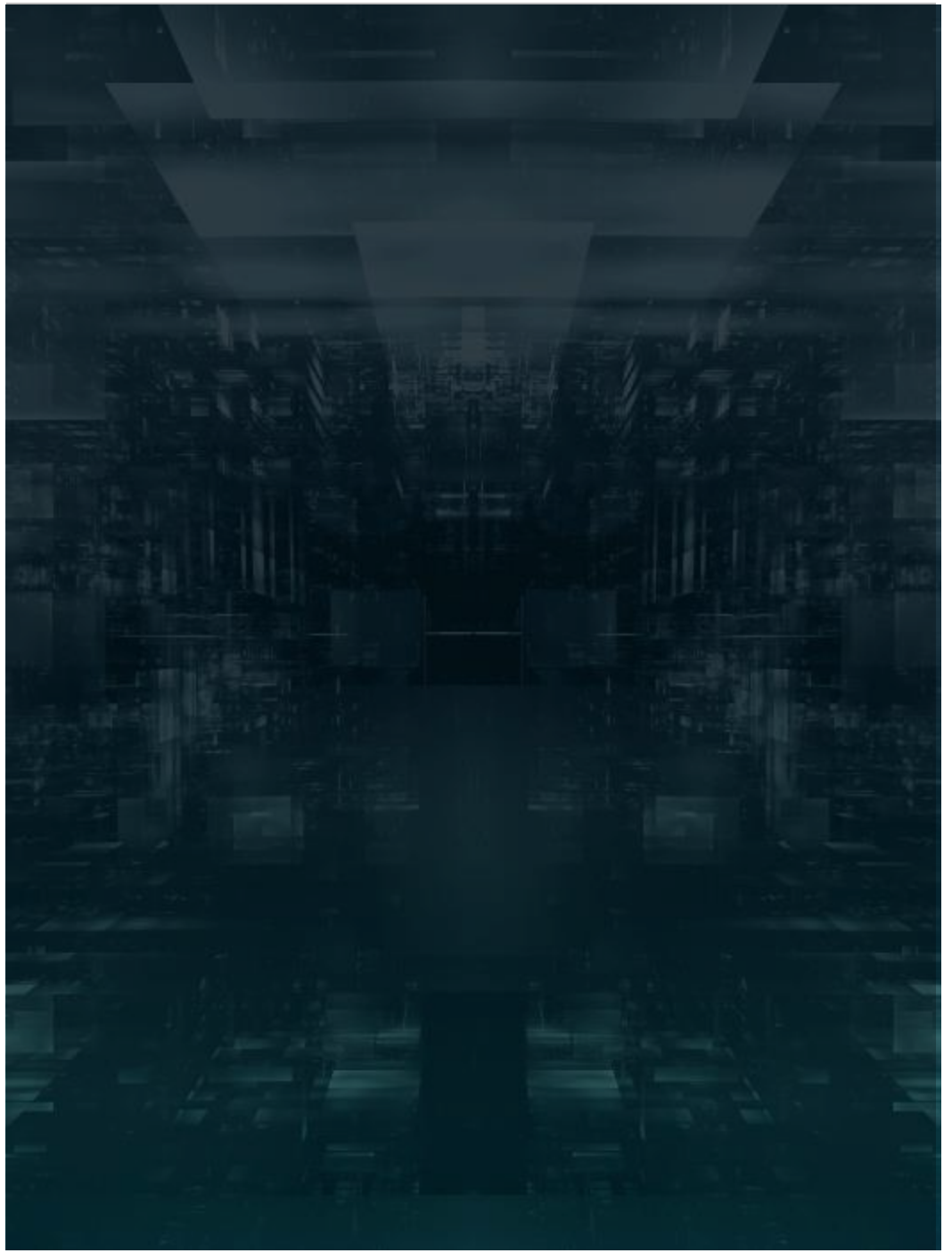
CMG数值模拟技术最新进展及研发方向
User Group meeting 2025

Computer Modelling Group (CMG) | June 2025

AGENDA

- Introduction to CMG
- CMG 4.0
- Recent Advances 2024
- The Way Forward 2025+



2) Introduction to CMG

Greetings, Best Wishes from CMG Calgary

CMG

WHO WE ARE

CMG are innovators in simulation technology

We combine science and technology with deep industry expertise to solve complex subsurface and surface challenges for the new energy industry.

40+
years of unprecedented innovation

50%
employees focused on innovation & research

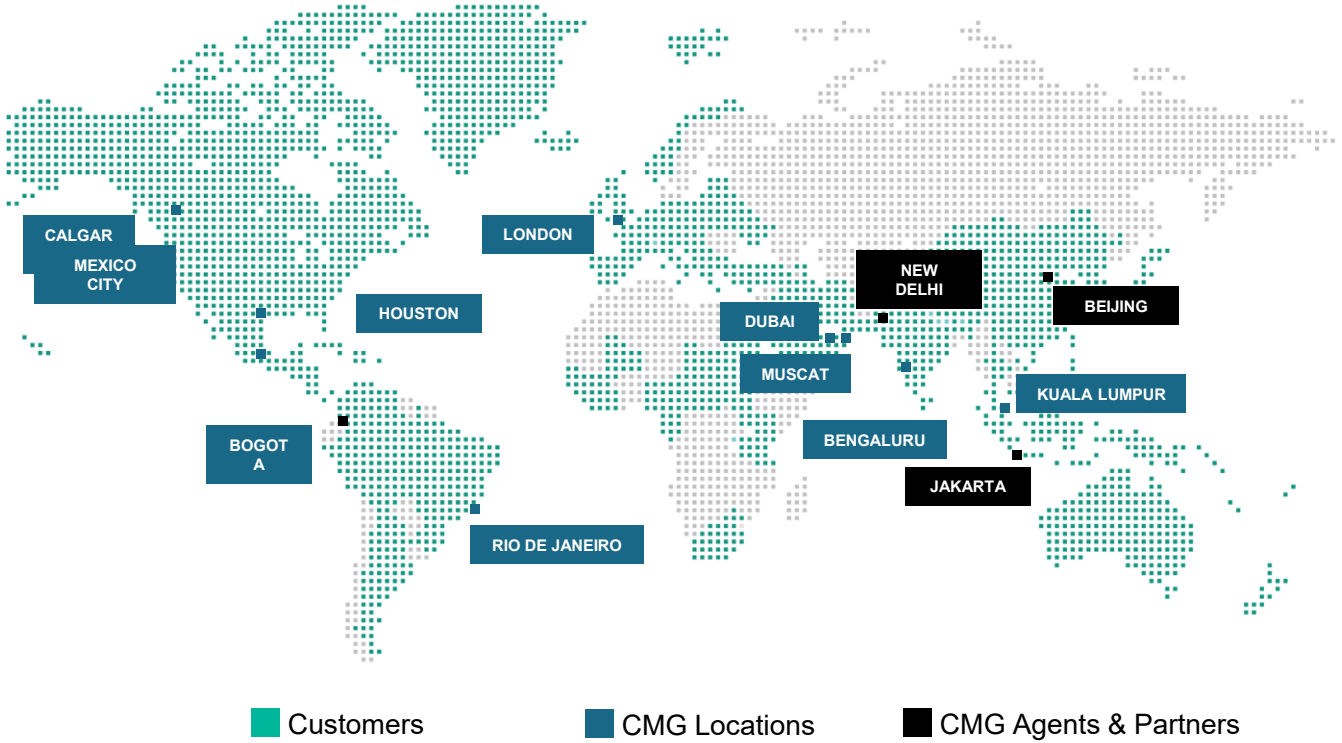
600+
customers

75+
countries

unionst
合力石油科技

CMG

CMG's Global Prescence



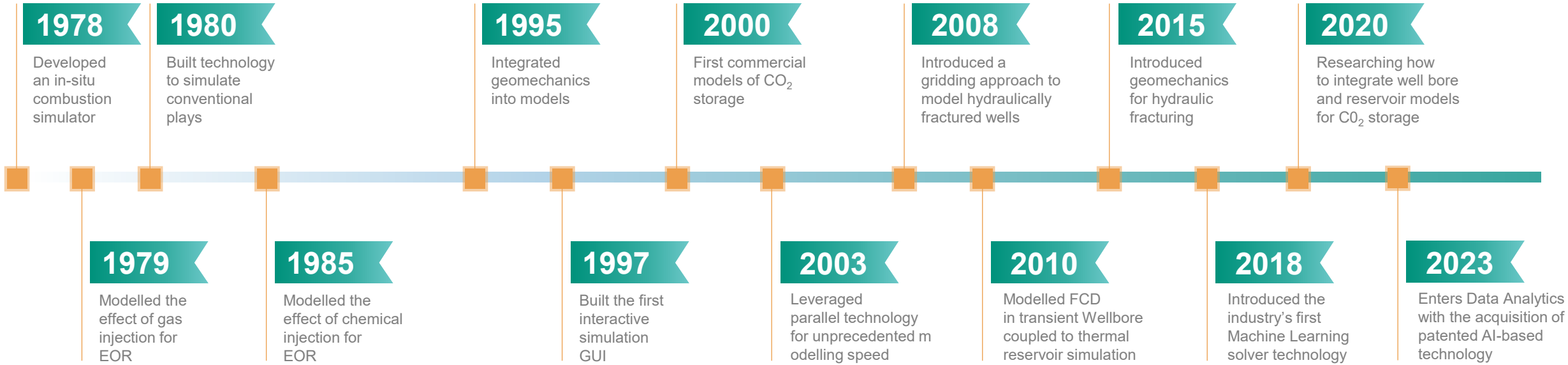
100%
of the Super Majors

90%
of the top-10 National Oil Companies

75%
of the world's top-25 largest oil companies

70%
of the top unconventional producers

Helping clients unlock value from their assets through continuous innovation



Imagine how good you'd be at something you did everyday **since 1978**

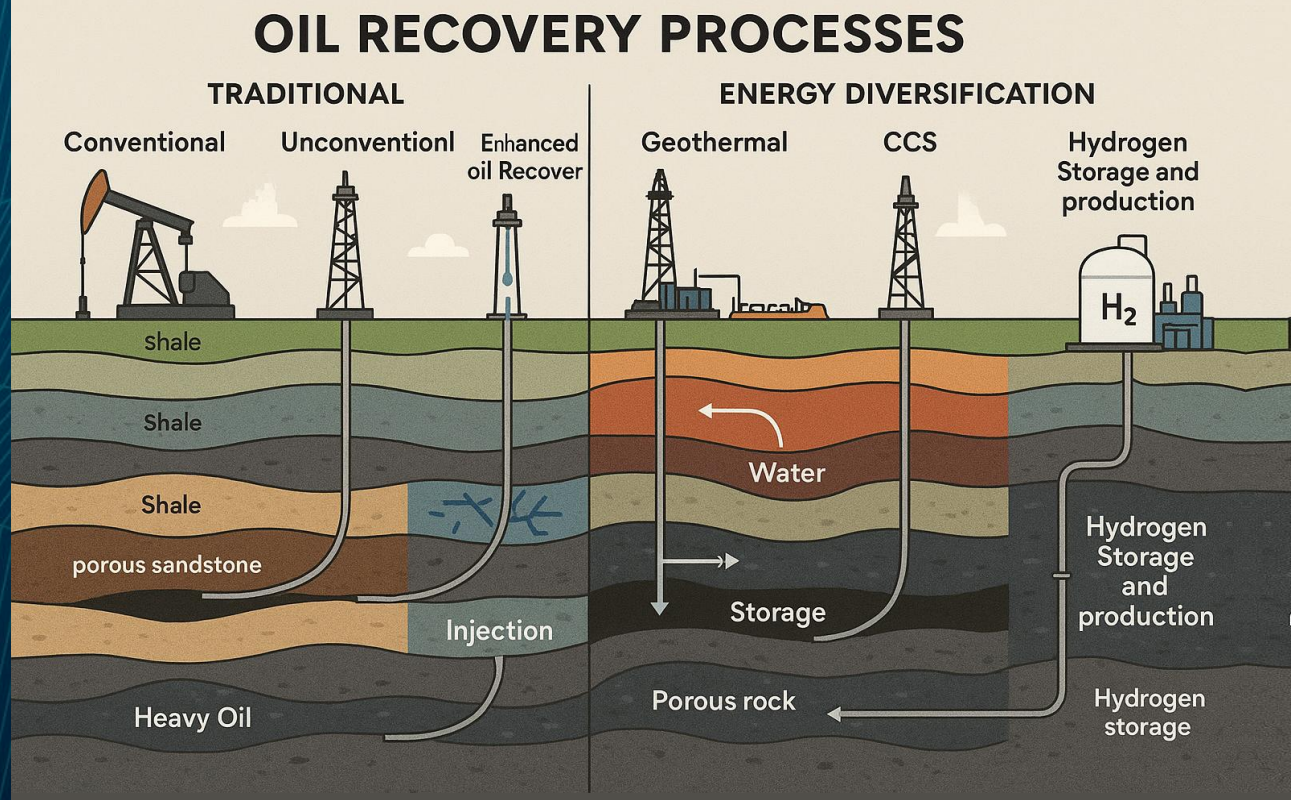
The gold standard in reservoir simulation

50% employees focused on R&D

+600 Customers in +75 countries

B's In NPV created

67 NPS



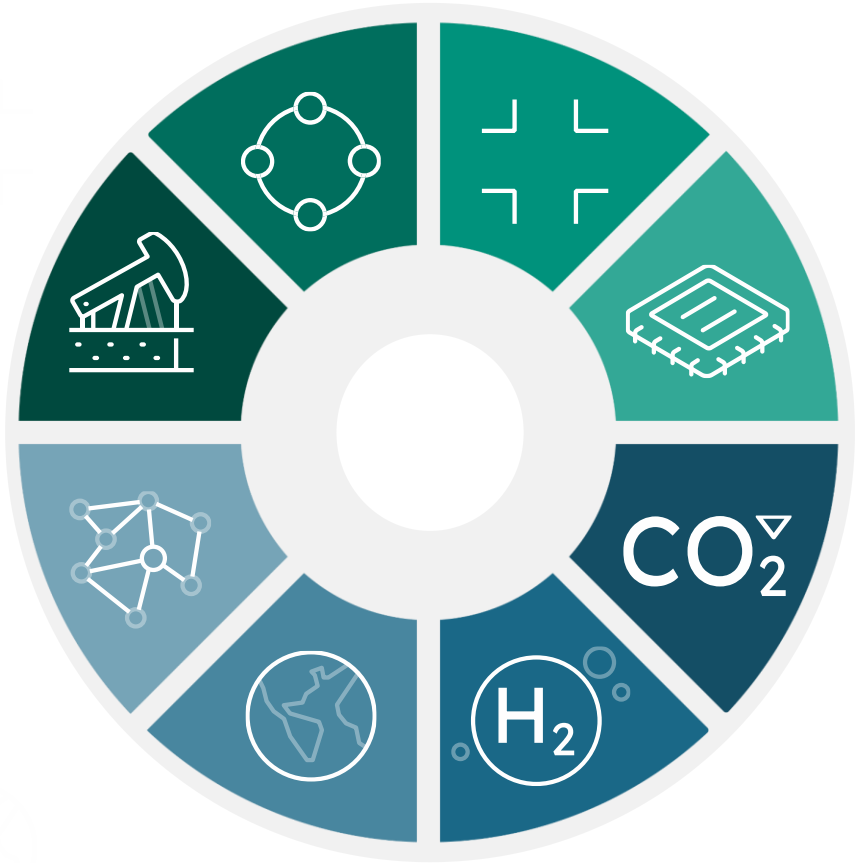
OUR EXPERTISE

CMG has a rich history of bringing industry-first solutions to the market

Our expertise spreads across a broad spectrum of energy workflows, and our technology can help energy companies navigate this complex landscape.

Traditional Oil and Gas

Conventional | Enhanced Oil Recovery | Unconventional | Heavy Oil



Energy Transition

Emerging Technologies | Geothermal | Hydrogen Storage & Production | Carbon Capture Storage (CCS)

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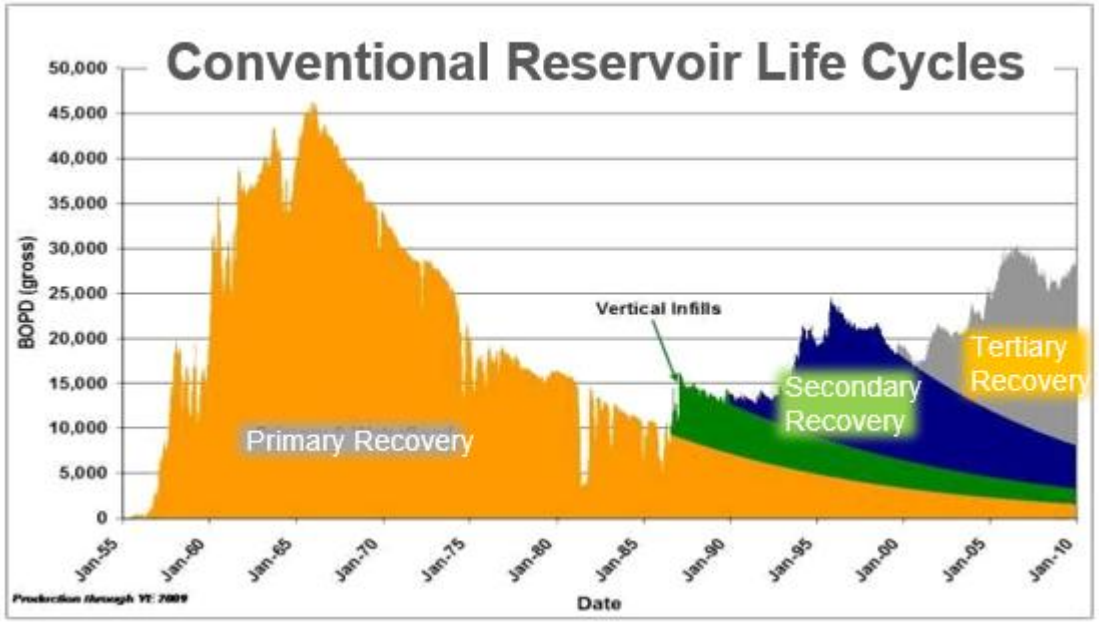
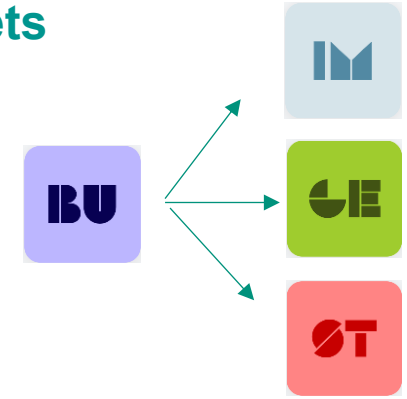
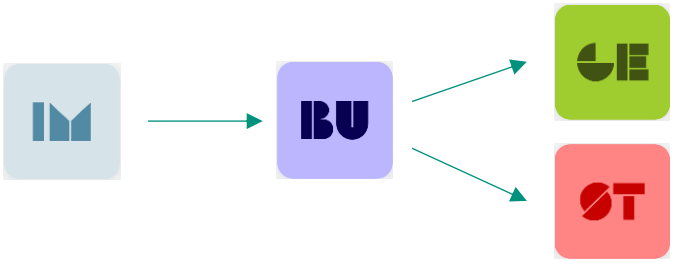
Simulator modelling workflow



Primary Recovery	Secondary Recovery	Tertiary Recovery
• Natural Depletion	• Gas Injection • Water Injection • Pressure Maintenance	• Thermal • Chemical • Miscible/Immiscible Processes

Use BUILDER to construct IMEX, GEM and STARS datasets



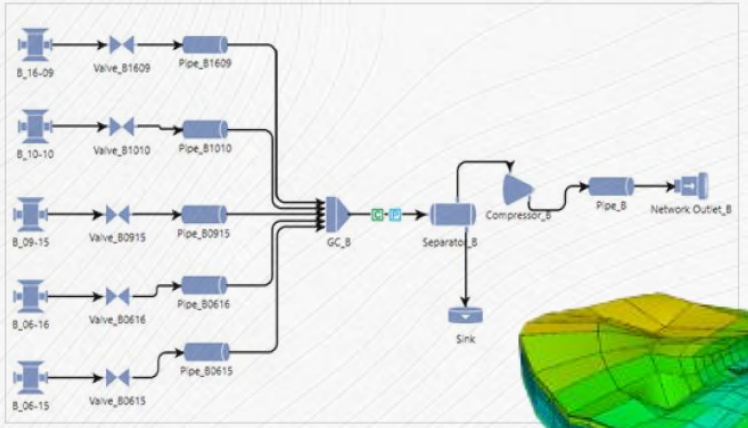


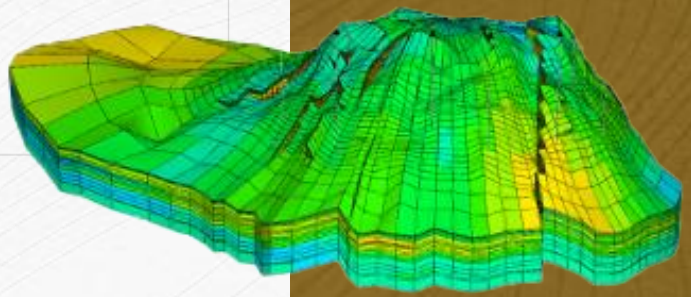
Use BUILDER to convert IMEX to GEM and STARS

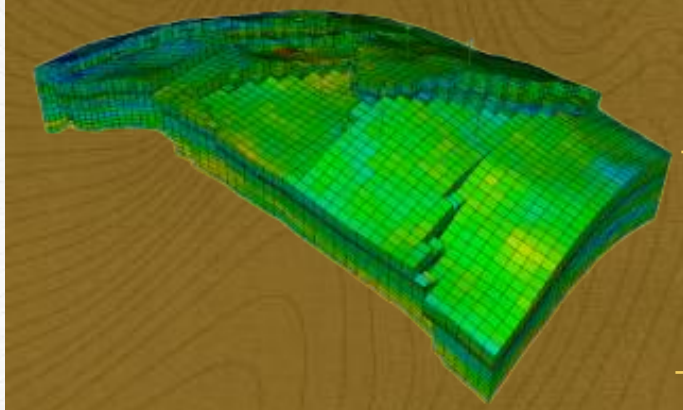
CMG

CoFlow

Fully-integrated reservoir and production solution







Less time handling data,
more time engineering

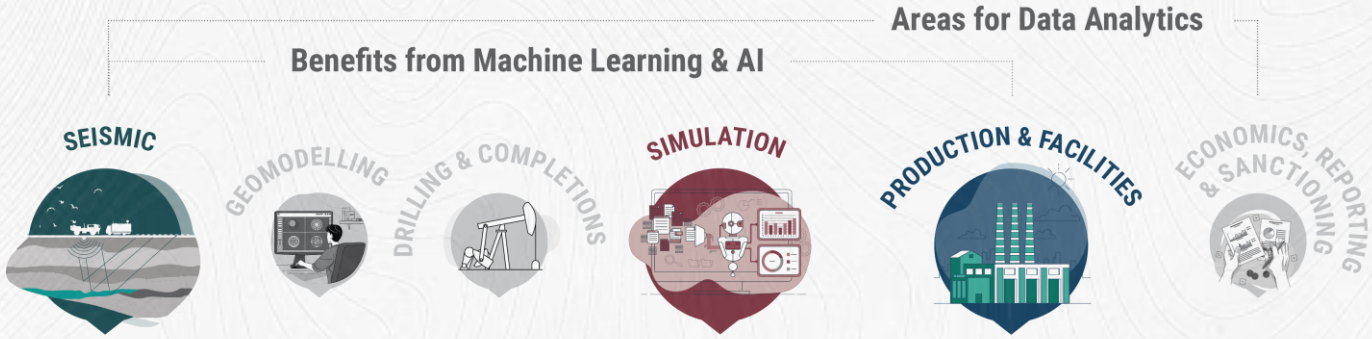
15% Average increase in production (that's $383M/year)

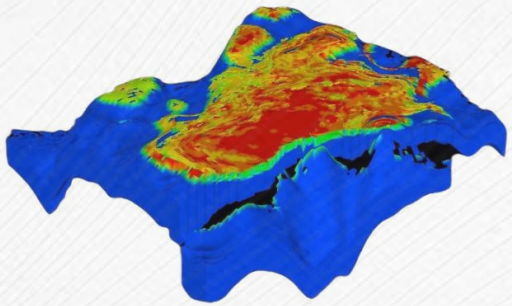
+50
Assets deployed

$3B*
in cumulative NPV created

2) Introduction to CMG 4.0

We started with simulation and are **building an upstream powerhouse** that helps operators improve decision quality, mitigate risk and increase profitability.





SHARP REFLECTIONS
A CMG COMPANY

- ✓ Processing
- ✓ Inversion
- ✓ 4D Timelapse

- ✓ VDS Storage & Interoperability
- ✓ AI Seismic Analysis

bluware
a CMG company

CMG

- ✓ Black oil simulator
- ✓ Wellbore and facilities modelling
- ✓ Compositional simulator
- ✓ Thermal/ Adv Process simulator
- ✓ Uncertainty & optimization
- ✓ Integrated reservoir and production modelling

1978 IMEX: Single simulator

Seismic Solutions

Today

Simulation Solutions

Seismic solutions

SHARP REFLECTIONS
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Predict reservoir quality and hydrocarbons from HUGE 3D and 4D pre-stack seismic datasets

SHARP REFLECTIONS
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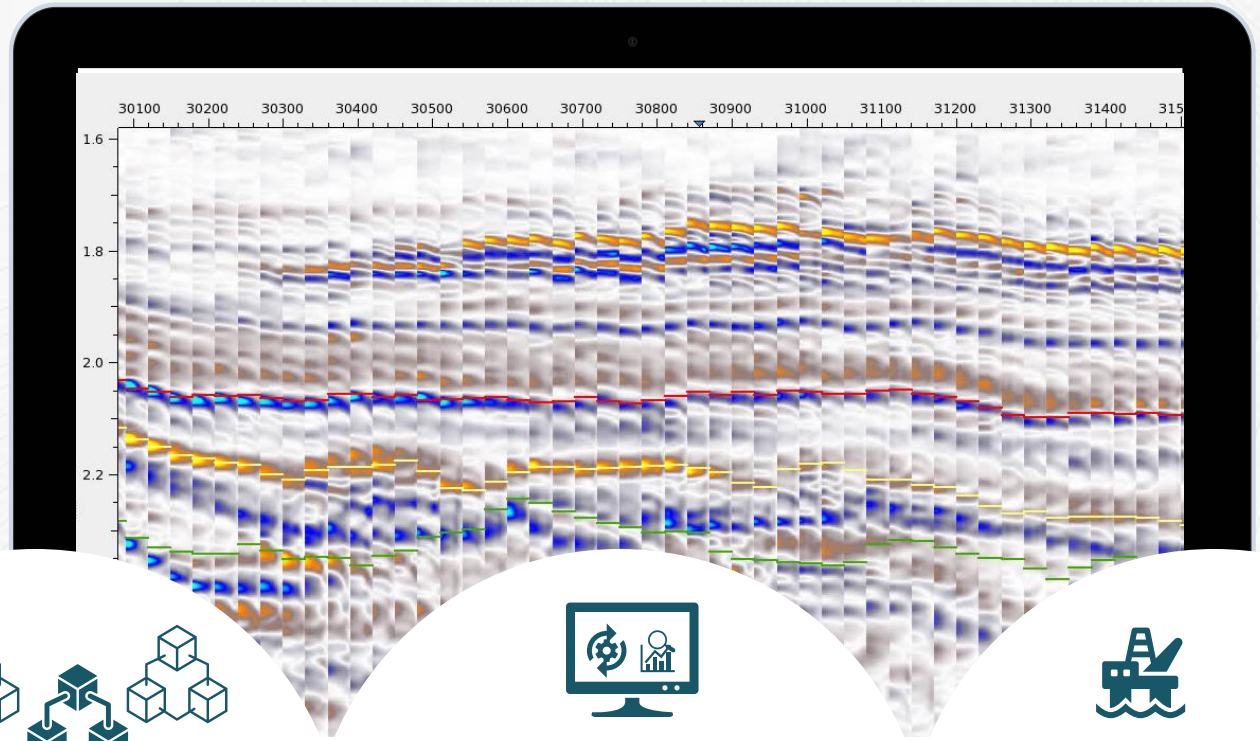


Use 100% of your source data

High Performance Computing engine

Integrated **processing** and **interpretation**, straight from migrated **pre-stack gathers**

Find **otherwise missed** reservoirs

Client saves $170M in drilling costs to avoid a well failure

Background:

- 2022: super major planning an exploration well conducted typical 3–5-year interpretation process.

Goal:

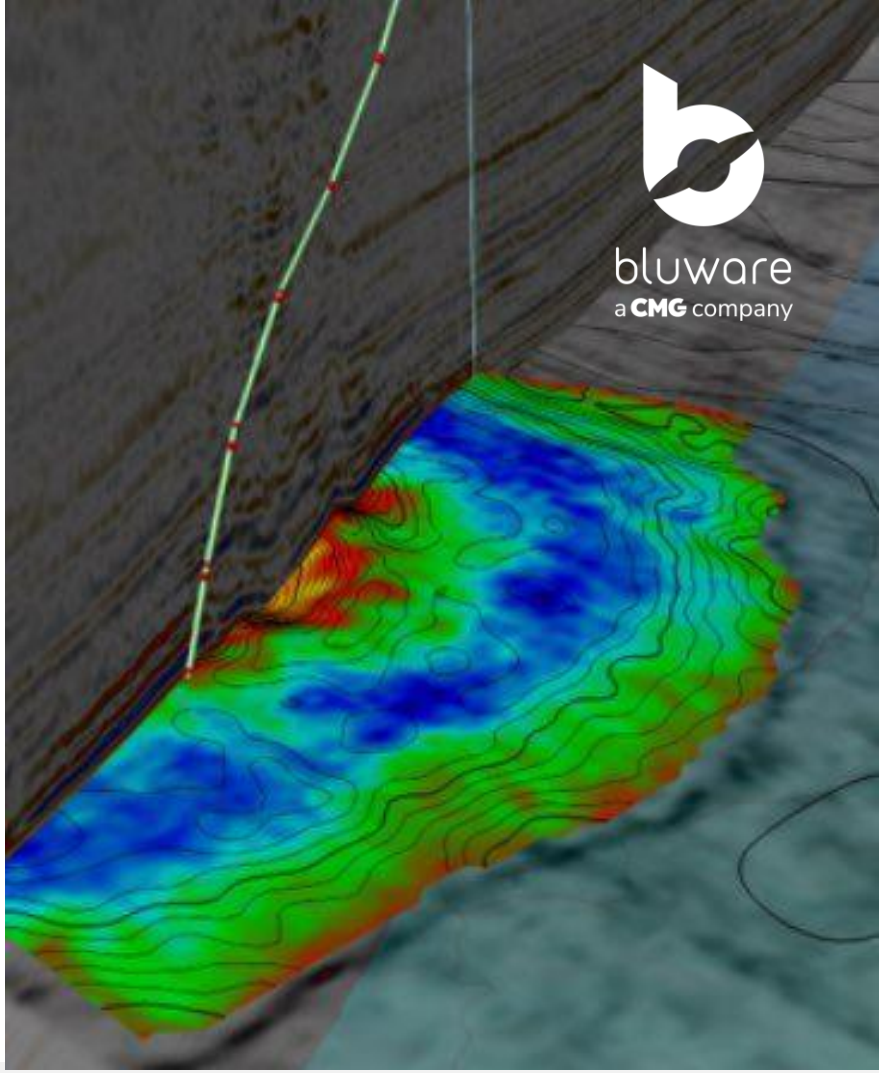
- Test large accumulation with fault compartmentalization risk.

Challenge:

- Days before spudding, asset team used InteractivAI and detected unknown fault near well's reservoir penetration point.
- Fault invisible in stacked data due to orientation.

Solution:

- Team scrutinized data based on InteractivAI's prediction.
- Fault structure was confirmed and well path was redesigned to avoid the hazard.

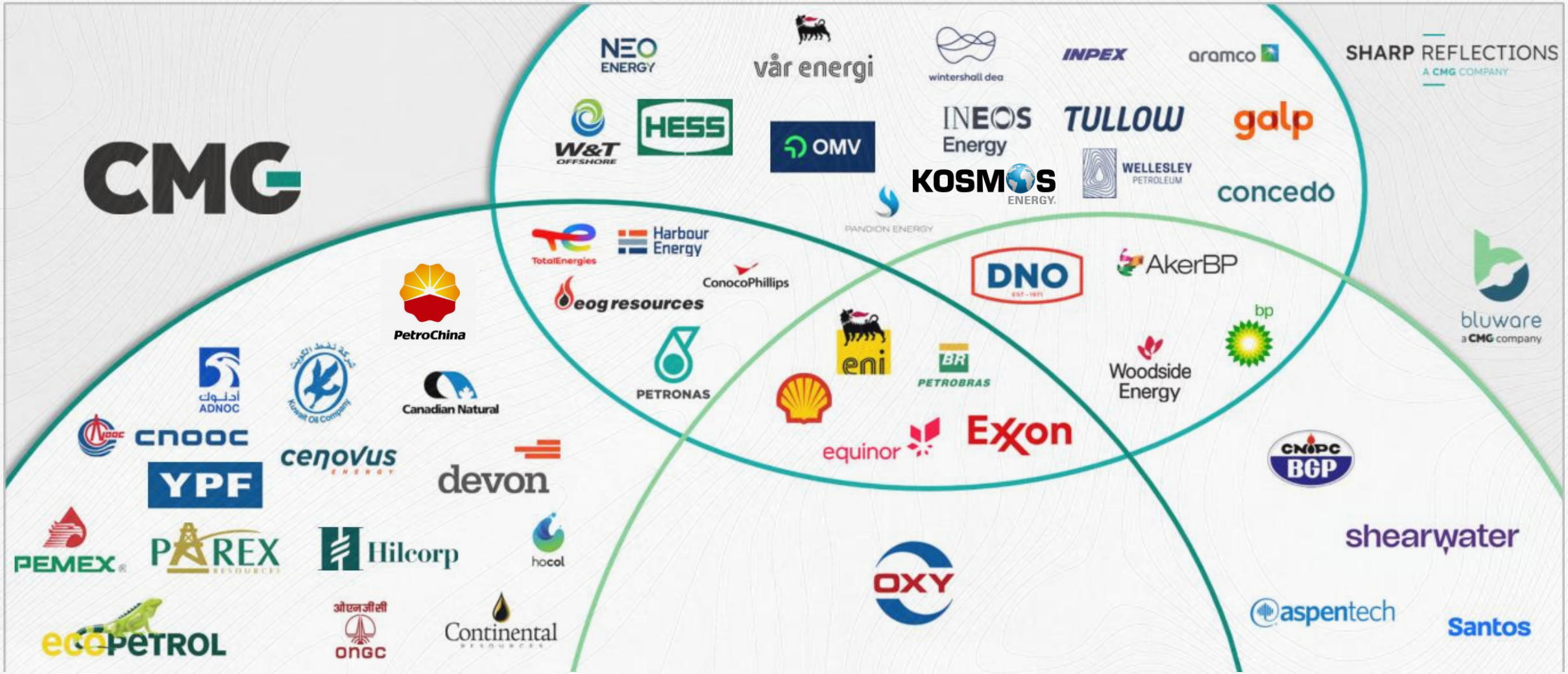


Key Takeaway:

InteractivAI's last-minute validation prevented a costly failure and ensured project success.

From raw stacks to model-ready interpretations

The world's most efficient energy companies powered by CMG



CMG 4.0 Partnerships

3) Year In Review 2024

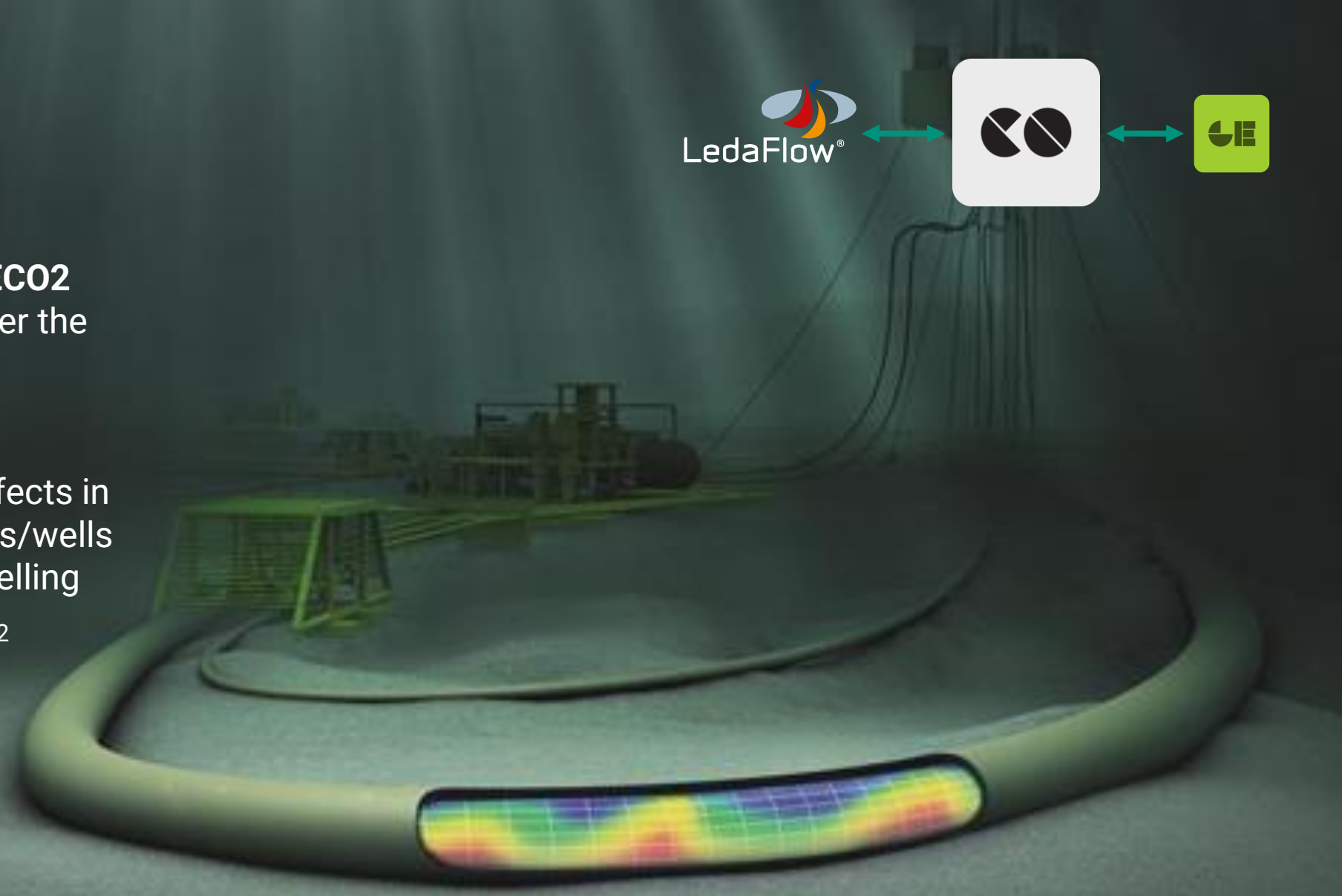
NEW
Products Released This Last Year

CO2LINK

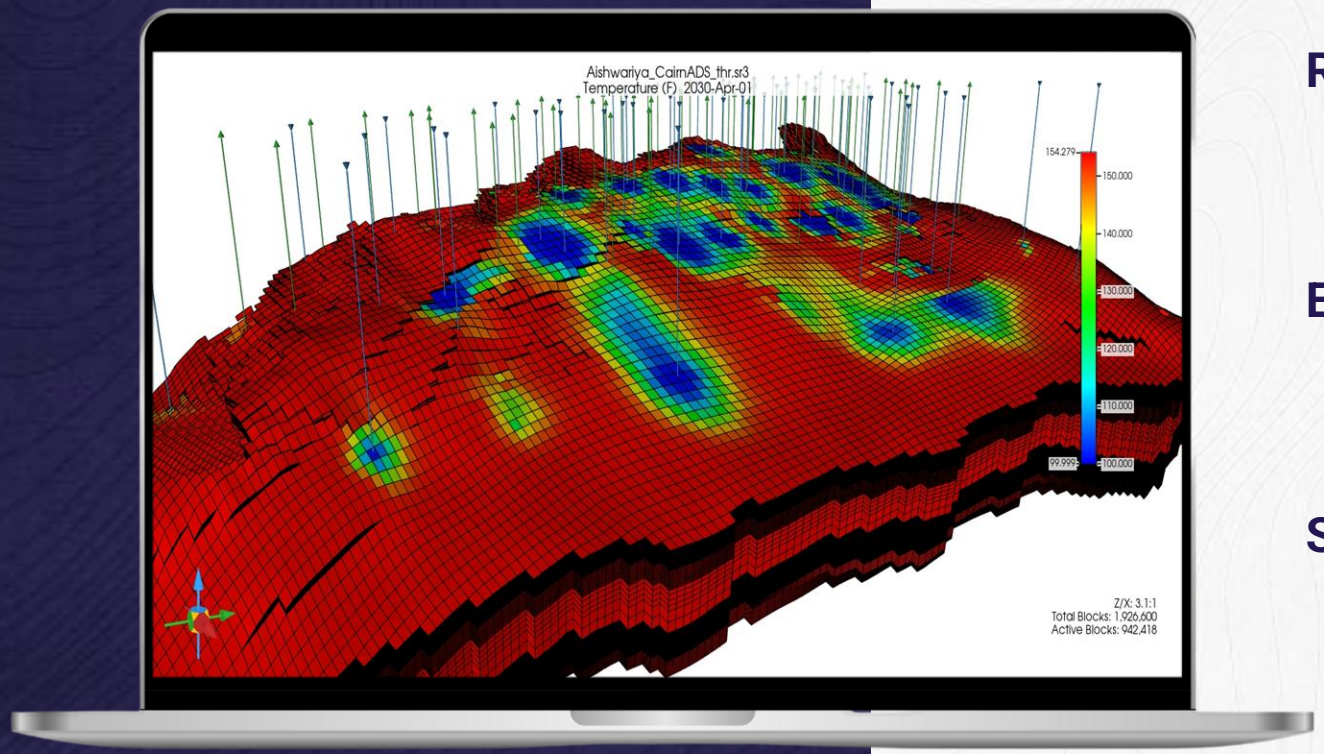
The CO2LINK Controller was developed as part of the **GELECO2** Joint Industry Project (JIP) over the last two years.

JIP's Focus:

- Understanding transient effects in CCS operations within pipes/wells
- Enhance the reservoir modelling capabilities of complex CO_2 systems.



CMG Petrel Plugin



Ease of data transfer

- Plug directly into Petrel
- No need for 3rd party formats
- Load CMG simulation result files (SR3) directly into Petrel

Reduce time to decision

- Less time on mis-communications
- Less time spent on data transfer

Ease of use

- Run IMEX directly in PETREL
- Compare and verify in a familiar environment

Seamless conversion from ECL to IMEX

- Drag and drop any ECL dataset to IMEX or Builder

Energy Transition New Features 2024

Providing the Tools to Answer the Hard Questions

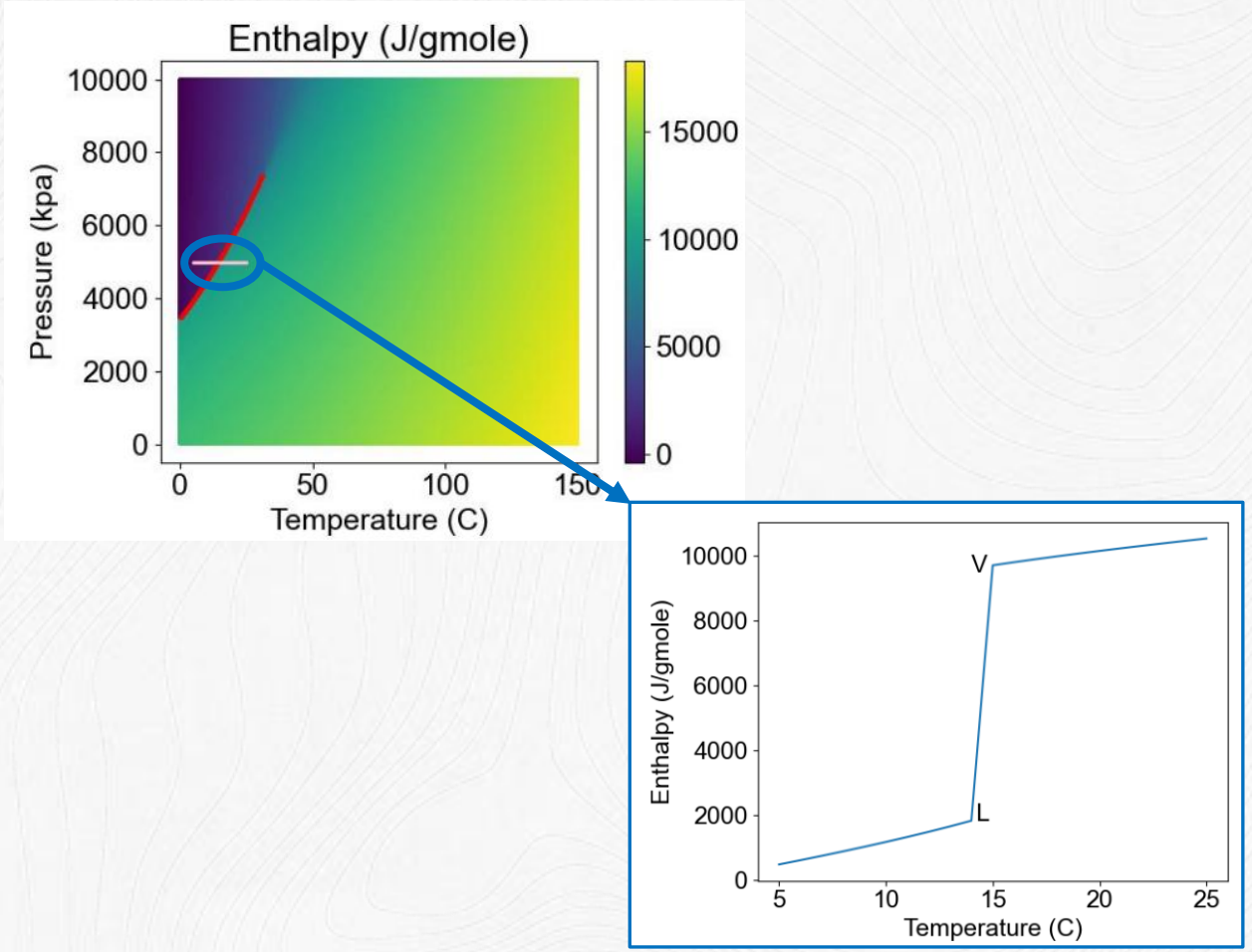
Capturing the Complex Dynamics of Pure CO_2 Phase Behavior

Challenge

Displacement of fluids around injection wells can lead to a Pure-CO_2 Condition

Accounting for the phase transitions and properties of Pure-CO_2 can be challenging

- Errors in calculated mobilities and pressures



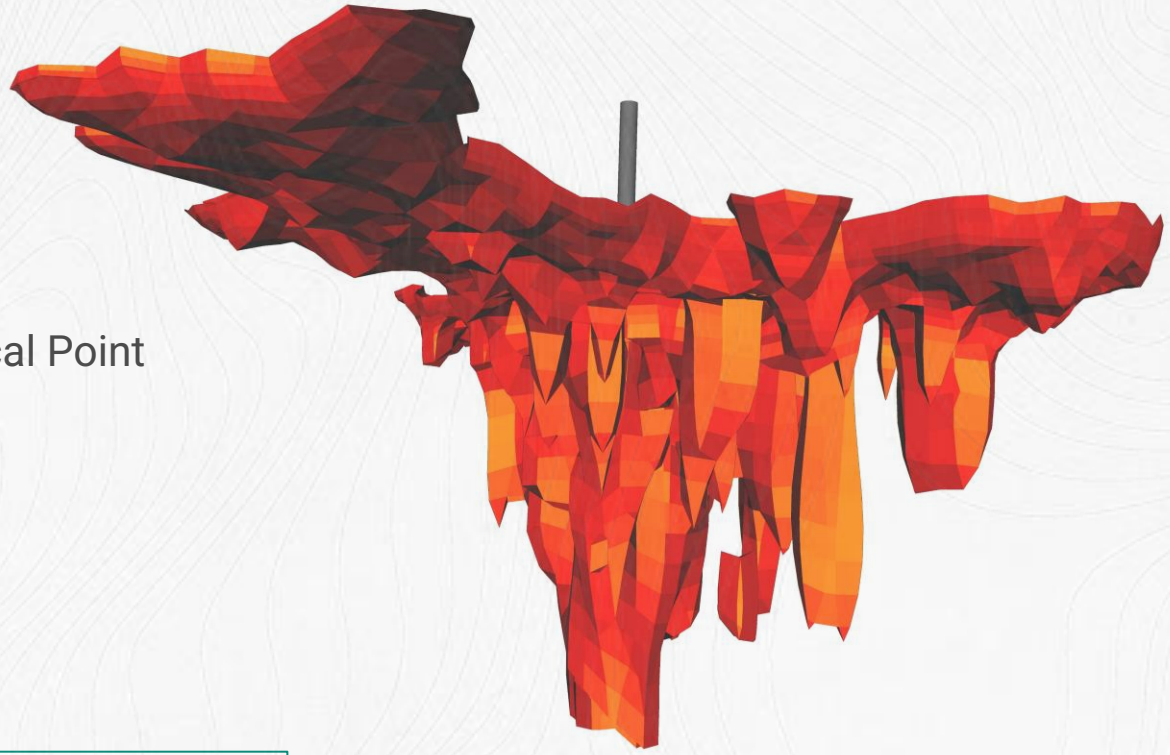
Capturing the Complex Dynamics of Pure CO_2 Phase Behavior

v2025.10

Solution

Mechanistic Modelling
of Pure CO_2 Conditions (Comp-1C):

- Isenthalpic Flash
- Auto-extension of Widom saturation curve above Critical Point
  - Proper determination of phases
  - Density interpolation



Enabled in 2025.10 (Beta*)

Pure-CO_2 Modelling Support With:

- Dissolution/Solubility
- H_2O Vaporization
- Geochemistry

*Development efforts planned in 2025 to further enhance options and provide greater stability

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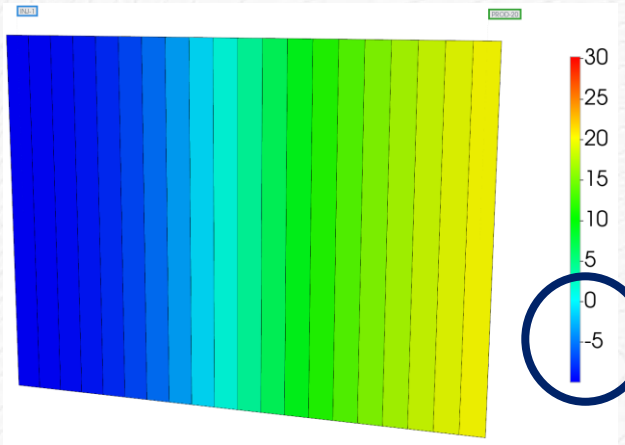
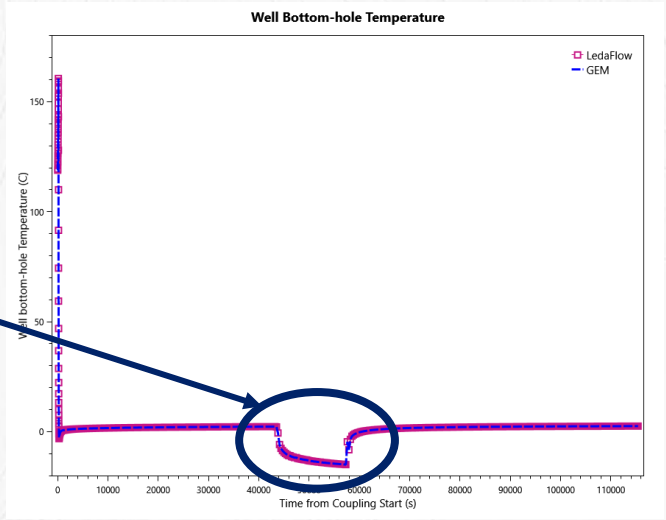
Model the Impact of Subzero Conditions

Injection of fluids (especially CO_2) can be considered in subzero temperature conditions.

- Option is automatically enabled when using the new Isenthalpic flash (Comp-1C)
- **Consider impacts to density, viscosity, phase behavior, injectivity, etc.**



Subzero Regions



Customizable Geochemical Reaction Definitions

v2025.10

Input geochemistry with PHREEQC Format

- GEM generally utilizes a defined format for calculation of constants associated with equilibrium geochemical reactions
- Connection to Geochemical databases provides you with ability to quickly setup reactions via WinProp

$$\text{GEM}: \log K_{T(C)} = a_{0GEM} + a_{1GEM}T + a_{2GEM}T^2 + a_{3GEM}T^3 + a_{4GEM}T^4$$

- **New Option** - Directly input custom equilibrium reaction kinetics based on common **PHREEQC format**

$$\text{PHREEQC}: \log K_{T(K)} = a_{0PHR} + a_{1PHR}T + \frac{a_{2PHR}}{T} + a_{3PHR}\log T + \frac{a_{4PHR}}{T^2}$$

Key Benefit
Directly transition from Lab experiments to the Simulator without needing to go through a Database or WinProp

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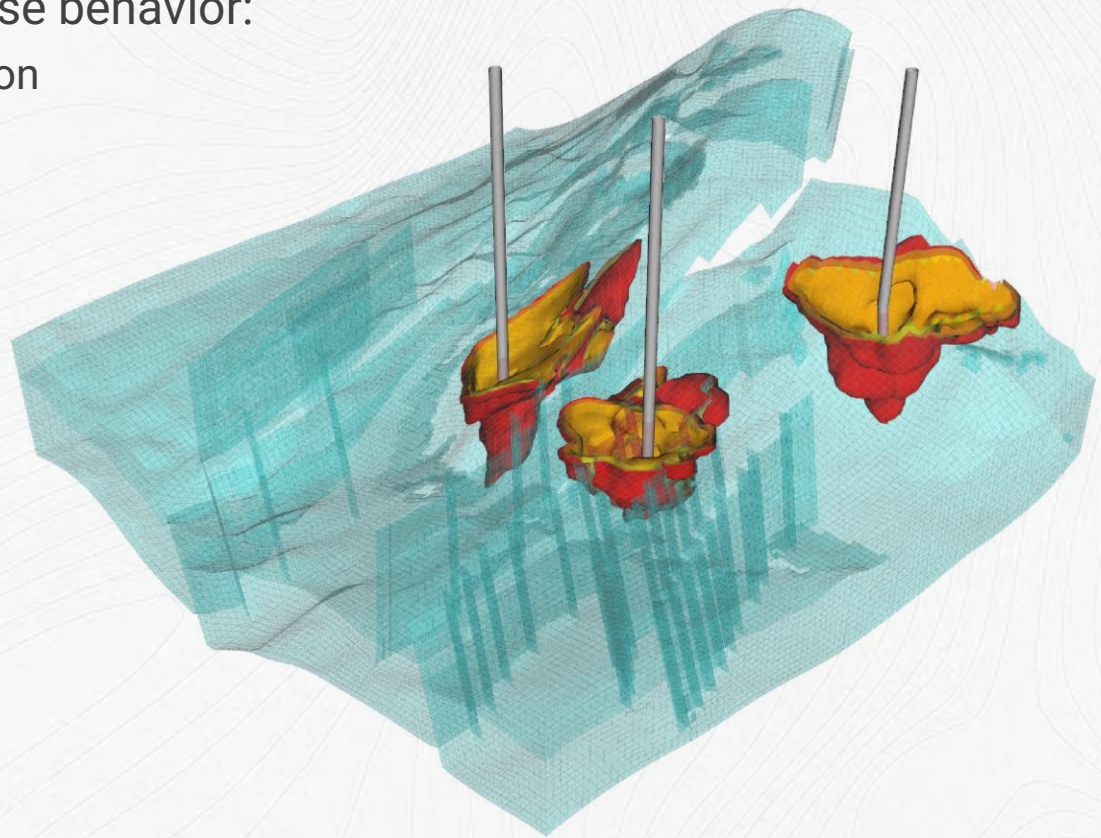
Span-Wagner Equation-of-State for CO_2 Properties

Derive CO_2 properties and phase behavior:

- CO_2-Brine K-Values (as function of pressure and temperature)
- CO_2 Molar Density
- CO_2 Viscosity
- CO_2 Enthalpy
- CO_2 Heat Capacity
- Thermal-effect capable



Works with all Solubility/Dissolution Methods:

- Spychur-Pruess
- Harvey's Correlation
- Henry's Constants
- K-Value Equil Parameters

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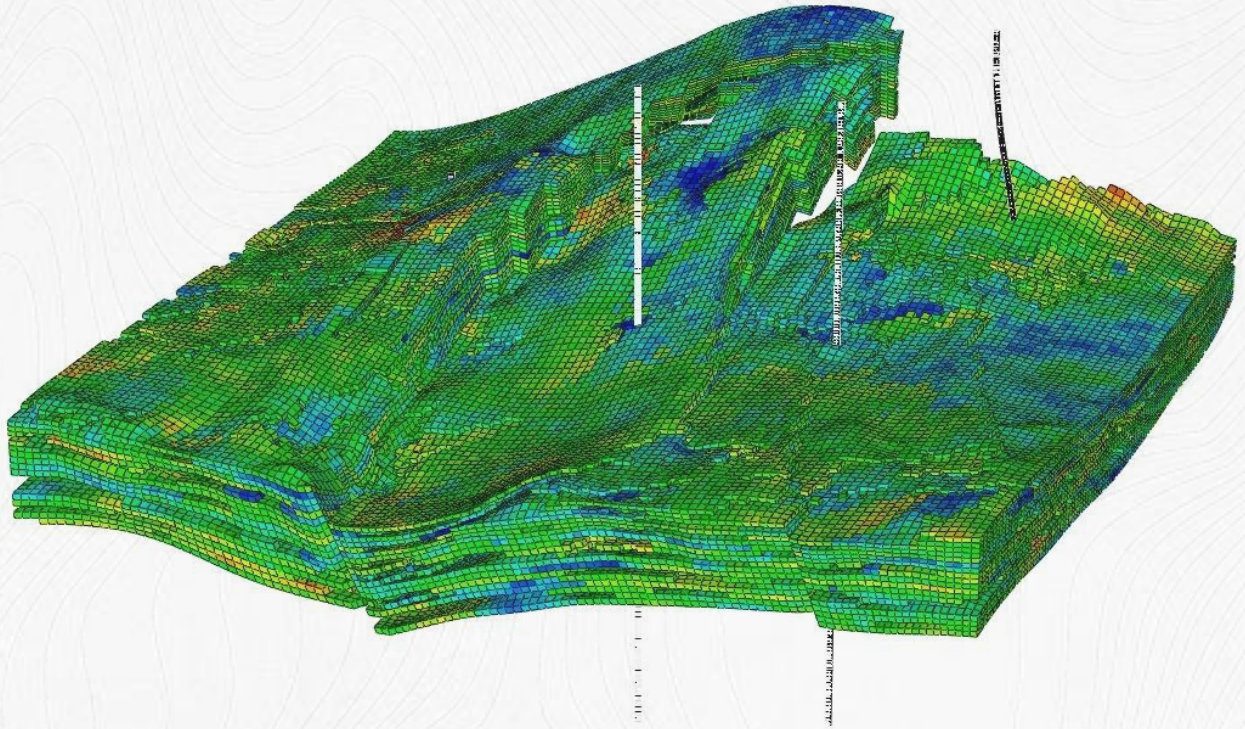
Supporting Energy Transition and Complex Scenarios

Define and Output Gas Injection Rates by Mass

Reduce scenario setup time in Builder:

- (Metric) Tonne/Day or (Imperial) Ton/Day
- RESULTS can also show in mass-based format



Sector-Based CO_2 Inventory Outputs

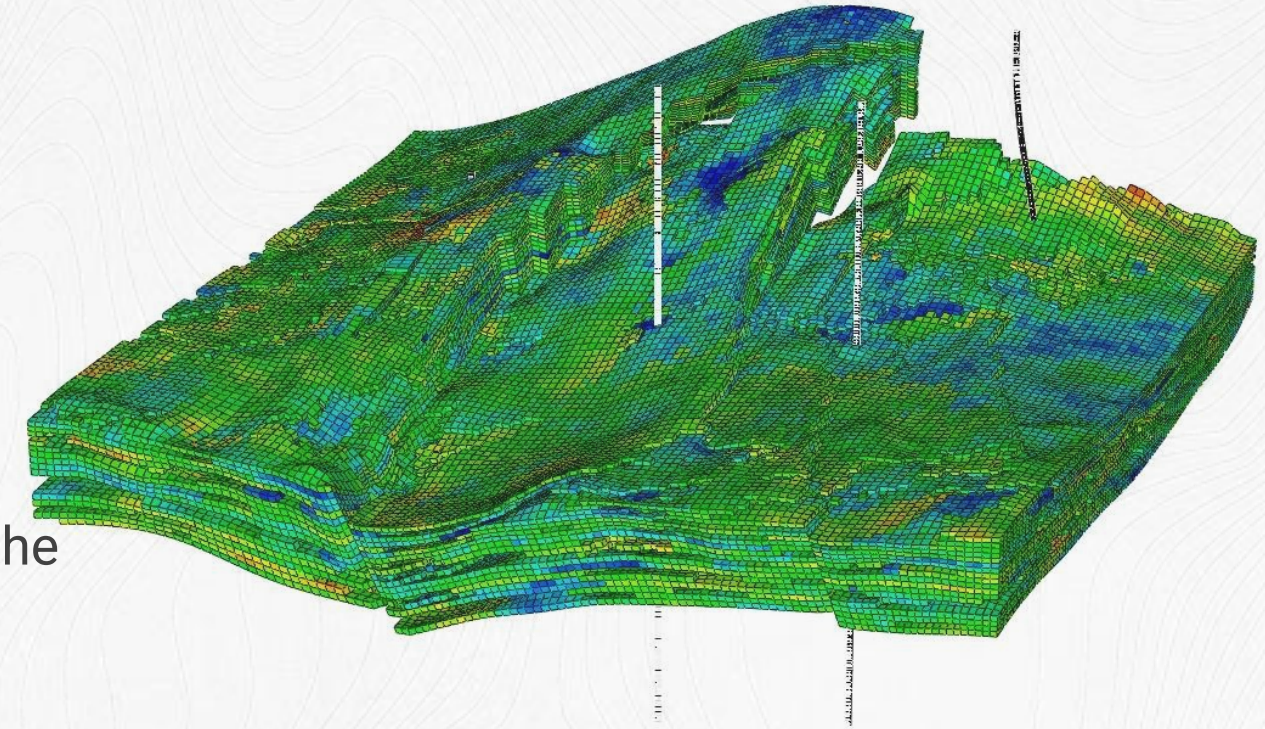
Track the state of CO_2 throughout defined regions:

- Supercritical, gaseous, liquid
- Soluble in aqueous phase
- Trapped by hysteresis (residual gas trapping)
- Trapped by mineralization/geochemistry

Supporting Energy Transition and Complex Scenarios

Component-Based Water Tracking Output

- Mole fraction of water in various phases
- Particularly important when considering Vaporization



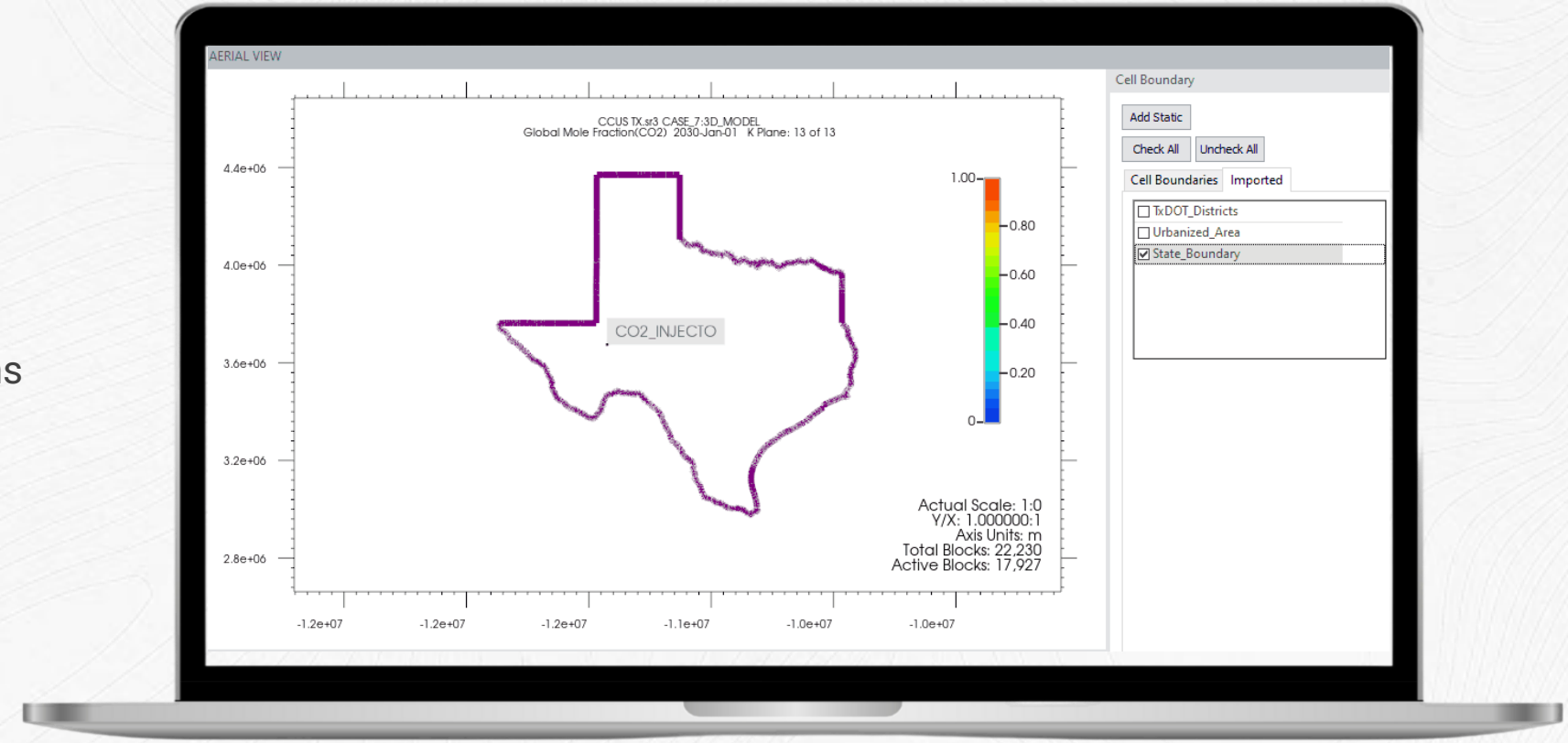
Heatloss through Null Blocks

- Better accounting of energy loss away from the reservoir boundary
- Analytical heatloss at the boundary has been updated to consider connection with the last active gridblocks

Directly Import Shapefile

Compare model results to a variety of areas of interest:

- CO2 plume size
- Contour maps
- Land maps
- Lease planes/boundaries
- Pipeline overlays
- River or body of water locations
- Operational boundaries



CO2 injection horizontal plume captured within Texas state boundary

General & Common Updates

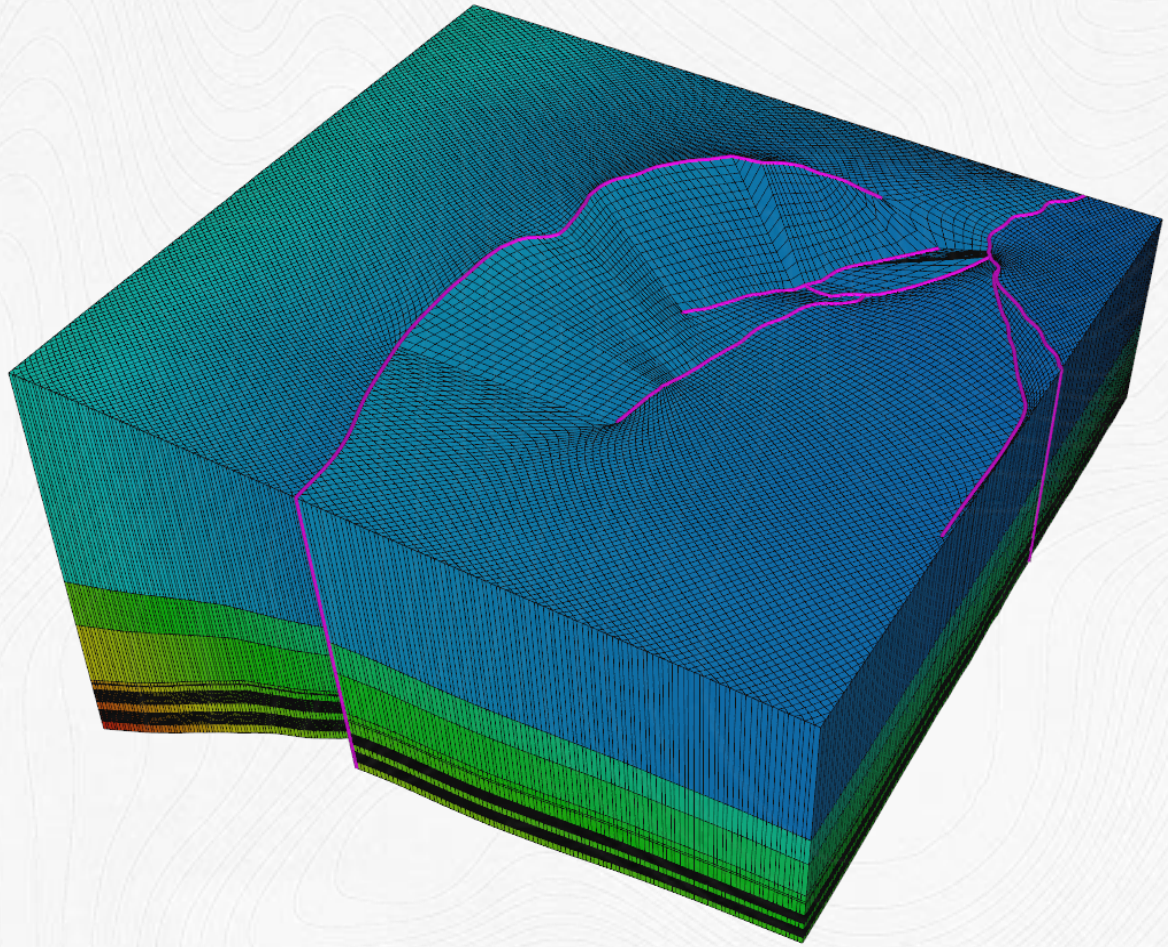
Model Larger Plastic Strain with Terzaghi's

Terzaghi's Effective Stress

Introducing an alternative to the Nur's effective stress approach

Unlike Nur's, Terzaghi's is independent of Biot's Coefficient:

- Define per-rocktype and used for calculating effective stress
- During plastic deformation, the plastic strain will be greater with Terzaghi's
- Can assign at a fault when evaluating the potential for fault reactivation



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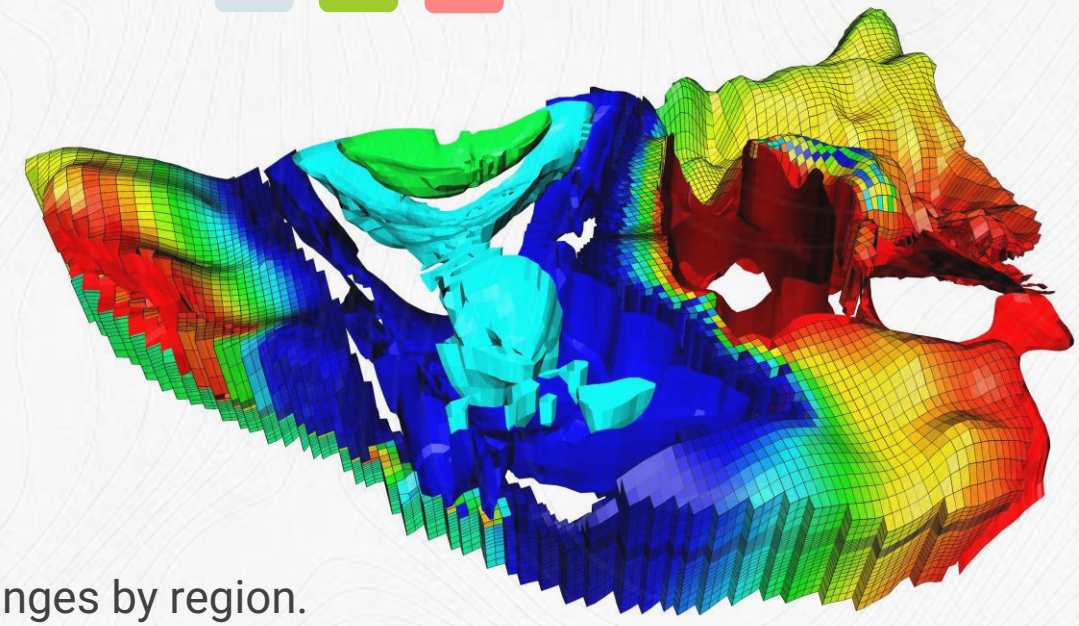
Greater Operational Control - Enhanced Outputs and External Scripting

With Outboard and PyControl – access external applications and scripts for controlling recurrent, operational effects

Grid Property Information Available via PyControl and Outboard

- Block geometries
- Rock and fluid properties
- IPR Tables



Component Rates in Outboard

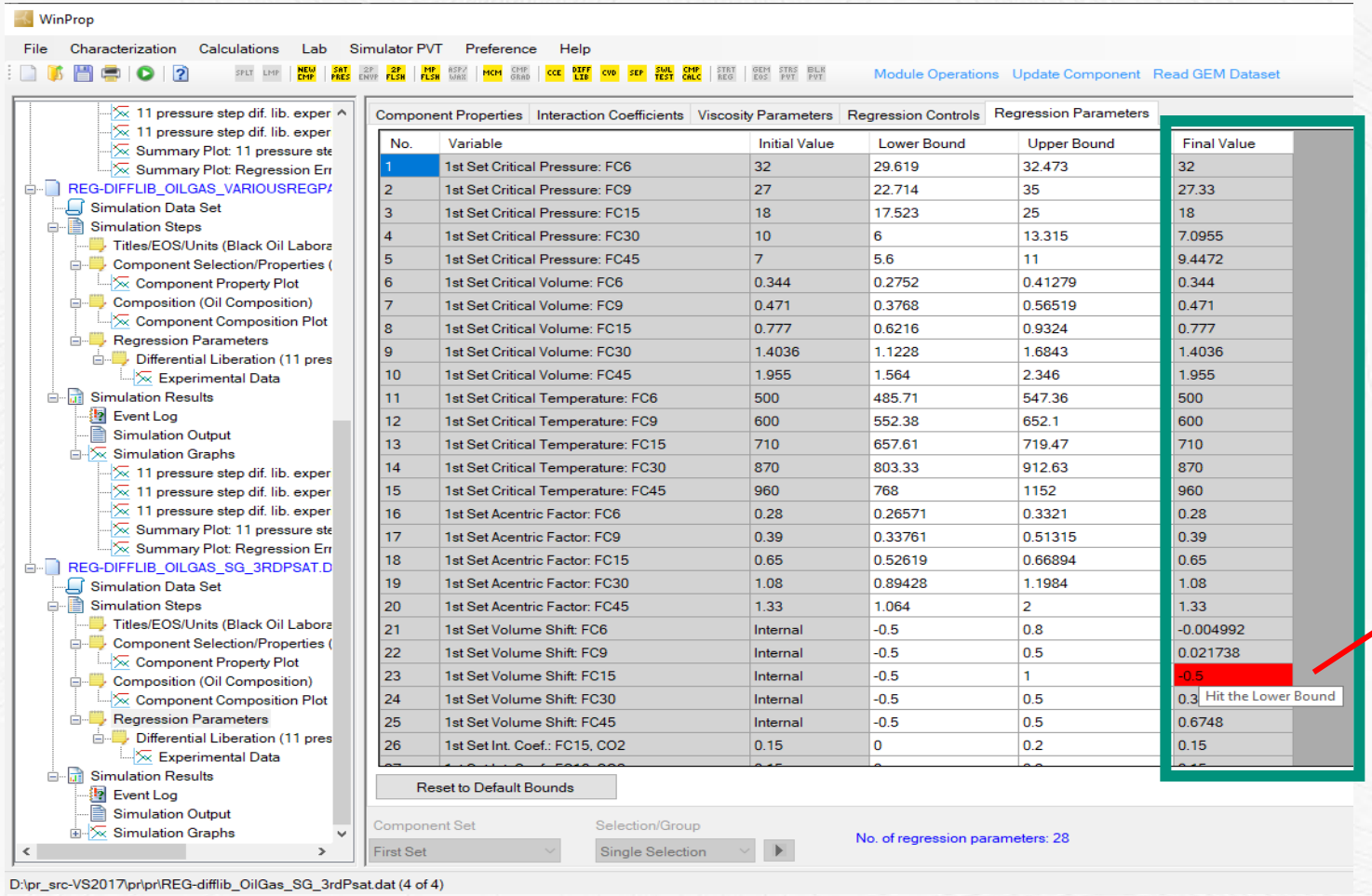
Access component rates in GEM and STARS for defining well logic

Sector Mole Fractions Output

Output average component mole fractions by sectors and plot changes by region.

Access Regression Parameter Changes Directly from Interface

Provide a quick, direct path to viewing, adjusting and re-running the workflow



No.	Variable	Initial Value	Lower Bound	Upper Bound	Final Value
1	1st Set Critical Pressure: FC6	32	29.619	32.473	32
2	1st Set Critical Pressure: FC9	27	22.714	35	27.33
3	1st Set Critical Pressure: FC15	18	17.523	25	18
4	1st Set Critical Pressure: FC30	10	6	13.315	7.0955
5	1st Set Critical Pressure: FC45	7	5.6	11	9.4472
6	1st Set Critical Volume: FC6	0.344	0.2752	0.41279	0.344
7	1st Set Critical Volume: FC9	0.471	0.3768	0.56519	0.471
8	1st Set Critical Volume: FC15	0.777	0.6216	0.9324	0.777
9	1st Set Critical Volume: FC30	1.4036	1.1228	1.6843	1.4036
10	1st Set Critical Volume: FC45	1.955	1.564	2.346	1.955
11	1st Set Critical Temperature: FC6	500	485.71	547.36	500
12	1st Set Critical Temperature: FC9	600	552.38	652.1	600
13	1st Set Critical Temperature: FC15	710	657.61	719.47	710
14	1st Set Critical Temperature: FC30	870	803.33	912.63	870
15	1st Set Critical Temperature: FC45	960	768	1152	960
16	1st Set Acentric Factor: FC6	0.28	0.26571	0.3321	0.28
17	1st Set Acentric Factor: FC9	0.39	0.33761	0.51315	0.39
18	1st Set Acentric Factor: FC15	0.65	0.52619	0.66894	0.65
19	1st Set Acentric Factor: FC30	1.08	0.89428	1.1984	1.08
20	1st Set Acentric Factor: FC45	1.33	1.064	2	1.33
21	1st Set Volume Shift: FC6	Internal	-0.5	0.8	-0.004992
22	1st Set Volume Shift: FC9	Internal	-0.5	0.5	0.021738
23	1st Set Volume Shift: FC15	Internal	-0.5	1	-0.5
24	1st Set Volume Shift: FC30	Internal	-0.5	0.5	0.3
25	1st Set Volume Shift: FC45	Internal	-0.5	0.5	0.6748
26	1st Set Int. Coef.: FC15, CO2	0.15	0	0.2	0.15

Hit the Lower Bound

New Output View

Flagging for when a parameter's regression bounds are hit

Common Output Enhancements for Well Information

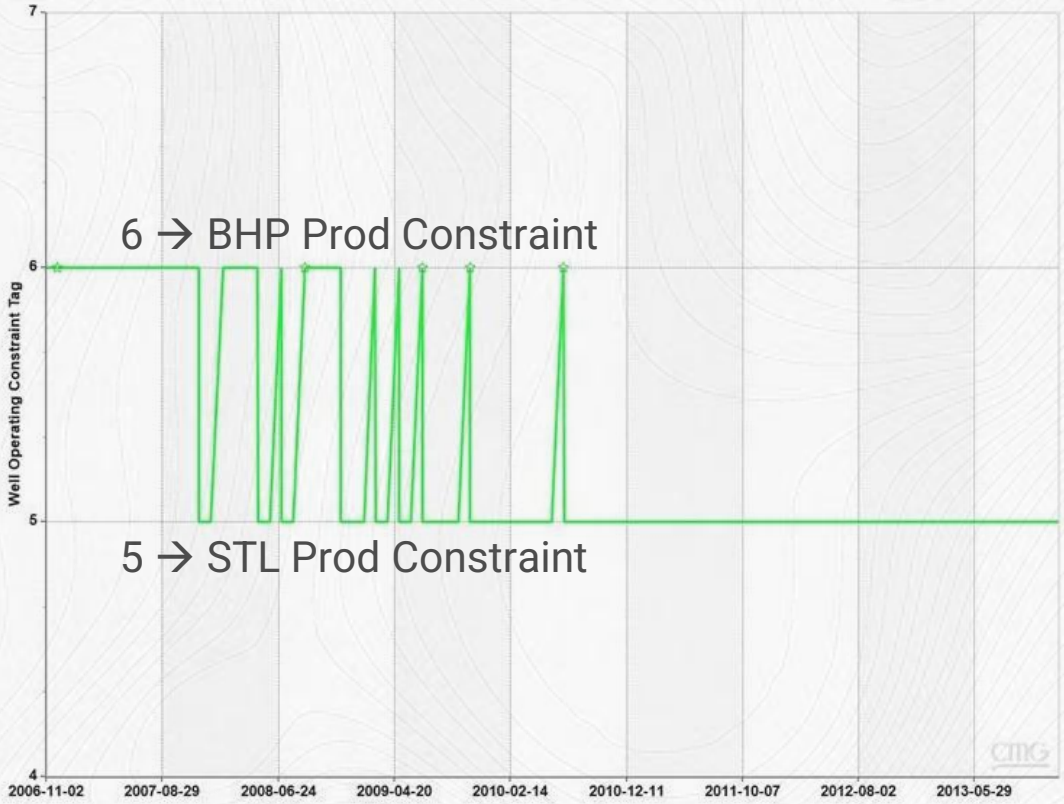
v2025.10

Plot Well Index per Perforation

- See how well index is defined over the length of a well
- Cross-plot WI versus rates and pressures for enhanced understanding

Dynamic Primary Well Constraint Outputs

- Plot the current primary operating constraint of a well with time
- See how the primary constraint changes based on model dynamics



Options coming to STARS in 2025.20

Profile Plot Performance

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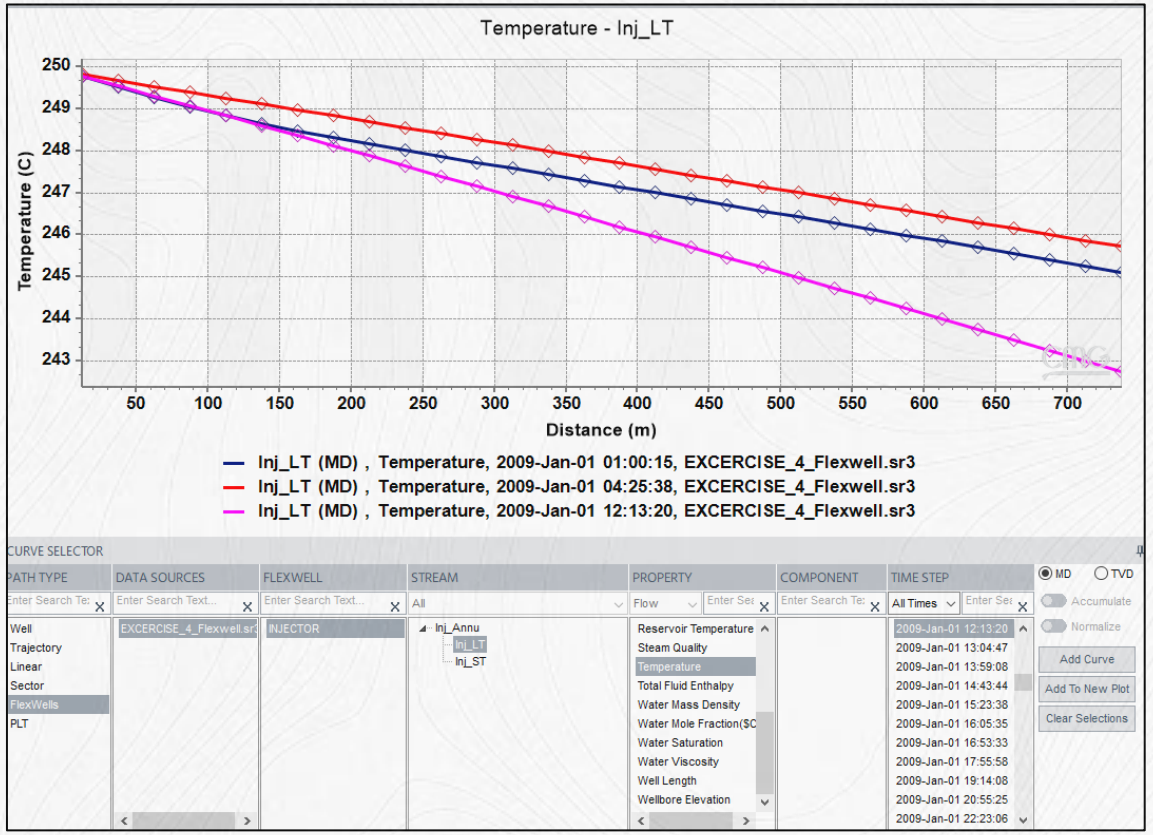
Profile plotting is now faster for **FlexWell**, **PLT**, and **Flow properties**, improving efficiency.

- Improved performance for profile plotting, reducing wait times
- Applies to data from both optimized and source simulation outputs
- Works seamlessly with existing workflows for smoother analysis



For the best performance in Results, we continue to recommend using the SR3 Optimization feature within Launcher

CMG

Simplified Optimization Workflows

Robust Objective Functions Flexibility

- Pre-defined functions or customizable scripts

Smart Study Validation

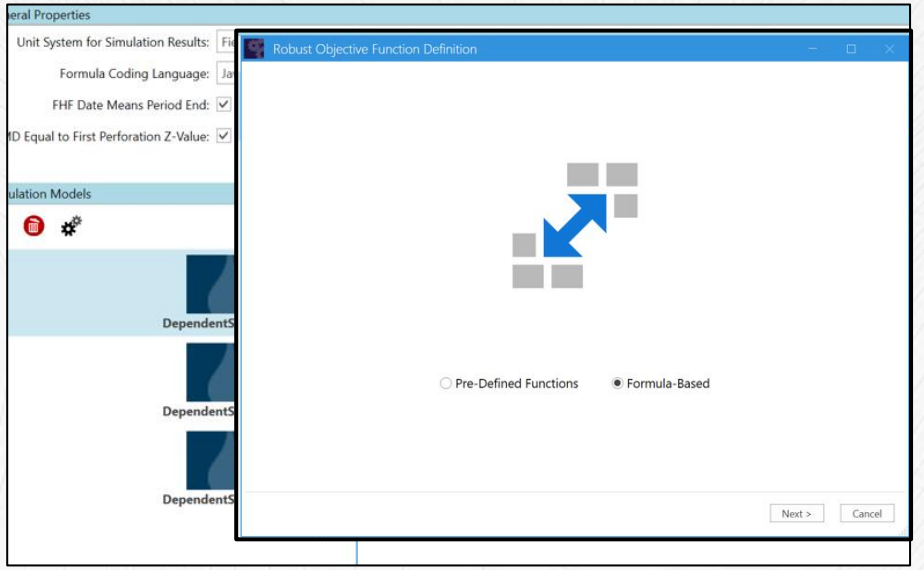
- Real time feedback ensuring accuracy and reliability of study configuration

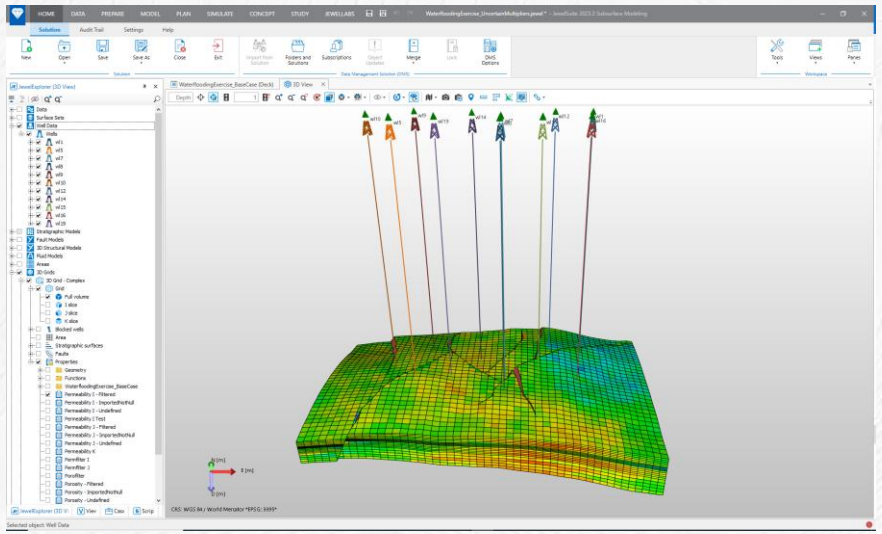
Seamless Integration with G&G Packages – JewelSuite:

- Ensure smooth end-to-end workflows

CoFlow Integration Enhancements:

- Truncated Log-Normal Distribution
- Parametrization in CoFlow





Monte Carlo Simulation Data Export

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Monte Carlos Simulation Workflow Efficiency

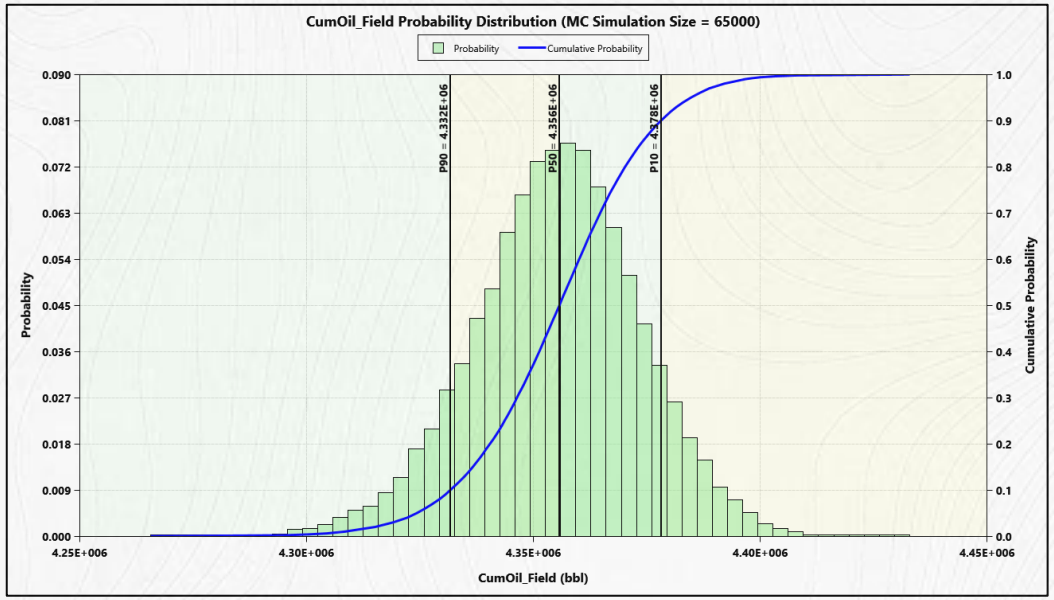
Full Data Export:

- Export all 65,000 Monte Carlo simulation results to Excel for seamless analysis

Selective Data Integration:

- Add chosen Monte Carlo data directly into the CMOST Experiment Table for streamlined evaluations

These enhancements provide greater flexibility and efficiency in working with Monte Carlo simulation results.



Uncertainty Management, Infrastructure & Openness

- Expanded parameterization to include subsurface parameters in DAT files (beta) → **End-to-end uncertainty management with IPSM**
- Significant application performance gains & DB storage optimization → **enabling more IPSM scenario analysis**
- Coupling with MoReS reservoirs now possible (beta) → **More flexibility**

CoFlow's first API toolkit is now available

Available Now

- Build & update models, run simulations, & analyze results using Python (beta) – selected properties

Vision

- Run automated DOF workflows
- Enrich CoFlow workflows with external Python libraries

Accelerating Decisions

Speed & Stability Enhancements

PyControl Enablement with MPI

With the PyControl tool you can script simple-to-complex controls with Python that the simulators can use when running

With this latest extension to MPI, even the largest of models can leverage the external scripting and capabilities that PyControl workflows provide.

AWS Datacentre
https://aws.amazon.com/compliance/data-center/data-centers/

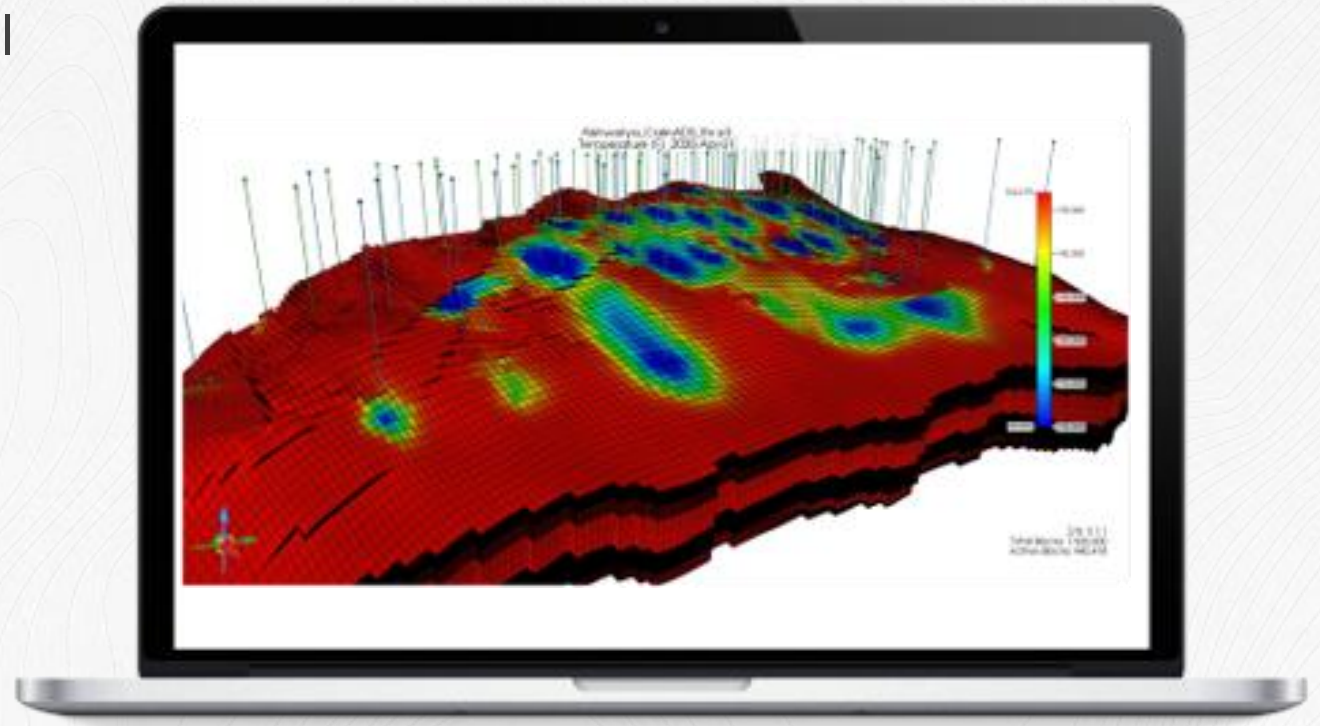
Dual-Continua Model Support for GEM MPI

Support for Dual Permeability/Porosity model types with MPI

- Subdomain and MINC options are not currently supported

Particularly useful for:

- Large carbonate, shale, or CBM models
- Expansive aquifers while scoping energy transition studies (CCS, Lithium Brine, etc.)



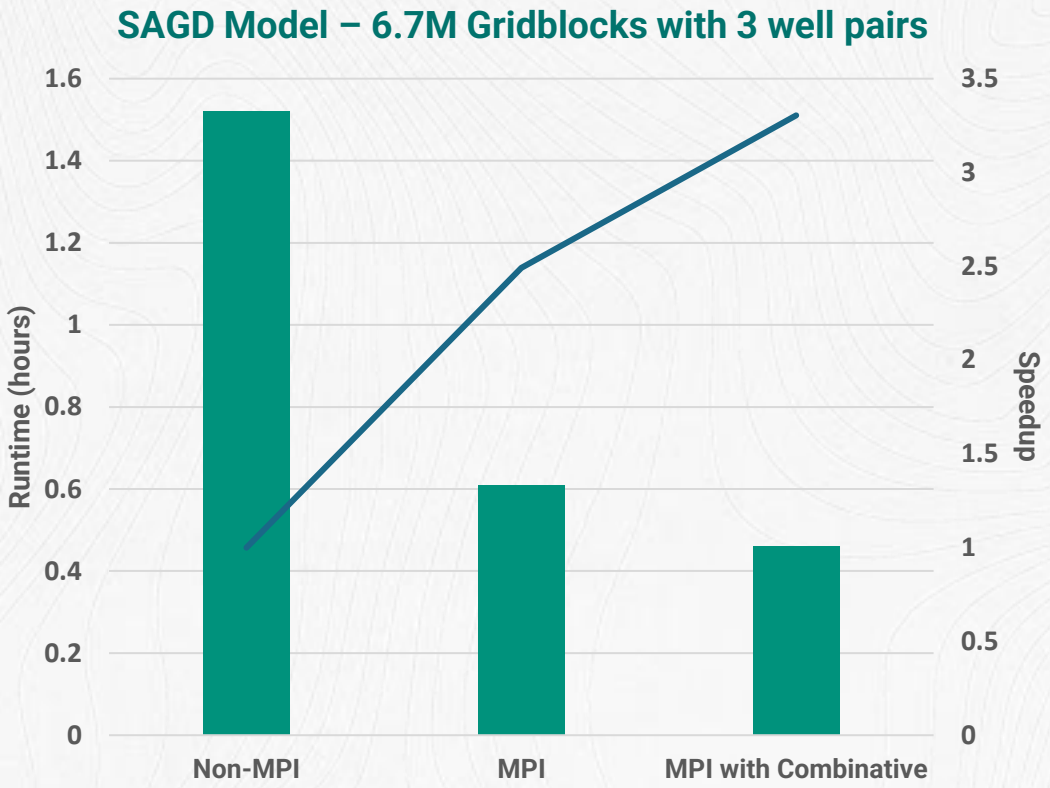
Faster Distributed Runs across All Simulators

Now available with both shared and distributed memory - MPI (IMEX, STARS, & GEM)

- Combinative ILU method
- IMEX MPI/STARS MPI in 2024
- GEM MPI as of **2025.10**

Example **1.3X Speedup**
GEM MPI + Combinative ILU

- 100 Million Cells
- 8 Components
- CO_2 WAG Scenario



Average **40+% Speedup**
STARS MPI + Combinative ILU

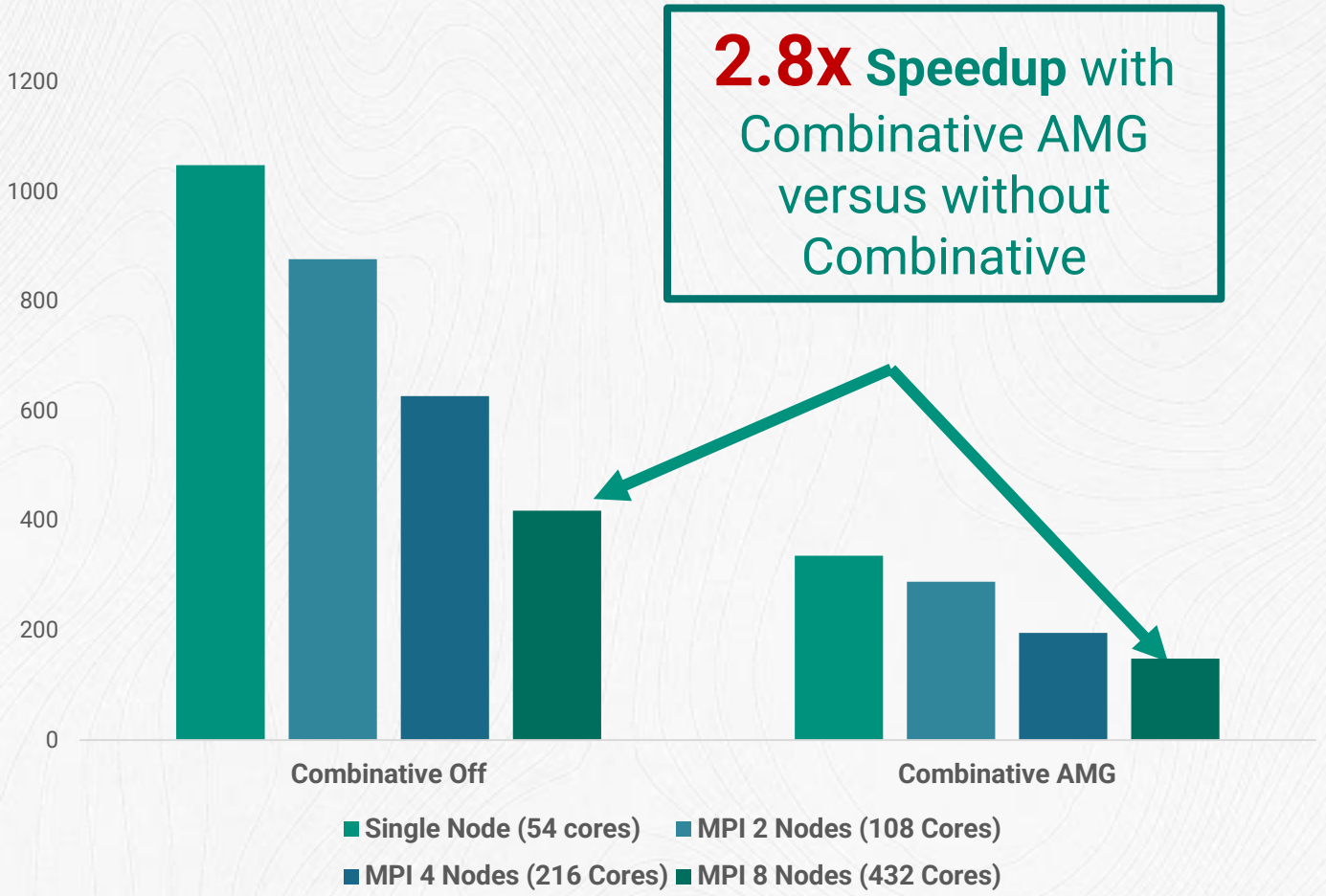
Combinative AMG with MPI for Large Model Acceleration

IMEX MPI + Combinative AMG

- Additional Option to Combinative ILU
- Can provide greater speedup in models with frontal processes (e.g. floods)

Upcoming Developments

- **Automatic-Combinative** for dynamic switching between ILU and AMG
- Implementation of Combinative AMG in **GEM MPI** and **STARS MPI**



1 Million Gridblock **IMEX** Waterflood Model

CMG

Forecast Mode – Simpler Transitioning from History to Forecast

Challenge

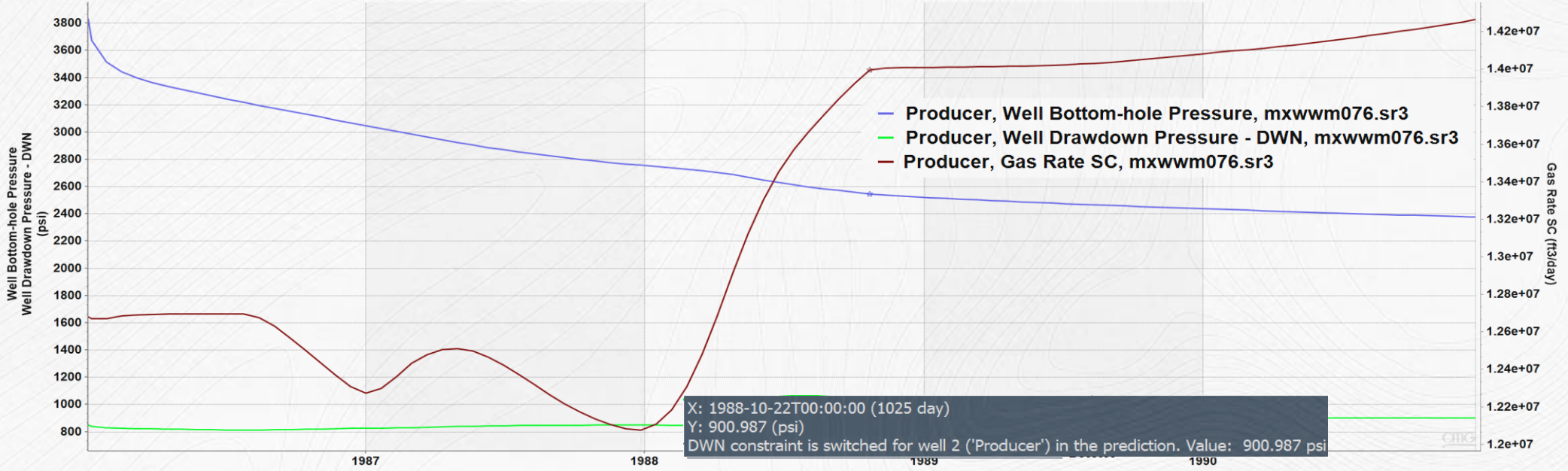
Historical Period Simulation that you want to now run forward into the future (**Prediction**).

Want to hold the last well constraints constant going forward as per the last historical.

Solution

New Forecast Mode

- Define per-well controls on go-forward constraint
- Pressure, Rates, Drawdowns
- Takes the last calculated value for the rate (even if not an active constraint) and automatically applies it



Intelligent Active Block Options

Current method for creating pinchouts limited to *block thickness* criteria.

New option for defining pinchout/inactive cells:

- **Volume-based pinchout** – user defined based on Pore-Volume*
- Provides **direct, out-the-box performance improvement**, particularly for models with lots of heterogeneity

To Supplement, Check-Only Mode Option:

- Analyze pinch-out impacts based on potential defined Volume parameters
- Users can define a P-value and see the resulting distribution of blocks that would be pinched-out

Viscosity Mixing Models for Every Occasion

Inclusion of **12 different Viscosity Mixing rules** added to STARS

- Standard – Linear, Power-Law, Arrhenius, Double-double Log mixing
- Newer – Kendel, Bingham, Crago, Forth-root, Wilkie, Mehrorta, Refutas, Chirinos

Match Laboratory and field-derived hydrocarbon mixing with the most applicable approach for the situation.

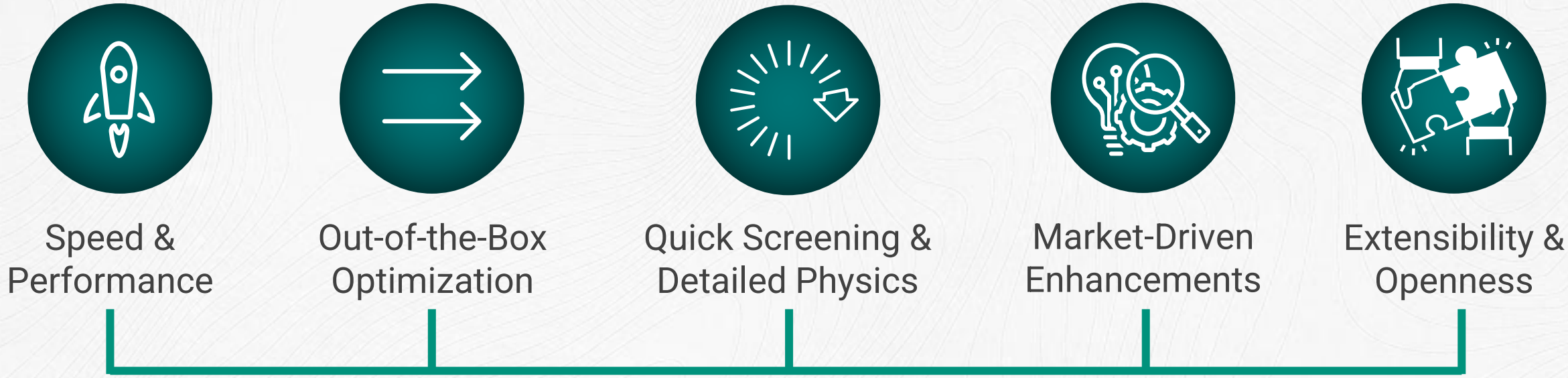
Some newer options found to provide very good matches for solvent systems.

Next Phase

Generalized Viscosity Mixing Table Input (2025.30 – Sept)

2025 Development Roadmap

CMG's 2025 Development Themes and Focus Areas



2025 Development Initiatives

New Solvers **GEM Speed**	**Builder Performance**	**Solvents** **CMG Labs**	**ShaleSim** **CoFlow IPSM**	**CoFlow Steam**

Meet your new

Unconventional Toolbox

CMG

HIGH FIDELITY

ShaleSim

Integrated fracture and reservoir simulation for optimizing development plans

ShaleMES

(within IMEX)

Field-scale modelling of hydraulic fracturing performance

LOW FIDELITY

ShaleIQ™

Data analytics for reserves estimation, production surveillance, and reporting

Download the
latest version today

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Thank you!

Questions?