



Perspectives on stimulating deep geothermal systems

Jos Okkerman, October 17th, 2023

Agenda

1.

Fishbones introduction

Company and technology

2.

Fishbones track record

Case histories

3.

Fishbones in geothermal

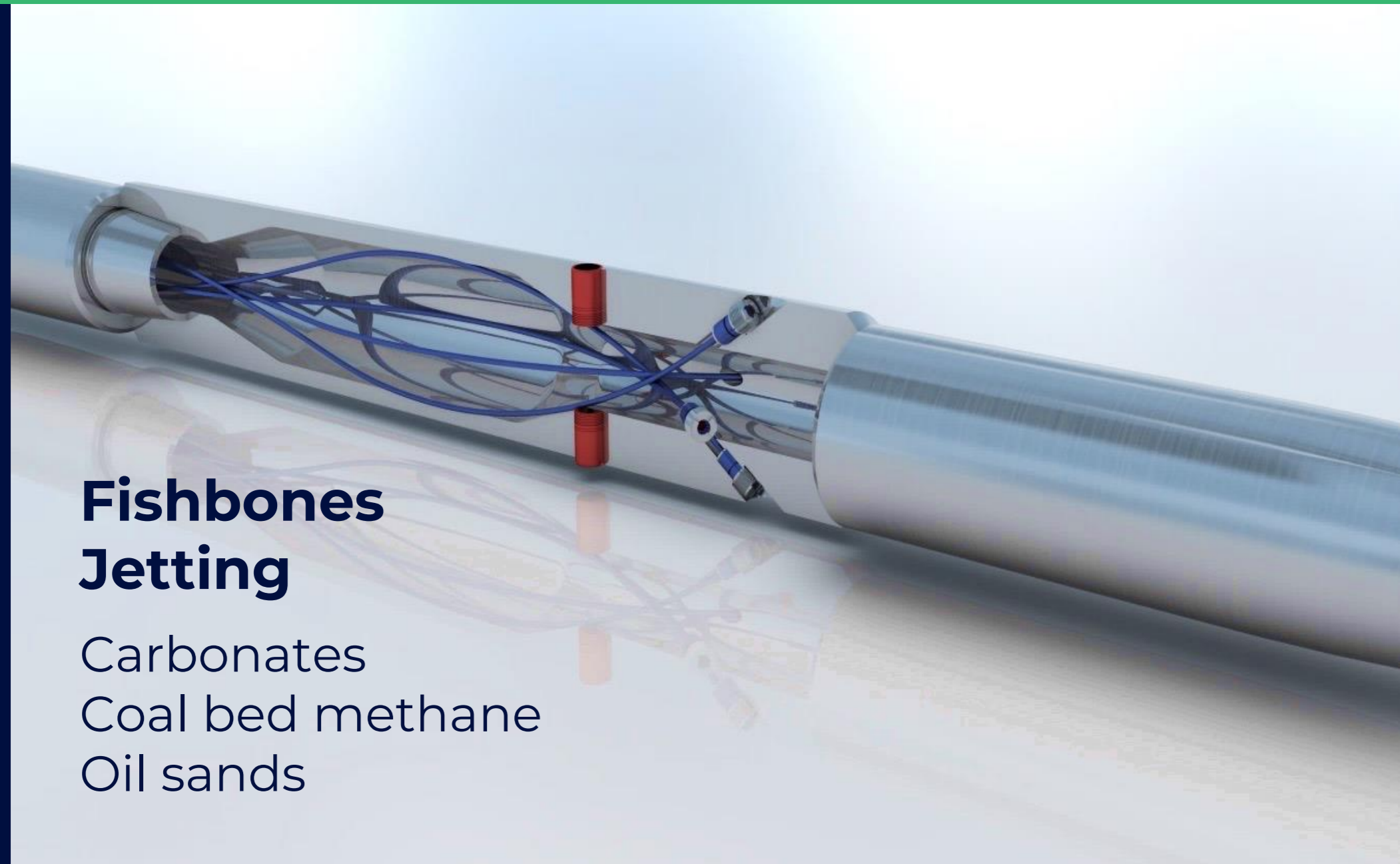
Outlook

OUR VISION

**First consideration
for stimulation of
reservoirs worldwide**

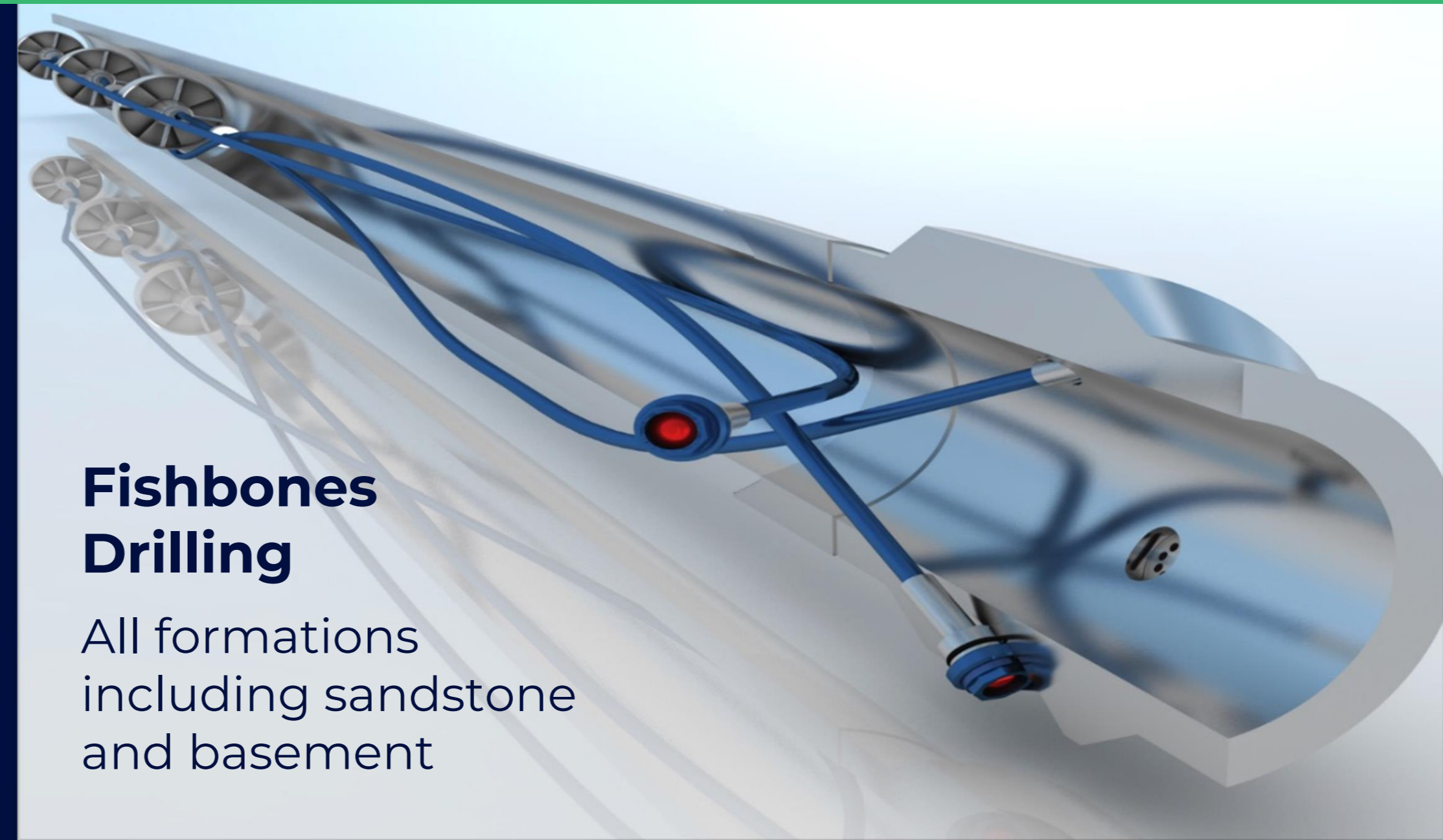
Technology

Product Portfolio



Fishbones Jetting

Carbonates
Coal bed methane
Oil sands



Fishbones Drilling

All formations
including sandstone
and basement

Dimensions:

- ✓ 4-1/2" liner for 6" to 6.5" open holes
- ✓ 5-1/2" liner for 8.5" open holes

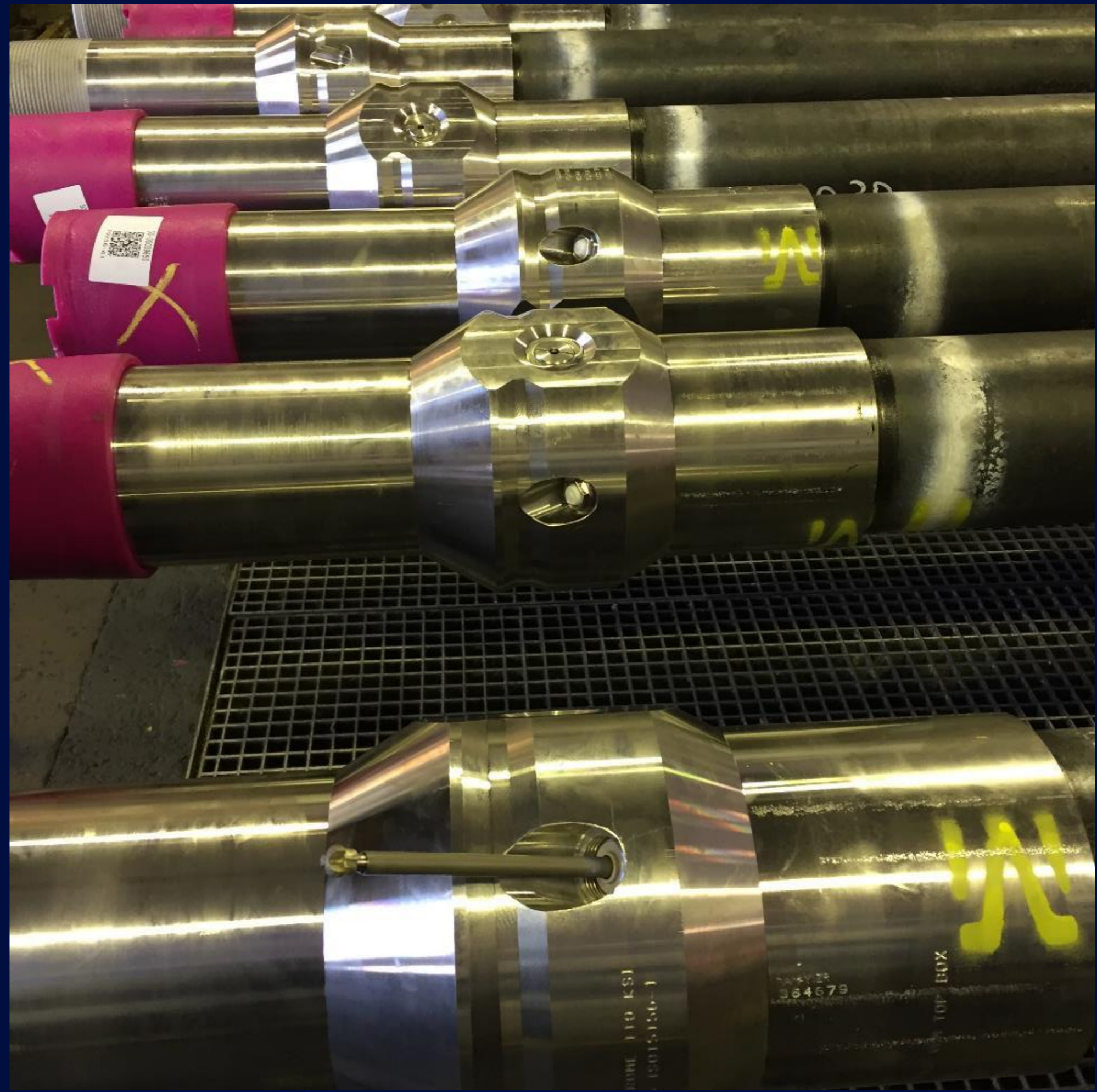
Specifications:

- ✓ Available in all materials to match liner specifications
- ✓ Available in all types of threads to match liner specifications



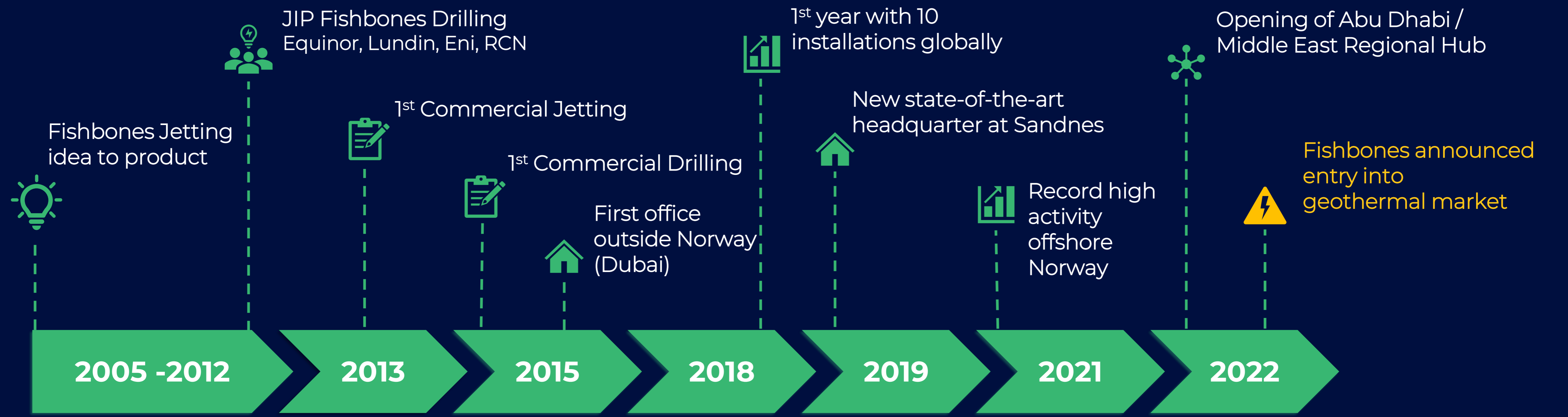
Technology

Fishbones Drilling System



Company

Fishbones timeline

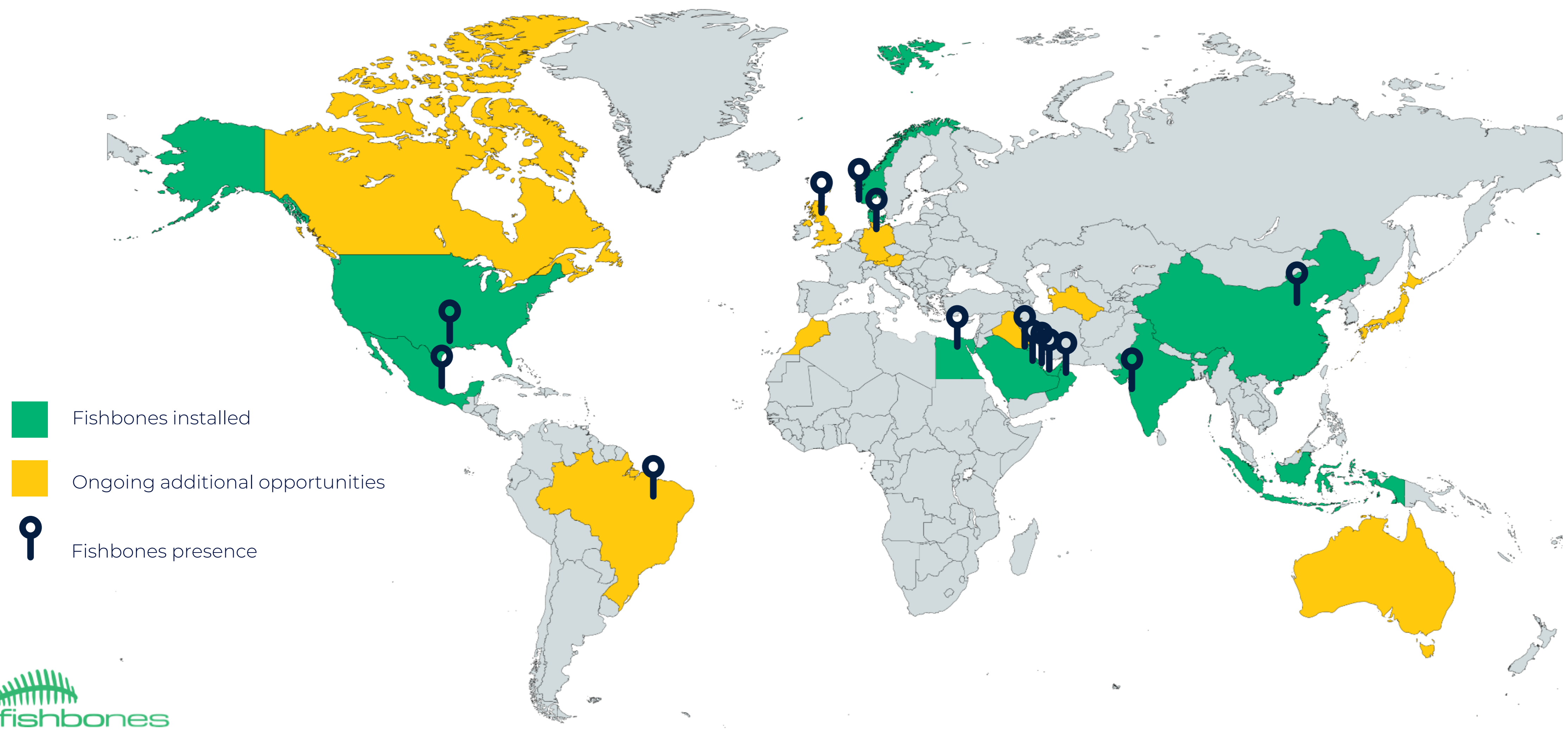


- 40 employees, hiring more
- 14 nationalities
- 12 agents / partners globally
- Planning installations in 8 countries / 4 continents
- 14 SPE / IADC technical papers
- Dedicated resource for BD Geothermal



Company

Fishbones global footprint



What we do

Track Record Oil & Gas

We continue to extend our geographical reach and increase the number of both on and offshore wells



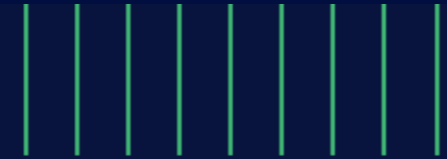
43

Installations globally to date



24/19

Onshore/
Offshore wells



3964

Needles installed



61

Max Fishbones subs



2675m

Longest horizontal section



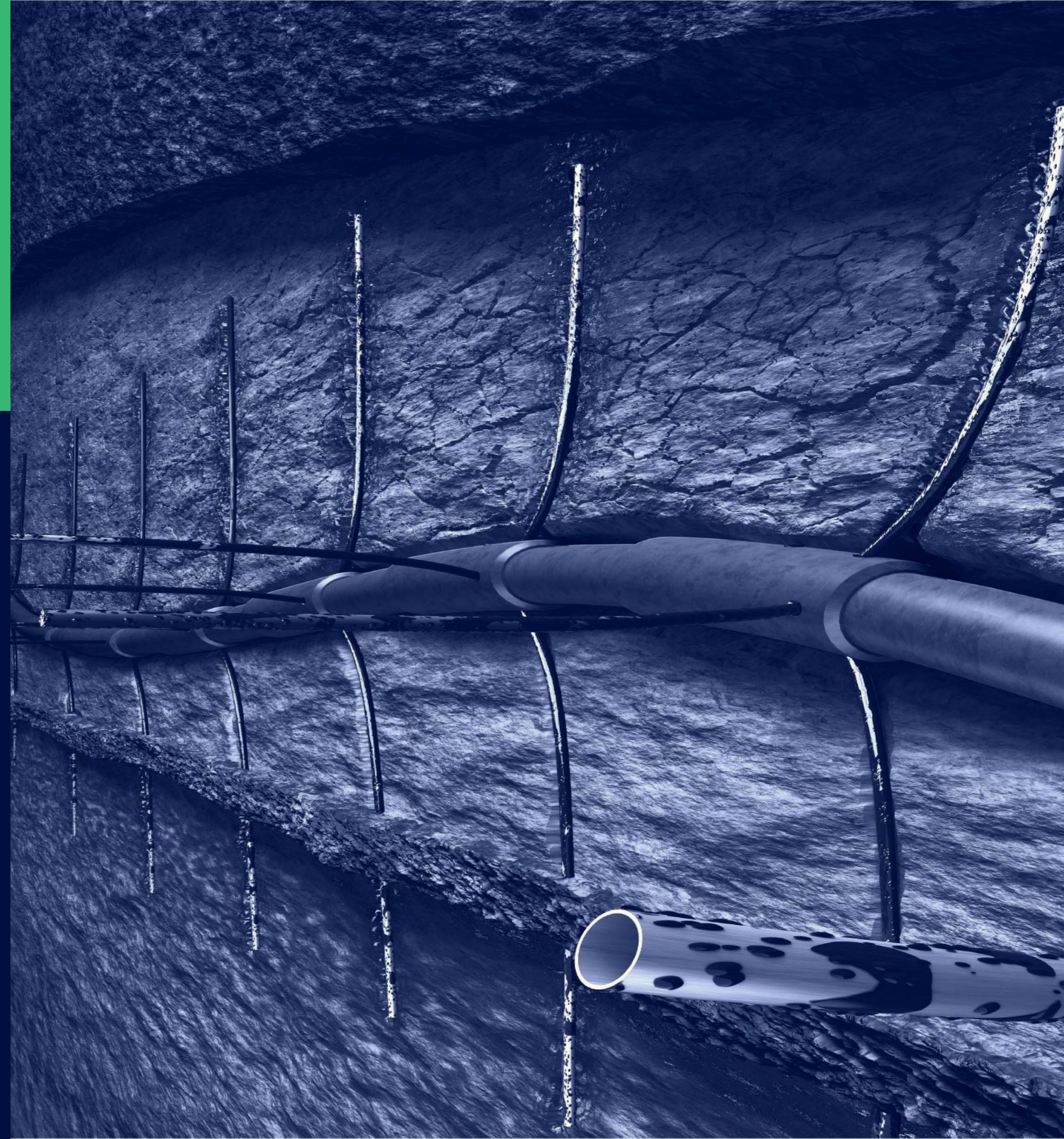
5495m

Deepest installation (TVD)



190°C

Highest temperature application



What we do

Applications to-date

Formations

- Naturally fractured carbonate
- Layered carbonate
- Chalk
- Layered sandstone
- Fractured basement
- Conglomerate
- Coal bed methane

Well types

- Oil producers
- Gas producers
- Water injectors
- Exploration
- Appraisal
- **Geothermal**

Combinations

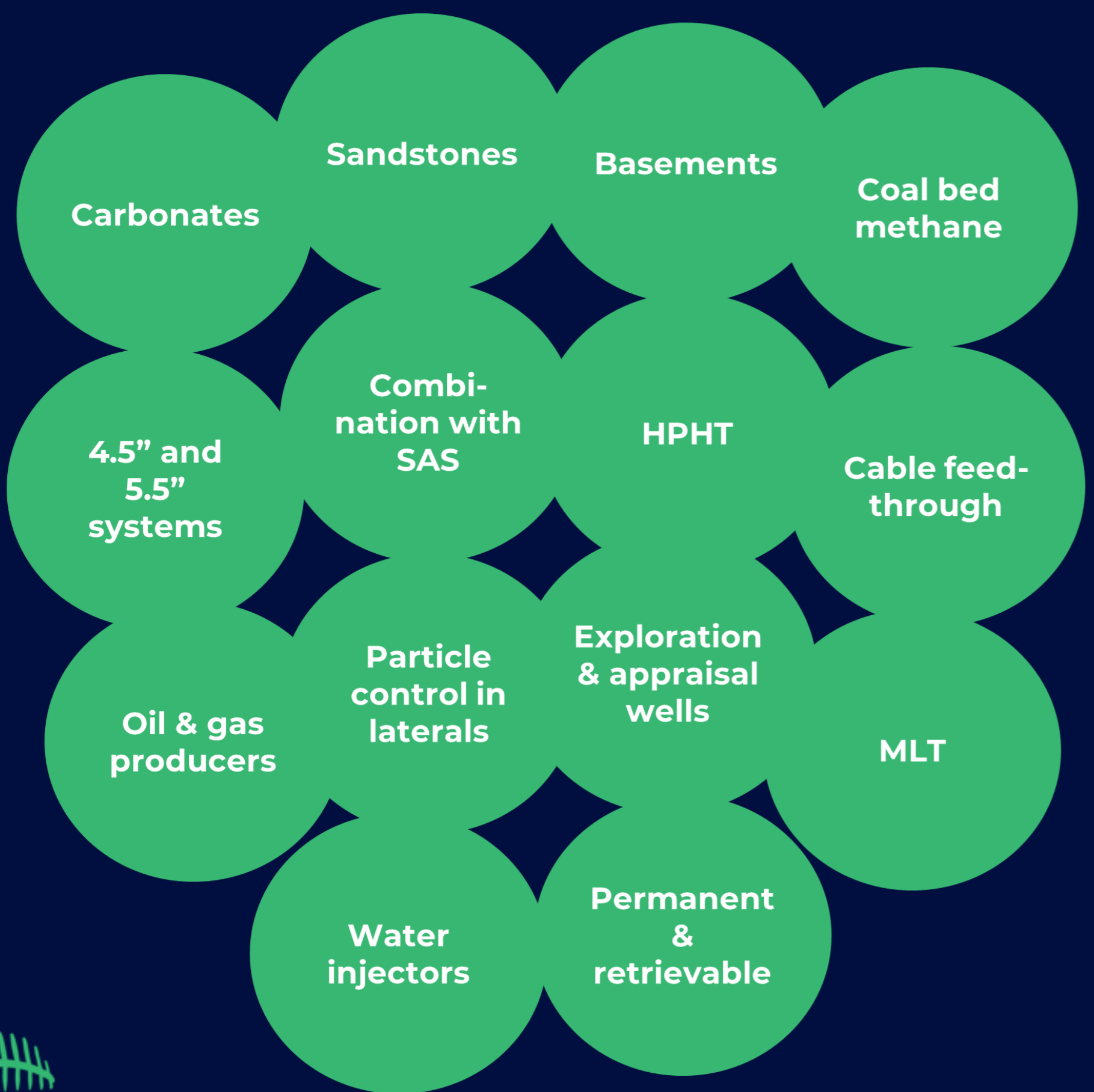
with other well construction methods

- Multi-lateral wells
- Sand screens & ICDs
- Swellable packers
- Frac sleeves
- Tracers
- Timer shoes
- Perforations

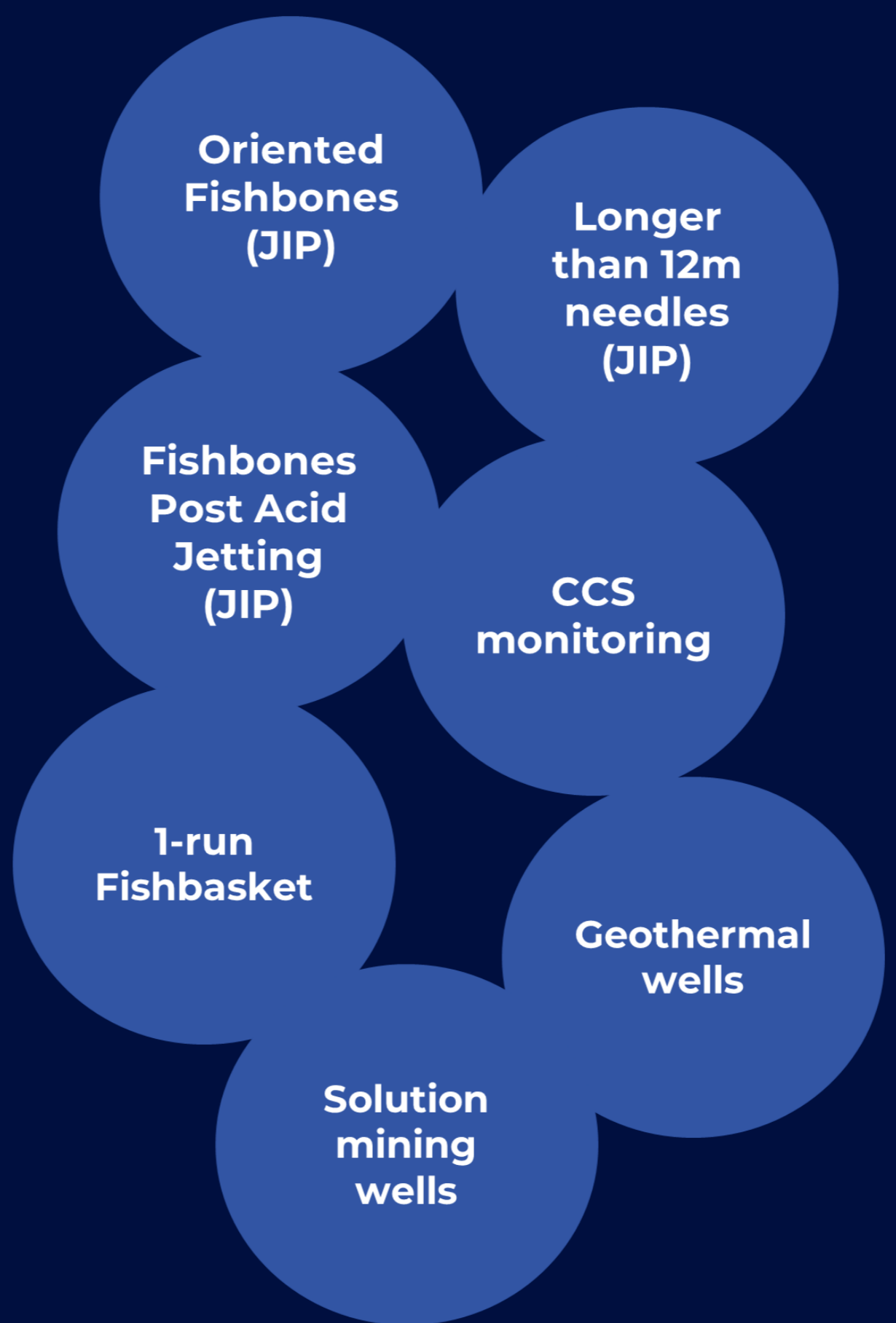
What we do

Fishbones technology & application design

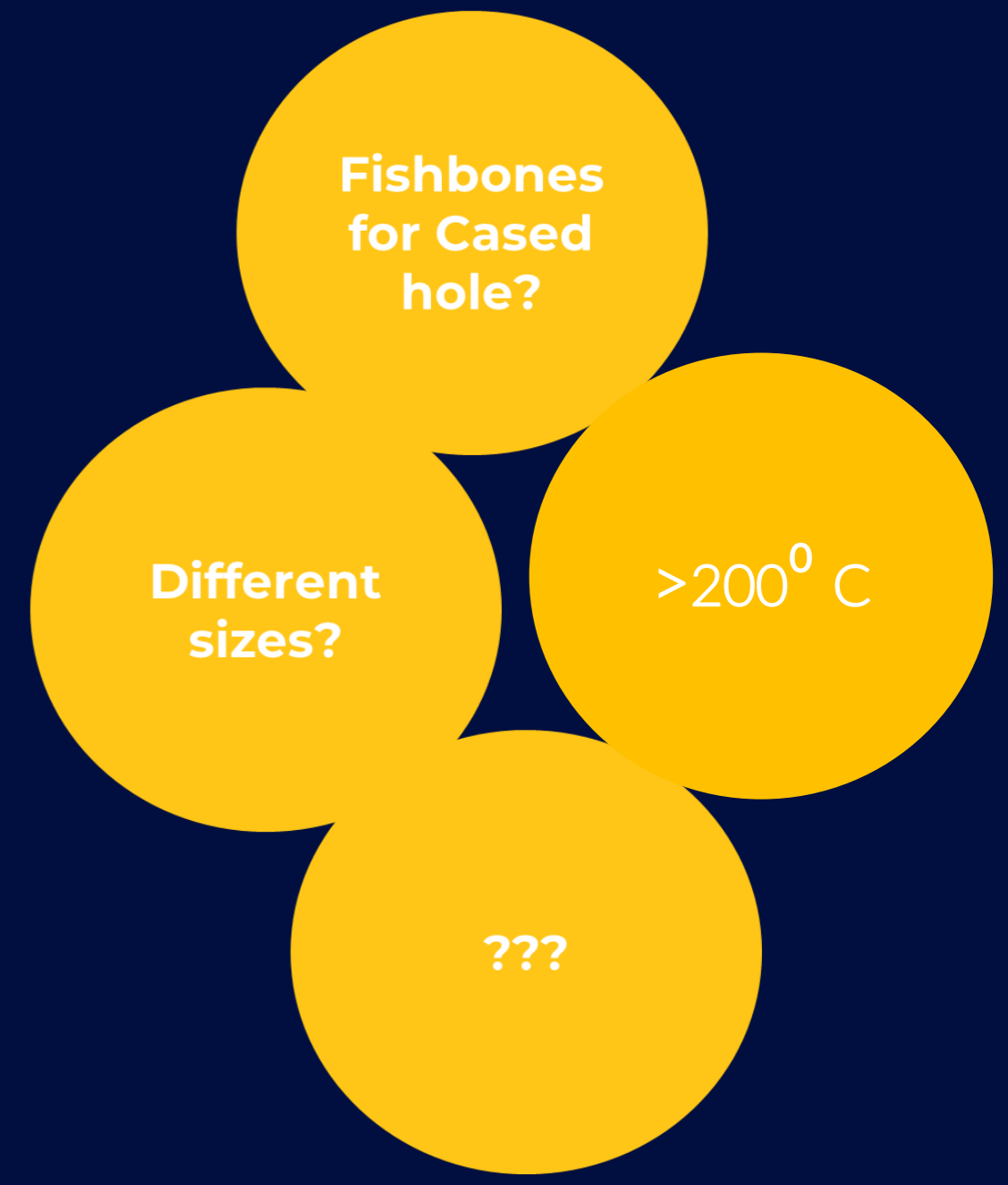
Established



In development



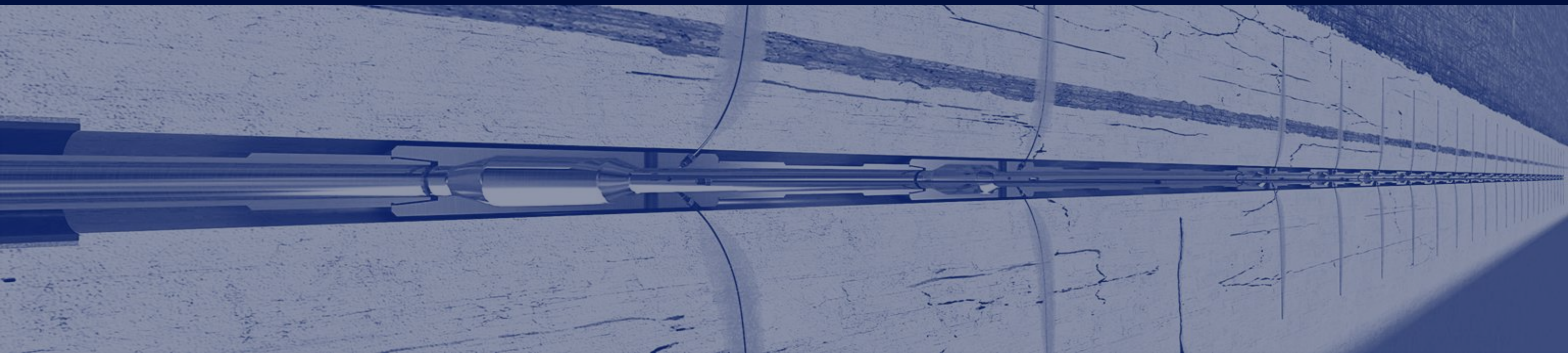
Future potential



Benefits

The value of Fishbones stimulation technology

- ✓ Increase reservoir exposure
- ✓ Connect layered reservoirs
- ✓ Connect to & through natural fractures
- ✓ Connect with sweet spots and lenses
- ✓ Increase production rates and / or reduce drawdown
- ✓ Accurately stimulate zones
- ✓ Bypass damaged zone
- ✓ Reduce risk of early breakthrough
- ✓ Reduce well and operating costs
- ✓ Reduce CO₂ footprint and HSE exposure



Track Record Oil & Gas Applications

Case Histories



Case Study: Norway subsea installation

Fishbones doubles oil rates (2015)

Challenge

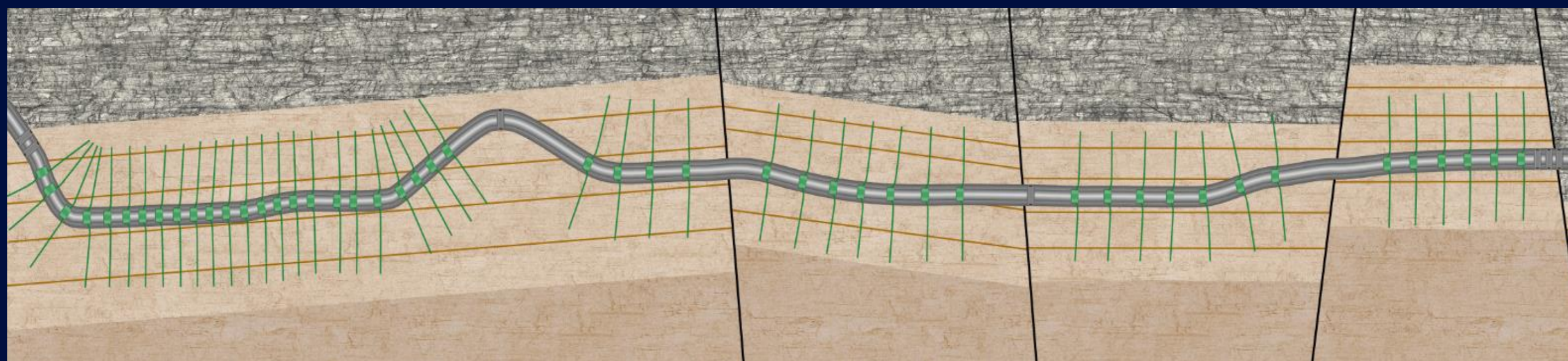
- New well in subsea development
- **Tight, layered sandstone formation** (0 - 10 mD)
- Vertical flow barriers
- 30 meter reservoir thickness
- Need for accurate stimulation
- Dual lateral well with 2000m / 6600ft 8 ½" horizontals

Solution

- 5 ½" liner with 48 Fishbones Drilling subs (**144 laterals**) to accurately connect the reservoir
- The downside risk was assessed by Equinor to be limited

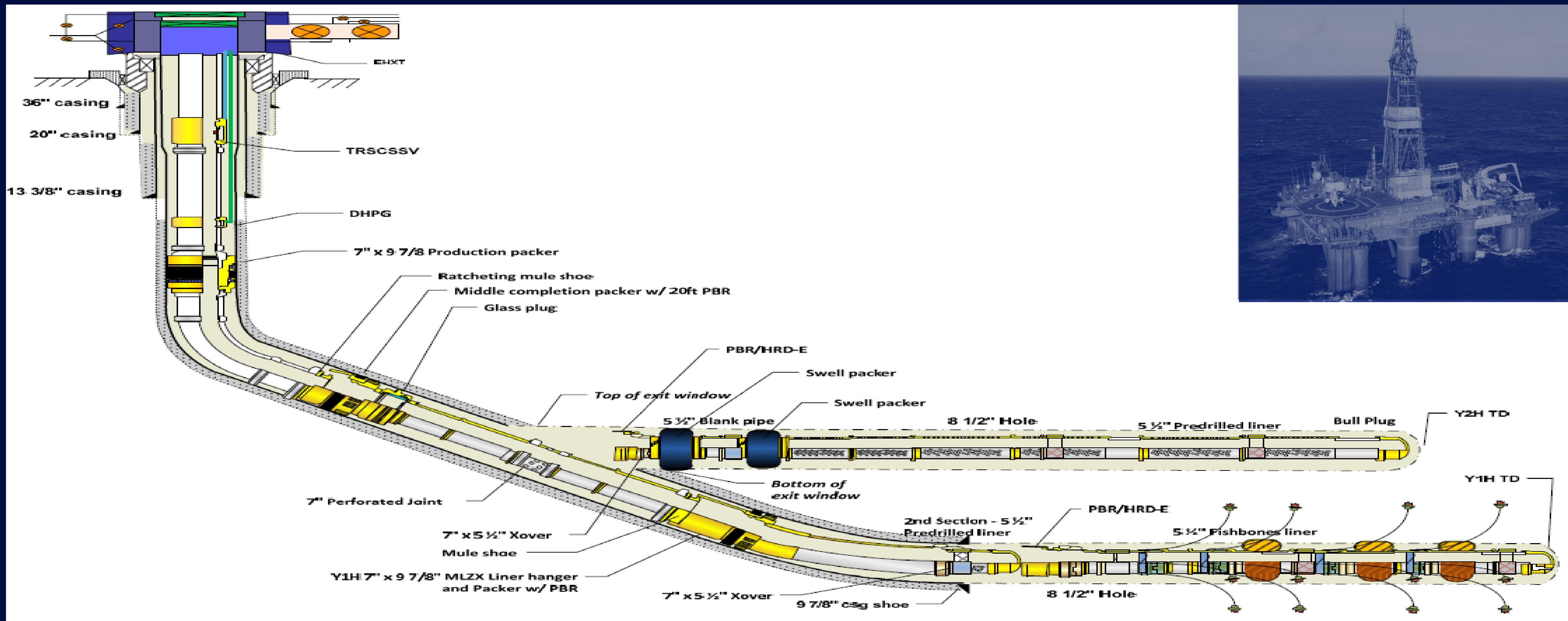
Results

- Equinor interpretation of production log (September 2017) concludes that 2/3 of the production is originating from the main bore i.e. **100% higher production with Fishbones**
- SPE-180390
- 2nd well completed with Fishbones August 2021, on production Jan 2022



Case Study: Norway subsea installation

Fishbones doubles oil rates (2015)



Installation successfully completed in a long dual lateral subsea horizontal well



Case Study: China offshore installation

Fishbones Drilling increases gas rates in HPHT application (2019)

Challenge

- Vertical exploration well in **fractured gneiss formation**
- HPHT: 550bar/8000psi, 190°C/375°F
- Compare rates before and after Fishbones by DST

Solution

- 4 ½" Fishbones liner with 22 Fishbones Drilling subs (**66 laterals**) in the 430 meter 6" open hole

Results

- Successful deployment
- **5 hrs circulation time for the laterals drilling**
- **69% increase** in rates compared to barefoot DST results
- **Order received for 4 more wells** (H2 2023 installations)



Case Study: North Sea Fishbones Drilling record installation

10 times increase in productivity in conglomerate formation (2021)

Challenge

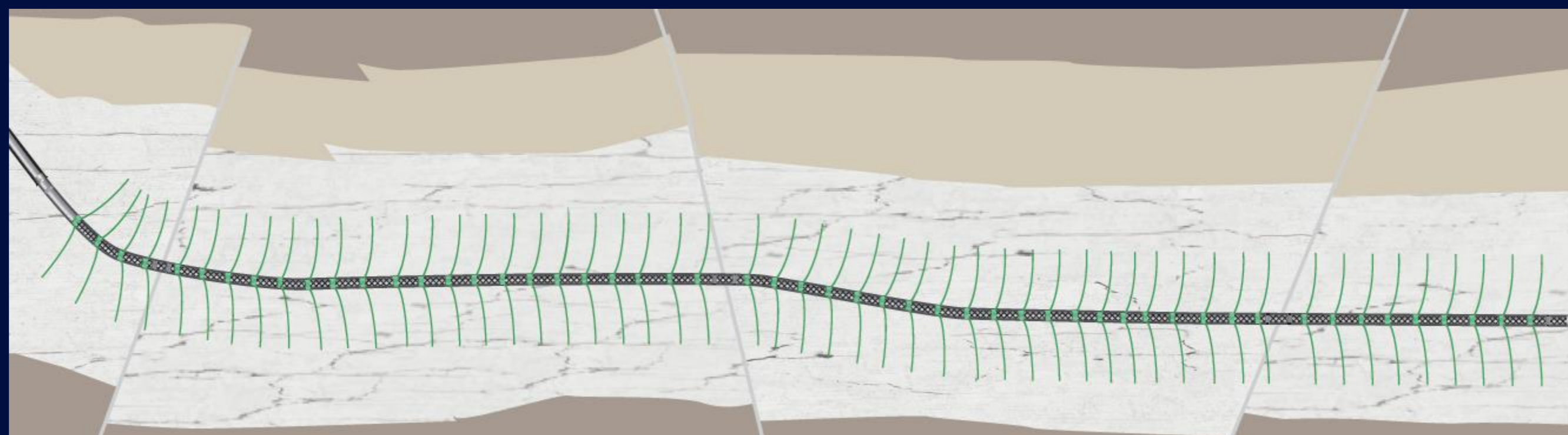
- Basement infill project
- New well in fractured conglomerate formation
- 1100 meter 8.5" open hole
- Sand control requirement
- Risk for losses

Solution

- 5 ½" Fishbones Drilling system with 53 subs (159 laterals)
- Hard rock drill bit developed in JIP
- Fishbones in combination with standalone ICD screens
- Swell packers to isolate loss zones

Results

- Successful installation
- Excellent production results, **10x** better productivity than original prognosis
- 2nd well with 61 subs (183 lat) completed June 2021, on production Jan 2022
- SPE-209953-MS
- **3rd well completed Aug 2023**

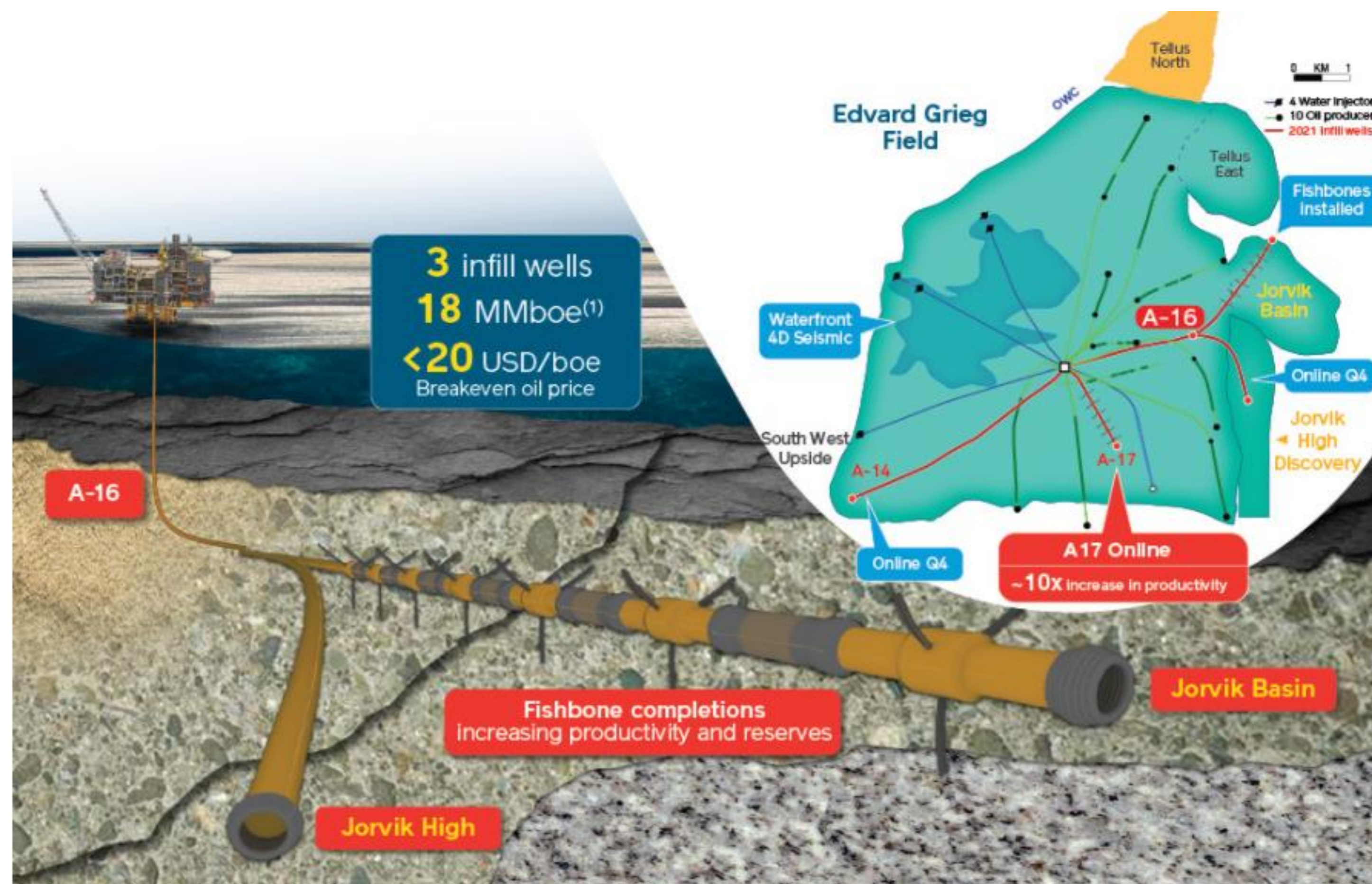


2021 North Sea case history

10 times increase in productivity in conglomerate formation (2021)

Lundin Energy website: “The first of the three infill wells came on stream in June 2021, equipped with the innovative “Fishbones” completion, which has contributed to well productivity around 10 times greater than the original prognosis.

This increases reservoir penetration and enables us to produce more from the same reservoir rocks.”



Status & Outlook

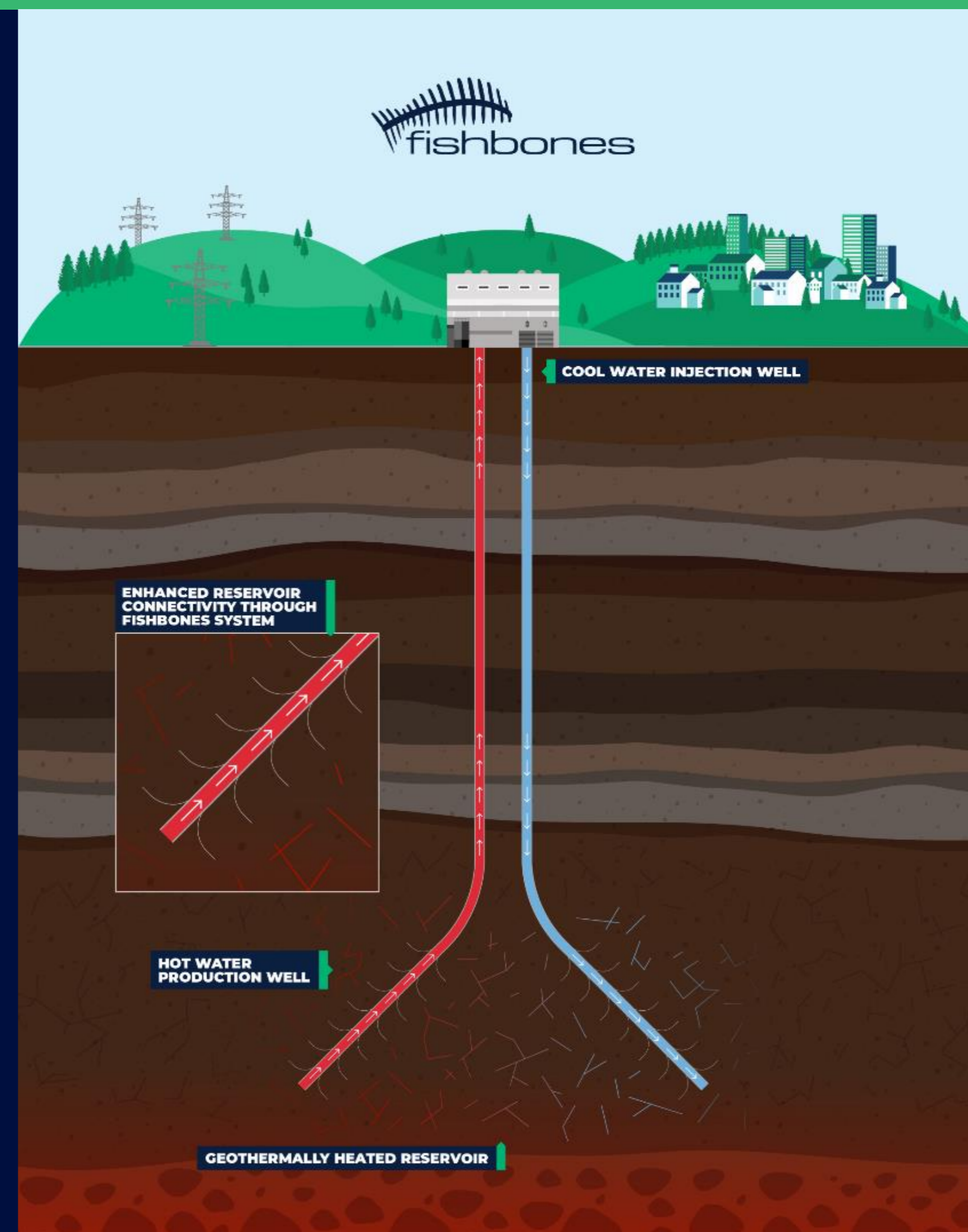
Fishbones in the geothermal market

Status

- 3rd Party Market Study 2021
- Conducted a reservoir simulation illustrating the added value with Fishbones in conventional hydrothermal wells based on a real case hydrothermal doublet in the Netherlands
- Ongoing communication for several projects
 - USA
 - Continental Europe

Outlook

- Secure a first geothermal project to validate benefits of Fishbones technology for geothermal use



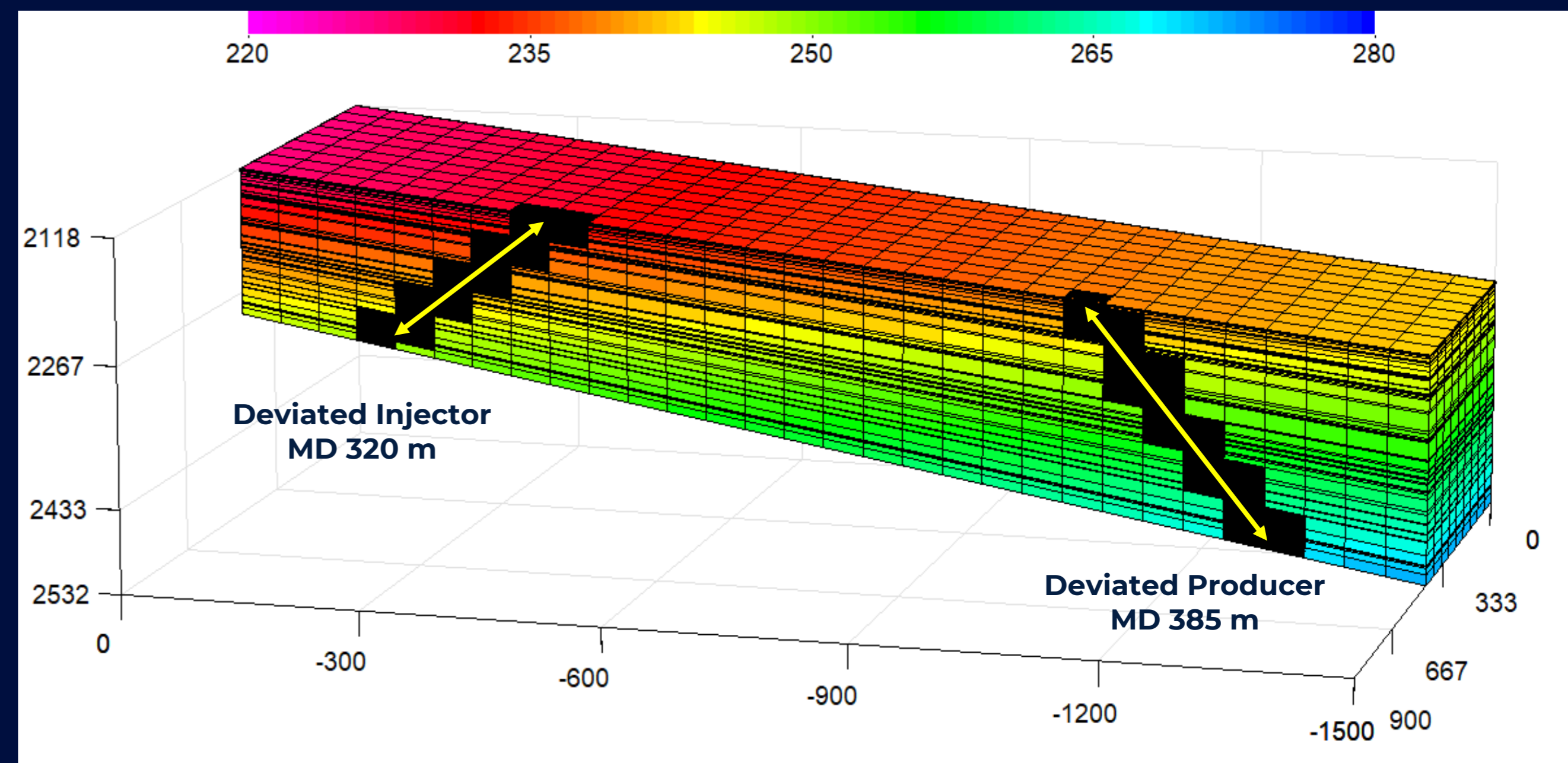
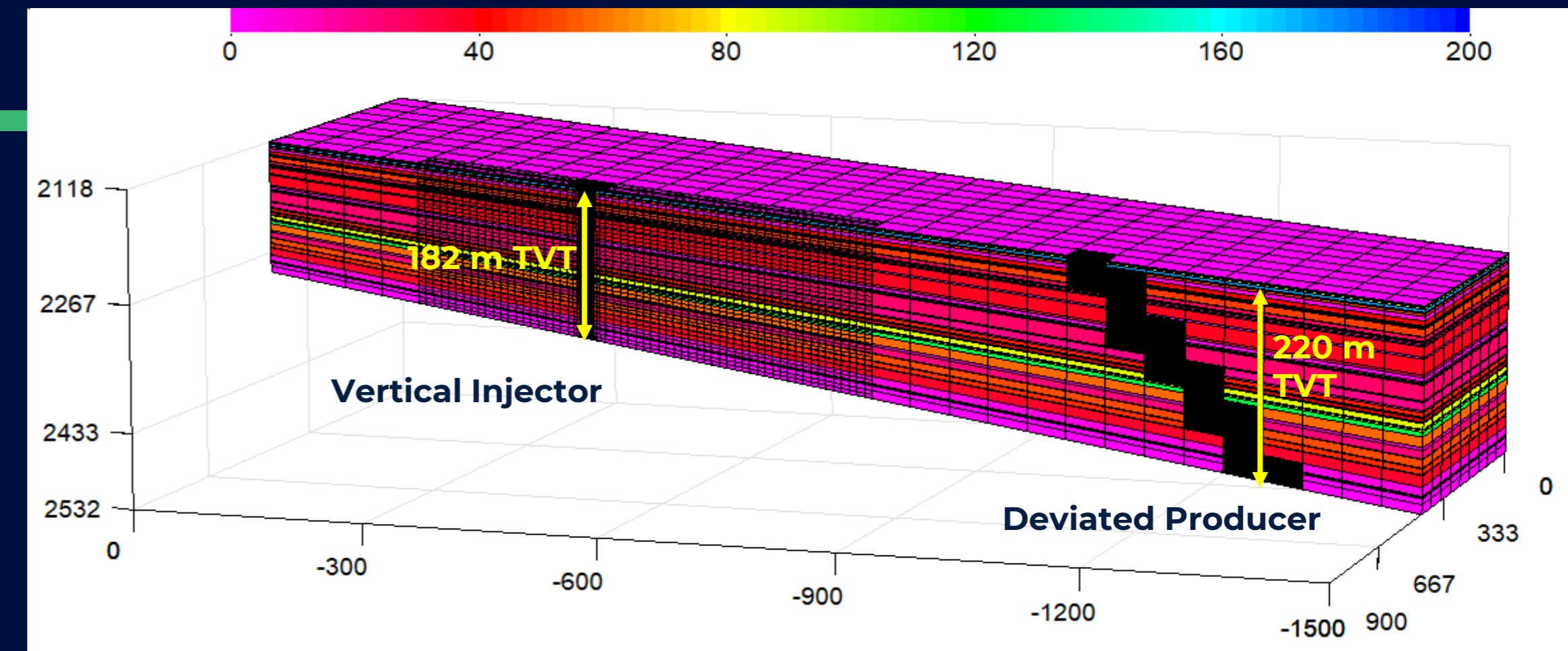
Case Study Geothermal

Reservoir simulation model

- Fishbones engaged Fenix Consulting Delft (NL) for simulation study to quantify benefit of FB drilling technology in geothermal wells
- Initial history matched model developed based on actual doublet with vertical injector & deviated producer
- Local grid refinement (LGR) used around wells to allow well test matching

Fishbones model set-up

- For Fishbones simulation, both production and injection wells were implemented as deviated wells, which is the most common doublet well design
- For Fishbones base case, small positive skin of +2 was defined
- Permeability set from log-derived porosity data, calibrated to well test analysis
- Average permeability in model is 42 mD, with average kh of 8300 mD-m

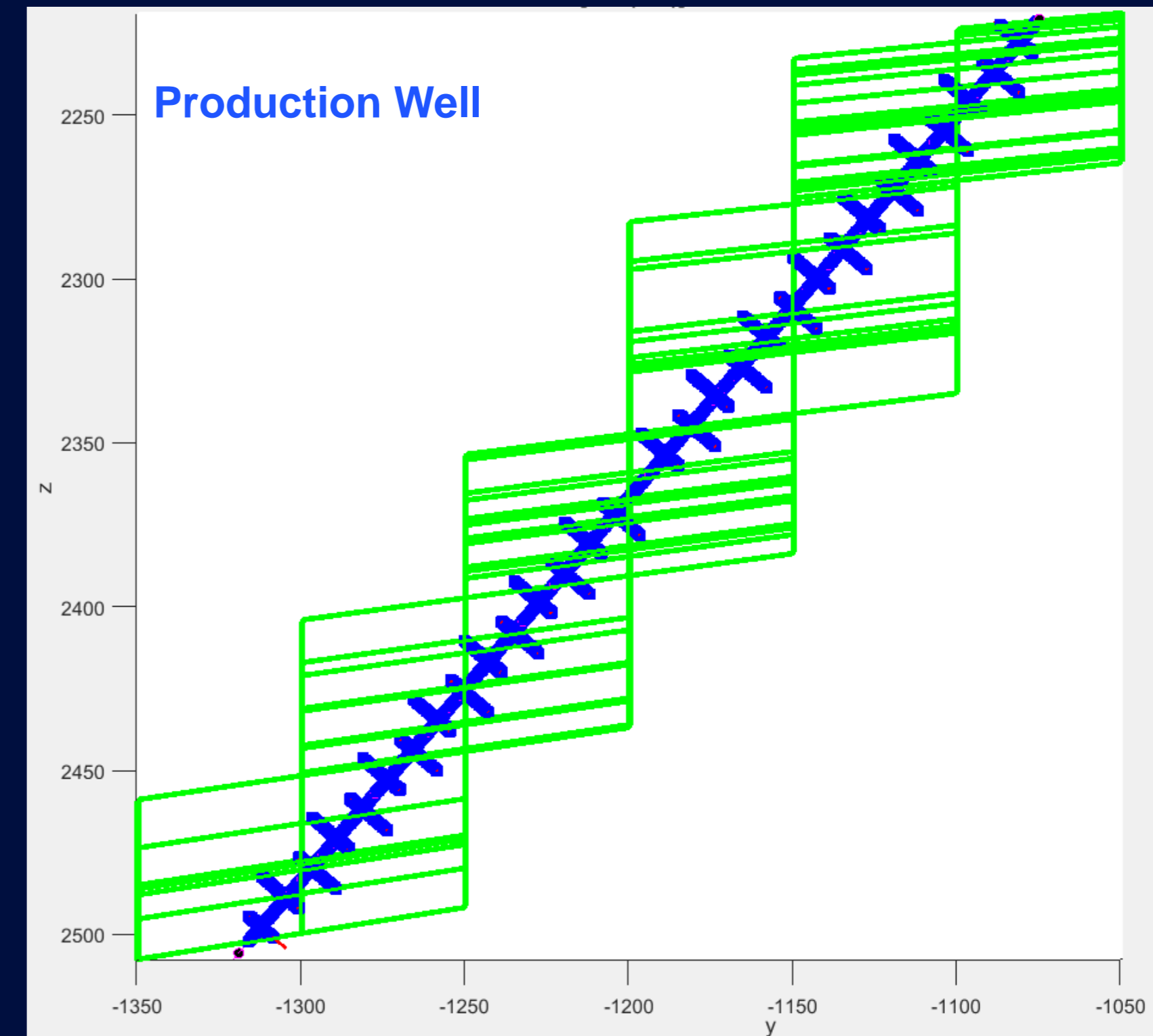
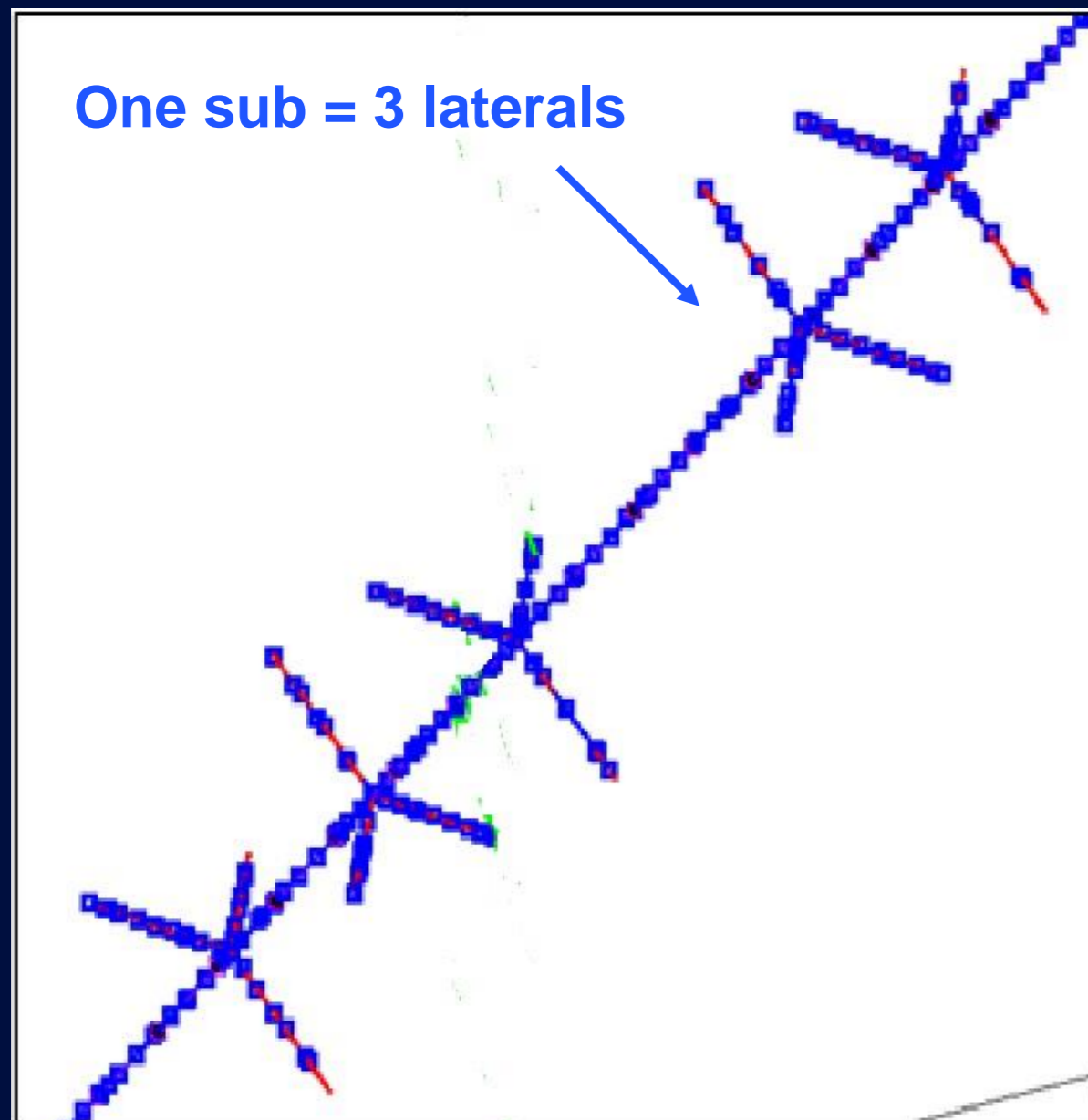


Case Study

Reservoir simulation model

Fishbone Drilling Completion

- Each Fishbone Drilling sub comprises 3 laterals phased 120 degrees
- Effective lateral length of the needles is 10 m
- Subs can be placed tailored to the reservoir extension



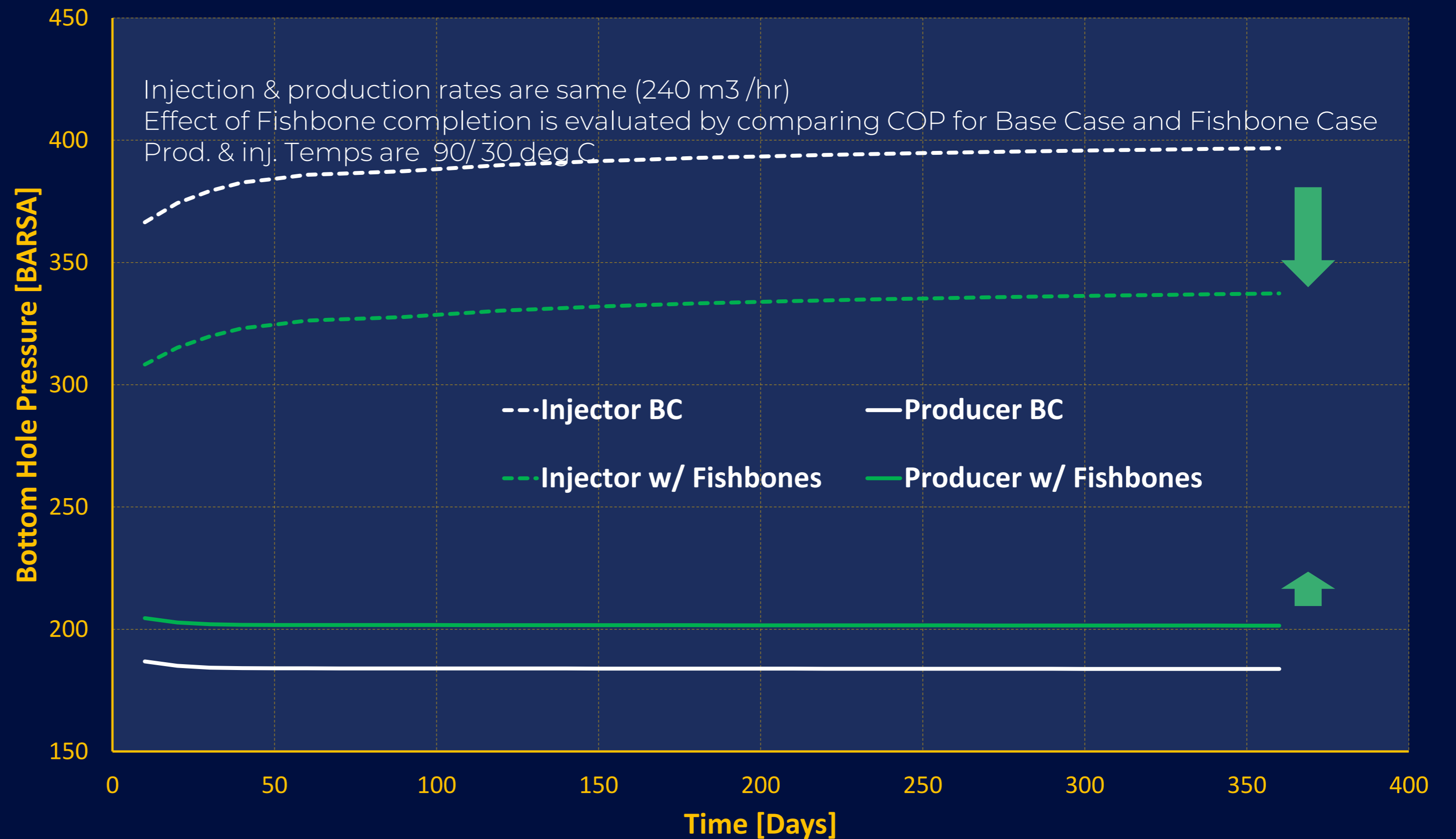
Case Study

Reservoir simulation model

Base Case simulation results

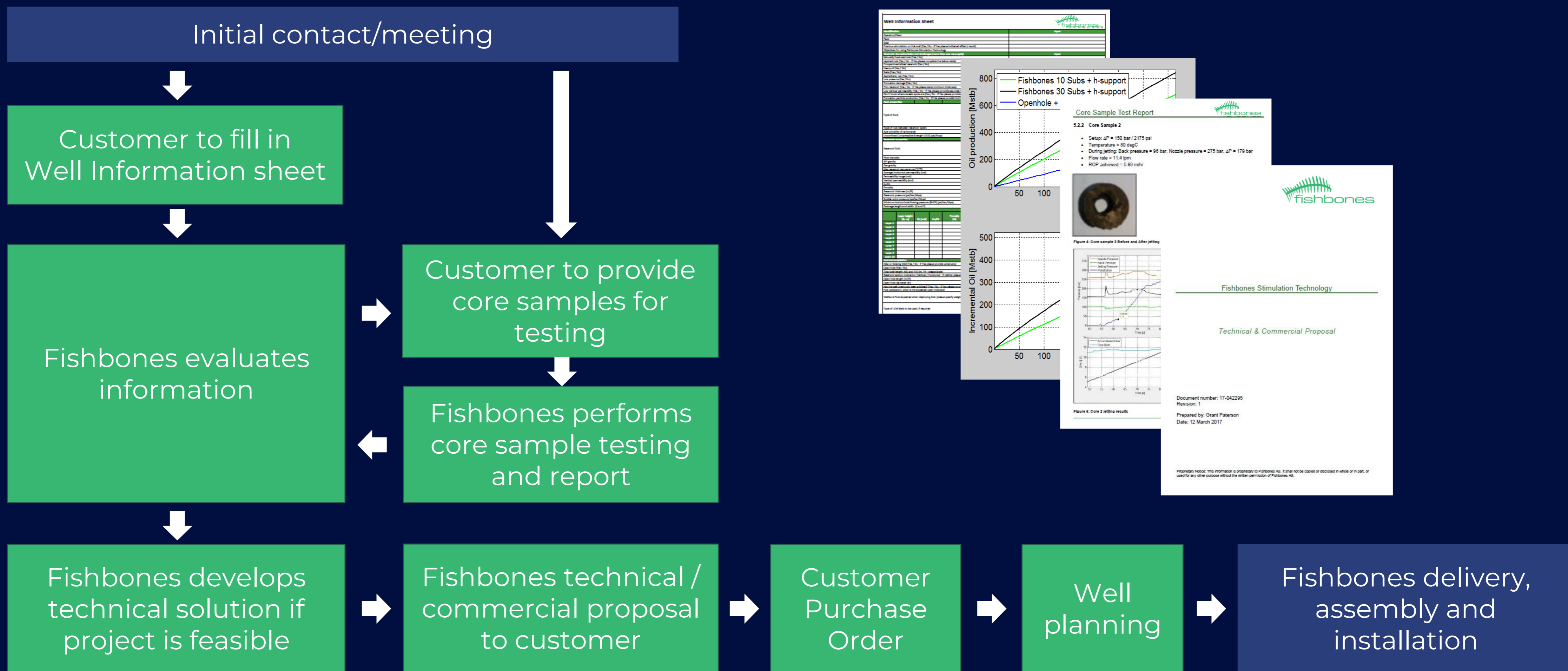
- In base case scenario with skin of +2 and average perm of 42 mD, stimulation of the reservoir with Fishbones (24 subs) leads to **reduction of the injection pressure by 60 bar**
- For the production well **bottom-hole flowing pressure could be increased by 20 bar** (reduction of drawdown) with Fishbones (30 subs)

Fishbones Base Case [Perm 42 mD & Skin +2]



How we work

Business process



Germany geothermal development projects: Clear potential for effective reservoir stimulation

North German Basin

- Triassic & Rotliegend clastics - FB drilling

Southern Germany

- Malm carbonates - FB jetting
- Molasse & Flysch clastics - FB Drilled system

Western Germany

- Carboniferous Dinantian karstic carbonate - FB drilling or FB jetting
- Jurassic & Cretaceous sandstones – FB drilling system

Rhine Graben

- Triassic Buntsandstein clastics - FB drilling system

Thank You

Q & A

fishbones.as

Follow us on LinkedIn

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Summary of benefits of Fishbones stimulation for geothermal development

- Very effective and focussed reservoir stimulation
 - Small spatial and environmental stimulation footprint
 - Logistically simple – completion system is delivered to wellsite ready to deploy.
Liner joints + FB subs with pre-installed Fishbone assemblies
 - Fast and operationally straightforward deployment as open hole liner system.
 - Rapid pumping program needing only 2-6 hours to create all drilled or jetted laterals
 - Can rapidly create 100's of laterals in wide range of rock types
 - Works well in vertical, deviated and horizontal wellbores
-
- Hydraulic fracturing is a sensitive issue in Europe, also for Geothermal wells
 - Fishbone completion & stimulation delivers significant improvement in well performance with simple and rapid deployment, lower cost and no regulatory issues
 - Especially effective for reservoir stimulation in layered, naturally fractured and laterally heterogeneous reservoir types - typical of many geothermal development targets in Germany

Simulation technology

Simfish reservoir simulator

- ✓ Developed by Fenix Consulting Delft
- ✓ Uses Sintef MRST simulator
- ✓ Fishbones vs. Open hole
- ✓ Estimates rates, PI increase and incremental production
- ✓ Producers and injectors
- ✓ Generates Eclipse compatible wellbore geometry

