ETIP Geothermal

Webinar 2024

Developing a marginal reservoir for urban heating in Zwolle: Optimized well and completion design

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Geothermica RESULT- Enhancing REServoirs in Urban deveLopmenT: smart wells and reservoir development

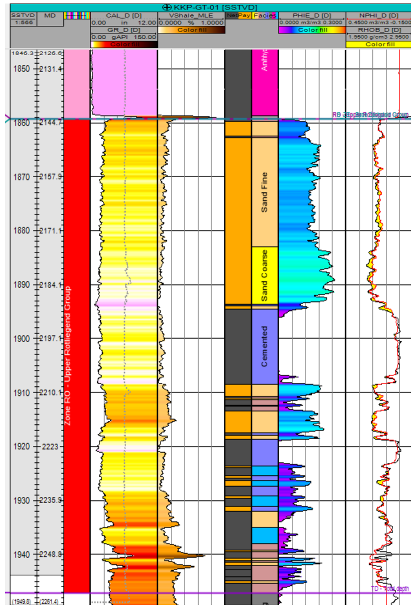
- **The main objective is to demonstrate the potential for increased performance of major (marginal) reservoirs for heating in urban areas in the northern EU at limited investment costs.**
- RESULT achieves this by deploying:
  - Reservoir models and uncertainty; and integrating best in class.
  - Well technology scenarios: different well concept designs.
  - Reservoir Development Optimization.
  - Demonstration in sites operated by seasoned industry partner.
- **Goals of this study:**
  - **What is the best techno-economic solution of extracting heat given subsurface uncertainty:**
    - **What is the best drilling location?**
    - **What is the best well concept?**

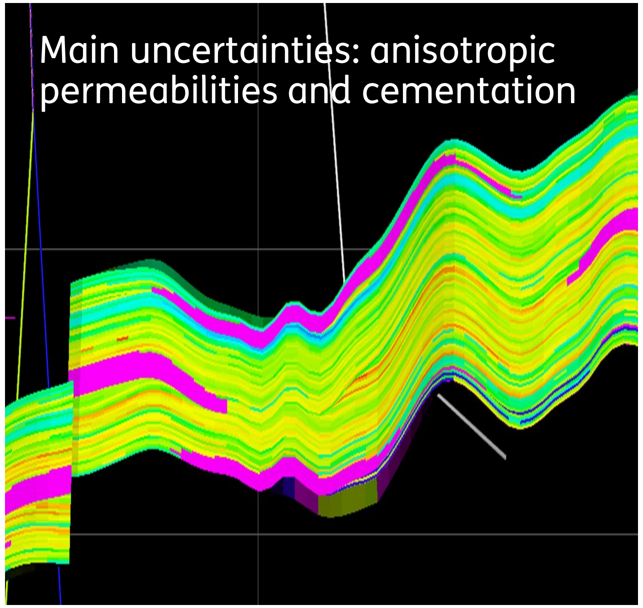
Zwolle Case Study: geological scenarios

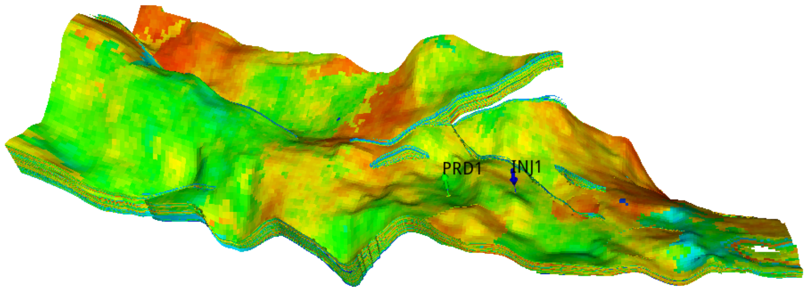
- Data collation.
- Geological interpretation & petrophysics.
- Seismic interpretation.
- Depth conversion & structural analysis.
- **Static model (facies, properties).**

Stochastic simulation

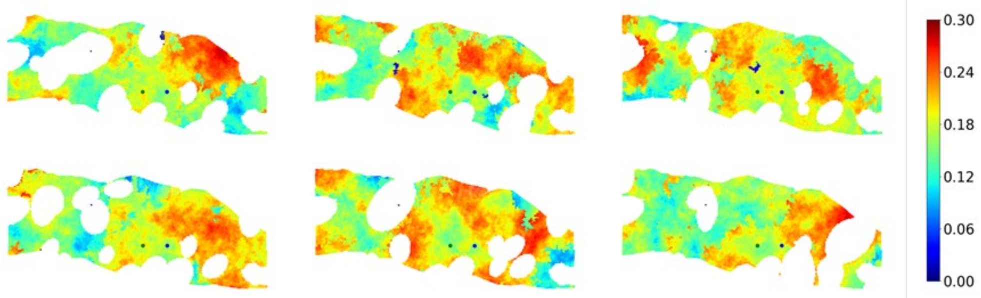
- **Multiple dynamic geological realizations.**
- 45 km² with about 950,000 active cells.
- Average depth: 2,400 m
- Thickness from 50-80 m







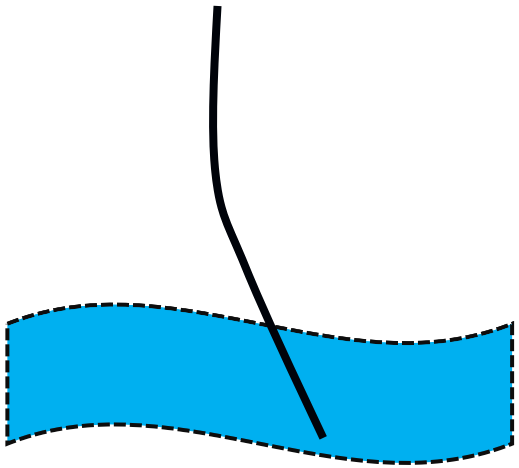
Subsurface uncertainty represented by geological models.



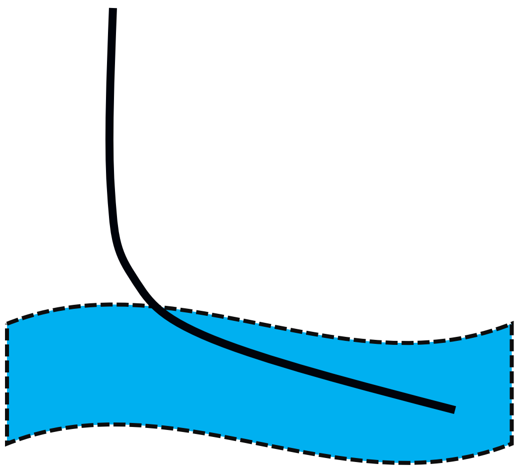
Decisions considered in this study

- **What is the best well shape?**
- **What is the best well location?**

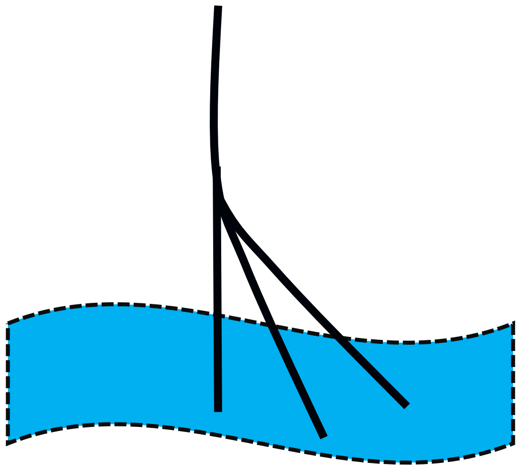
1. Slightly deviated wells (**quasi-vertical**)



2. Strongly deviated (i.e. **horizontal**) wells

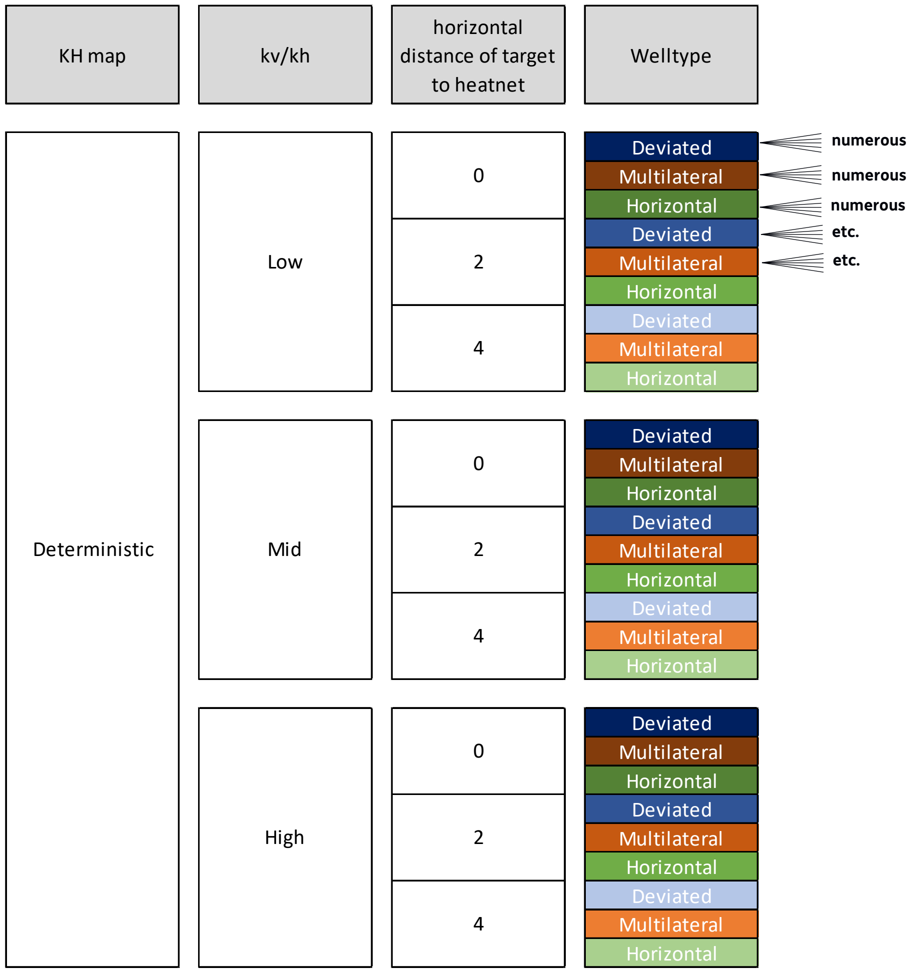


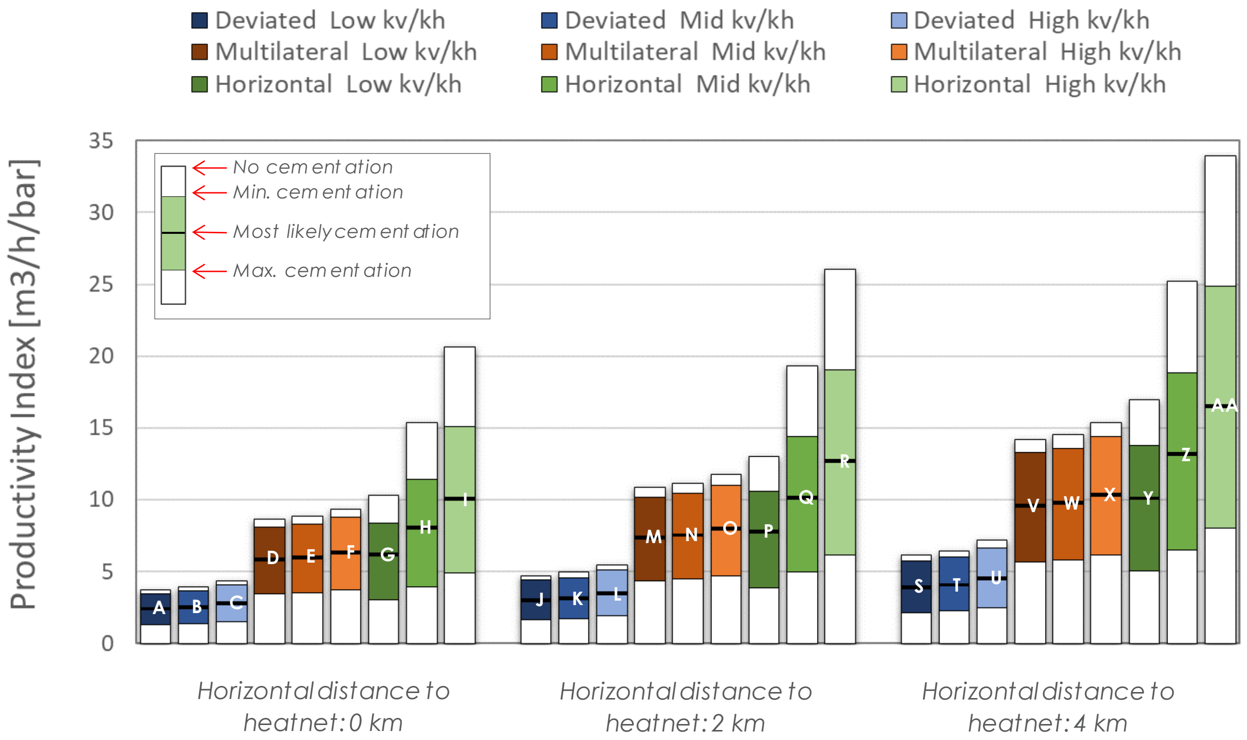
3. **Multi-lateral** wells (3 quasi-vertical branches)



Results

Sensitivity analysis: productivity index





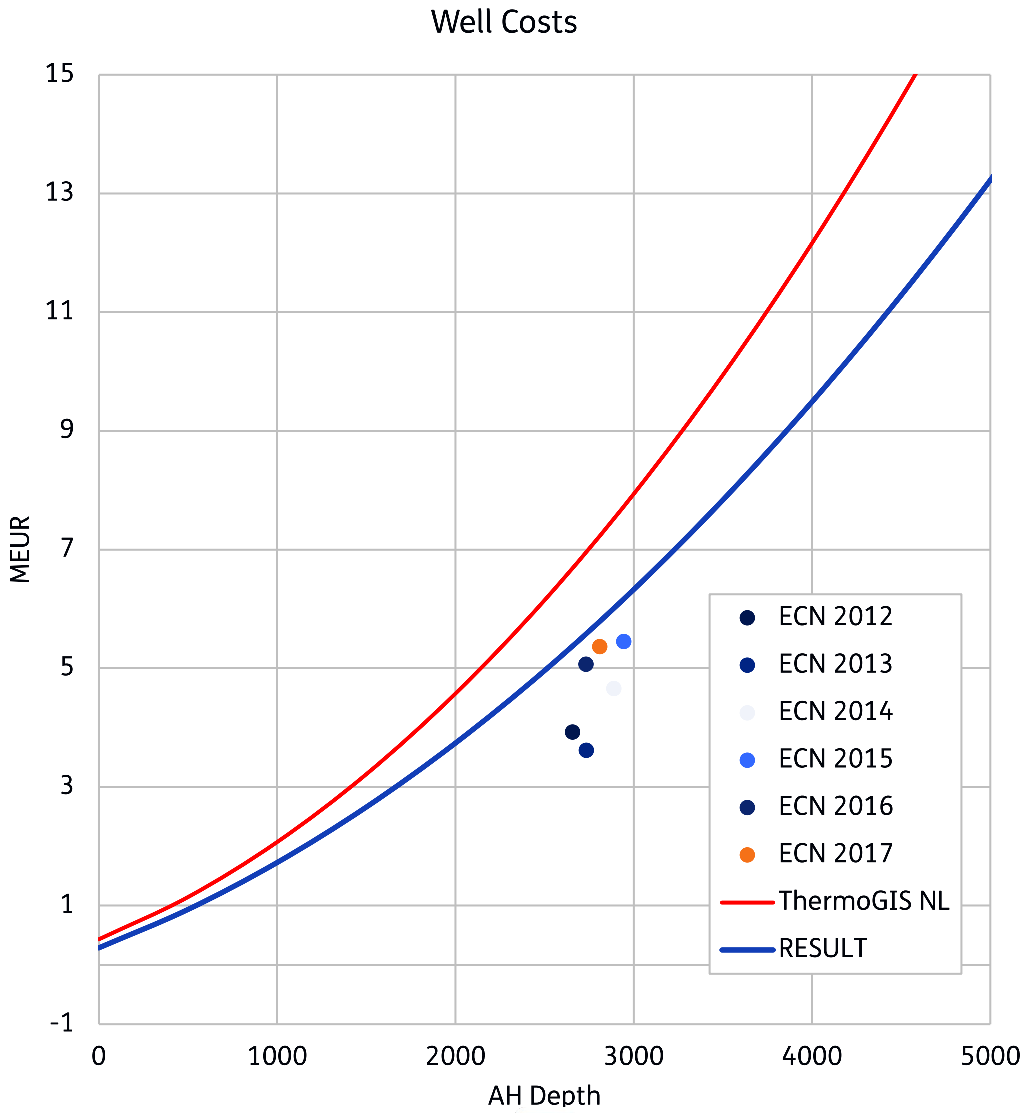
- 27 x ‘large amount’ of stochastic realizations, to determine impact of the ‘unknown’ location of cemented bodies. Based on a sufficiently large number (>100) of random realizations, a minimum-most likely-maximum distribution can be obtained
- Observation: irrespective of the uncertainties (kv/kh, distance to heatnet, well type), the relative impact of cemented bodies remains constant for each of the 27 deterministic cases.

Techno-economic model

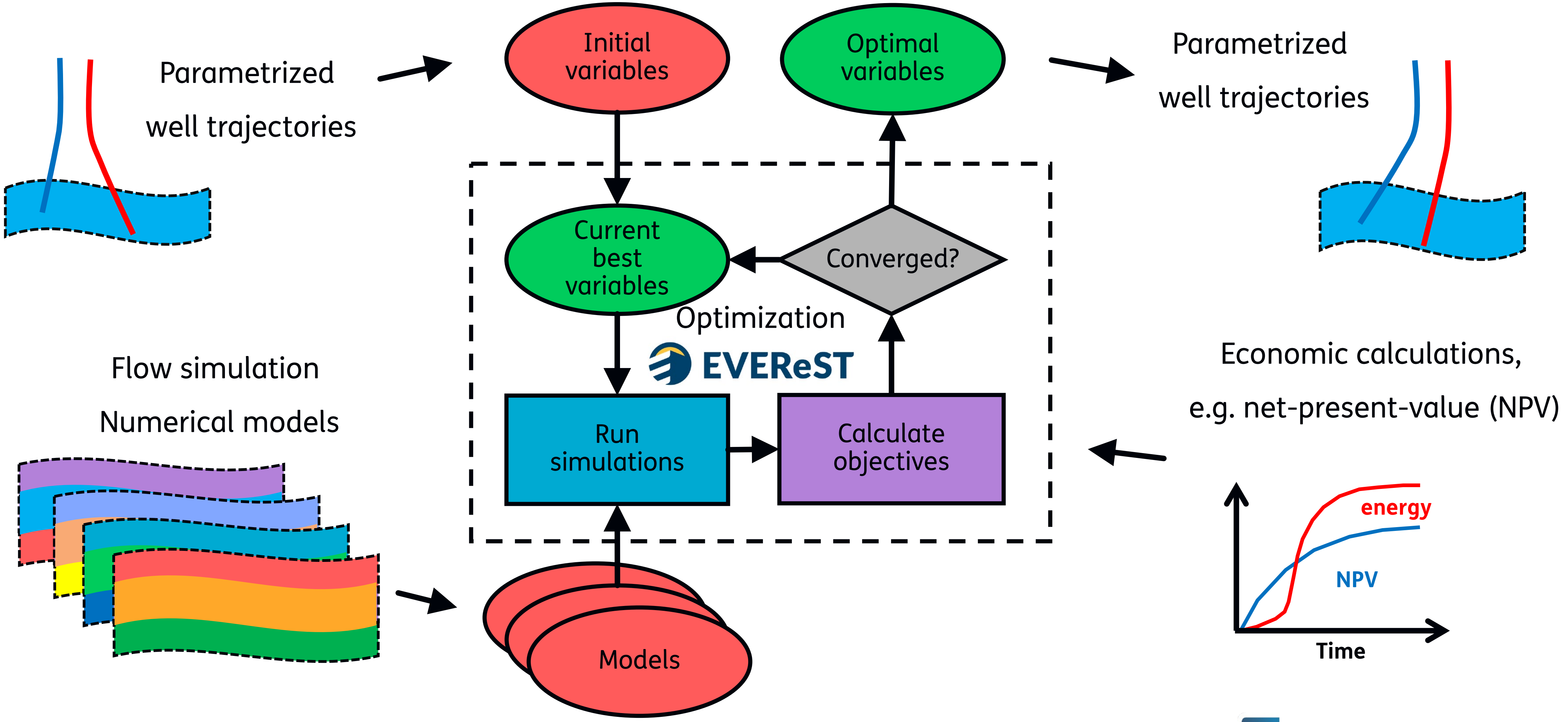
- Maximize the economics of heat production over the production life-cycle of the project (**30 years**).
- **Discounted net present value (NPV)** computed from the simulation forecasts.

Parameter
Reservoir salinity
Injection temperature
Well tubing diameters
Well tubing roughness
Economic lifetime
Load hours
Feedin period
Inflation
Equity share
Loan interest rate
Loan period
Effective discount factor
Tax rate

Parameter
Wellcost base
Wellcost linear
Well cost cubic
Well cost scale factor
Well curvature factor
Pump cost
Pump efficiency
Pump life
Surface CAPEX base
Surface CAPEX variable
CAPEX contingency
OPEX base
OPEX variable
Heat price
Electricity price

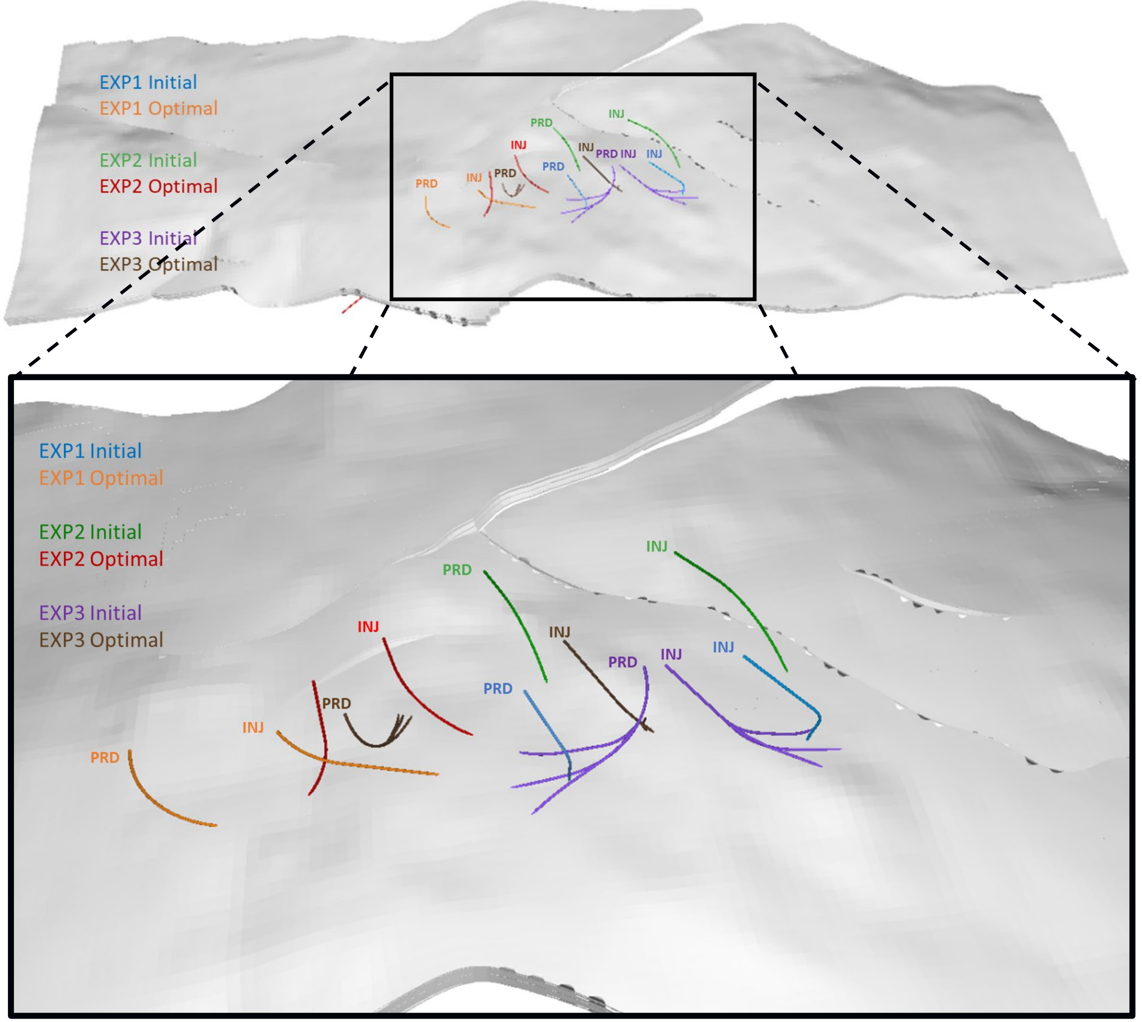


Optimization workflow



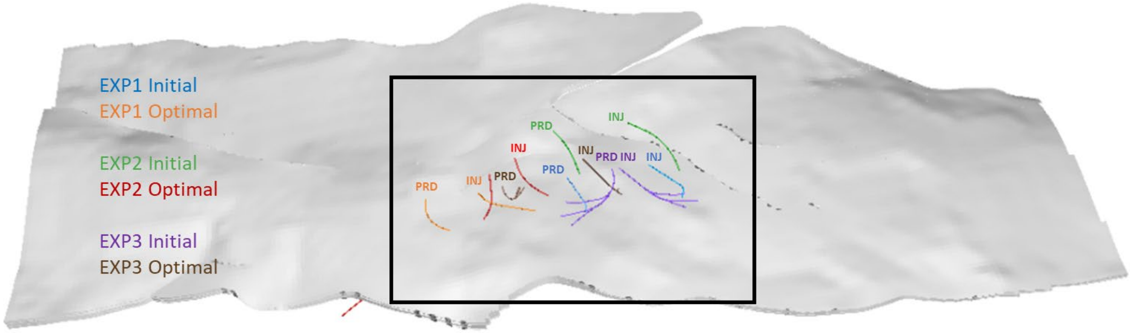
Optimization results: well locations

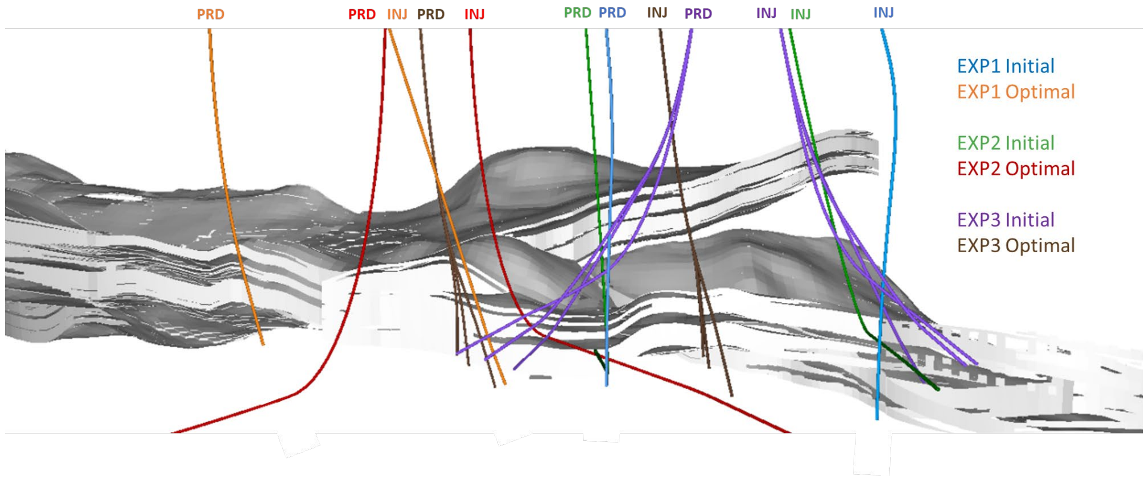
- **Three well location/trajectory optimization experiments** have been performed with different initial well concepts:
  - Experiment 1 starts with **slightly deviated wells**.
  - Experiment 2 starts with **strongly deviated wells**.
  - Experiment 3 considers **multilateral wells** with two additional leg
    - Constraint : maximum allowed inclination of **60°** for each branch.
- Similar locations and the distance between the injector and producer in the reservoir for the initial guesses of all experiments, i.e. ~1 km.
- **Included cost per length of each well**. For multilateral wells the total combined well length was considered.



Optimization results: trajectories

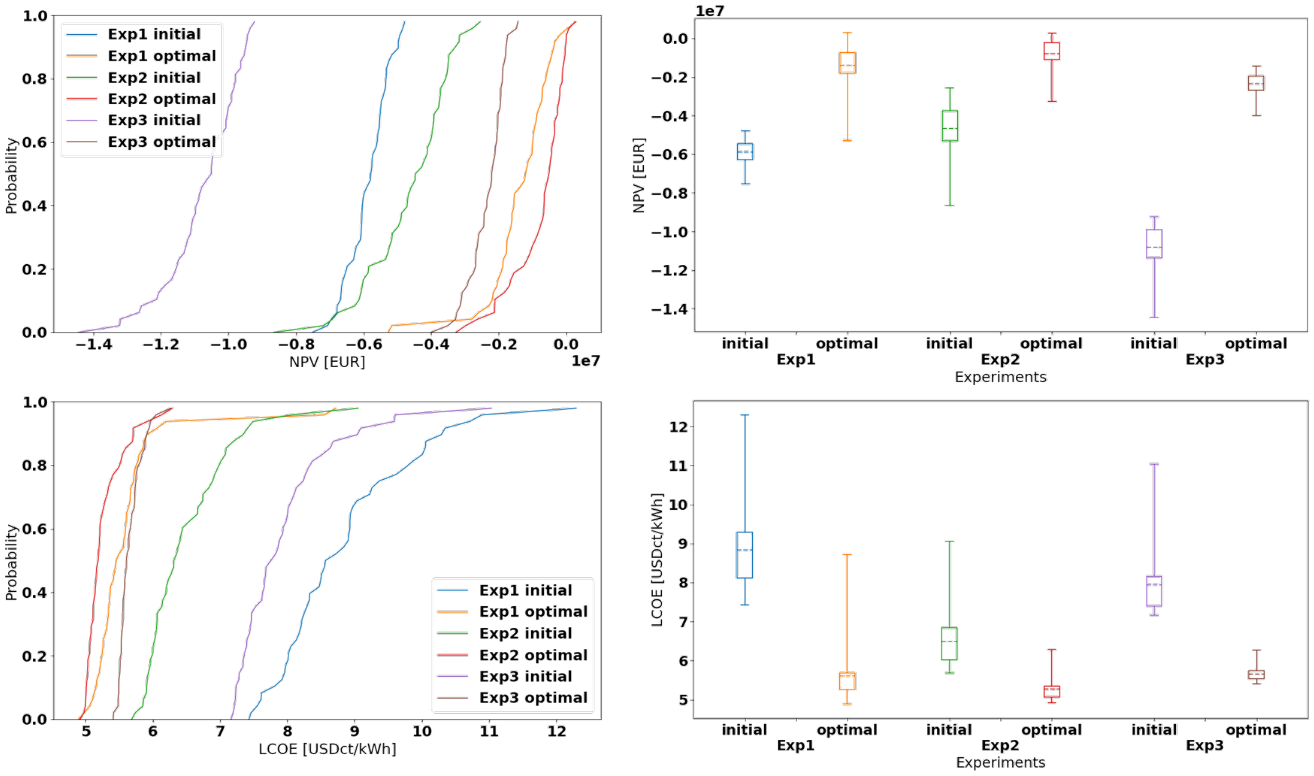
- We notice that optimal locations of the wells for all the three experiments follow a pattern by moving in the same (west) direction.
- The shapes of the optimized well trajectories differ considerably across the experiments.
  - Experiment 1
    - Trajectories for **both wells stay slightly deviated**.
  - Experiment 2
    - **Producer**'s shape becomes **slightly deviated**
    - **Injector**'s shape **remains strongly deviated** as in the initial guess in order to sustain high enough injection rate (affected by higher viscosity of cold water) to meet the production rate.
  - Experiment 3
    - **Optimal branches are closer to vertical shape** and the tie-in is deeper due to constraint on maximum inclination for each leg.





Optimization results: NPV and LCoE

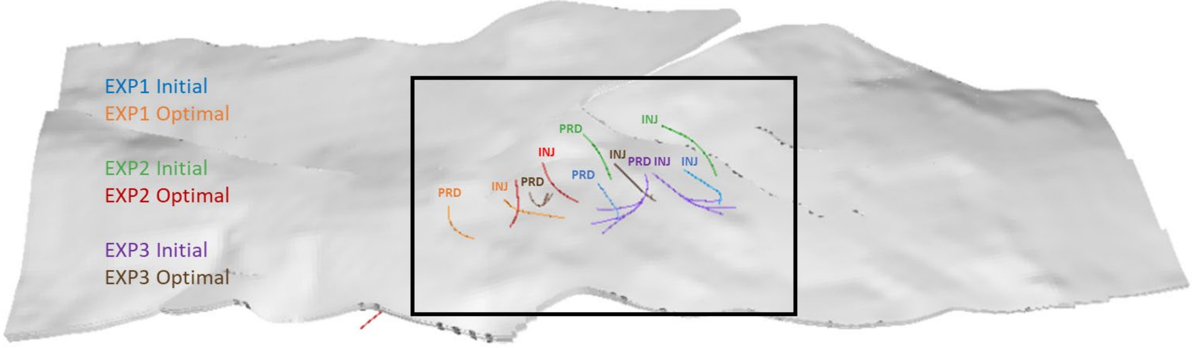
- **Higher NPV** (and lower average LCoE) on average when the optimal shape of the **injector is strongly deviated** (Experiment 2).
- **Uncertainty (values spread)** on both NPV and LCoE associated with the optimal solution for multilateral wells **(Experiment 3) is the lowest**, even though the optimization was not explicitly set up to reduce this spread.
- **Initial solutions with stronger deviated wells** resulted in improvement.
    - However, this improvement is significantly lower comparing to the improvement found by any of the optimization experiments.

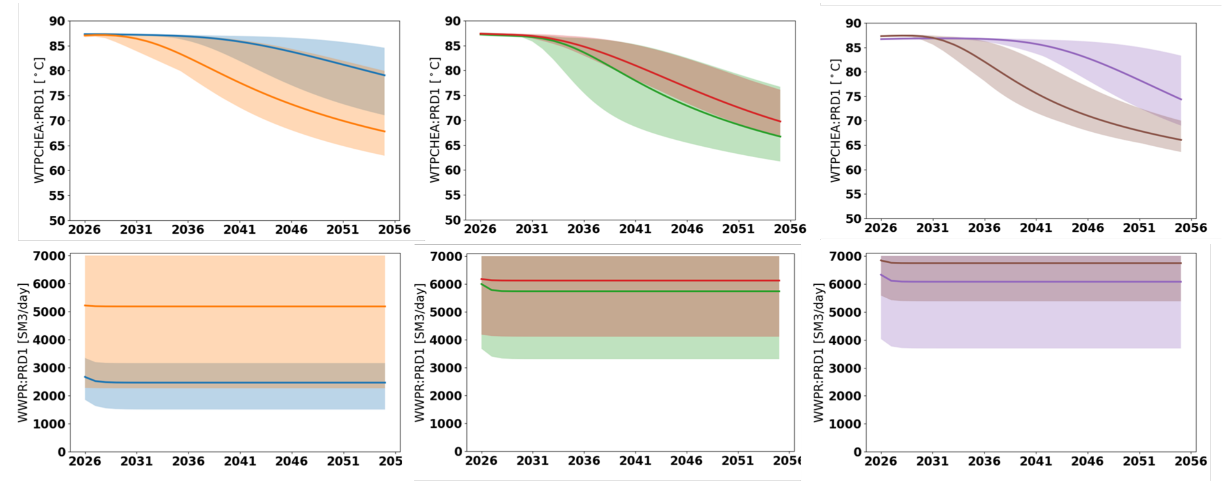


- Shape of wells is not the only factor, but the **combination of shape and location of wells** which determine the techno-economic performance.
- **For multilateral wells (Experiment 3) initial solution is the worst** in terms of economics which is due to higher drilling cost.

Optimization result: production rate and temperature

- **Experiment 1** (with slightly deviated wells) was able to **increase injectivity** mostly by finding better well locations.
  - This, however, resulted in **significantly earlier arrival of the cold water** in the producer.
- In Experiment 2, (initial guess with strongly deviated, longer wells):
  - We start with better injectivity.
  - However also with **earlier cold water breakthrough in the producer**.
- In Experiment 2, by simultaneously determining optimal well locations (including well distance) and adjusting well trajectory shapes optimization was able to improve upon both aspects:
  - **Delaying the arrival of the cold water**.
  - **Increasing injection/production well rates.**
- For Experiment 3 (multilateral wells):
  - **Increasing injectivity comes at the cost of earlier cold water breakthrough.**





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Conclusions and discussion

- The three well concepts (subvertical, sub-horizontal, and multi-lateral have been compared for Zwolle case study in the context of well location and trajectory optimization.
- For each well concept, optimization was able to significantly improve techno-economic performance of the doublet system in Zwolle site by changing locations and trajectories of both wells.
- Resulting improvement of economic performance from prior LCOE from 7-9 €cts/kWh to ca. 5€cts/kWh.
- Optimal well locations are significantly different than the initial guess and they reveal a trend in location of optimal development area. This suggests that it is not only the shape of wells, but the combination of shape and location of wells which determine the techno-economic performance of the doublet.
- Sub-horizontal and multilateral well concepts are good candidates outperforming the sub-vertical choice.
- Sub-horizontal scenario resulted in higher NPV on average across the geological realizations, however multilateral solution delivers lowest economic risk (reduced spread in NPV and LCOE).

Thank you

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