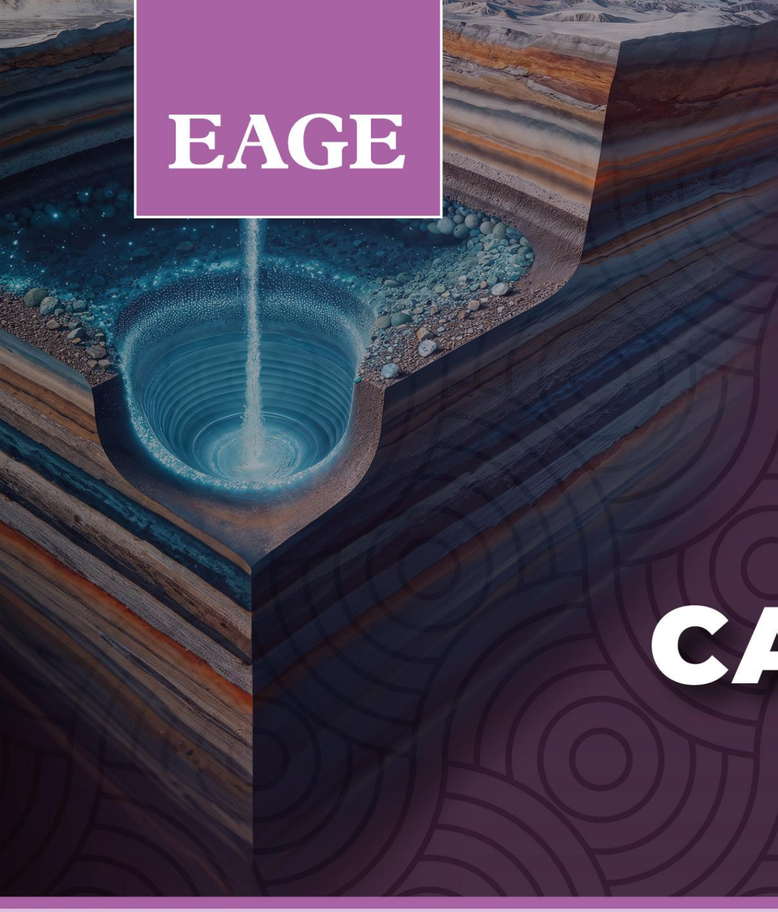

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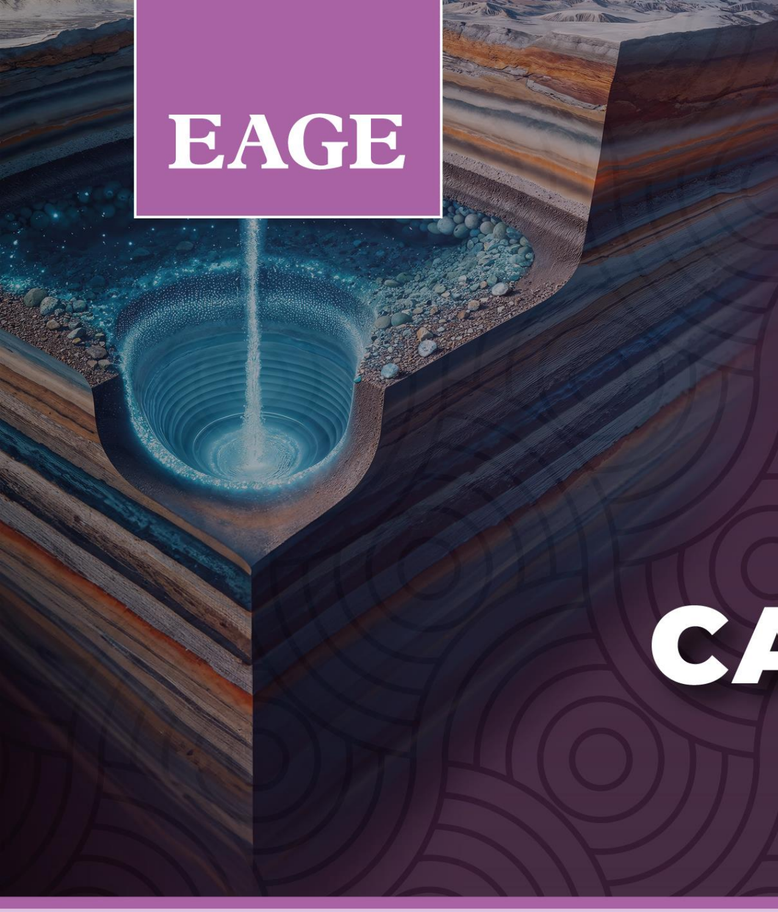
CARBON CAPTURE & STORAGE

CONFERENCE

THE PORTHOS PROJECT: HOW TO MANAGE CO_2 INJECTION IN A HEAVILY DEPLETED GAS FIELD

Marcel Bouts, Jean-Claude Hild EBN B.V. (Porthos)



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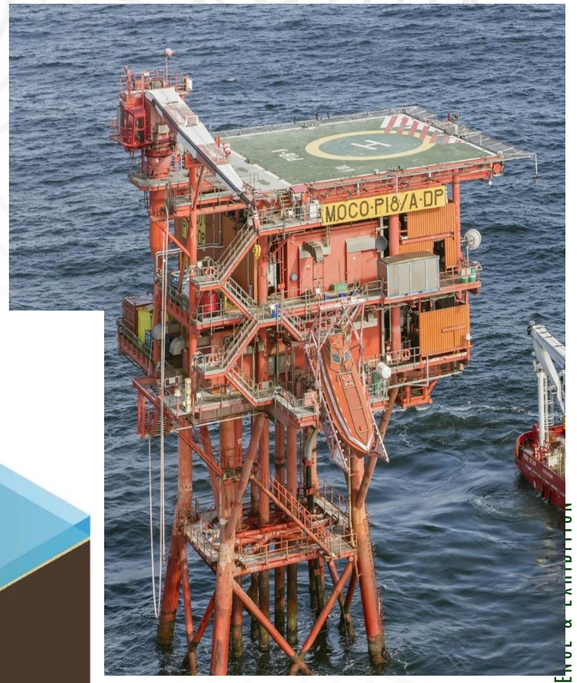
OUTLINE

- Introduction Porthos project
- Managing low CO_2 temperatures:
  - Store fill strategy
  - Pipeline and wells
  - Operational strategy supported by CALYSTO-OPM tool
  - Monitoring
- Conclusions


GAS FIELD
P18-6
GAS FIELD
P18-4
GAS FIELD
P18-2
License holder
TAQA
Platform P18-A
Compressor station Aziëweg
Porthos
gasunie
Porthos
Port of Rotterdam
Porthos
ebn
Client
Client
Air Liquide
Client
Exxon
Client
AIR PRODUCTS
Client
Rijksoverheid
Porthos
CO2 TRANSPORT & STORAGE
's-Gravenhage
Zoetermeer
Delft
's GRAVENZANDE
NAALDWIJK
HOEK VAN HOLLAND
EUROPOORT
Oostvoornse Meer
OOSTVOORNE
BRIELLE
Meer
Schiedam
Rotterdam
Vlaardingen
Heenvliet
Geervliet

PORTHOS PROJECT OVERVIEW

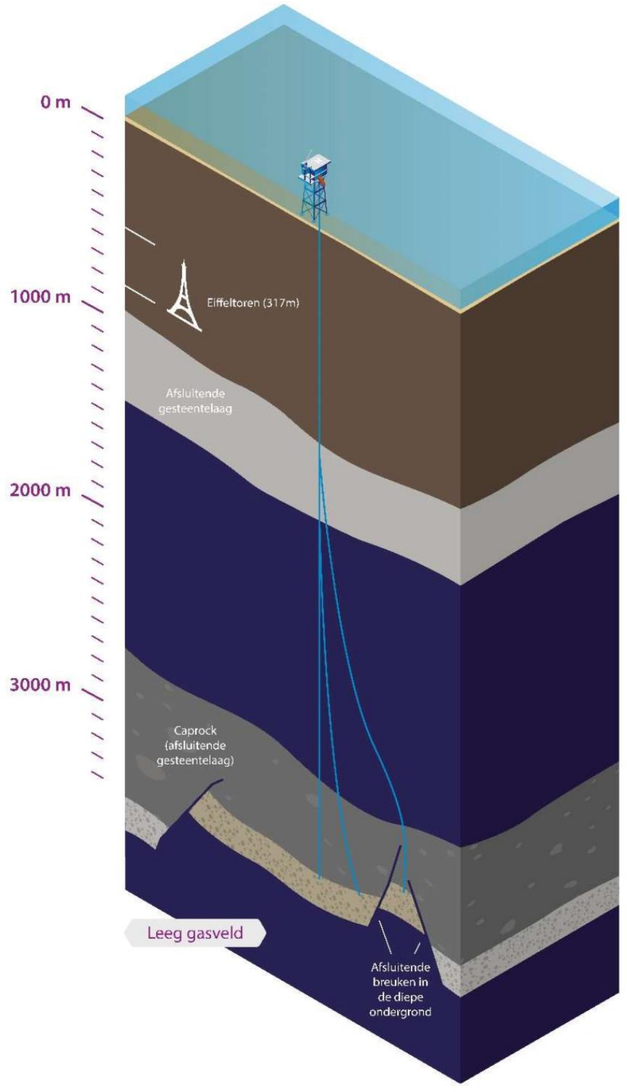
Port **O**f **R**otterdam CO_2 **T**ransport **H**ub and **O**ffshore **S**torage



- P18/A platform in 25 m water depth
- Normally unmanned satellite platform

- 6 gas production wells, originally drilled in the 90's
- 4 wells being converted to CO_2 injectors, the other 2 wells on P18/A decommissioned
- Deviated wells, max hole angle 55°

- P18-2 and P18-4 Buntsandstein reservoirs > 3200-meter depth will be filled with CO_2 (Temp res: 120 °C)
- Good perm sands: kh: 3100 – 23000 mD.m
- Gas reservoir produced from 375 bar (5400 psi) to 17 bar (250 psi)



STORE FILL STRATEGY

Volume of CO_2 to be stored:
- Total 37.5 MT
- 2.5 MT per year

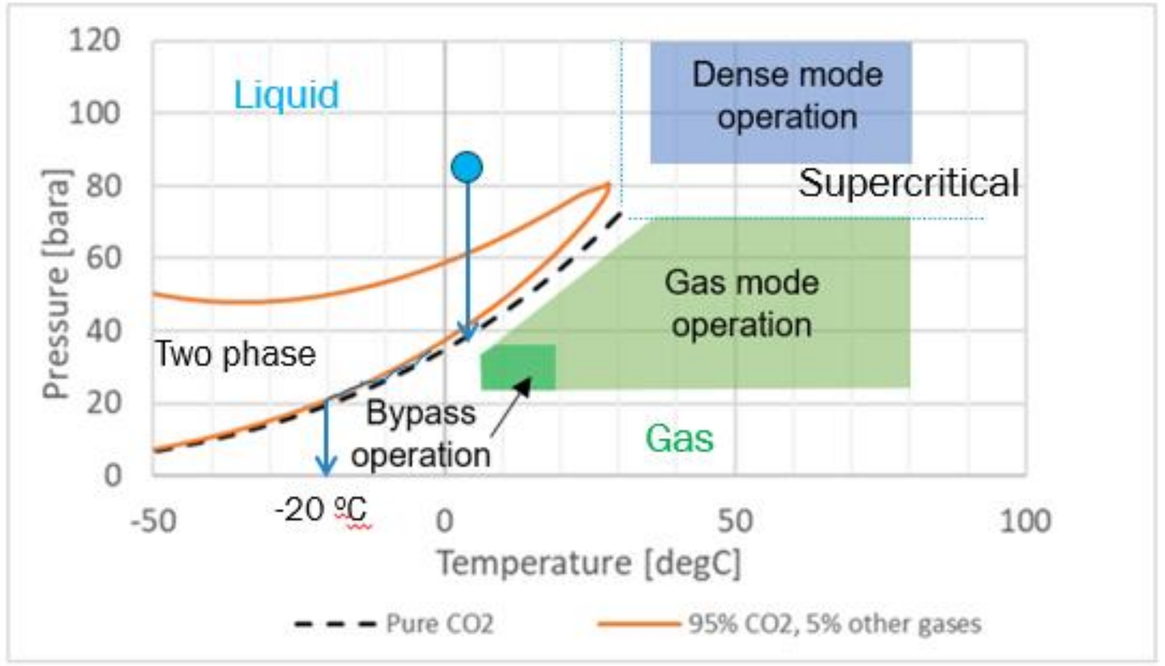
Low temperature challenge addressed:
- *CO_2 transported warm → insulated offshore pipeline*
- *CO_2 initially injected in gas phase*

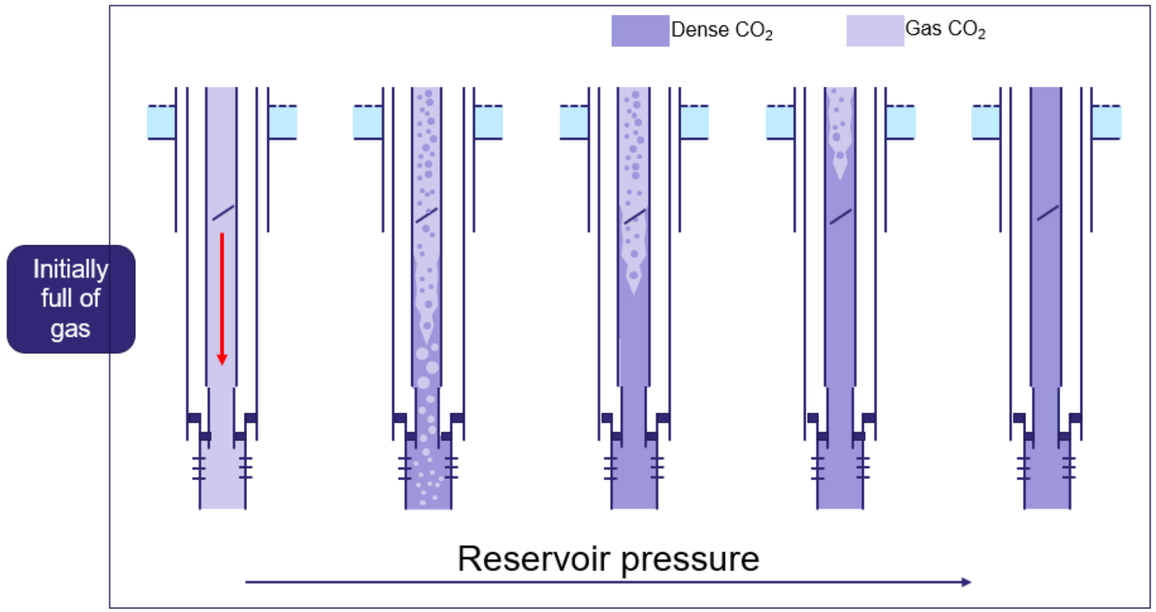
Reservoir pressure 17 – 50 bar:
- *Gas phase ~1.5 yrs*
- *max 220 t/h, 4 wells*

Reservoir pressure > 50 bar:
- *Pipeline in dense phase, wells 2-phase*
- *BHT > 15 °C*

Reservoir pressure > 250 bar
- *Pipeline & wells in dense phase*

Dense phase: 360 t/h with 3 wells

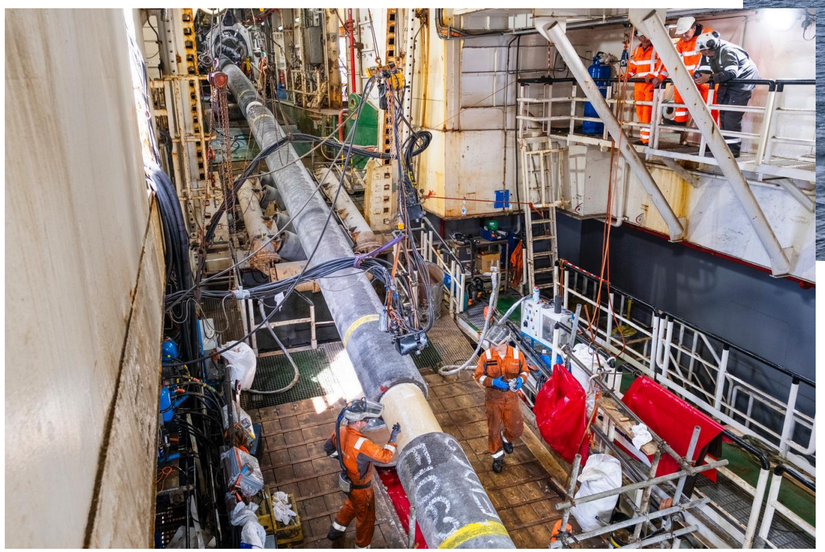




OFFSHORE PIPELINE

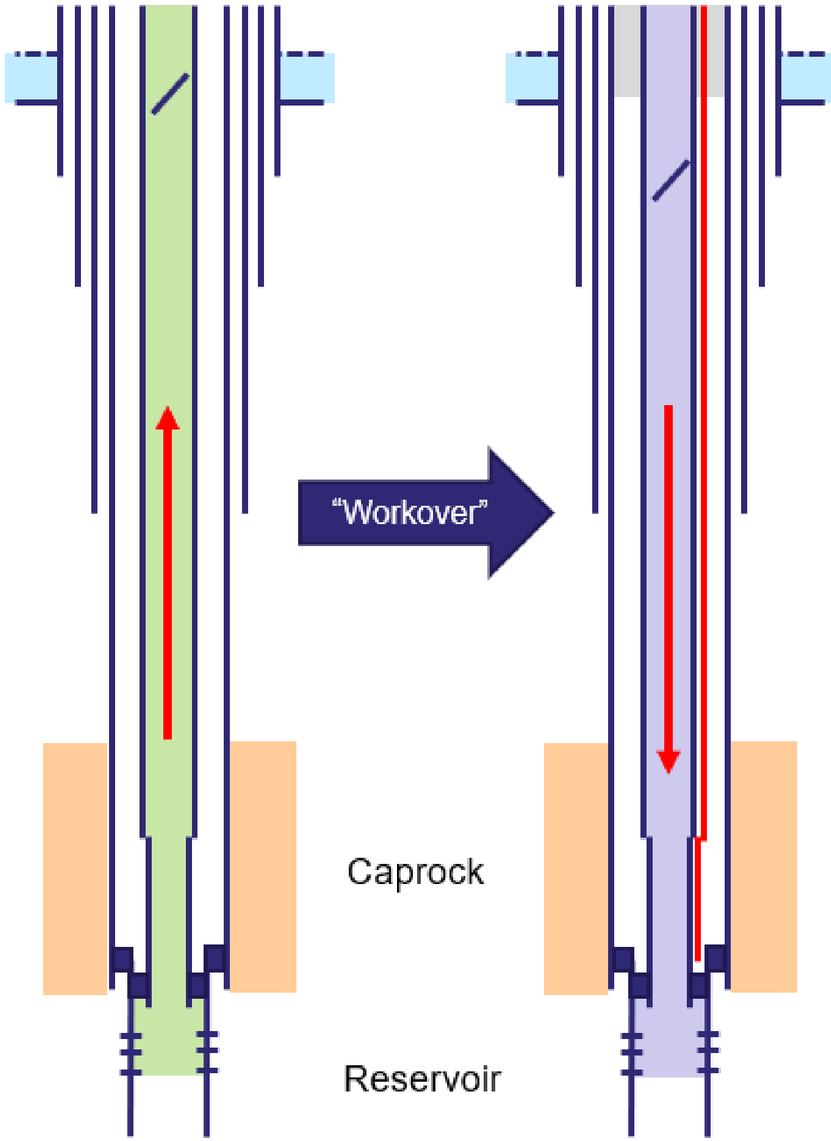
Offshore pipeline:

- Insulated: concrete, PP foam
- ± 0.8 m – 3m burial depth.
- U value: 2.4 W/m^2K
- Length ± 22 km, 16” (max. 130 bar) to P18-A.
- **Making use of the compressor heat (CO_2)**



MATERIALS WELLS

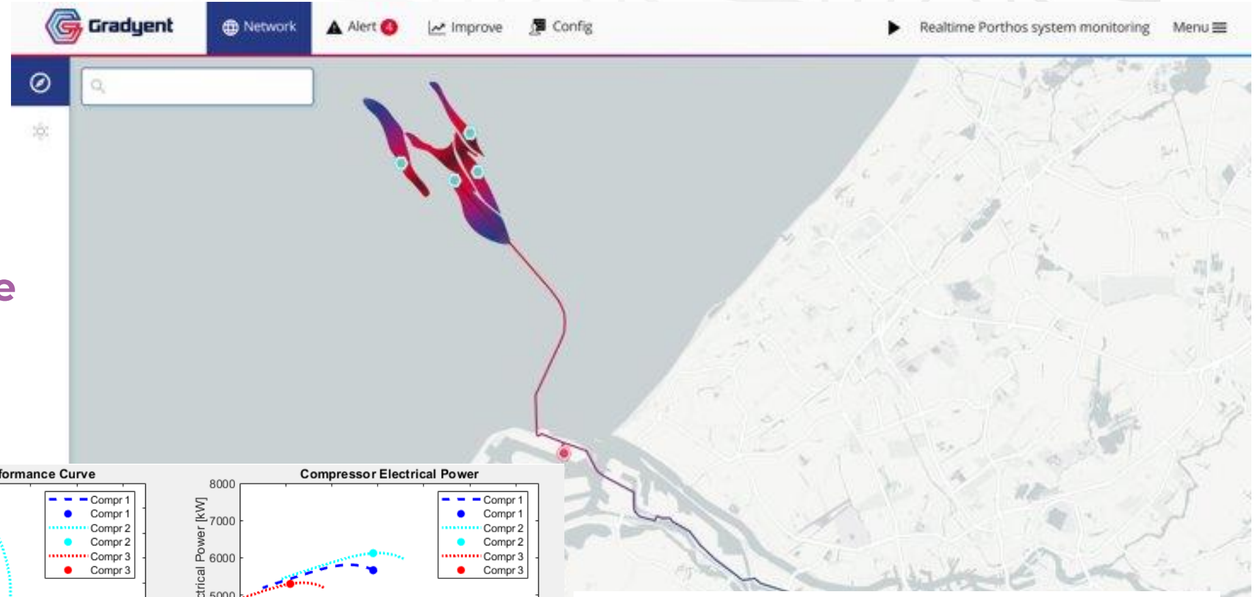
- Recomplete wells with equipment currently on the market:
  - Tubing – 5 ½” x 4 ½” string
  - Corrosion resistant materials selected (25Cr & 13sCr)
  - Further qualification tests performed where necessary
- New X-Tree and tubing spool: K rated (-60 °C), Inconel cladding
- Subsurface Safety Valve:
  - Porthos-specific low-temperature testing performed
  - -21°C functioning temp. (subsequently tested to -35 °C)
  - Survival temperature of -78.5 °C
  - Set at 500 m depth
- All elastomers/thermoplastics assessed for suitability in CO_2 and low temperatures
- Water/glycol based A-annulus fluid, with nitrogen cushion at top. Nitrogen is an excellent thermal insulator

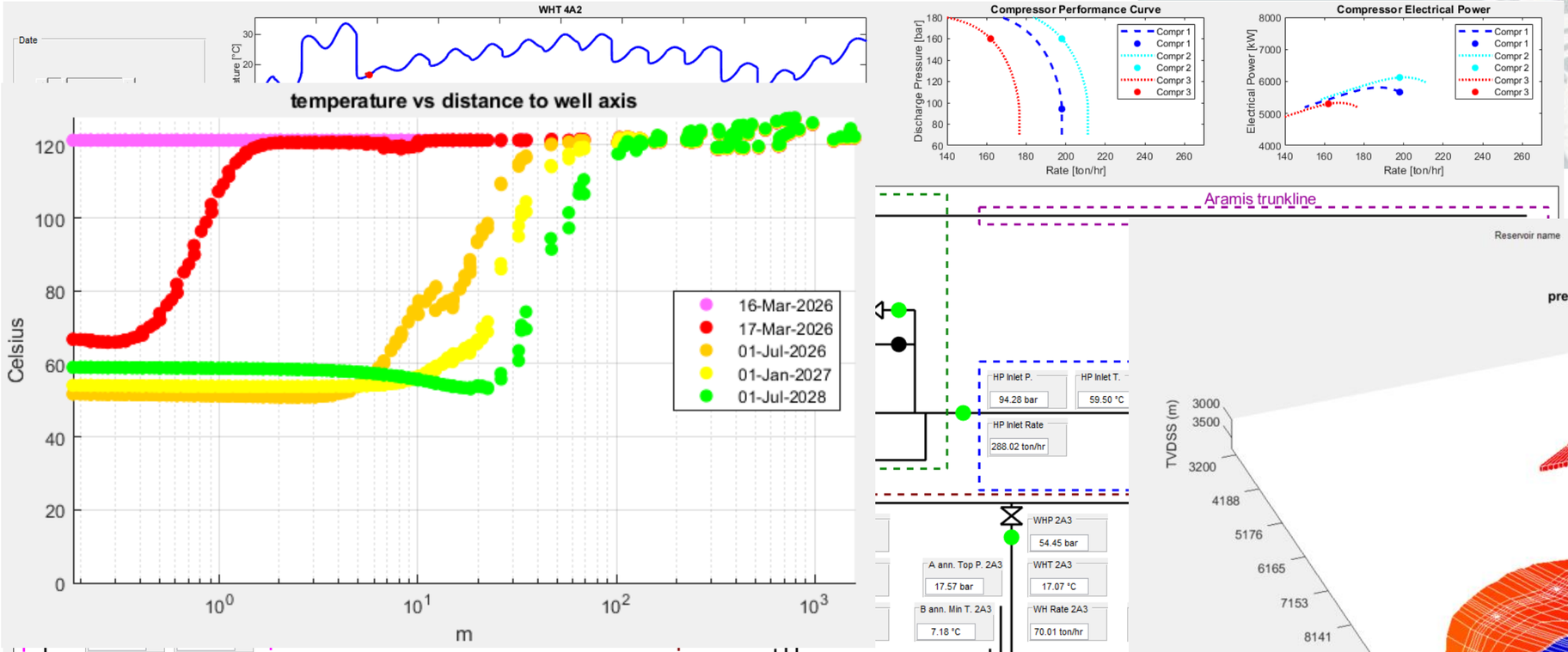


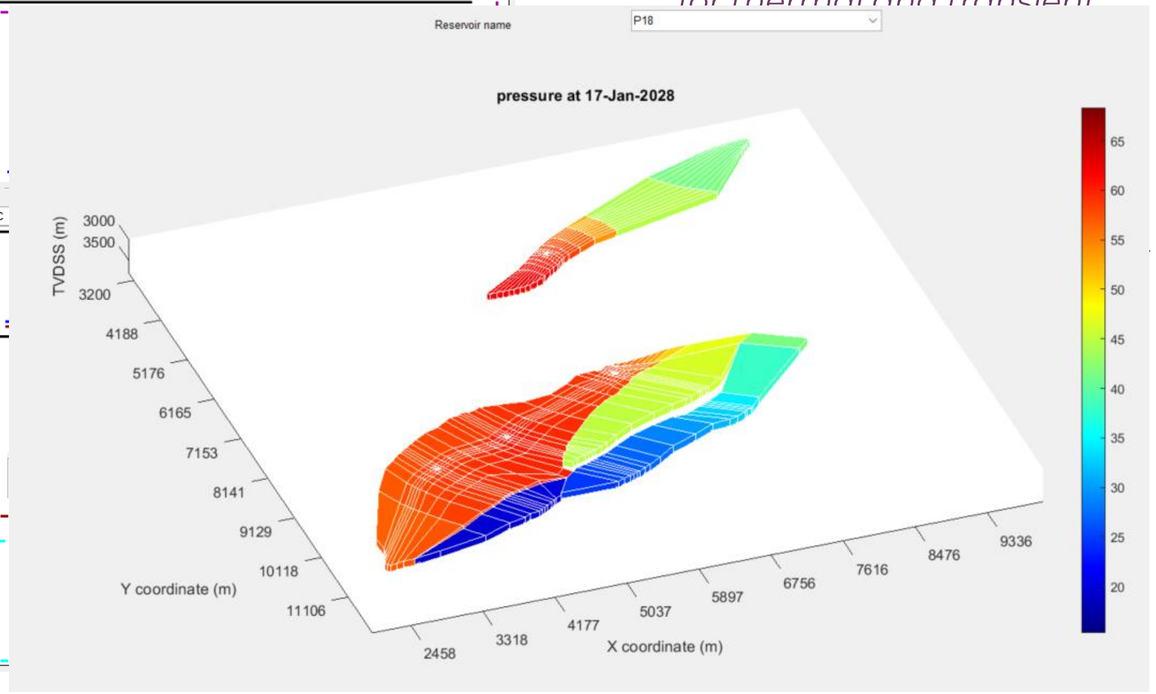
CALYSTO-OPM

Overall PORTHOS Model (OPM) is based on CALYSTO software

CALYSTO (CArbon Low enthalpY Storage Tool)



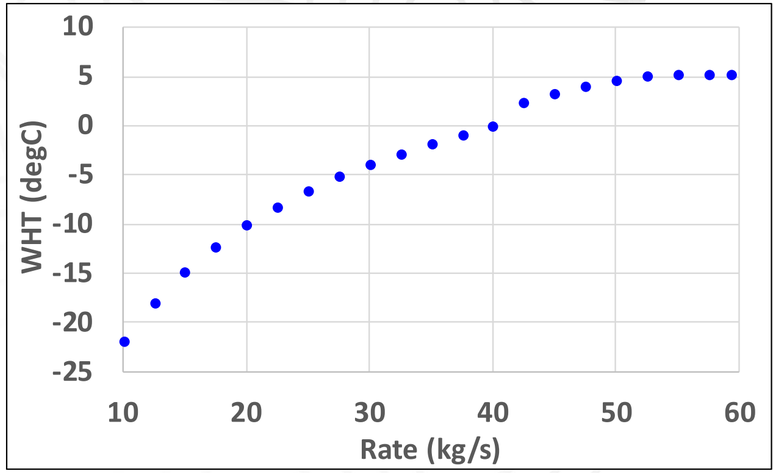




- Model Specifics:
  - *Physic based model allowing for thermal and transient*

INTEGRATED APPROACH

Well operating envelope



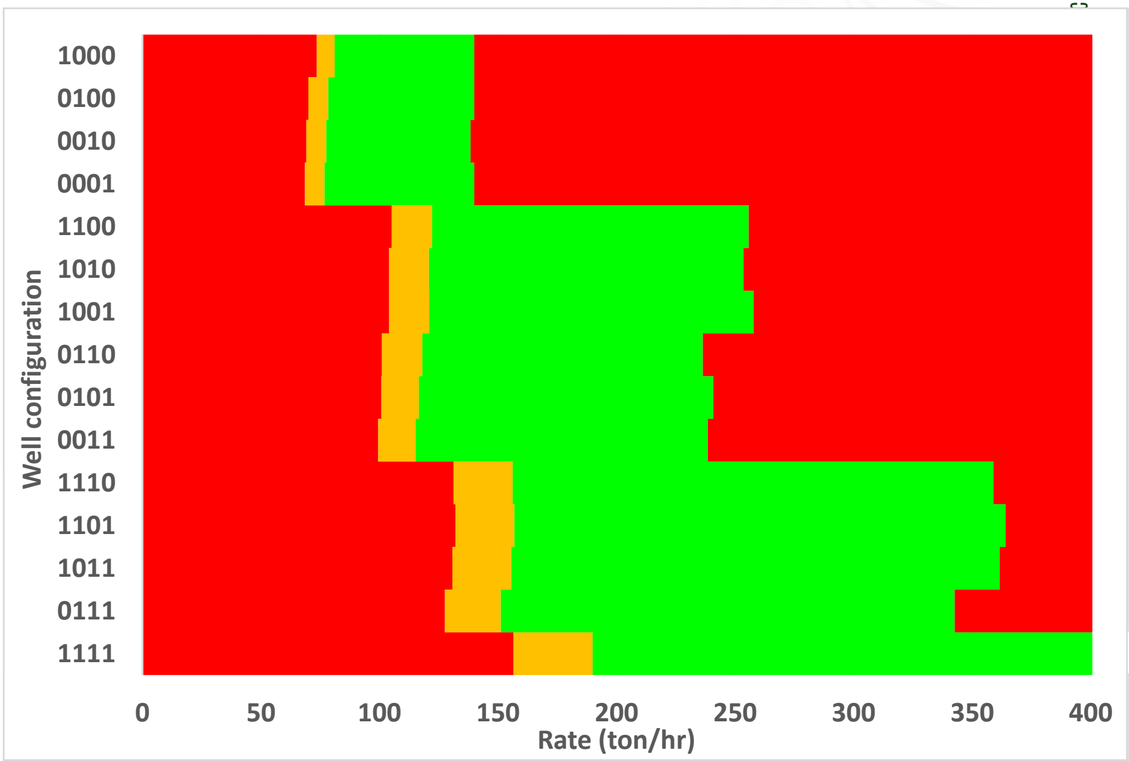
- Well challenges (some of)
  - *While injecting CO_2 wellhead conditions can go to very low temperatures*
    → minimum injection rate is required to prevent from annulus freezing, thermal failure equipment…
  - *Maximum injection rate dictated by network pressure constraint (or other constraint: erosion velocity…)*
- PORTHOS Operating Envelopes

	Min rate	Max rate	Min rate per well	Max rate per well
1 well	~70 ton/hr	~140 ton/hr	~70 ton/hr	~140 ton/hr
2 wells	~100 ton/hr	~240 ton/hr	~50 ton/hr	~120 ton/hr
3 wells	~130 ton/hr	~345 ton/hr	~45 ton/hr	~115 ton/hr
4 wells	~160 ton/hr	~440 ton/hr	~40 ton/hr	~110 ton/hr

- Individual well rate decreases with nr of wells

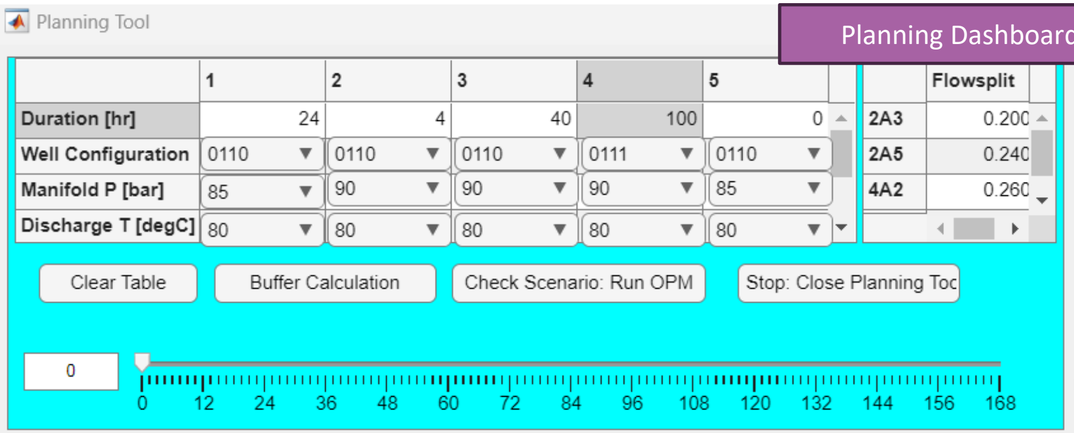
Adding wells increases the rate in the subsea pipe
→ CO_2 arrives at higher temperature and thus lower density
→ Higher friction losses in the wells, reducing each well rate

Only a fully integrated model can tackle this kind of phenomenon

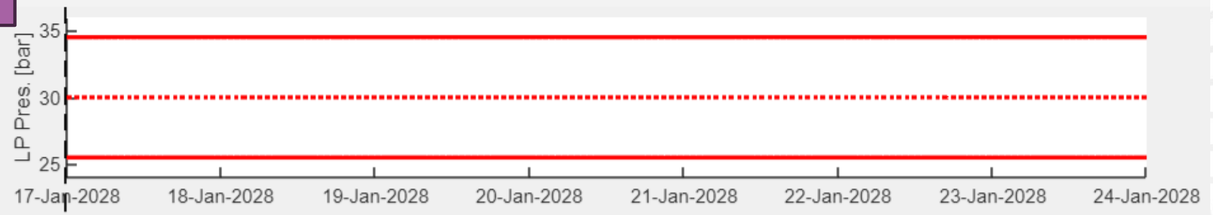


OPM “Planning tool”

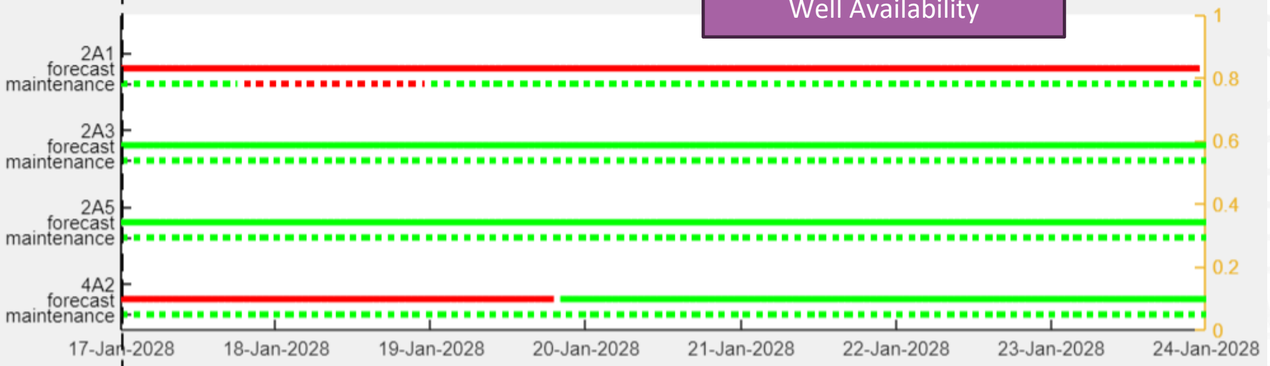
Planning Dashboard



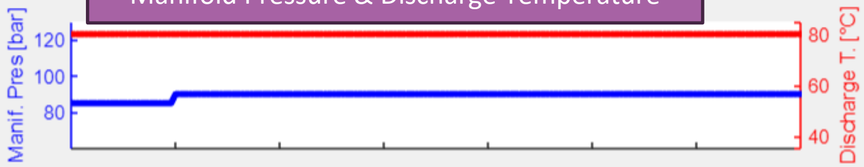
LP Pipeline Buffering



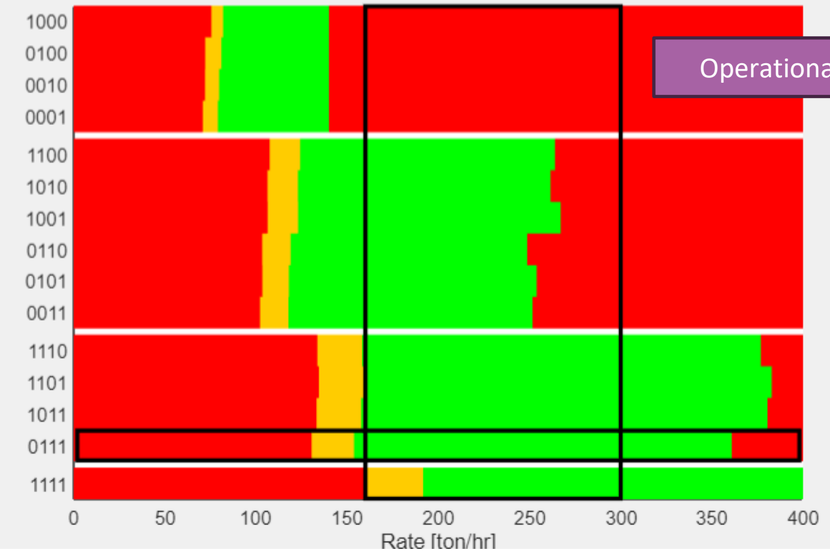
Well Availability



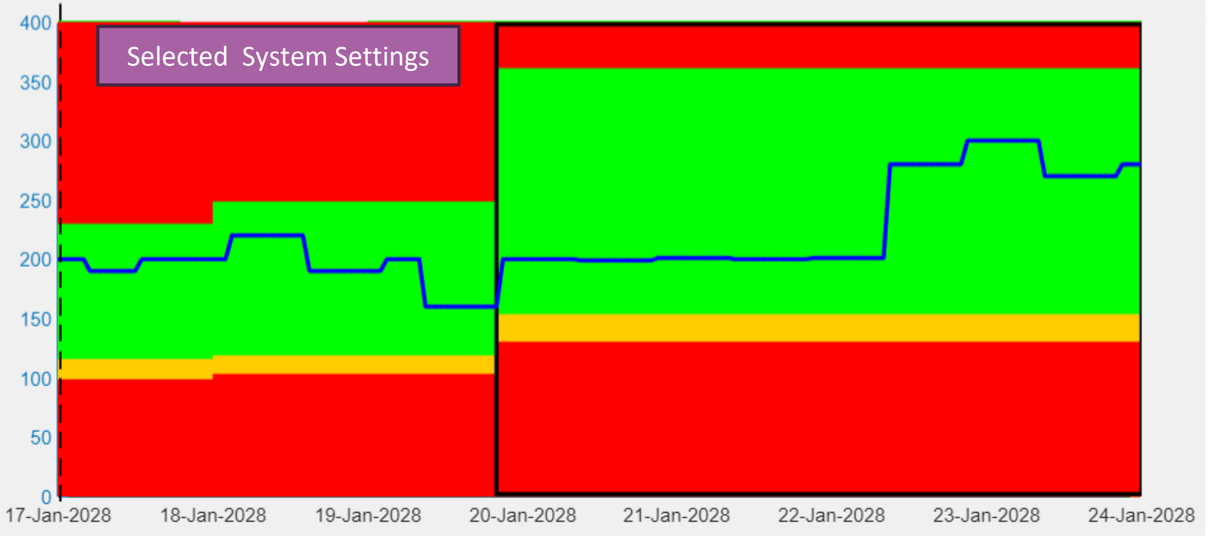
Manifold Pressure & Discharge Temperature



Operational Envelopes

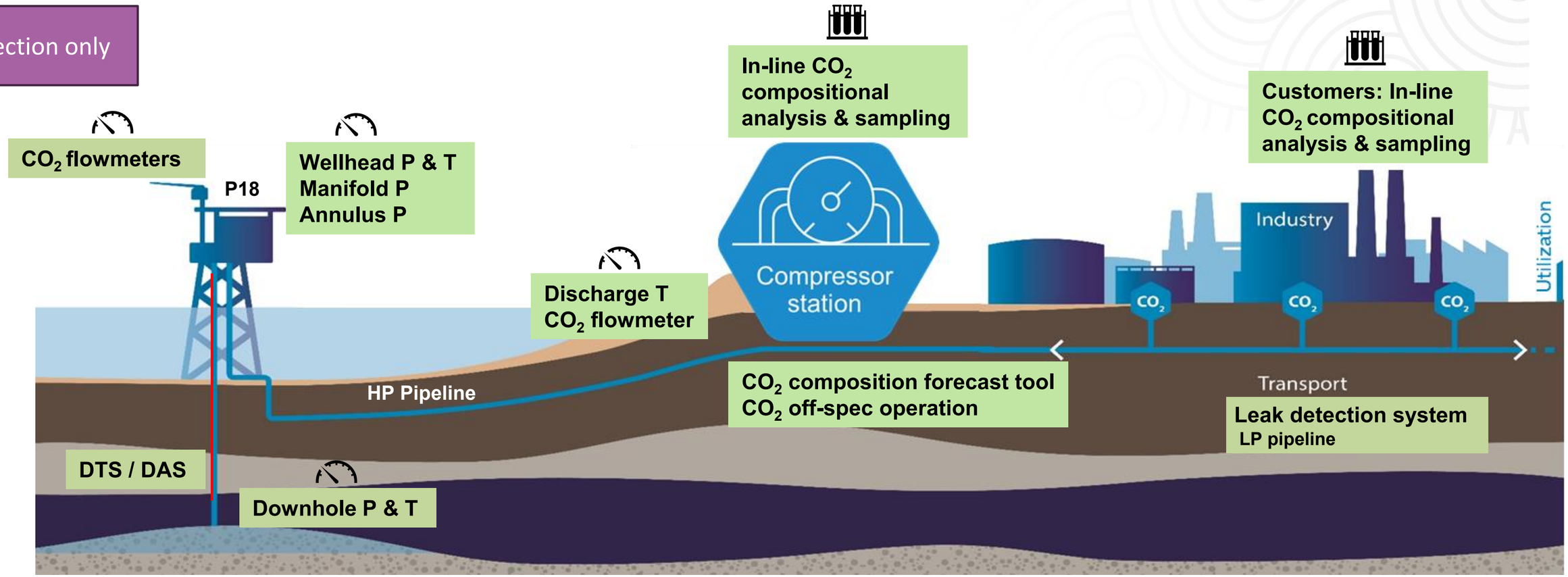


Selected System Settings



Porthos System: Metering & Analysis Overview

Selection only

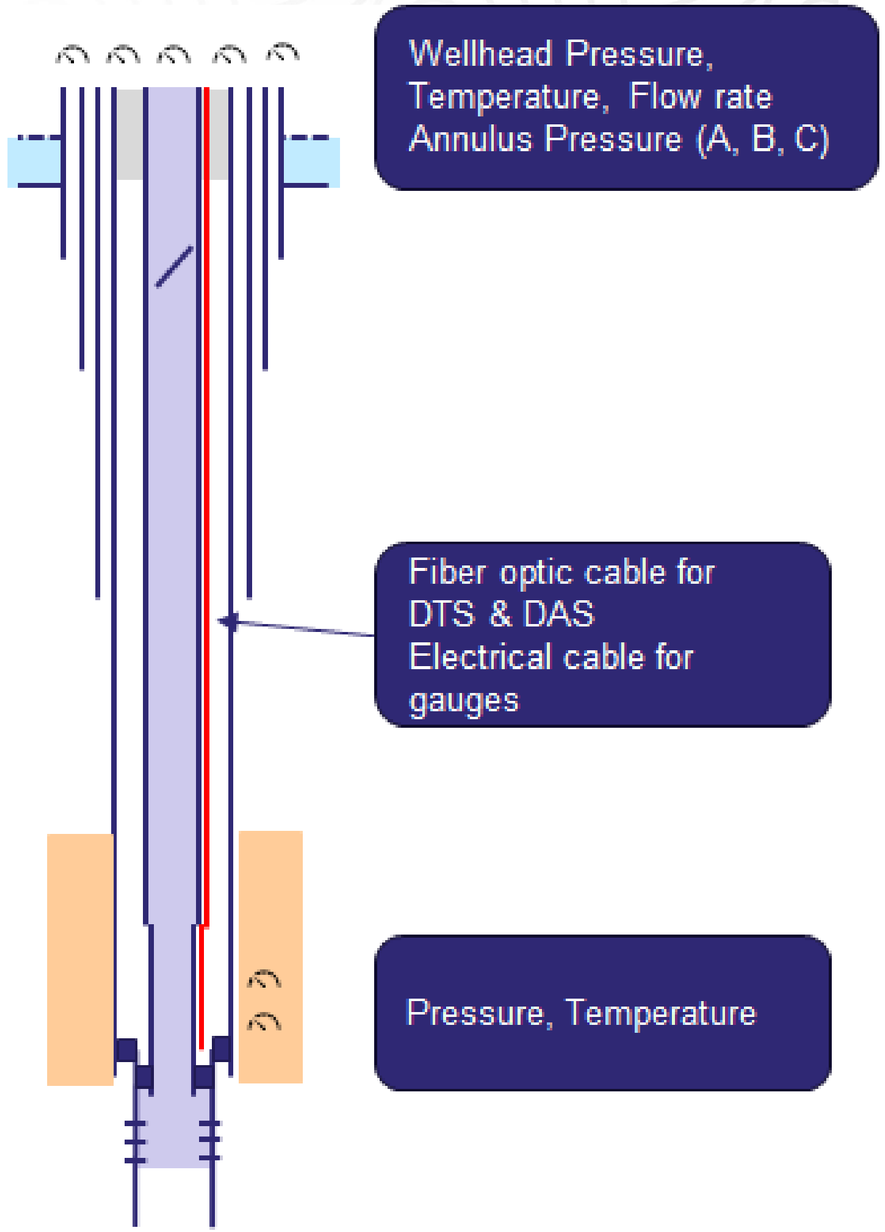


Continuous monitoring to safeguard the system and manage injection of CO_2 in wells at low pressure:

- **CO_2 compositional analysis for safety (NOx, S, H_2O etc.) and phase behavior**
- **Pressure and temperature monitoring, especially for the wells**
- **Each well equipped with downhole temperature and pressure sensor**
- **Each well has fiber optic cables for DTS and DAS surveys**

WELL MONITORING

Monitoring item	Purpose
Surface: Wellhead pressure Flow rate (Coriolis meters) Wellhead temperature Annulus pressure (A, B, C)	 Injection control Injection distribution wells Avoid freezing annulus Well integrity
Fiber optic cable, along well: DTS (Distributed Temperature Sensing) DAS (Distributed Acoustic Sensing)	 Temperature control, leak detection, SSSV testing Detection flow in cement, overburden
Downhole: Pressure Temperature	 Injectivity, conformance control Prevent hydrate formation



CONCLUSIONS

Safe injection of CO_2 into heavily depleted reservoirs should include the following:

- Where possible, adjust your store fill strategy to avoid subzero temperatures
- Make use of existing heat from the compressors and insulated pipelines
- Select the correct well design and materials
- An integrated CO_2 system injection tool (CALYSTO-OPM) has been developed that can assist in the correct setting of the system (compressor, manifold, well line-up) to avoid low temperatures.
- Monitoring of a large number of parameters during injection is important for safe injection and history matching of the model

ACKNOWLEDGEMENTS

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