

Spot history match to reduce uncertainties and secure FID



Risk, certification & insurance for CCS



Evidence

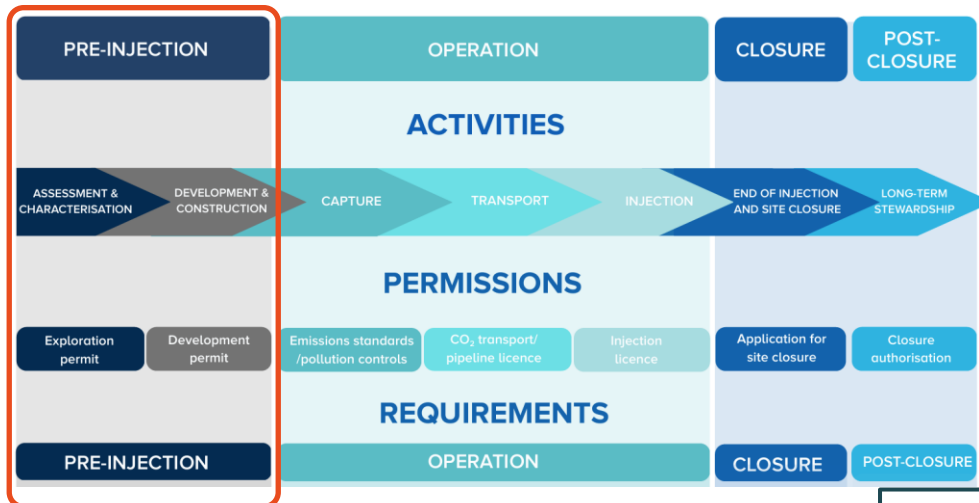
Turn monitoring
into proof.

Elodie Morgan
Habib Al Khatib



CCS, uncertain?

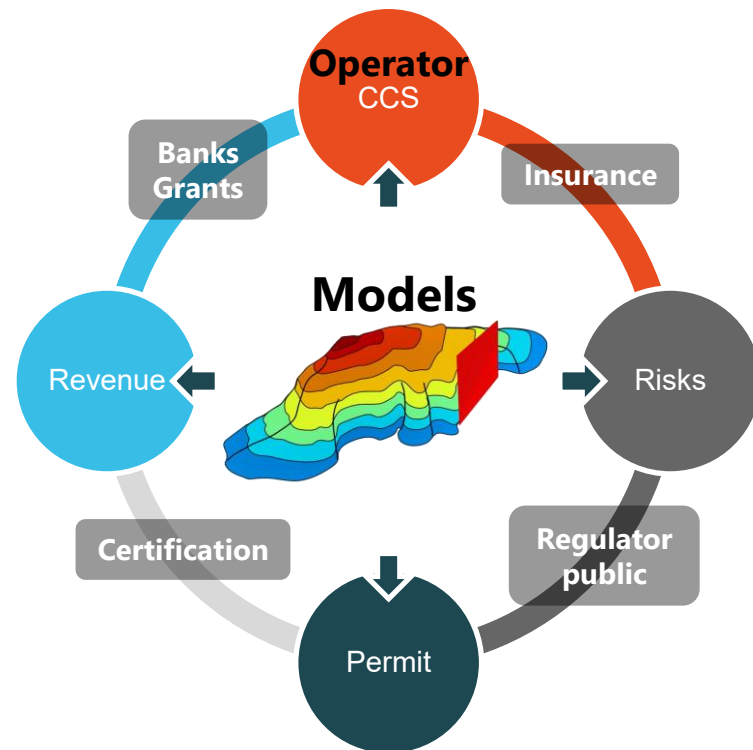
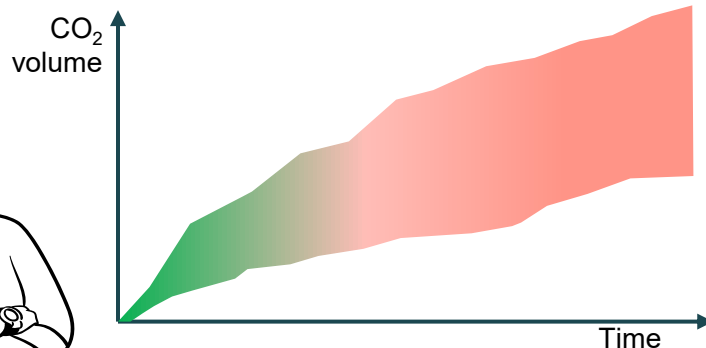
- Pre-injection permits leads unlock the full CCS value chain (*CCS Global Institute, 2025*)
- Before any molecule of CO₂ is injected into the ground, all stakeholders are referring to models



- ✓ Characterisation
- ✓ Stakeholders onboarding
- ↗ Latent uncertainties



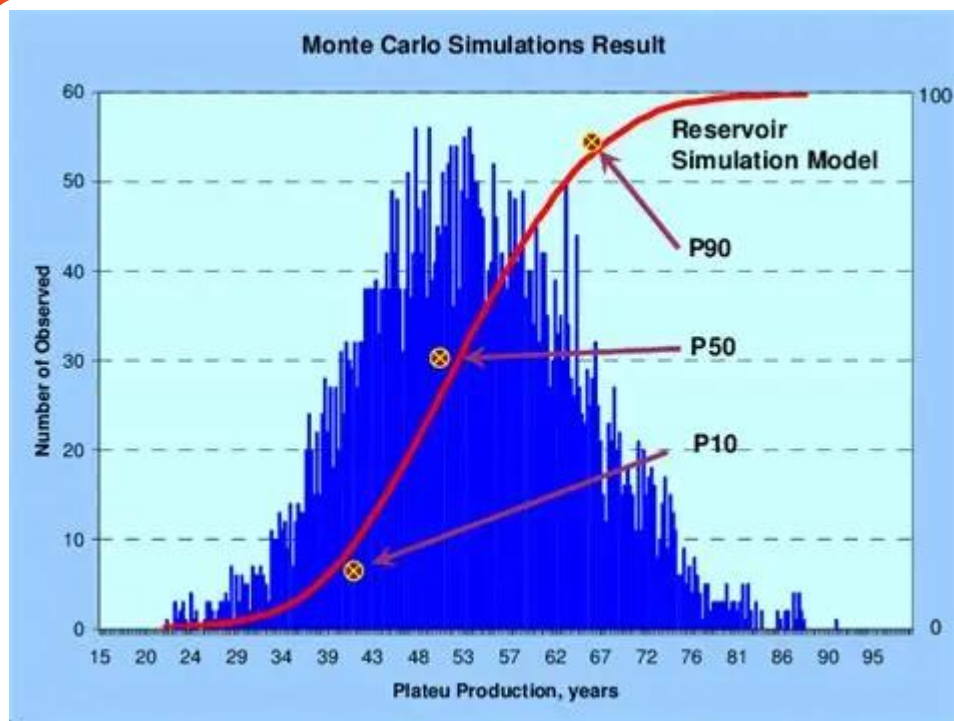
Models are necessary to capture uncertainties



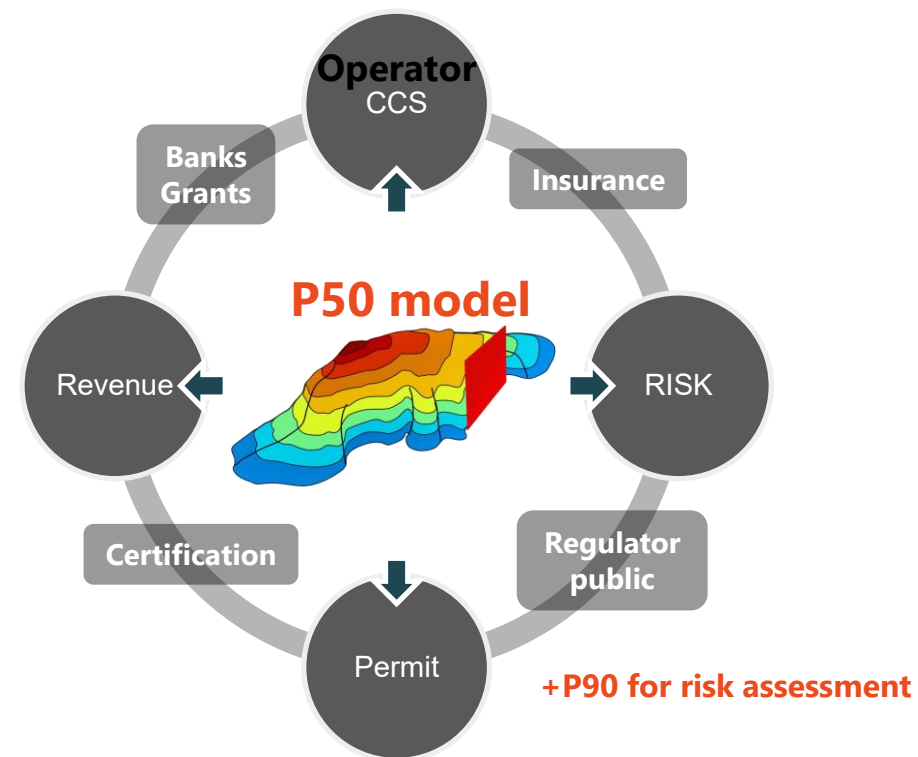


Modelling: what for?

- Model the most probable outcome:



Hoang et al., Geothermal Field Expansion Performance-A Probabilistic Forecast.



What if: we use ensemble to capture uncertainties & **Monitor for convergence**

The paradox:



Quantify risks with **uncertainties**

VS

Gather **certainties** to reach FID?



EVIDENCE: A solution to avoid surprises

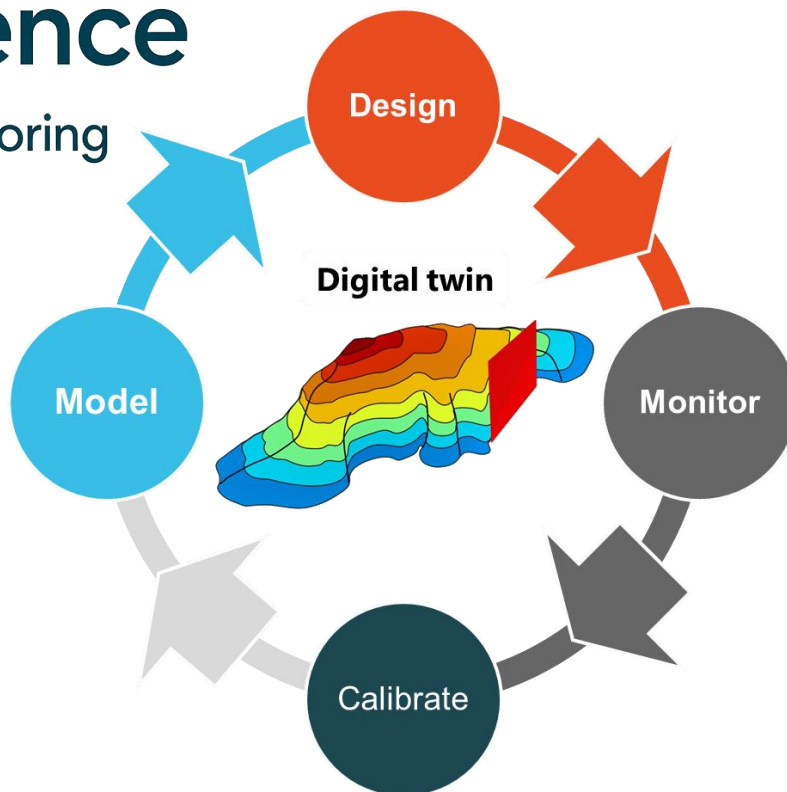
Regulation is requiring to calibrate models regularly

Securing a CCS project with regular calibration can ensure:



Evidence

Turn monitoring
into proof.



Project
finance



Phasing
CAPEX



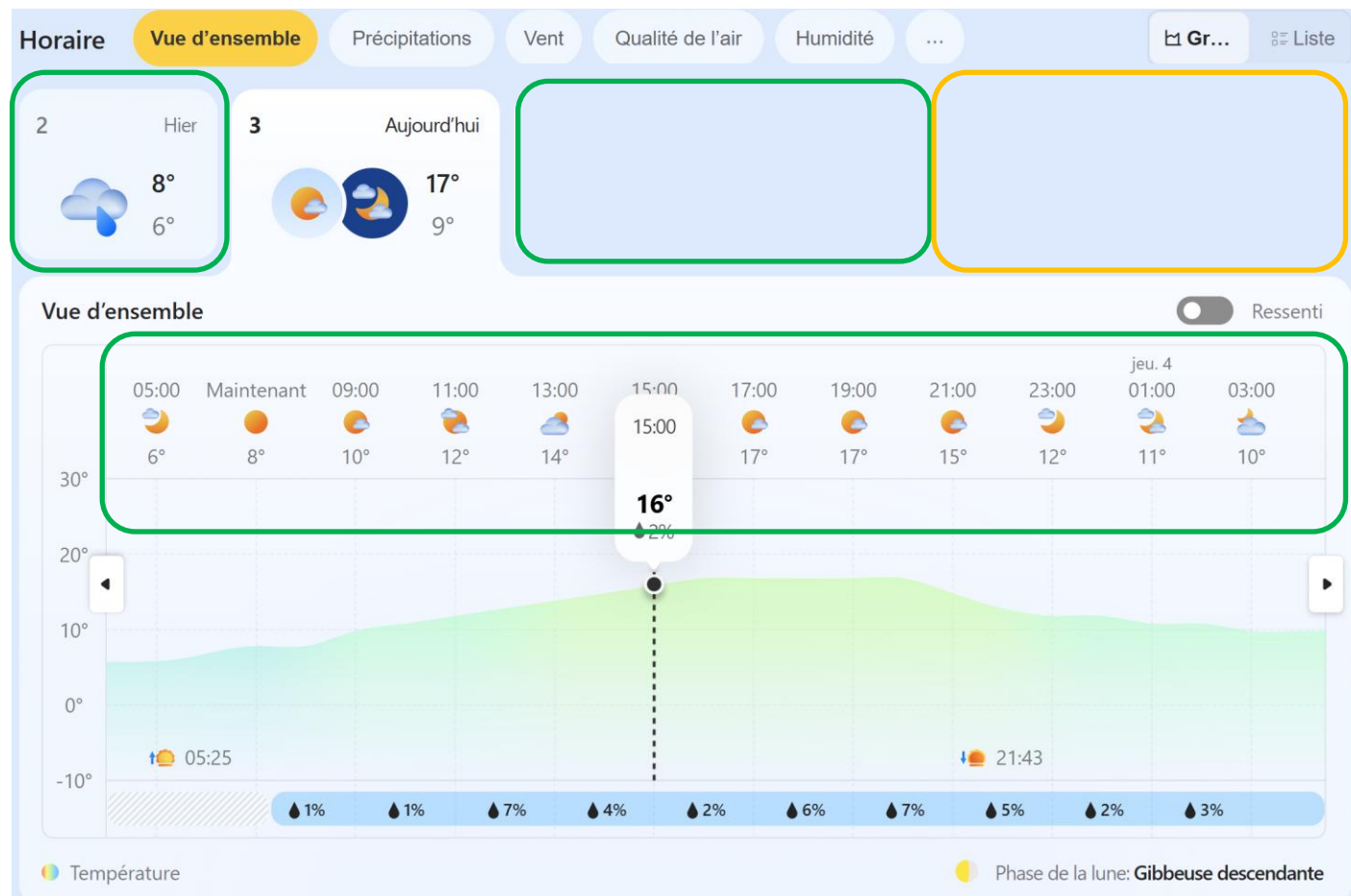
Secure
Permits



Uncertainties and how to deal with it



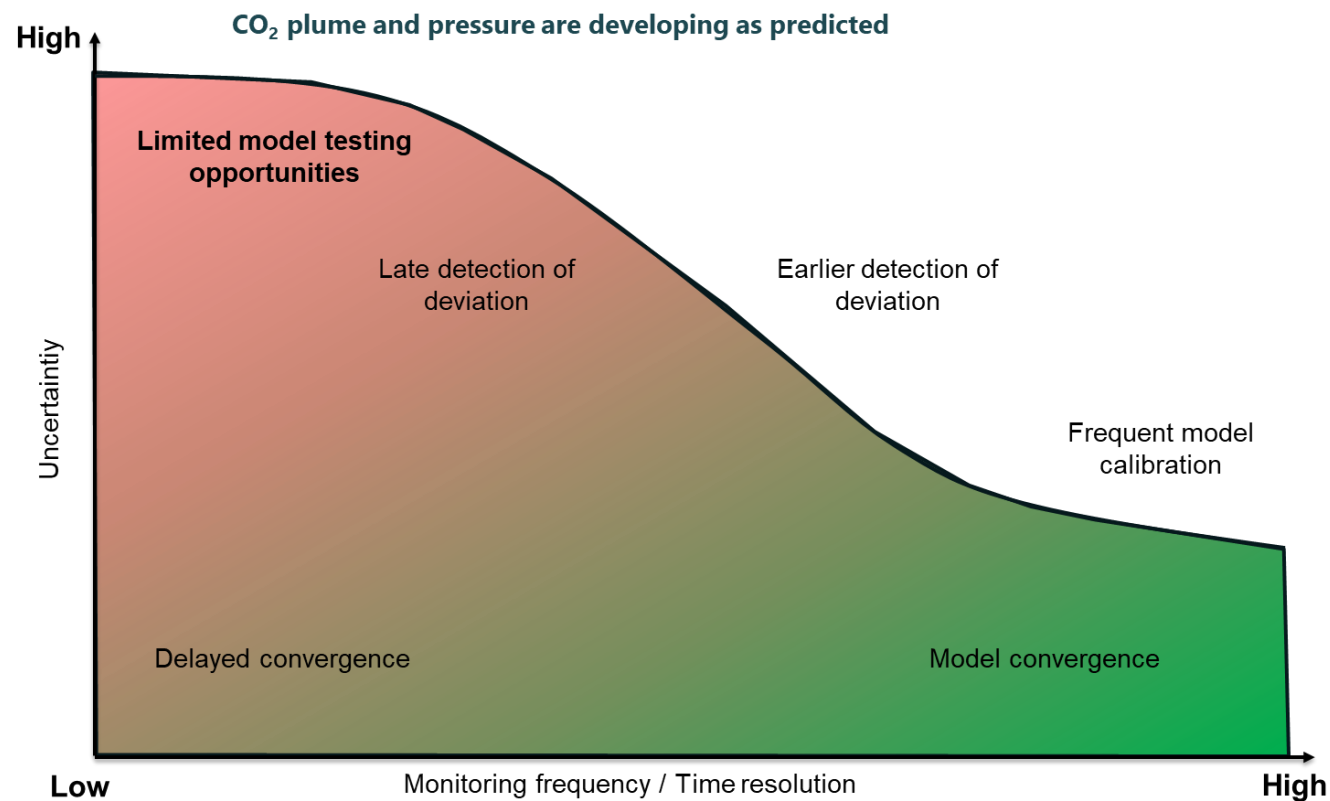
Unpredictable weather – Calgary Last Week forecast



→ Weather forecast uncertainties are growing with time



Unpredictable reservoir ?



→ Just like the weather forecast, **subsurface model uncertainties are growing with time** if not calibrated often

Use case

How to unlock value pre-injection

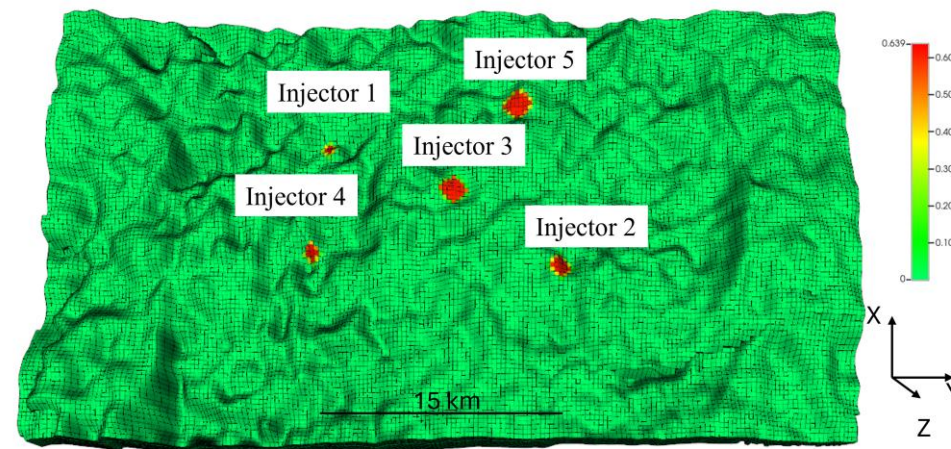


Case study: CO₂ injected in saline aquifer

- CO₂ injection with 5 injections wells over 10 years
- Saline aquifer characterized with a 3D seismic and few appraisal wells
- Variations in petrophysics capturing the full uncertainty space of the reservoir.

→ The ensemble acts as a **Monte Carlo representation** of subsurface uncertainty

Risk: AOR maximum limit to 30km²

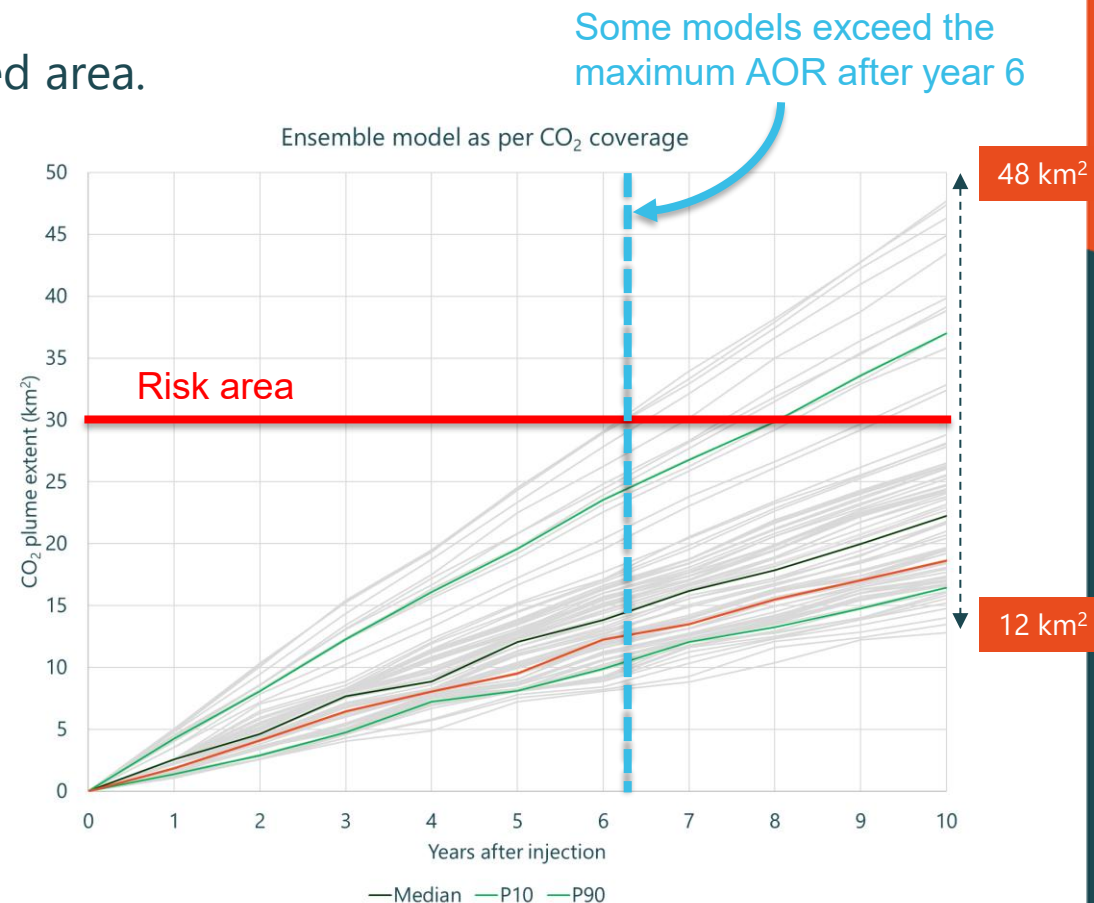
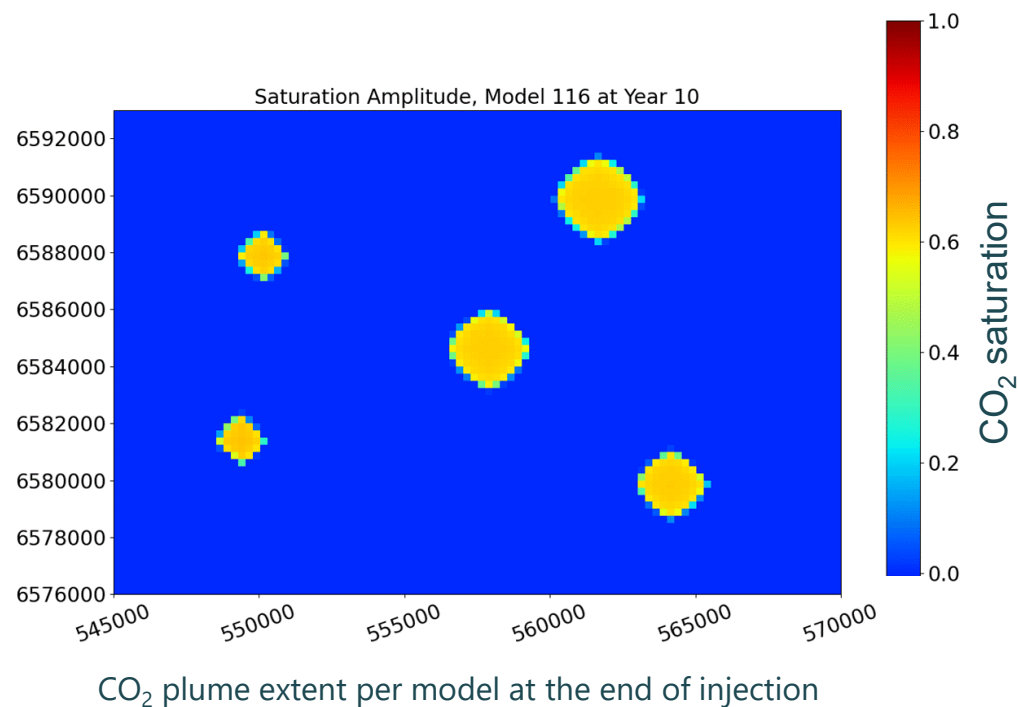


Quantified uncertainties	
Parameter	Distribution (min, max, average)
Porosity(%)	Poro Multiplier (0.50, 1.50, 1.02)
Permeability (D)	Perm Multiplier (10, 40, 25.5)
Rock compressibility (1/kPa)	(5.10^{-6} , 2.10^{-5} , $1.24.10^{-5}$)
Thermal conductivity (J/m·s)	(0.70, 2.10, 1.35)
Heat capacity (J/kg·K)	(730,1030, 751.43)
Residual CO ₂ saturation (%)	(0.20, 0.50, 0.347)
→ An ensemble of 120 models is generated based on one scenario	



Model uncertainties

- Multiple models lead to quite different final impacted area.



1. Pre-injection the risk is estimated at year 6 and onward
2. How can we help reduce uncertainties?

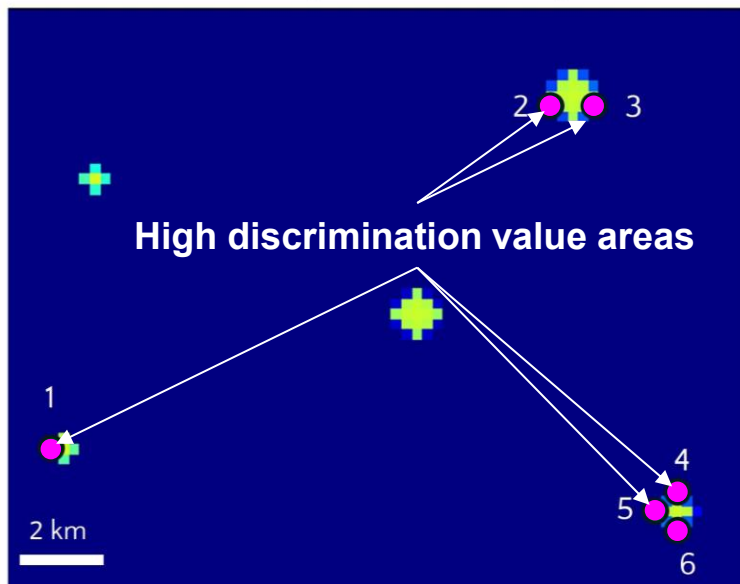




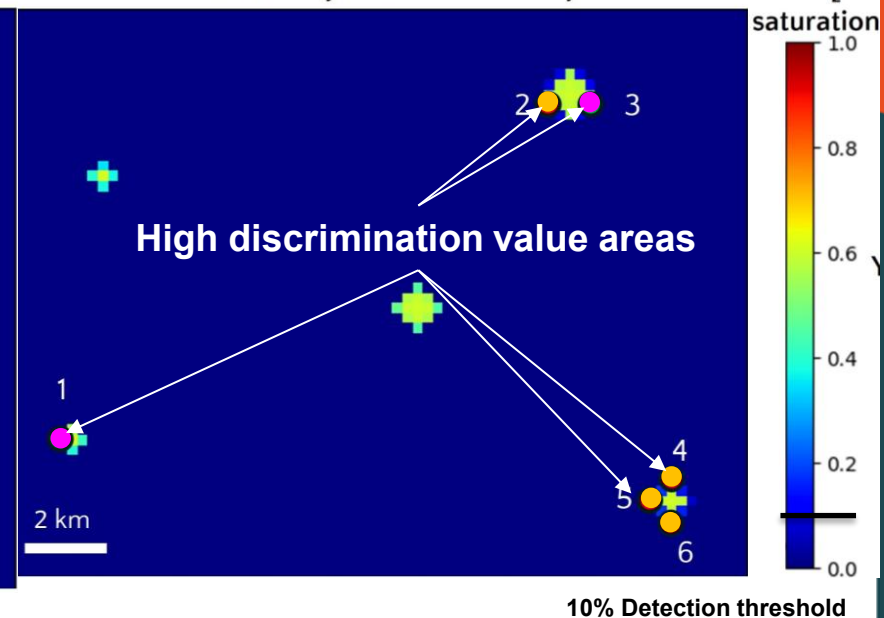
Guess who ? *(is the most probable model)*



Spot Identity Card
for model 63 at year 2 after first injection



Spot Identity Card
for model 73 at year 2 after first injection

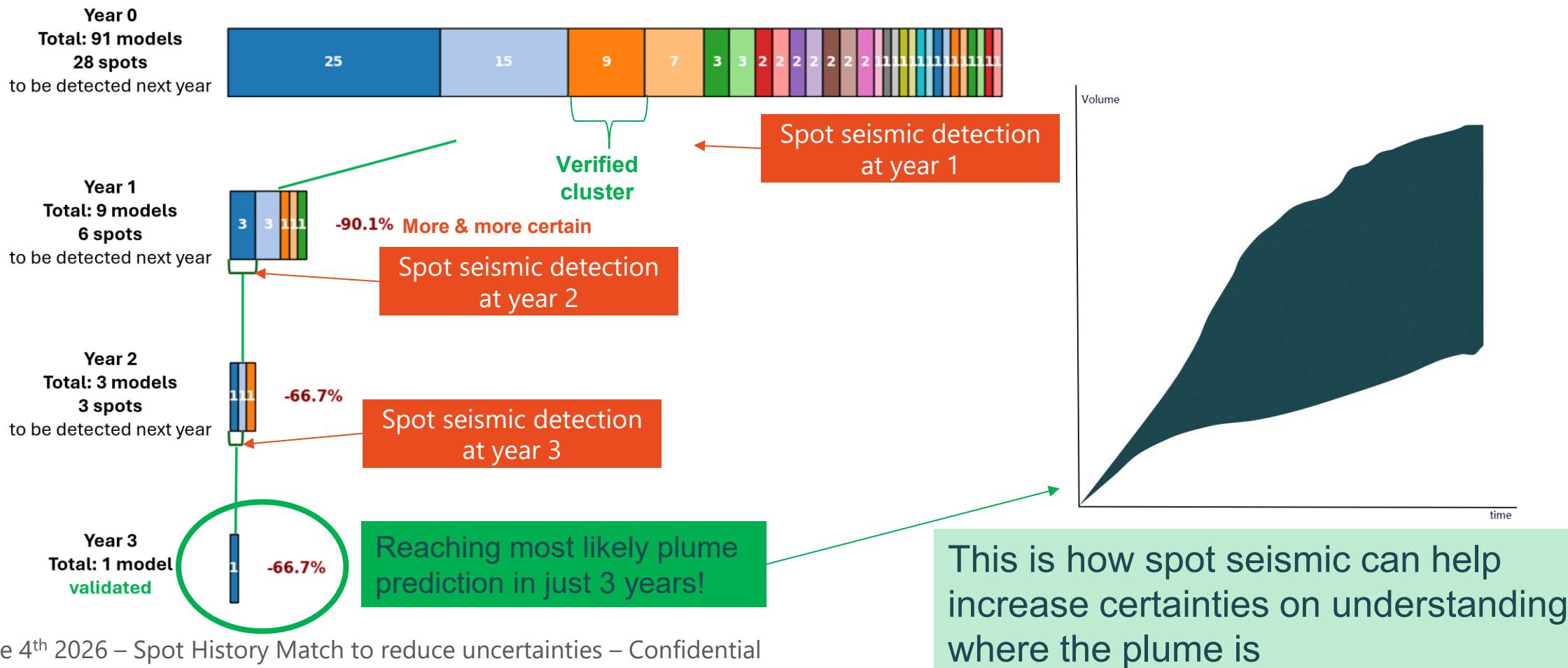


● CO₂ detection expected ● No CO₂ detection expected



Only 3 yearly acquisitions are needed to converge toward the most likely plume outline scenario

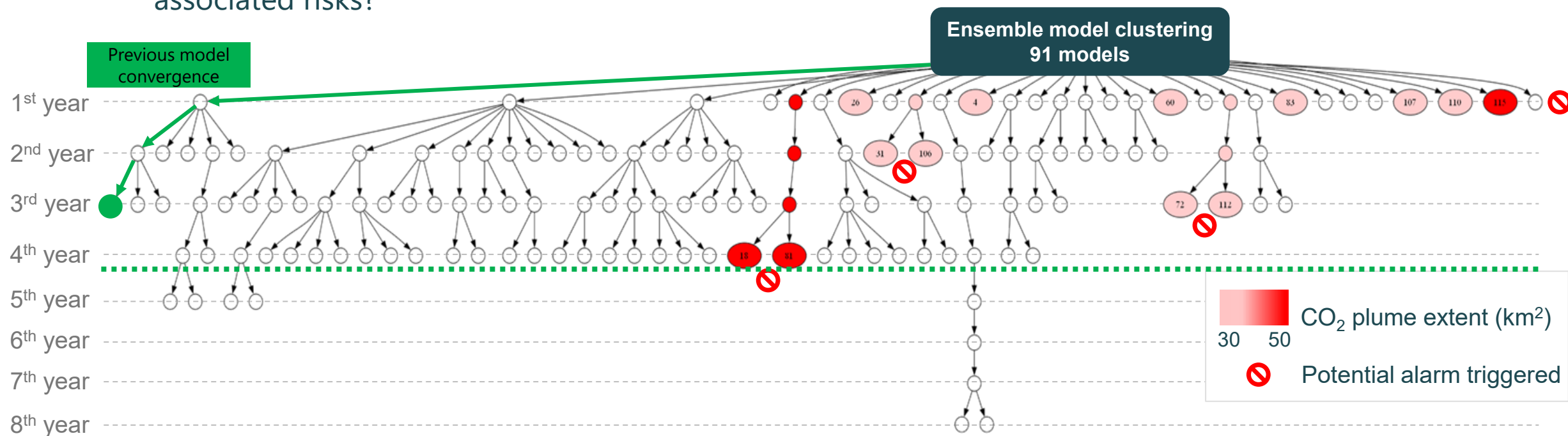
Modelling and clustering strategy from ensemble model





Convergence potential and risk associated

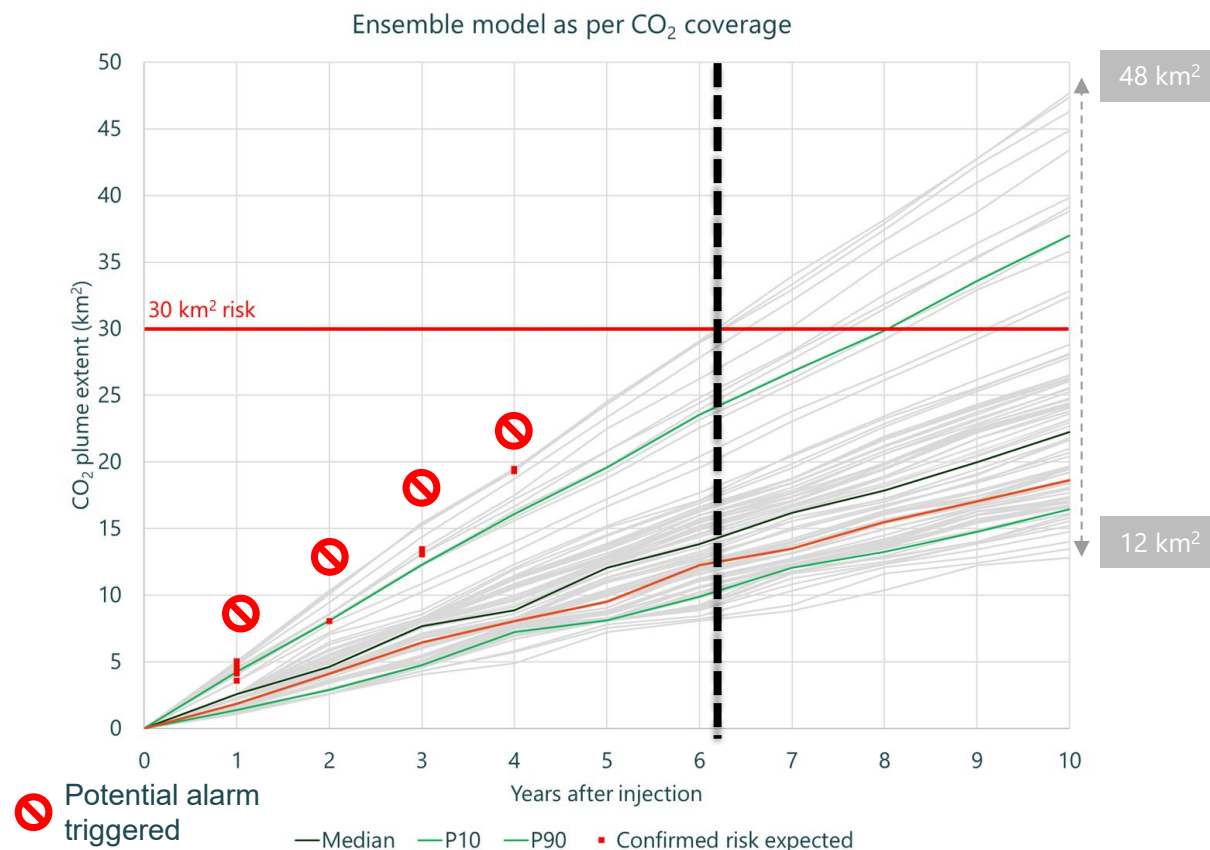
- The clustering strategy is made pre-injection over the ensemble model
- Each model could be true. How long will it take to converge for each model? What are the associated risks?



- All models mostly converge in year 4
- The riskier model, above 30 km², converge the first year or year 2 or 3 → alarm triggered
- The riskiest models, close to 50 km² at the end of injection, converge in year 4 → alarm triggered



Projecting convergence potential over time & potential alarms



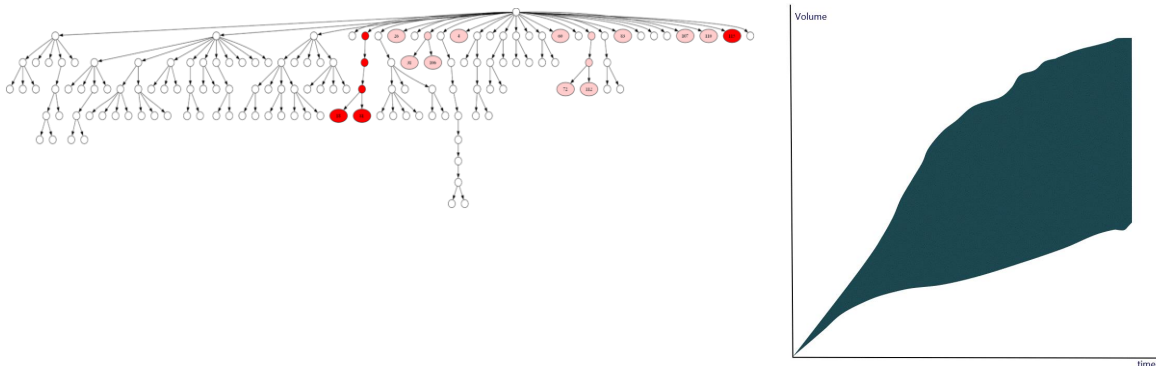
1. CO₂ exceeding AOR risk is highlighted **at the latest** at year 4
2. **4 potential alarms during the first 3 years**
3. If **alarm** is raised, operators have minimum 2 years **to implement contingency**



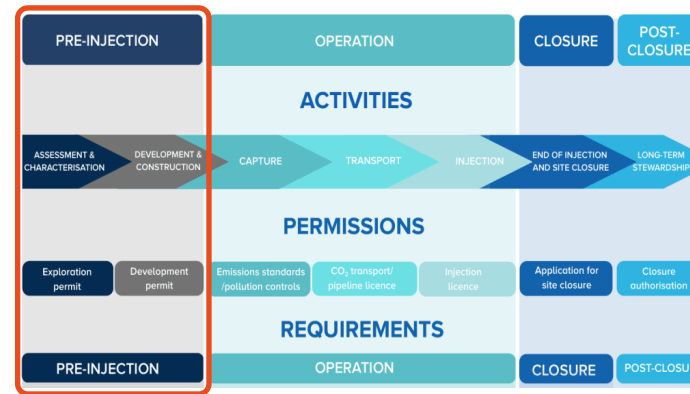


Spot History Matching & wrapping

- Frequent model calibration enable early model convergence & reduces uncertainties



- You can model & estimate risks & convergence opportunity **pre-FID**



➔ By assessing the potential and strategy to address uncertainties, we can **build confidence with regulator from day 1** during permitting processes, ensure :



Project
finance



Phasing
CAPEX



Secure
Permits



HEREMA
Hellenic Hydrocarbons and Energy
Resources Management Company



Let's tackle uncertainties together

Thank you!

www.spotlight-earth.com

37 rue du Saule Trapu
91300, Massy
France

 @spotlightearth



Convergence overview

