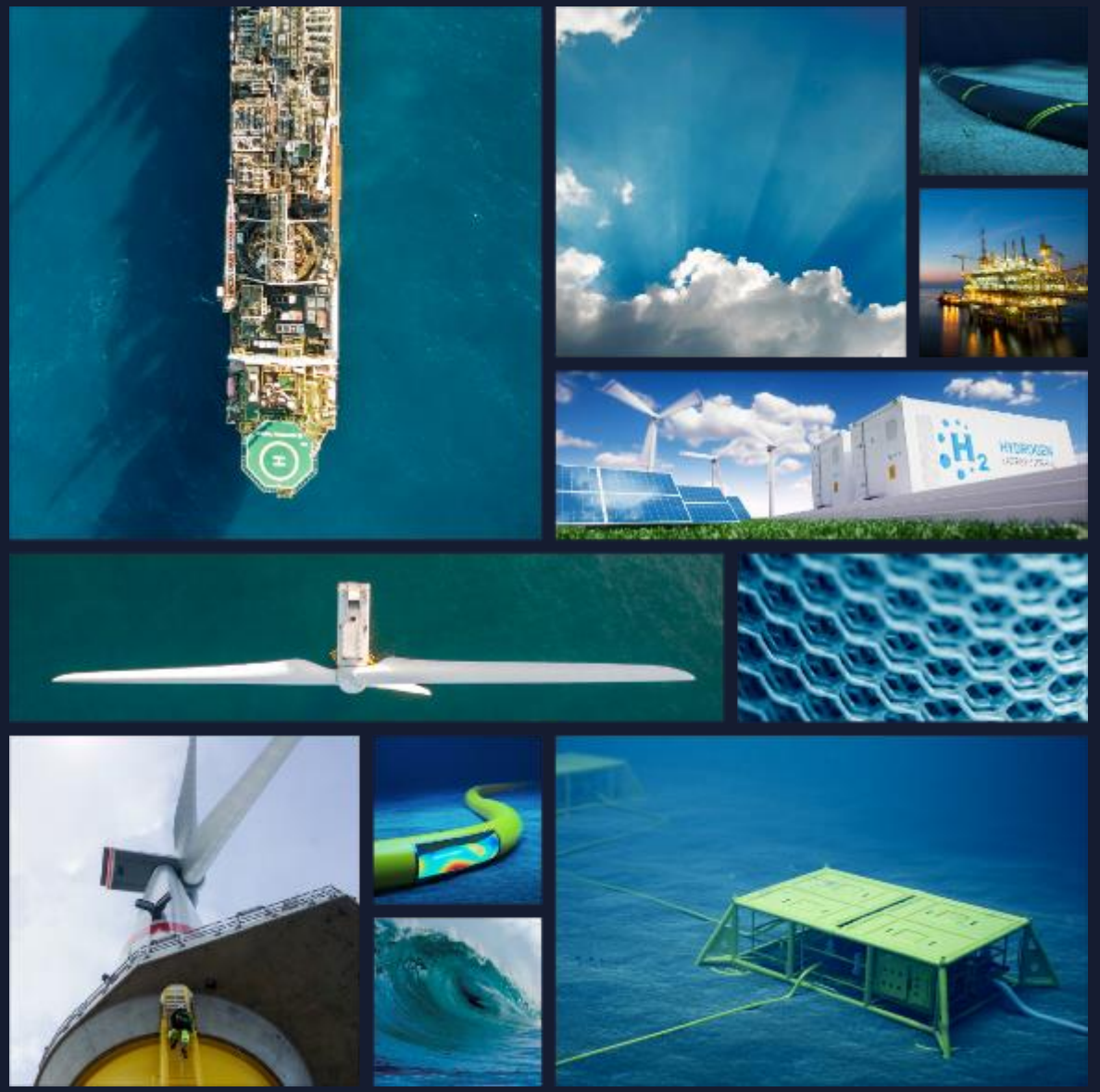
XODUS

SUT
Society for Underwater Technology

OFFSHORE CHALLENGES FOR CCUS



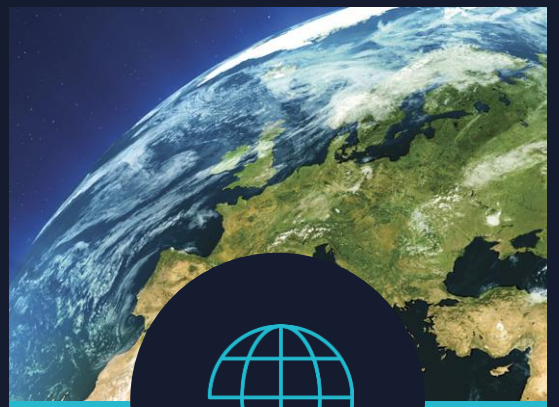
TRUST · RESPONSIBILITY · EXCELLENCE

WHAT WE DO

Helping our clients thrive in an evolving energy world.

ADVISORY
Integrating our diverse technical and commercial expertise

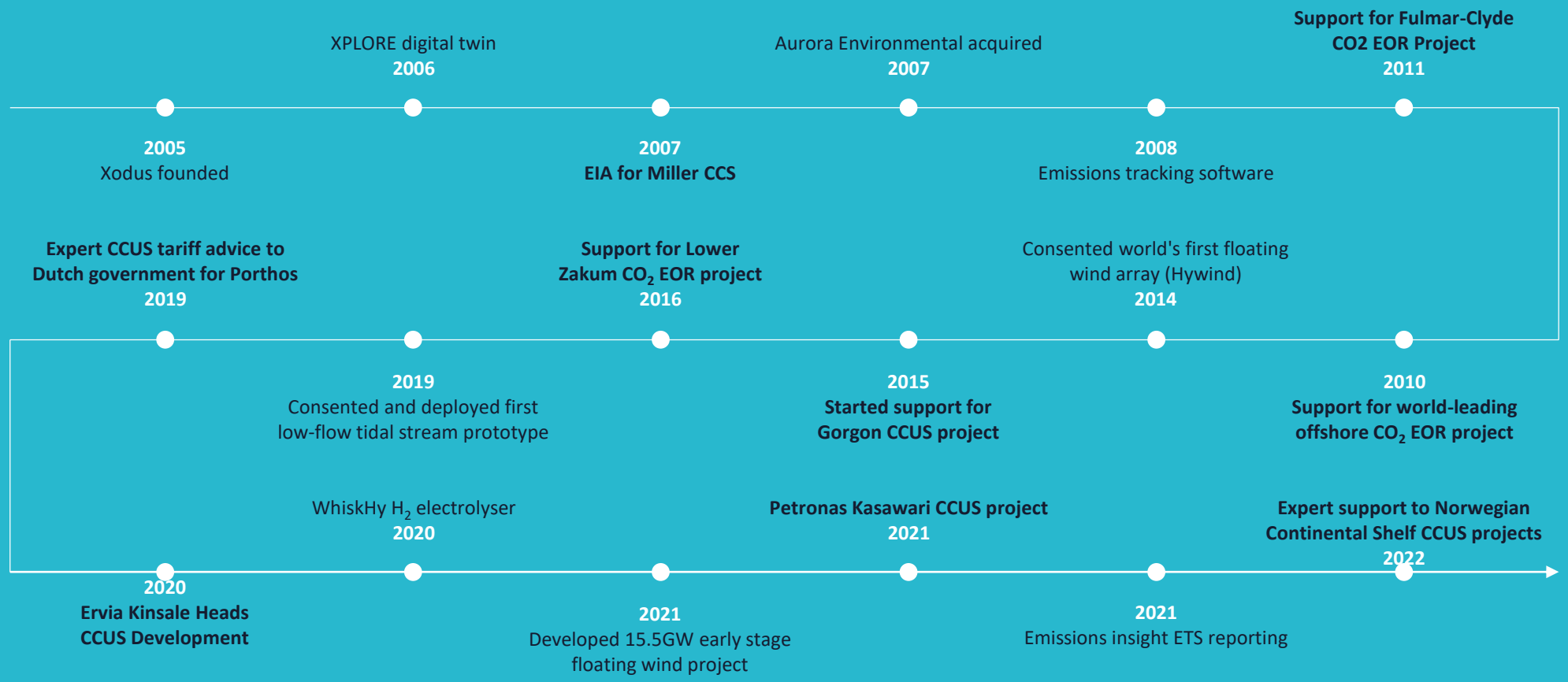
ENGINEERING
Using experience and knowledge to maximise performance

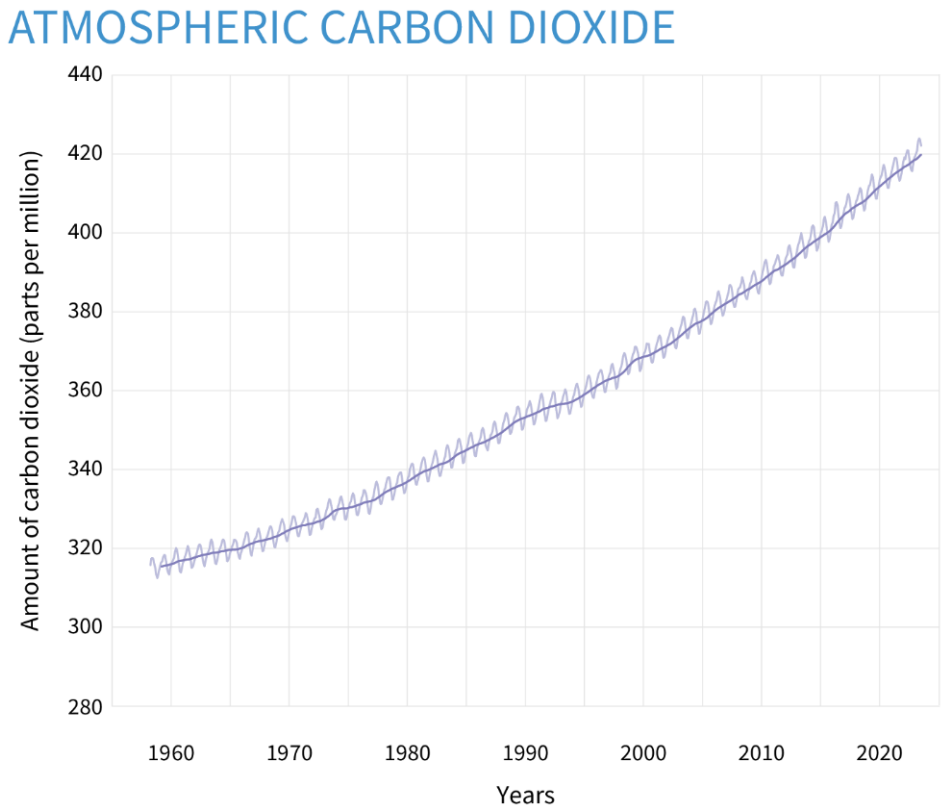


ENVIRONMENT
Delivering a sustainable and responsible energy future

SECTOR ENABLEMENT Adding value to projects, communities and consumers

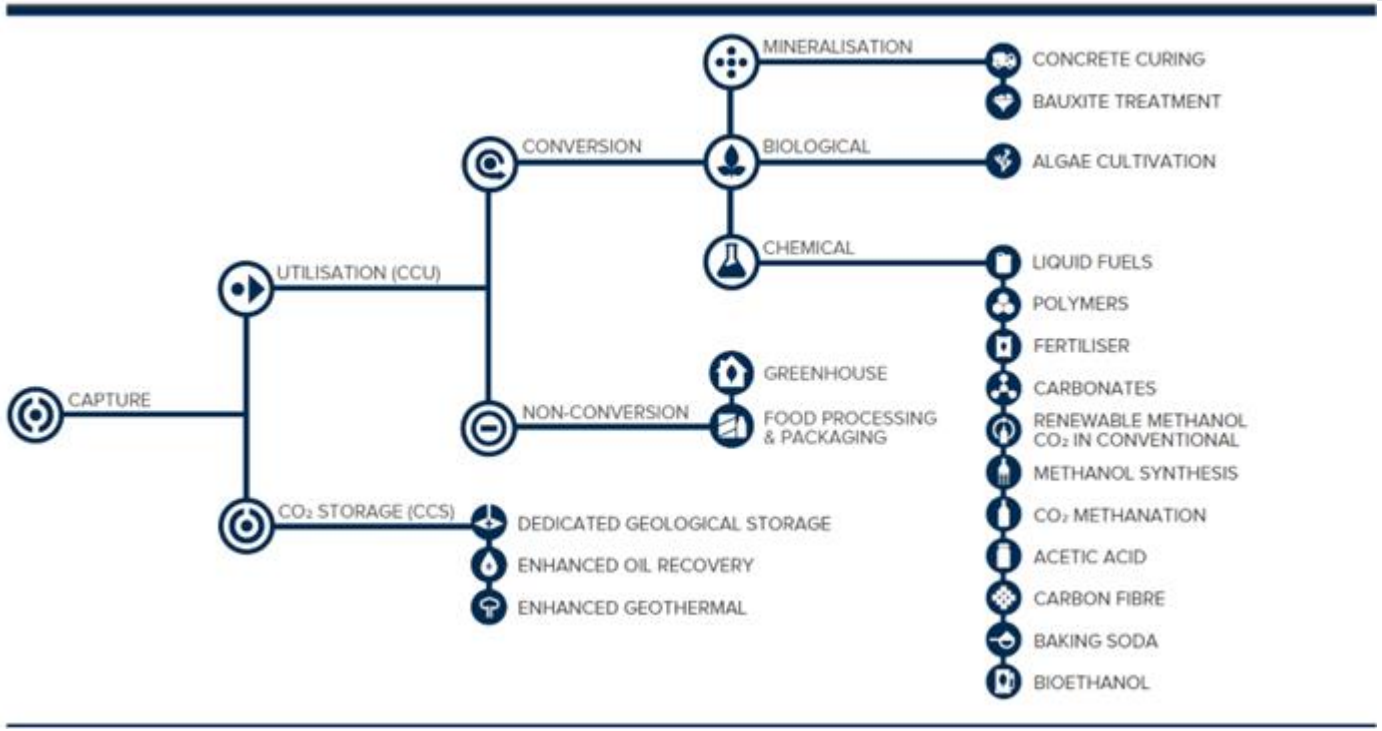
PROVIDING ENERGY TRANSITION SERVICES FOR 17 YEARS





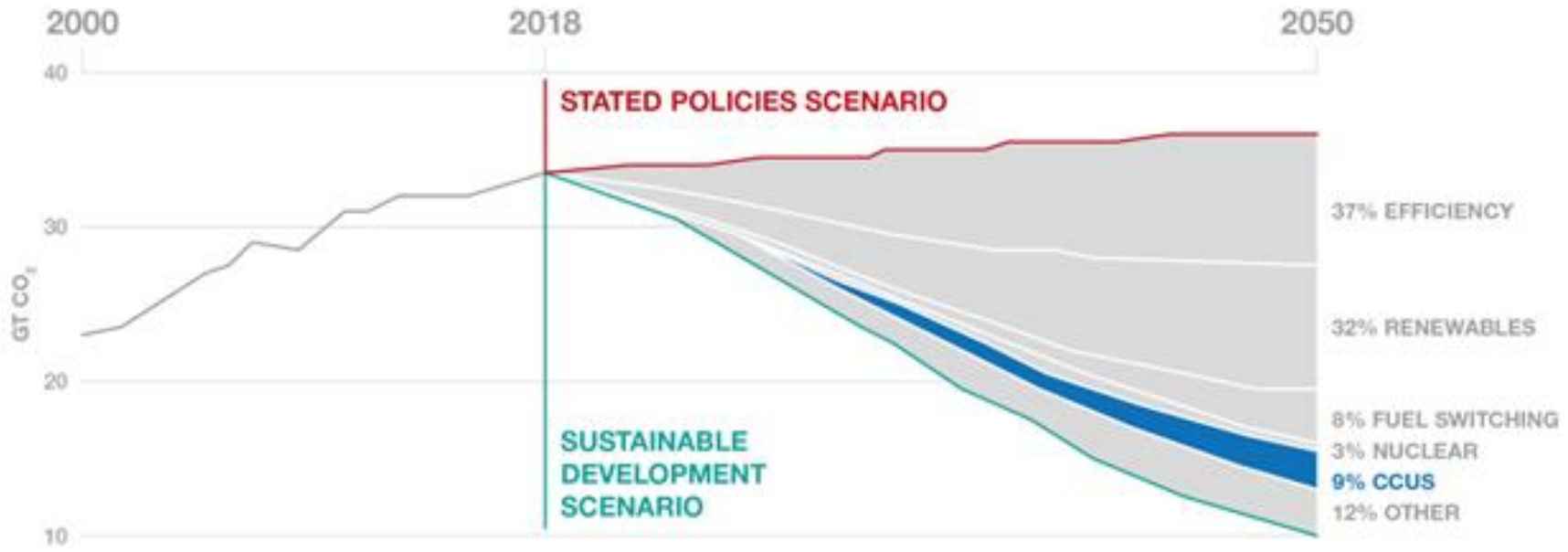
National Oceanographic and Atmospheric Administration – US Government

- It’s a well known gas, the oil and gas industry has been handling it since day 1
- It is corrosive when saturated with water
- It has been shown to be a key contributor to climate change
- Industry is likely to be emitting CO2 for the foreseeable future (not just through energy production), so we need to find a safe and sustainable way forward



Global Status of CCUS 2019 – Global CCS Institute

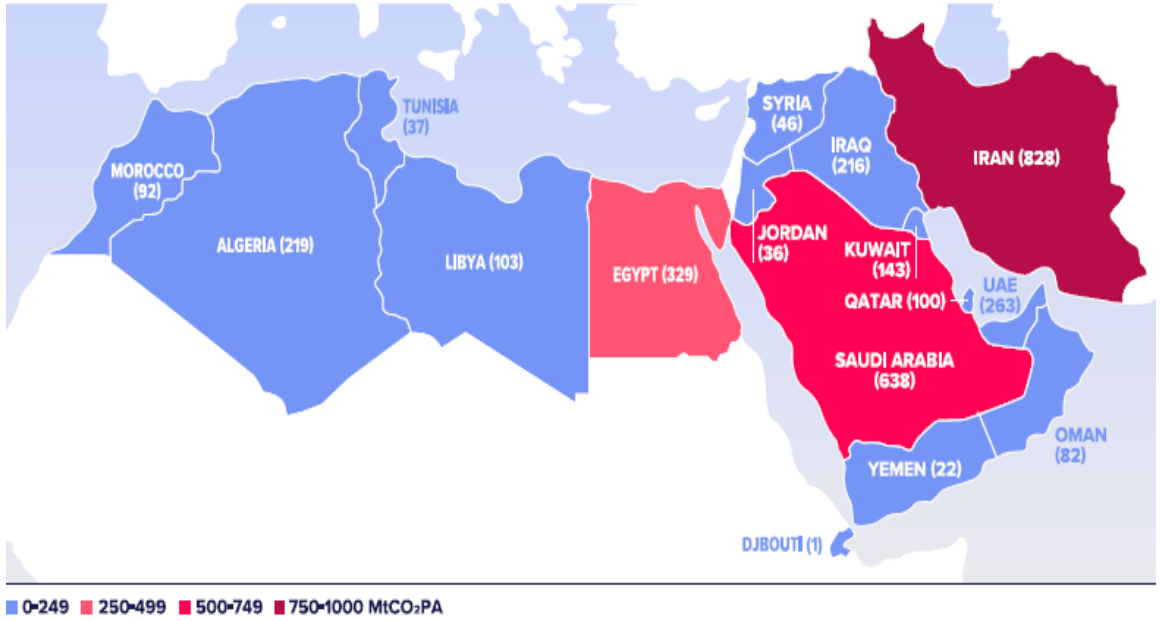
- Carbon Capture, Utilisation, and Storage
- Take CO2 from the atmosphere and put to somewhere else – “hazardous waste disposal”
- Capture either removes CO2 from an emissions source or removes CO2 already in the atmosphere
- Utilisation uses CO2 to create new, valuable products
- Storage puts the CO2 into a place where it can’t leak back to the atmosphere



Global Status of CCUS 2019 – Global CCS Institute

- CCUS is an essential part of the energy mix to reduce global emissions
- IEA 2019 sustainable development scenario estimated 2.3 gigatonnes per year of CO2 emissions need to be stored by 2050
- “Net zero by 2050” scenario would increase this to 4 gigatonnes per year
- Current global installed capacity is 0.04 gigatonnes per year
- Need to increase capacity in order of 100 times by 2050 to meet climate goals

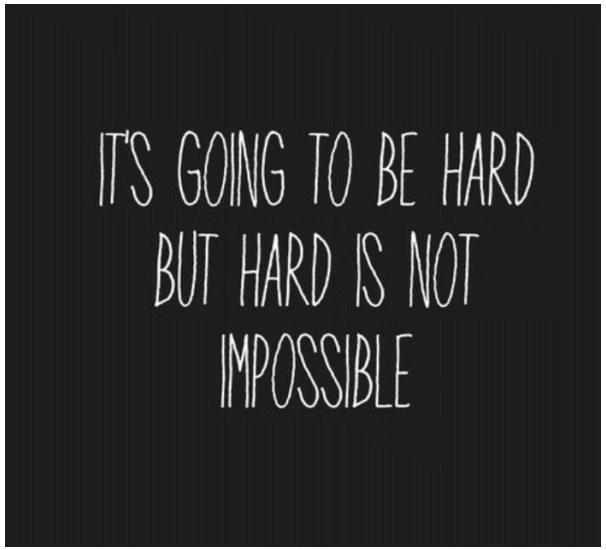
- CCUS is very relevant to MENA region
- Around 85% of CO2 emissions in the region come from energy production / industry
- Qatar, Kuwait, UAE, Bharain, and Saudi Arabia in top 10 per capita carbon emitters in the world
- CCUS is needed to help deliver a sustainable future for the MENA region
- ***Other region are considering producing lower carbon LNG (and other fuel) by using CCS to reduce the carbon footprint of the LNG plant. The ME region has tremendous potential to offer such product***



Global Status of CCUS 2022 – Global CCS Institute

A few challenges face the CCUS industry worldwide:

1. There's not a lot of "intrinsic value" in CO2, so limited profit available (at the moment)
2. Capturing, conditioning, transporting and using or storing CO2 is technically challenging, expensive and energy intensive
3. CCUS has a stigma associated with it in some parts of the world – "it allows industry to stay dirty"
4. Ensuring that CO2 stays put once you've captured it is both technically challenging and requires a heavy burden of proof
5. Commercial



Children of War Foundation

- Capture from low pressure / concentration sources – CO2 capture is well established, but generally at moderate to high pressure (e.g. 50barg) and moderate concentrations (>5mole%).
- Many sources are at or near atmospheric pressure (e.g. power generation exhausts) and can be low concentration (e.g. the atmosphere) – this makes capture equipment large, expensive and energy intensive
- CO2 being corrosive – results in the need for either very efficient dehydration or high materials specification
- Custody transfer – as it is being considered like a hazardous waste, it is highly important to know exactly where each molecule of CO2 goes and if it stays put … more on this later
- Other challenges – trace contaminants make it hard to exactly predict behaviour, soft goods don't play well with CO2, metallurgy issues with crack propagation following pipeline leaks, the list foes on.

Transport

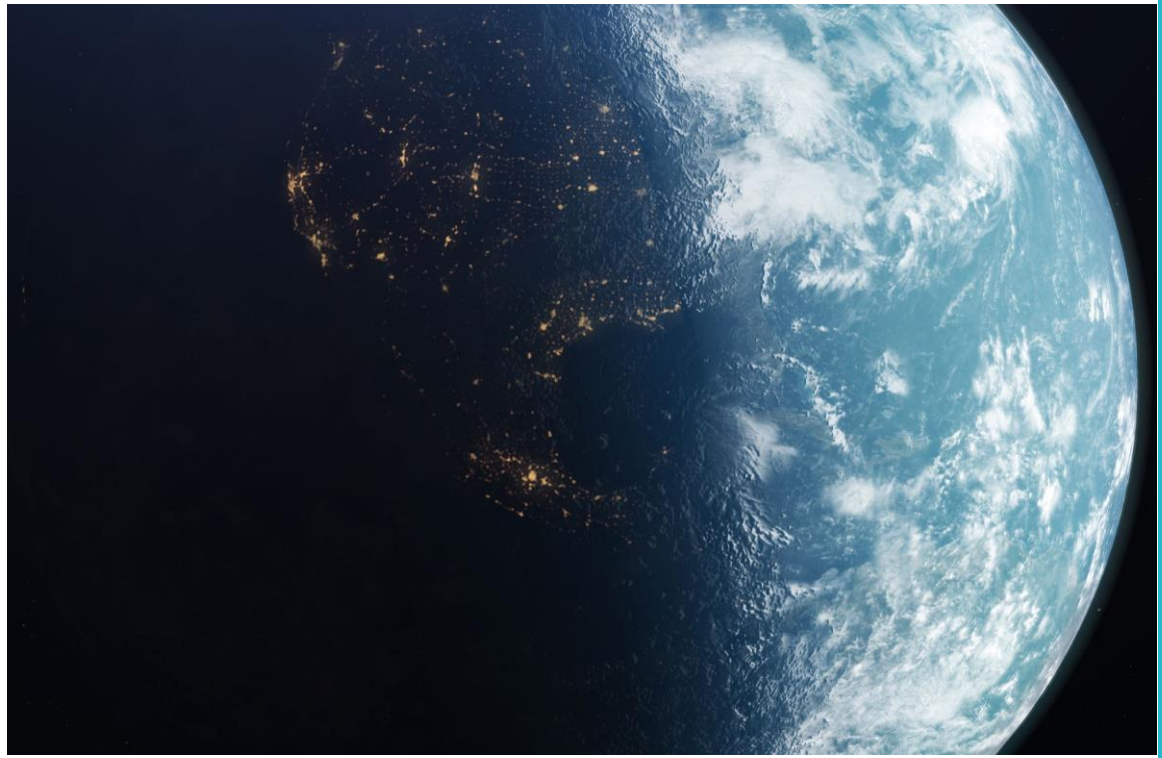
- Available stores are generally quite far away from emissions sources, resulting in the need for long-distance transport.
- Pipeline transport relatively easy, but needs very careful consideration on how to commission to get pipeline dry and operation to ensure it stays dry. Leak monitoring and detection is key, but difficult to achieve in long pipelines where you need to track every molecule.
- Ship transport is more complex. Want to transport as a liquid, either high pressure or semi-refrigerated. No large CO2 ships currently in operation worldwide and CO2 does present some unique challenges in terms of storage tank design and ship stability.

Stores and Injectivity

- Two main types of stores offshore – saline aquifers or depleted hydrocarbon reservoirs.
- Saline aquifers – not a lot storage capacity per m^3 of store, but generally very large reservoirs. Little track record of their geology, so difficult to “prove” CO2 will stay in store. Potential need to relieve pressure by pumping brine out of store, which brings a whole host of other issues.
- Hydrocarbon reservoirs – a lot of storage capacity per m^3 of store if pressure depleted. Good track record of geology, so easier to “prove” CO2 will stay in store. However, previous wells may represent leak paths to atmosphere due to reasons like not being P&A to a depth that allows repressurisation, use of cement that isn’t CO2 resistant, potential corrosion of remaining tubing in wells.

How do we know it stays in store and not in atmosphere?

- Possibly the biggest technical challenge associated with offshore CCUS.
- How do you ensure that all the CO2 that is transported to the store is injected and stays in the store “permanently”?
- Needs a lot of reservoir monitoring, far in excess of oil and gas reservoir monitoring, to satisfy regulatory authorities, often on reservoirs (saline aquifers for example) that aren’t very well understood.
- Future risk of leak from stores after injection is also a significant concern and how to handle that for long term.



Commercial Dynamics: Onshore vs. Offshore storage

Choice of location driven by perception

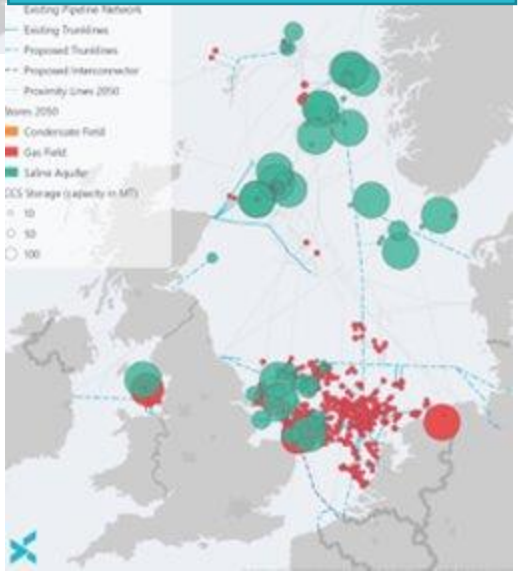
- Offshore options is dominating the CCS market is Europe with 100% of most advanced storage using a NS storage sites
- The selection is driven by societal constraints with populations opposed to onshore storage due to negative perceptio and limited land availability as these are very dense region.
- This perception against onshore storage is not shared in the US where local populations are more familiar with onshore oil and gas production and onshore CCS is being developed

Storage cost is only a small part of the value chain,

- Onshore storage can be less expensive but only represents a small part of the value chain
- Size and locations compensate for the cost differential quickly particularly when equipment can be re-used
- We have conducted an analysis of the potential roll-out of CCS in the North Sea (“2050” forecast draft) and we expect that a wide range of offshore sites can be very competitive

CCS 2030 Projects

CCS 2050 Forecast



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FIND OUT MORE

Experts with Energy

As a leading global energy consultancy, we help clients overcome challenges, add value to opportunities and maximise returns on investments, responsibly.

Our values of trust, responsibility and excellence underpin our vision. They are at the heart of decision making and inform our future strategy.

In offering expert advice and solving complex problems, our multi-skilled specialists work across the energy spectrum to address industry problems. By combining technology with our knowledge, we create better business outcomes whether it is advisory, project development or in operational support.

Together, we will deliver a responsible energy future.

Headquartered in Aberdeen, Scotland with a global operations centre in London, Xodus has offices in the United Kingdom, United States, Australia, Egypt, Dubai, Abu Dhabi Japan and Malaysia.

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