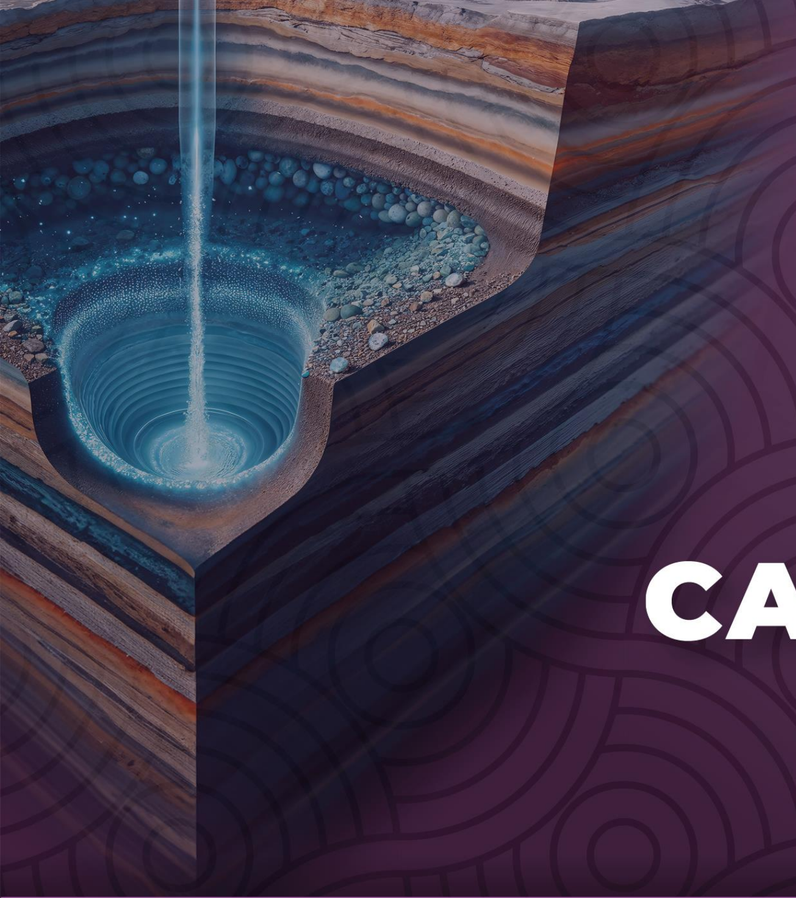

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ROTTERDAM, THE NETHERLANDS

GET2024

CARBON CAPTURE & STORAGE

CONFERENCE

"END-TO-END" MODELING APPROACH FOR CO_2 INJECTION INTO DEPLETED GAS FIELDS

HILD Jean-Claude EBN B.V.

“END-TO-END” MODELING APPROACH FOR CO_2 INJECTION INTO DEPLETED GAS FIELDS

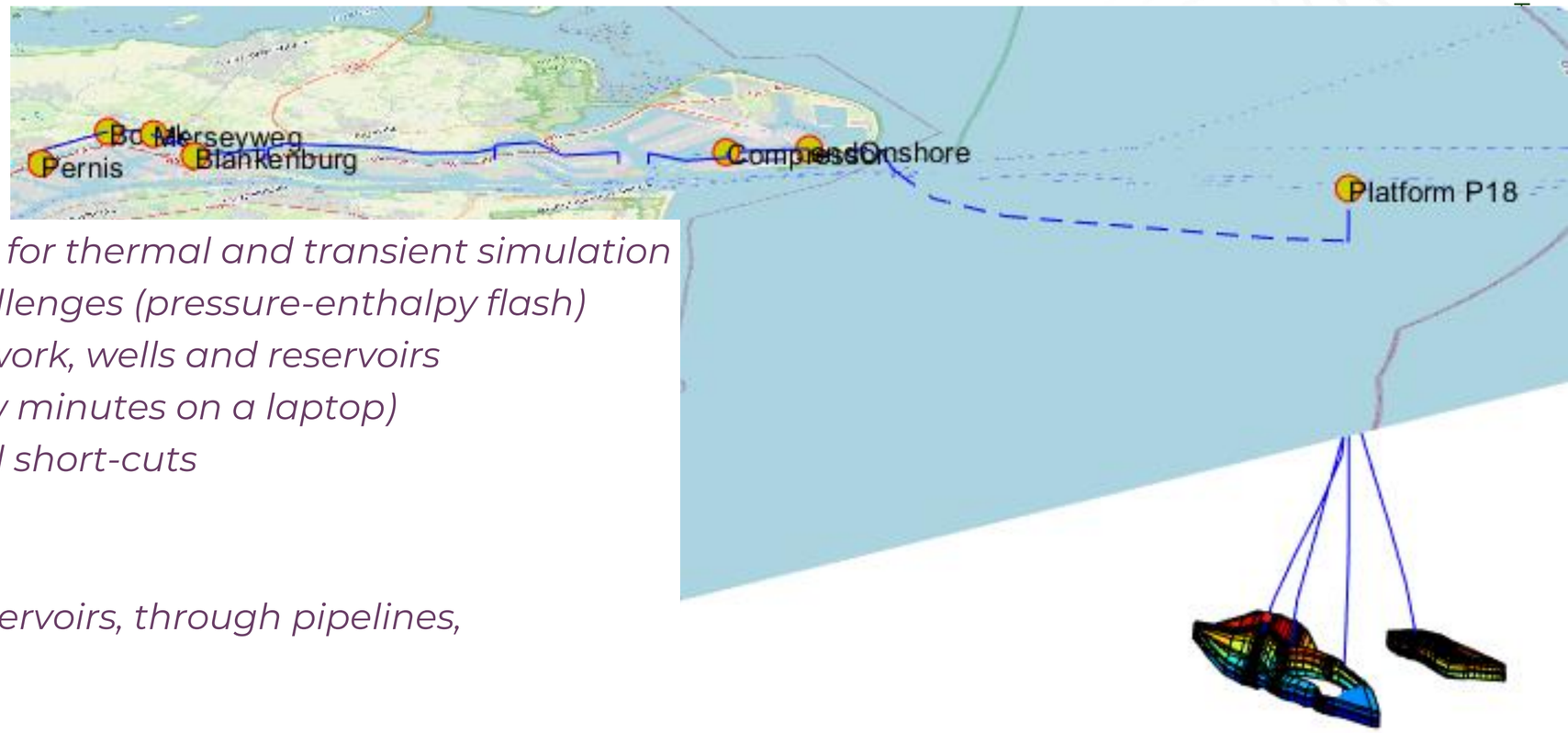
AGENDA

- **CALYSTO** (**CA**rbon **L**ow enthalp**Y** **S**torage **TO**ol) in a nutshell

- Integrated approach applications
  - *Thermal plume modeling*
  - *Well operating envelopes*
  - *Forecast planning*

CALYSTO IN A NUTSHELL

- CCS projects need <u>integrated simulation tools</u>
  - *EBN has developed its own "in-house" modeling tool devoted to CO_2 injection in depleted gas reservoirs:* ***CALYSTO*** *(**CA**rbon **L**ow enthalp**Y** **S**torage **TO**ol)*

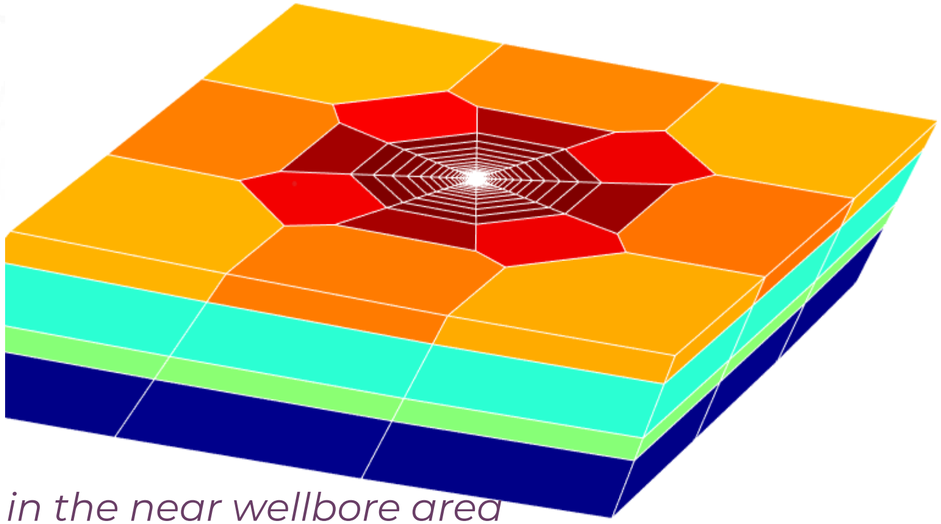


- Specificities
  - *Physic based model allowing for thermal and transient simulation*
  - *Applied to CO_2 modeling challenges (pressure-enthalpy flash)*
  - *Fully coupling of surface network, wells and reservoirs*
  - *Simulations must be fast (few minutes on a laptop)*
    → implies simplifications and short-cuts

- Overall PORTHOS model
  - *From emitters down to P18 reservoirs, through pipelines, compressor station and wells*

CALYSTO IN A NUTSHELL

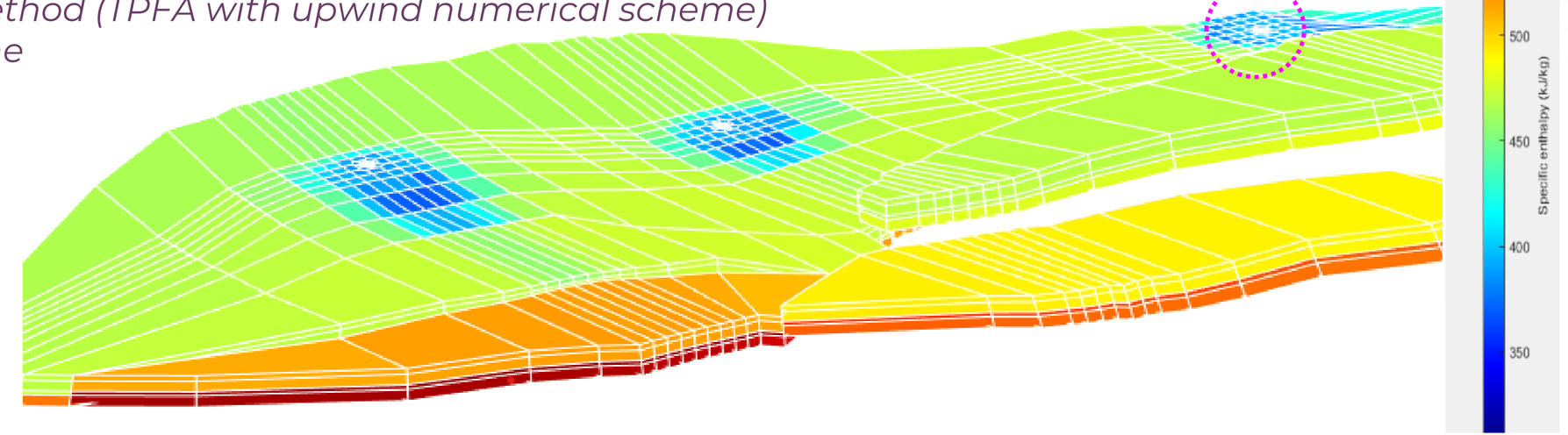
Focus on reservoir modeling



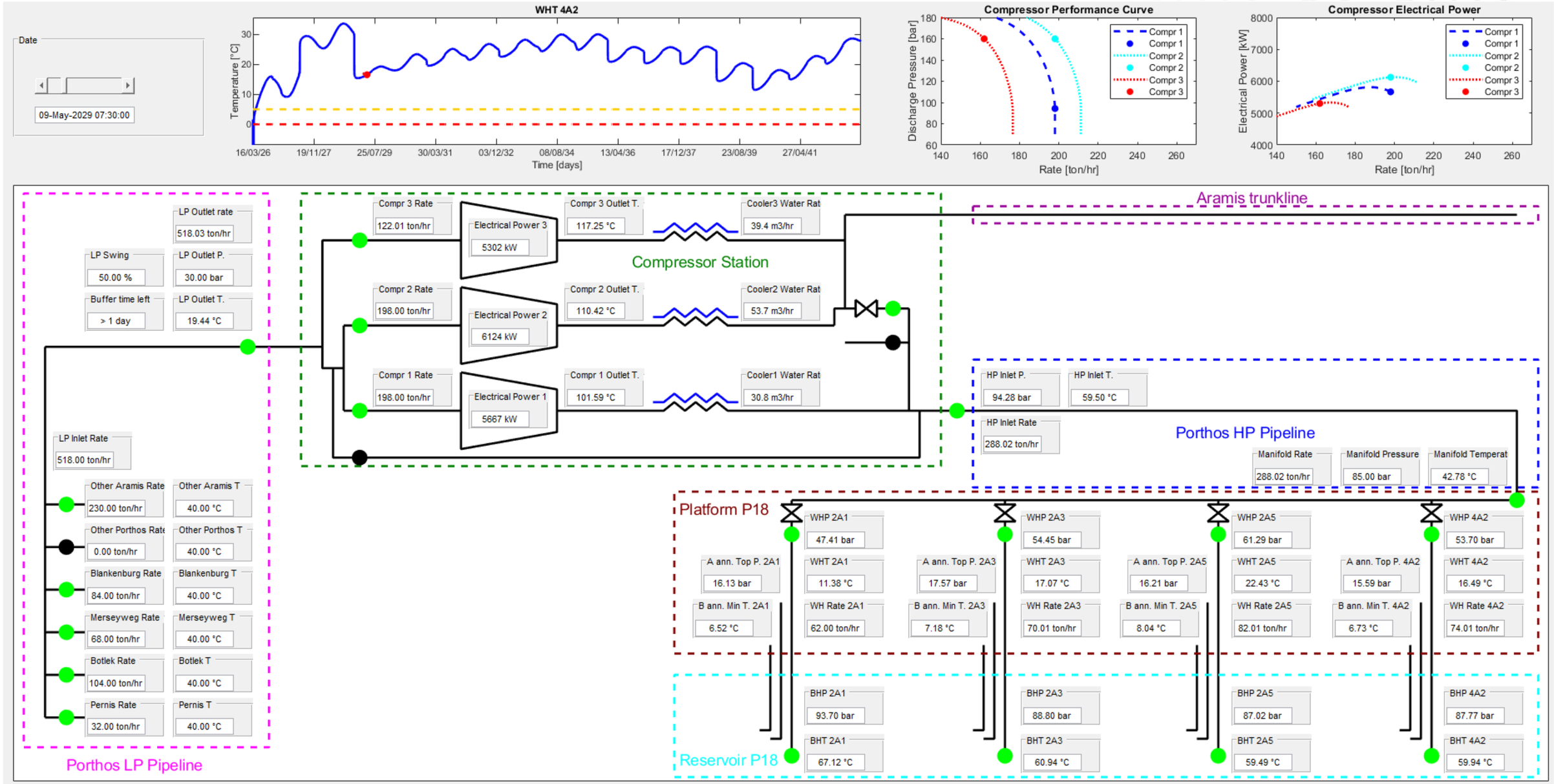
- Reservoir description
  - *Combination of classical CPG grid (tartan grid) and refined PEBI grid in the near wellbore area*
    → Unstructured grid (with cell size from 5 cm up to 500 m) aiming at describing near wellbore and far field evolution

- Physics based model
  - *CO_2 and water mass balances (considering water vaporization)*
  - *Energy balance for all phases + rocks*

- Numerical method
  - *Finite difference method (TPFA with upwind numerical scheme)*
  - *Fully implicit scheme*



INTEGRATED APPROACH

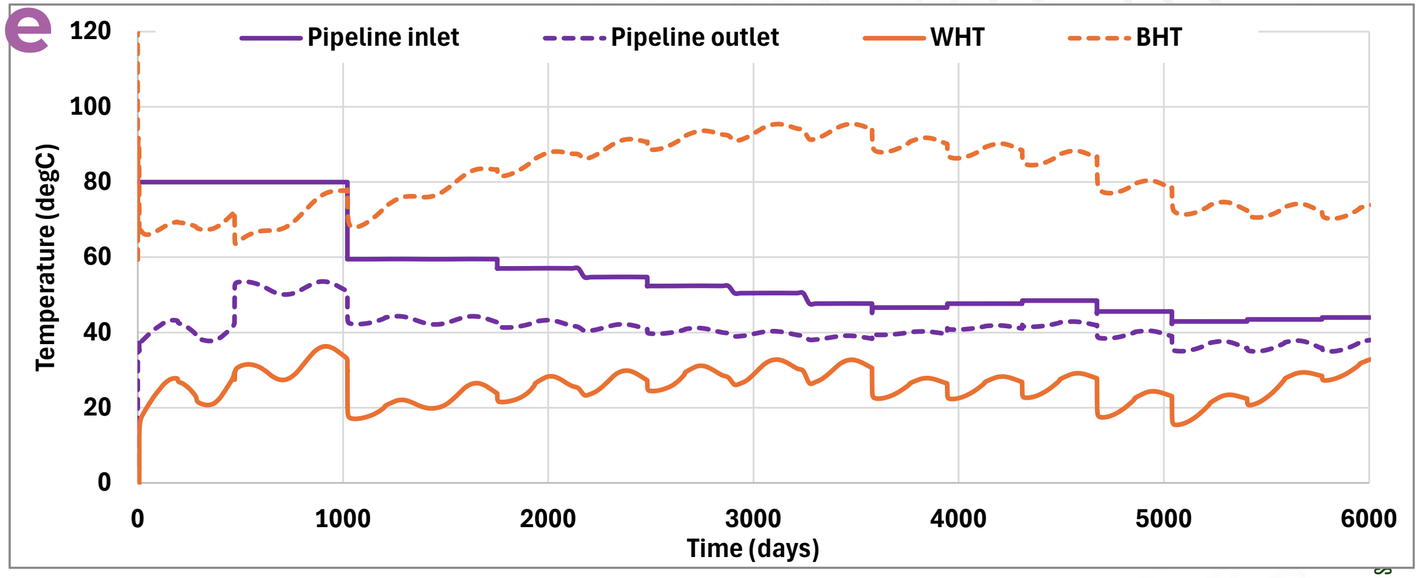


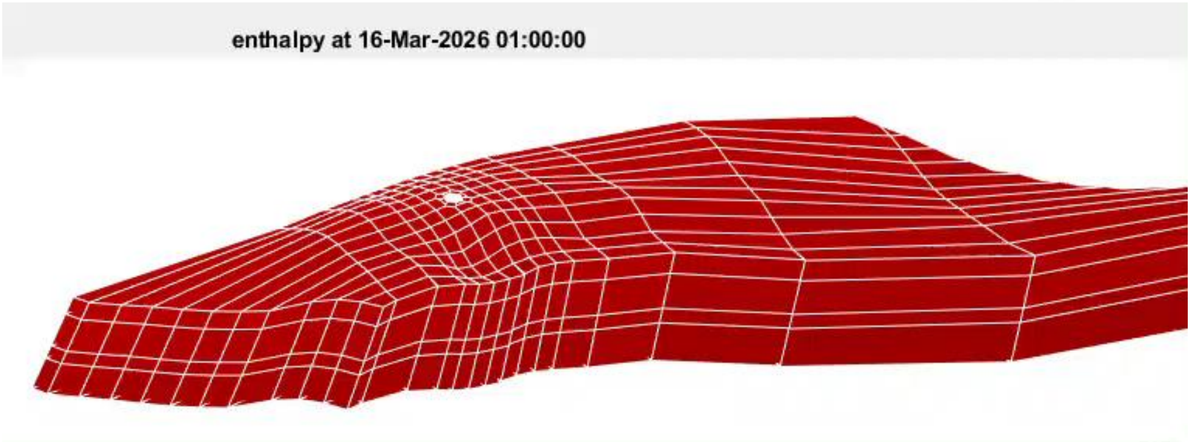
INTEGRATED APPROACH

Reservoir thermal plume

- CO_2 thermal plume modeling in the reservoir is one of CCS main (numerical) challenges and (safety) concerns

- Strongly depends on reservoir inlet conditions (BHP and BHT), which are a complex mixture of
  - *Network inlet conditions (P/T and rate)*
  - *Operationnal constraints*
  - *Thermal exchanges along CO_2 path (pipelines and wells), seasonal temperatures variations…*

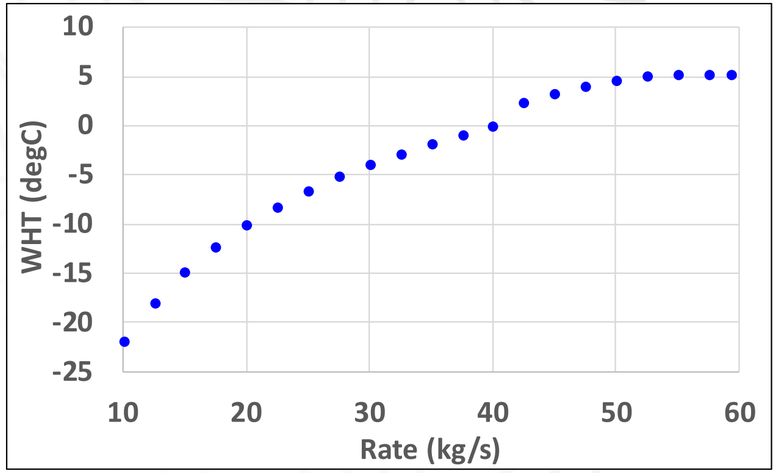




Only a fully integrated model can tackle this kind of phenomenon

INTEGRATED APPROACH

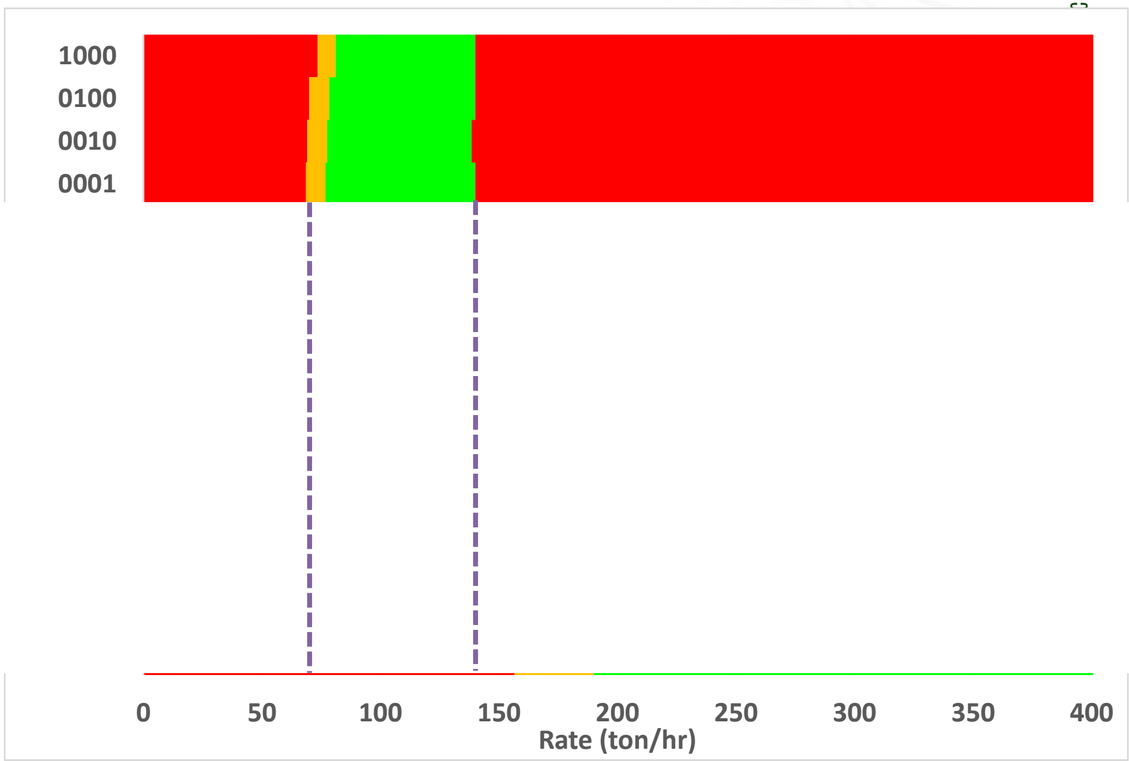
Well operating envelope



- 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		



INTEGRATED APPROACH

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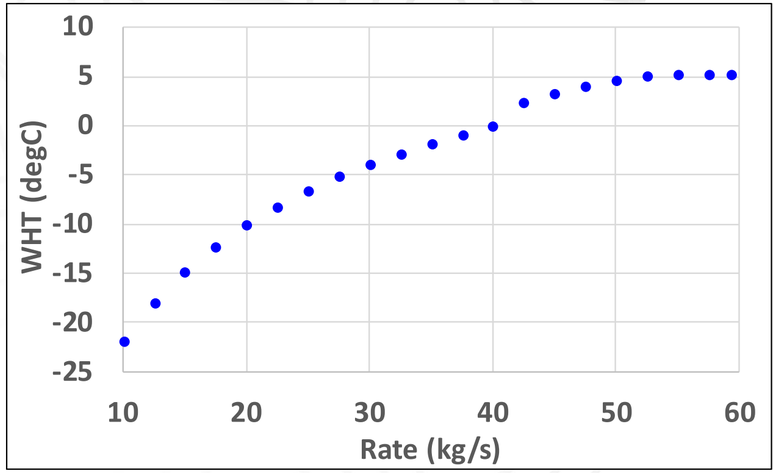

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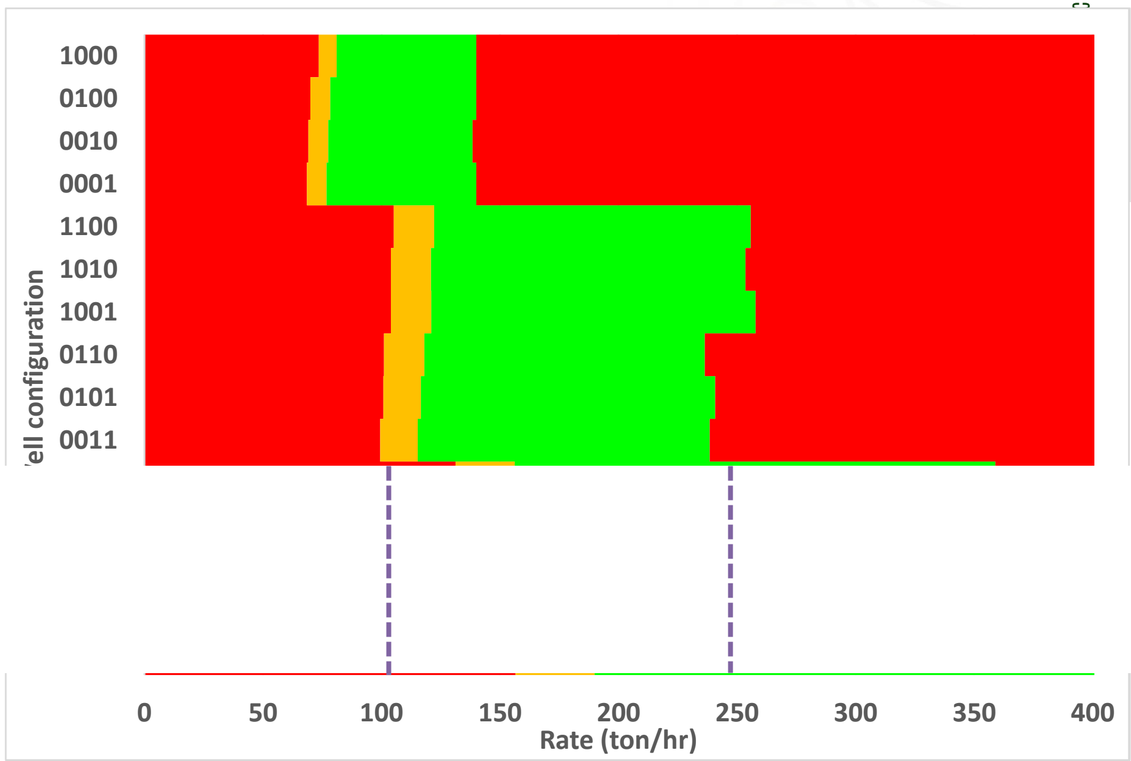
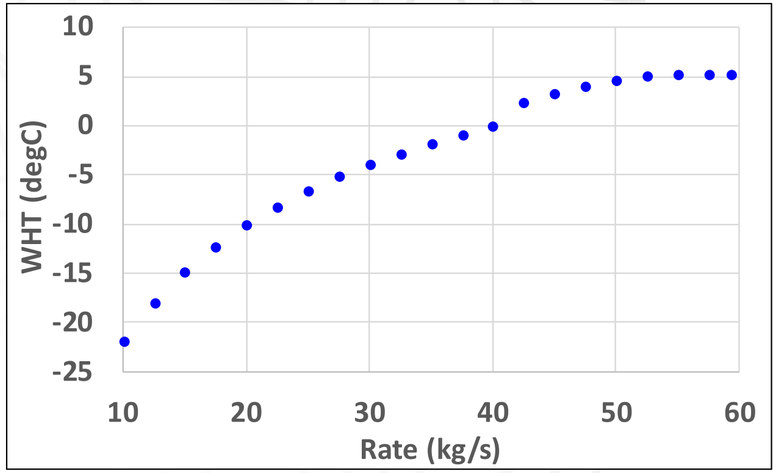


CE & EXHIBITION

INTEGRATED APPROACH

Well operating envelope



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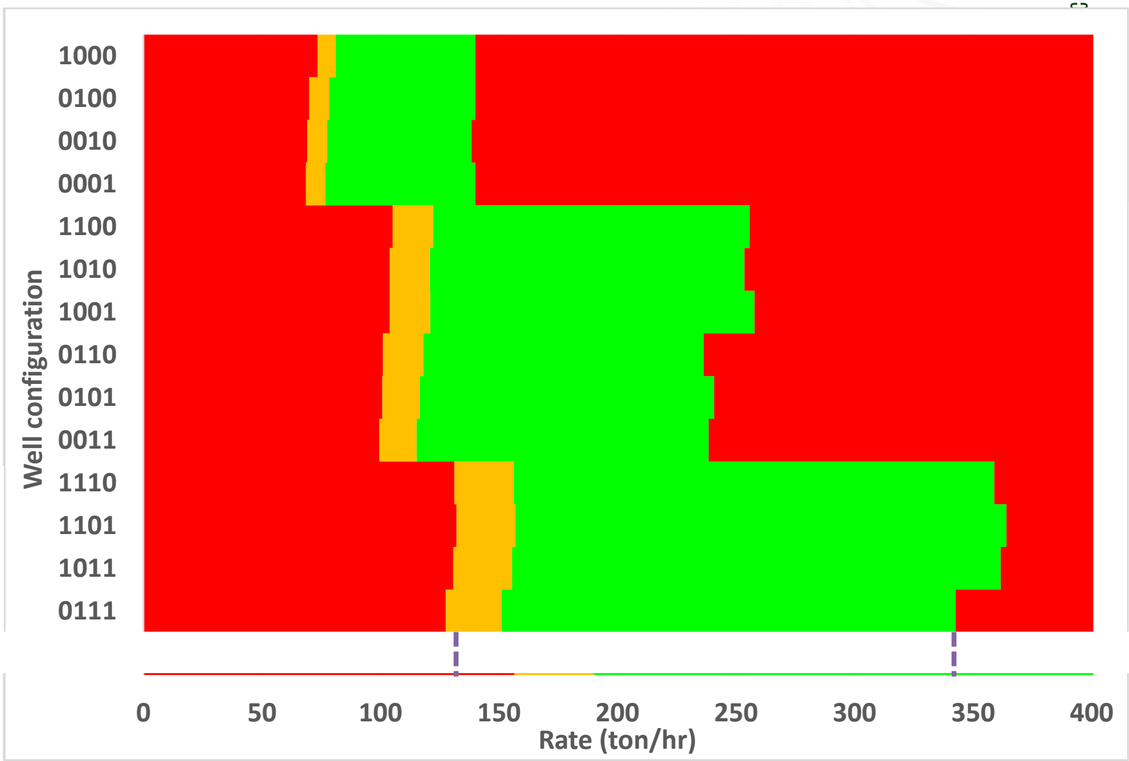

INTEGRATED APPROACH

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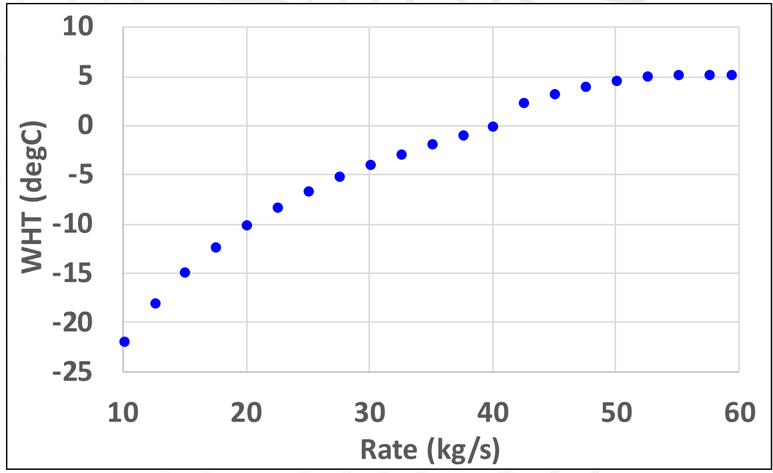

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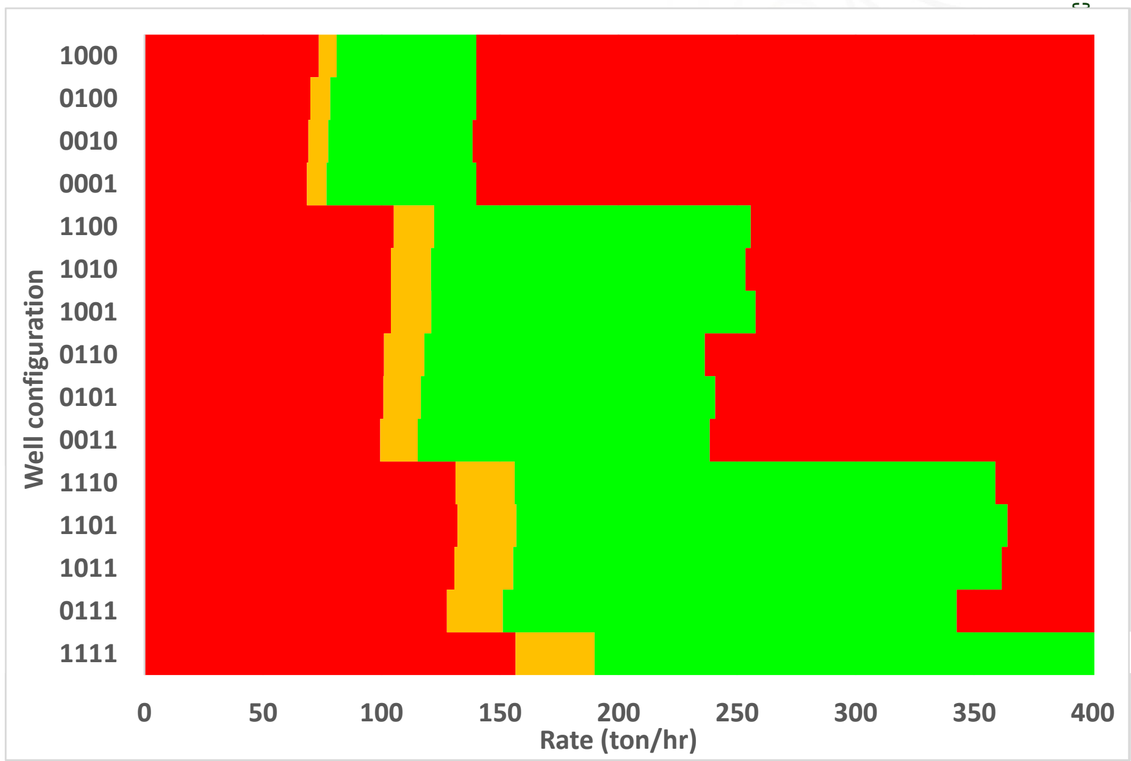
- Why well rates are not additive????



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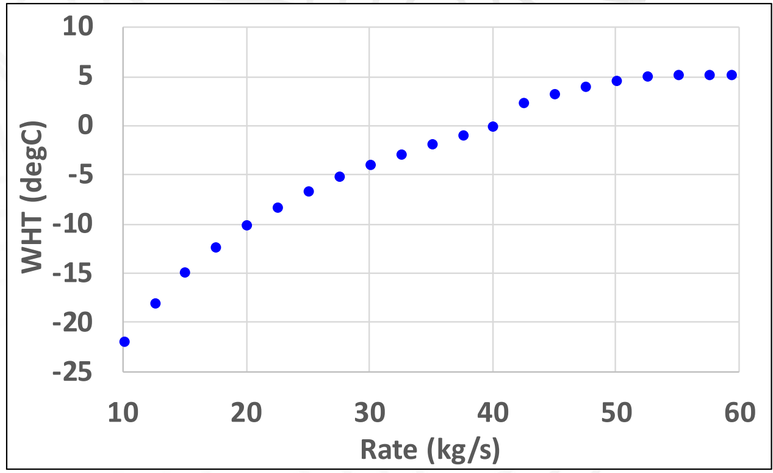

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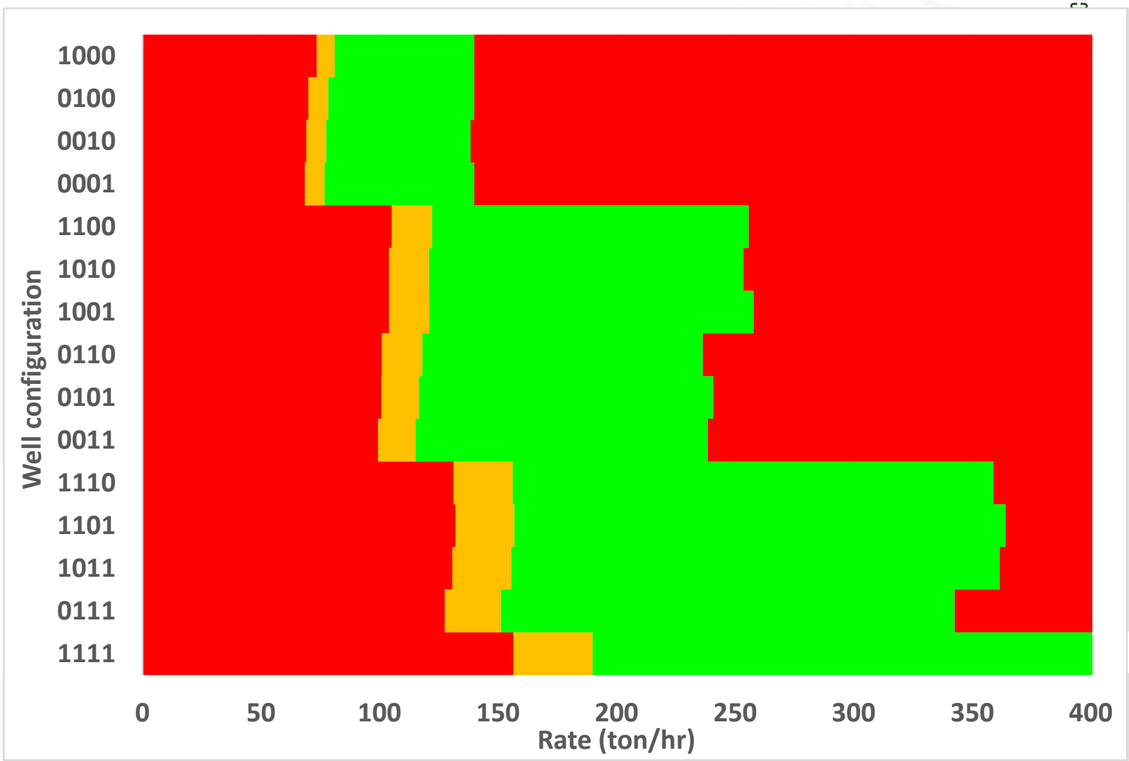
- Why well rates are not additive????

  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

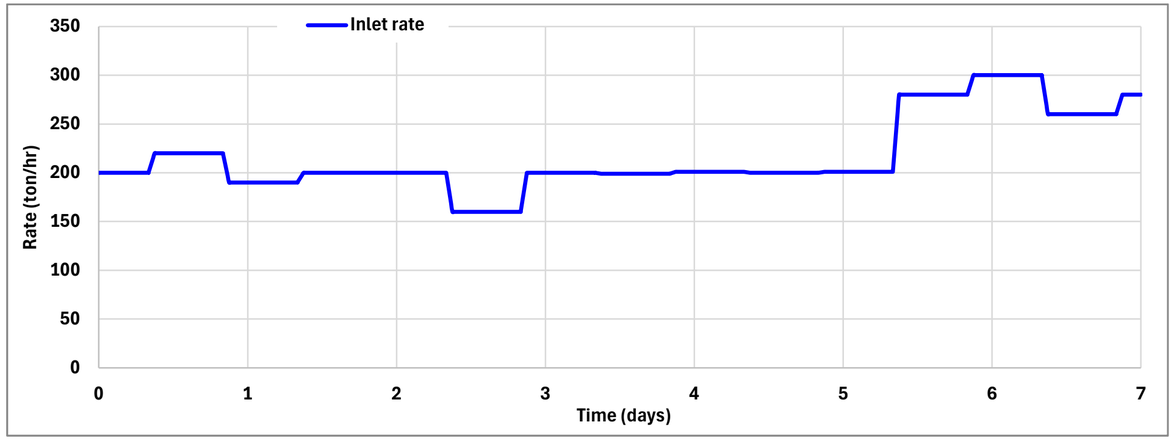
Only a fully integrated model can tackle this kind of phenomenon

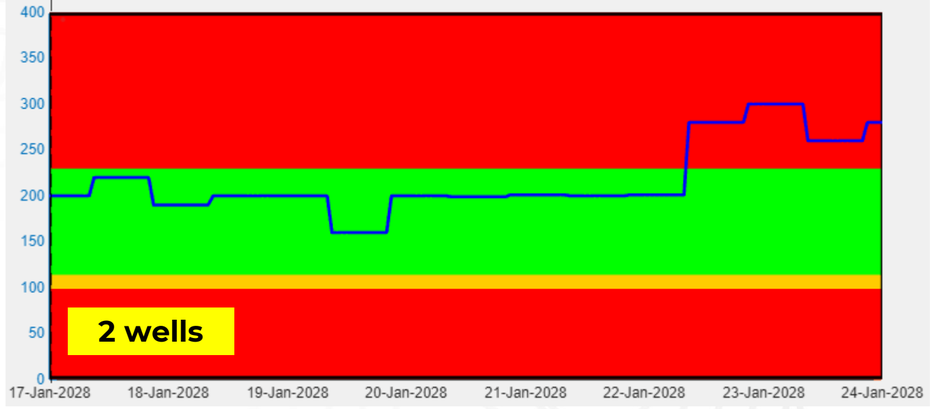


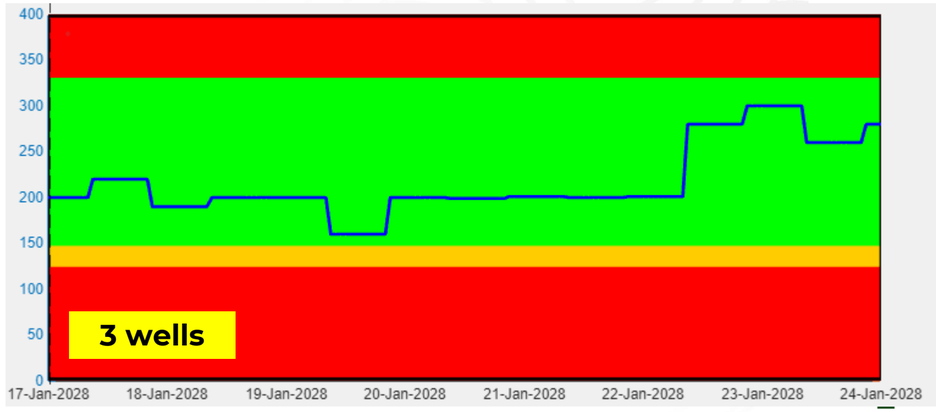
INTEGRATED APPROACH

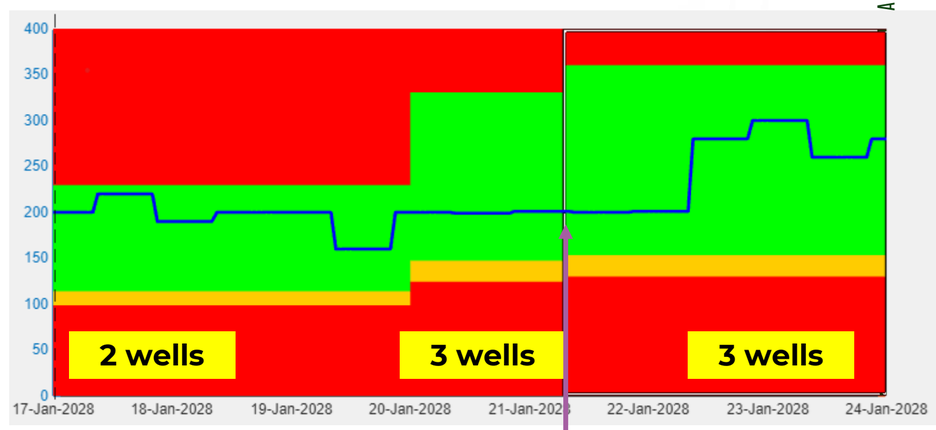
Operational planning

- How to operate safely a CCS project while accommodating customers' delivery rate?









Manifold pressure set point change: 85 → 90 bar

PPROACH

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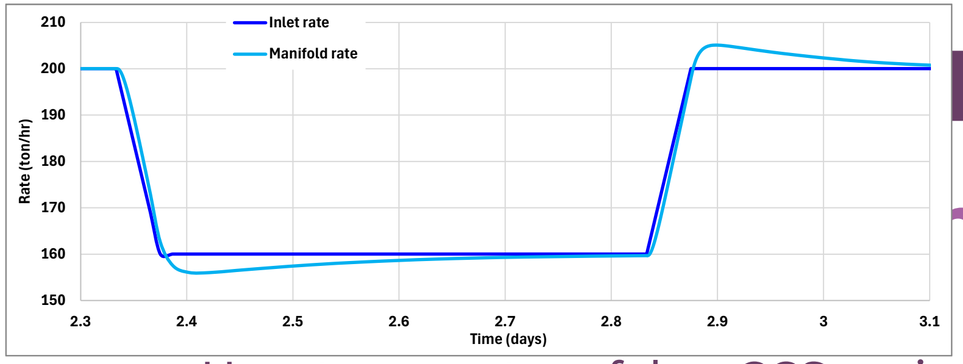

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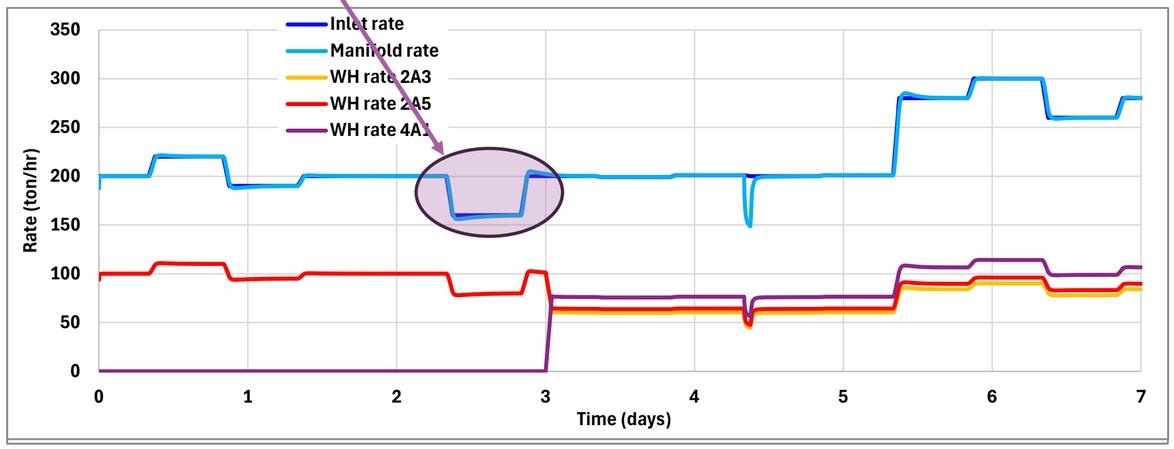

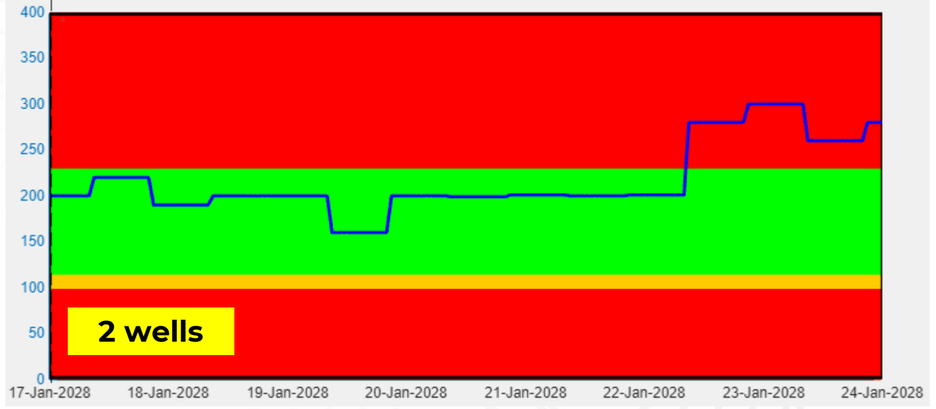

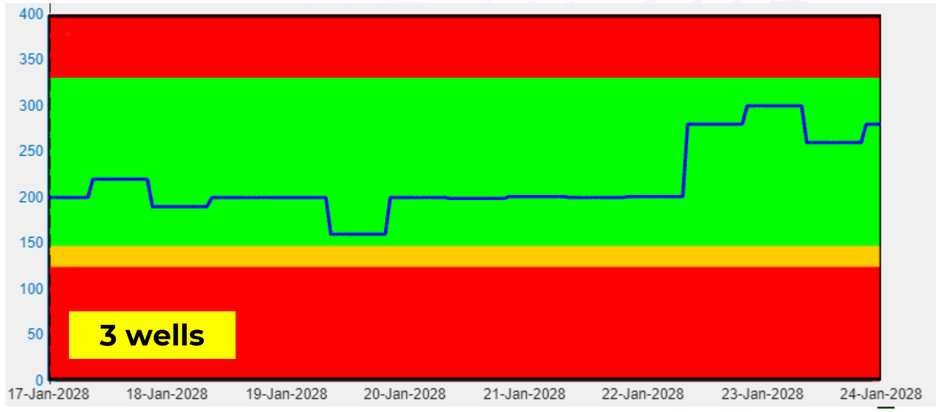

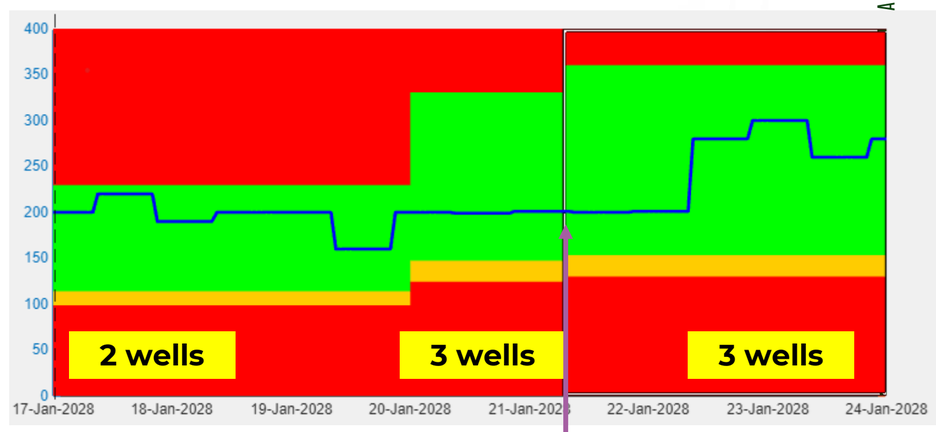

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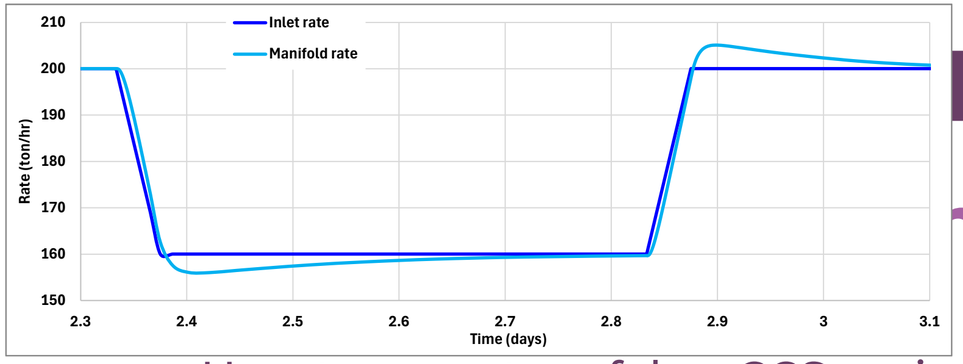

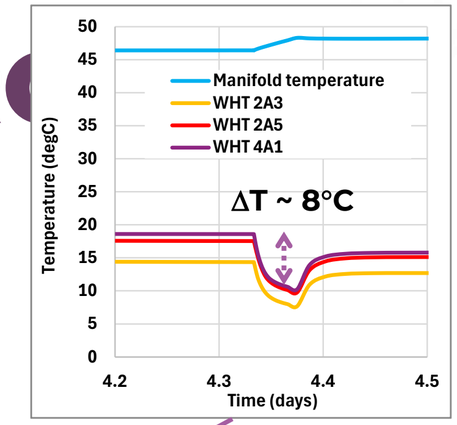

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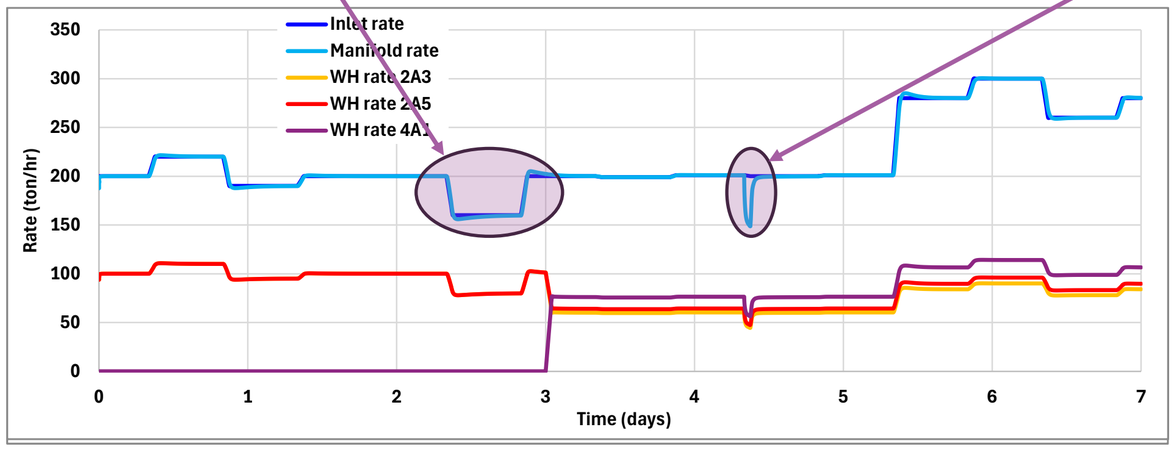

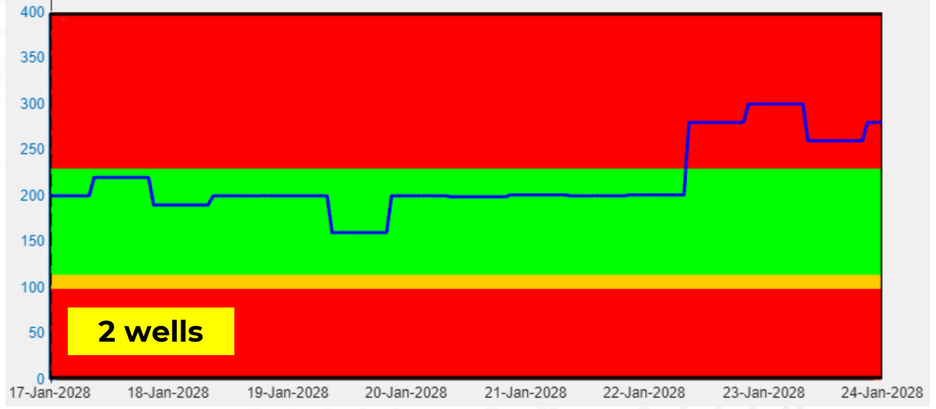

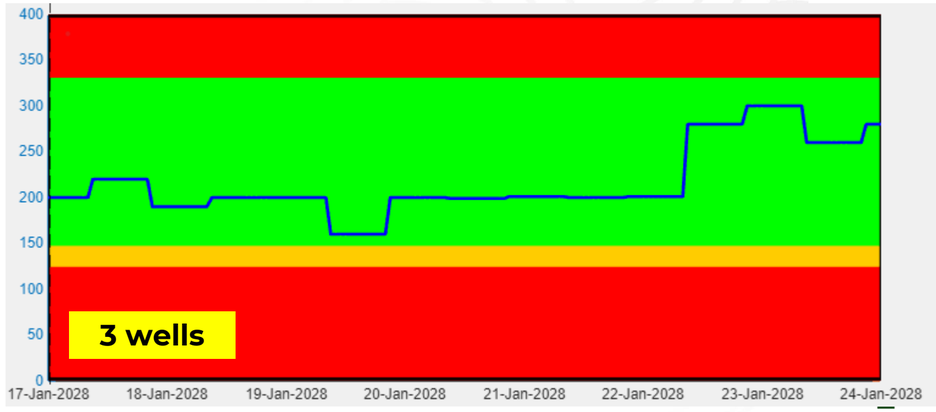

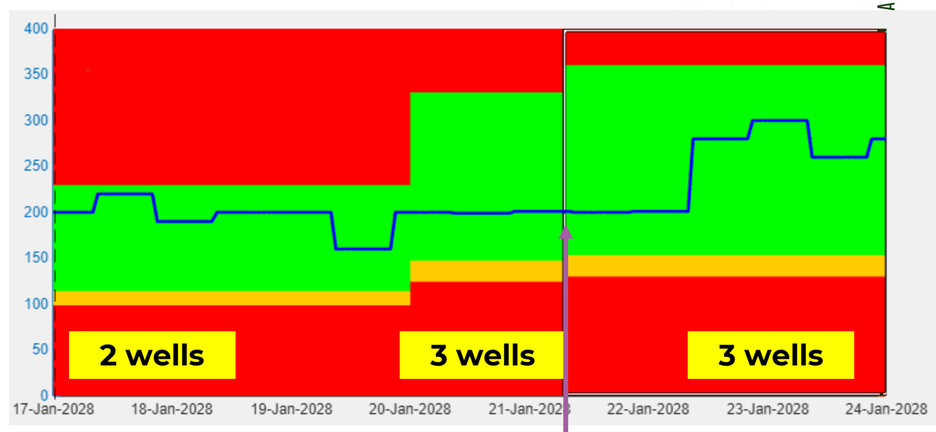

When increasing the manifold pressure set point, the system regulation will react by decreasing the well rate (to allow the pressure to increase in the pipe)
→ transient to be considered cautiously

Only a fully integrated model can tackle this kind of phenomenon

Manifold pressure set point change: 85 → 90 bar

“END-TO-END” MODELING APPROACH FOR CO_2 INJECTION INTO DEPLETED GAS FIELDS

Conclusion

- CCS projects need integrated simulation tools
- CALYSTO is one fully coupled solution for “end-to-end” integrated modeling
- Runtime in minutes, not in hours/days
- Is used for several CCS projects

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