RESULT: Enhancing REServoirs in Urban developmenT

Jan-Diederik van Wees

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ETIP Geothermal INNOVATION DAYS

European Technology & Innovation Platform on Geothermal

www.etip-dg.eu

3-4 DEC 2025 STRASBOURG

The RESULT project (Enhancing REServoirs in Urban deveLopmenT: smart wells and reservoir development) has been subsidized through the ERANET Cofund GEOTHERMICA (EC Project no. 731117), supported by the Ministry of Economic Affairs and Climate Policy (the Netherlands), Rannis (Iceland) and GSI (Ireland).

RESULT project

- Enhancing REServoirs in Urban deveLopmenT

- Confirmed heat demand + matching adjacent, prolific geothermal reservoir = successful geothermal projects
  - However, potential poor reservoir quality at locations of existing heat demand may result in poor business case
  - Advanced drilling solutions to improve the productivity of geothermal system do exist
- Main objective: investigate innovative approaches to guide well concept selection and engineering design of geothermal wells
  - Use of state-of-the-art modelling and optimization frameworks
  - Demonstration of scientific methodology in various case studies (Netherlands, Ireland, Iceland)
  - Practical drilling demonstration of innovative well designs

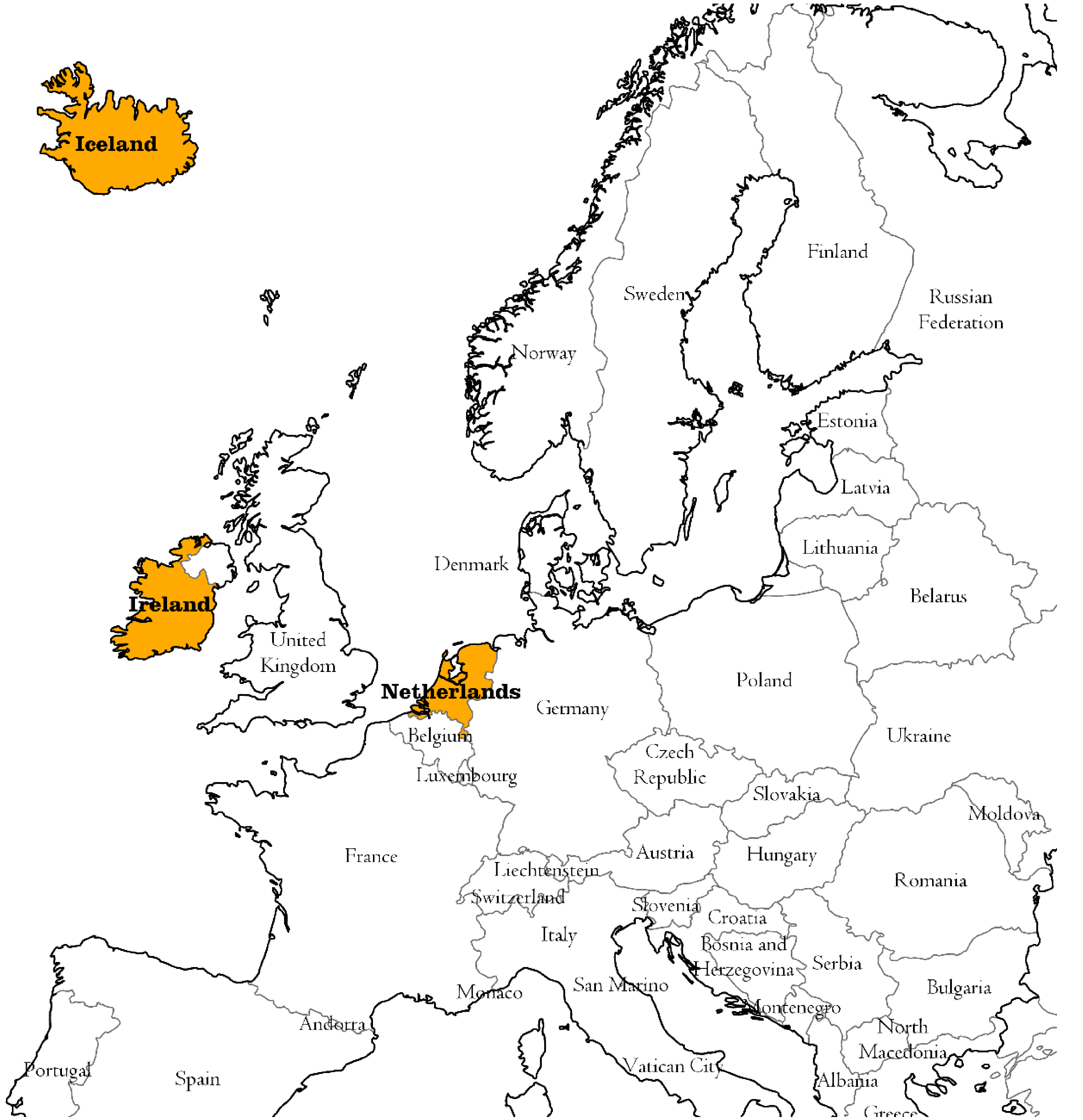
RESULT

Enhancing REServoirs in Urban deveLopmenT: smart wells and reservoir development
Geothermica Project Number 200317

https://www.result-geothermica.eu/home.html

Consortium

Partner	Country/Region
TNO	The Netherlands
EBN	The Netherlands
ENGIE	The Netherlands
Huisman	The Netherlands
Aardwarmtebron Zwolle	The Netherlands
GDG	Ireland
ISOR	Iceland
Reykjavik Energy	Iceland



RESULT: SMART WELLS and RESERVOIR DEVELOPMENT

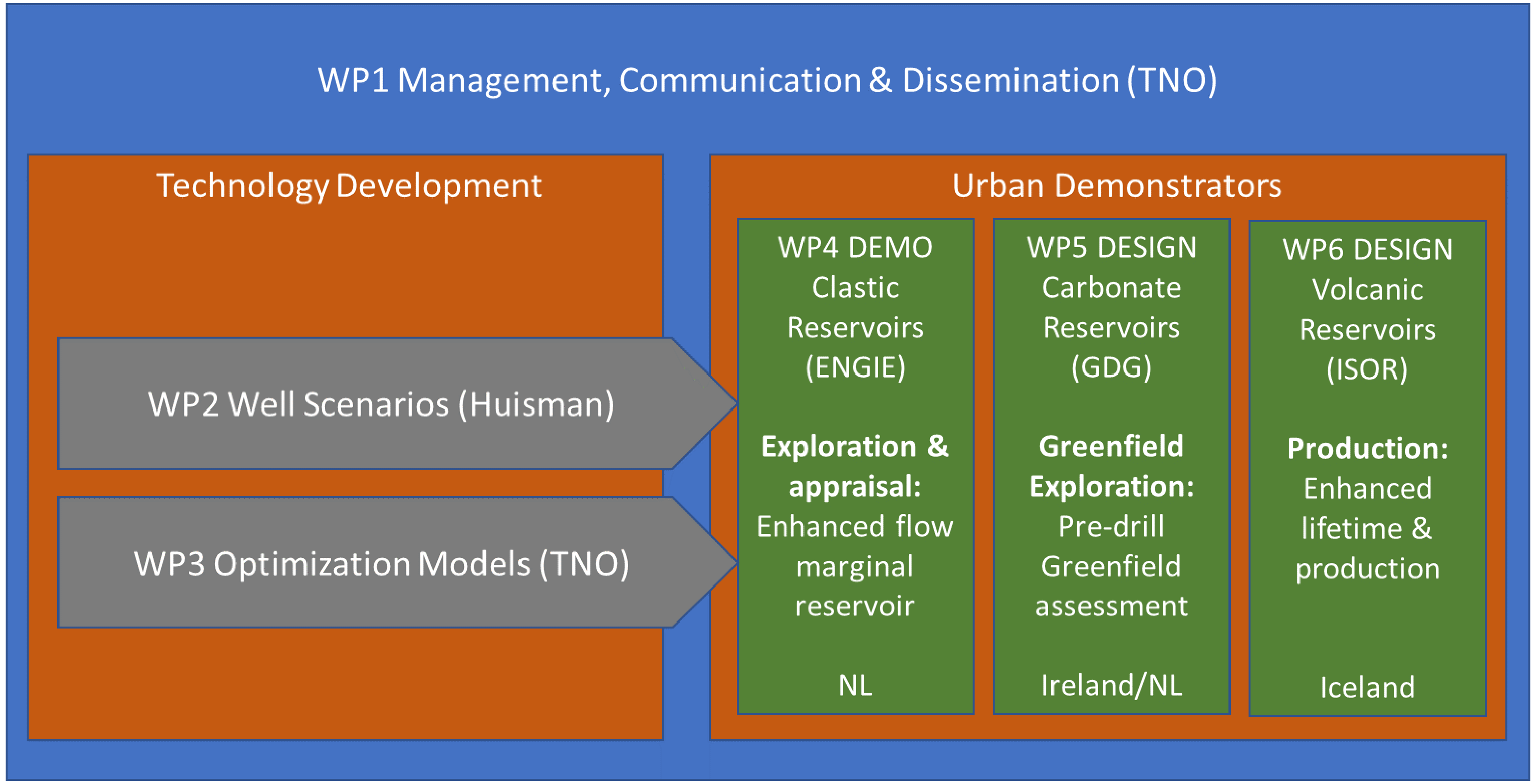
Well scenarios
- Well scenarios - vertical, horizontal, triplet, RJD, multilaterals: 30-100% gain in flow performance

Concept select
- Well Concept select: techno-economic trade-offs for single reservoir model

optimization
- Optimization under full reservoir uncertainty – EVEREST – 10-20% extra gain in performance

VoI
- Drill and Learn, >5% extra gain in performance

Work Packages & dependencies



WP-leads

- WP1: Jens Wollenweber (TNO)
- WP2: Korneel v/d Meer (Huisman)
- WP3: Jan Diederik van Wees (TNO)
- WP4: Edwin Slop (Huisman)
- WP5: James McAteer (GDG)
- WP6: Helga Tulinius (ISOR)

Project Duration:

- 2020.09.01-2025.08.31

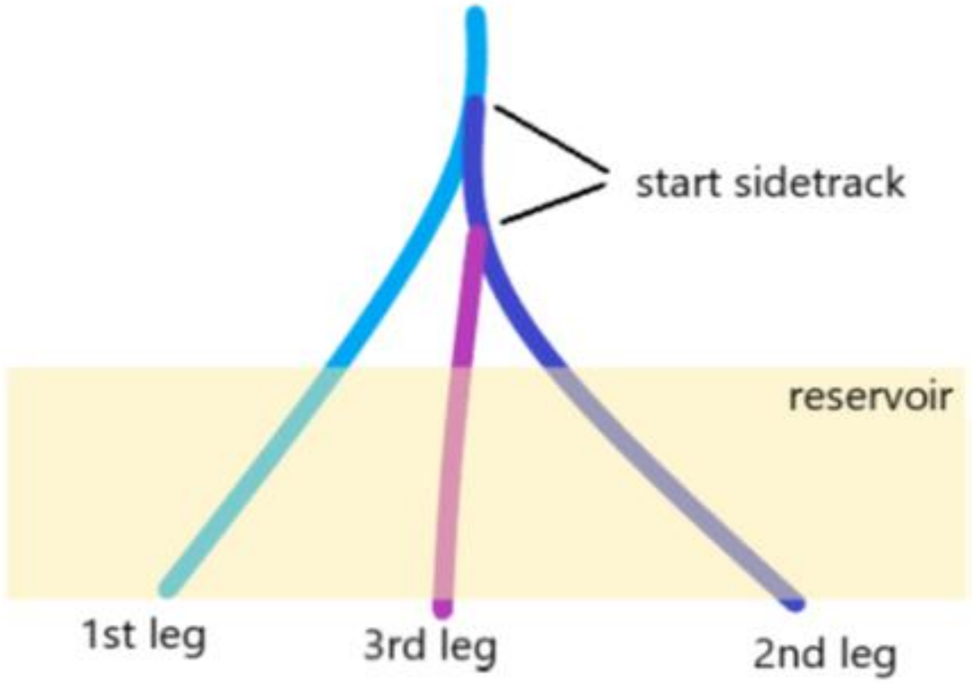
WP2: Well Scenarios

Multilateral Well

Preliminary results. Concepts might change and values will change over the course of the project.

Output (P50)	Single Well	Multilateral Well (3 laterals)		
Pump Power[1]	142	281		kW
Geothermal Power[1]	2.47	5.25		MW
COP[1]	17.2	18.4		kW/kW
CAPEX	100	210	150	%
		Conventional drilling	***ECI+RSS drilling***	

Huisman

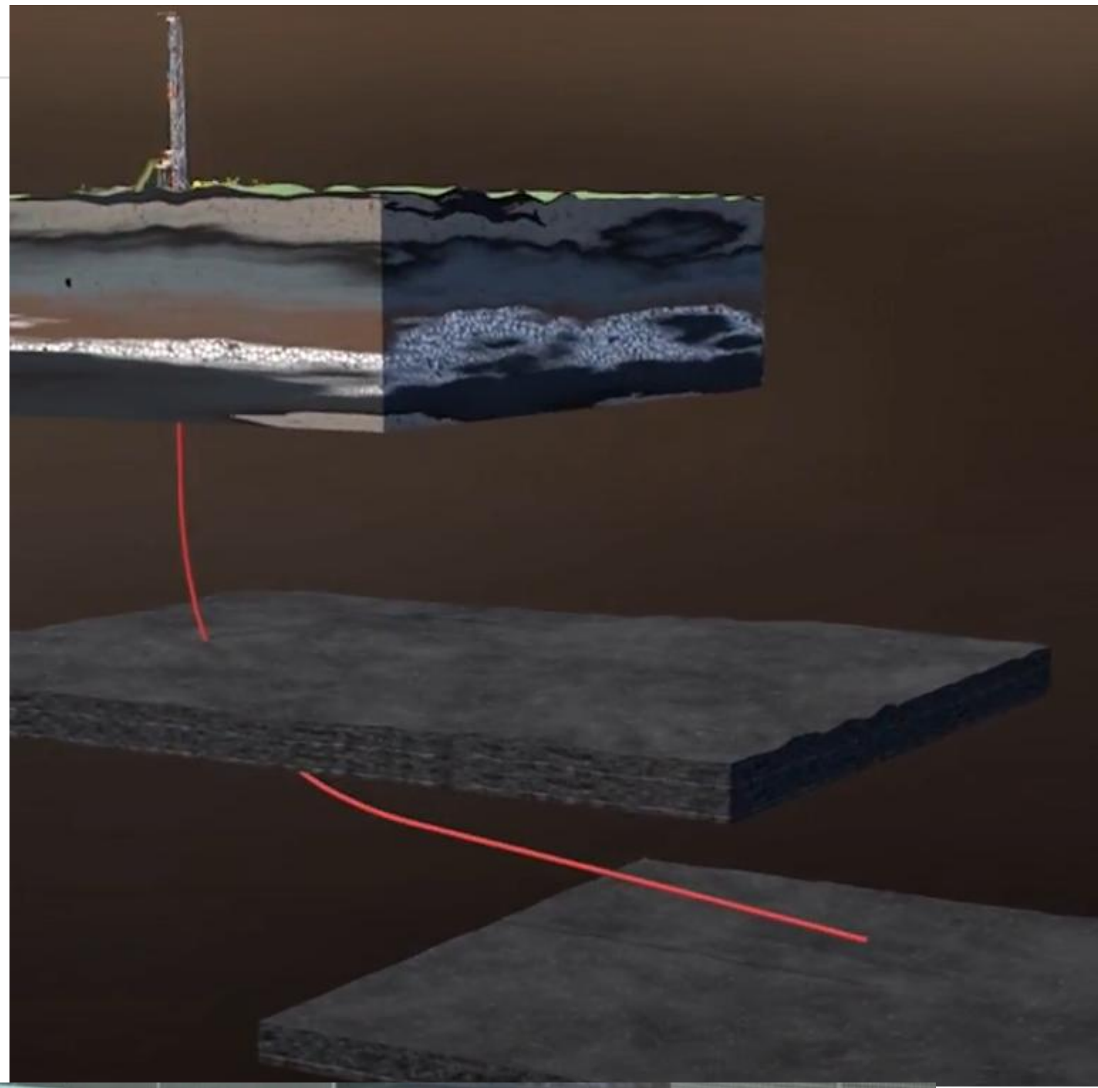


Conclusions

- Multilateral completions are a proven technology within the Oil & Gas industry
- Geothermal power output increases significantly when applying multilaterals
- The Coefficient of Performance (COP) is similar to a single well application
- Due to the increased construction complexity of a multilateral well, the Capital Expenditure (CAPEX) is higher.
- CAPEX can be addressed by using innovative drilling tools.

DRILLING TOOLS

Directional Drilling (SYNCRODRILL RSS)



RSS - Technology

- Rotary Steerable System (ECI + RSS or Syncrodrill)
- Mechanical, automated, Closed Loop, Point the bit RSS

Value proposition

- Cost effective directional drilling
- Open hole side track capabilities
- Simple mechanical design - low cost
  - Target = RSS functionality against mud motor + bent sub cost

Conventional RSS

Syncrodrill

Huisman

OPTIMIZATION CONTEXT

- Geothermal field development

  - Every geothermal project is **unique**, both from **subsurface** and **surface infrastructure** perspectives
  - Wells are **only drilled once**. There is generally **no second chance** to develop a geothermal project, at least not **without additional costs**
  - **Narrow margins** for project viability: **marginal reservoirs** in areas of confirmed heat demand put **pressure on business case**
  - All above point to the **need of optimizing geothermal wells** and field development strategies

Key ingredients

Computer-assisted decision support workflow

- EVEREST™ optimization framework
  - Flexible to be applied in different contexts
  - Robust in order to be reliable in real-life cases
  - Open-source in order to be accessible and transparent
- Techno-economic performance
  - OPM-Flow: high-fidelity 3D reservoir simulator supporting thermal effects
  - PyThermoNomics: dedicated economic calculation for geothermal projects
- Honoring constraints
  - Drilling constraints
  - Production constraints
  - Geomechanical constraints
- Accounting for uncertainties

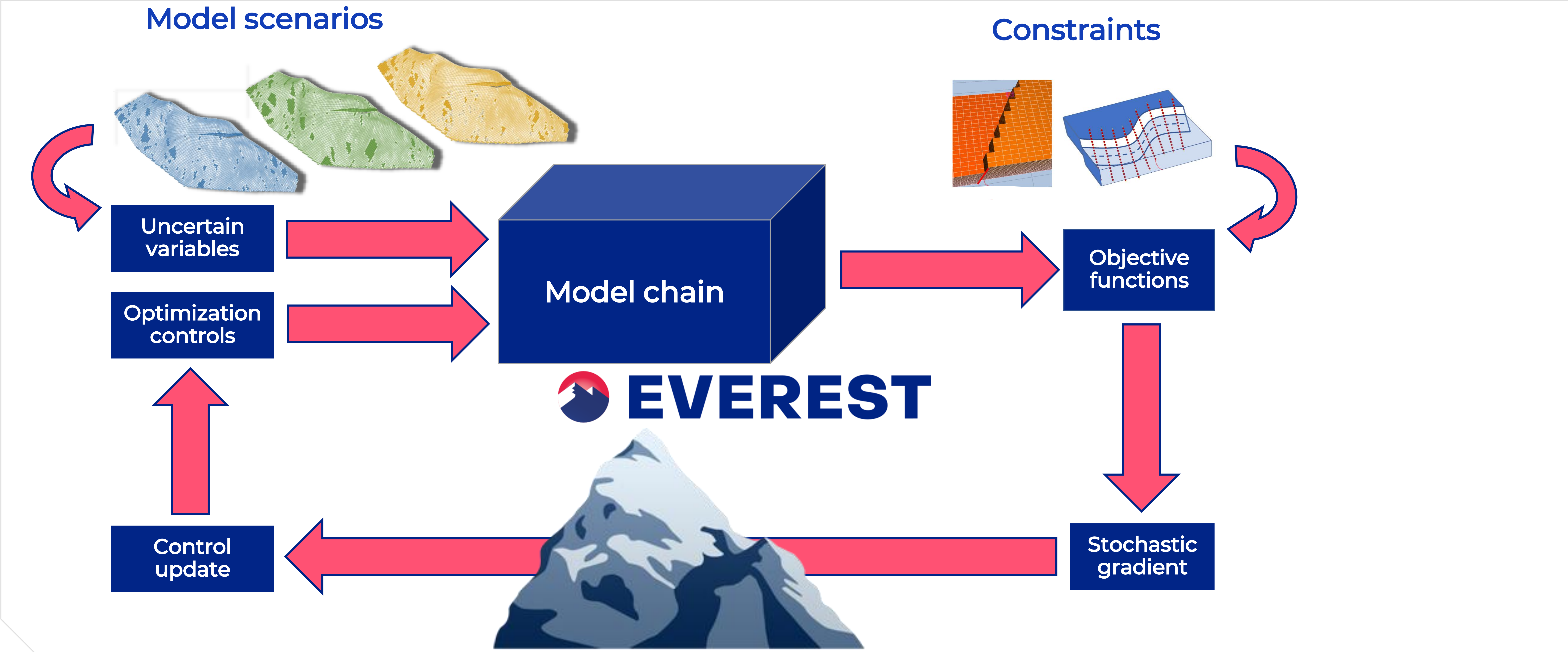
EVEREST
transforming uncertainty into opportunity
https://www.everest.tools/

OPM
OPEN POROUS MEDIA
https://opm-project.org/

PyThermoNomics
https://github.com/TNO/pythermonomics

EVEREST technology

- Model-based optimization framework



RESULT optimization • Well trajectory workflow

RESULT D1.6

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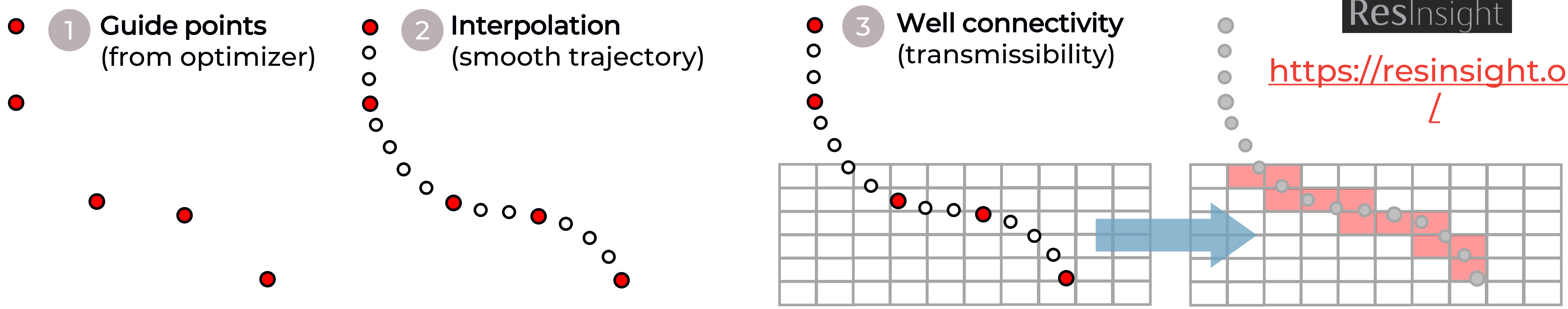
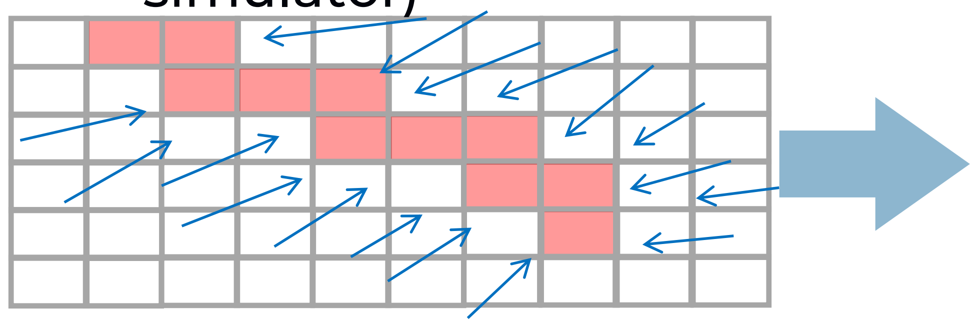


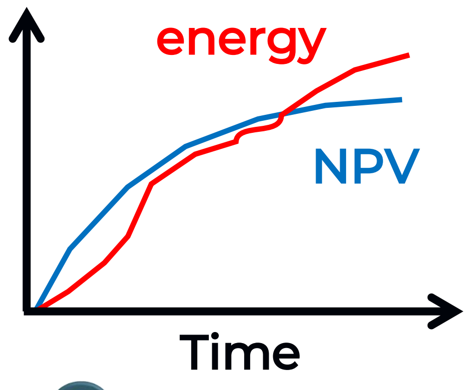
ResInsight

https://resinsight.org/

4 **Production forecast**
(from reservoir simulator)



5 **Objectives**
(energy, economics)



Well trajectories are grid-independent and need to be translated into trajectories for reservoir simulator, i.e. into grid well cells indices and connection factors

OPM OPEN POROUS MEDIA

https://opm-project.org/

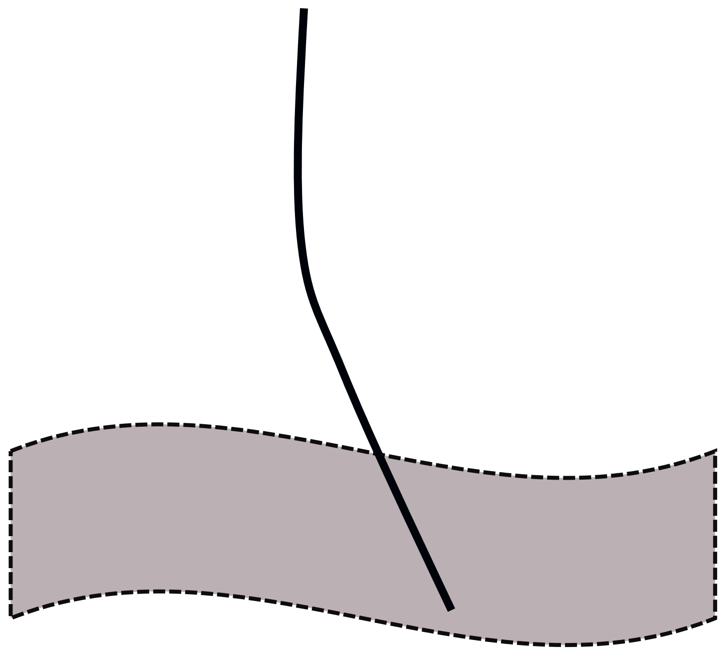
PyThermoNomics

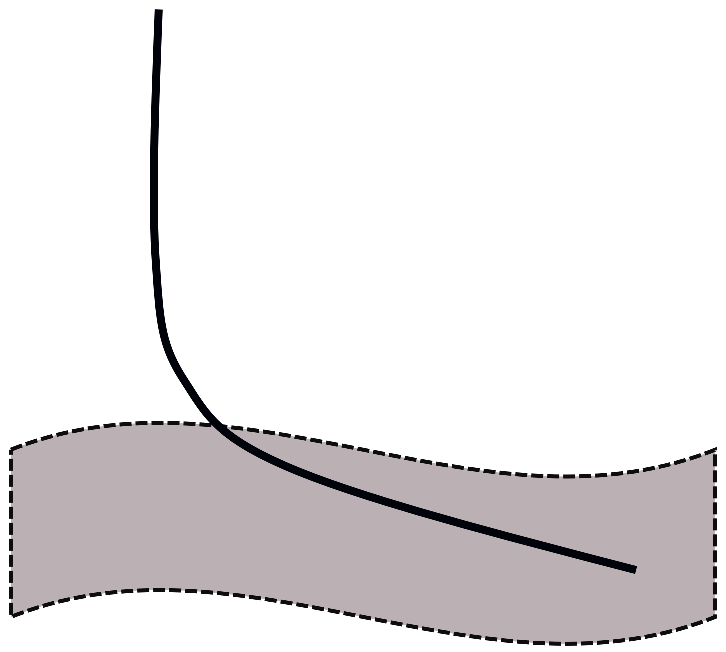
https://github.com/TNO/pythermonomics

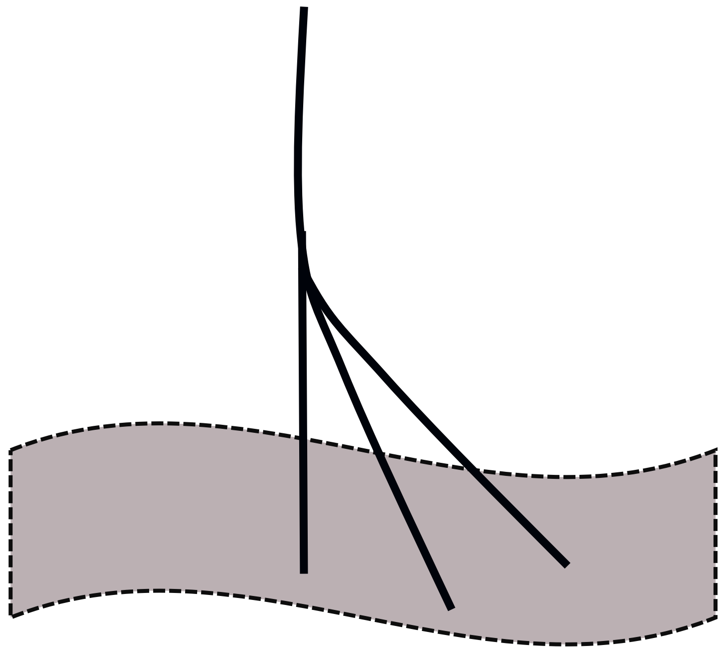
RESULT optimization • Assisting in well concept selection

- Numerical optimization approach is used to support the selection of the well concept for the Zwolle site by enabling the comparison of considered well concept designs
- Well trajectory optimization functionality from EVEReST allows for simultaneous optimization of well locations and well shapes
- 3 optimization experiments have been performed with different initial assumptions (and inclination constraints) regarding the shape of the wells, namely:

1. Slightly deviated wells (i.e., quasi-vertical)
2. Strongly deviated wells (i.e., sub-horizontal)
3. Multi-lateral wells (3 quasi-vertical branches)

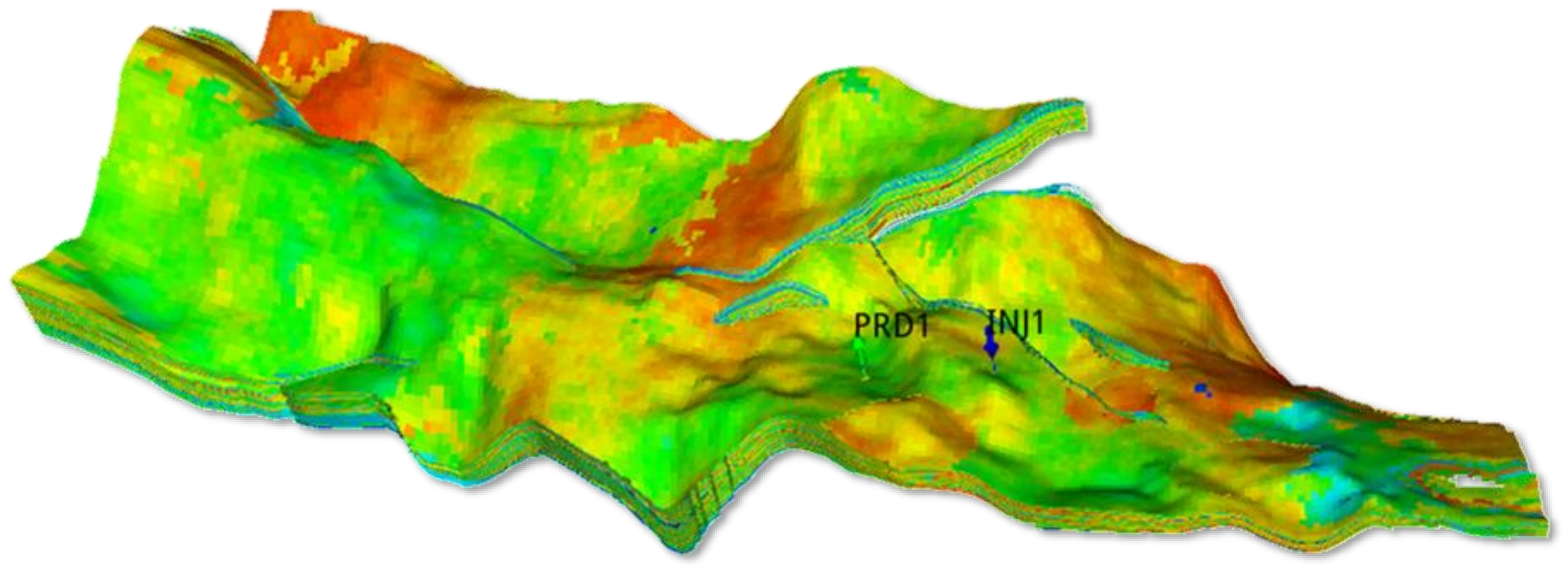


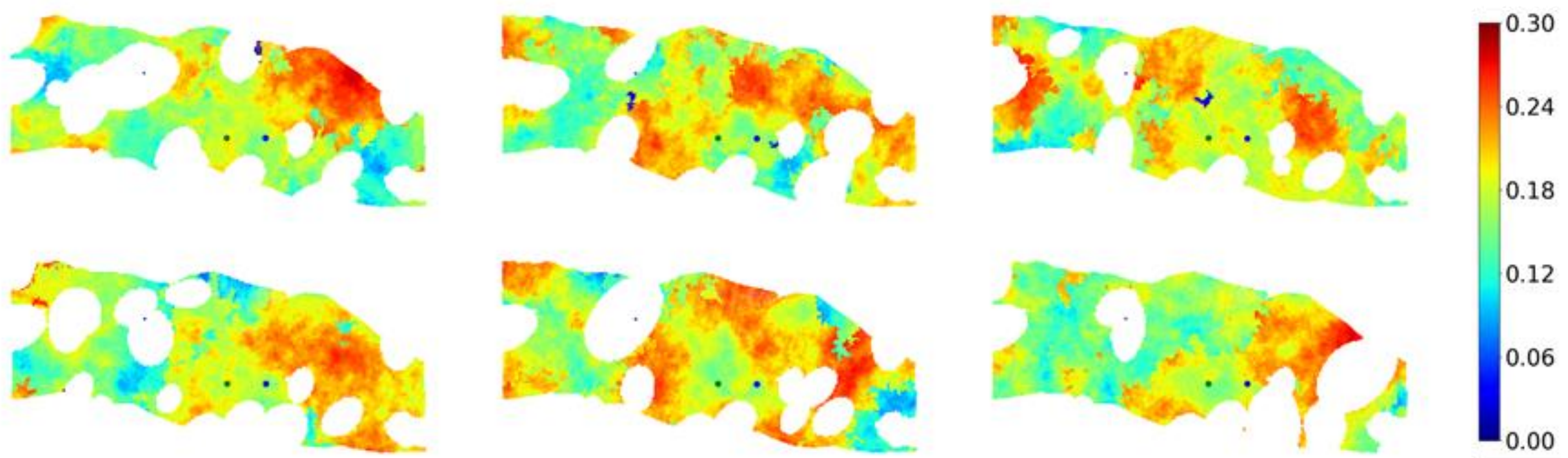




RESULT • Zwolle case study: reservoir model

- The numerical model is a representation of reservoir at the Rotliegend formation
- The geological static model was generated by EBN based on geological knowledge
- Best-guess scenario concerning the cementation assumptions was used to create ensemble of 100 realizations
- Spatially heterogenous model with different static properties (i.e., porosity and permeability fields) to reflect the inherent geological uncertainties
- The model specifics:
  - Grid with 219 × 101 × 169 grid cells
  - Area of approximately 45 km² (= 11 km × 4 km)
  - Average depth: 2,400 m
  - Thickness from 50-80 m
  - Total of about 950,000 active cells (which varies slightly per model realization)





RESULT • Zwolle case study: improved well trajectories

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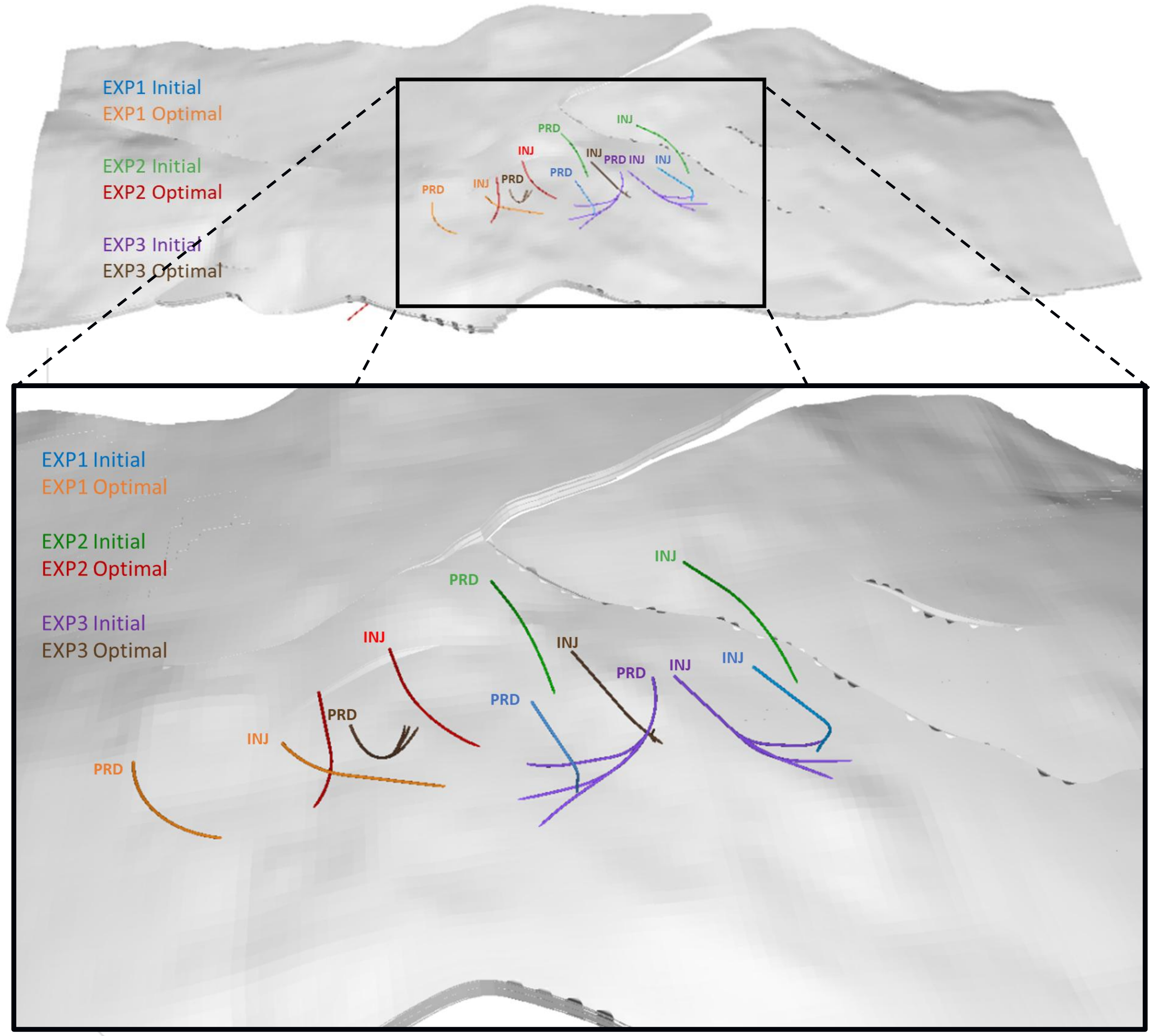
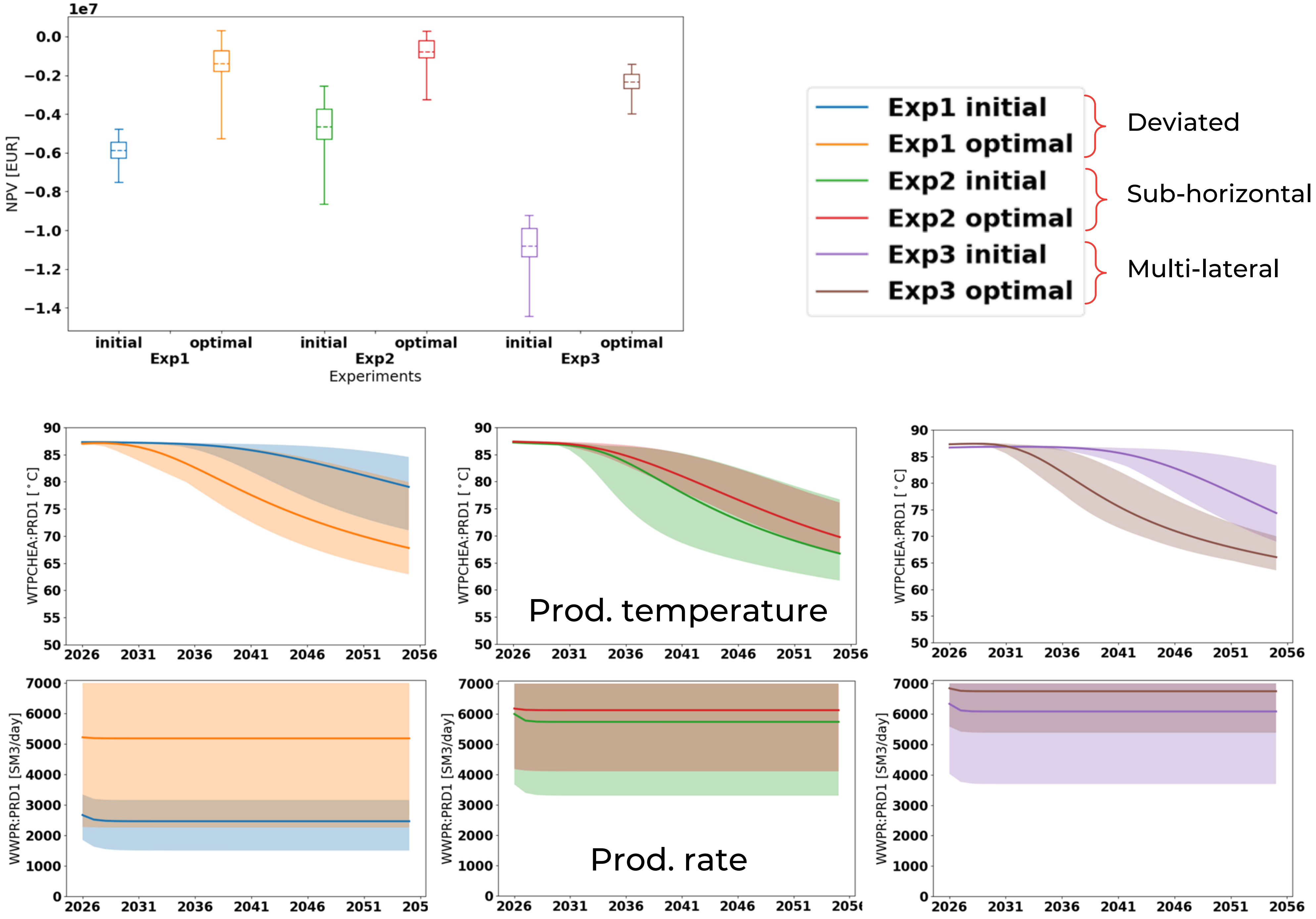
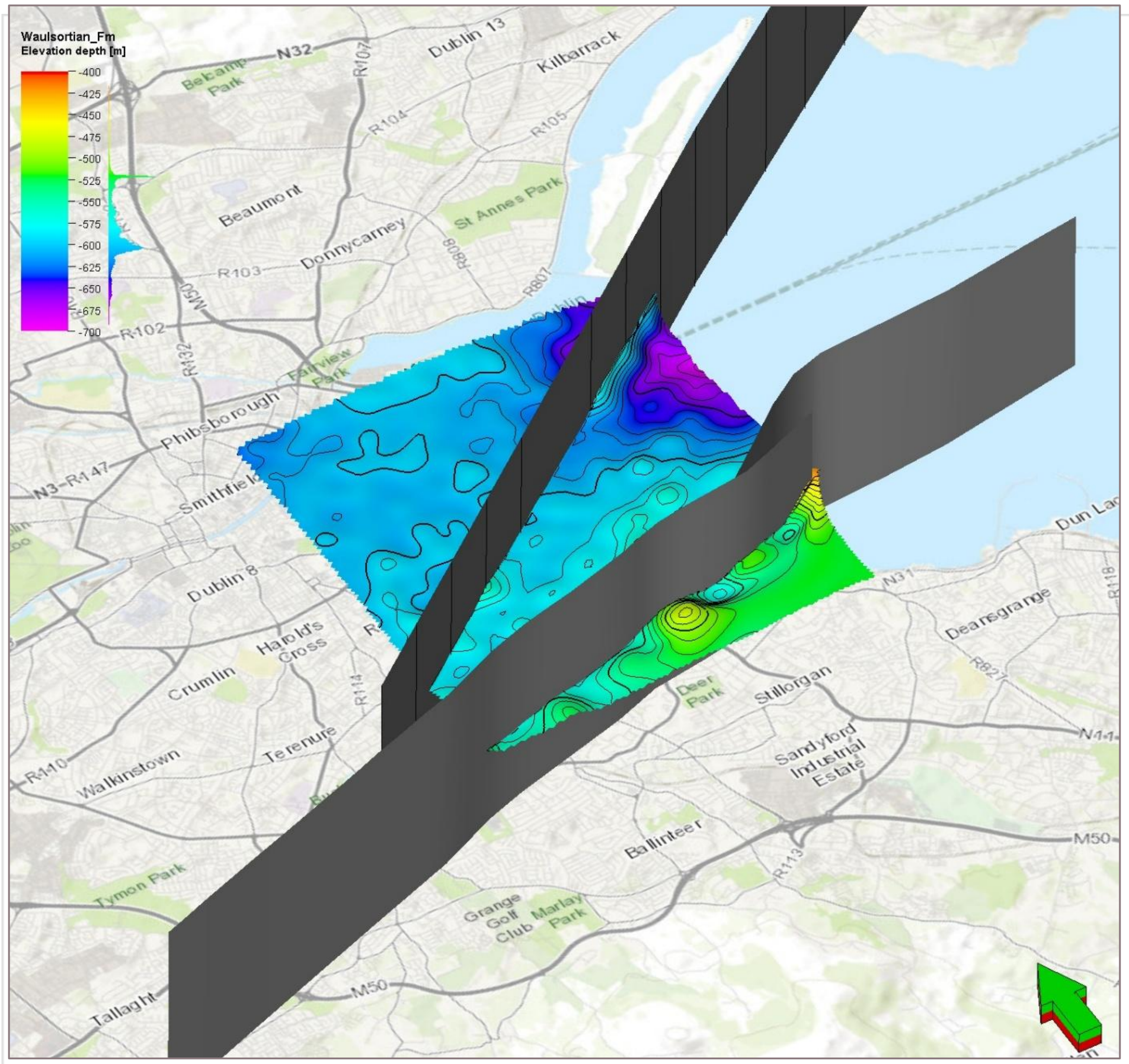
- For each well concept, optimization was able to significantly improve techno-economic performance of the doublet system by changing locations and trajectories of both wells
- Optimization helps find the fine balance between flow rates, cold water breakthrough and costs

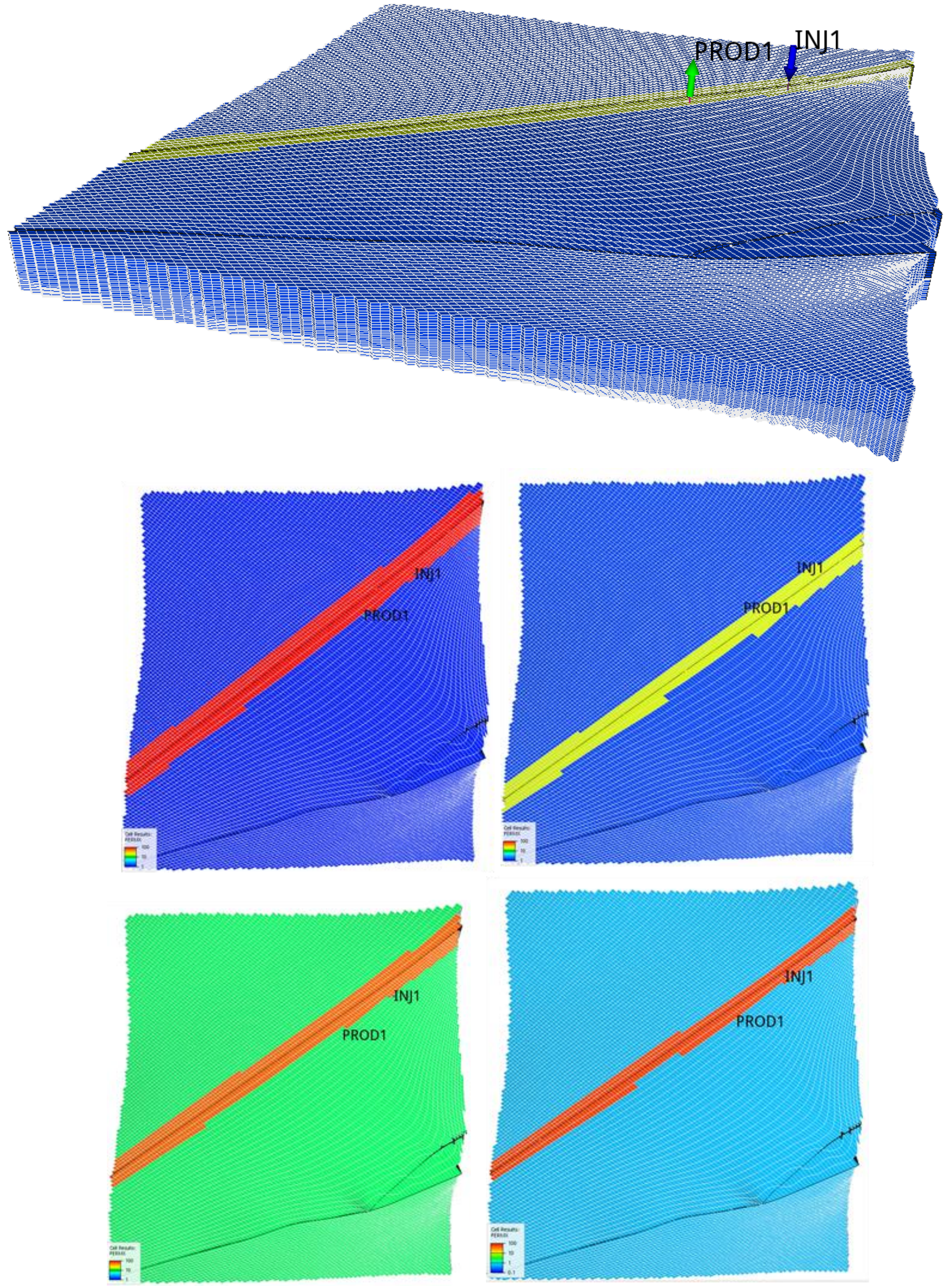




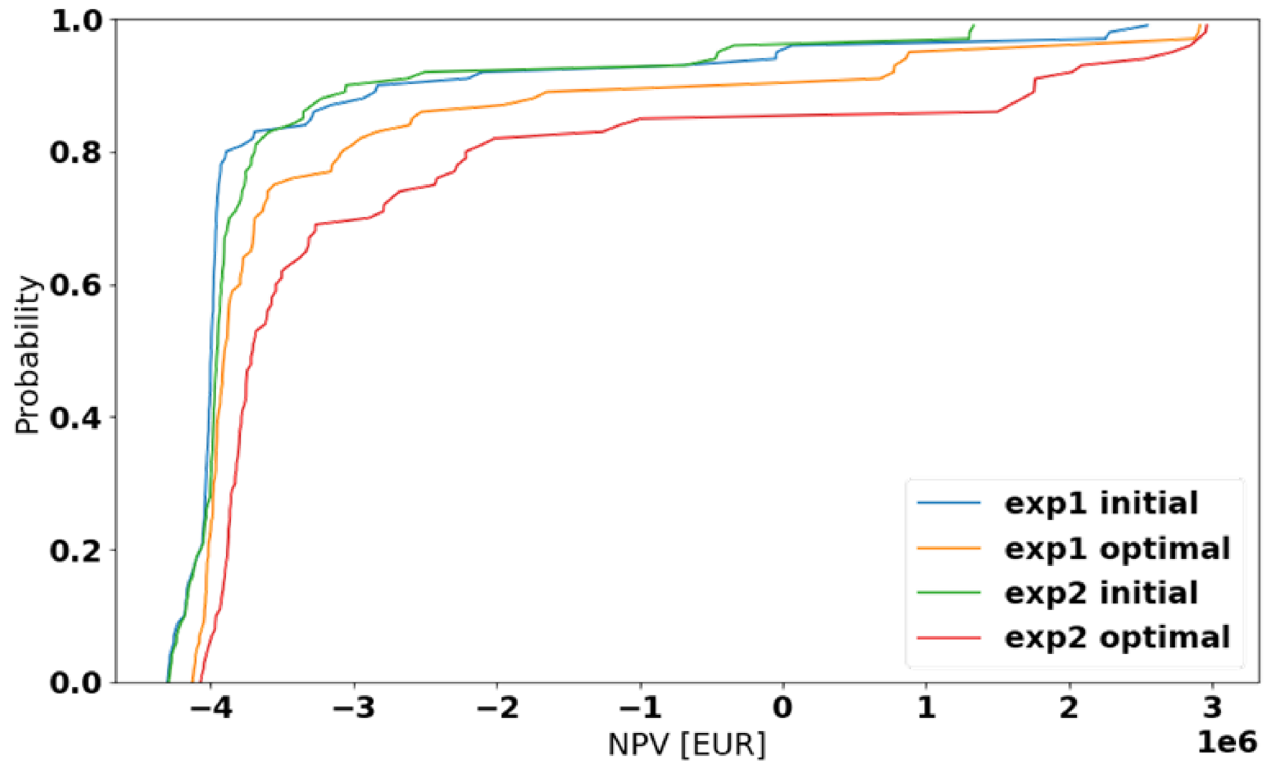
RESULT • Dublin design case study

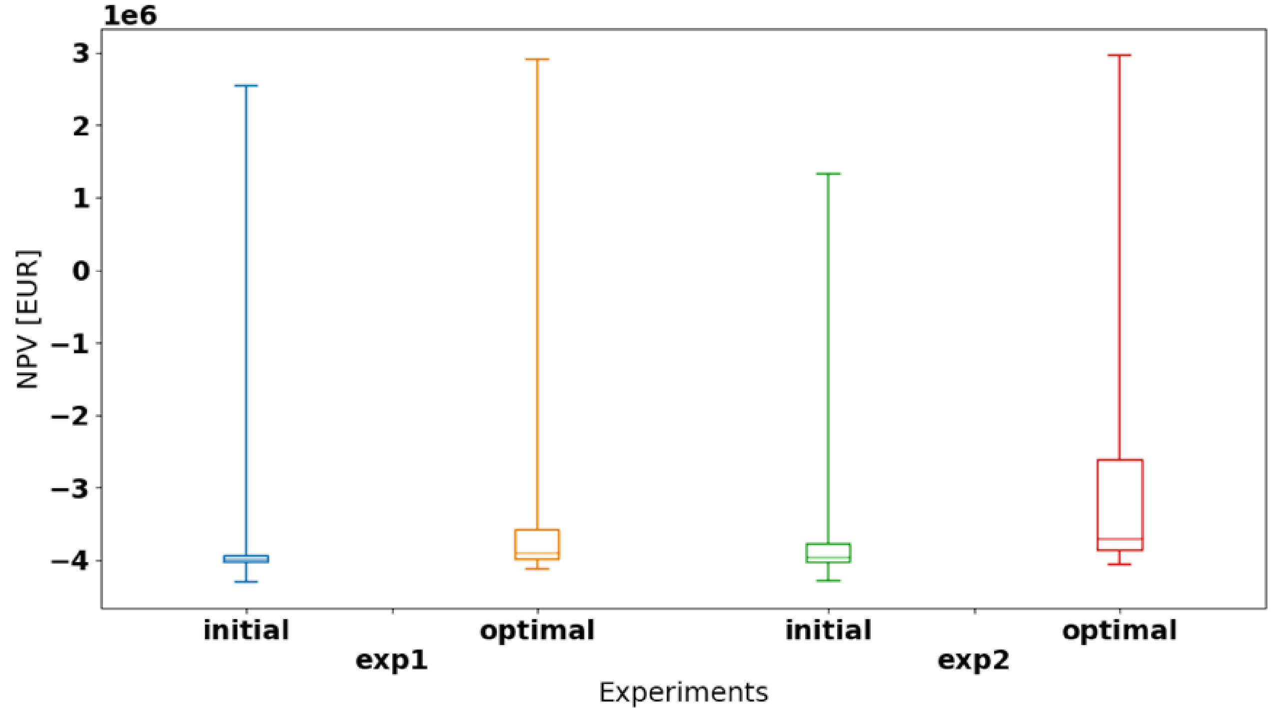


Top limestone formation in Dublin area
and major fault zones

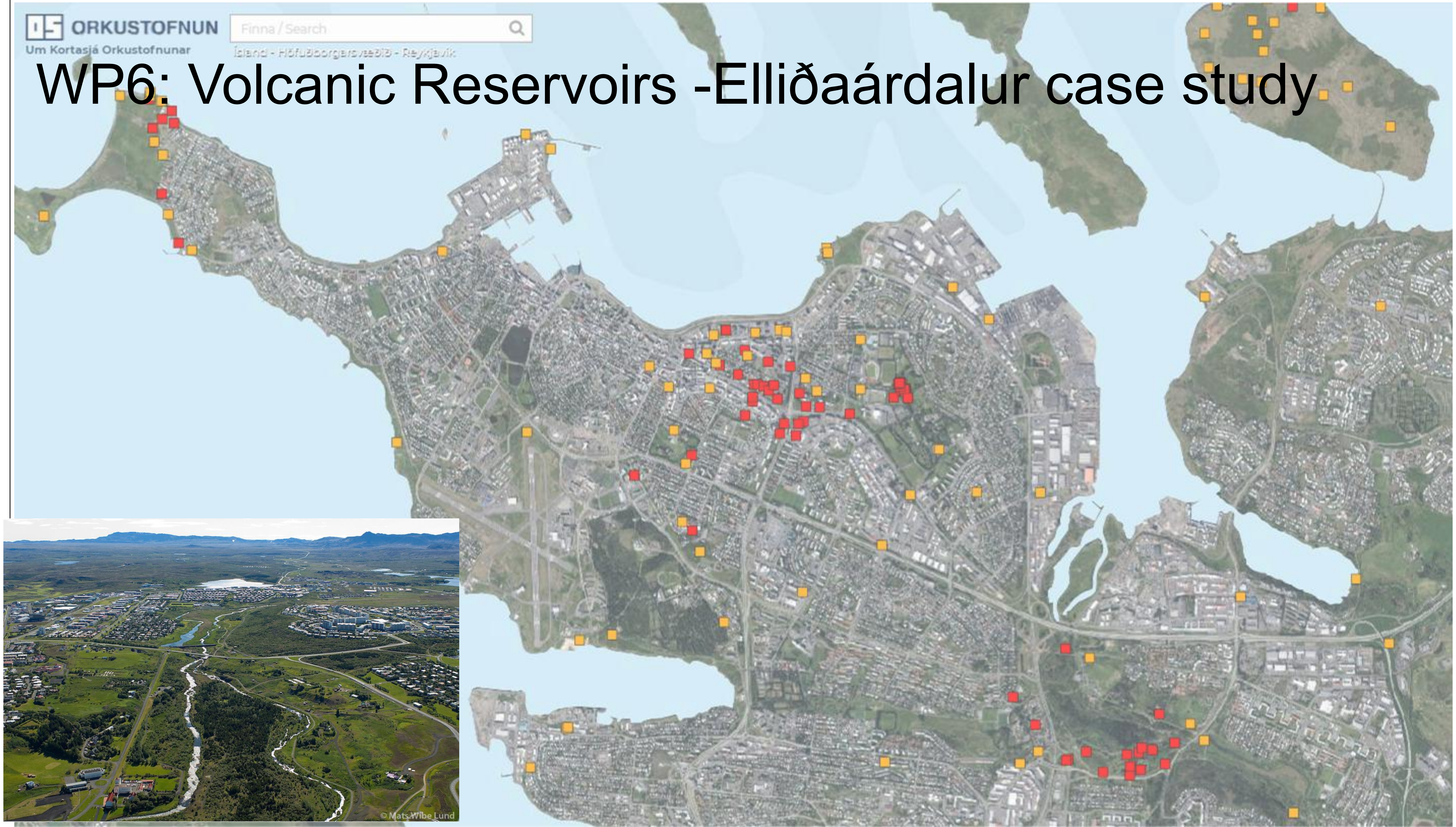


Stochastic Reservoir simulation model





WP6: Volcanic Reservoirs -Elliðaárdalur case study



WP6: Design Study Volcanic Reservoirs

Review of stimulation efforts and guidelines for drilling and completion of low temperature wells in Elliðaárdalur

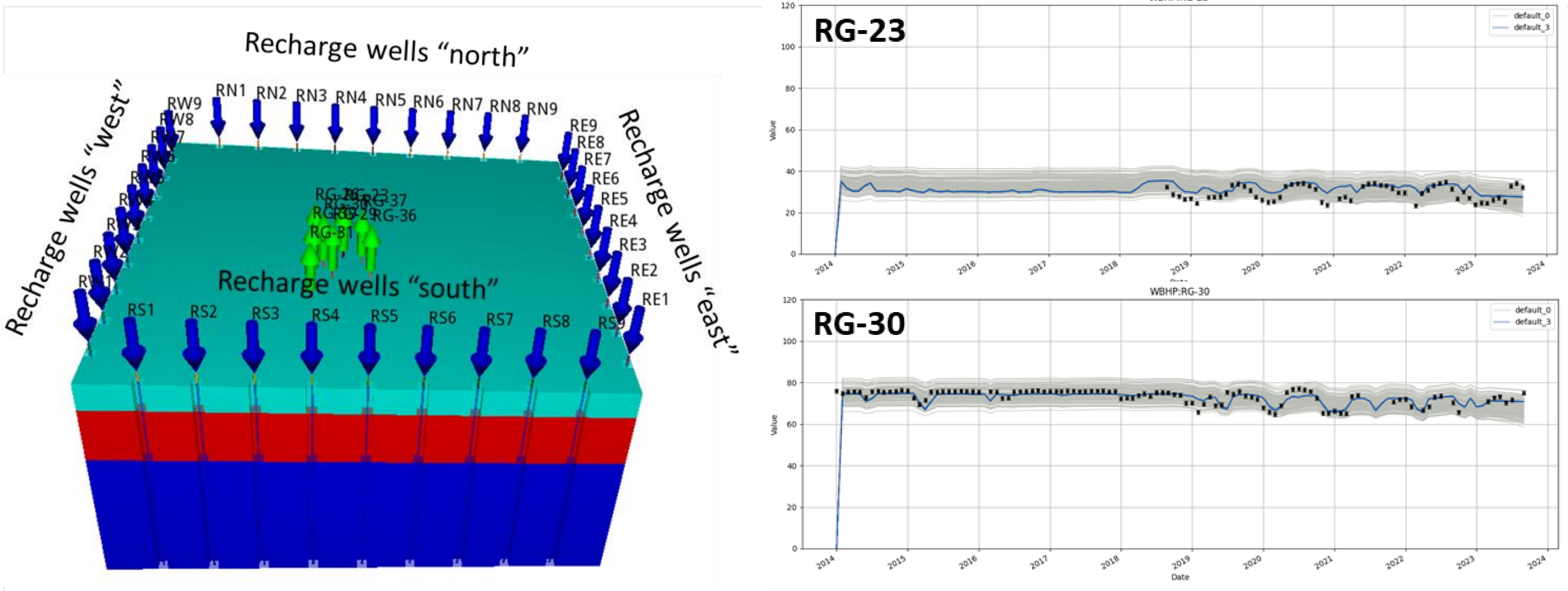
Datasets:

- 34 wells drilled from 1932 to 1996 up to 2312 m deep
- Drilling histories – 10 drill rigs
- Well design
- Stimulation
- Well logs
- Production history

Questions:

- What drilling method gave the best result?
- Connection between well design and production?
- How much did stimulation enhance the production?

RESULT • Elliðaárdalur case study



Bottom-hole pressure values over time for selected wells from the simplified reservoir model of the Elliðaárdalur site: historical observations (black dots), initial numerical models (grey) and updated numerical models (blue). Source D.4.4

RESULT Fast Models for well architectures

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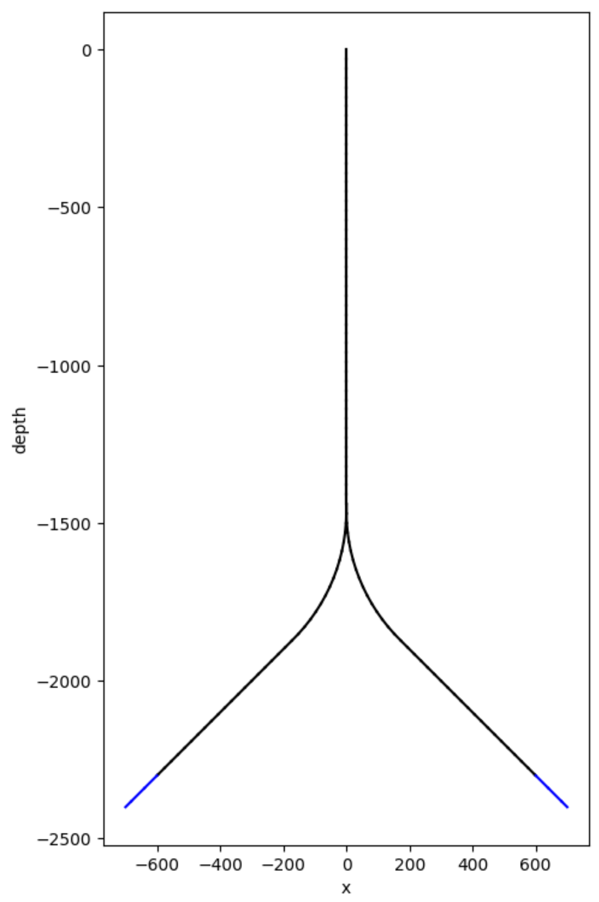

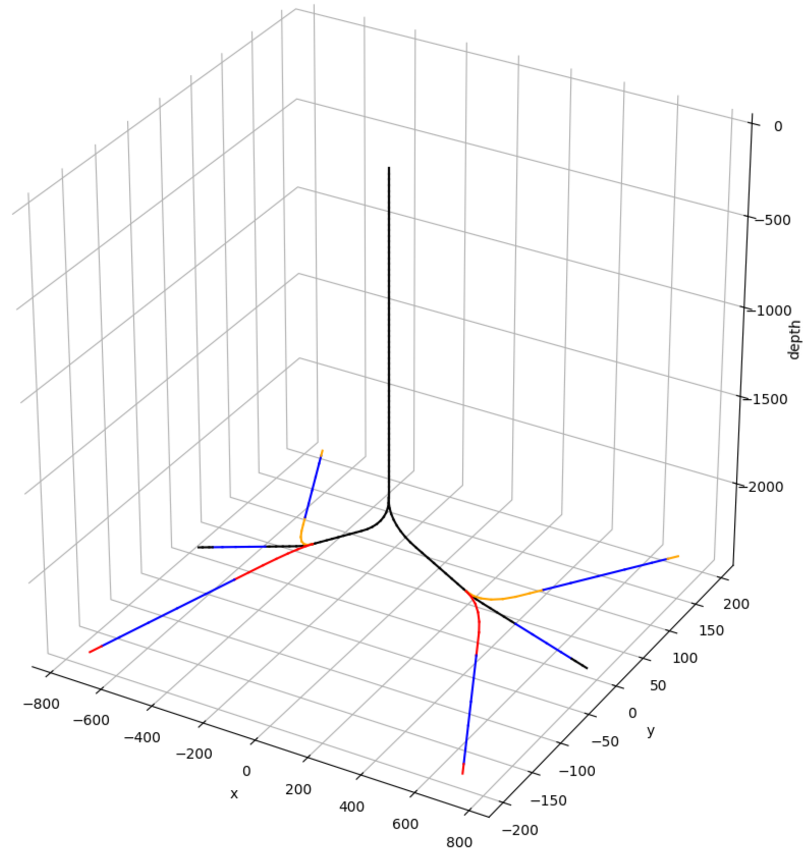

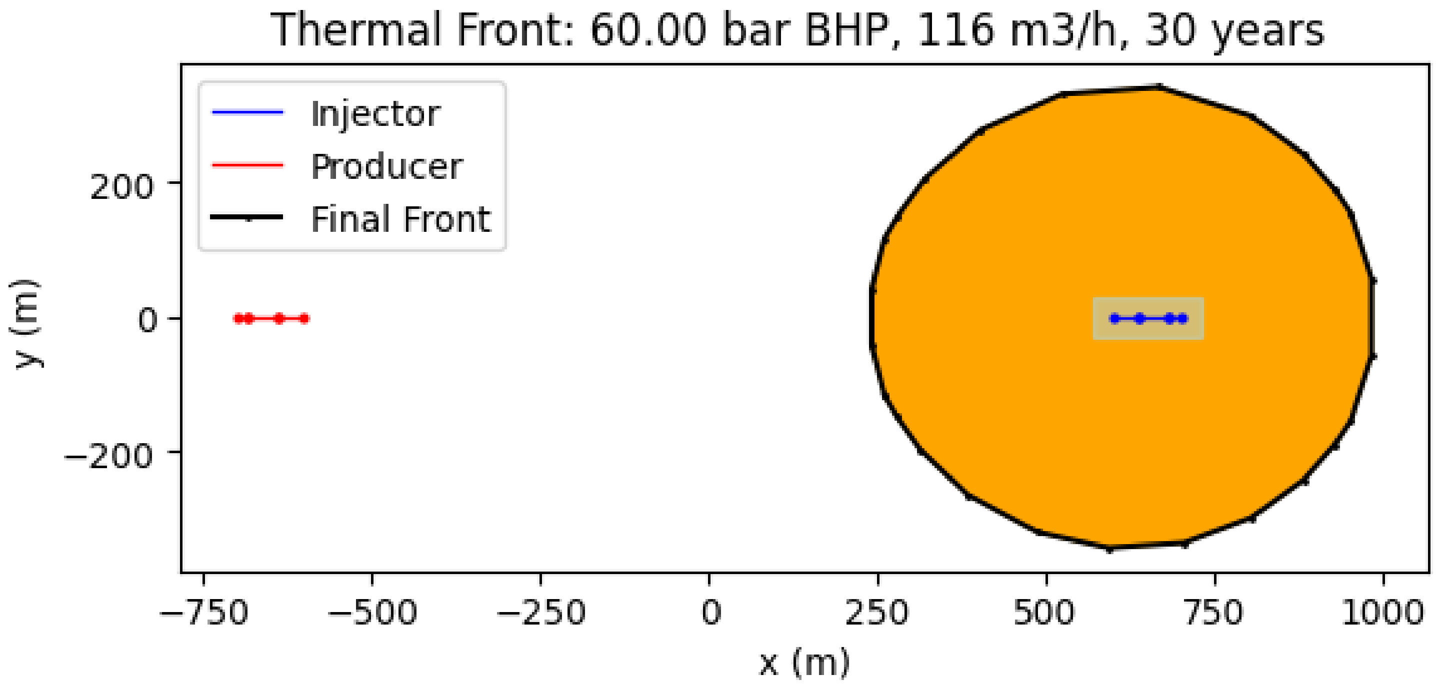

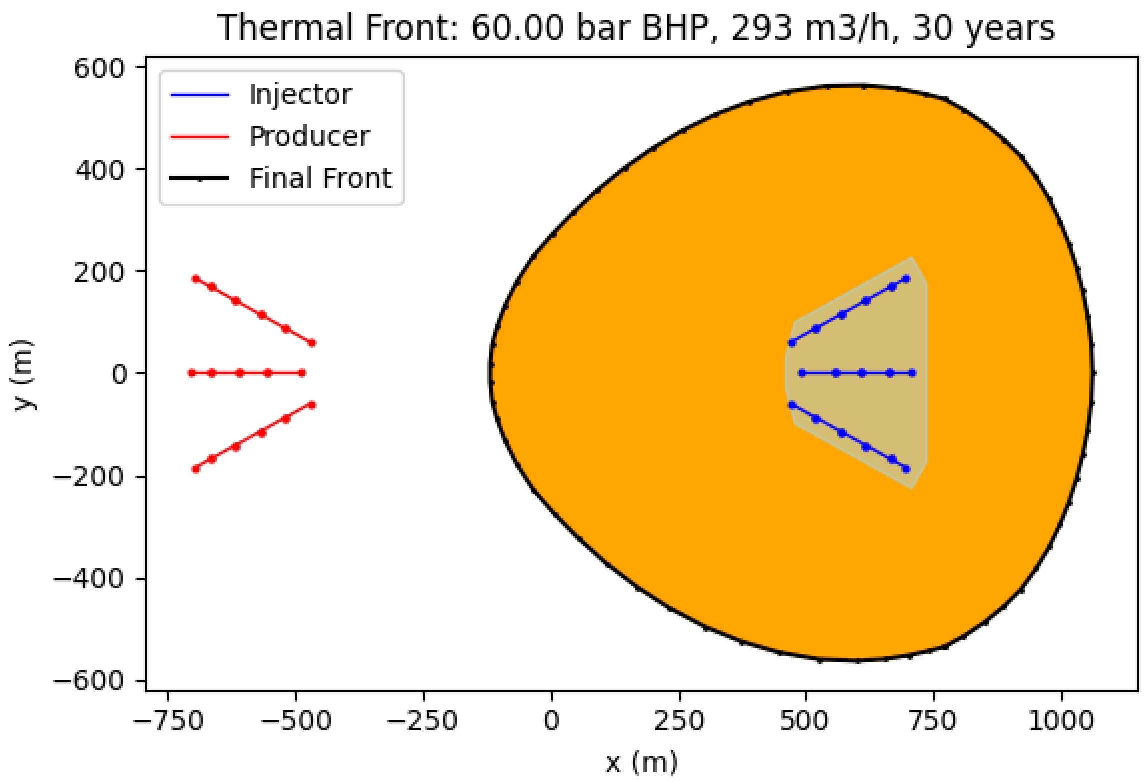

PyFastWell

https://github.com/TNO/pyfastwell

PyThermoNomics

https://github.com/TNO/pythermonomics

RESULT : deliverables -- https://www.result-geothermica.eu/

RESULT D1.6

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DOWNLOADS

NEWSLETTERS

D1.4 Result Newsletter October 2022	2022 October
D1.2 Result Newsletter November 2021	2021 November
D1.1 Kick-Off Newsletter 2020	2020 November

REPORTS

D2.1 Lessons learned from hydrocarbon well technologies	2020 November
D4.2 Optimized well and completion design for demo site (in Zwolle)	2025 January
D4.4 Drill & Learn recommendations from all demo sites	2025 August
D4.5 Open-source flow performance models for advanced well architecture - Attachment 1_pyfastwell_examples_fastmodel_example.ipynb at main · TNO_pyfastwel - Attachment 2_pythermonomics_examples_main_example_notebook.ipynb at main · TNO_pythermonomics	2025 August
D5.2 Optimised well concept for Dublin area	2023 November
D6.2 Characterization of the changes in the reservoir in the Elliðaárdalur field	2022 October
D6.3 Improved field management, lessons learned and guidelines for sustainable use of the Elliðaárdalur field (OR)	2023 May
D6.4 Results of Borehole Televiewer Logging in Wells R-23 and R-39 in Elliðaárdalur, Reykjavík - appendix 2a - appendix 2b	2021 October
D6.5 3D Modelling of Lithology and Temperature in the Elliðaárdalur Low Temperature Geothermal Area Reykjavík, SW-Iceland	2021 December
D6.6 Analysis of reservoir and production behavior of the Elliðaárdalur field case with data-driven approaches	2024 June

Acknowledgements

- Thank you for your attention! Questions?

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