Porthos

CO2 transport and offshore storage from Rotterdam, the Netherlands

Michiel Spits
June 14, 2022

Co-financed by the Connecting Europe Facility of the European Union

Porthos
CO_2 TRANSPORT & STORAGE

Development of CC(U)S in the Netherlands

Porthos CO_2 TRANSPORT & STORAGE & ARAMIS

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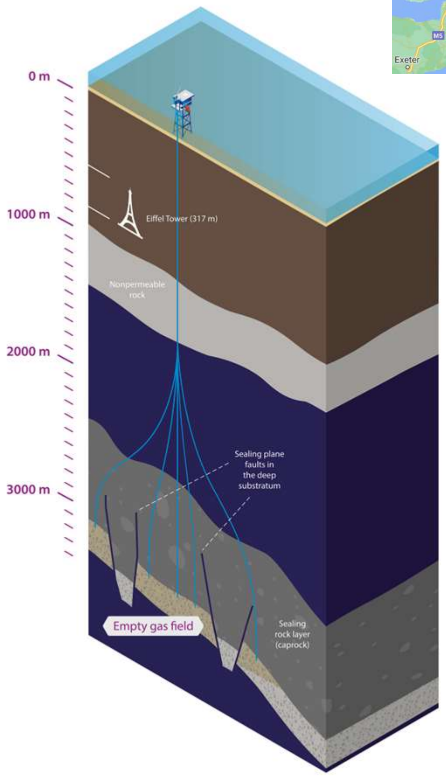
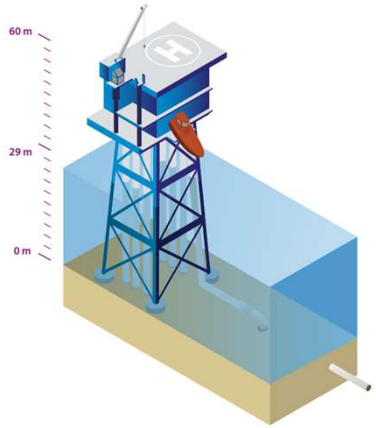
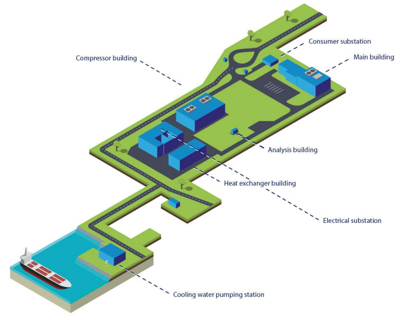


Re-use of depleted gas fields

Onshore & offshore pipelines



Re-use of platform



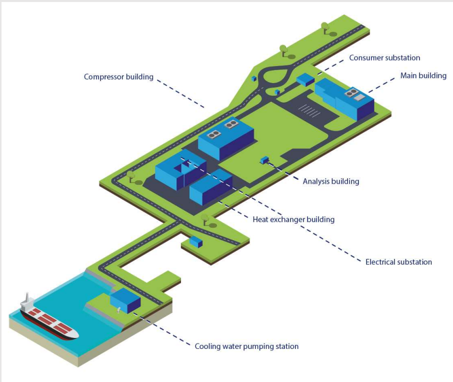
New compressor station

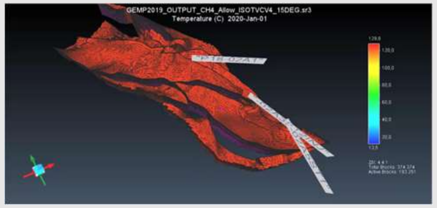
Ready for FID

Client contracts
have been signed, subsidies have been granted

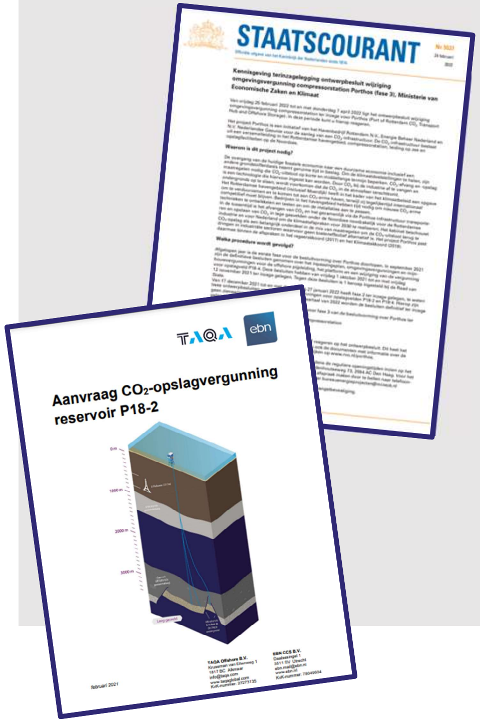
Air Liquide, Air Products, ExxonMobil, Shell

FEED engineering
has been completed





Storage license
concept received from Ministry



Succesfull decommissioning
of complex well

Look ahead

Current

- Permit procedures
- Technical preparations
- FID deliverables
- European tenders construction compressor station and offshore pipeline

Second half of 2022

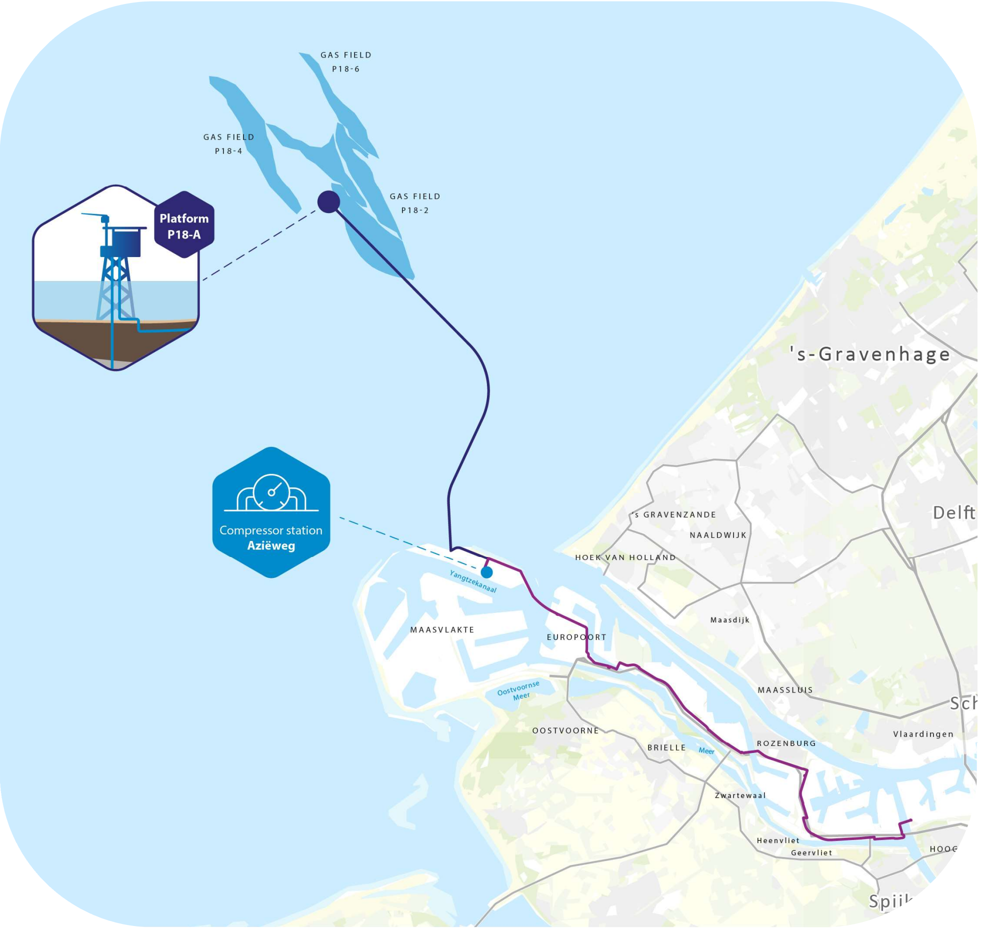
- Final Investment Decision (FID)

2023

- Start construction

2024/2025

- System operational



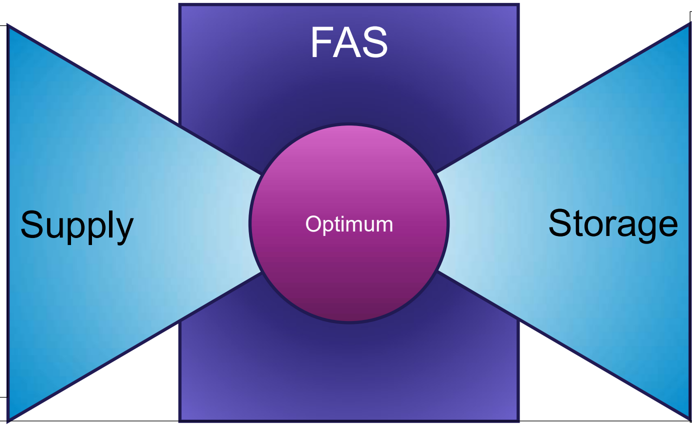
Goal and System Approach for start-up and operation

Goal:

Have a safe and operable system able to transport, inject and maintain CO_2 from emitter into storage reservoir.

Supply:

- Storage capacity, at least 2.5 Mton CO_2/annum
- Transport capacity 360 t/h
- 4 Emitters, supply curve data
- SDE++ criteria (subsidy 15 years)
- CO_2 composition



Storage:

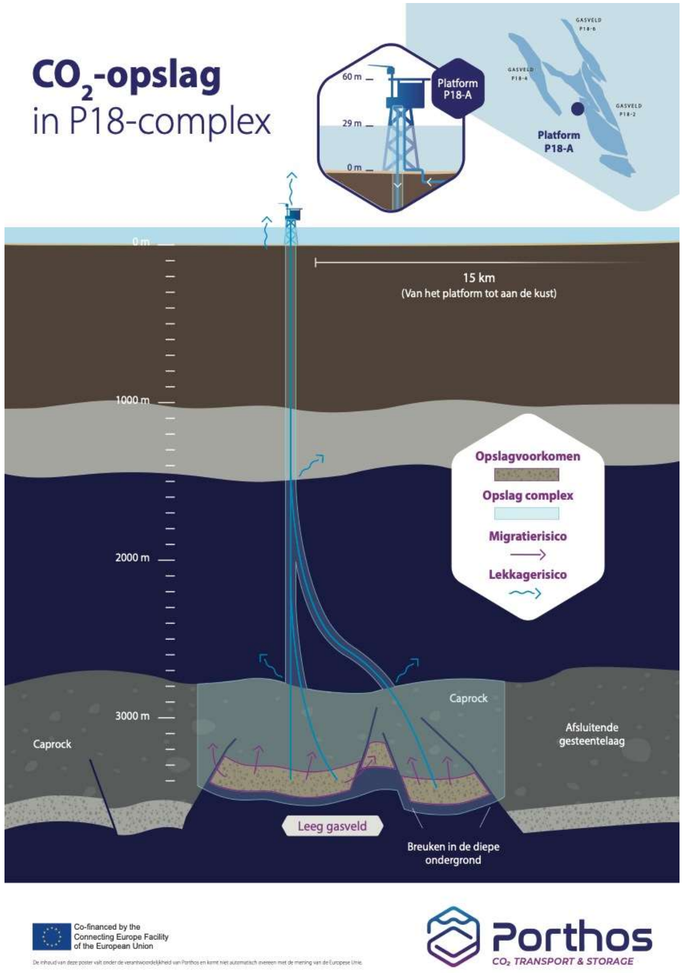
- P18-2/4/6 Reservoir characteristics
- Constraints: Injectivity, Well Integrity, Geo-mechanical, Near well behaviour, Max. cooling potential reservoir (Thermal effects on formation)
- Function of each reservoir
- Storage Capacity: 37 Mton

FAS (flow assurance study):

- Operating Envelope (normal, transients, start-up, depressurisation and shutin)
- Constraints: Thermodynamics (downhole temp > 15°C and wellhead > 0°C @ steady state), JT effects, Cold start-up, Slugging
- CO_2 phase behaviour, ref CO_2 specification.

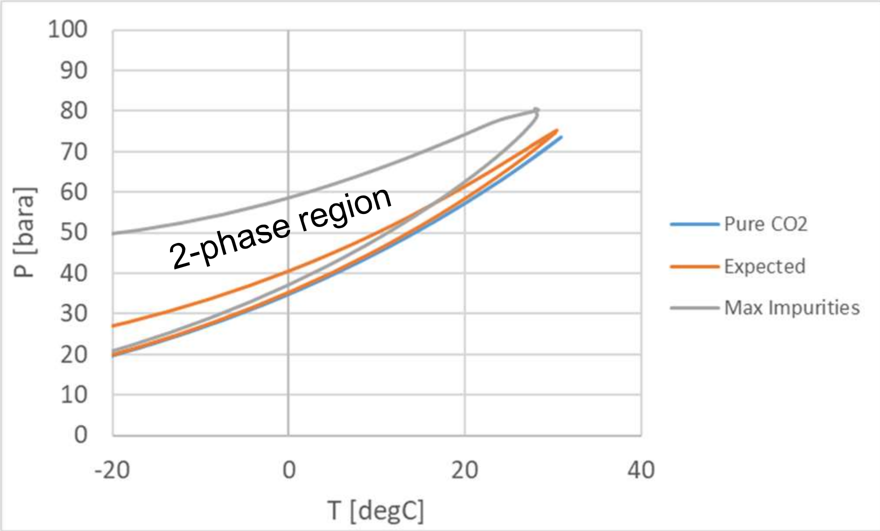
Storage in depleted gas fields is new

- Gas fields have a proven **geological containment**
- Reservoir pressure is **low** (20 bar, was >350 bar)
- CO2 **transport** is high pressure, **dense** mode
- Challenge is **pressure drop**
- **Temperature** drops with pressure drop
- **Low** temperatures in wells and reservoir
- Reservoir pressure will remain lower than (CO2) **virgin pressure**
- CO2 specification affects **phase behaviour**



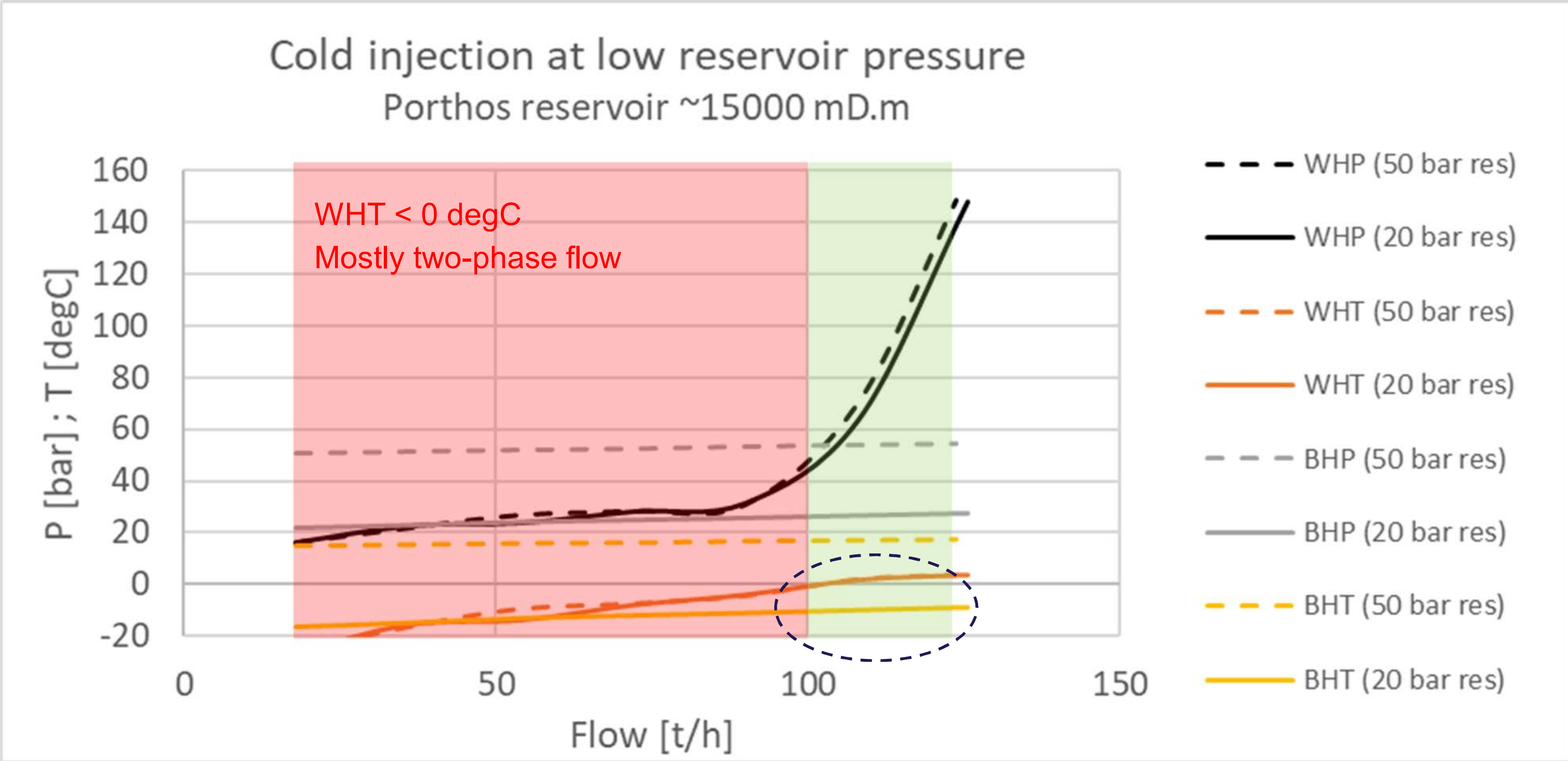
Effect of composition

Component	Mole basis:
CO_2	≥ 95%
H_2O	≤ 70 ppm
Sum [H_2+N_2+Ar+CH_4+CO+O_2]	≤ 4%
H_2	≤ 0.75%
N_2	≤ 2.4%
Ar	≤ 0.4 %
CH_4	≤ 1%
CO	≤ 750 ppm
O_2	≤ 40 ppm
Total sulfur-containing components (COS, DMS, H_2S, SO_x)	≤ 20 ppm
H_2S	≤ 5 ppm
Ethanol	≤ 20 ppm
Methanol	≤ 620 ppm
Hydrogen cyanide (HCN)	≤ 2 ppm
Ammonia (NH_3)	≤ 3 ppm
Total NO_x	≤ 5 ppm
Total aliphatic hydrocarbons (C2 to C10)	≤ 1200 ppm (0.12%)
Total aromatic hydrocarbons (C6 to C10 incl.BTEX)	≤ 0.1 ppm
Total volatile organic compounds (excl. methanol, ethanol, aldehydes)	≤ 10 ppm
Total aldehyde components	≤ 10 ppm
Total amine components	≤ 1 ppm
Total glycol components	Covered by dewpoint line
Total carboxylic acid and amide components	≤ 1 ppm
Total phosphorous-containing components	≤ 1 ppm
Dew point for all liquids (for full composition)	< -10 °C (at 20 bara)

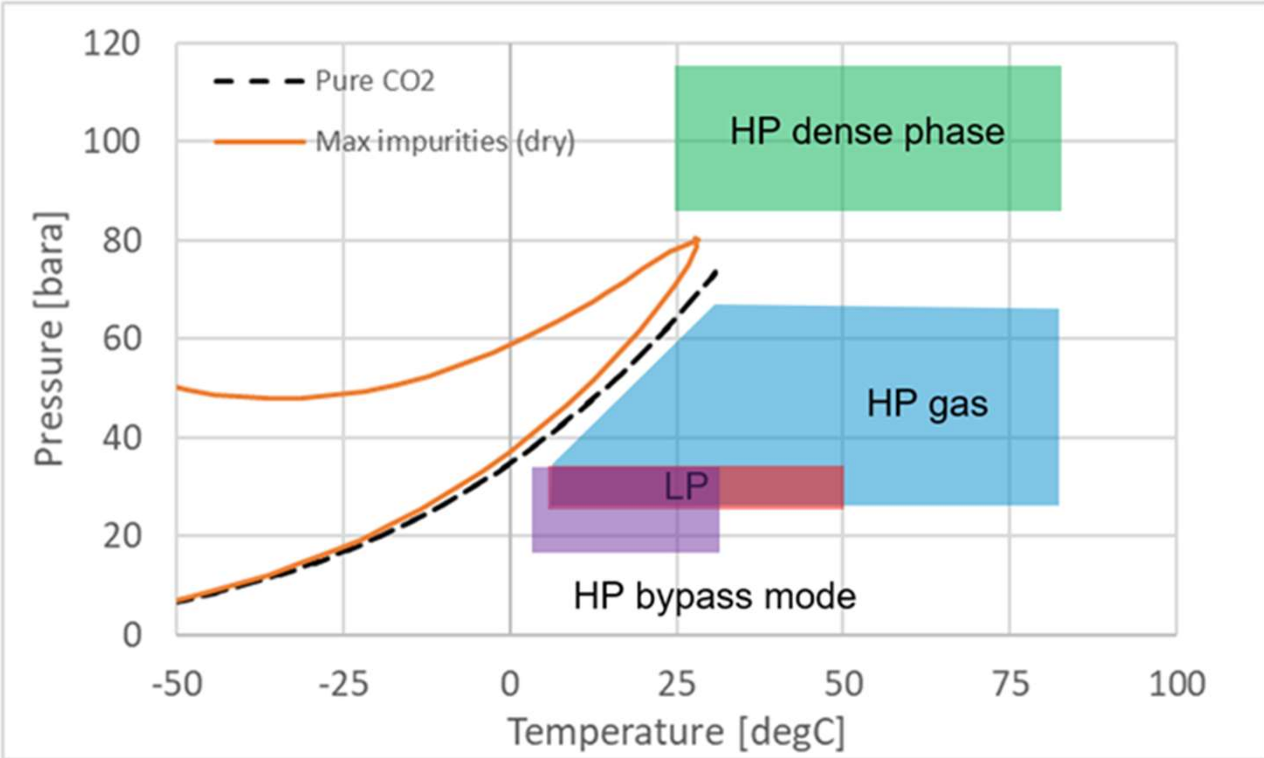


Comp	Pure CO_2	Expected	Max impurities
CO_2	100	99.04	95.45
H_2		0.19	0.75
CH_4		0.14	1
CO		0.05	0.4
N_2		0.58	2.4

Rationale of Warm Injection Philosophy:
What if => Cold injection – bottomhole conditions



Rationale of Warm Injection Philosophy: Solving BHT issue – gas phase injection



Rationale of Warm Injection Philosophy: Compared to cold injection above 50 bar

- Above 50 bar BHT problems disappear
- Narrow operating envelope remains issue!

- Top: Porthos operating envelope

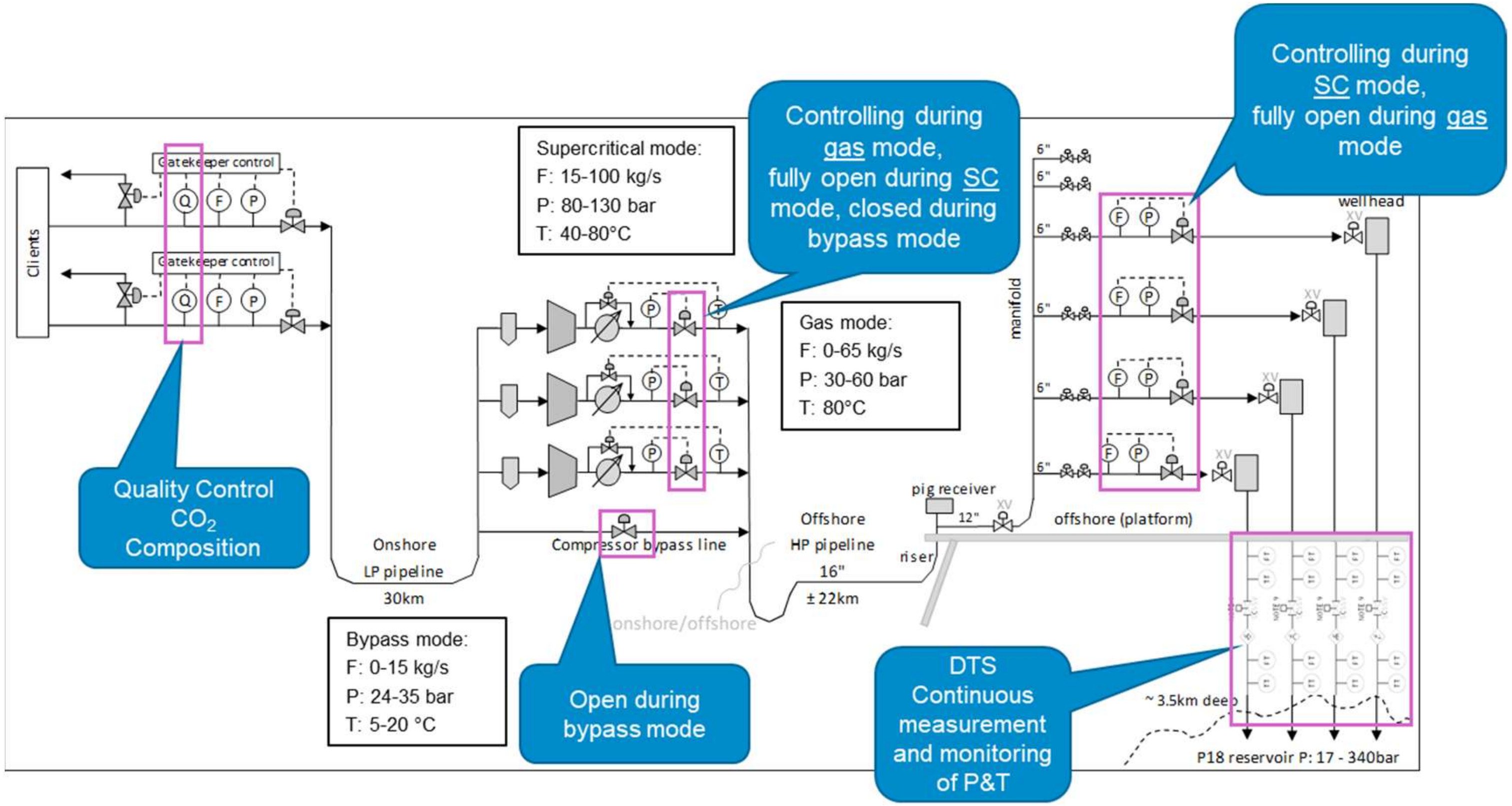
Pres = 50 bar; Sep model; Pman = 85 bar; Tinlet = 80 C; minimum Twh = 0 C																								
Config	Opene	20t/h	40t/h	60t/h	70t/h	80t/h	90t/h	100t/h	120t/h	140t/h	150t/h	160t/h	170t/h	180t/h	200t/h	220t/h	240t/h	260t/h	280t/h	300t/h	320t/h	340t/h	360t/h	380t/h
1000	1	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0100	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0010	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0001	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100	2	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
1010	2	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
1001	2	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0110	2	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
0101	2	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0011	2	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
1110	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1101	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1011	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0111	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1111	4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

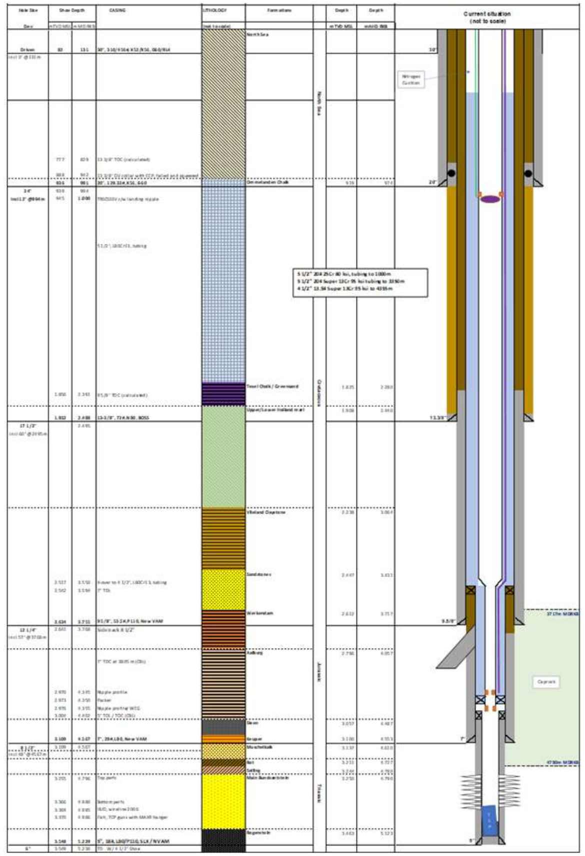
- Bottom: operating envelope with cold injection

- Project requirement for Porthos to have continuous flow range between 80 – 360 t/h cannot be met

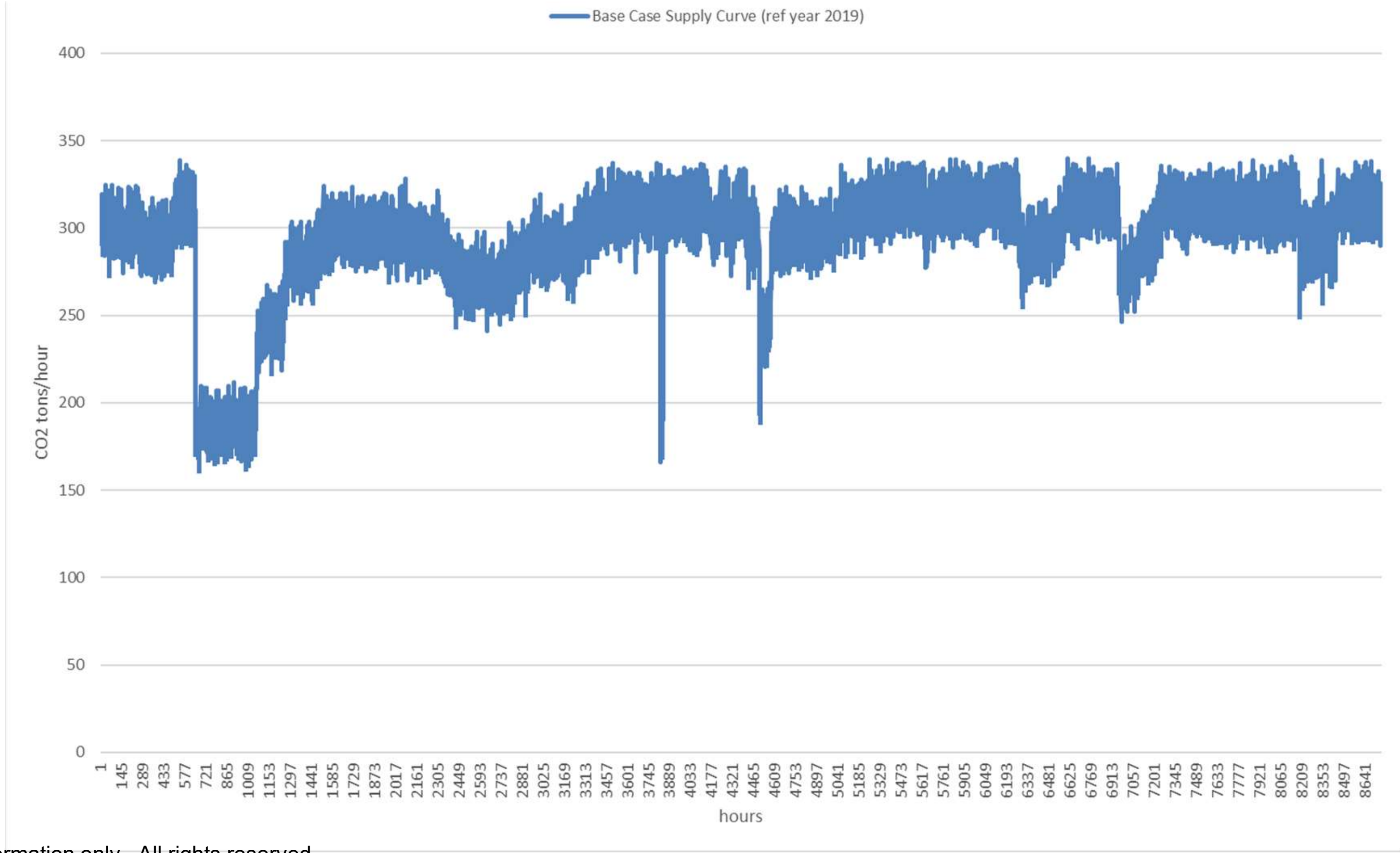
Pres = 50 bar; Sep model; Pman = 85 bar; Tinlet = 80 C; minimum Twh = 0 C																								
Config	Opene	20t/h	40t/h	60t/h	70t/h	80t/h	90t/h	100t/h	120t/h	140t/h	150t/h	160t/h	170t/h	180t/h	200t/h	220t/h	240t/h	260t/h	280t/h	300t/h	320t/h	340t/h	360t/h	380t/h
1000	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0100	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0010	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0001	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
1010	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
1001	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
0110	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
0101	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
0011	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
1110	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
1101	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
1011	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
0111	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
1111	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Operational limits & control philosophy

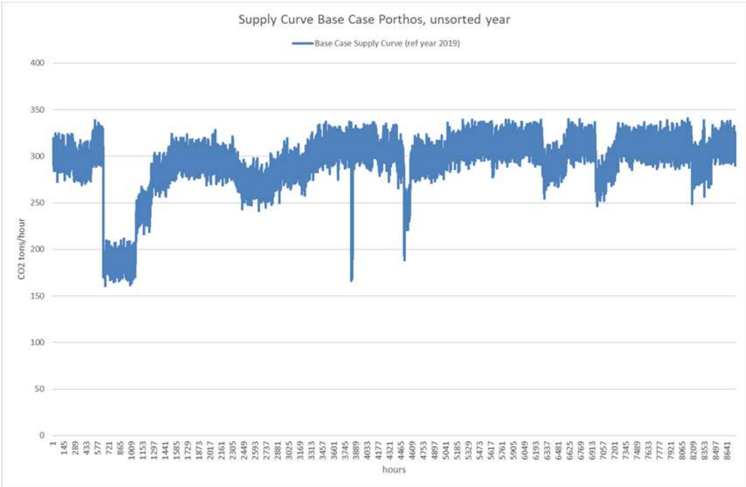


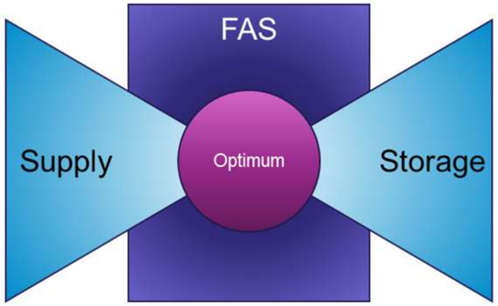


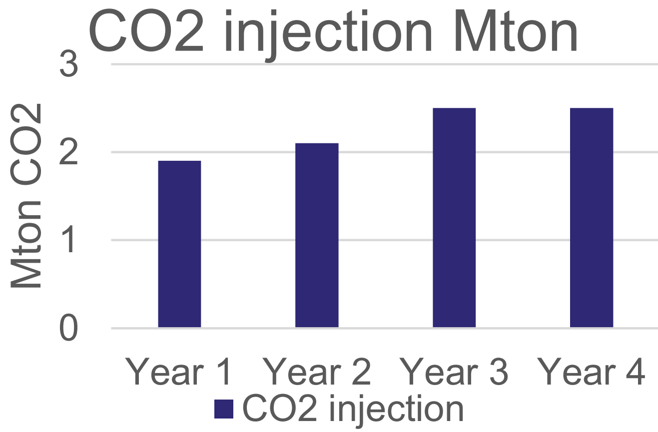
Supply Curve from Emitters to Porthos



Operating the base case:

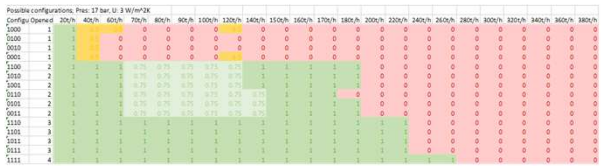


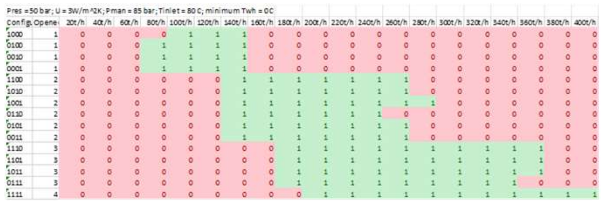




Injection plan / Operating Envelopes Wells

Technical operation (T.O.)	Step	Time ending	P.res. [bar]	Short description	Flow rate avg [t/h]	Flow rate range [t/h]	Nr. of wells	Mode	Annual avg (8500 hrs) [Mt/a]	Accum. P18-2 & P18-4 [Mt]
	1	Day 1	17	First start-up, increase to 80t/h & 3 wells	80	0 - 80	1-3	Bypass mode	1,86	1,86
	2	Day 5		Commission compressor		0 - 80	3			
	3	Day 6		Increase flow		40 - 220	3	Gas phase mode		
	4	Month 5	20	Operate flows < 220-240t/h with 3 wells, depending on configuration and < 280t/h with 4 wells.Note1	200	40 – 220 (– 280)	3 (-4)			
	5	Month 9	30	Operate flows < 240t/h with 3 wells and < 280t/h with 4 wells.Note1,2	220	40 – 240 (– 280)	3 (-4)			
	6	Month 15	40	Maximum 240t/hNote2 with configurations 0111, 1011 and 1101Note1 and with 4 wells.	220	0 – 240	3 (-4)			





Thank you for your attention!

For more information, please visit:
www.porthosCO2.nl

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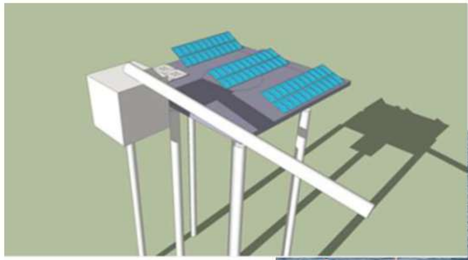
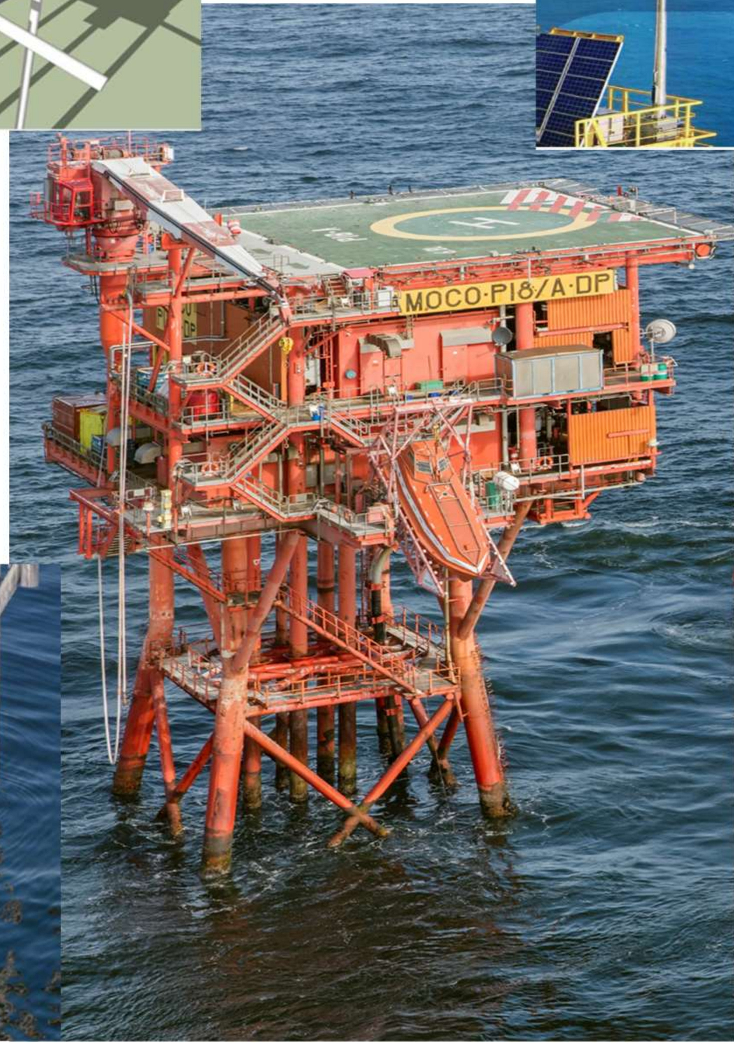
Back-Up

Reuse of Facilities

- Life time extension assessment
- Convert to zero emissions platform
- Maintenance philosophy: from break-down to preventive
- Concurrent operations: gas production & CO_2 injection
- Change operations & logistics to daylight only and boat access
- Gas price development impacts cease of production dates





Re-use of gas wells

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Well integrity
- Cement bond logs reliable?
- Status of casing, liners and conductors
- Annulus pressures

Well Design
- New completions
- Thermal loads and tubing of Cr25
- DTS / DAS monitoring
- Developed SSSV’s for arctic conditions

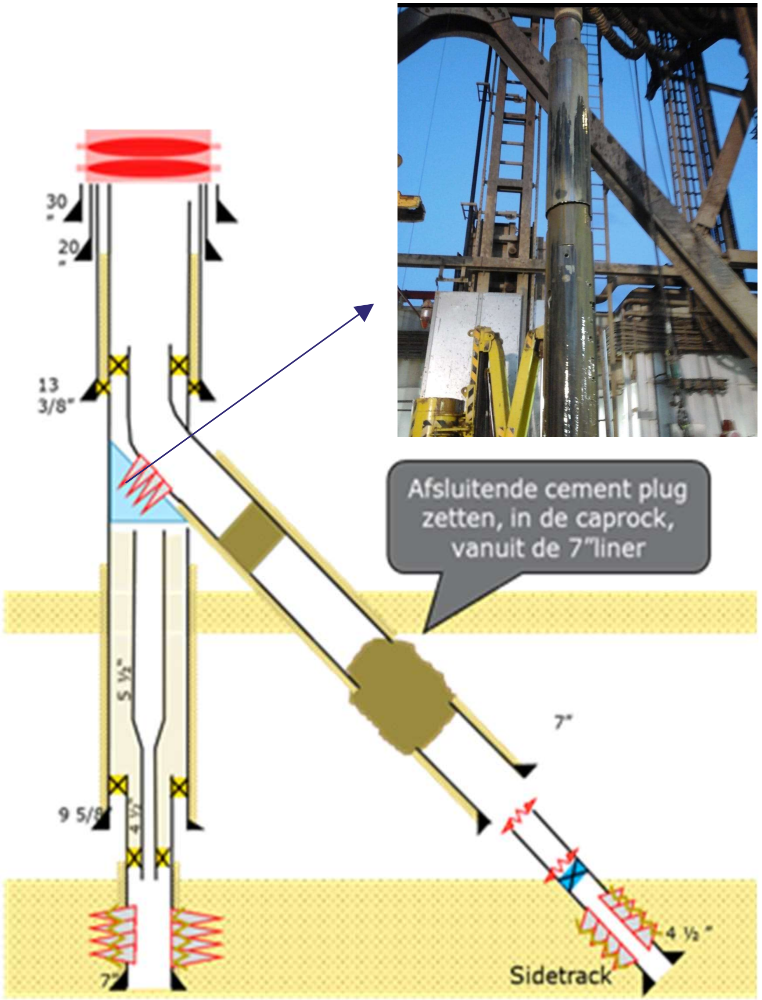
Well Containment
- Thermal loading: debonding of casing-cement-rock face
- Hydrostatic head/pressure as containment barrier

Closure of gas production wells

Well Abandonment:

- Re-entry of suspended wells
- Complex wells, not designed for re-use or re-entry
- Full bore formation plugs become the standard?

Successful well campaign pre-FID to de-risk the project



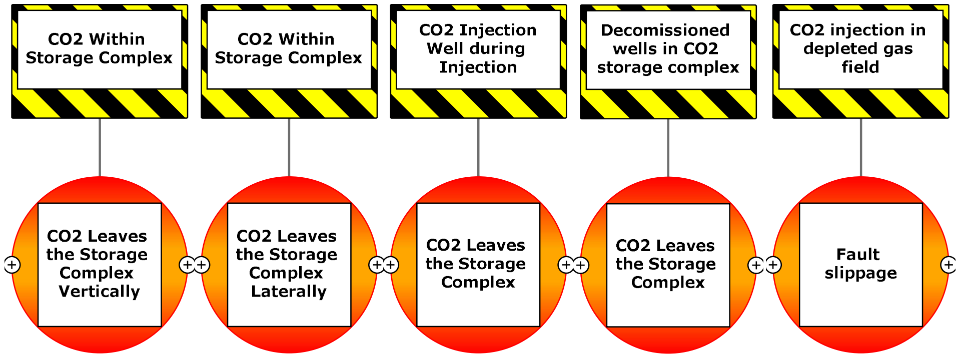
Key Technical Aspects

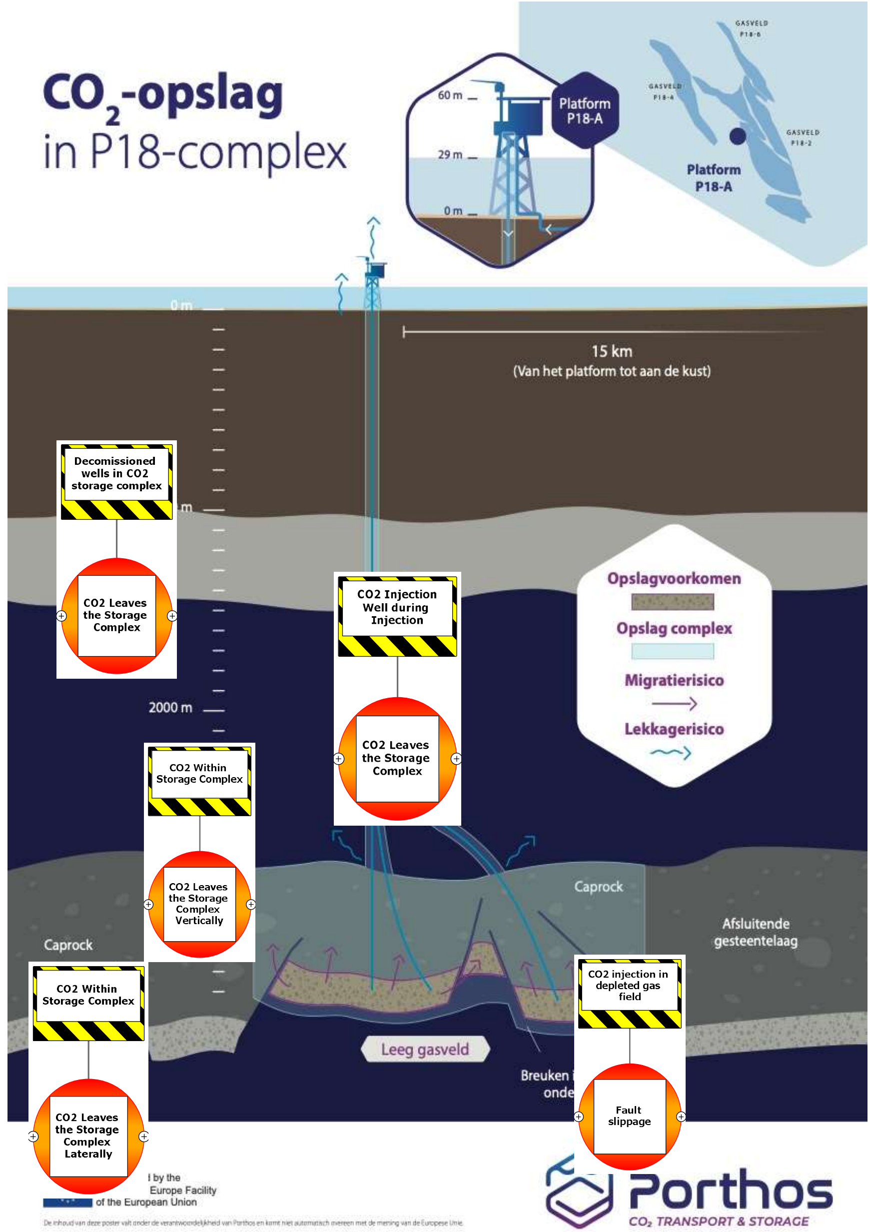
A.Containment

1. from the reservoir laterally
2. from the reservoir vertically
3. from injection wells, during injection
4. from wells after plugging and abandoning

B.Seismicity

5. Fault slippage -> “earthquake”





Storage in depleted fields is new

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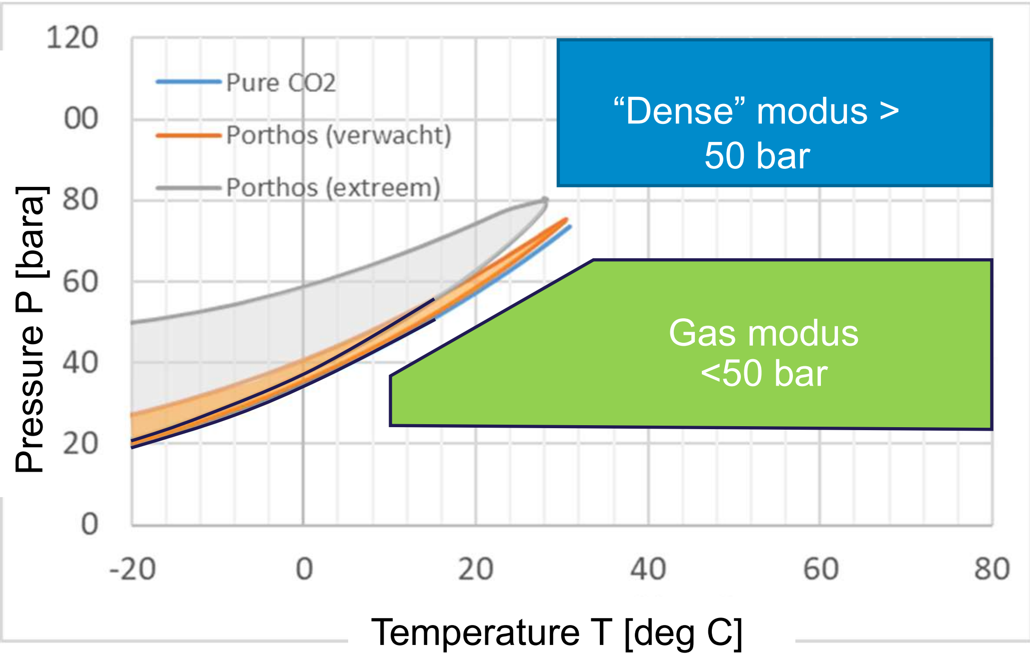
- Gas fields have a proven geological containment
- Reservoir pressure is low (20 bar, was >350 bar)
- CO2 transport is high pressure, dense mode
- Challenge is pressure drop
- Temperature drops with pressure drop
- Low temperatures in wells and reservoir
- Reservoir pressure will remail lower than (CO2) virgin pressure
- CO2 specification affects phase behaviour



Steady state operation envelopes

- Flow simulations – done by TNO/EBN – lead to a range of allowable well configurations

Pres = 50 bar; U = 3W/m^2K; Pman = 85 bar; Tinlet = 80 C; minimum Twh = 0 C																					
Configu	Opene	20t/h	40t/h	60t/h	80t/h	100t/h	120t/h	140t/h	160t/h	180t/h	200t/h	220t/h	240t/h	260t/h	280t/h	300t/h	320t/h	340t/h	360t/h	380t/h	400t/h
1000	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0100	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0010	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0001	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1100	2	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
1010	2	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
1001	2	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0110	2	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0101	2	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0011	2	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
1110	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
1101	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
1011	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]
0111	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]
1111	4	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]

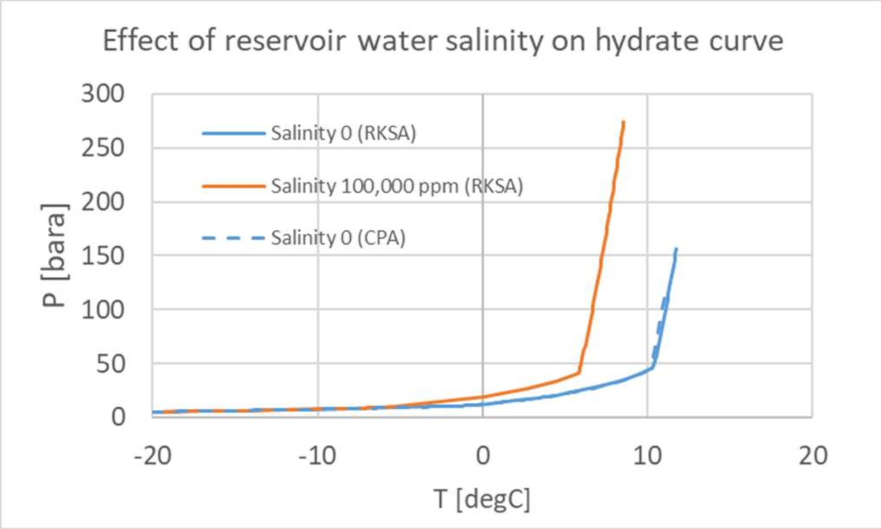
- These are translated into injection plan covering full injection period

	Step	Time ending	P.res. [bar]	Short description	Flow rate avg [t/h]	Flow rate range [t/h]	Nr. of wells	Mode	Annual avg (8500 hrs) [Mt/a]	Accum. P18-2 & P18-4 [Mt]
Technical operation (T.O.)	1	Day 1	17	First start-up, increase to 80t/h & 3 wells	80	0 - 80	1-3	Bypass mode	1,86	1,86
	2	Day 5		Commission compressor		0 - 80	3			
	3	Day 6		Increase flow		40 - 220	3	Gas phase mode		
	4	Month 5	20	Operate flows < 220-240t/h with 3 wells, depending on configuration and < 280t/h with 4 wells.[Note1]	200	40 – 220 (– 280)	3 (-4)			
	5	Month 9	30	Operate flows < 240t/h with 3 wells and < 280t/h with 4 wells.[Note1,2]	220	40 – 240 (– 280)	3 (-4)			
	6	Month 15	40	Maximum 240t/h[Note2] with configurations 0111, 1011 and 1101[Note1] and with 4 wells.	220	0 – 240	3 (-4)			

Hydrate formation in near-wellbore

- Water salinity is estimated at 80,000 – 120,000 ppm NaCl
- This reduces HET (Hydrate Equilibrium Temperature) by 4 degC
  - HET at 50 bar reduces from 10.4 to 6.0 degC
- The minimum temperature in the near-wellbore model was obtained from all runs used for BHP tables

Well	k.h [mD.d]	Min T [degC]
2A1	3150	8.5
2A3	17426	15
2A5	22875	14
4A2	9175	9

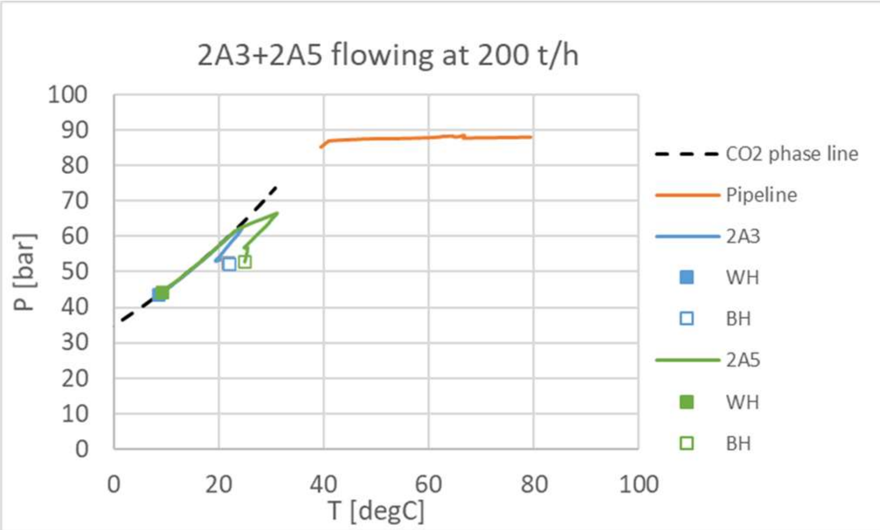


- 15 degC injection (BHT) does not result in a hydrate risk for any wells

k.h: product of reservoir permeability and thickness

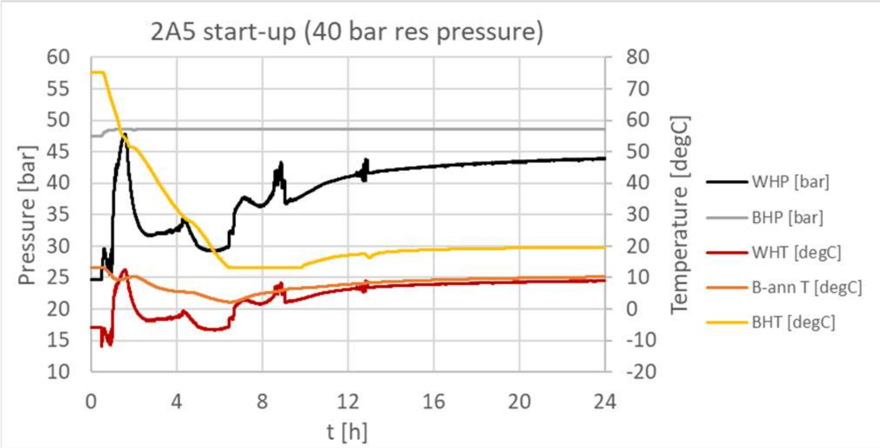
Flow conditions in well – normal injection (pure CO_2)

- In normal operation, platform arrival temperatures are kept high by pipeline insulation
- CO_2 arrives at choke in supercritical state
- As it expands to FTHP, conditions drop to the phase line
  - Wellhead temperature is entirely determined by FTHP
  - Phase fraction is determined by the arrival temperature
- As it travels down the well it is heated by the formation
- At high arrival temperature, wellhead liquid fraction is low
  - Liquid CO_2 evaporates, until only gas is left BH (see plot)
  - BHT is now not determined by the phase line
- At lower arrival temperature, wellhead liquid fraction is higher
  - Some liquid CO_2 remains at bottom hole conditions
  - BHT is determined by the local pressure
- At low reservoir pressure, WHP and BHP are low
  - This can result in unacceptably low temperatures due to the above behaviour
  - The pipeline should not be operated in supercritical mode at low reservoir pressure

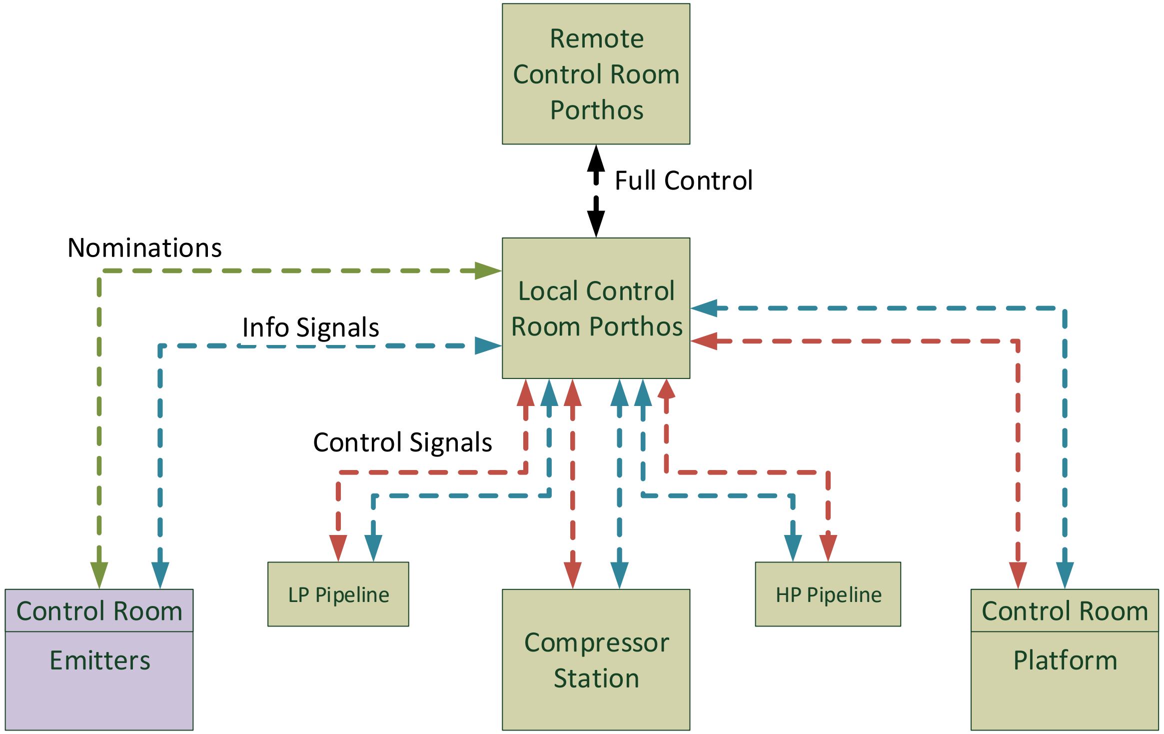


Flow conditions in well – cold start-up (pure CO_2)

- OLGA simulations were used to determine at which reservoir pressure dense phase operation is possible
  - Cold start-up: pipeline has cooled to seawater temperature
  - Wellbore temperatures lower than during steady injection
- Simulation shown was done at reservoir pressure of 40 bar
- CO_2 arrives at choke in much colder conditions
- As it expands to FTHP, conditions drop to the phase line
  - Wellhead temperature is entirely determined by FTHP
  - The simulated temperatures do not pose a risk to the annulus fluids
- Liquid fraction is much higher due to lower temperature in pipeline
  - Formation heat influx cannot fully evaporate CO_2
- Bottomhole conditions also lie on the phase boundary
  - BHT dictated by BHP.
  - BHP of 48 bar results in a BHT of 12 °C, below the 15 °C limit for hydrates
- Simulations were repeated at 50 bar reservoir pressure
  - Higher BHP results in acceptable BHT
  - Base operating philosophy is to switch to dense phase injection at 50 bar



Operating & Control Philosophy

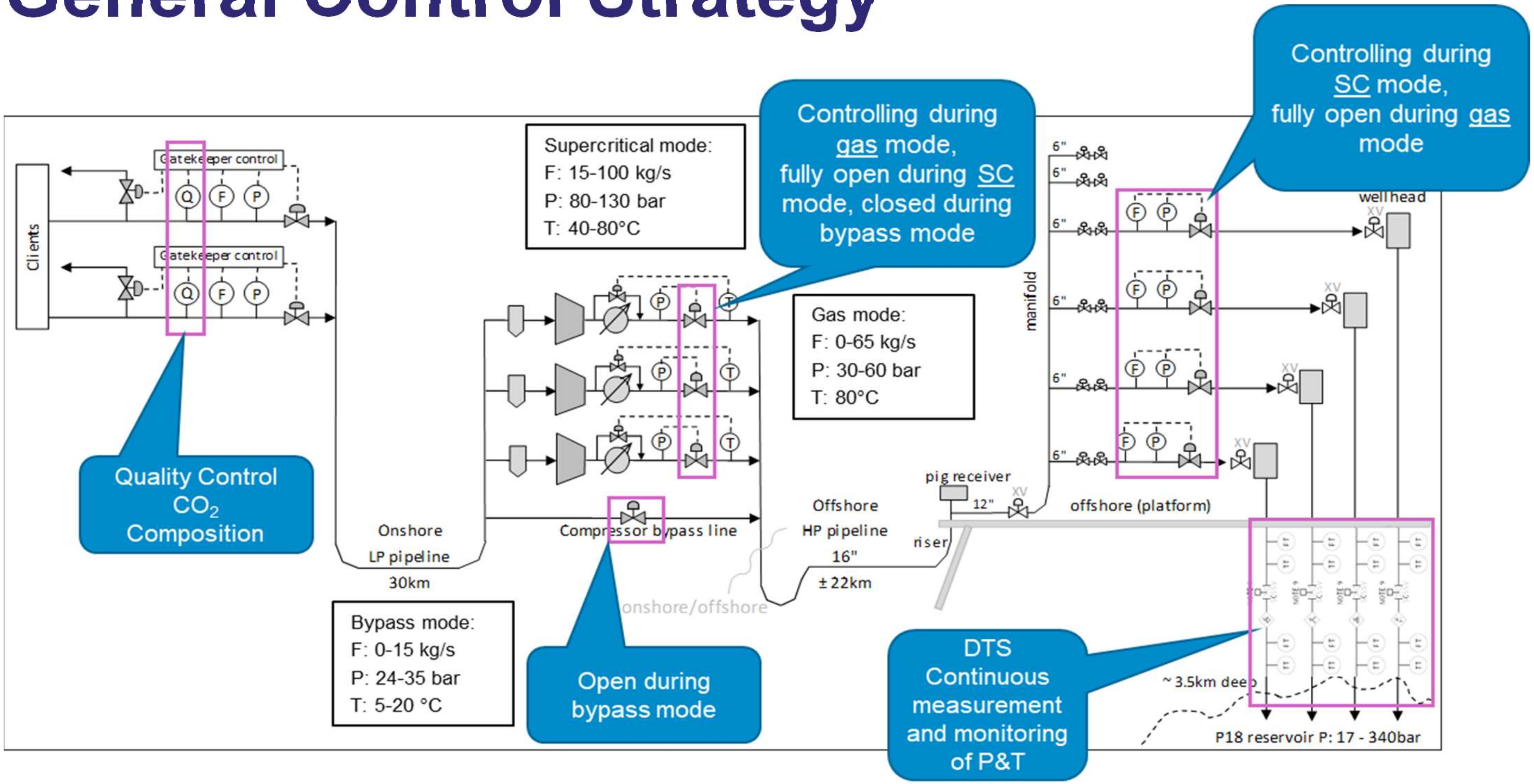


Nominations – Information for planning of capacities, exchanged 24 hours ahead. In Technical operation phase dictated mainly by Gas field limitations. In Commercial operation phase dictated mainly by emitters

Info Signals – Instrument signals exchanged for info (not controls), including information when systems have tripped

Control Signals – Instrument signals exchanged including setpoints and selection of operating modes and opening closing of valves

General Control Strategy



What-if scenario’s

1. Emitter delivers off spec CO2

2. Emitter measurement instrument fails (no real time data available)

3. Spec at compressor station does not comply with emitter measurements

4. Pipeline rupture (near Rozenburg)

What-if scenario 1:
Emitter delivers off spec CO2

Preventive measures:

- Measurement system emitters according to requirements as defined in Annexes
- Measurement system at Porthos compressor station
- In case of an Outage due to off spec delivery, Customer shall be required to pay to Porthos the full Fees for those Outage hours
- Customer's liability is limited to EUR 50,000,000 (fifty million euros) (TSC Article 13.3 unlimited liability) per event or series of related events if and to the extent caused by Non-compliant CO2 that has not been accepted by Porthos in accordance with GCFI Article 3 and that has been fed into the Porthos System by Customer (TSA Article 9.4)

Actions:

- If Customer detects Non-compliant CO2 that is labelled as "safeguarding" in Annex B it shall ensure that the CO2 Flow is immediately and automatically discontinued (TSC/GCFI Article 3.2)
- If Customer detects Non-compliant CO_2, it shall (i) promptly notify Porthos thereof and include in its notification all relevant information relating to the Non-complaint CO_2 (TSC/GCFI Article 3.3)
- Porthos is entitled to discontinue Customer flow
- Porthos shall inform Customer of decision if proceeding supply of CO2 is allowed and under which conditions (TSC/GCFI Article 3.4).
- Customer is only allowed to re-start CO2 supply after Operator has been convinced the off-spec. CO2 is solved
- In case Customer violates agreement more frequently, Porthos is entitled to suspend the performance of the TSA until Customer has demonstrated to Porthos' satisfaction that it has taken adequate measures to ensure that the chance of such situations reoccurring has been significantly reduced (TSC Article 6.4)

What-if scenario 2:
Emitter measurement instrument fails
(no real time data available)

Preventive measures (TSC/GCFI Article 4 Metering and Measuring terms):

- Customer shall continuously meter the CO2
- Customer shall comply with provisions w.r.t construction, maintenance, and operation of metering station
- Customer shall comply with the standards and provisions in Annex A, B, C and E, including requirements regarding the use of the Porthos Information Service (or its successor) and the transmission of all (telemetry/metering) data.
- Measurement outage limited to max. five days

Actions:

Flow:

- Emitter to solve issue asap. Flow monitored and calculated with use of Porthos metering at compressor station

Quality:

- Safeguarded components: If measurement is labelled as “safeguarding” (Annex B) it shall ensure that the CO2 Flow is immediately and automatically discontinued (TSC/GCFI, Article 3.2)
- Non-safeguarded components: Flow to continue, compressor station measurement is leading.

What-if scenario 3: Spec at compressor station does not comply with emitter measurements

Preventive measures:

- Strict requirements w.r.t. measurement equipment
- Inspection rights
- Regular calibration/ validation requirements

Actions:

- Step 1: Observe the different compositions of the customers and the trend of these compositions
- Step 2: Based on the comparison with the CS composition, determine the most likely deviating customer composition (for example, a distinctive peak of one of the components)
- Step 3: In case of risk- consider discontinuing the flow of this customer. Ask for verifications, corrective actions.

What-if scenario 4:
Pipeline rupture (near Rozenburg)

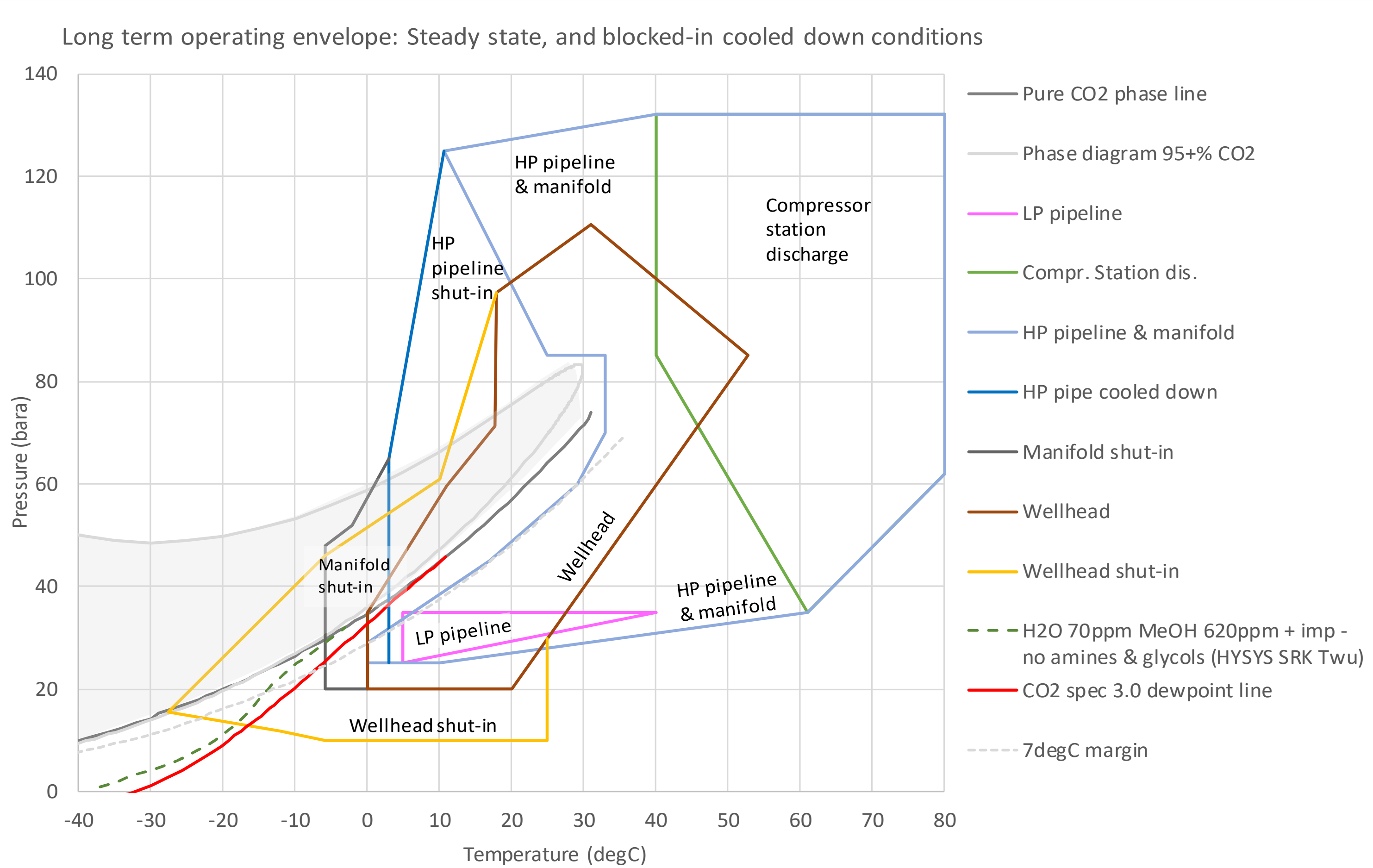
Preventive measures:

- The Porthos backbone lies in the pipeline corridor (leidingenstrook) which requires strict supervision of excavation work
- At the area Rozenburg the pipeline has been built stronger (20%) than in the rest of the route
- Valve locations have been planned to be able to block the pipe section along Rozenburg in the event of a pipeline incident
- Pressure sensors are installed and a monitor that closes the block valves when a large pressure drop is detected in the system unexpectedly, e.g. due to a pipe rupture
- Once the pipeline is in service, there will be continuous monitoring of the operational and structural conditions within the pipeline
- "Safety and Risks for Porthos CO2 pipeline"- study by DNVGL- risks are negligible

Actions:

- Pipeline section (Rozenburg) will be blocked in by means of remote operated shut-in valves
- Inform legal authorities and emitters

Long term operating conditions



Steady state and blocked-in cooled down

<u>LP pipeline and compressor station:</u>

- ≥ 4°C and ≥ 24bar

<u>HP pipeline:</u>

- ≥ 0°C and ≥ 30bar

<u>Platform and wellheads:</u>

- ≥ -5.8°C and 10bar

Methanol sensitivity

- The following graphs indicate the composition of the liquid that would knock out and the P & T range where this would occur.

- The graphs show these for the different amounts of methanol (0ppm, 350ppm and 650ppm) at same amount of water (50ppm) and CO2 as the remainder.

Notice that:

- methanol moves the dewpoint lines to the right and up (liquid to start dropping out at higher temperatures and pressures), which means that the water will knock out sooner, when approching from the gas side.

- Liquid CO2 is also present in the liquid phase (dissolved in the methanol). So it is not purely H2O and methanol.

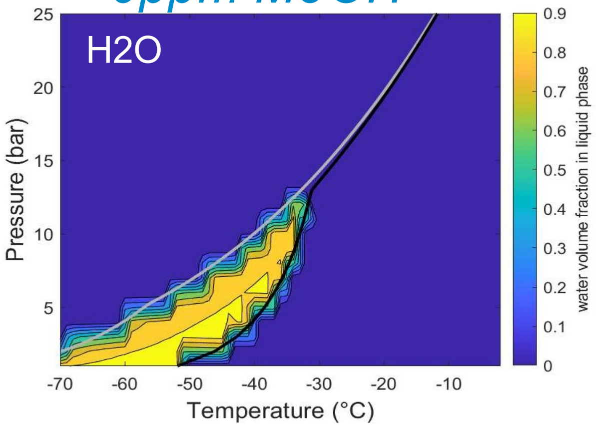
- The concentration of H2O in the liquid will be less due to the presence of methanol and CO2. At 10bar, this reduces from ~80% (with 0 methanol) to ~ 15% (with 350ppm methanol) to ~6% (with 650ppm methanol).

Methanol sensitivity

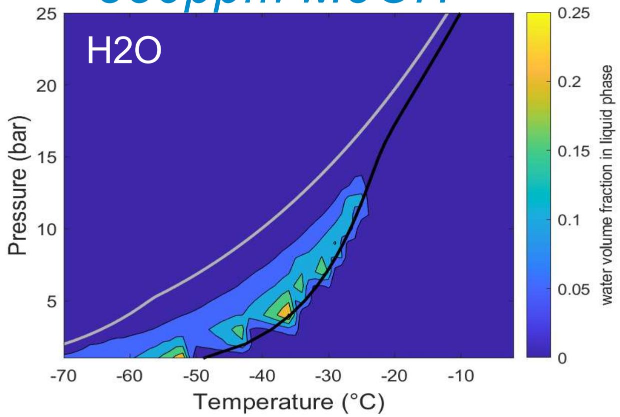
***with 50**ppm H_2O*
(HYSYS SRK Twu)

Porthos
CO₂ TRANSPORT & STORAGE

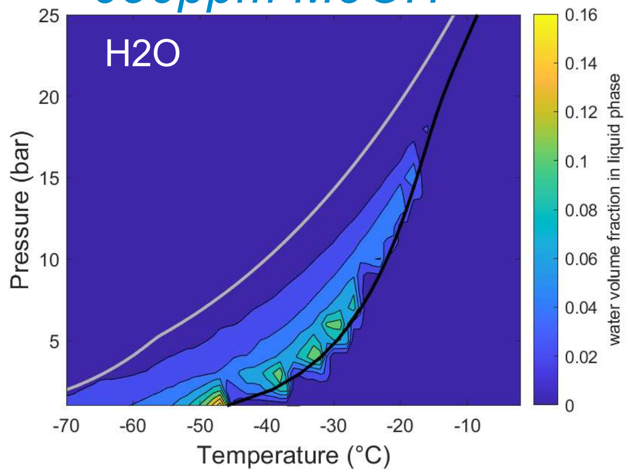
***0**ppm MeOH*

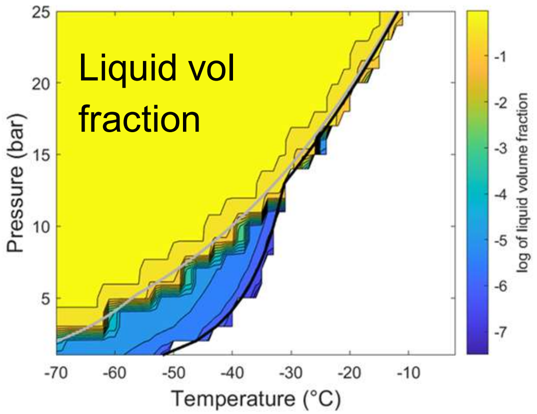


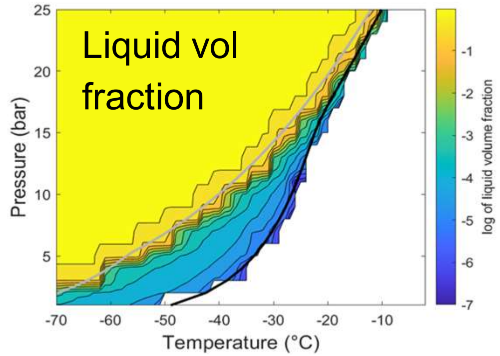
***350**ppm MeOH*

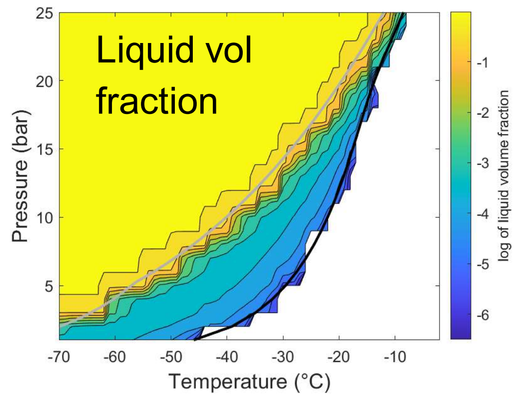


***650**ppm MeOH*





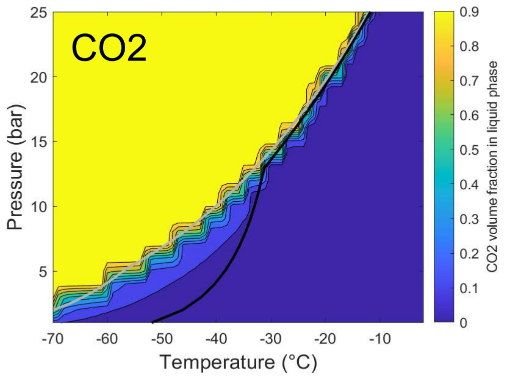




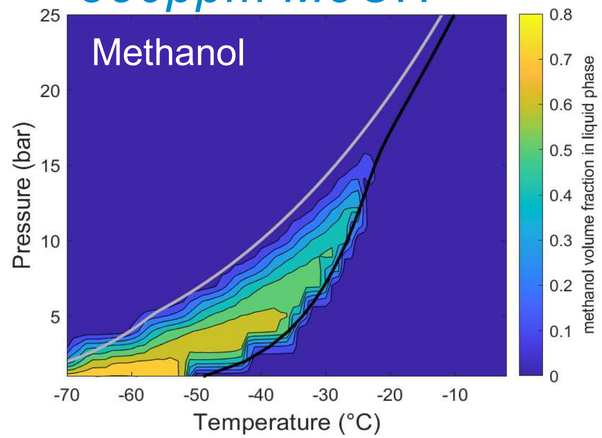
Methanol sensitivity

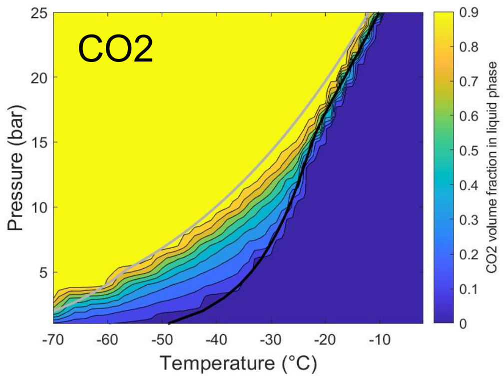
***with 50**ppm H_2O (HYSYS SRK Twu)*

***0**ppm MeOH*

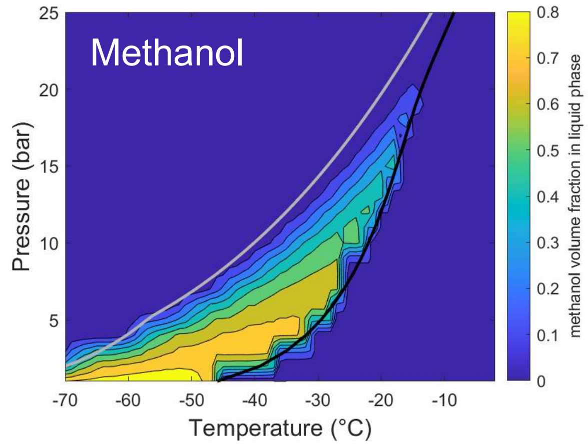


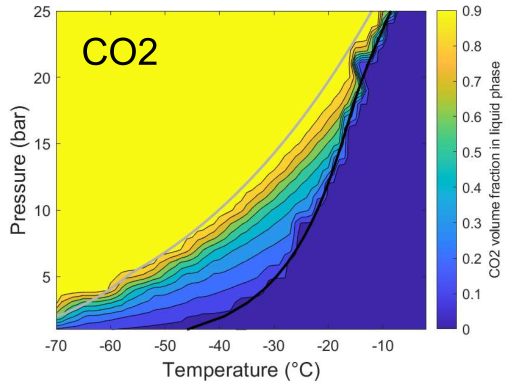
***350**ppm MeOH*



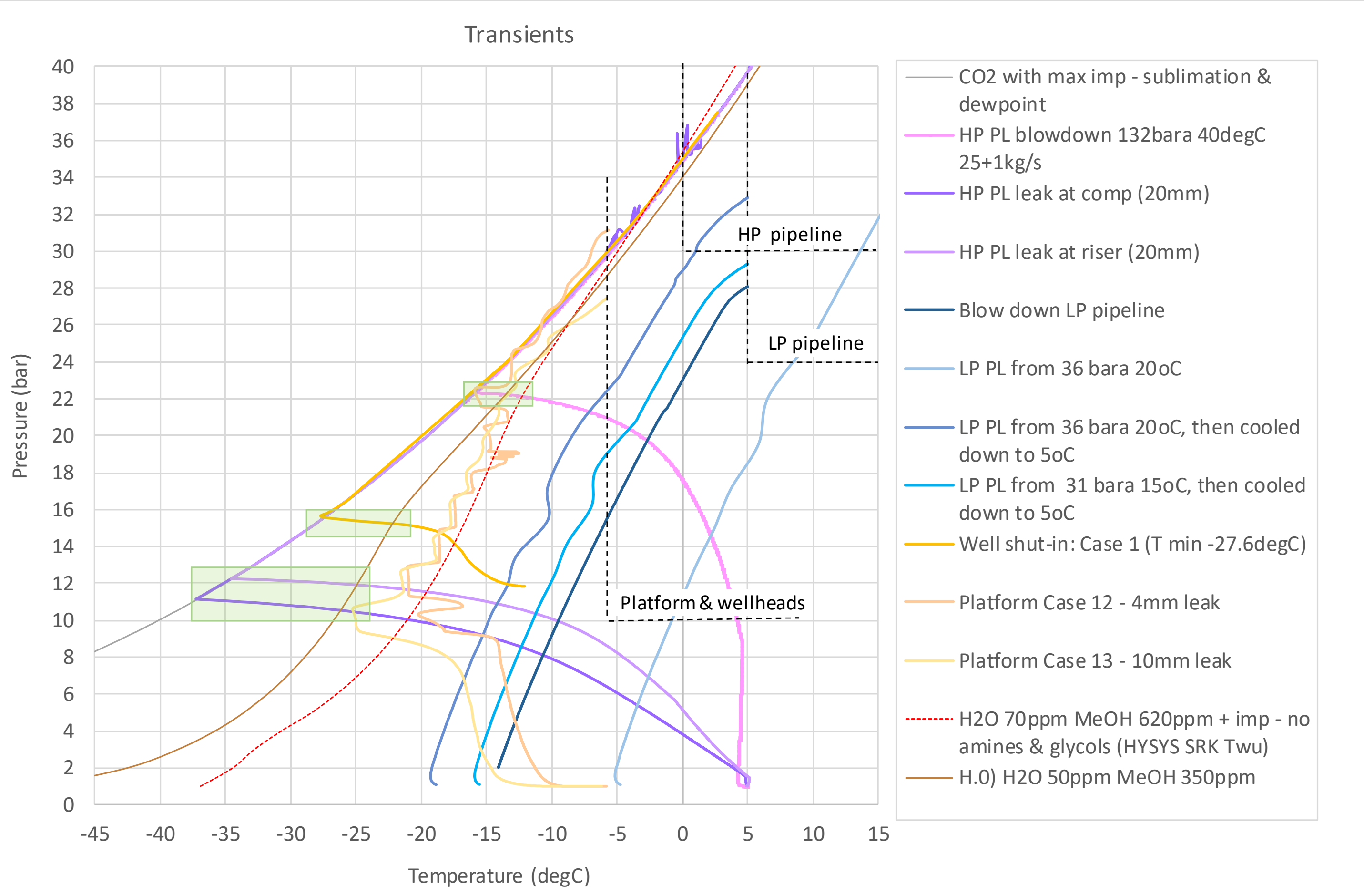


***650**ppm MeOH*





Calc for amount of H2O present from transients



- The rectangles indicate at which pressures some of the the transient lines would cross the dewpoint line.
- An example is shown in the next slide for 50ppm and 350ppm MeOH composition. (This has not yet been done for higher amounts.)

Calc for amount of H2O present

350ppm MeOH + 50ppm H2O + CO2

HYSYS (SRK Twu)

Liq frac * H2O frac on a volume basis

Pressure	-54	-52	-50	-48	-47	-45	-43	-41	-39	-38	-36	-34	-32	-31	-29	-27	-25	-23	-22	-20	-18	-16	-14	-13	-11	-9
25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
24	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
22	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
21	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
19	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
18	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.6%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	1.3%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	1.1%	3.5%	7.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	1.0%	3.1%	6.1%	14.1%	14.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	1.3%	3.3%	5.5%	8.0%	11.2%	15.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.7%	2.0%	3.9%	5.5%	7.4%	9.8%	13.1%	17.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	0.0%	0.0%	0.0%	0.1%	0.6%	1.7%	3.3%	4.6%	5.8%	7.3%	9.2%	15.6%	15.6%	20.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6	0.2%	0.9%	2.3%	3.5%	4.4%	5.3%	6.4%	7.7%	9.4%	11.7%	15.0%	19.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4	4.2%	4.8%	5.5%	6.3%	7.3%	8.6%	10.3%	12.8%	16.2%	20.9%	26.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	7.0%	7.9%	9.2%	10.9%	13.3%	16.8%	21.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1	19.0%	24.7%	32.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

- The water fraction x liquid fraction can be used to calculate how much water would be present at certain temperatures and pressures.
- This is shown in the above graph for 50ppm H2O and 350ppm MeOH. Volume fractions are shown because this number can be multiplied by the volume of the pipe to calculate how much water would be present. (Mass flow rate cannot be used when the flow rate is zero, such as during a shut-in case.)
- The transient sims can be used to determine how long the water would be presen, but note that in practise it will take longer to boil-off liquids.