Traceable Measurements for Liquid CO_2?

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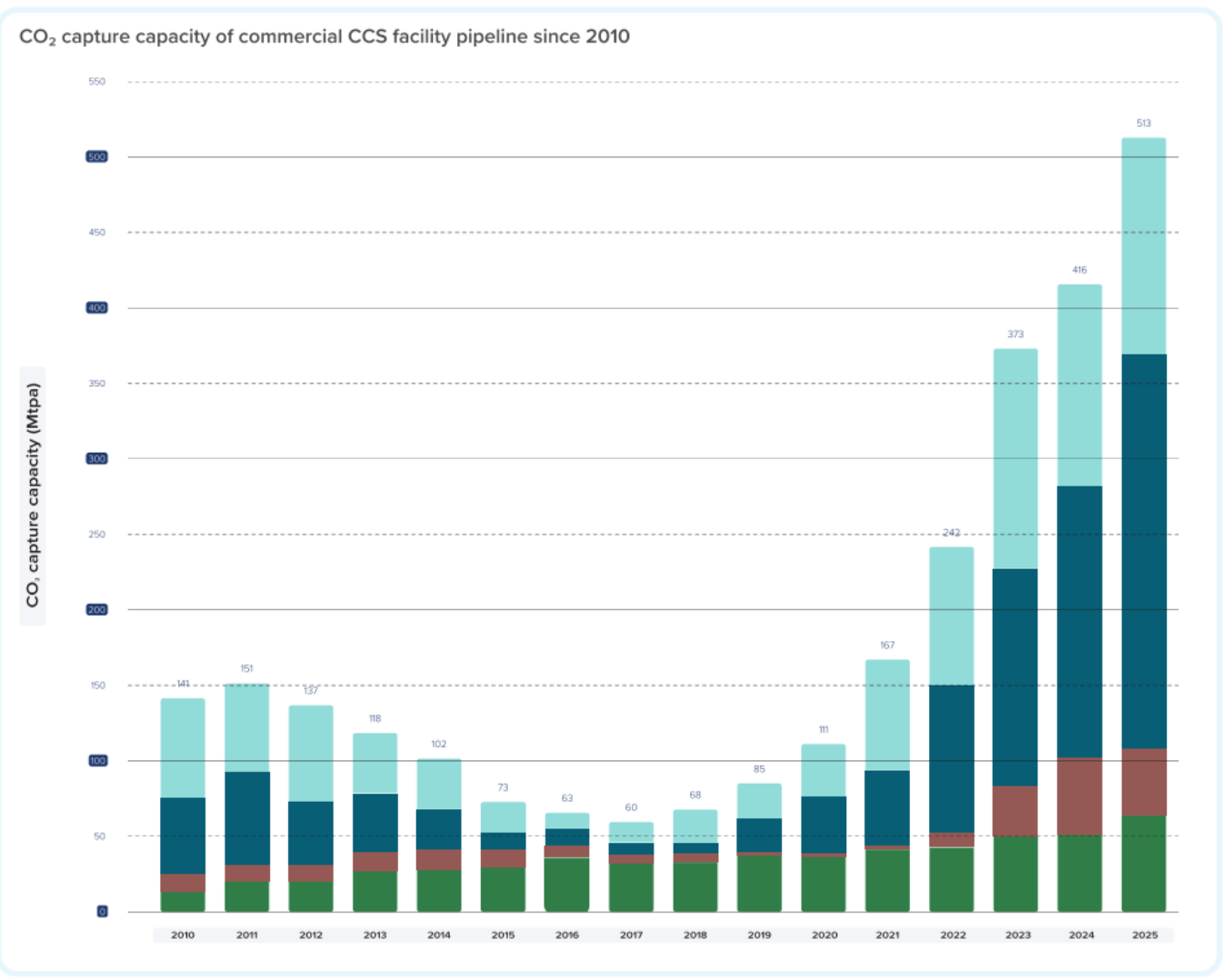
Flow Measurement Focus Group, Birmingham, 2026-05-29

Add value.
Inspire trust.

CCS Global Development



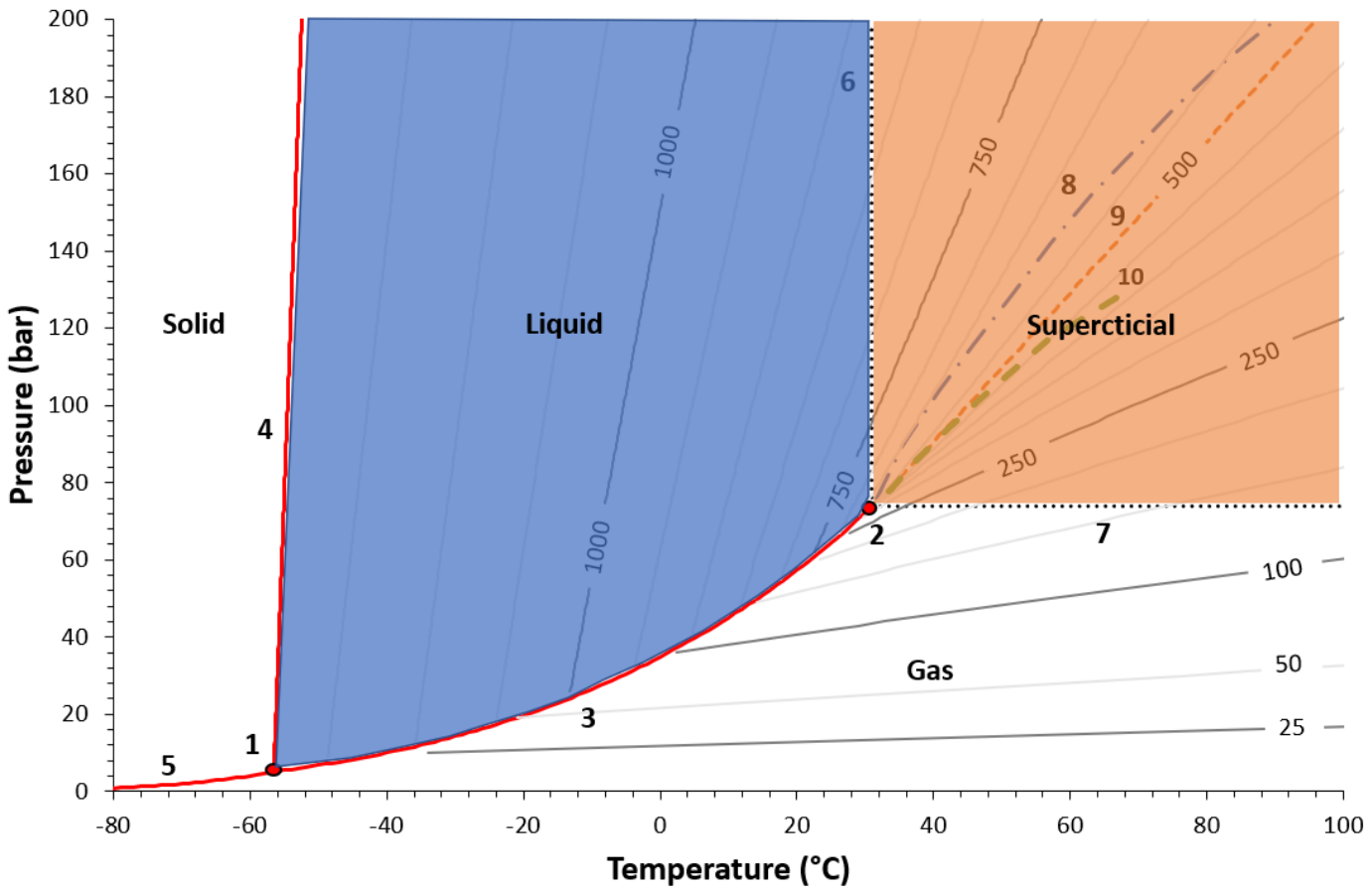
- The number of CCS projects continues to grow each year.
- Since 2017 total planned capture capacity has grown over 30% annually

Source: Global CCS institute, “Global status of CCS 2025:Staying the course”, Online at: https://www.globalccsinstitute.com/wp-content/uploads/2025/10/Global-Status-of-CCS-2025-report-9-October.pdf

CO_2 as a Fluid

- There are three fluid states that CO_2 can exist in.
  - Gas
  - Liquid
  - Supercritical

- Supercritical is anything above the critical pressure and temperature
  - 30.97 °C
  - 72.8 bar



CO_2 Phase Diagram – in 3D

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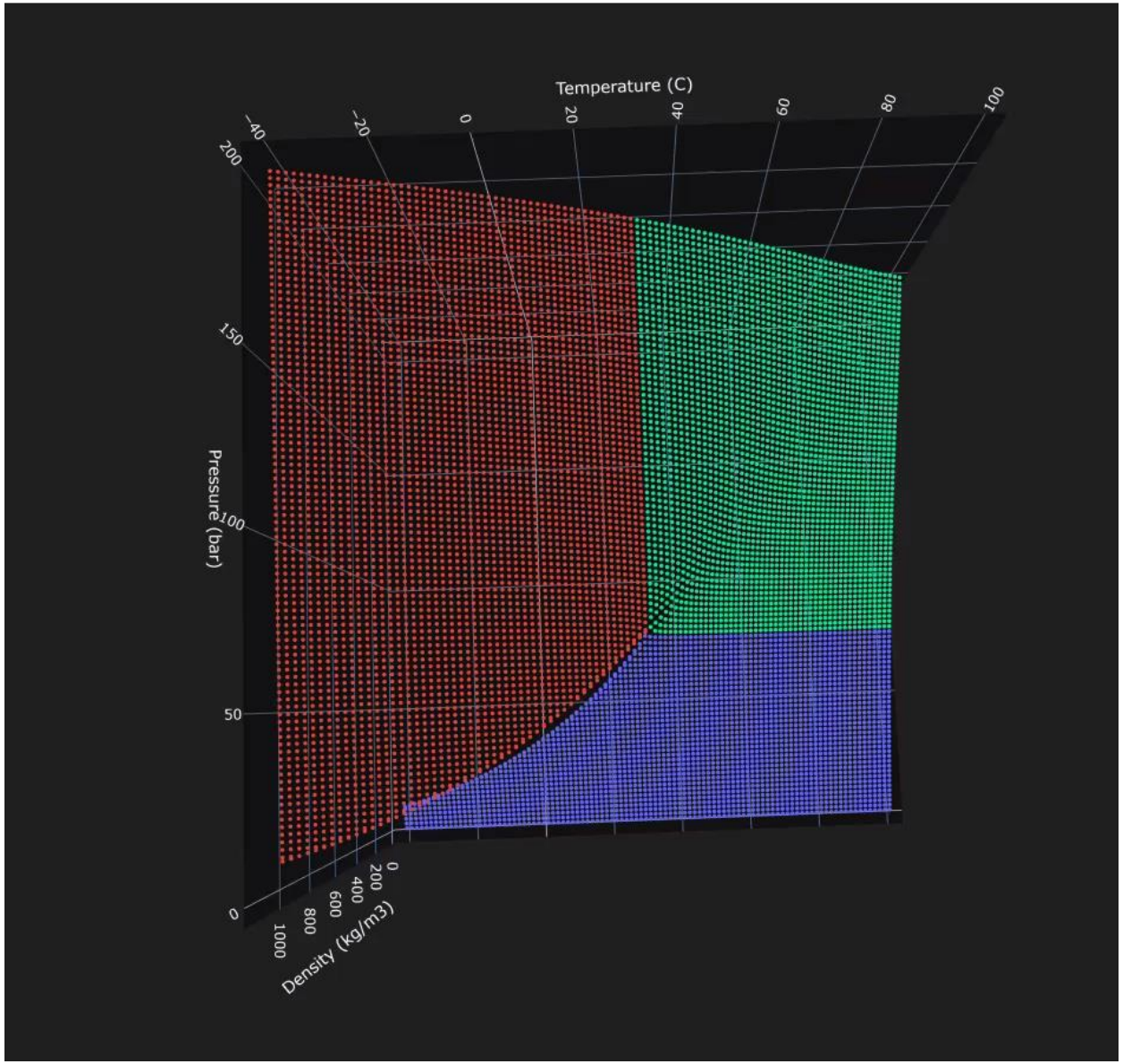
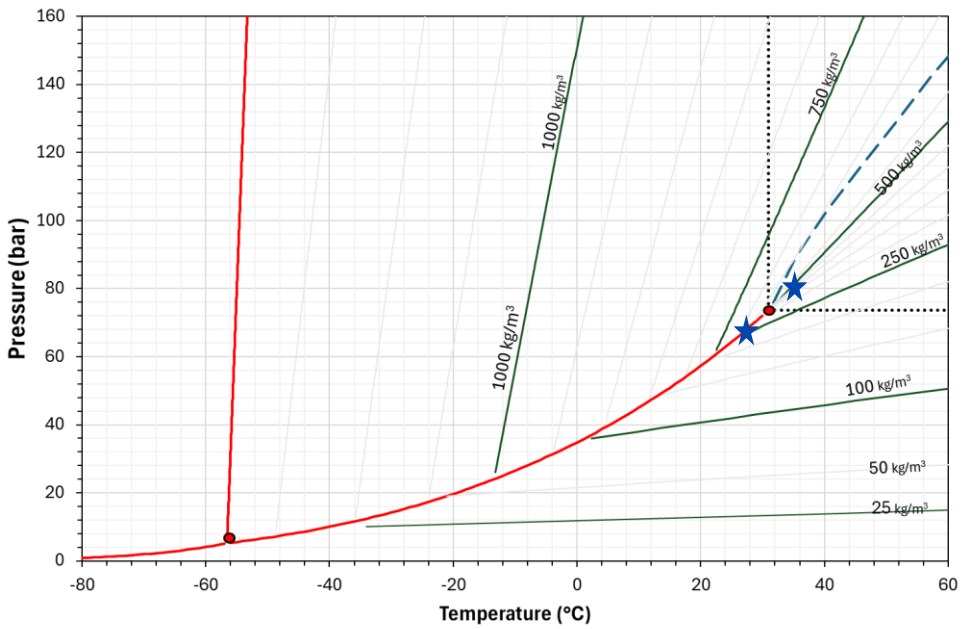
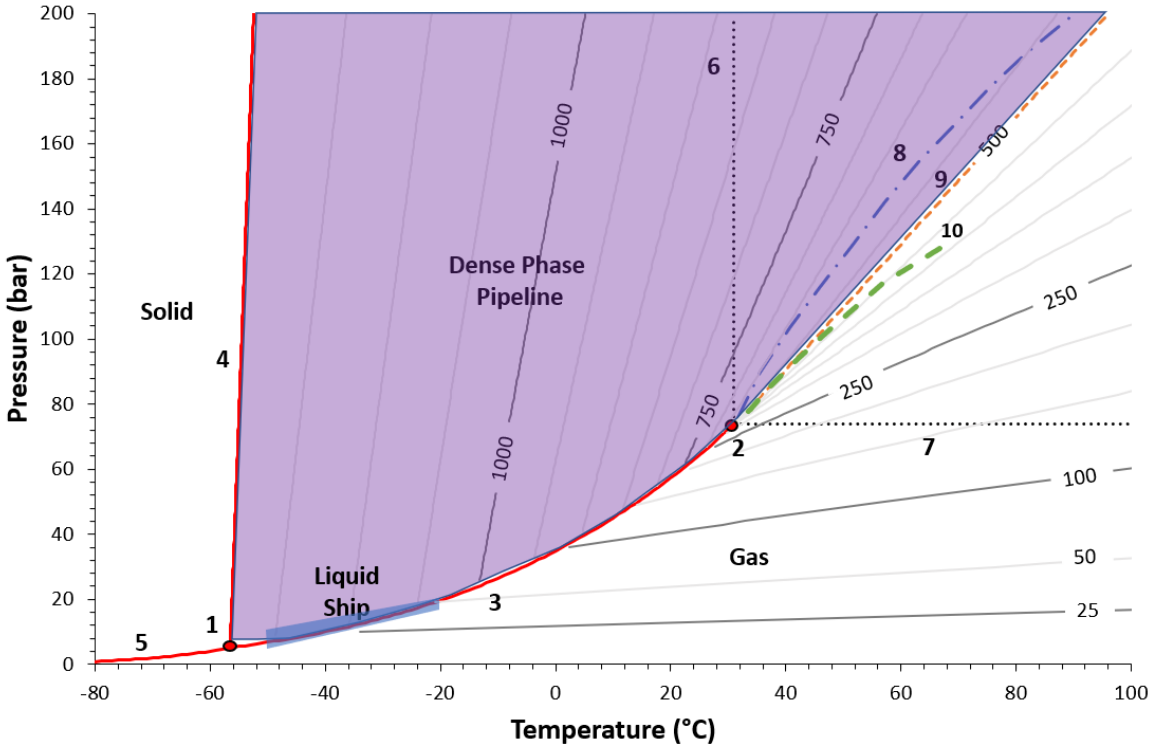


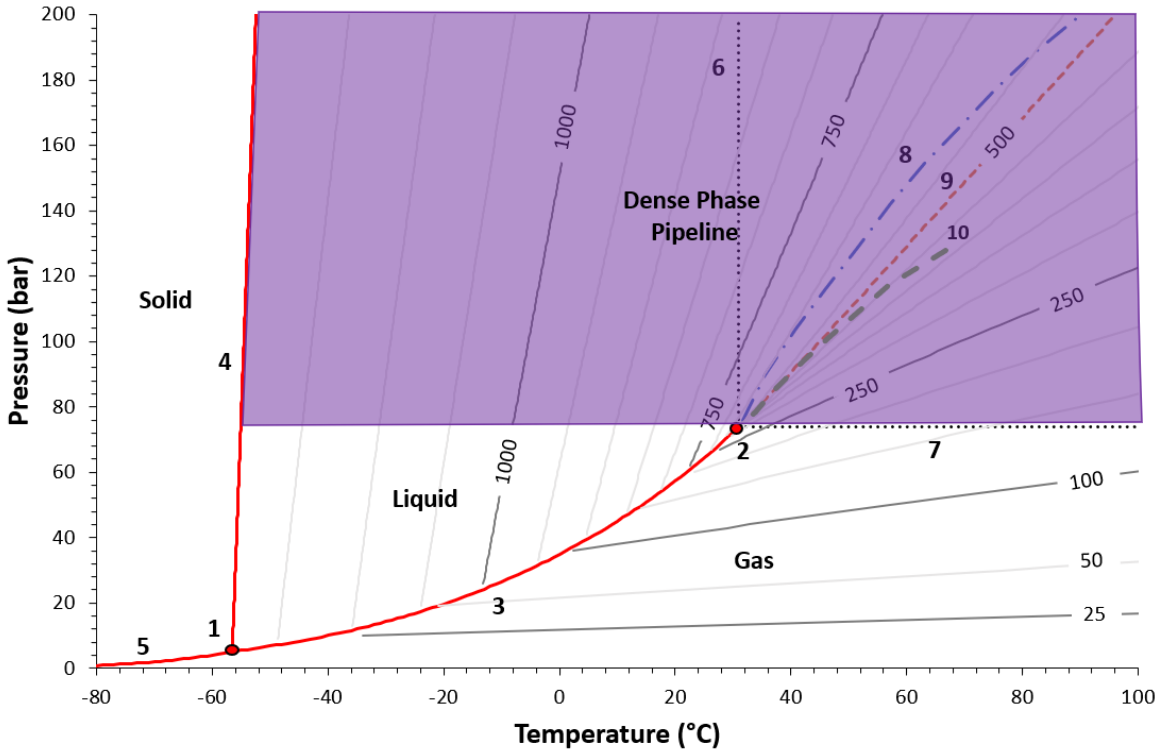
What Does Supercritical CO_2 Look Like?
2-phase to Supercritical



What is Dense Phase?



CO_2 or CO_2 stream in the single-phase fluid state above a density of 500 kg/m^3



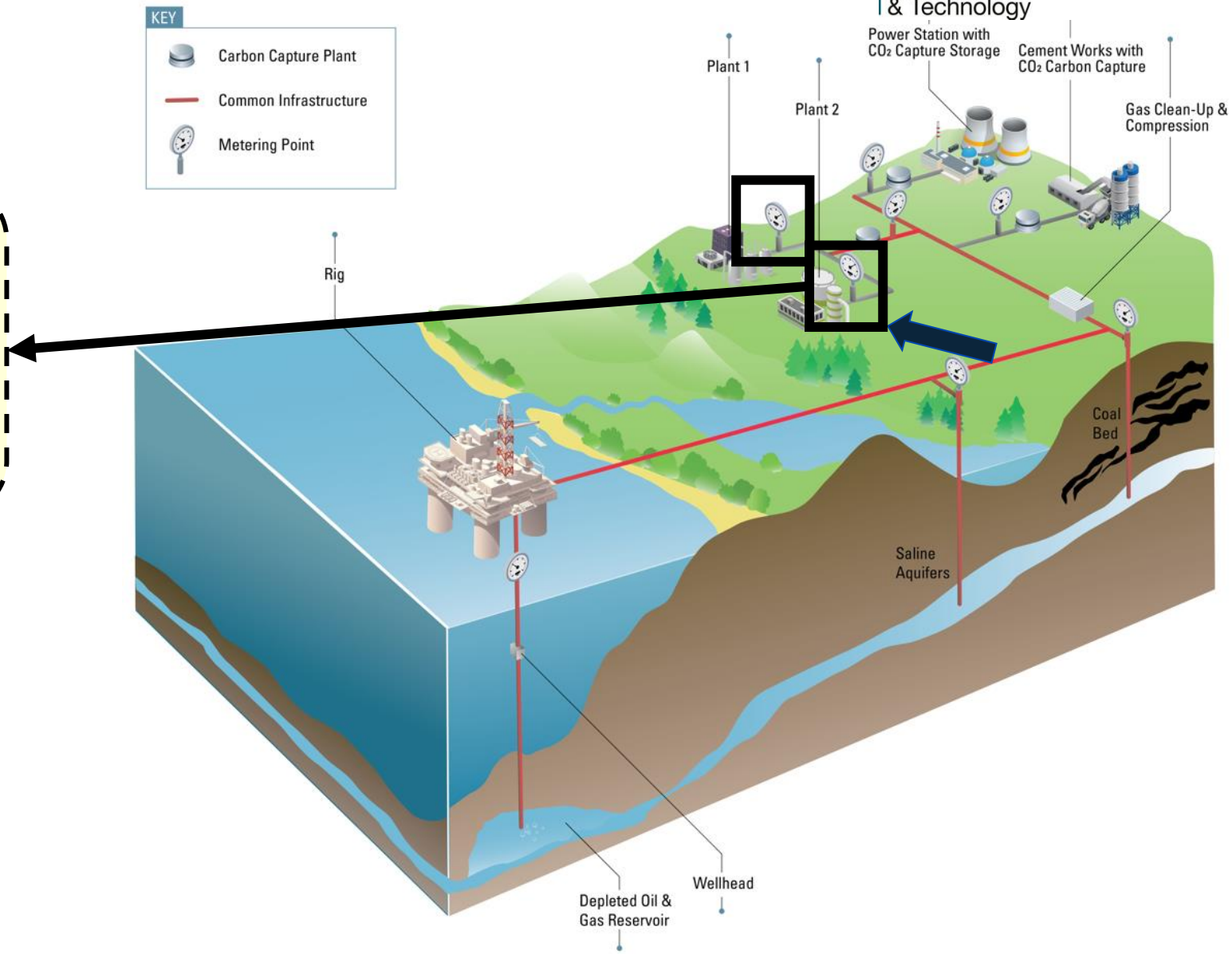
CO_2 or CO_2 stream in its liquid or supercritical phases above the critical pressure (pure CO_2 stream) or cricondenbar (CO_2 rich stream)

This definition is aligned with: CCUS Forum Expert Group on CO2 Specifications, "An Interoperable CO2 Transport Network-Towards Specifications for the Transport of Impure CO2," 2023

Measurement stages for CCUS

Capture stage

Measurement uncertainty ≈ 7.5 % (k=2)
Temperature 10 to 150 °C
Pressure < 10 bar(g)
Gas Phase

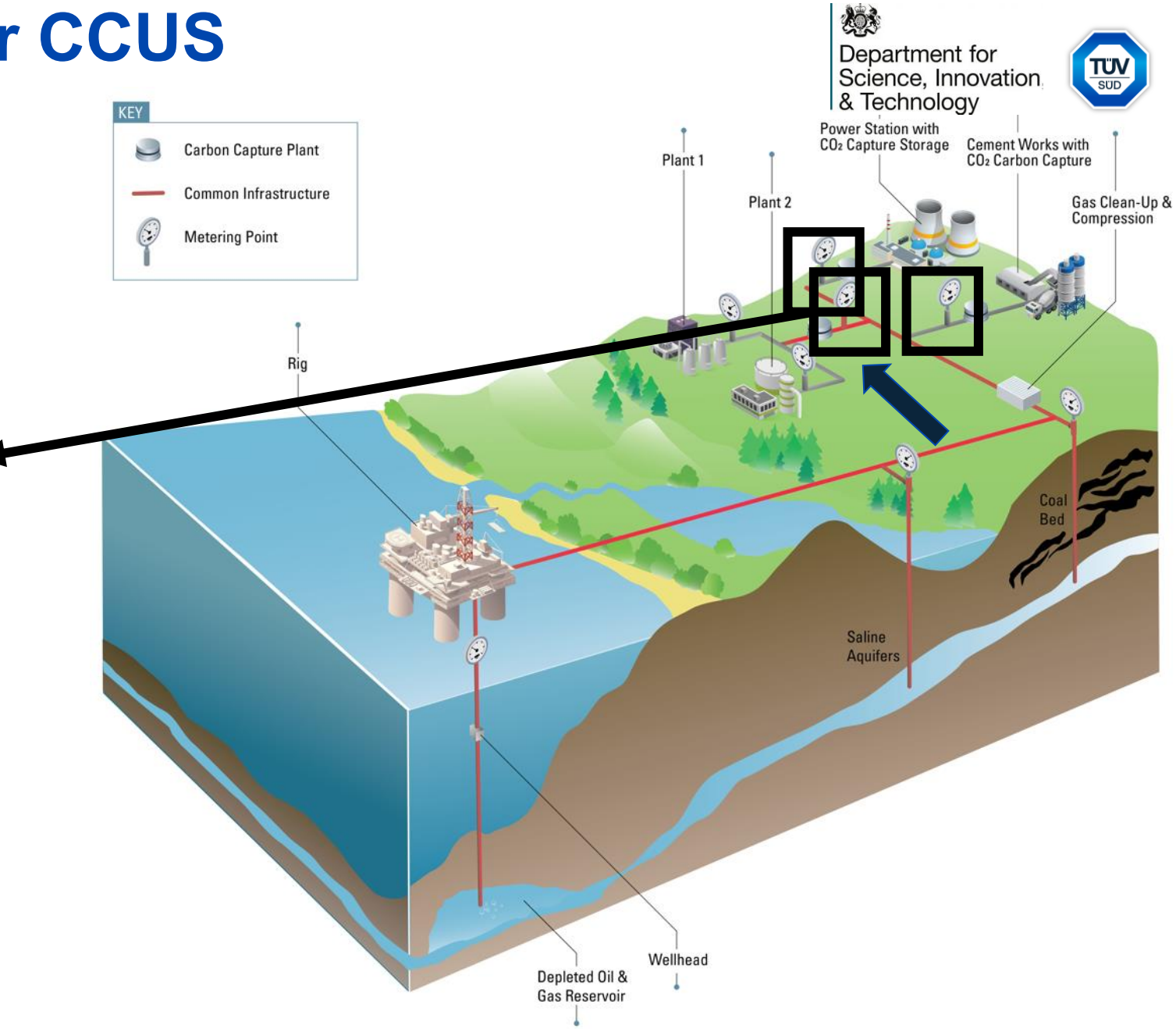


Measurement stages for CCUS

Transportation stage

Measurement uncertainty ≈ 2.5 % (k=2)
Temperature ≈ 5 °C to 60 °C
Pressure ≈ 10 to 45 bar(g)
Flowrate 30 – 300 tonne/h
Gas Phase

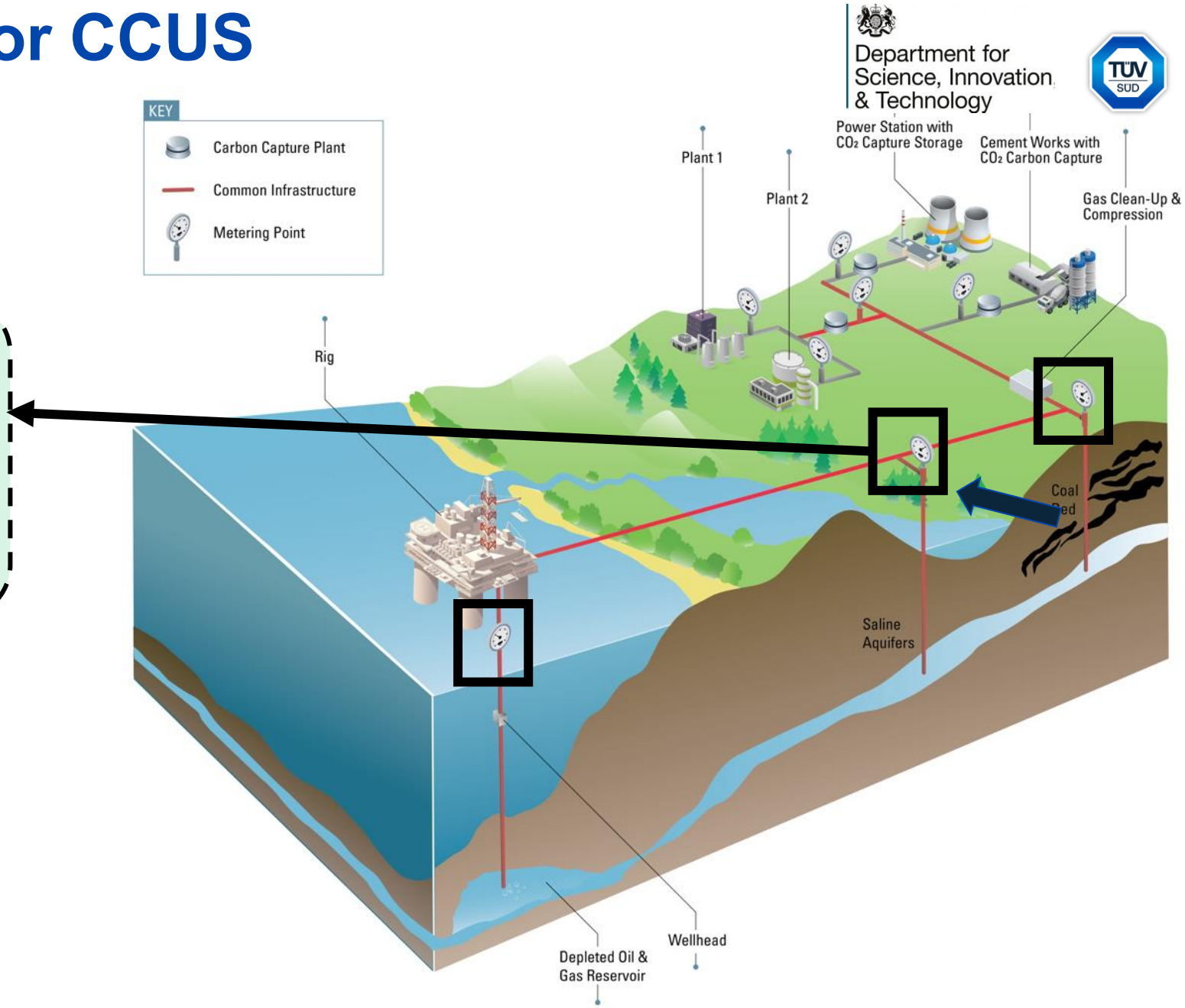
Measurement uncertainty ≈ 2.5 % (k=2)
Temperature ≈ 2 °C to 40 °C
Pressure ≈ 75 to 175 bar(g)
Flowrate 20 – 1000 tonne/h
Liquid/Dense Phase



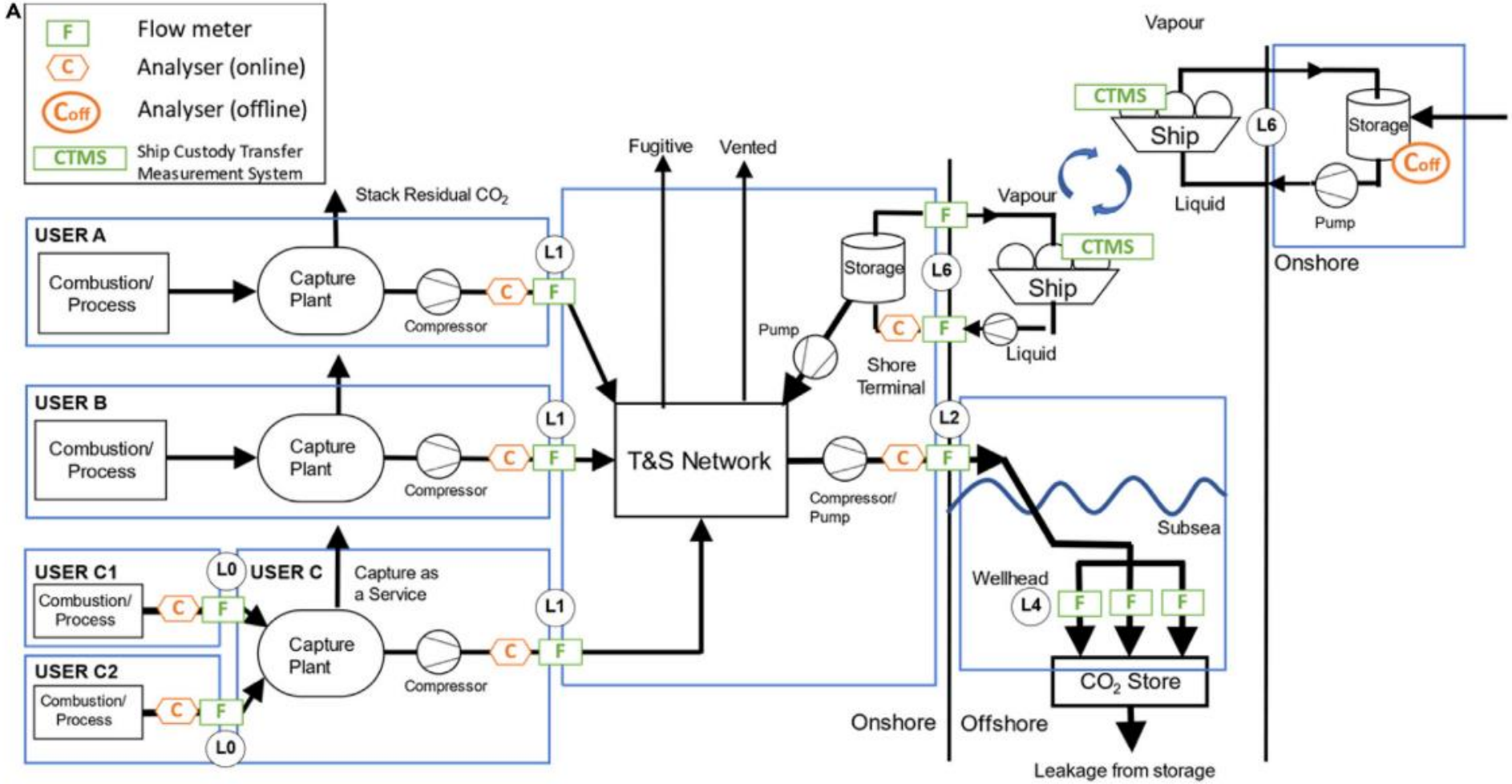
Measurement stages for CCUS

Storage stage

Measurement uncertainty ≈ 2.5 % (k=2)
Temperature ≈ 4 °C to 7 °C
Pressure ≈ 70 to 195 bar(g)
Flowrate 30 – 205 tonne/h
Liquid/dense phase



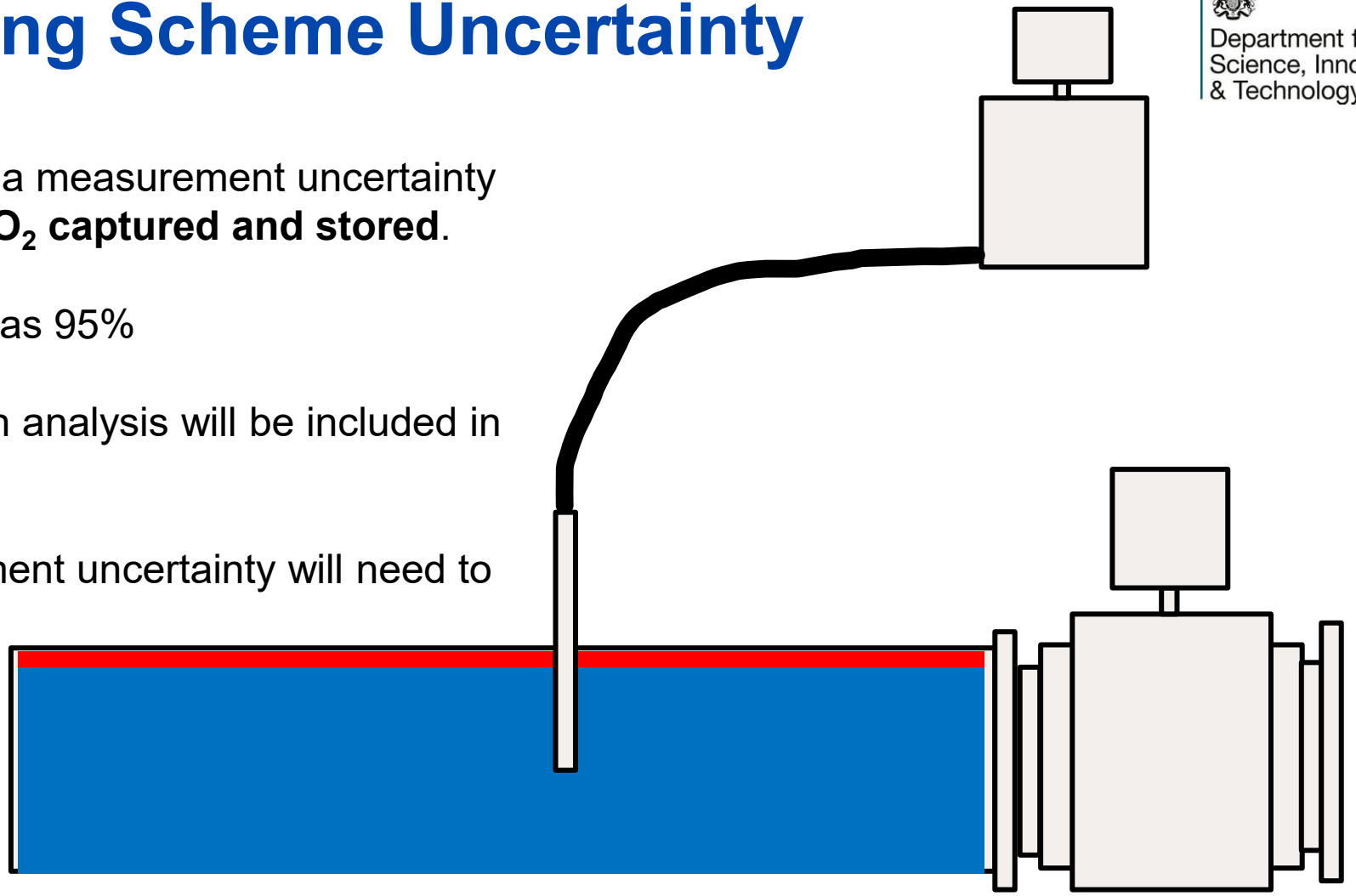
CCUS Metering Stations



Source: Towards Standardised Measurement of CO2 Transfer in the CCS chain, Chinello et. al, Nexus, 2024

Emission Trading Scheme Uncertainty

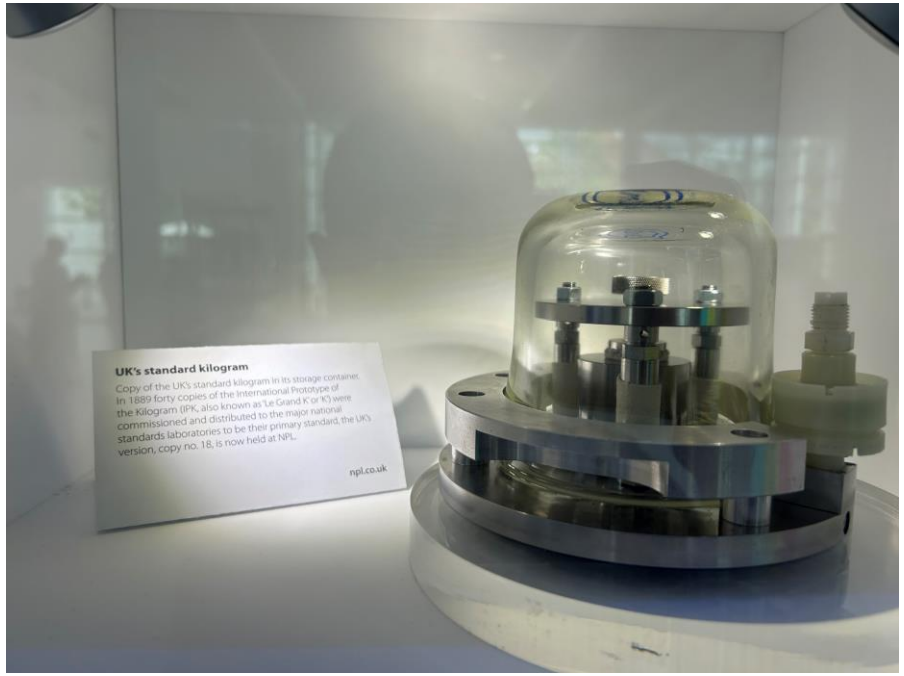
- UK and EU ETS stipulate a measurement uncertainty of 2.5% of the **mass of CO_2 captured and stored**.
- CO2 purity can be as low as 95%
- Sampling and composition analysis will be included in flow metering uncertainty
- Therefore, flow measurement uncertainty will need to be lower than 2.5%



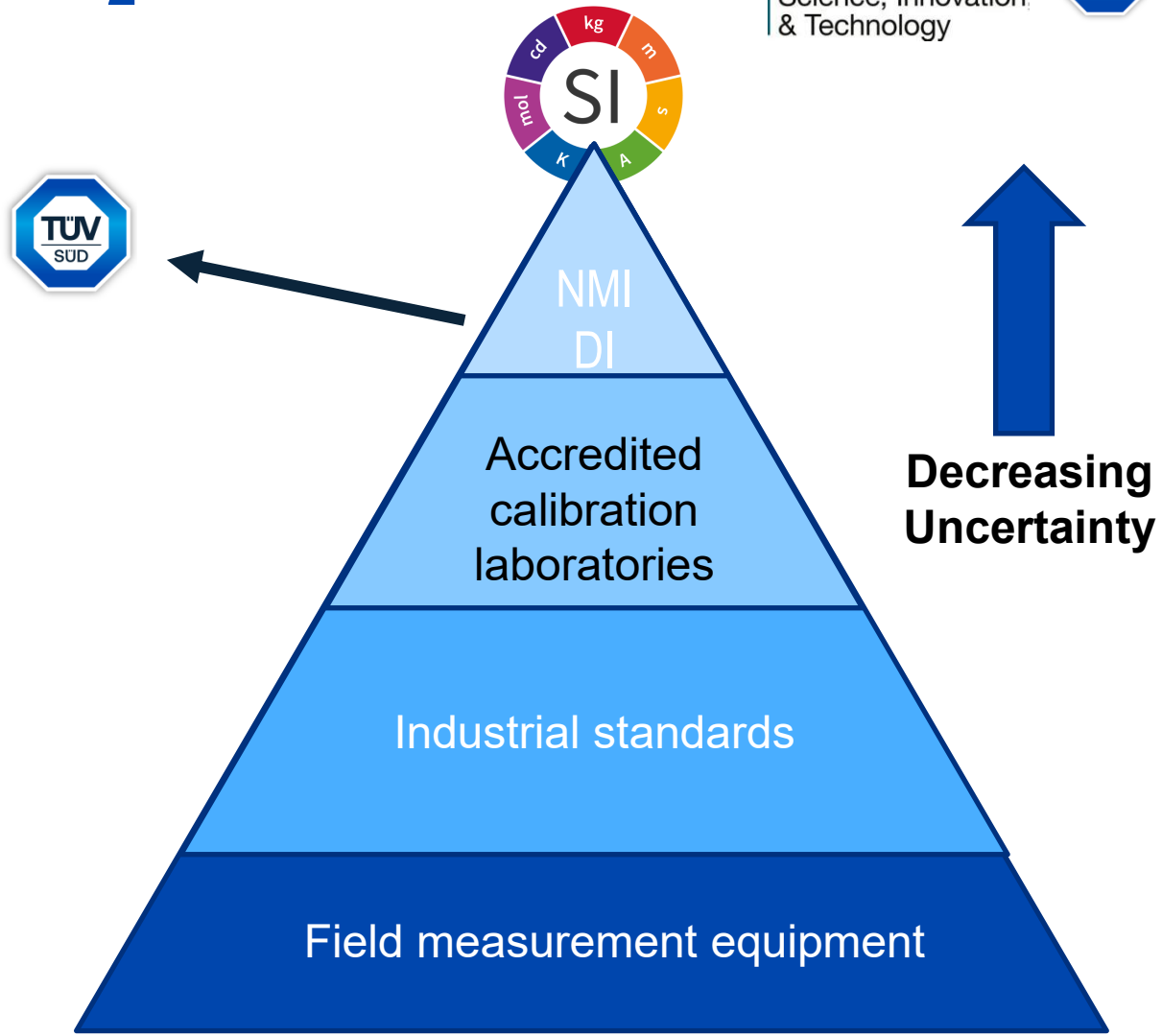
Many CCS contracts have stipulated 1 – 1.5% uncertainty

Measurement Traceability for CO_2

Measurement traceability
Property whereby a result can be related to stated references through an unbroken chain of comparisons, each having a stated uncertainty

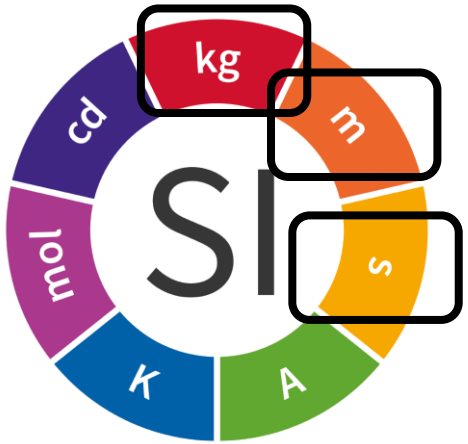


The UK's reference standard kilogram until 2019



Liquid CO_2 Traceability at TÜV SÜD NEL

- TÜV SÜD NEL has built a flow loop for liquid & supercritical CO_2
- This is be a primary standard facility, traceable to the SI



Your Flow Meter!

Liquid and Supercritical CO_2 Flow Facility – $GLASCO_2$

- **Test Fluids:**
  - Pure CO_2
  - CO_2 Mixture (custom dosing of impurities)
- **Flow Range:**
  - 0.7 – 70 m^3/h
- **Pressure Range:**
  - Saturation Curve – 200 bar.g
- **Temperature:** 5 - 50 °C
- **Line Size:** 1“ – 4“ (nominal 3“)
- **Reference Standard:**
  - Primary Piston Prover

Traceability for CO_2 Composition Measurement

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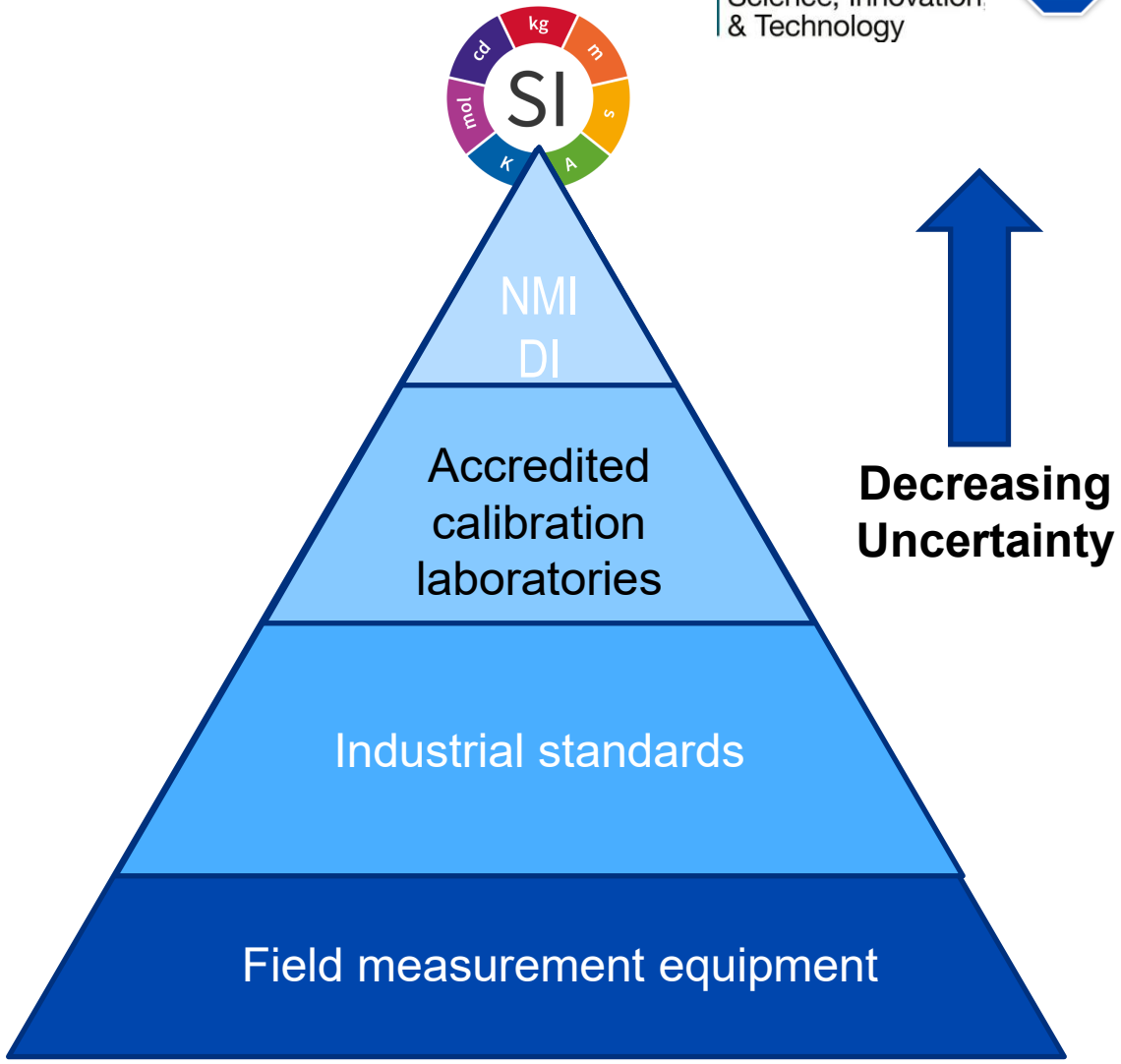
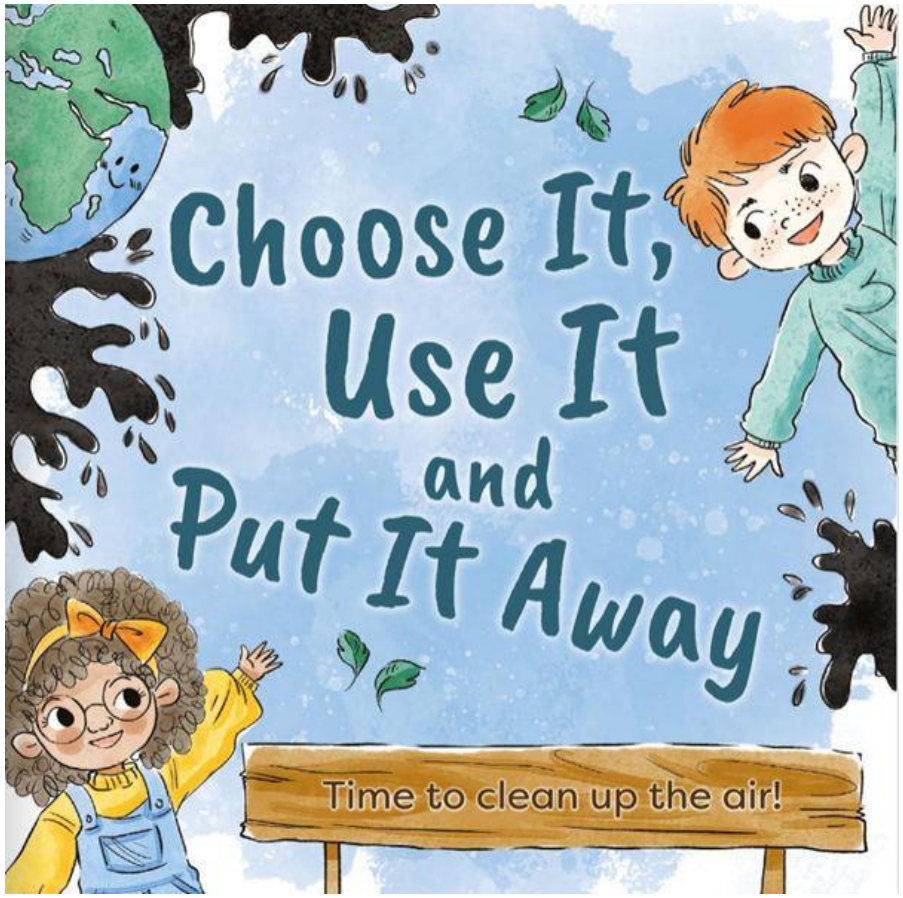
Primary Reference Materials (PRM)

- Composition analysers are calibrated against known gas mixtures
- National Measurement Institutes (NMI) can produce primary reference gas mixtures, prepared gravimetrically.
- However, the available PRMs do not cover full range of impurity concentration in CO_2.



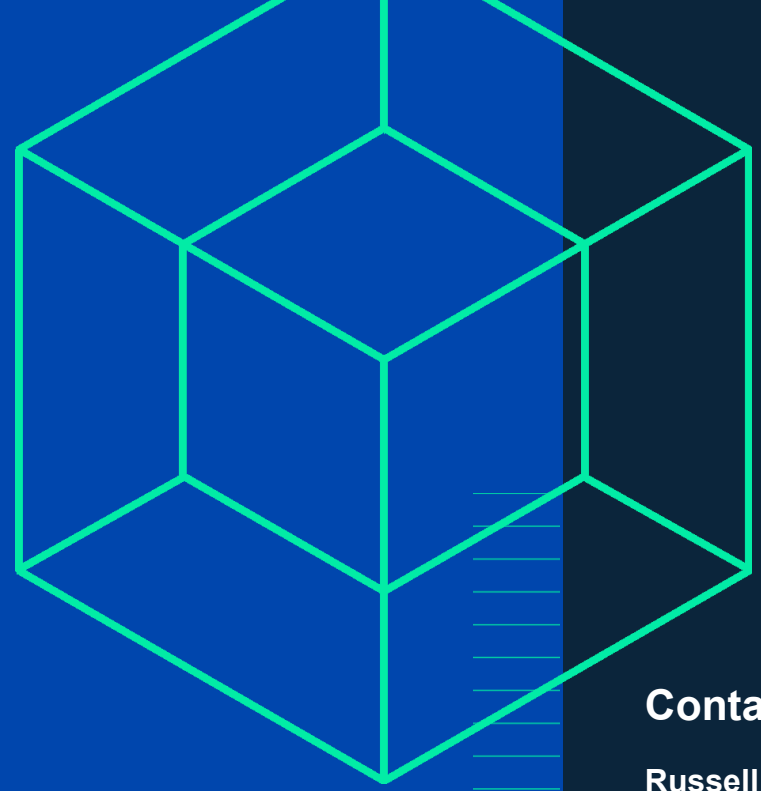
Choose It, Use It and Put It Away – Co-creation from the ENCASE Project

- NEL, The Open University & Kirkhill Primary School have co-created a children's storybook.
- The aim of the book is to teach young people about environmental responsibility and sustainable living
- In the process of developing the book the school children got the opportunity to learn more about engineering and NEL's work.



Read the free online version here!

Thank you



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