Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

Novel One-Trip Sidetracking System for Multi-Lateral Closed-Loop Geothermal Wells

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INTRODUCTION

Closed-loop geothermal systems require dense multi-lateral well architectures, often involving multiple casing exits from a single vertical well. Conventional sidetracking relies on separate trips for whipstock deployment, casing window milling, and directional drilling, leading to excessive rig time, increased operational risk, and escalating well construction costs (Miller).

For example, an ongoing Eavor-Loop development in Bavaria, Germany, requires eight main wells with eleven casing exits each — amounting to 176 individual trips if executed using conventional methods — highlighting a major bottleneck to the scalable and cost-effective deployment of closed-loop wells (Figure 1).

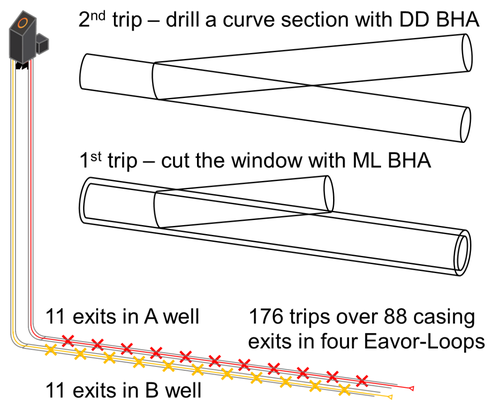


Figure 1. Problem statement for CLGS.

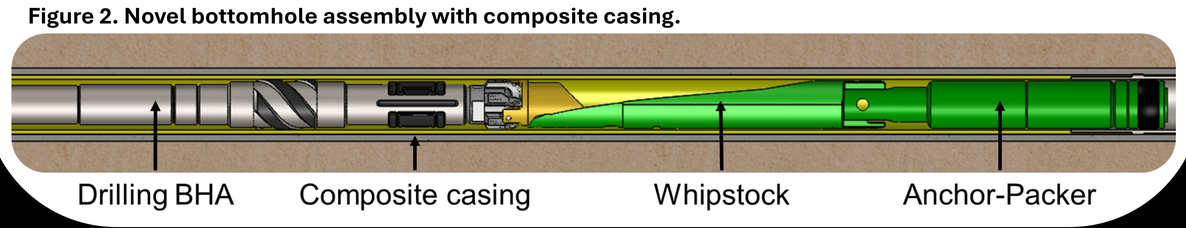
Objective: Develop a one-trip sidetracking system to set a whipstock and anchor-packer, mill a casing window, and drill an extended-reach lateral in a single continuous run to total depth. This approach is expected to reduce sidetrack-related operational time by approximately 50% while maintaining directional control, window quality, and long-lateral drilling performance.

METHODS

The proposed solution is a one-trip integrated bottom-hole assembly (BHA) designed to mill a casing window and drill an extended-reach lateral without pulling out of hole (Dewey, 2011). The system combines a retrievable whipstock with a hydraulic anchor/packer, a locked RSS drilling assembly, and a millable bit-to-whipstock connector that enables seamless transition from milling to drilling (Swadi, 2014). Once the composite casing window is milled, the same PDC bit continues drilling the lateral to total depth, eliminating the need for additional trips.

Composite casing is a key enabler of this approach, offering improved millability while preserving drill bit integrity for long lateral sections. In real-world applications, the composite casing must be cemented in place prior to sidetracking, and the subsequent milling and drilling operations are performed using the same drilling BHA to directly compare one-trip performance against conventional two-trip sidetracking workflows (Figure 2).

Figure 2. Novel bottomhole assembly with composite casing.



RESULTS

After multiple design iterations and final prototype manufacturing, four bench tests were conducted in 2025 in Houston (USA) to iteratively validate the integrated one-trip sidetracking system. The test setup included cemented composite casing, a full-scale horizontal drilling test fixture, and the integrated directional milling-and-drilling BHA with an RSS for controlled steering (Figure 3).

The final testing simulated downhole drilling parameters, confirmed that the bit-to-whipstock connector sheared precisely at the design load, meeting the targeted shear specification. RSS steering successfully guided the bit through the connector and away from the whipstock, enabling smooth ramp engagement without damage to the PDC cutting structure. During milling, connector fragments were effectively managed and milled, with no formation of long debris wedges observed (Figure 4). Following window milling and connector removal, the PDC bit remained operational, exhibiting only minor wear on sacrificial shoulder cutters while the primary cutting structure remained intact.



Figure 3. Bench test of novel one-trip sidetracking system.





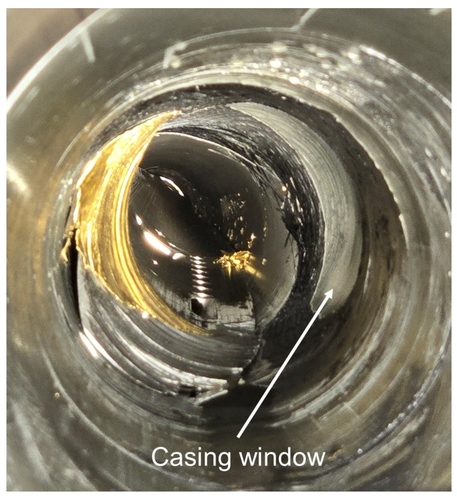
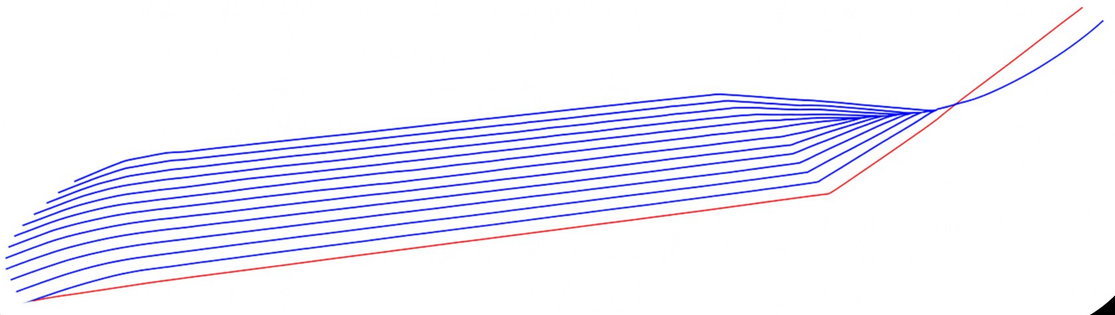


Figure 4. Bench test results with PDC bit wear and casing window geometry.

DISCUSSION

The bench test results validated the core premise of one-trip sidetracking: a controlled transition from casing window milling to extended lateral drilling is achievable using RSS steering in combination with a millable connector. RSS steerability played a critical role in minimizing whipstock contact and reducing the risk of PDC cutter damage during ramp engagement.

The tests also highlighted the importance of connector retention features to ensure that milled material remains captive during milling, preventing the generation of free debris. Overall, the results confirm that casing window milling can be effectively combined with extended lateral drilling in a single run, provided that BHA geometry, steering response, and material selection are properly optimized.

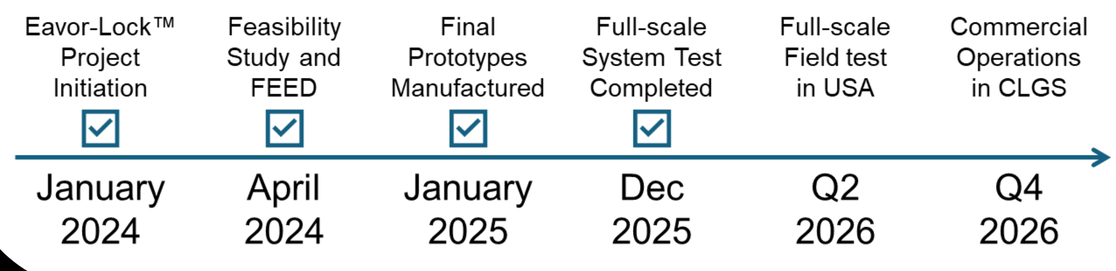


CONCLUSION

A one-trip whipstock milling and lateral drilling system was successfully designed and tested for closed-loop geothermal systems. The integrated BHA architecture eliminates redundant trips and is projected to reduce sidetrack-related operational rig time by approximately 50%.

Testing demonstrated reliable connector shear performance, controlled RSS steering during milling, and acceptable cutter condition following window exit. The system is scheduled for field trials in 2026, with repetitive deployment planned in Germany by year-end.

This technology represents a critical step toward factory-style geothermal well construction, accelerating learning curves and materially improving the economics of multi-lateral closed-loop geothermal projects.



Acknowledgements

The authors acknowledge Eavor Technologies for project sponsorship and technical leadership, our partners—Wellbore Integrity Solutions, Ulterra Drill Bits, Kinetic Upstream Technologies.

The authors further thank all additional project partners, laboratories, and service providers who contributed to the design, manufacturing, testing, and validation of the one-trip sidetracking system. Finally, sincere appreciation is extended to the multidisciplinary engineering, operations, and testing teams whose collaboration and technical rigor enabled the development and qualification of this technology.

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