Paving the Way for Electro Pulse Power Drilling: Techno-Economics and Environmental Assessment - Project DEEPLIGHT

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The Deeplight Project

- DEEPLIGHT project (2023-2026) formed a consortium of technology developers, researchers, operational experts, implementer
- Delivery of an integrated EPP drilling system tested at full scale in a realistic operational environment
- Full Overview given by Frank v. Bergen (TNO) - *Novel Concepts to Construct Cost-Effective Geothermal Wells with Electro Pulse Power Technology - Project DEEPLIGHT*

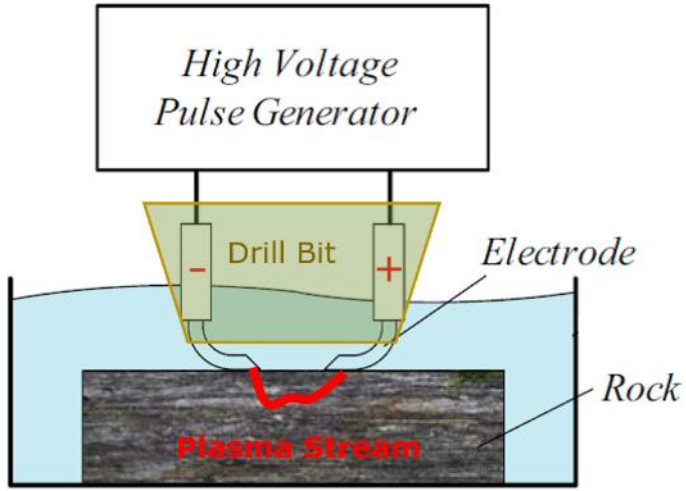


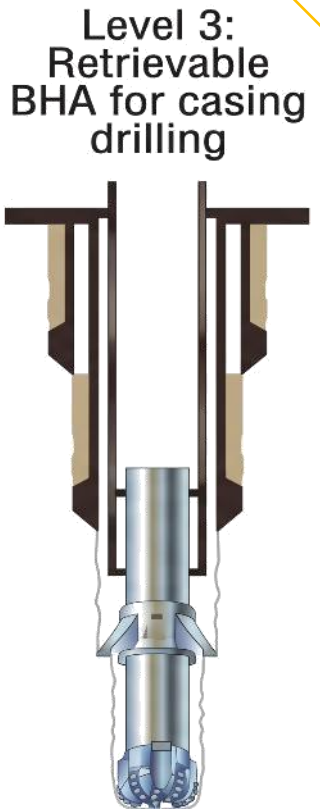
The Deeplight Project

Electro Pulse Power (EPP) produces discharges within rock matrix leading to spallation of rock fragments in tensile mode.

- Energy efficient hard rock drilling
- BHA integration – powered by mud stream
- Contactless – No mechanical wear – long bit life – long sections
- Low torque – Enabler for Casing-while-Drilling (CwD)







Retrievable Directional

- Steerable BHA locked within casing shoe
- Hydraulic Underreamer expands hole past casing OD
- Wireline retrievable

The Economic Case for EPP-CwD Drilling

Economic and Environmental Benefits using EPP-CwD, compared against conventional Rotary drilling



20,000 simulated wells, per technology

A Monte Carlo model runs 20.000 randomised wells each for Rotary, EPP, or EPP-CwD Drilling



Sampled, genuine uncertainty

Rate of penetration, Bit / BHA (EPP) life, and non-productive time are drawn from realistic distributions.



Realistic, representative well designs

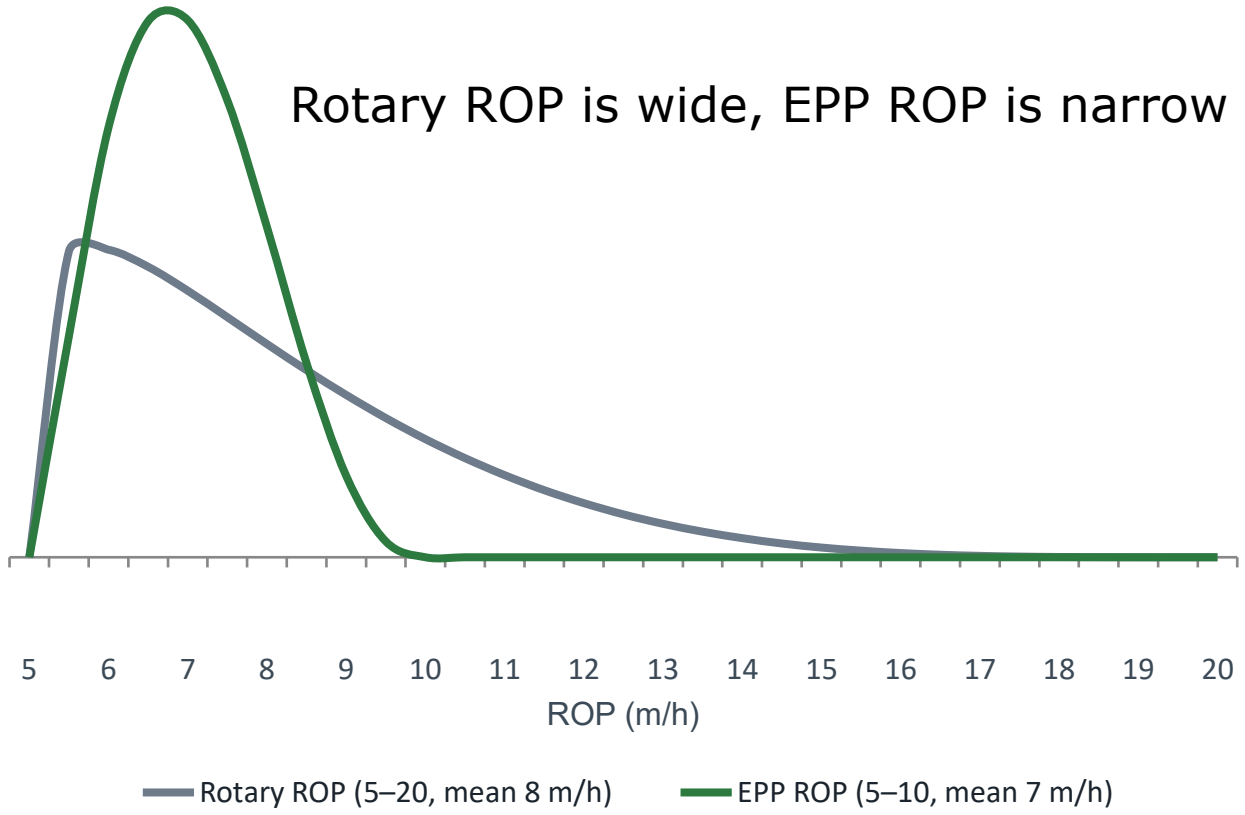
For three partner countries a realistic geothermal well design is selected. Two hypothetical ultra-deep cases are added.



Benchmarked against the field

Cost and duration assumptions are checked against published drilling data. CO_2-eq and energy/fuel consumption derived from literature.

Uncertainty inputs



Input	Min	Most likely	Max	Mean
Rotary ROP (m/h)	5	5.75	20	8
EPP ROP (m/h)	5	6.75	10	7
Bit / electrode life (× base)	0.6	1.0	1.4	1.0
NPT (% of operating time)	15%	30%	40%	29%
Rig day rate (€k per day)	30	35	40	35
Rotary ROP in the Dutch top hole (m/h)	30	35	70	40

- Beta-PERT distribution; the most-likely ROP is derived from the mean.
- One ROP draw per technology applies to the whole well in an iteration. In the soft Dutch top hole (S2 of Cases 1 and 4) Rotary uses its own 30–70 m/h range; EPP keeps 5–10 m/h.
- Life, NPT and day-rate draws are shared by Rotary and EPP.
- CwD sections use a lower NPT rate.

Four selected cases: 2.2 km – 6.0 km

Case 1 · Netherlands

–€79k

mean saving per well

-1.4% of well cost
EPP cheaper in 1% of runs
2.0 days longer

Case 2 · Turkey

€96k

mean saving per well

1.5% of well cost
EPP cheaper in 75% of runs
1.9 days shorter

Case 3 · Iceland

€141k

mean saving per well

3.3% of well cost
EPP cheaper in 71% of runs
1.6 days shorter

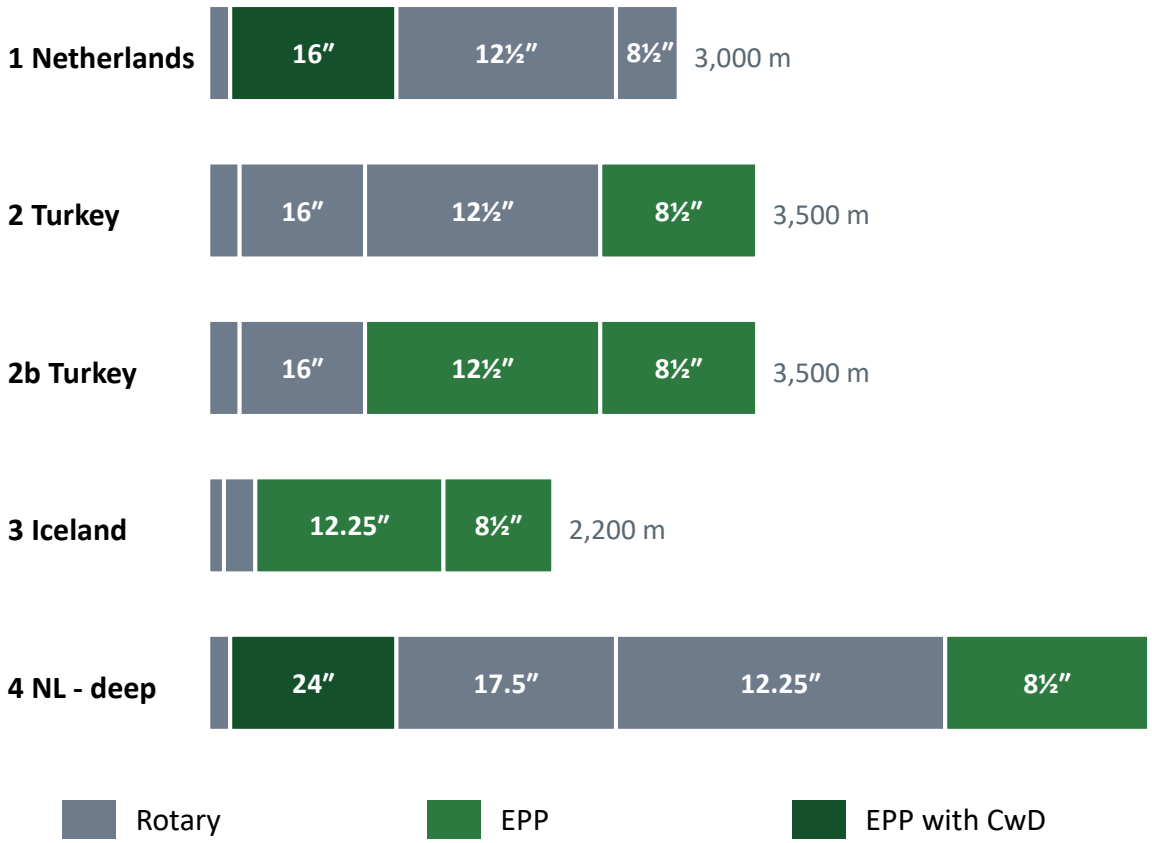
Case 4 · Netherlands ultra-deep

€154k

mean saving per well

1.2% of well cost
EPP cheaper in 74% of runs
2.8 days shorter

Section lengths by technology (top to bottom = shallow to deep)



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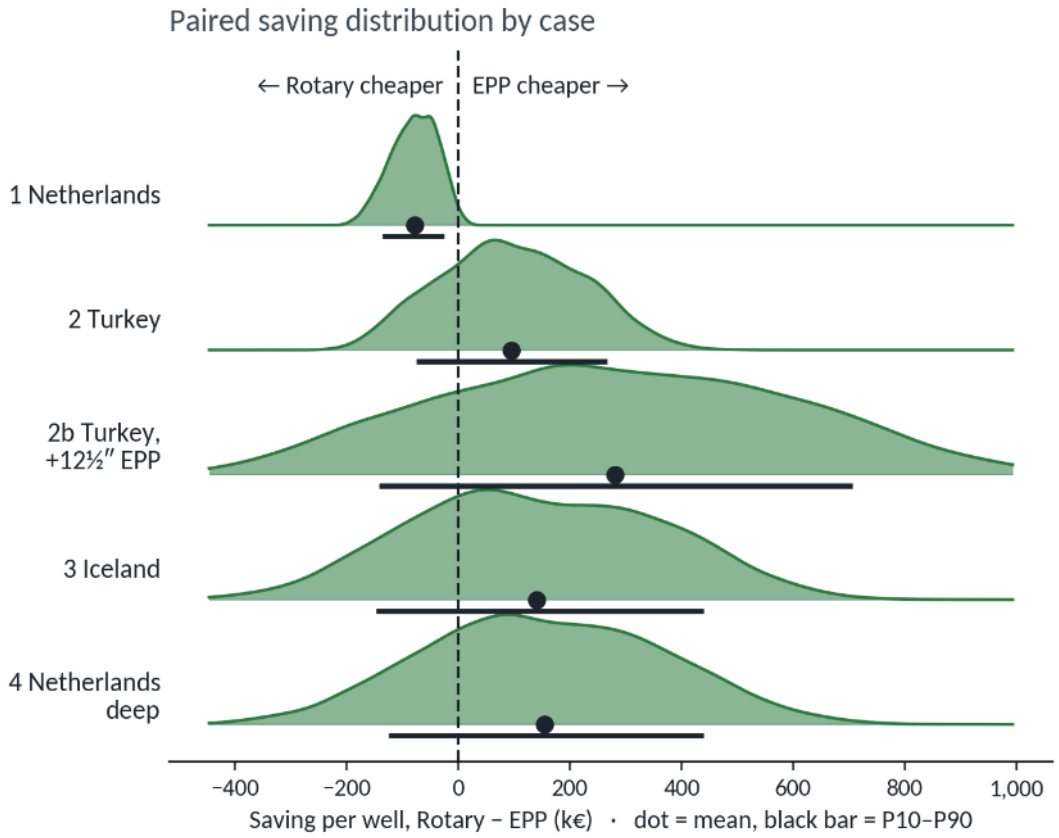
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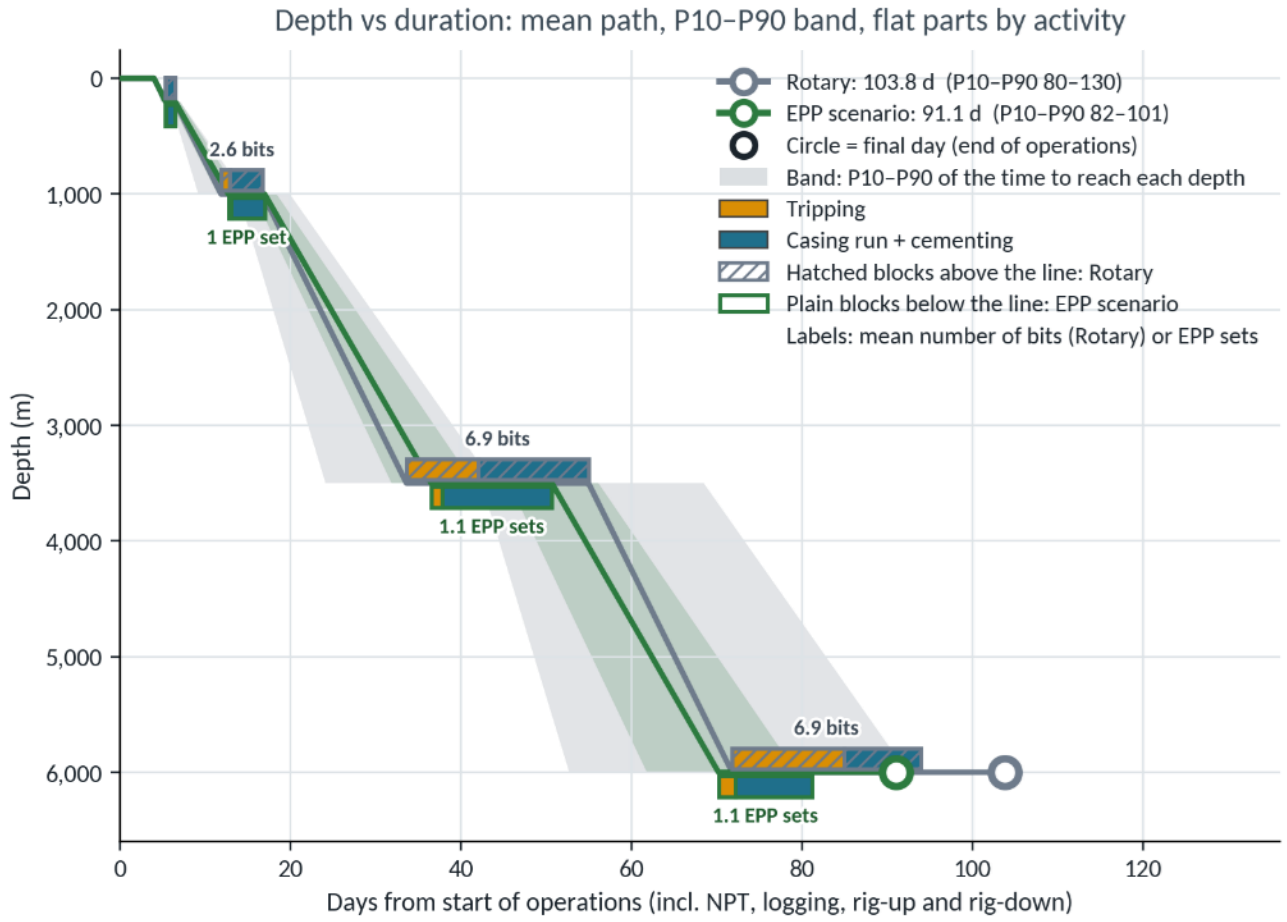
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Hypothetical deep, hard rock case: 6 km



Effect of the higher Rotary max ROP

	Rotary max 20 m/h (project)	Rotary max 25 m/h (Case 5)
Rotary ROP mean	8.0 m/h	8.8 m/h
Rotary well cost	€9.68M	€9.47M
EPP scenario cost	€8.69M	€8.68M
Mean saving	**€992k (10.2%)**	**€789k (8.3%)**
EPP cheaper in	88% of runs	79% of runs
Well duration	108 → 91 d	104 → 91 d

Mean saving

€789k

8.3% of well cost

EPP cheaper in

79%

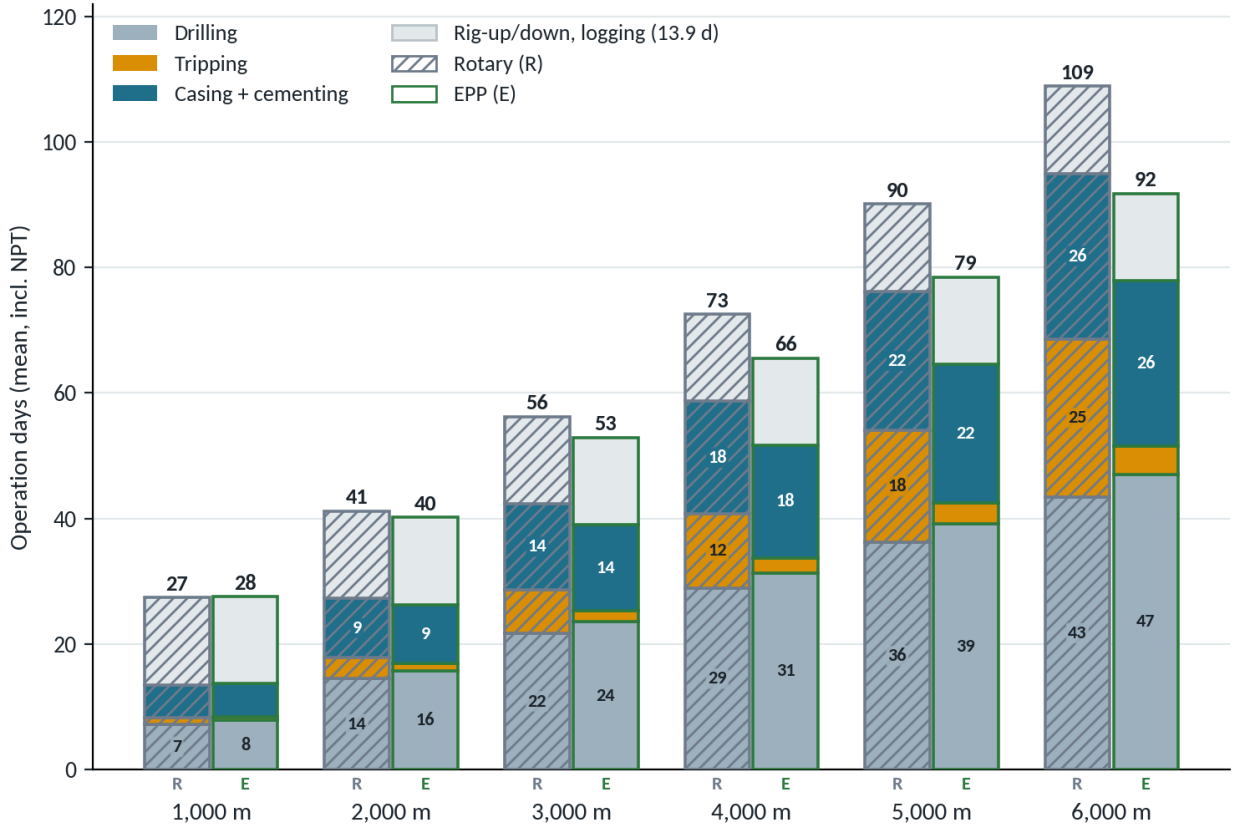
of 20,000 runs

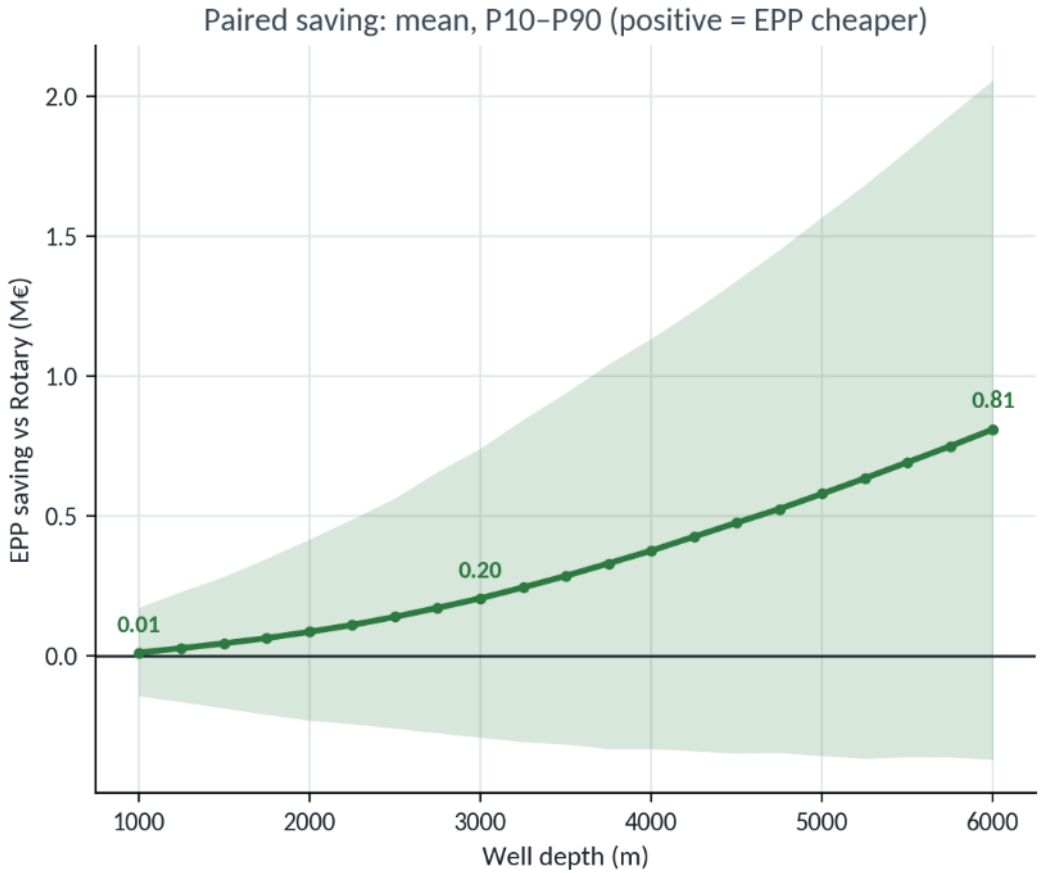
Time saved

12.7 d

104 → 91 d total

Well cost & EPP savings grow with depth





The CO_2-eq assessment reuses the cost model

1 Cost-model draws

ROP, bit and electrode life, NPT: 20,000 shared random draws per case

→

2 Activity model

Hours of drilling and tripping, bits and electrode sets, hole volume

→

3 Inventory

Diesel L at cost-model rates, steel, cement, mud, tools, cuttings, transport

→

4 Emission factors

Min / likely / max for every other input (Beta-PERT), shared by both technologies

→

5 Footprint

t CO2e per well, Rotary and EPP; difference per run

Input	Unit	Min	Likely	Max
Mud pumps while drilling	L diesel/h	fixed	271	fixed
Top drive, Rotary only	L diesel/h	fixed	113	fixed
Tripping (hoisting and pumps)	L diesel/h	fixed	86	fixed
Auxiliaries, every hour of the well	L diesel/h	fixed	49	fixed
Diesel emission factor	kg CO2e/L	2.90	3.08	3.40
Casing steel	kg CO2e/kg	1.80	2.05	2.30
Cement	kg CO2e/kg	0.75	0.82	0.90
Grid factor NL / TR / IS	kg CO2e/kWh	0.20 / 0.38 / 0	0.27 / 0.45 / 0.02	0.35 / 0.55 / 0.03

Reduced CO_2-eq with EPP in 5 of 6 cases

1 Netherlands

−47 t

mean saving per well, t CO2e

−3.3% of the Rotary footprint
EPP lower in 0% of runs

2 Turkey

+55 t

mean saving per well, t CO2e

+2.7% of the Rotary footprint
EPP lower in 81% of runs

3 Iceland

+85 t

mean saving per well, t CO2e

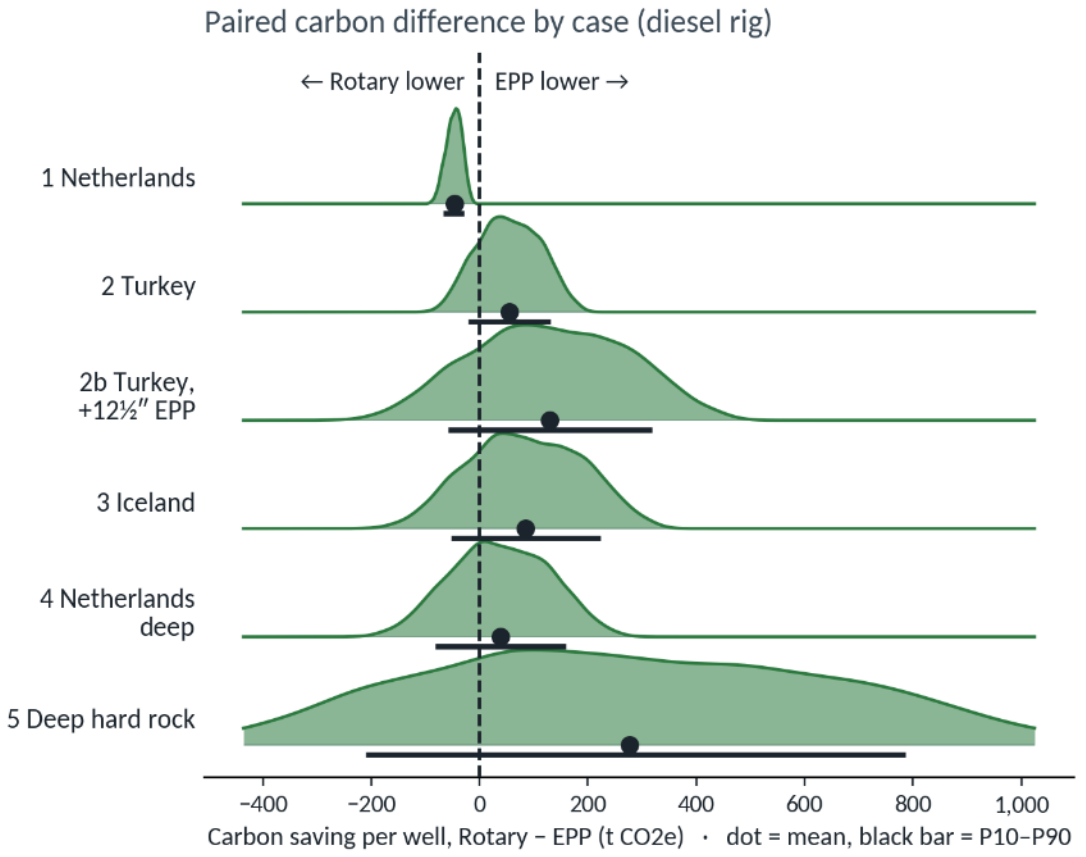
+7.3% of the Rotary footprint
EPP lower in 77% of runs

4 Netherlands deep

+38 t

mean saving per well, t CO2e

+0.9% of the Rotary footprint
EPP lower in 64% of runs



CO_2-eq cuttings by switching the rig to its national e-grid

Case	Grid	Rotary diesel	Rotary e-rig	Footprint cut	EPP – Rotary diesel	EPP – Rotary e-rig
1 Netherlands	NL	1,444	1,072	−26%	+47	+20
2 Turkey	TR	2,022	1,624	−20%	−55	−28
3 Iceland	IS	1,166	645	−45%	−85	+4.8
4 Netherlands deep	NL	4,212	3,304	−22%	−38	−0.9
5 Deep hard rock	TR	3,040	2,385	−22%	−276	−136

- Units are t CO2e per well. Each litre of diesel is replaced by 3.6 kWh at the country's grid factor (NL 0.27, TR 0.45, IS 0.02 kg/kWh).
- On the nearly carbon-free Icelandic grid rig energy almost vanishes. EPP and Rotary then differ by about 5 t (Case 3). The EPP tool body is no longer offset by diesel savings.
- On a coal-heavy grid electricity would be worse than diesel. Not run here.
- Key leaver for reduction of carbon footprint for well construction is rig electrification and a low-carbon grid electricity.

A promising case resting on prov. EPP data

EPP eliminates tripping

EPP drills slightly slower but its extended BHA EPP lifetime cuts tripping time (often one trip per section). The saving outweighs the slower drilling.

ROP dominates the uncertainty

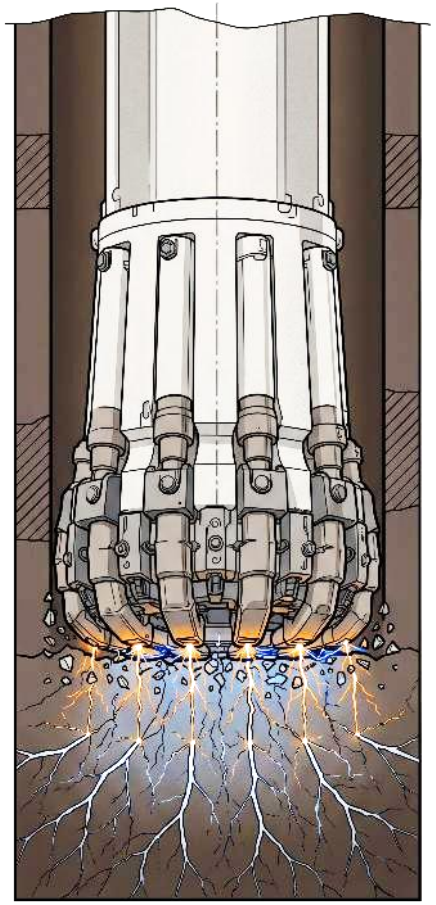
Rate of penetration (ROP) drives drilling cost variance. Rotary bit and EPP BHA cost barely move the outcome for either technology.

EPP's advantage is robust

A large swing in EPP's performance & costs assumptions is required to lose its edge over rotary drilling median cost.

EPP has environmental benefits, but e-rigs are key

Main CO_2-eq reduction is driven by electrification and grid factor. Footprint of deep, hard rock wells will benefit from EPPs reduced operational time & lower energy for rock removal.



Novel concepts to construct cost effective geothermal wells with Electro Pulse Power Technology

Deep Light

Thank you for your attention

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