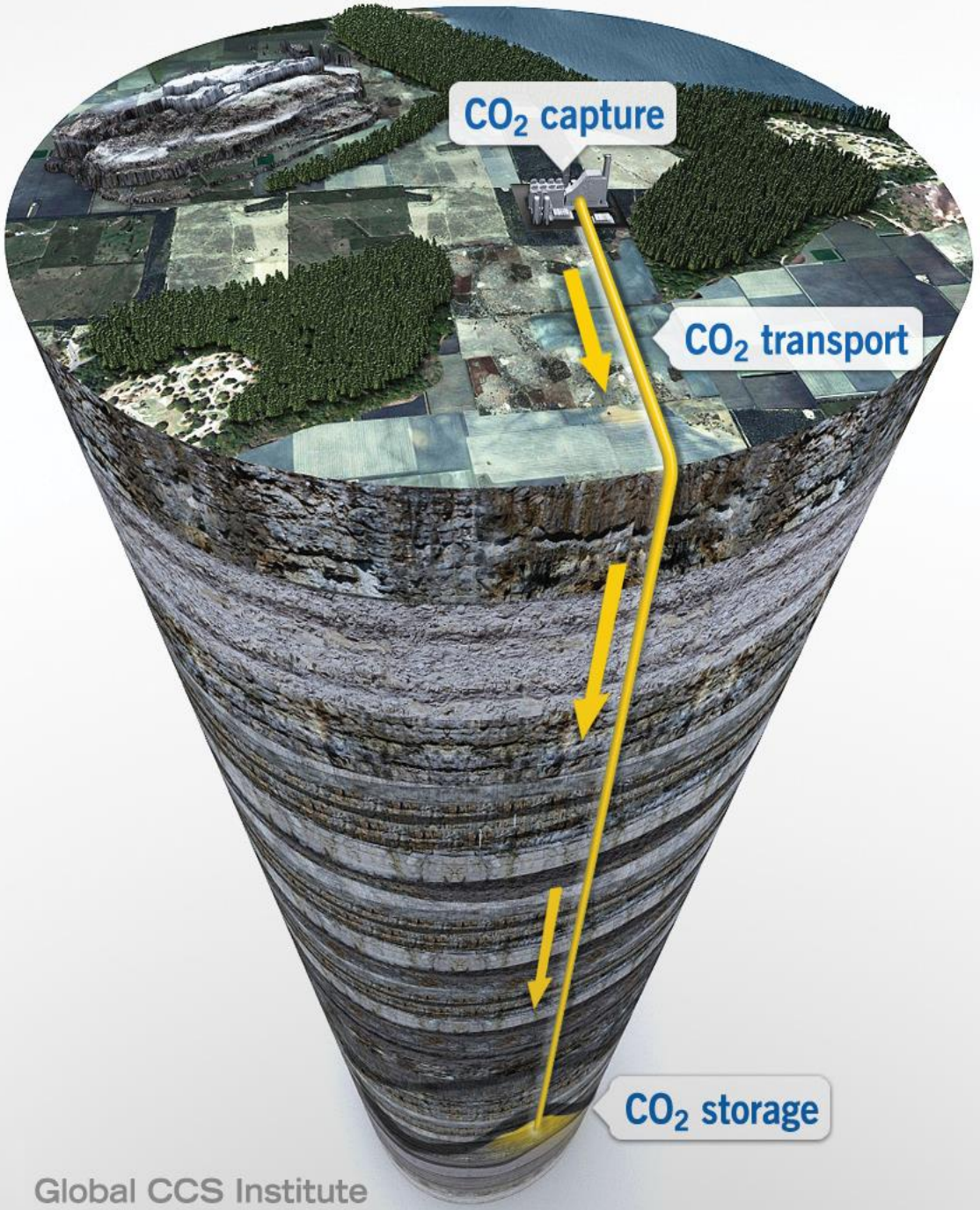


TotalEnergies

CO2 Transport and Storage

overview and field management questions

ESI seminar,

Alejandro Rodríguez Martínez

March 22nd 2022

Summary

1. HSE Moment
2. CCS Context
3. CCS projects generalities
4. Two Field Management questions
5. Discussion

01.

CCS HSE moment

Satartia CO2 + H2S pipe incident, February 2020

- Over 300 evacuated
- 46 hospitalizations
- Source Times
- Republished Summer 2021

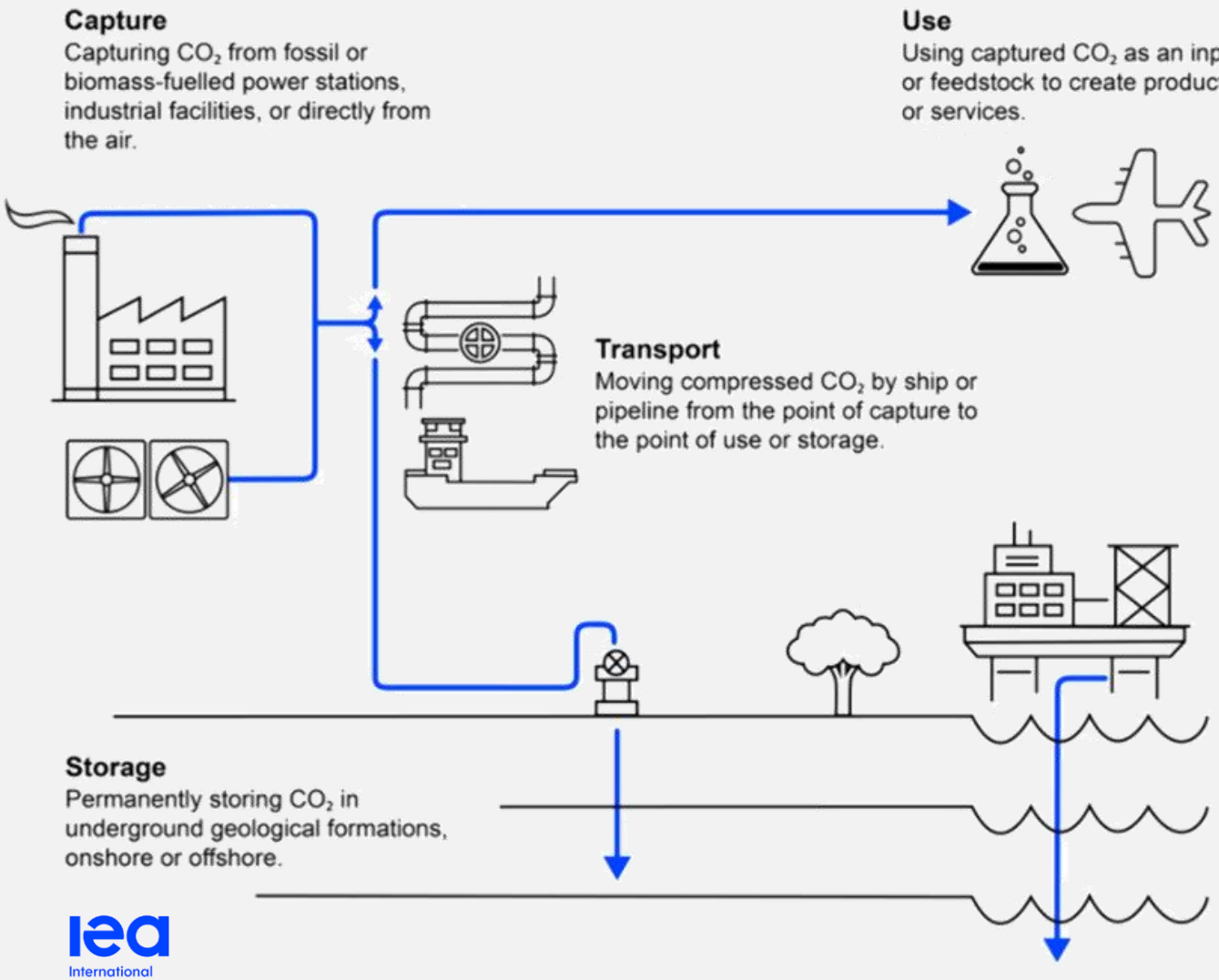
- Ecologists Push back on CCS
- Need to:
  - Keep it humble on the technical
  - Work on the Communication

A 24-inch pipe rupture in Yazoo County, Miss. occurred on Feb. 23, 2020

02.

CCS Context

What is CCS?

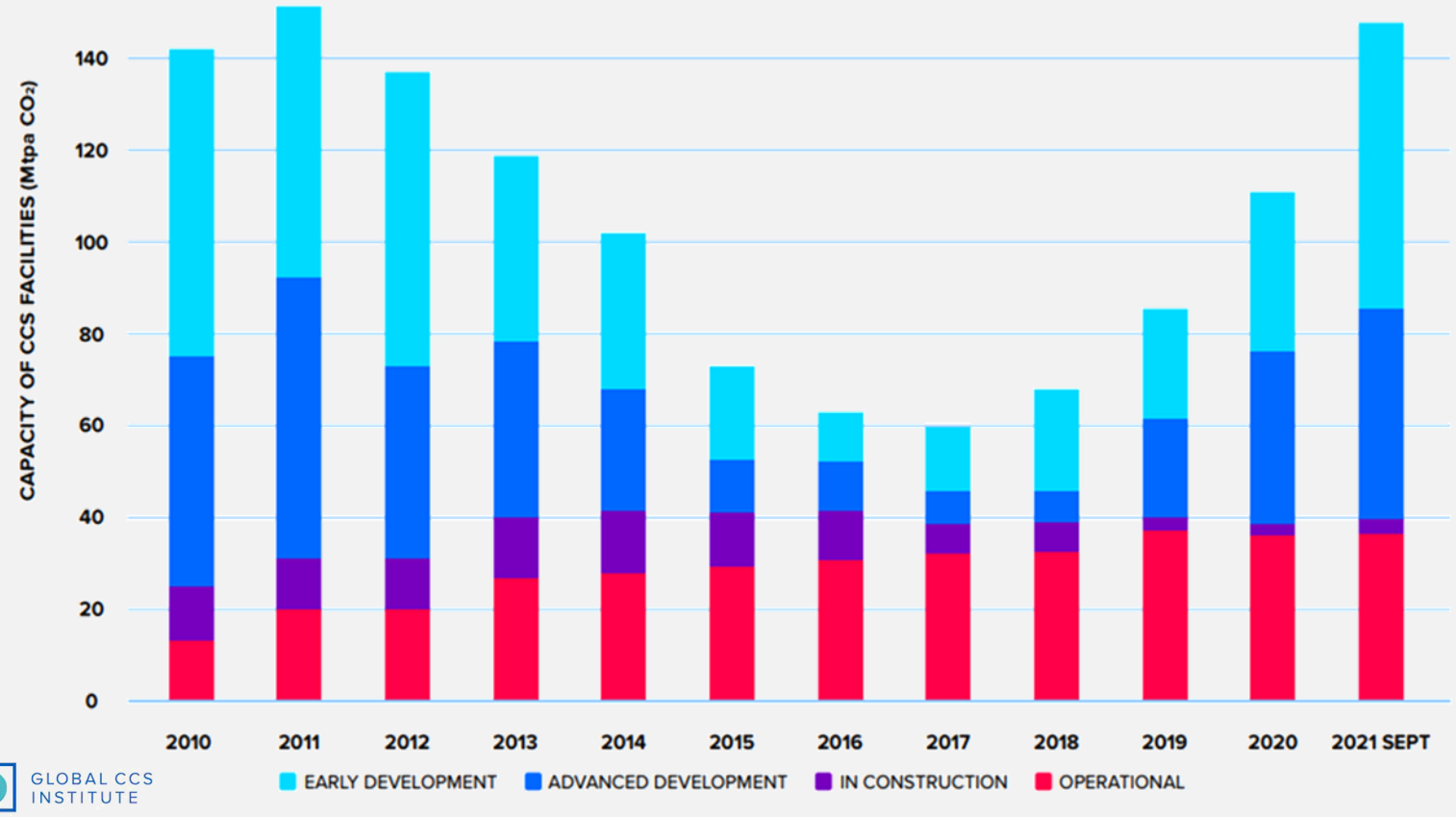


- Recover CO2 from heavy industries
  - Pollutants: H2S, NOx, He, Ar, H2, CH4….
- Transport CO2 to storage facilities/assets
  - Liquid transport is preferred
- Use of CO2
  - Chemical, Drinks, Greenhouses, slaughterhouses…
- Inject CO2 into Depleted Reservoirs/Aquifers
  - To be discussed later
- Later re-production and utilization?
  - Industrial Source of CO2

How much CCS?

	OPERATIONAL	IN CONSTRUCTION	ADVANCED DEVELOPMENT	EARLY DEVELOPMENT	OPERATION SUSPENDED	TOTAL
Number of facilities	27	4	58	44	2	135
Capture capacity (Mtpa)	36.6	3.1	46.7	60.9	2.1	149.3

COMMERCIAL CCS FACILITIES IN SEPTEMBER 2021 BY NUMBER AND TOTAL CAPACITY



GLOBAL CCS INSTITUTE

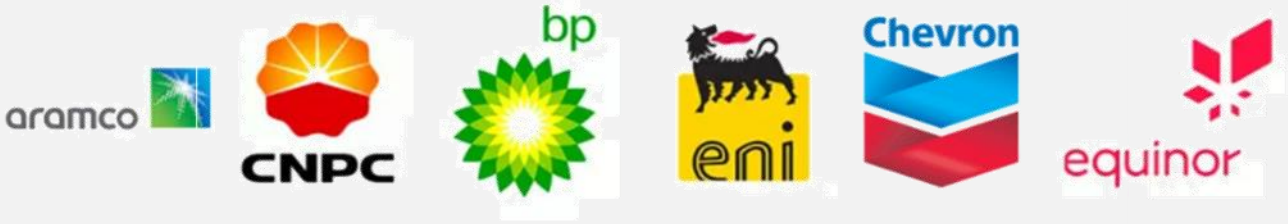
Facilities that have not announced their capacity are not included in this chart

PIPELINE OF COMMERCIAL CCS FACILITIES FROM 2010 TO SEPTEMBER 2021 BY CAPTURE CAPACITY

TotalEnergies CCS

- Projects in 5 continents
- Planned combined rate 20~40 MTPA
- Types
  - Native CO2
  - Native H2S + CO2
  - Process CO2
  - CCS
- Snøhvit (native CO2)
- Northern Lights (CCS)
- Aramis (CCS)

Who Does CCS?

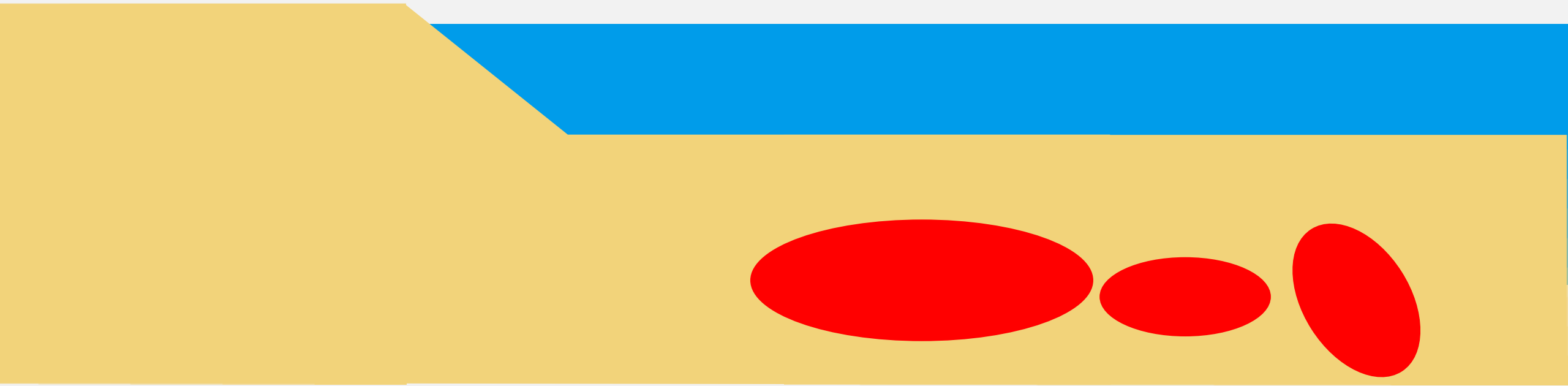


- Oil and Gas majors decarbonization need
  - Portfolio leaning towards gas
  - Direct CO2 sinks like forest plantation
  - Industrial decarbonization **CCUS**
- CCS Industrial knowledge requirements
  - Large/uncertain/long term investments
  - Gigantic logistic management
  - Gas transport
  - Gas Injection Wells drilling
  - Gas injection fields management

Where to do CCS?

	Pros	Cons
Depleted reservoir	▪ Good storage knowledge ▪ Lots of data and simulation models ▪ Reusable infrastructures	▪ Low pressure ▪ Legacy wells risk ▪ Possibly congested area
Aquifer	▪ High pressure ▪ No legacy wells risk ▪ No congested area	▪ Brine production/disposal ▪ No Models & Poor data set ▪ No infrastructures available

How to CCS? An example



How to CCS? An example

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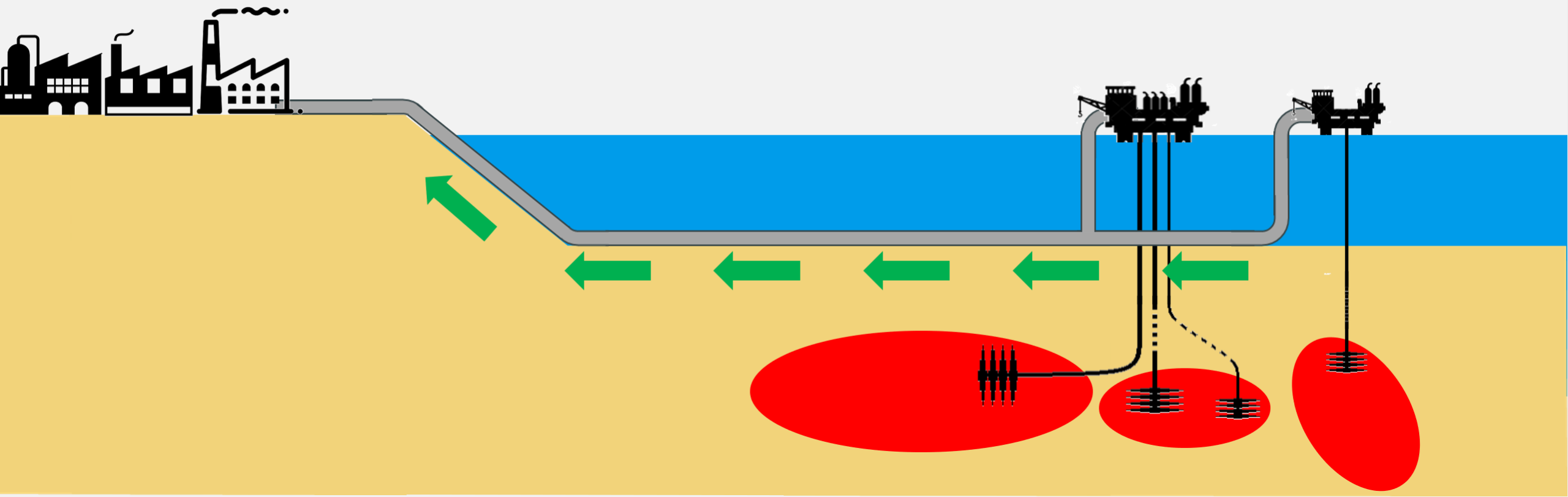

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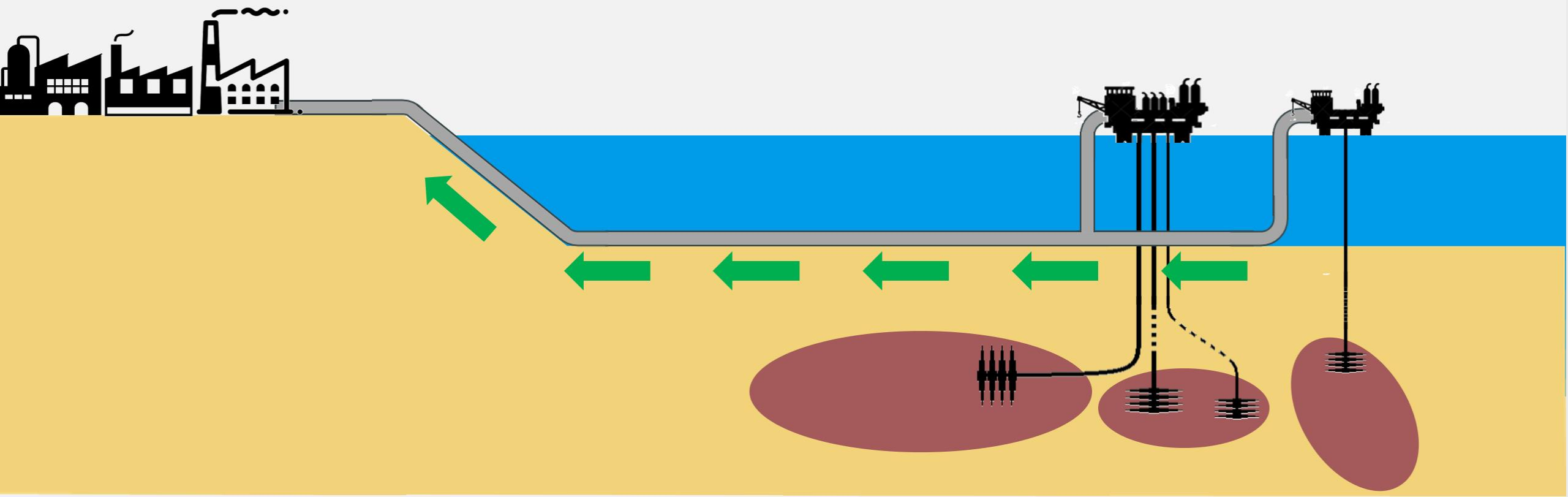

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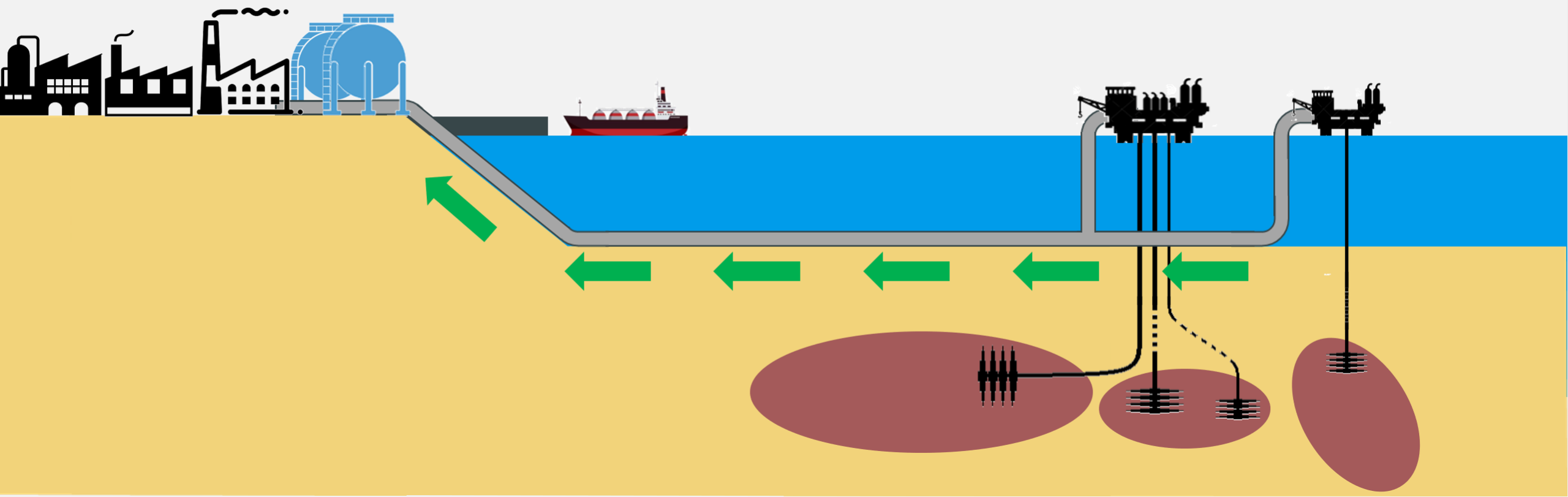

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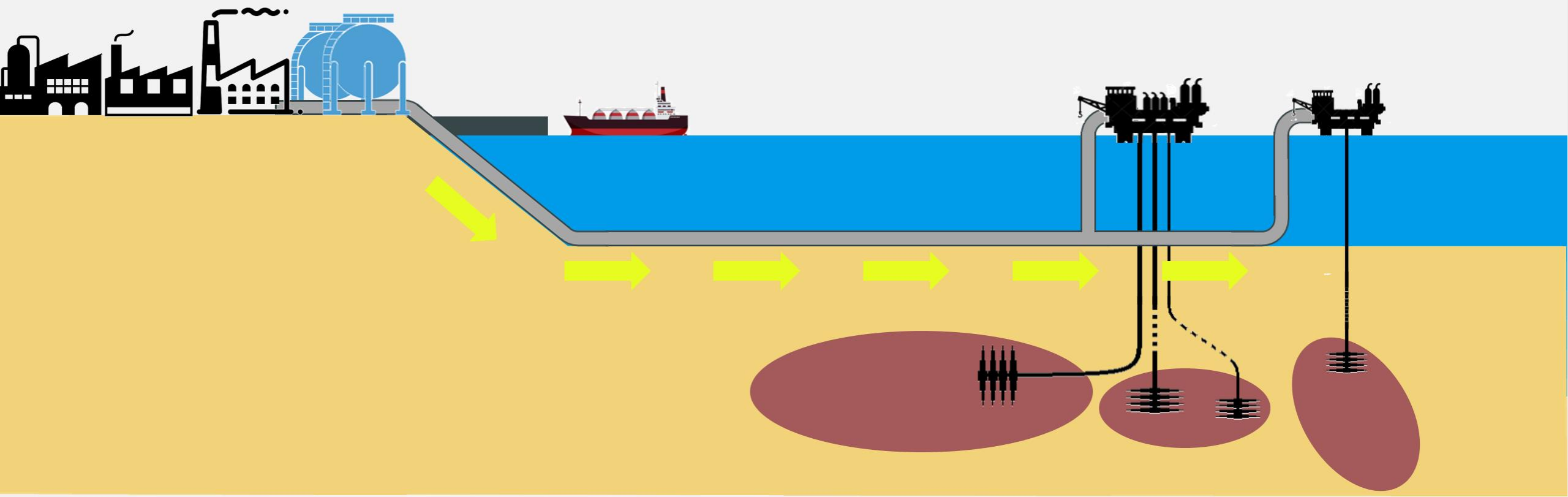

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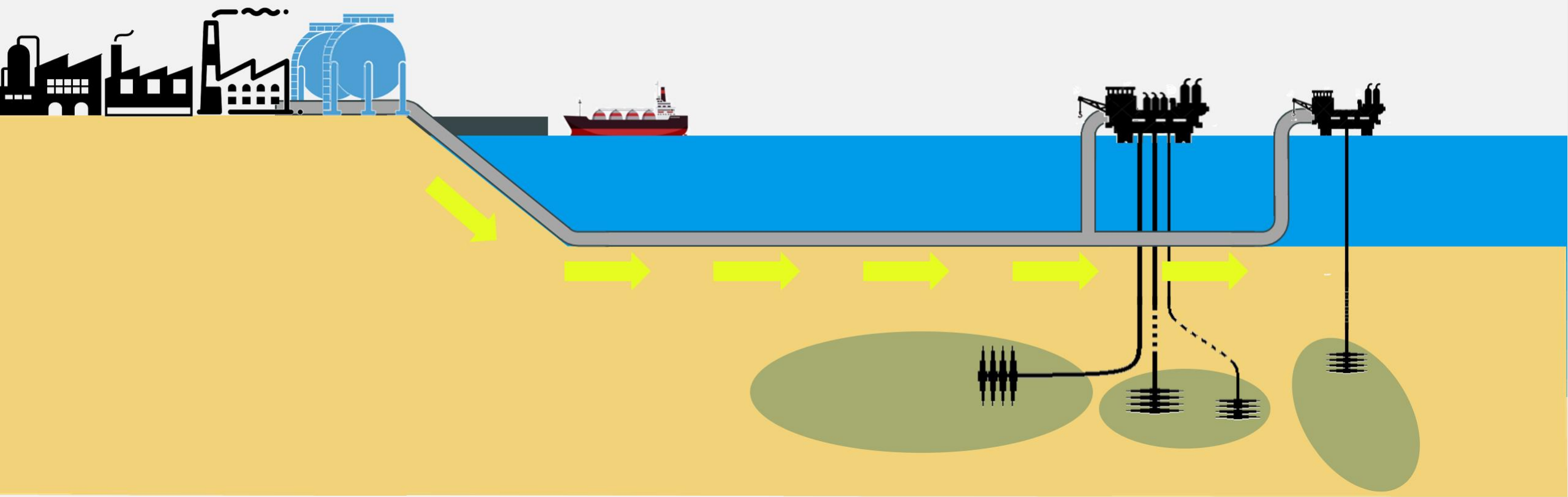
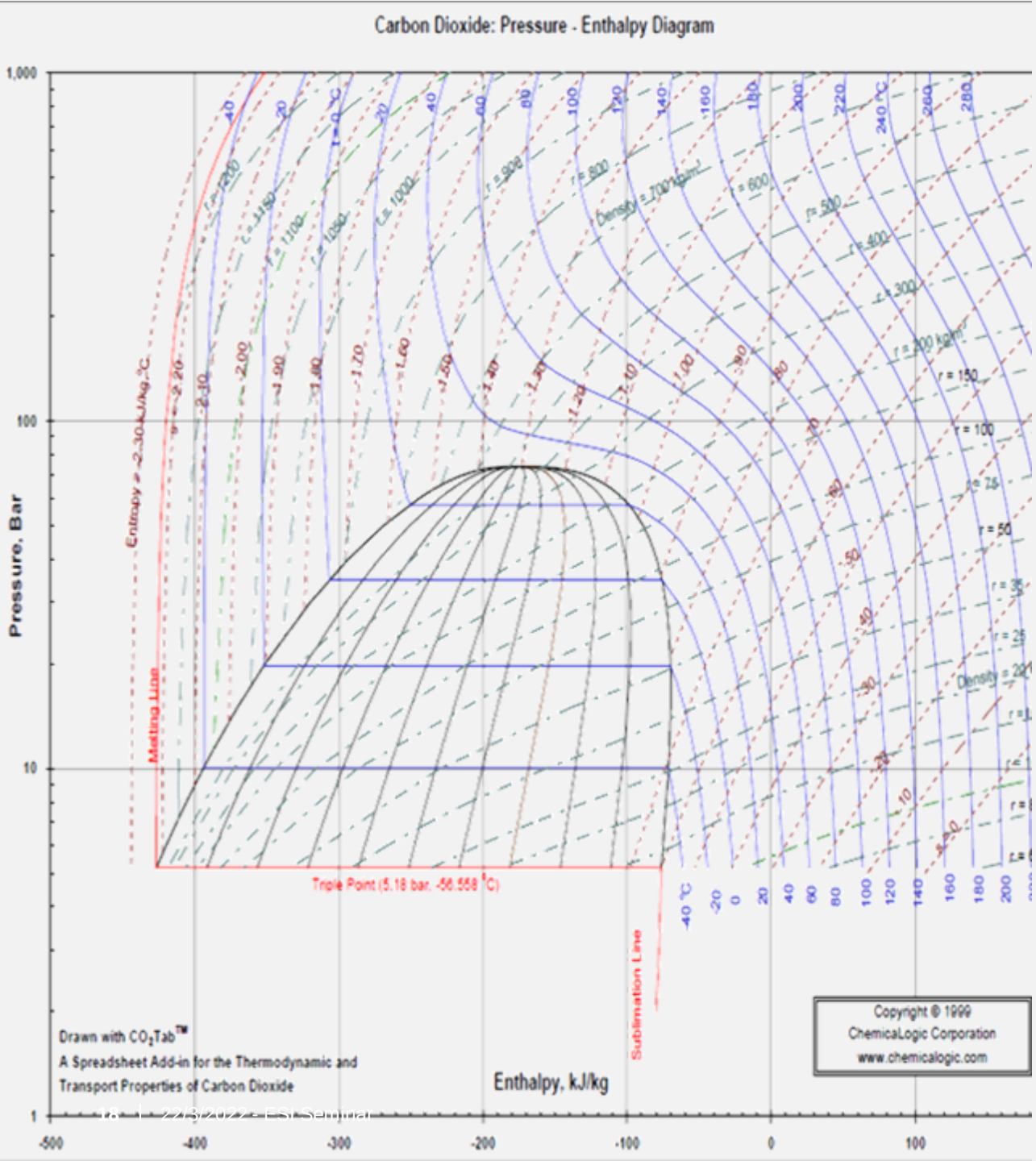


Why CCS?

Pale Blue Dot

February 14, 1990, by the Voyager 1 space probe from a record distance of about 6 billion kilometers

From NASA

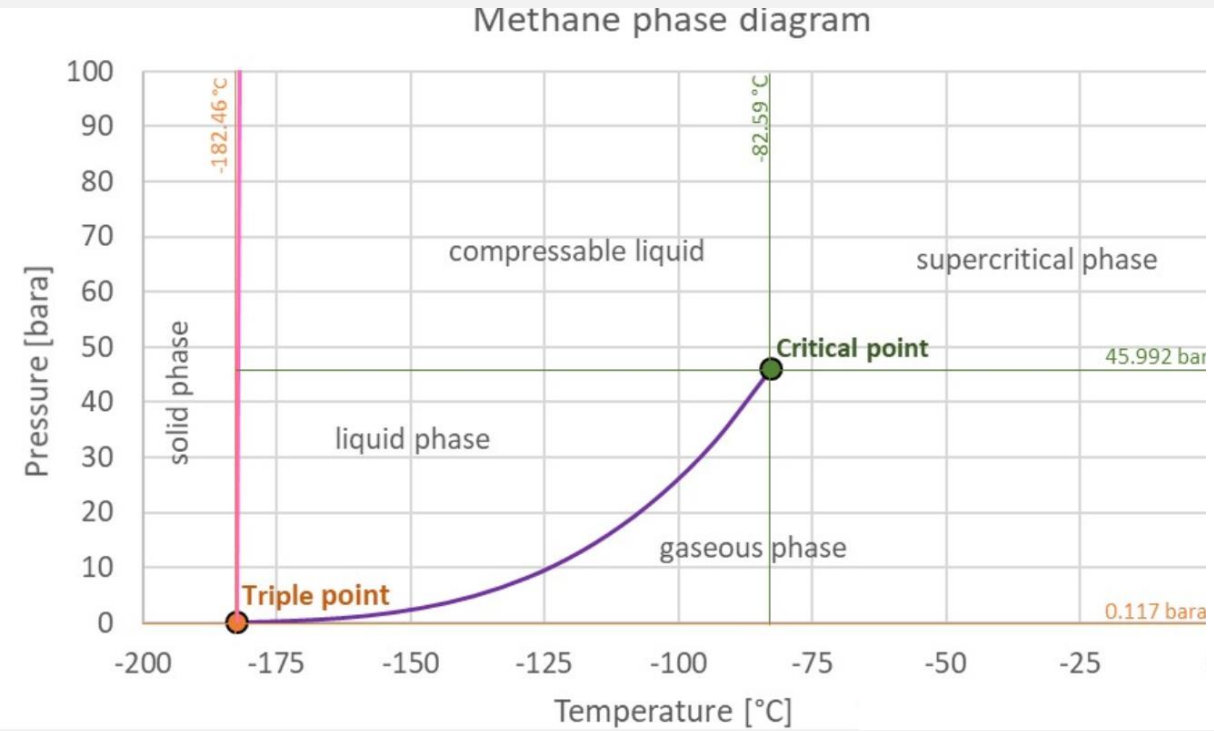


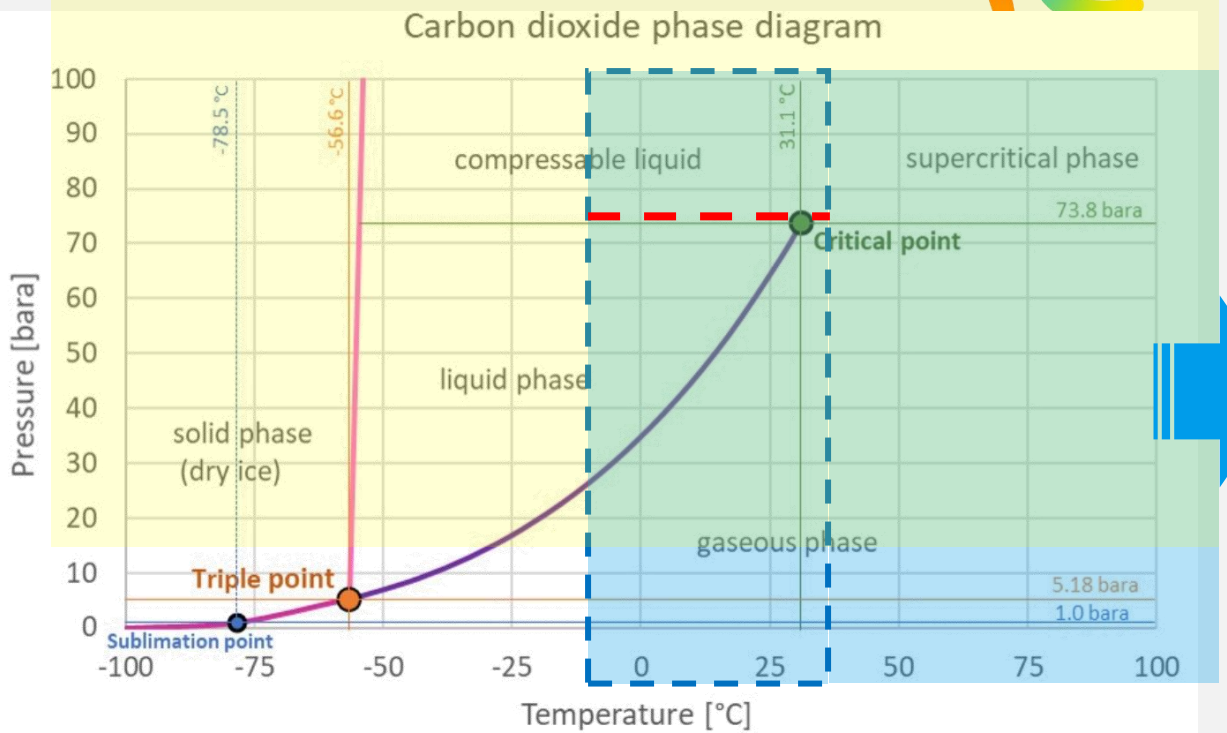
TotalEnergies

03.

CCS projects generalities

CO2 vs CH4: P/T/H

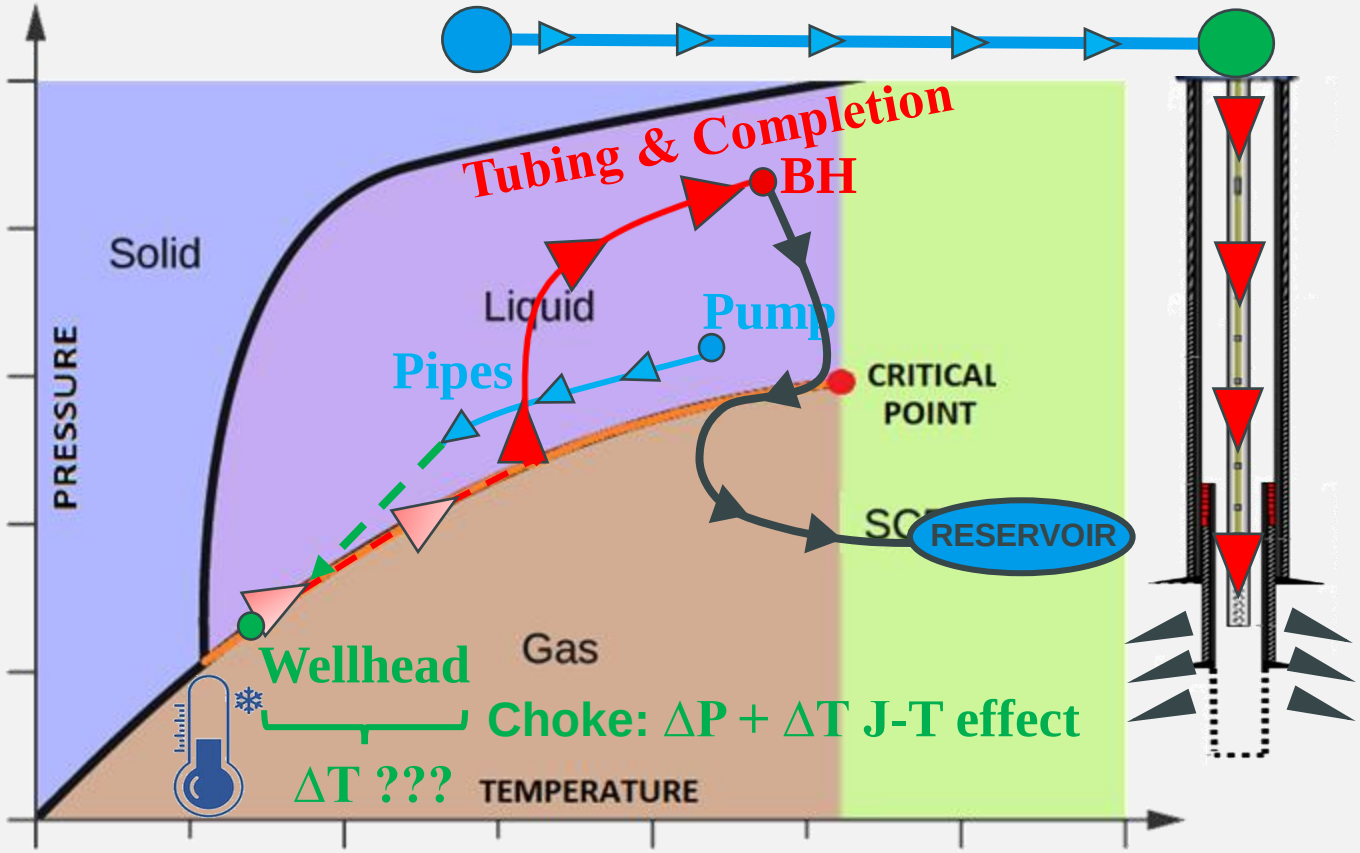


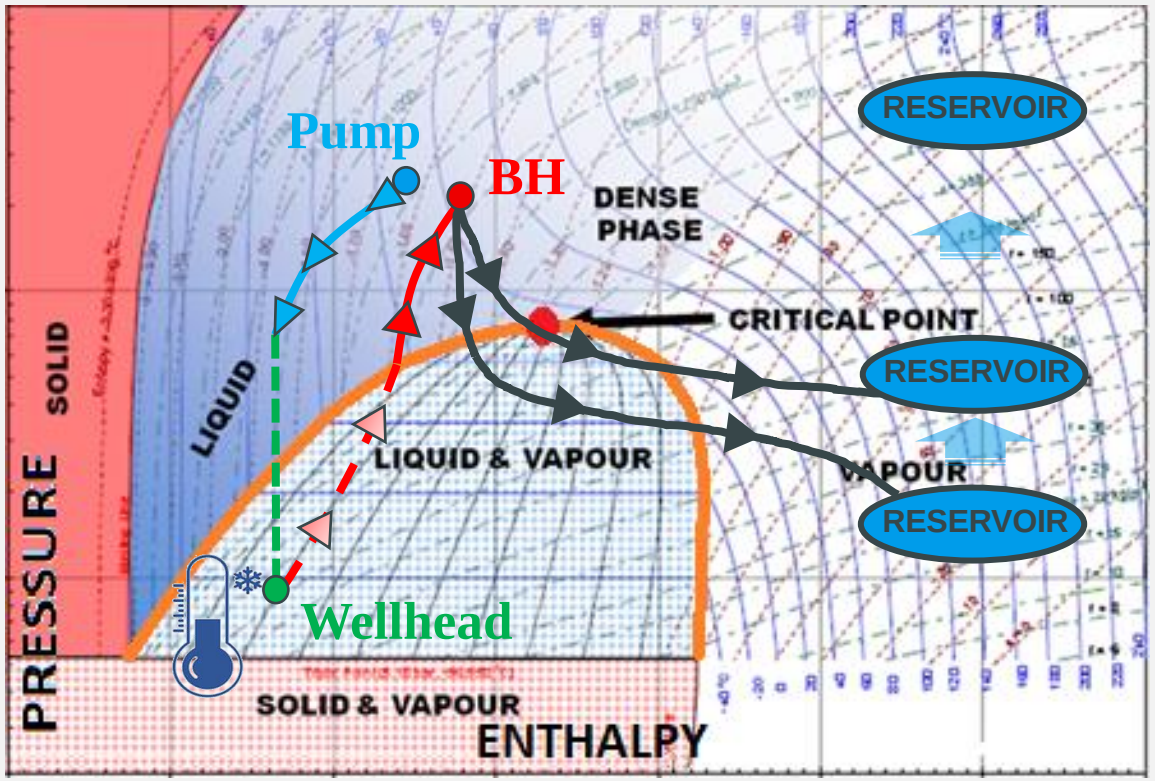


- Injection Rate proportional to Bottom hole pressure
- Well control on Wellhead Flowing Pressure
- Min WHFP = **74 bara**: subject to compo change & extr. temp. events

Pressure/Enthalpy vs Pressure/Temperature

Pipes => choke => well => Reservoir

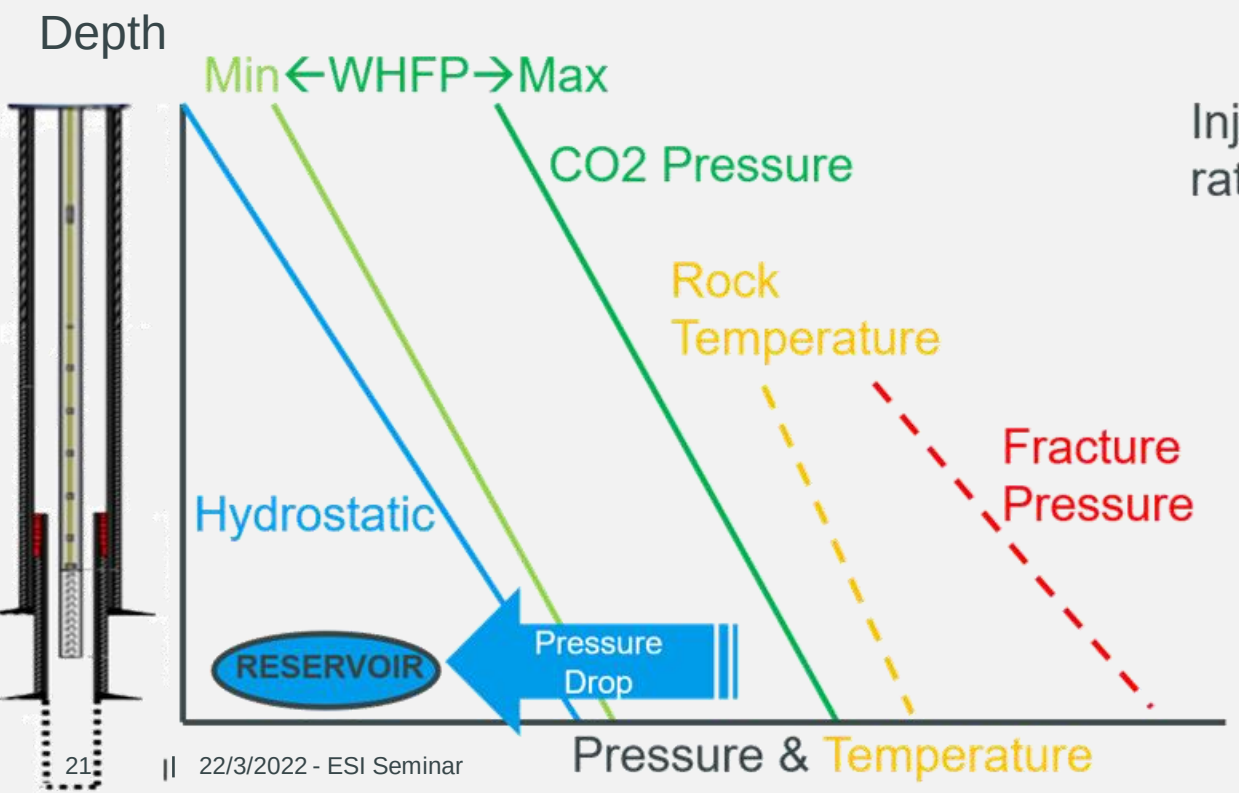


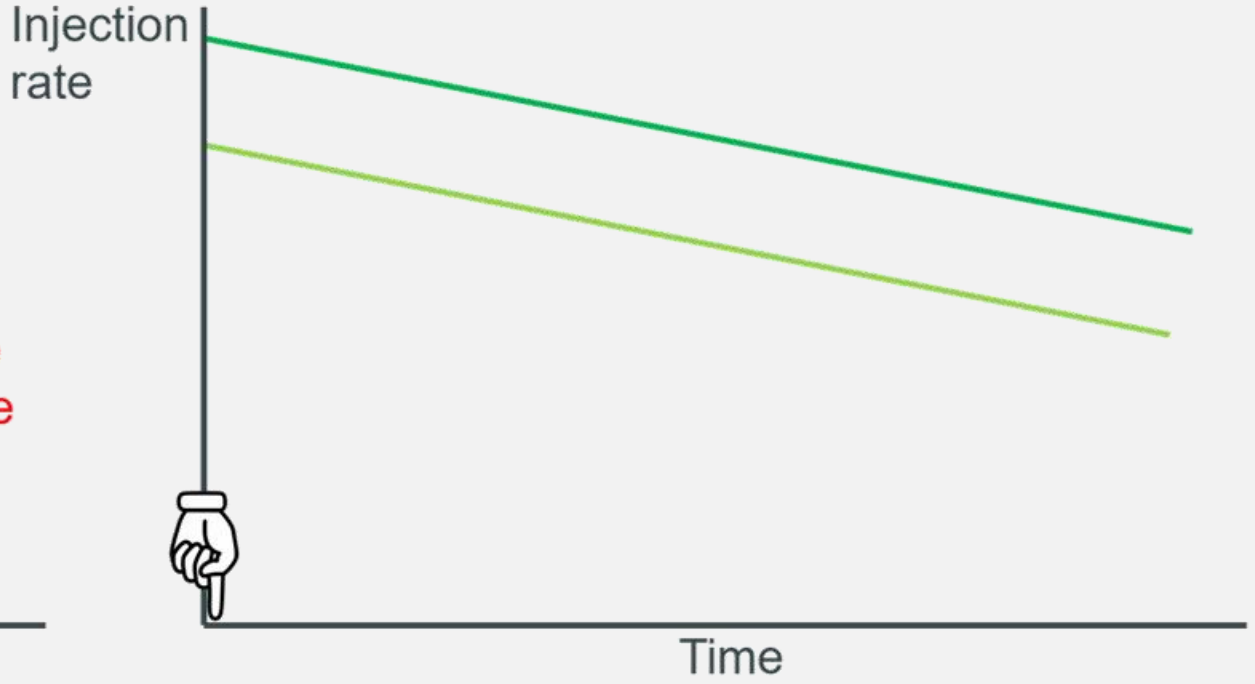


- A new generation of P/H tools is required to simulate from Surface to Reservoir
- **RISKS**: Inaccurate injection profiles and actual blowout risk due to material failure

Well controllability and working range

- Target Rate is very high: fill up the reservoirs 3 times faster than they were emptied with same # of wells
- High rate → High Bottom hole Flowing Pressure
  - → Massive flash at low reservoir pressure
  - → Rock cooling around the well Rock fracture risk
  - → Well Integrity risk (Catastrophic)





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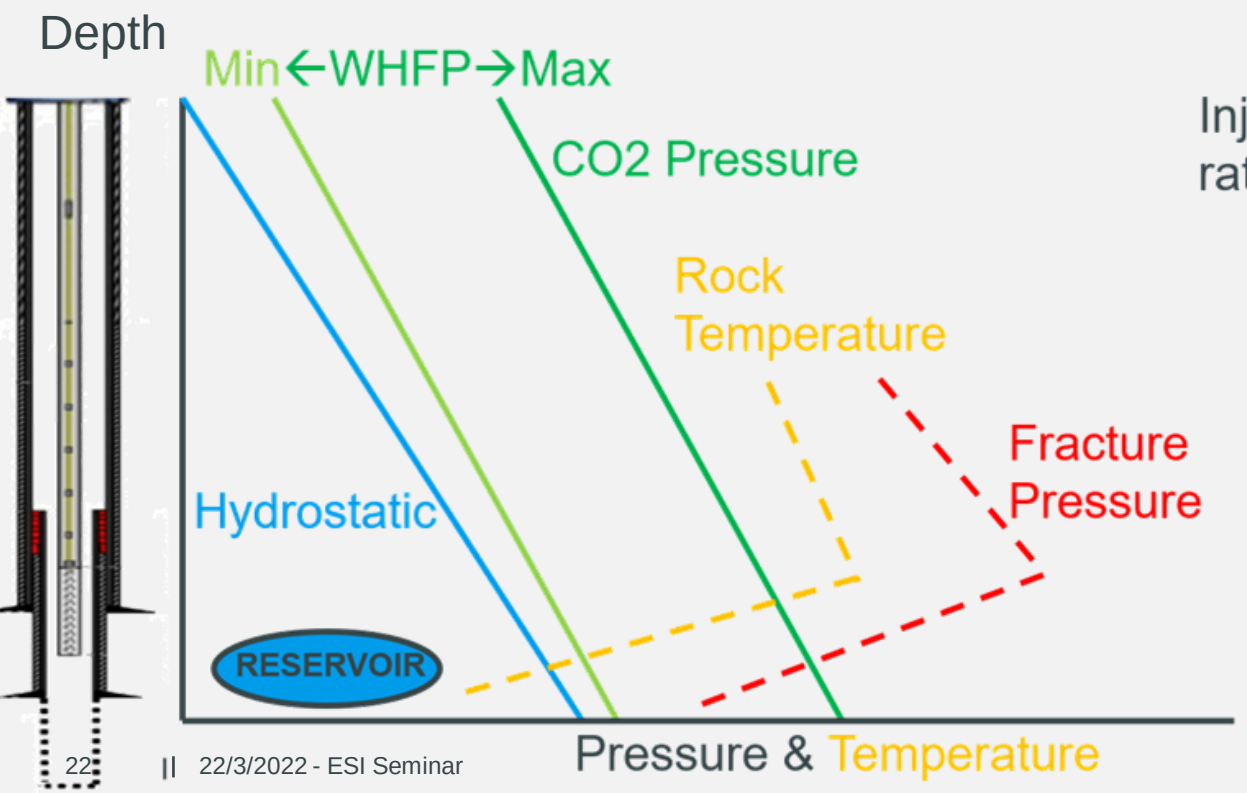

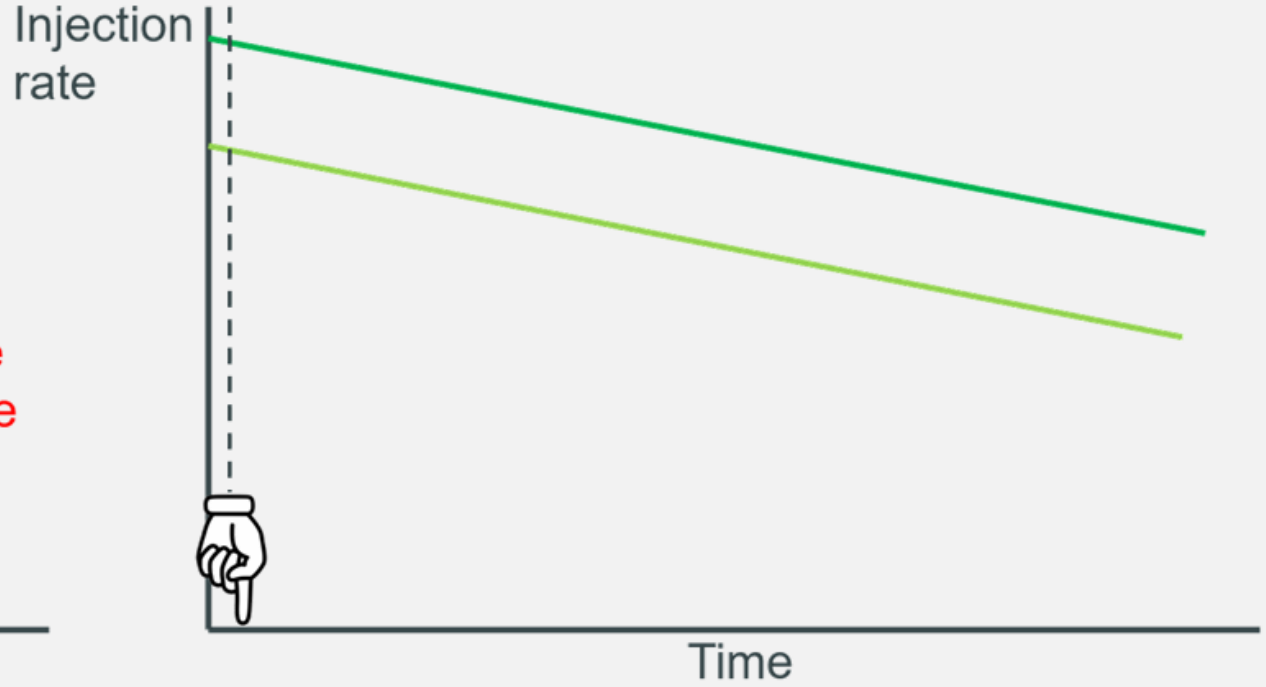

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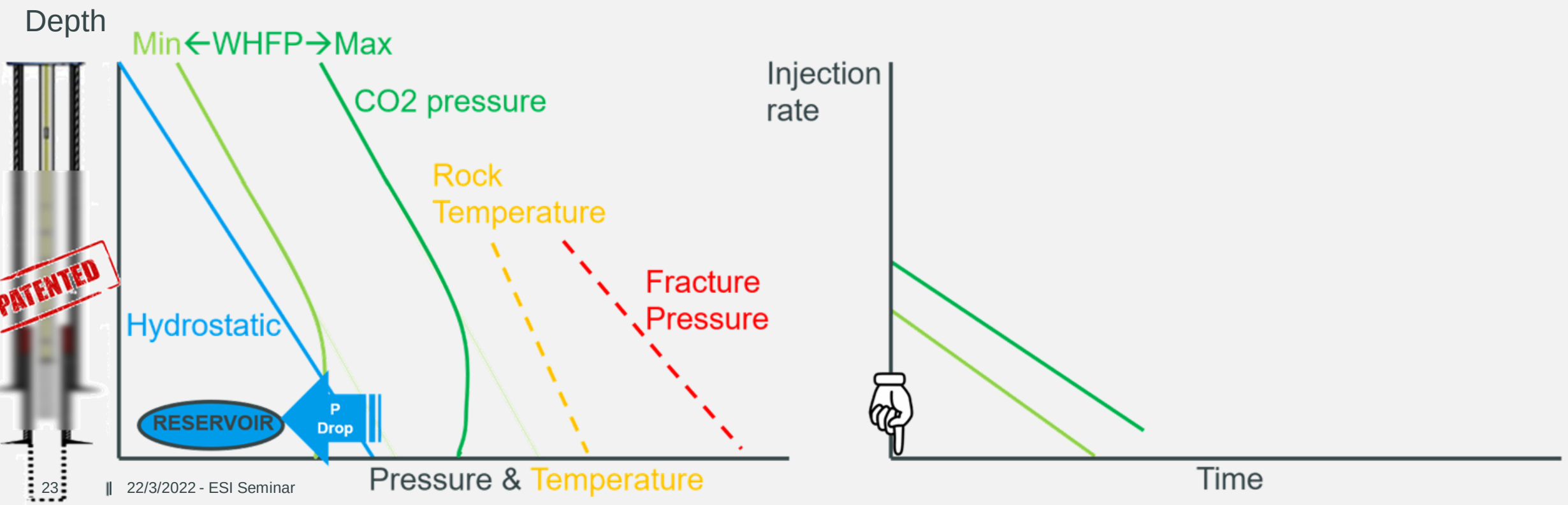

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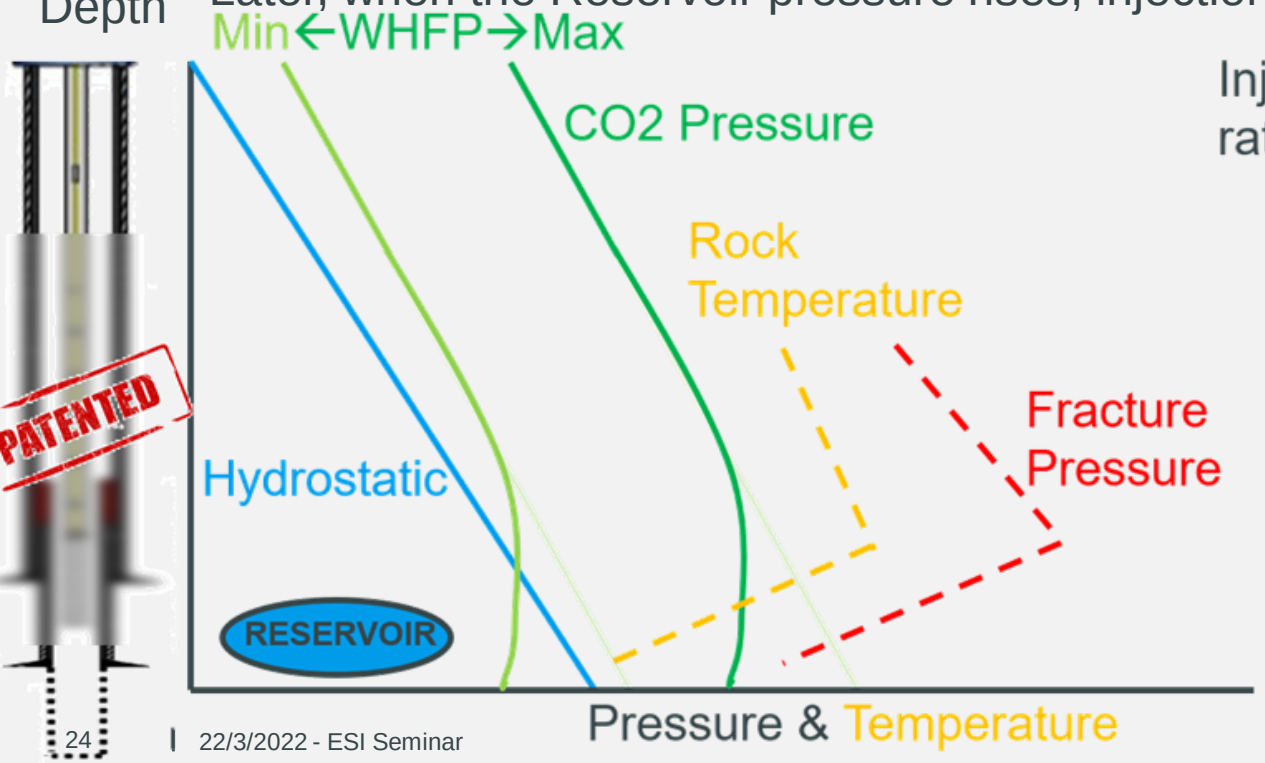

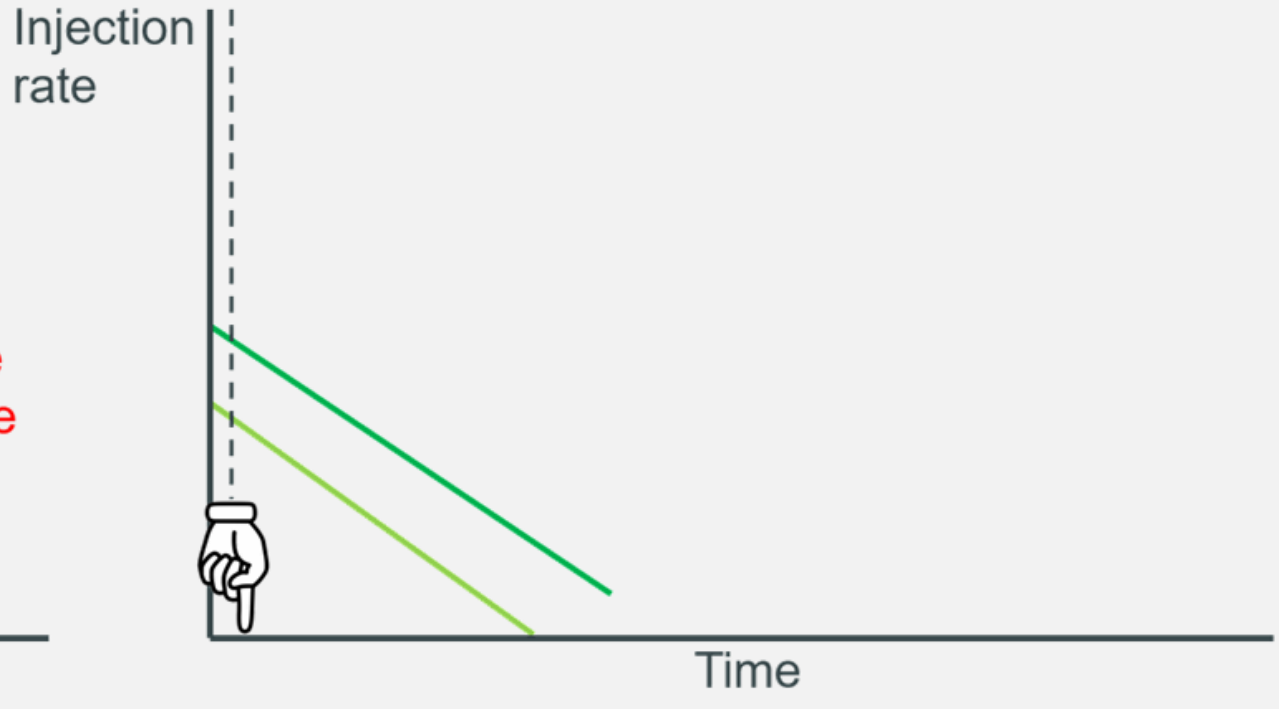

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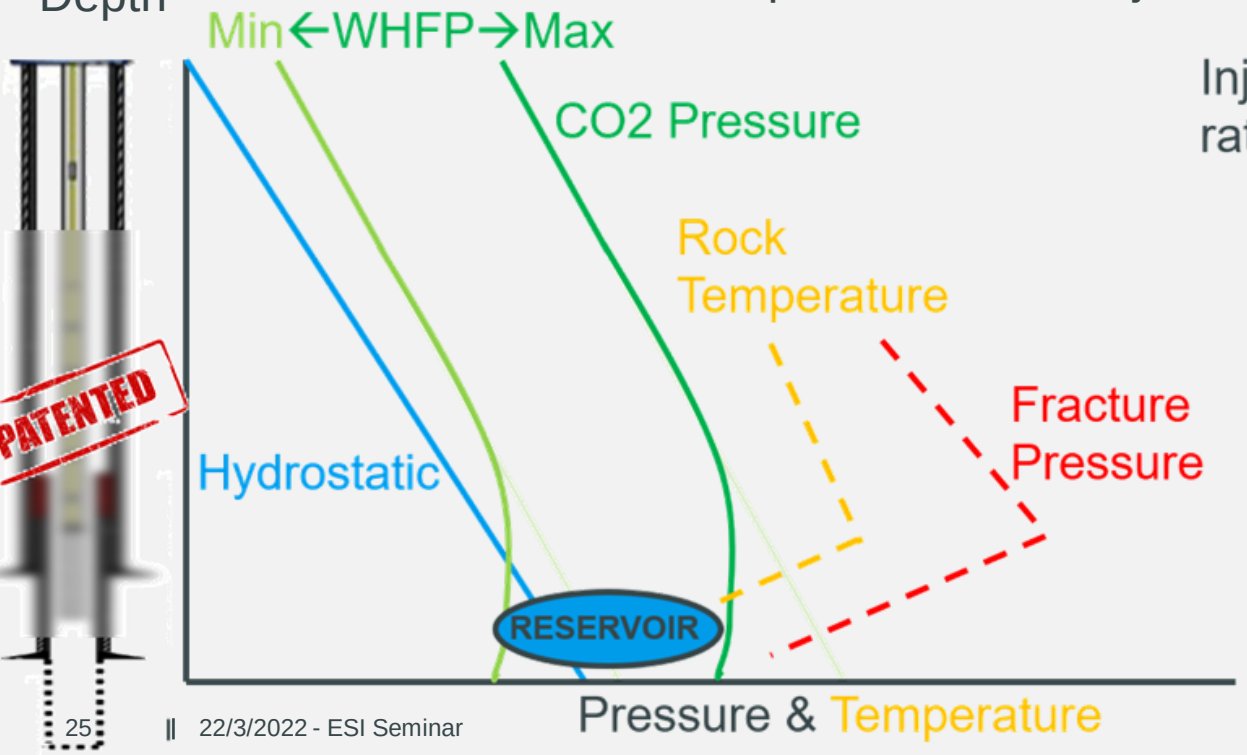

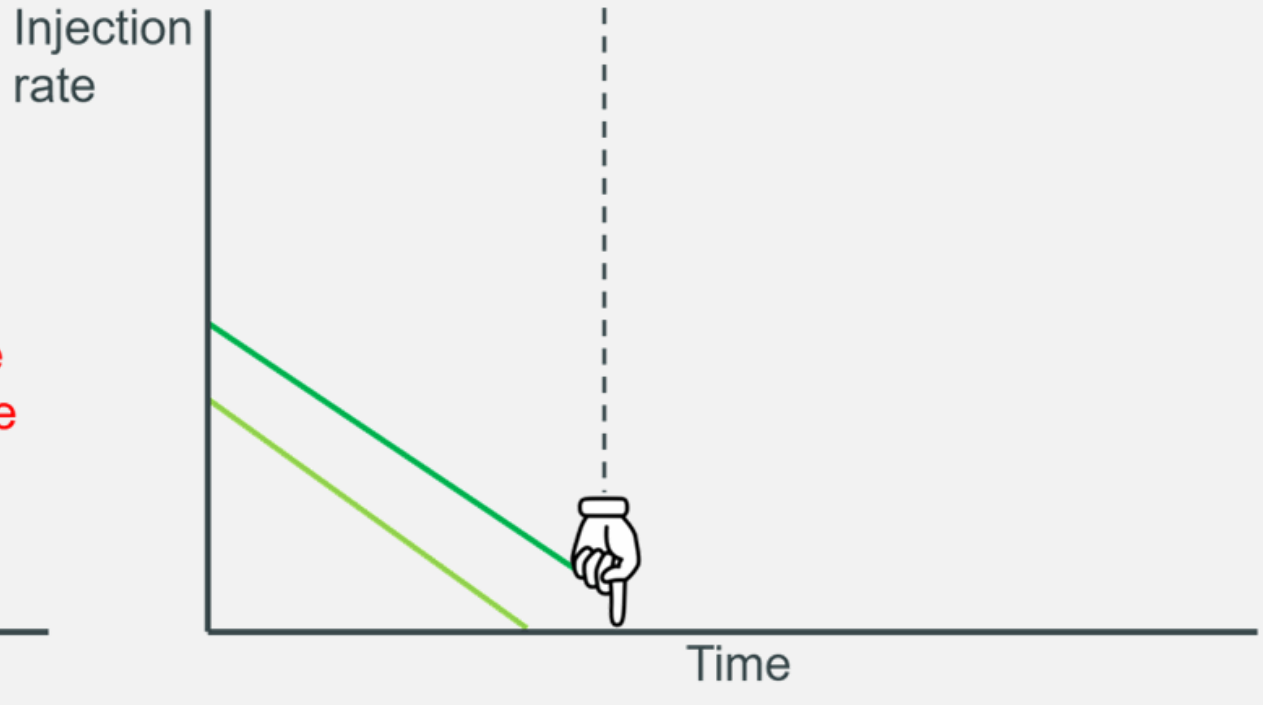

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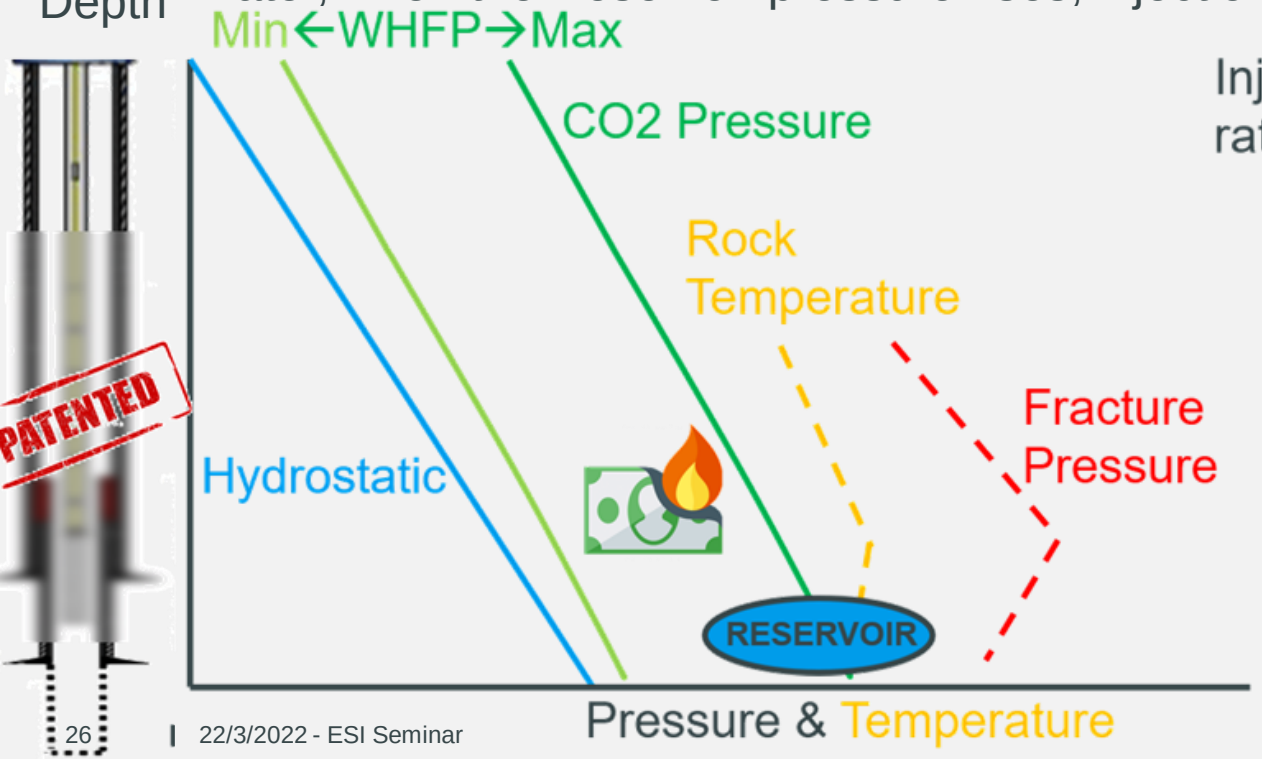
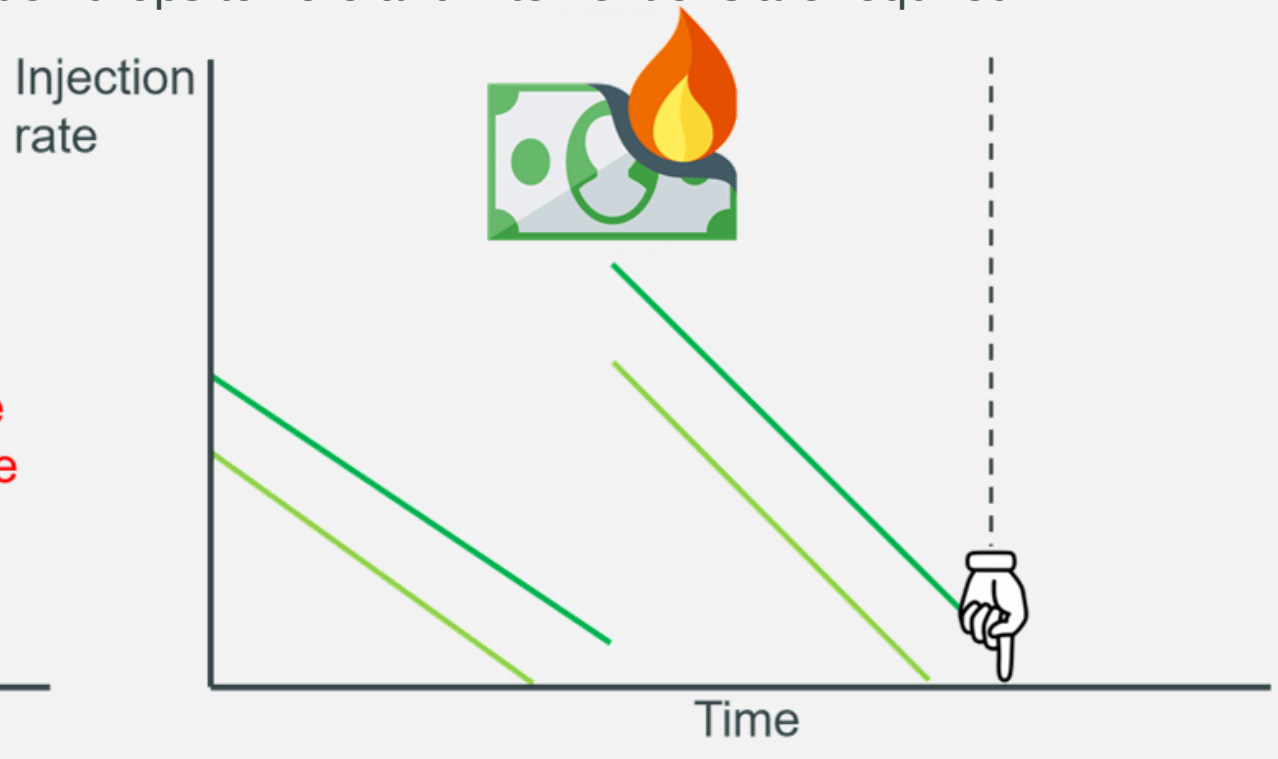
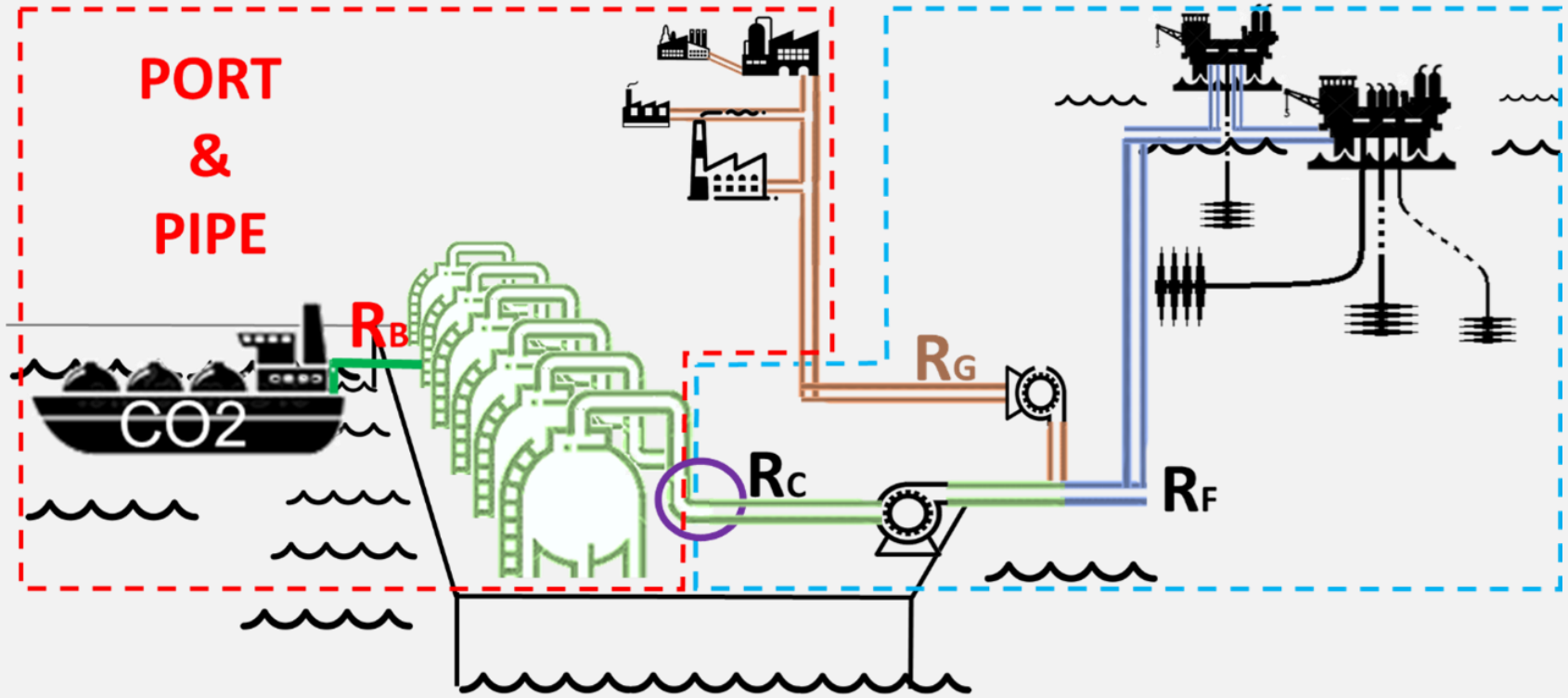






04.

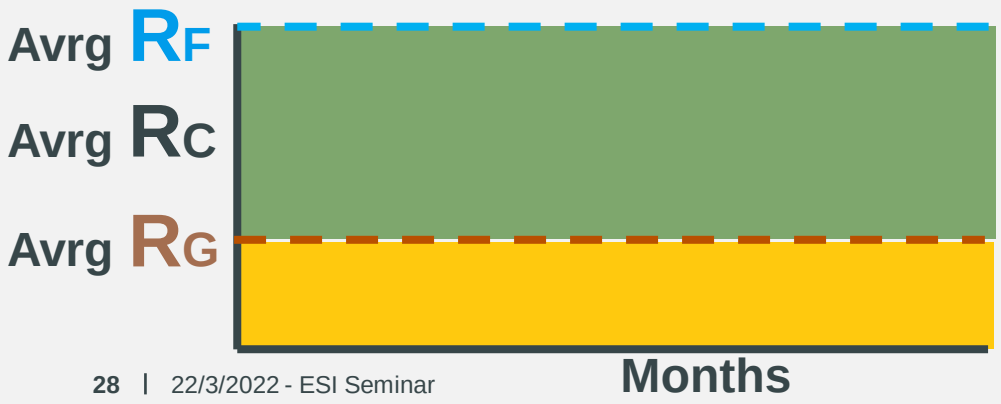
2 FM questions

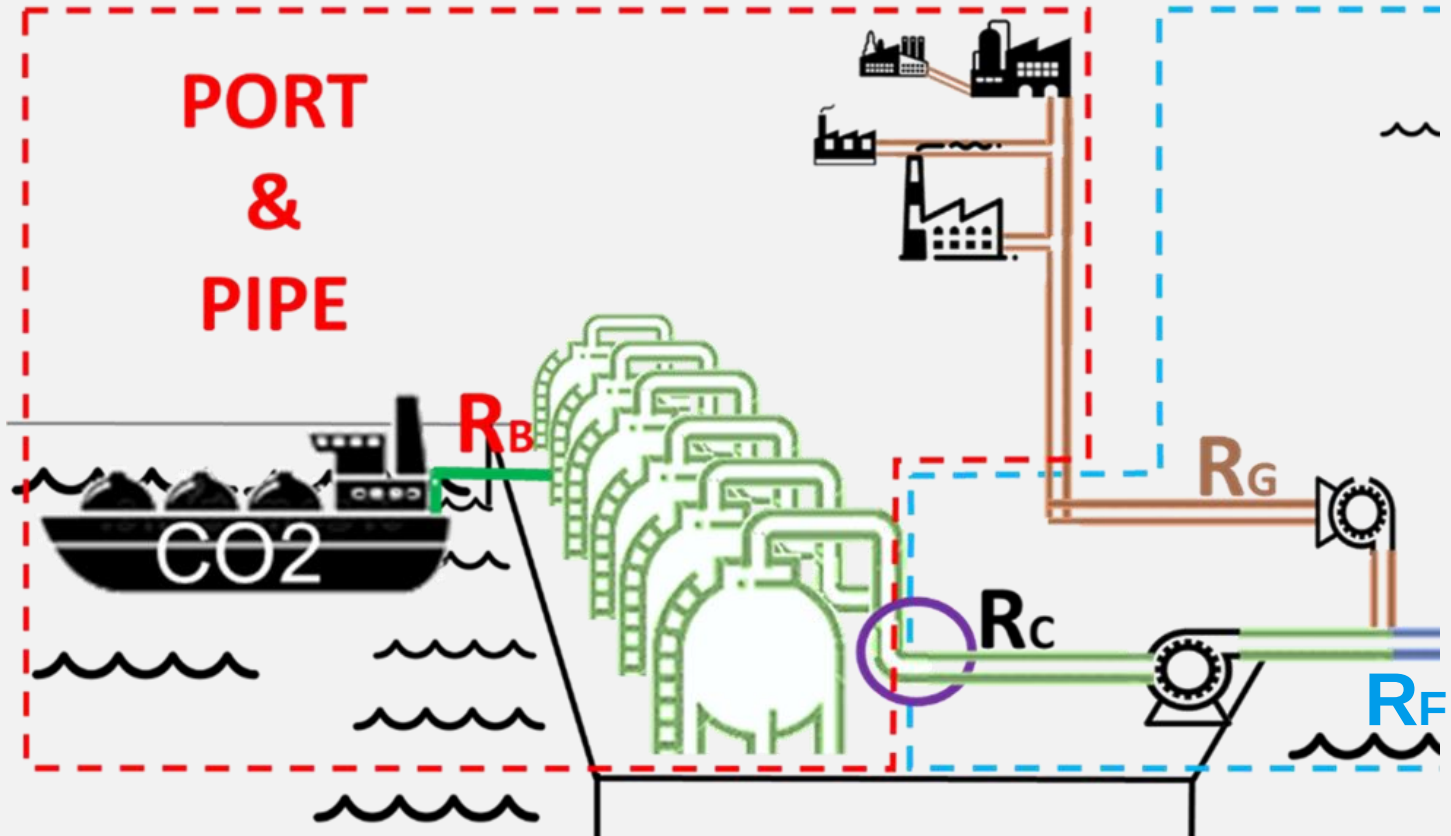
CO2 Supply to the Injection system

- Possibly combined gas – by pipe - and cryogenic – by boat – phases
- Cryogenic downloaded to terminal tanks → complement gas pipe
- Gas pipe directly to injection or vented
- Uncertain rates from both sources:
  - Boats schedule?
  - Boat sizes vs number of boats?
  - Storage tanks volume?
  - Maximum pump rate?
  - Tanks management strategy?
  - Venting vs investment?
  - Export rate stability: Definition and

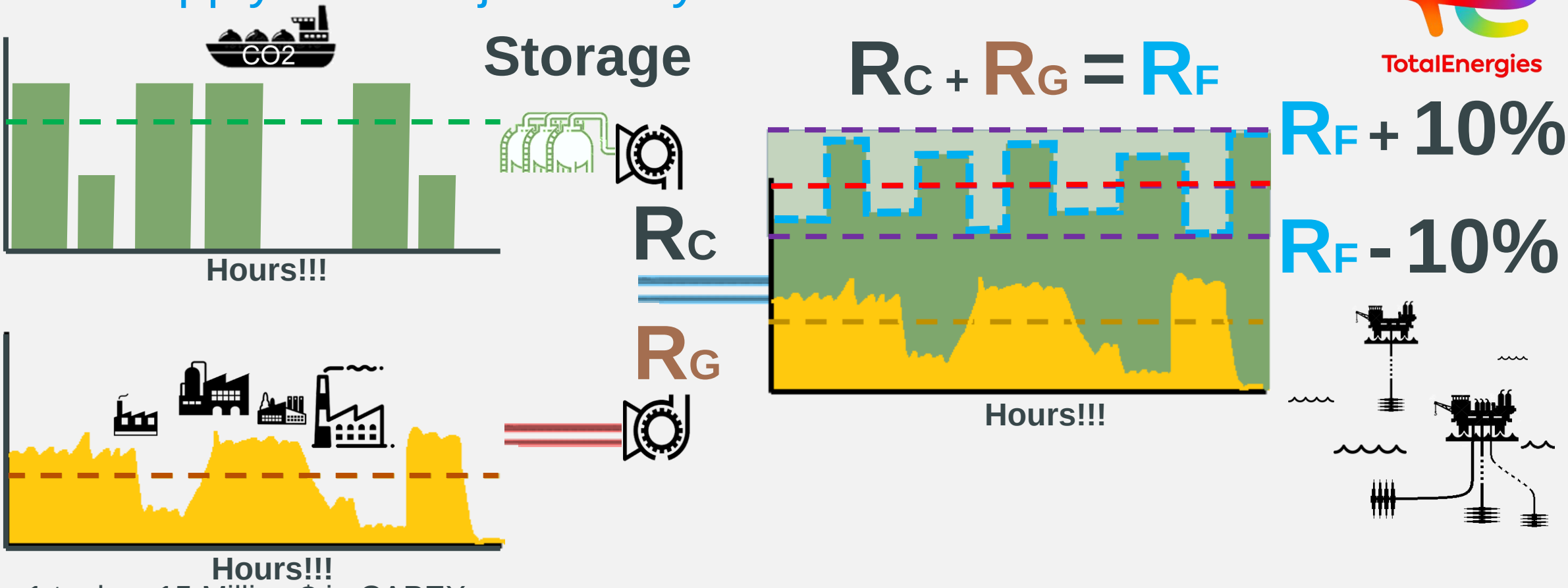
$R_F = R_G + R_C$

Stored Vol = $\sum_{Truncated} RB - RC$





CO2 Supply to the Injection system: “Instantaneous” rate



- 1 tank = 15 Million $ in CAPEX:

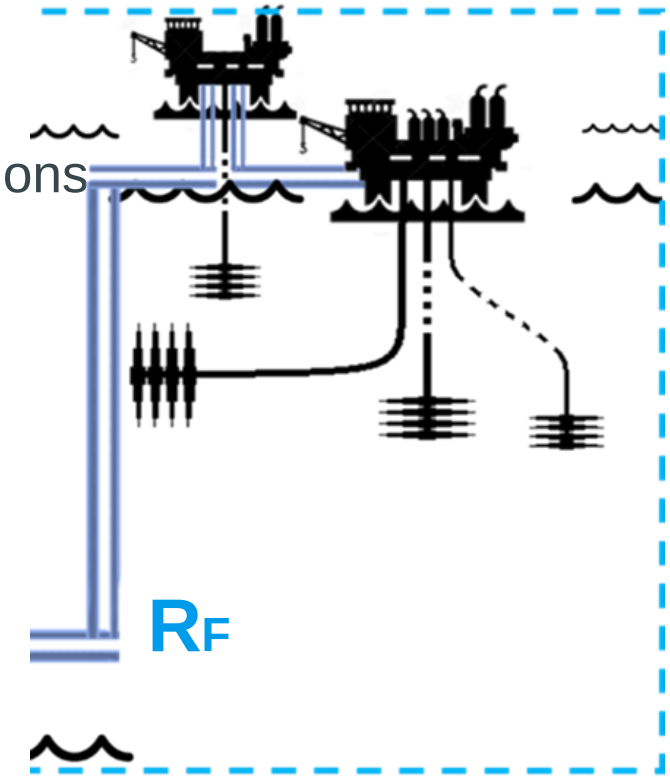
Optimize on number and size of boats, number and size of tanks, tank management strategy, min/max pump rates in order to minimize the vented CO2 and the rate variability around a target in the hourly scale

- Solutions currently implemented internally at TotalEnergies
- Cooperation with CMU EWO in order to explore Stochastic Multiperiod optimization problems

Wells selection on target injection rate

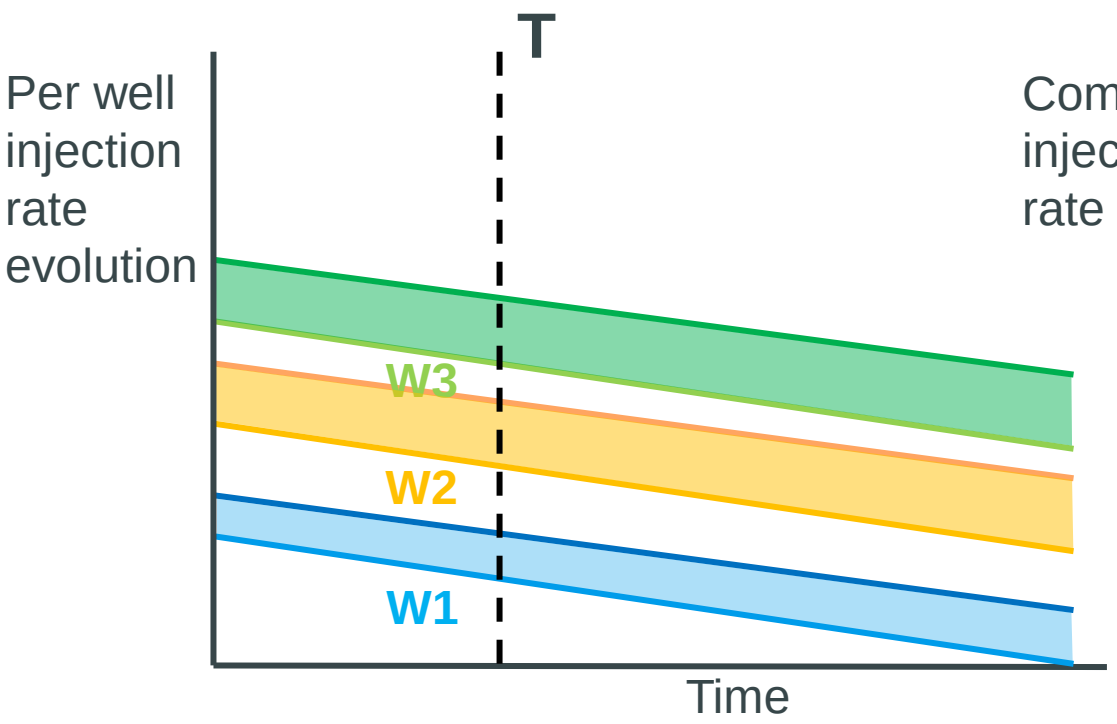
- **R_F changes** → Well rate changes
  - → **"Slow"** well stabilization
  - → Wells interdependence / System stability
  - → Limited working range per well
- **R_F** fluctuates hourly, under stress scenarios, seasonally…
- Wells usage → reservoirs occupation (fluid distribution over storage)
- Restricted well rates make it hard to match a given target
- Well action: chokes operations, well open/close, smart completion actuations
- Very successful cooperation with CMU EWO

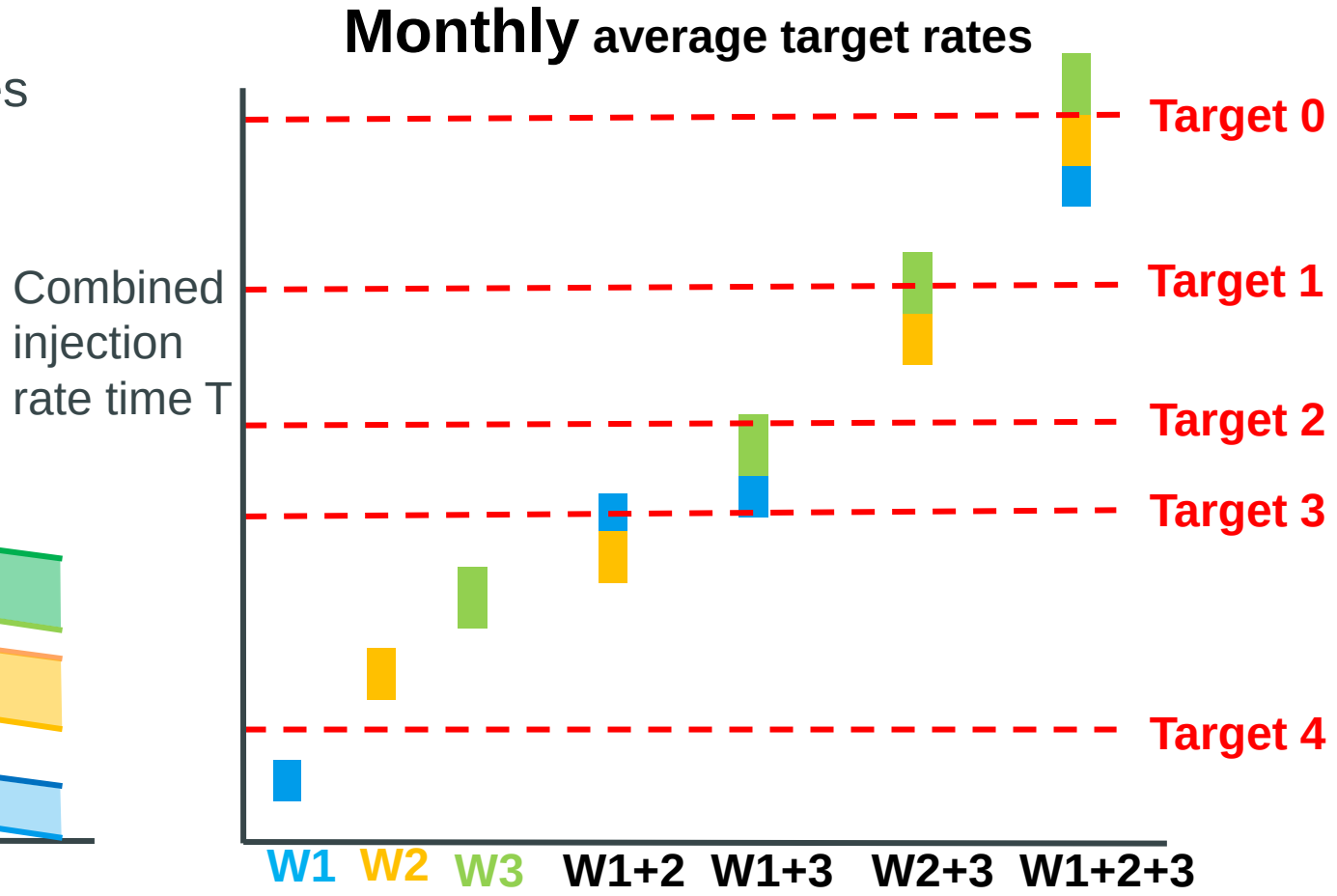
$$R_F = \sum R_{well\ i}$$



Wells selection on target injection rate

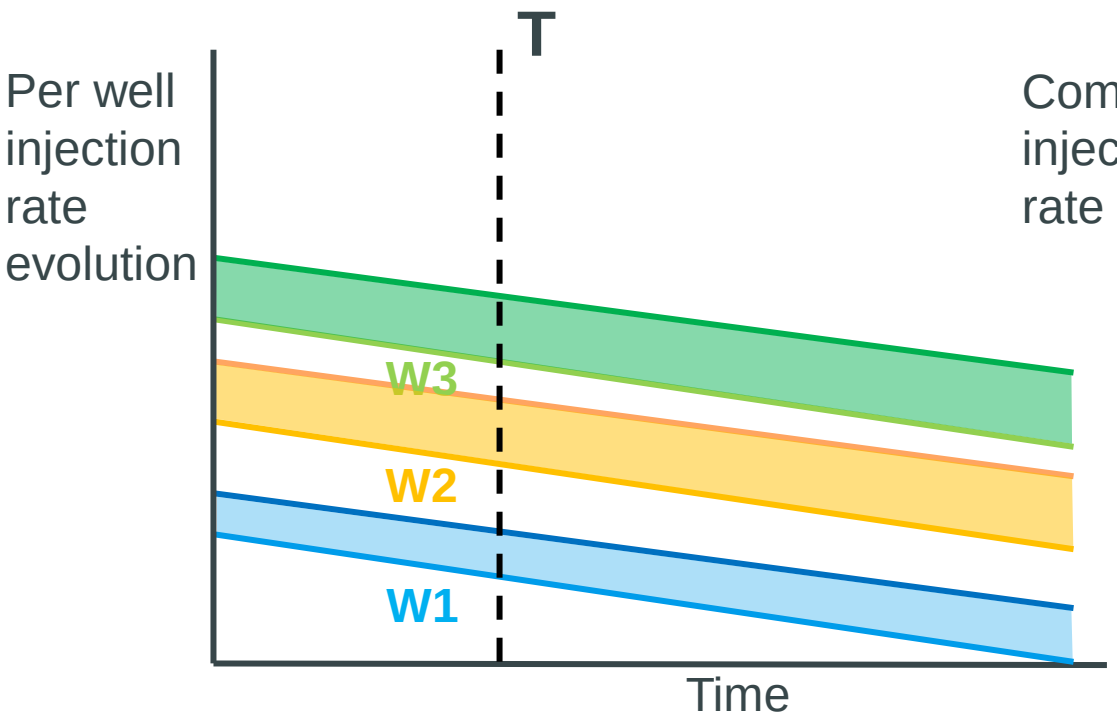
- Monthly average targets give a false sense of solution
- Stress scenarios must be considered at excess and shortage rates
- Very successful cooperation with CMU EWO
- Multiperiod optimization MINLP
- Patented solutions exist in TotalEnergies

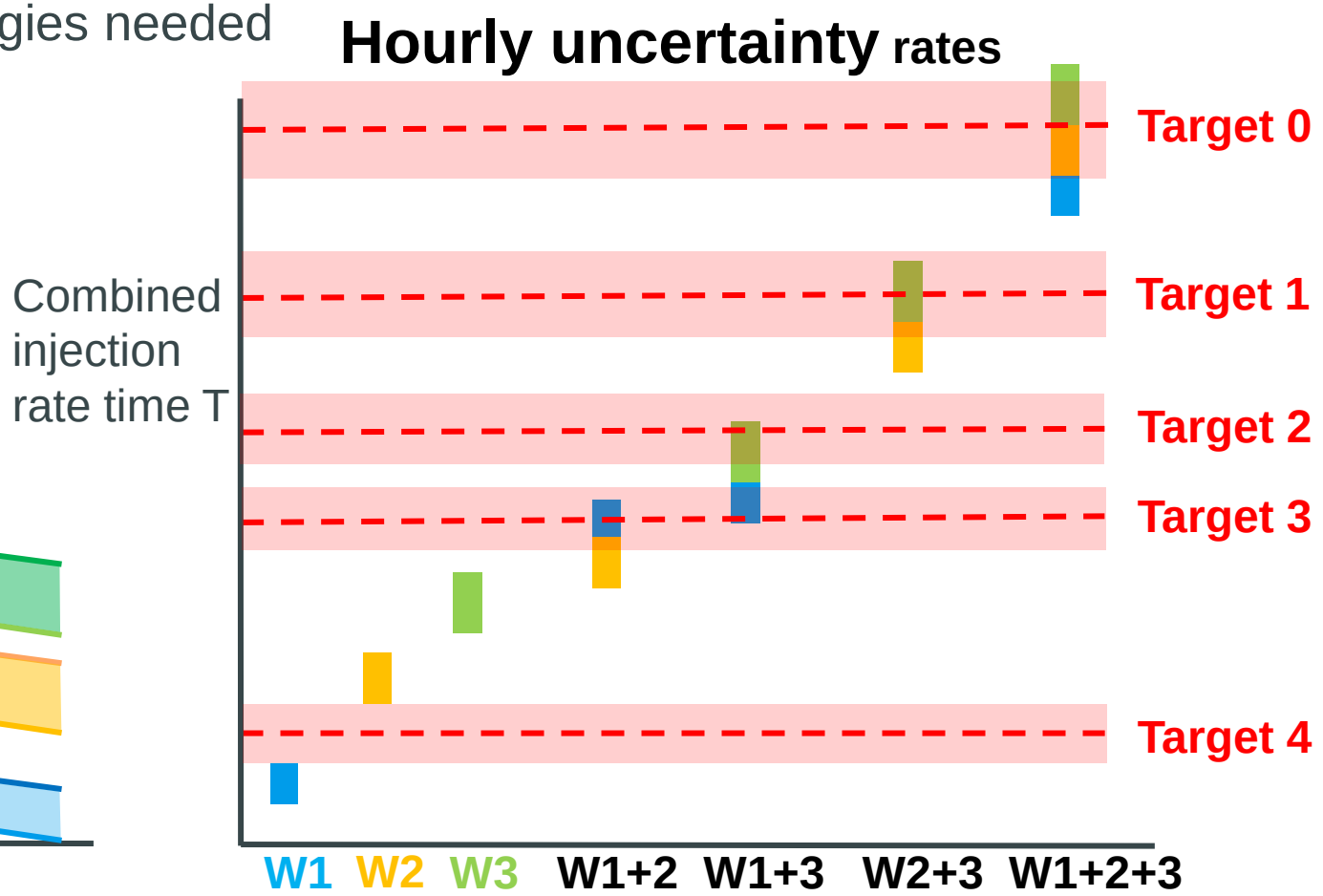




Wells selection on target injection rate

- Stochastic multiperiod optimization version of the MINLP
- Terminal rate variations + partners rate variations + 100's of pipe kilometers
- Time scale dependent
- Innovative facilities management strategies needed
- Starting cooperation with CMU EWO





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GRACIAS !
THANK YOU!
Takk skal du ha
આભાર
obrigado
Vielen Dank
Terima kasih
Weebale