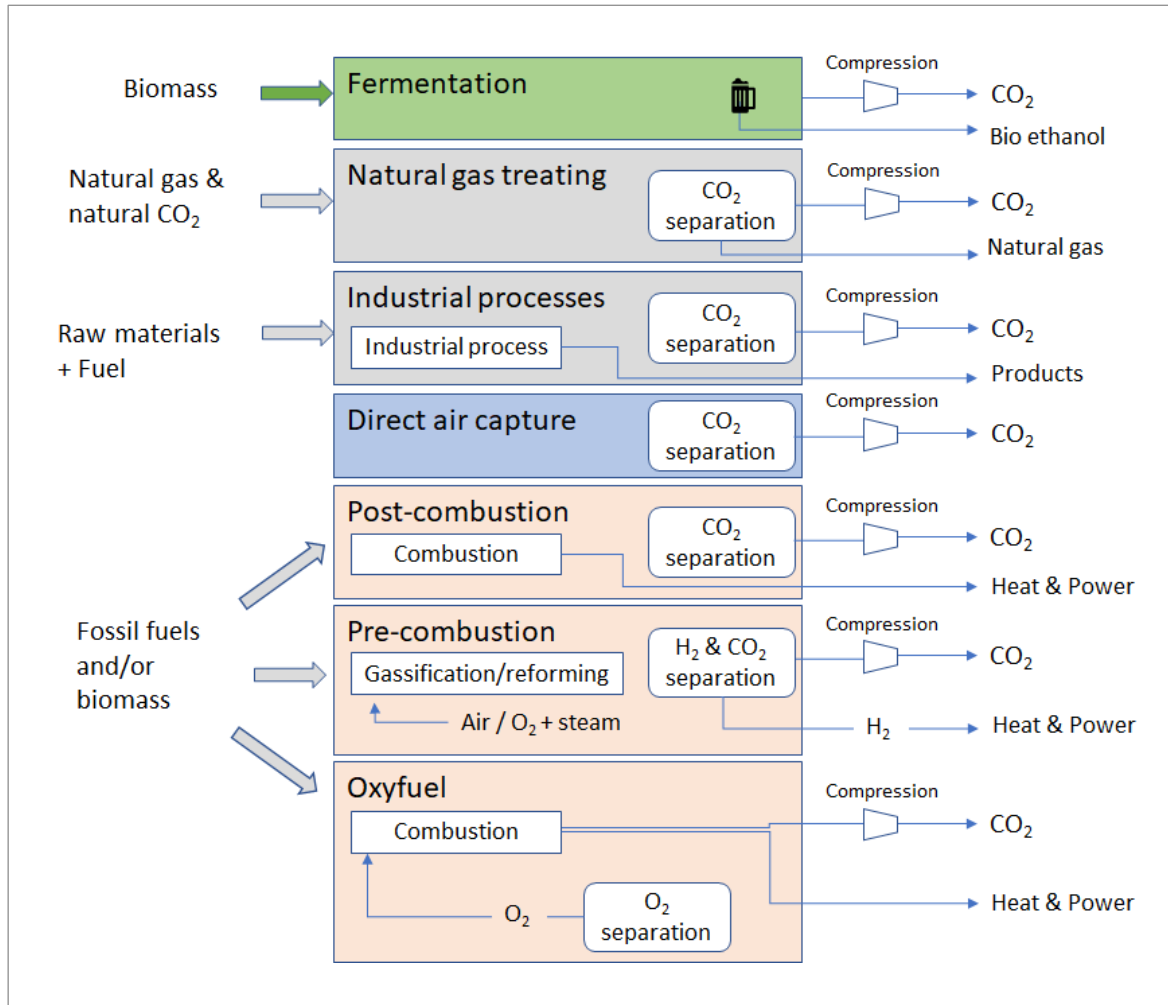


# CCS Projects are moving from point-to-point to multi-client hubs to drive economy of scale ...leading to increased complexity

- Technical Complexity – e.g.
  - CO<sub>2</sub> 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<sub>2</sub> - e.g. London protocol



# CO<sub>2</sub> quality requirements need to be optimized along the entire chain



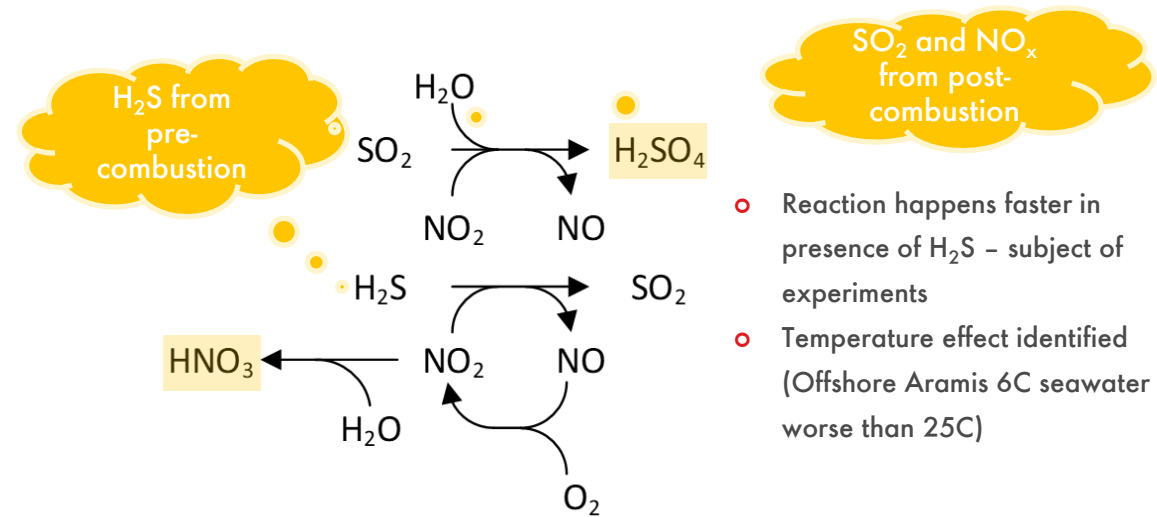
## Key impurities by industry source

Power, Waste-to-energy	SO <sub>x</sub> , O <sub>2</sub> , NO <sub>x</sub> , H <sub>2</sub> O
Cement	NO <sub>x</sub> , SO <sub>x</sub> , O <sub>2</sub> , H <sub>2</sub> O
Fertilizer, Blue hydrogen	CO, H <sub>2</sub> , CH <sub>4</sub> , H <sub>2</sub> O, MeOH
Gas production/EOR	CH <sub>4</sub> , H <sub>2</sub> , CO, H <sub>2</sub> S, H <sub>2</sub> O
Refineries (post-comb)	H <sub>2</sub> O, O <sub>2</sub> , SO <sub>x</sub> , NO <sub>x</sub>
Refineries (pre-comb.)	H <sub>2</sub> S, CO, H <sub>2</sub> , CH <sub>4</sub> , H <sub>2</sub> O, HCN, MeOH
Steel plant (Blast offgas)	CO, H <sub>2</sub> , H <sub>2</sub> S
Bioethanol	MeOH, CH <sub>4</sub> , H <sub>2</sub> S
CO <sub>2</sub> treatment	Amines (MEA), Glycol, MeOH

# Example of Challenging Chemistry Related to Hub Operation

## Examples where impurities impact design

- CO<sub>2</sub> transport and storage infrastructure typically has no CO<sub>2</sub> purification units and is based on non-corrosive fluid in CS pipe
- Mixing CO<sub>2</sub> from different sources in a hub design poses corrosion threats and new challenges for CO<sub>2</sub> specs....
- It is generally more economic to clean up CO<sub>2</sub> 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 products: **H<sub>2</sub>SO<sub>4</sub> + HNO<sub>3</sub> extremely corrosive**

- Removing SO<sub>2</sub> not sufficient, as H<sub>2</sub>S can form SO<sub>2</sub>
- Tighten spec on total Sulphur or NO<sub>x</sub>?

*Reference: J. Sonke, B.H. Morland, G. Moulie, M.S. Franke,  
Corrosion and Chemical Reactions in Impure CO<sub>2</sub>,  
[Int. Journal of Greenhouse Gas Control 133 \(2024\) 104075](#)*

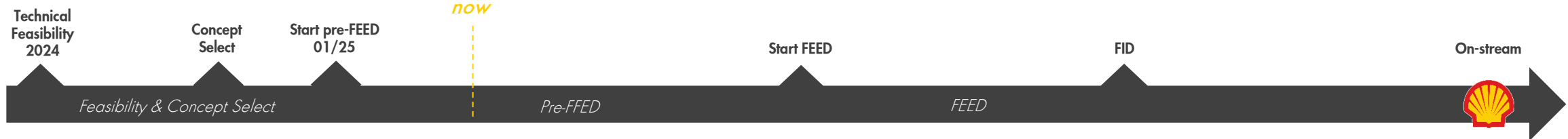
# Conclusions and recommendations

- 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<sub>2</sub> specifications
- There is no simple single solution for CO<sub>2</sub> 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 UPDATES

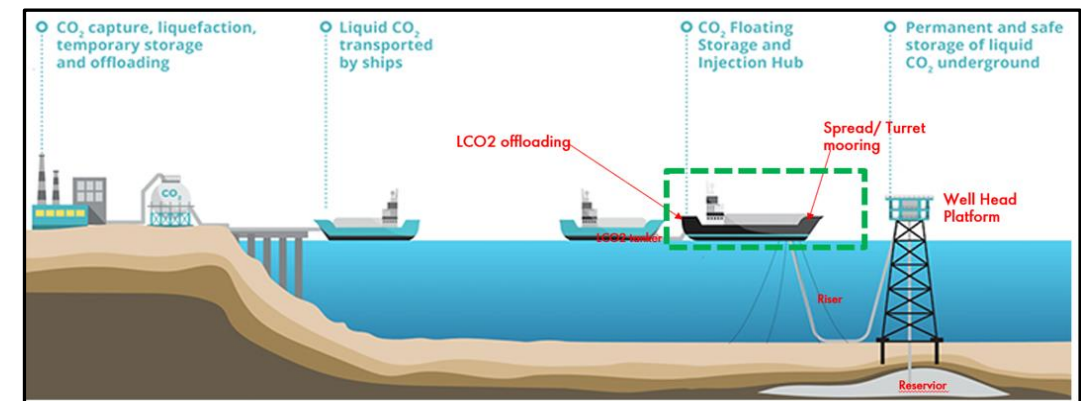
- Passed Technical Feasibility Assessment for Store & Terminal in 2024
- Selected Best Technical Concept of 5Mtpa, WHP & FSIU in Q4'24
- Start of pre-FEED work with selected contractors in Q1'25
- LP LCO2 vessel Concept Design (20-80km3) ongoing
- Pre-FEED and customer termsheet planned to complete in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

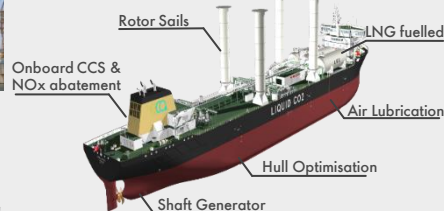


## LCO<sub>2</sub> SHIPPING

### What are we working on?



7.5k



35k

14k

### Medium Pressure LCO<sub>2</sub>

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



### LCO<sub>2</sub> Barge

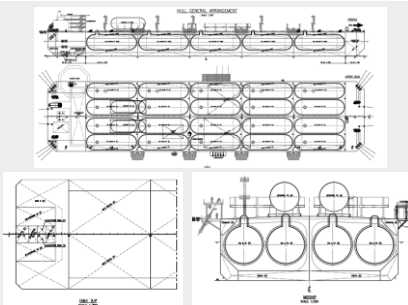
6km<sup>3</sup> to 9km<sup>3</sup> design (Inland Waterways)

### OCCS

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

### LCO<sub>2</sub> FSUI

Floating Storage & Injection Unit Feasibility Study completed



### Low Pressure LCO<sub>2</sub>

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



40k



74k



### Industry Engagement

Chaired ISO LCO<sub>2</sub> working group. Key participant in SIGTTO CO<sub>2</sub> working group. CETO Low Pressure (LP) Joint Industry Project (JIP) member. Chairing DNV JIP on LCO<sub>2</sub> direct injection



### Materials Studies & Qualification

Working with several Steel Mills & Classification Society for the development of new materials for LCO<sub>2</sub> cargo containment systems at MP and LP carriage condition