St1 Deep Heat Oy

First deep geothermal project in Scandinavia

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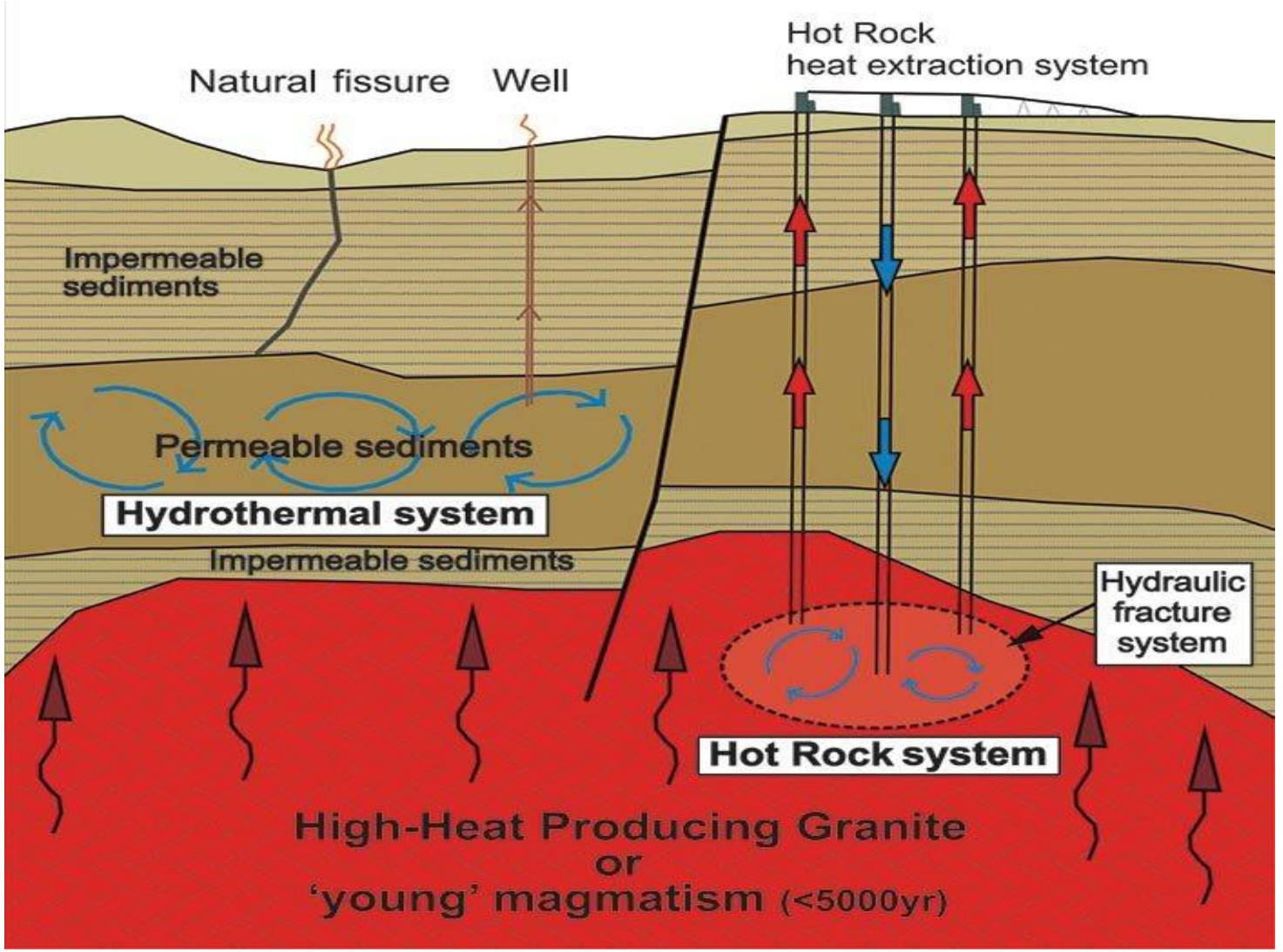
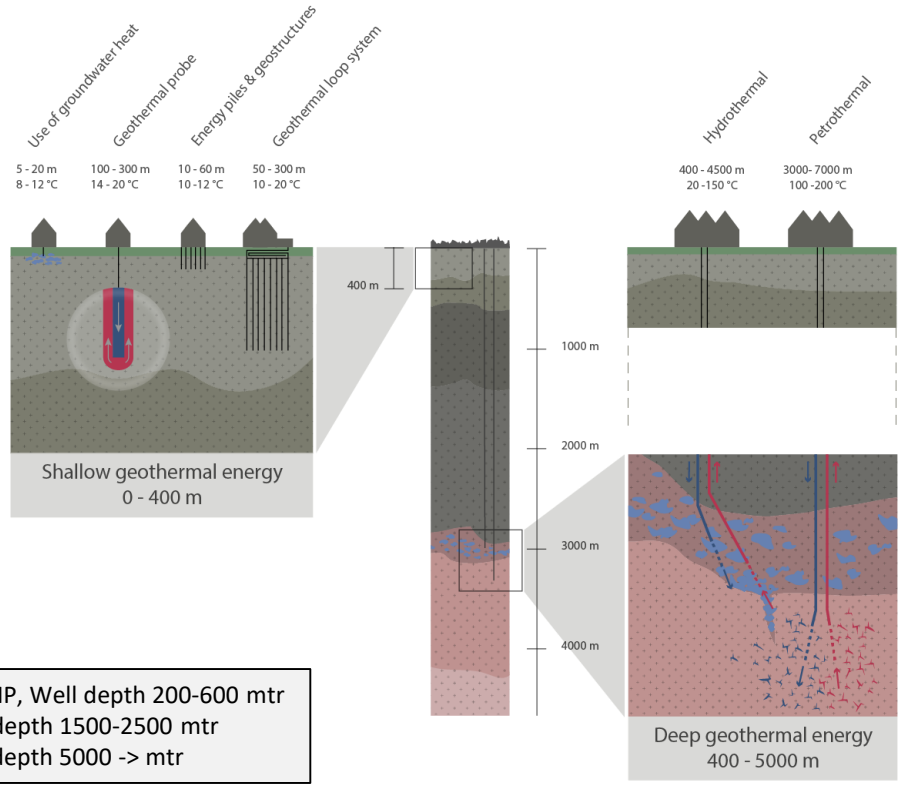
Basics and Otaniemi Project

Engineered Geothermal System – EGS - Basics



Geoscience Australia

Geothermal heat – Technologies to be involved in



- Shallow well technology -> GSHP, Well depth 200-600 mtr
- Mid Deep tech. -> GSHP, Well depth 1500-2500 mtr
- Ultra Deep tech. -> EGS, Well depth 5000 -> mtr

$$P \sim \eta * c * \Delta T * \dot{m}$$

Power ~ efficiency * specific heat capacity * temperature drop * mass flow

40 MW_T (> 80% Heat) (~ 100 C) (> 100 l/s)

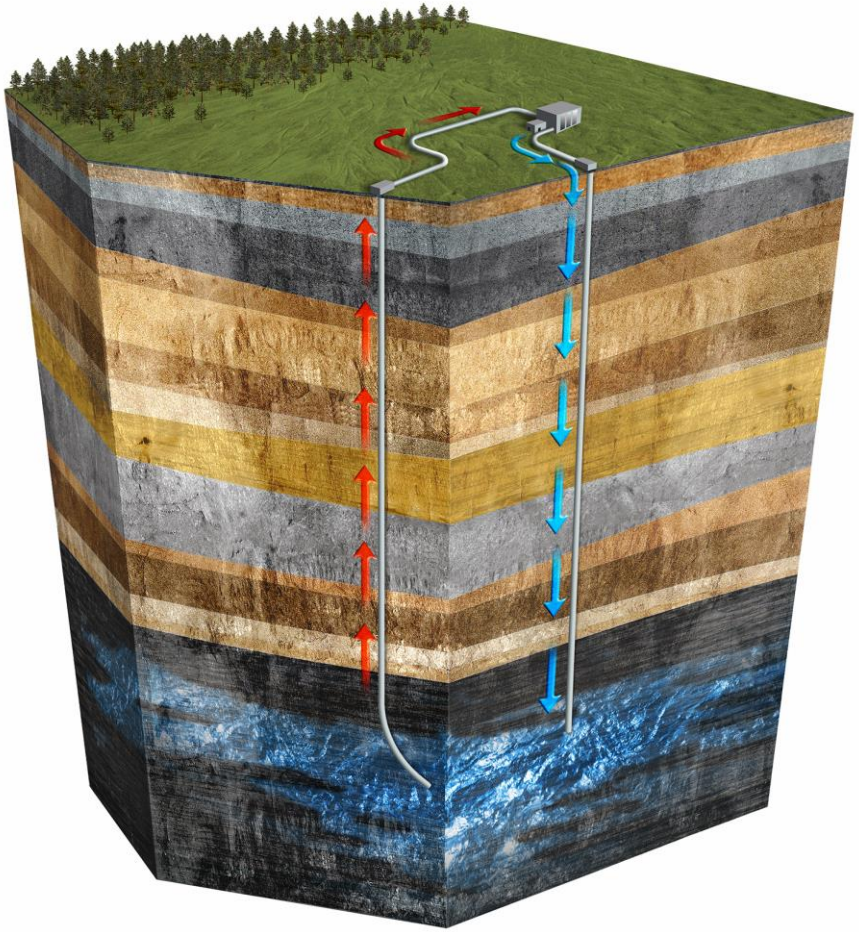
4 MW_E (<10% Electric) " "

1 liter of 100 ˚C water → 0.3 MJ

1 liter of crude oil → 30 MJ

Oil/Water = 100 / 1 (E are about the same)

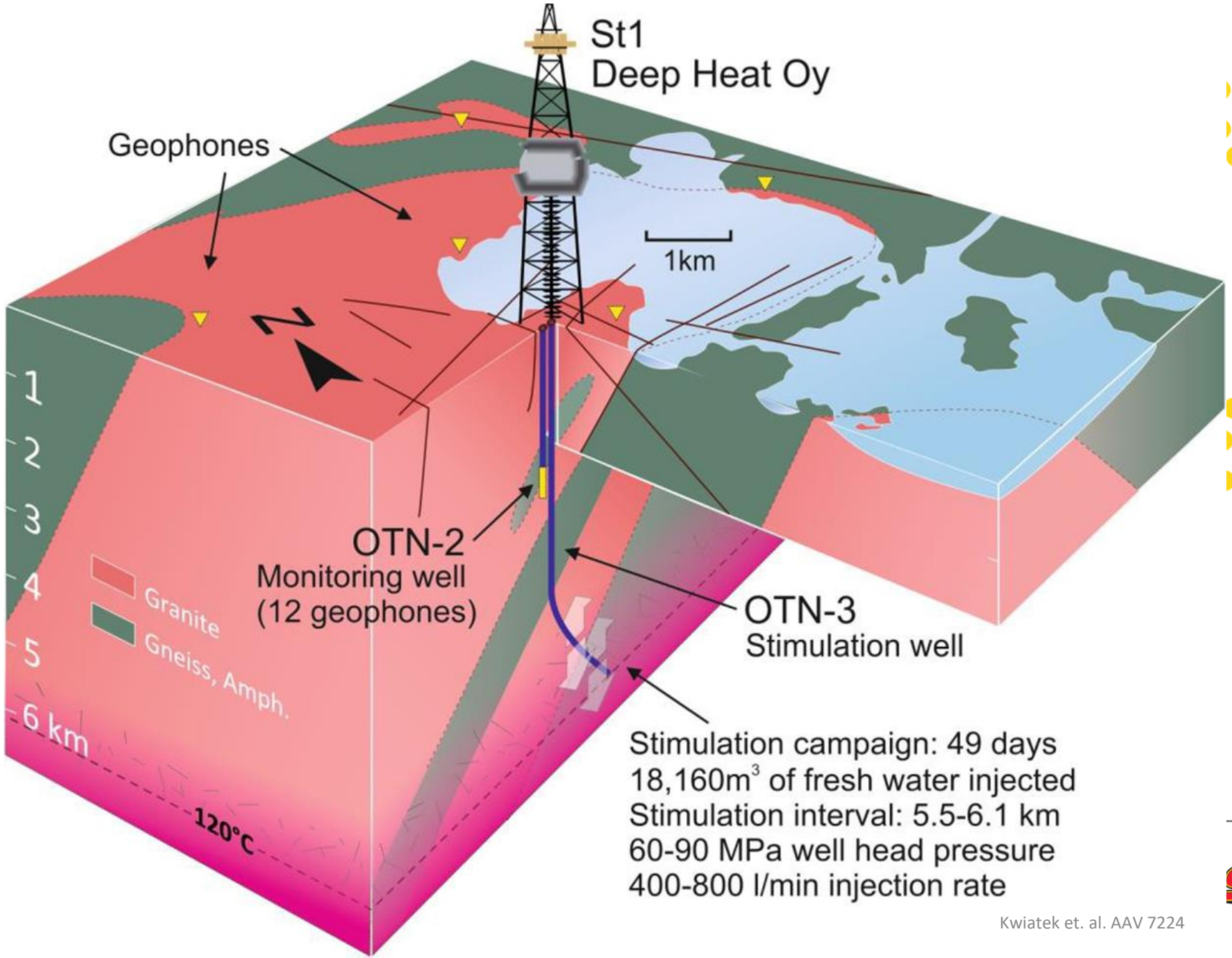
→ 100 l/s to match!



St1 Deep Heat project: plant concept

- St1 concept is basically an 40 MW EGS (Enhanced Geothermal System) heat plant
  - This gives better efficiency for the plant and allows more electricity to be used in pumping
- Finnish district heating networks are all designed with maximum temperature 120 °C and normal maximal operating temperature is around 115 °C.
  - Summer time minimum temperature is 75 °C
  - This causes the need to drill as far down as 6400 m in Southern Finland

YouTube: ”St1 Value Chain”

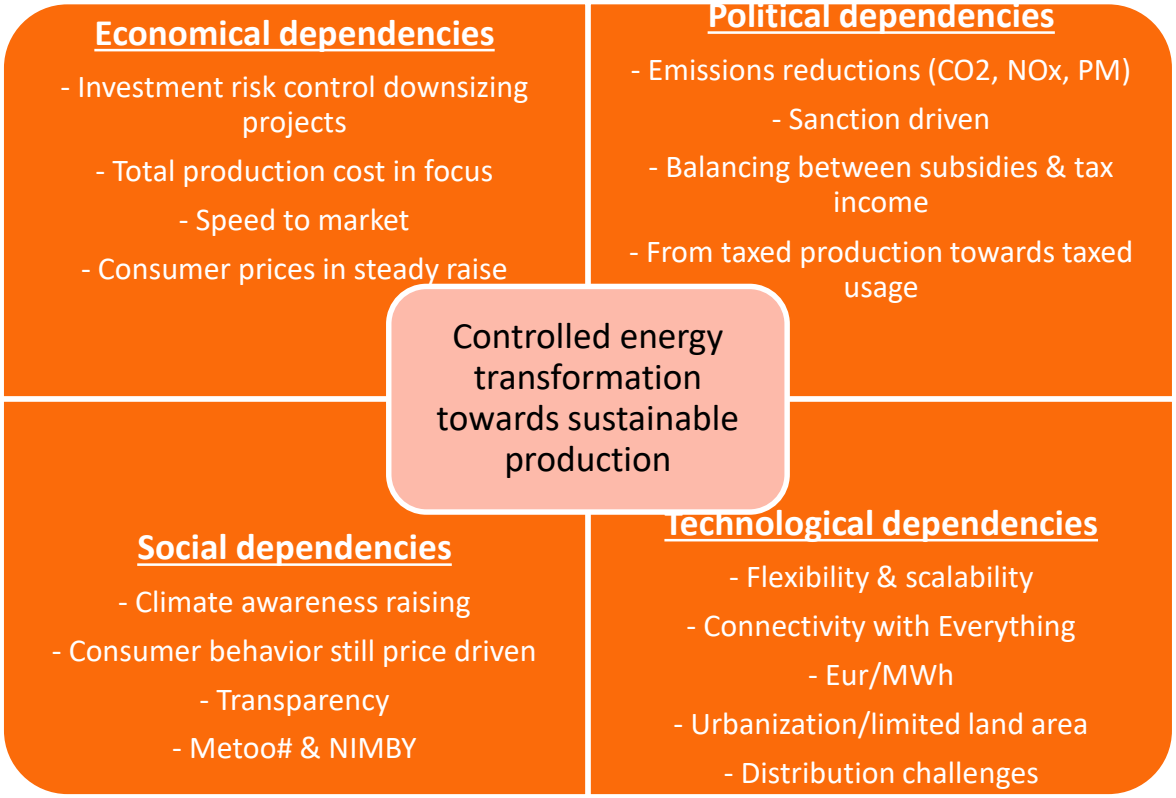


Kwiatek et. al. AAV 7224

Drilling Efficiency

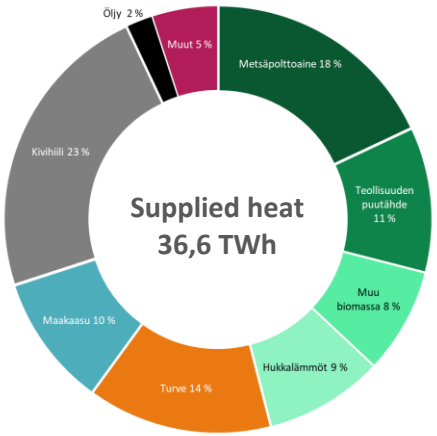
Market potential

Market environment – areas of consideration



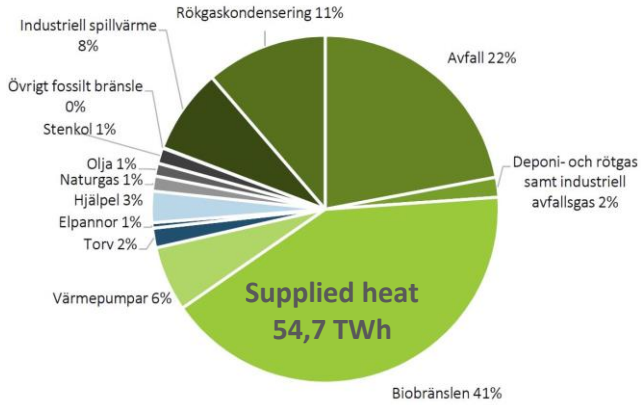
Market environment – District heating Fi & Swe

Fi



- Fading energy sources
  -> Oil, ongoing
  -> Coal , by 2029
  -> Peat, by 2040 est.
  -> Gas, tba
  -> Biomass, tba
- Amount of buildings attached to DH steadily growing

Swe

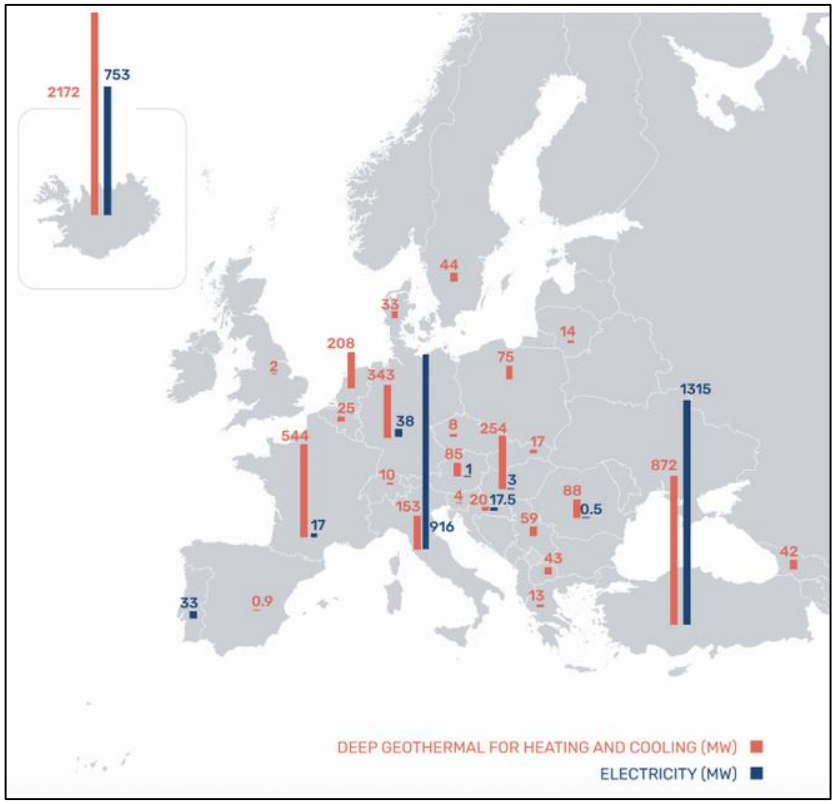


- Existing potential for EGS
  - Nordics 10+ plants
  - CE; Ger, Swi, Turkey….. 20+ plants
- Bottle necks
  - Capacity of deep drilling equipment
  - Engineering capability for EGS

Geo-energy market situation in Europe and global

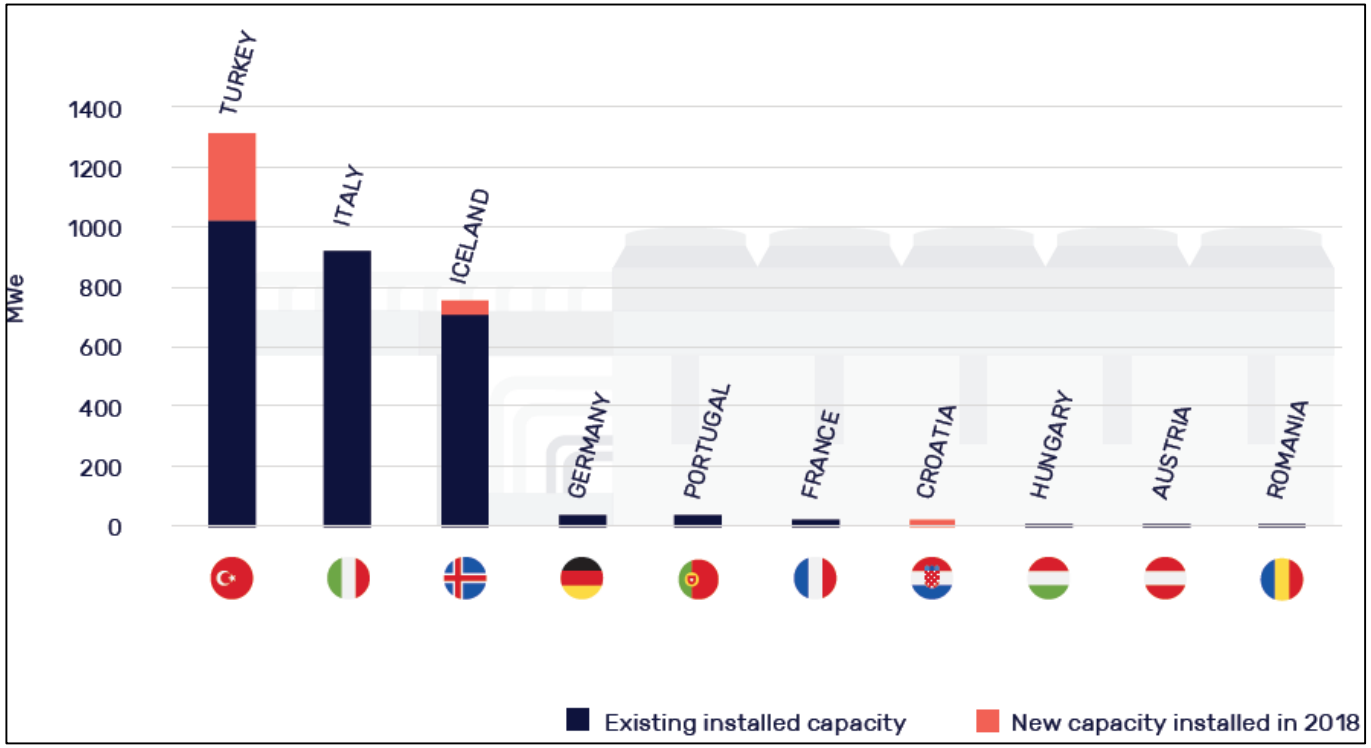
- Core markets have continued carrying developments in geothermal electricity, large geothermal heating and cooling projects and deployment of small scale geothermal heating and cooling systems.

- Meanwhile, the use of geothermal energy has also expanded geographically with such milestones as the commissioning of Croatia's first geothermal power plant during the year 2018.



Overview on geothermal capacity - power & heating
(Source: EGEC GEOTHERMAL MARKET REPORT – Key Findings, 2018)

Geo-energy market situation in Europe and global

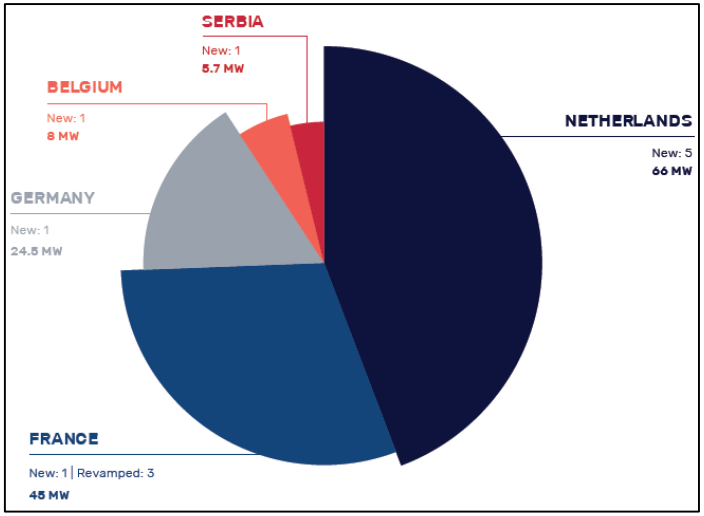


(Source: EGEC GEOTHERMAL MARKET REPORT – Key Findings, 2018)

Geo-energy market situation in Europe and global

- The EGEC Geothermal Market Report confirms the trend towards the steady growth observed in recent years, ***but also notes the need for greater recognition in order to enable the full deployment of geothermal energy in Europe***

(Source: EGEC GEOTHERMAL MARKET REPORT – Key Findings, 2018)



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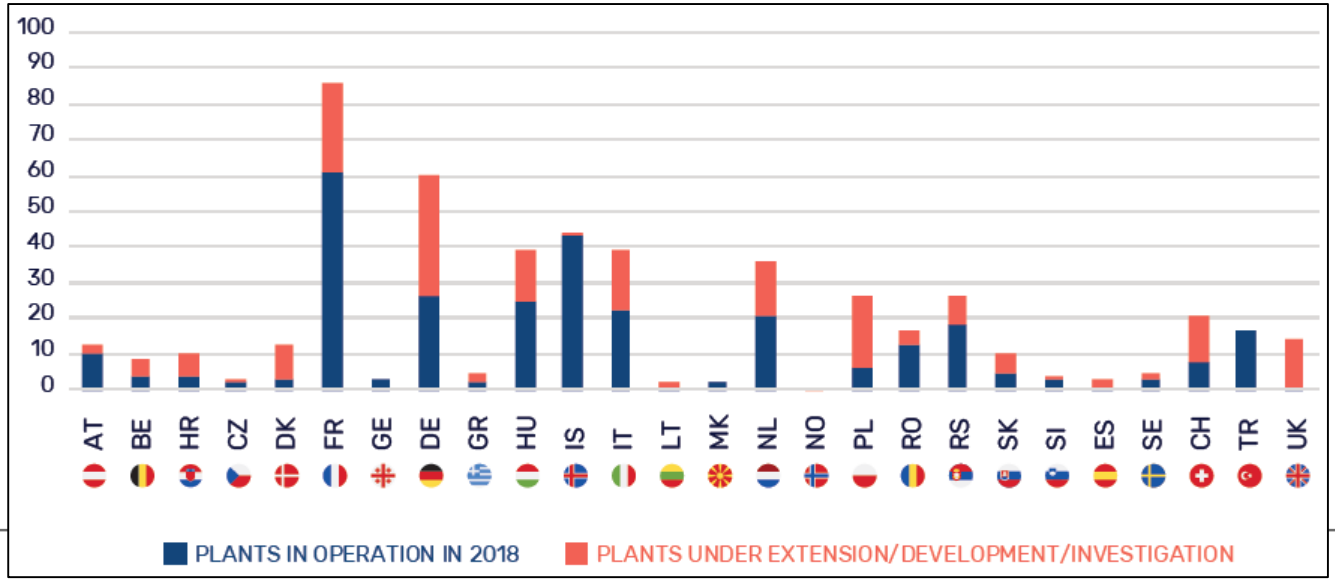
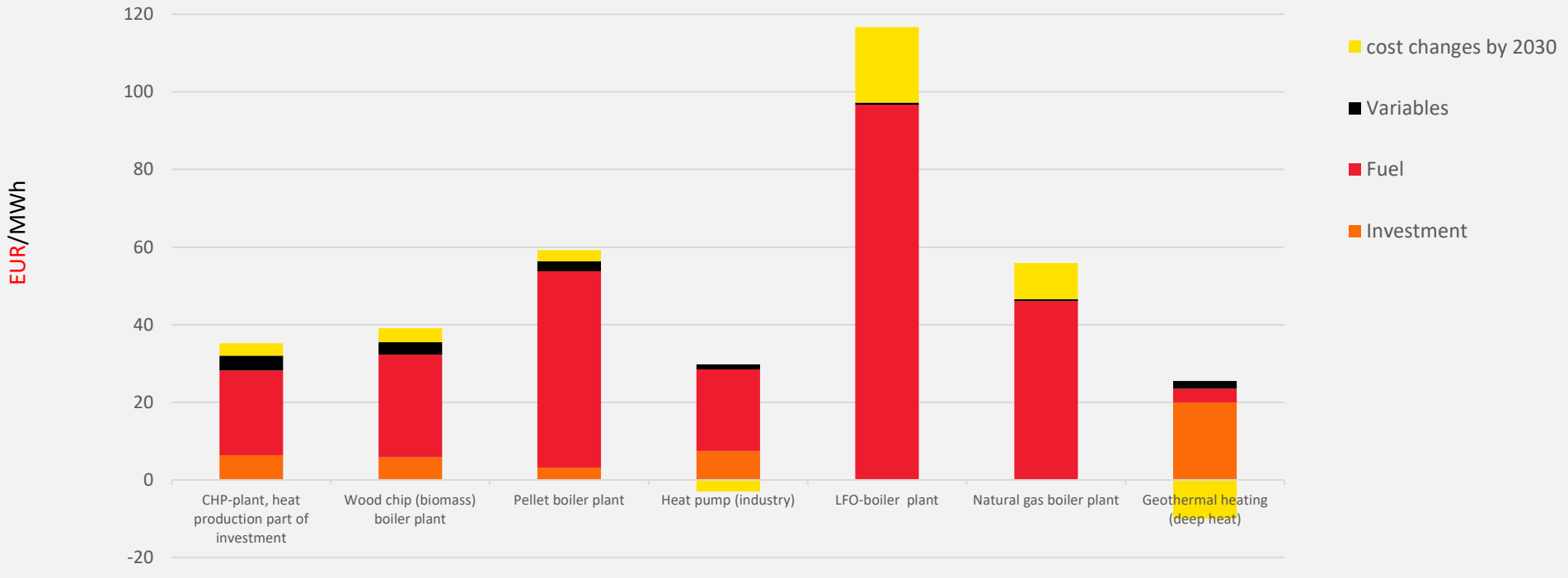
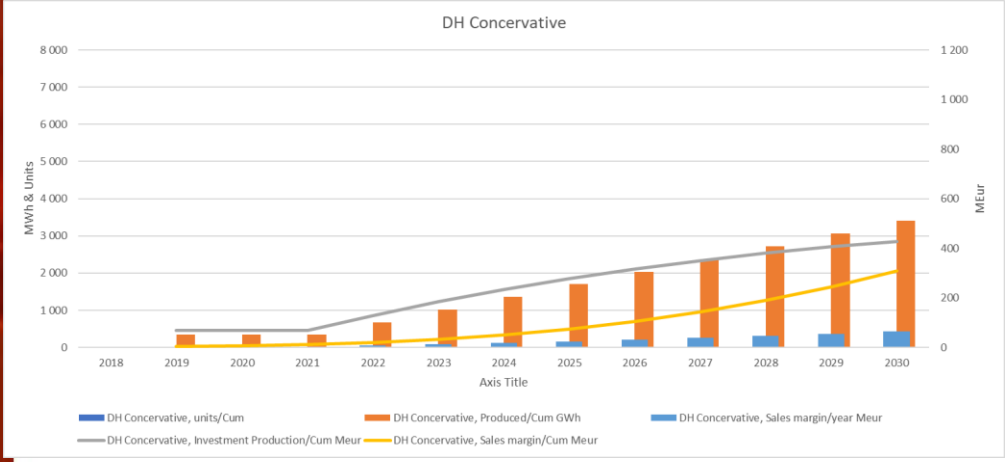


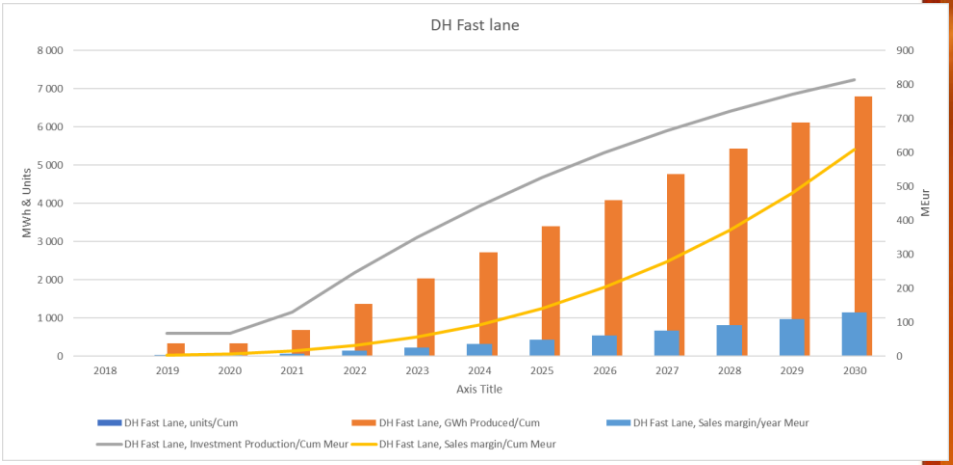
Geothermal heat – cost factor



- Geothermal will be the price setter
- Energy taxation driving change toward non-fossil (taxes incl. above)
- Target to build EGS plant with 1,0 Meur/MW during 202X

Growth potential - EGS





	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
DH Concervative, units/Cum	0	1	1	1	2	3	4	5	6	7	8	9	10
DH Concervative, Produced/Cum GWh	0	340	340	340	680	1 020	1 360	1 700	2 040	2 380	2 720	3 060	3 400
DH Concervative, Investment Production/Cum Meur		68,0	68,0	68,0	129,2	184,1	233,2	276,9	315,7	349,9	379,9	406,0	428,6
DH Concervative, Sales margin/Cum Meur		3,4	7,0	10,8	18,9	31,8	50,0	74,1	104,8	142,7	188,7	243,5	308,0
DH Concervative, Sales margin/year Meur		3,4	3,6	3,8	8,1	12,9	18,2	24,1	30,7	37,9	46,0	54,8	64,5

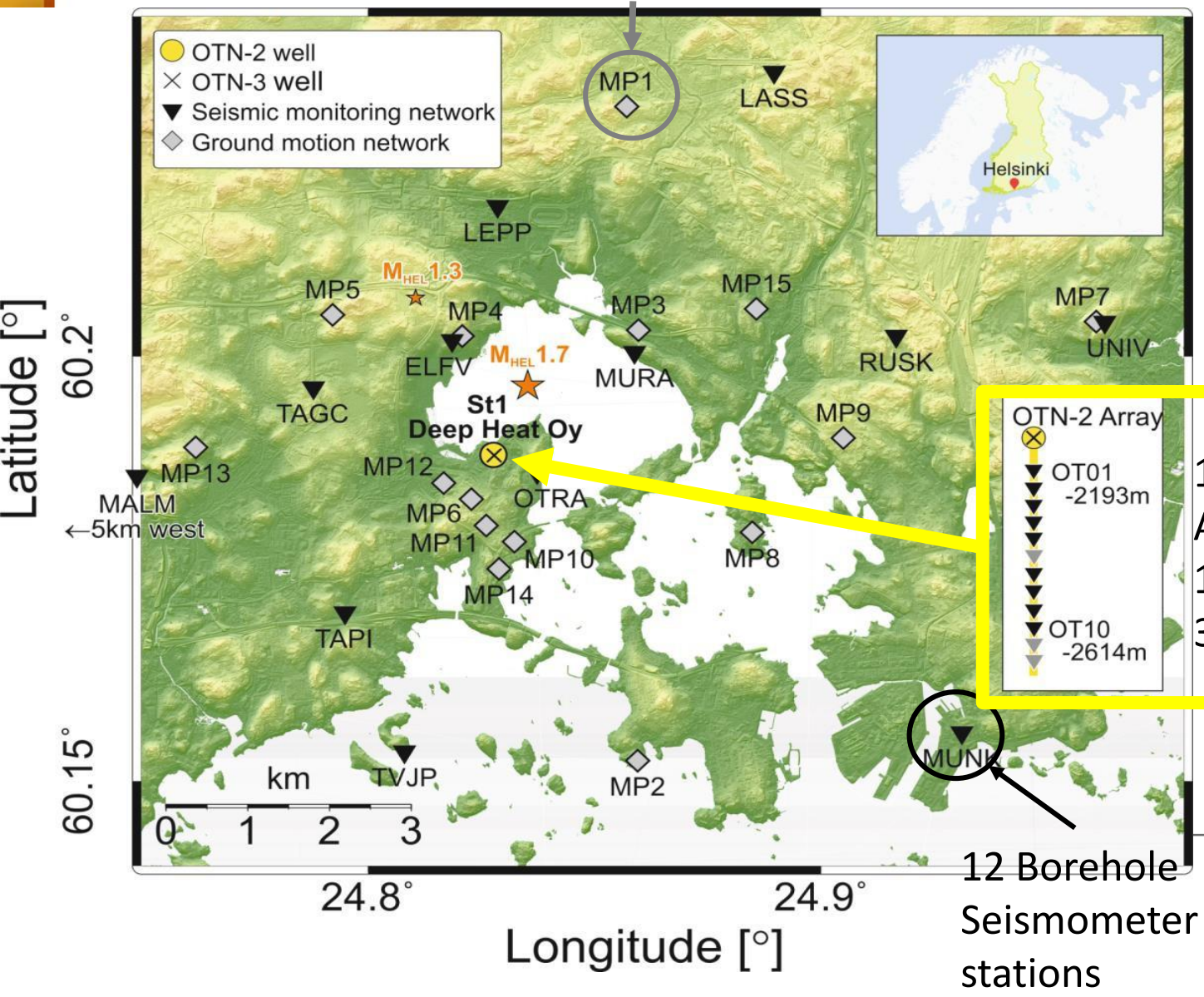
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
DH Fast Lane, units/Cum	0	1	1	2	4	6	8	10	12	14	16	18	20
DH Fast Lane, GWh Produced/Cum	0	340	340	680	1 360	2 040	2 720	3 400	4 080	4 760	5 440	6 120	6 800
DH Fast Lane, Investment Production/Cum Meur		68,0	68,0	129,2	245,5	349,8	443,1	526,2	599,8	664,8	721,8	771,4	814,3
DH Fast Lane, Sales margin/Cum Meur		3,4	7,0	14,6	30,8	56,6	93,0	141,2	202,6	278,4	370,3	479,9	609,0
DH Fast Lane, Sales margin/year Meur		3,4	3,6	7,6	16,2	25,8	36,4	48,2	61,3	75,9	91,9	109,6	129,1

- 1 unit -> 2 units / year
- Effect 40 MW/unit
- Inv. 2,2 Meur/MW -> 1,0 MEur/MW
- Running hours 8500/year
- Sales margin 10 -> 19 Eur/MWh

Seismics and Stimulation

Seismic Network

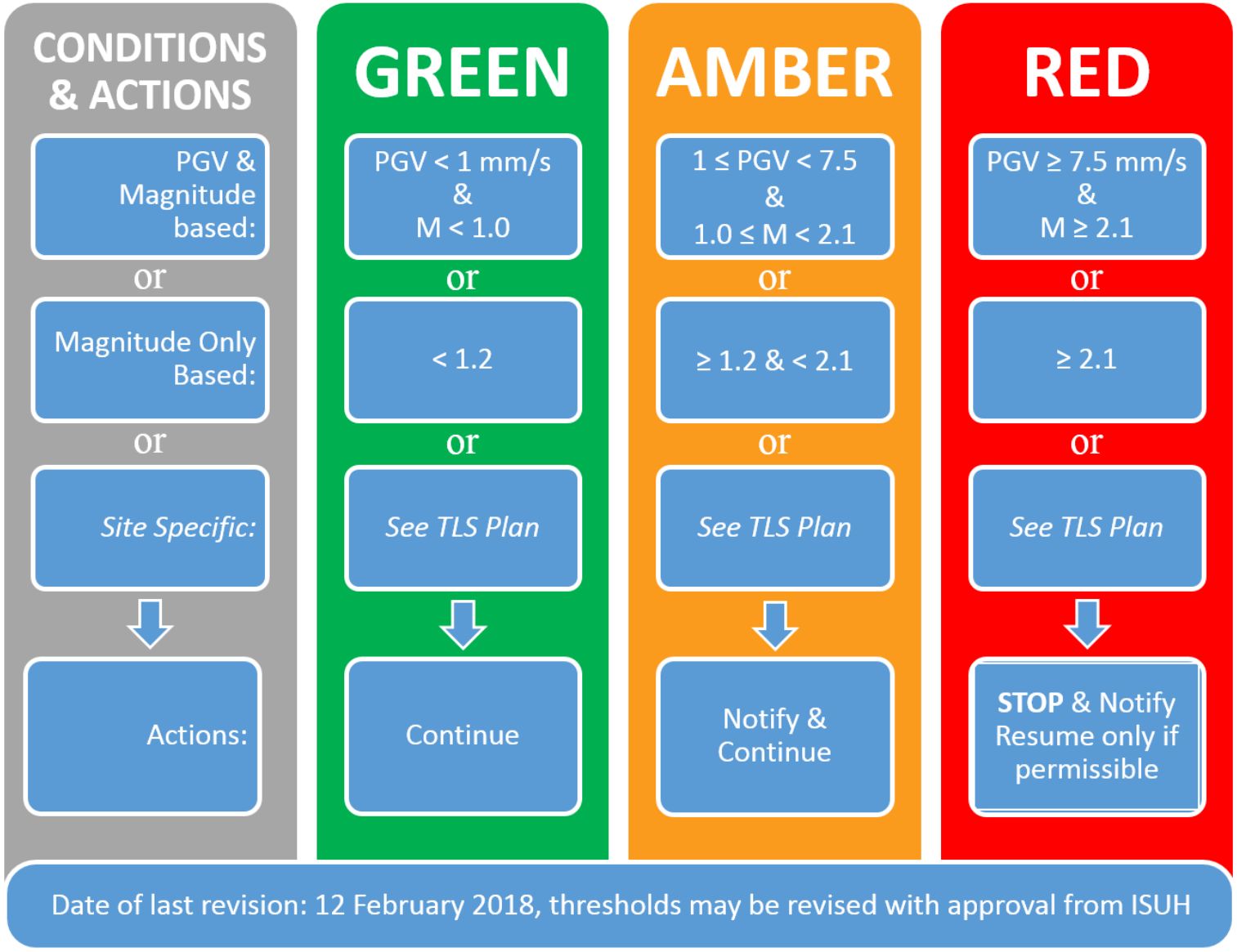
17 Surface PGV stations



1 Deep Array of 12 level 3C

12 Borehole Seismometer stations

Public Acceptance



Public Acceptance

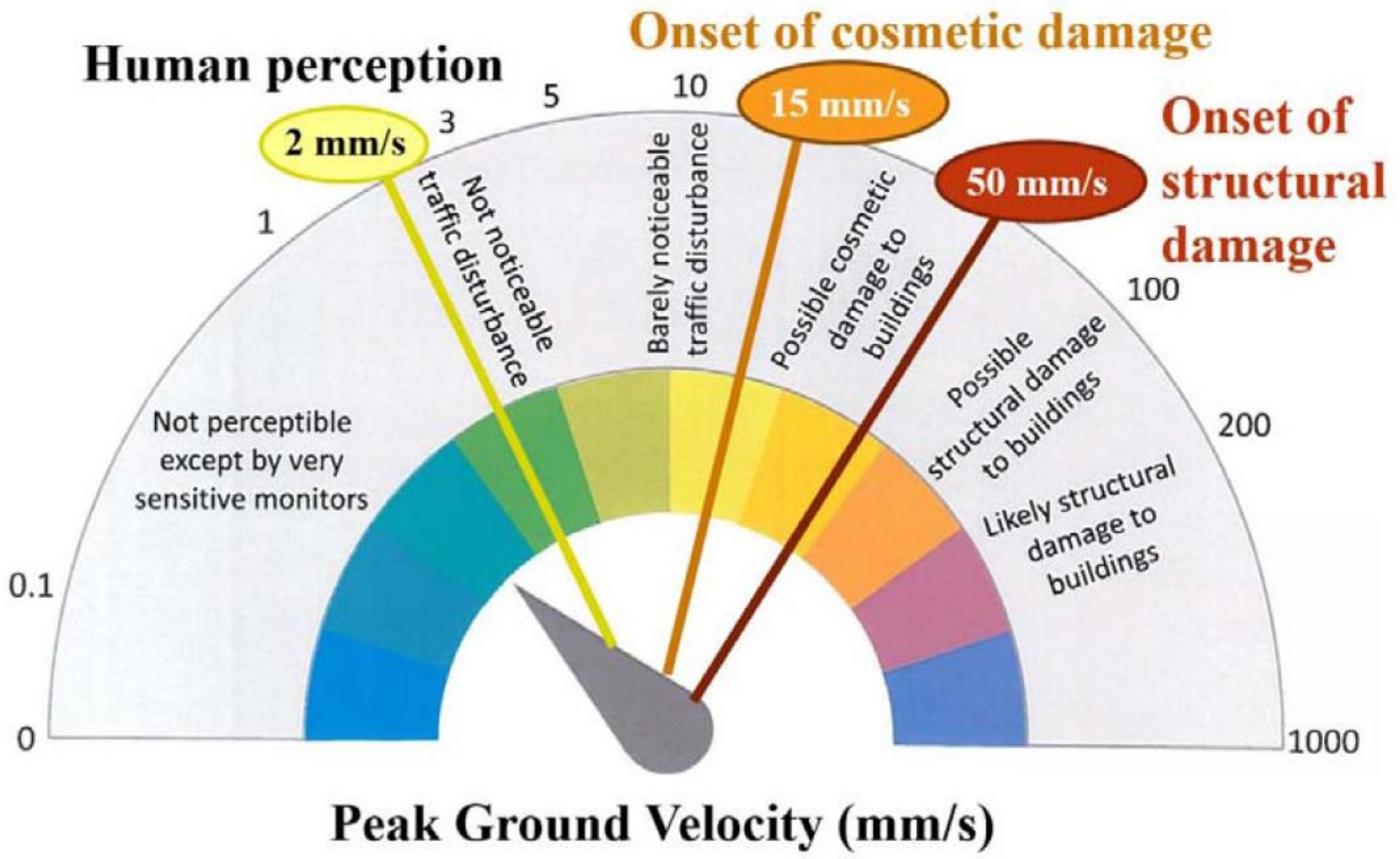
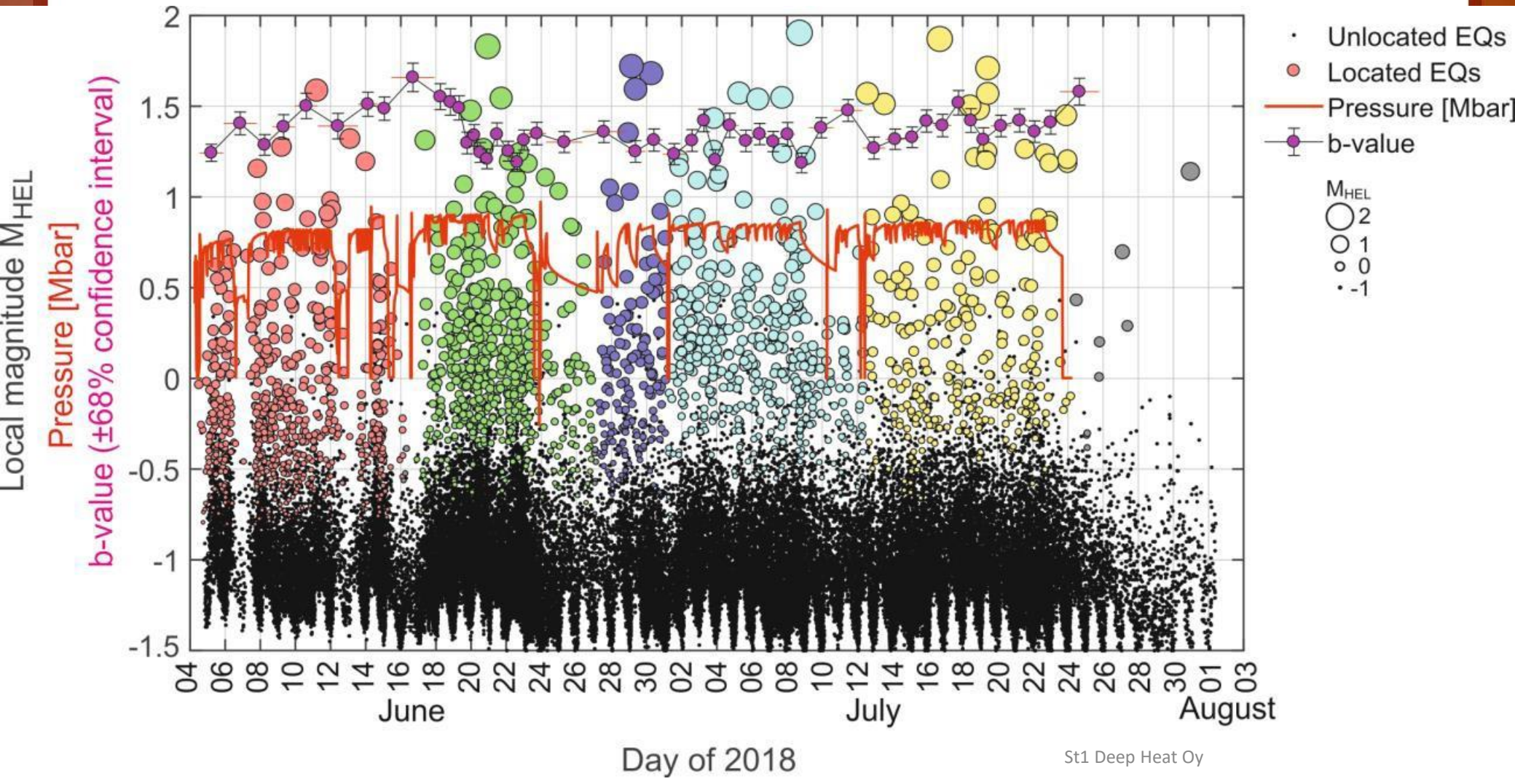


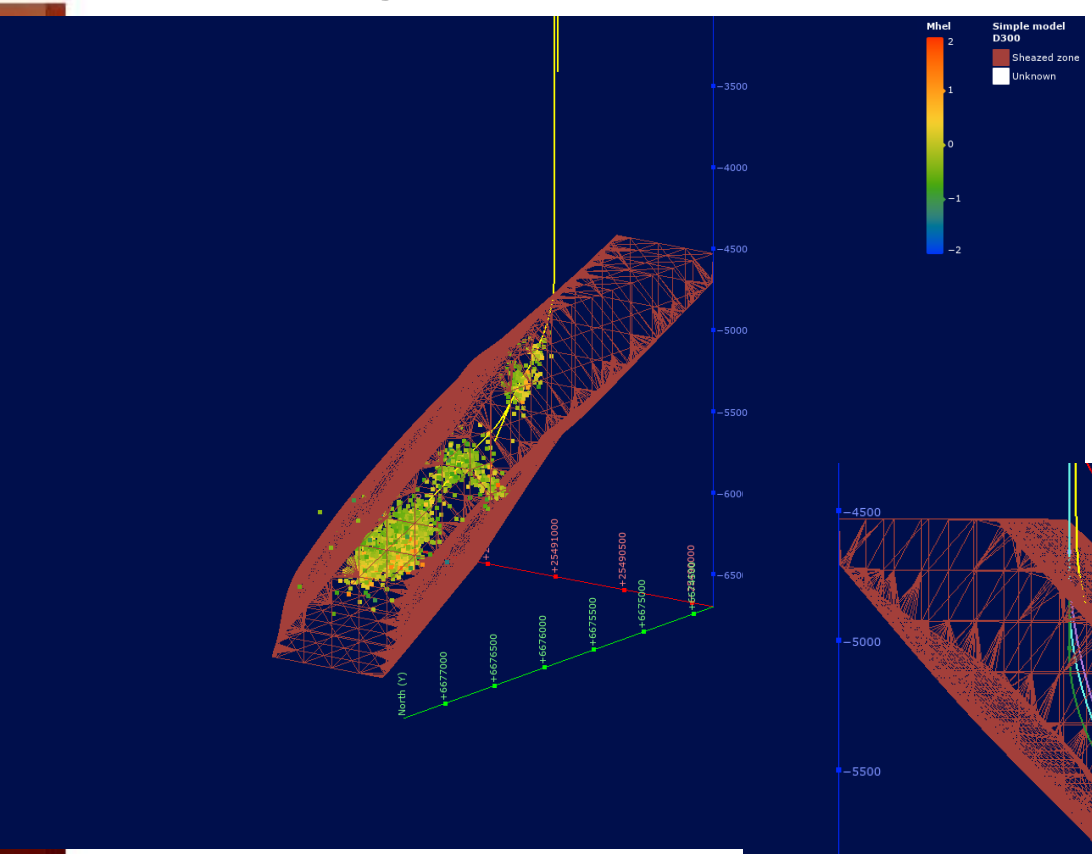
Figure 9. Relationship between PGV and impact (from Bommer, 2017).

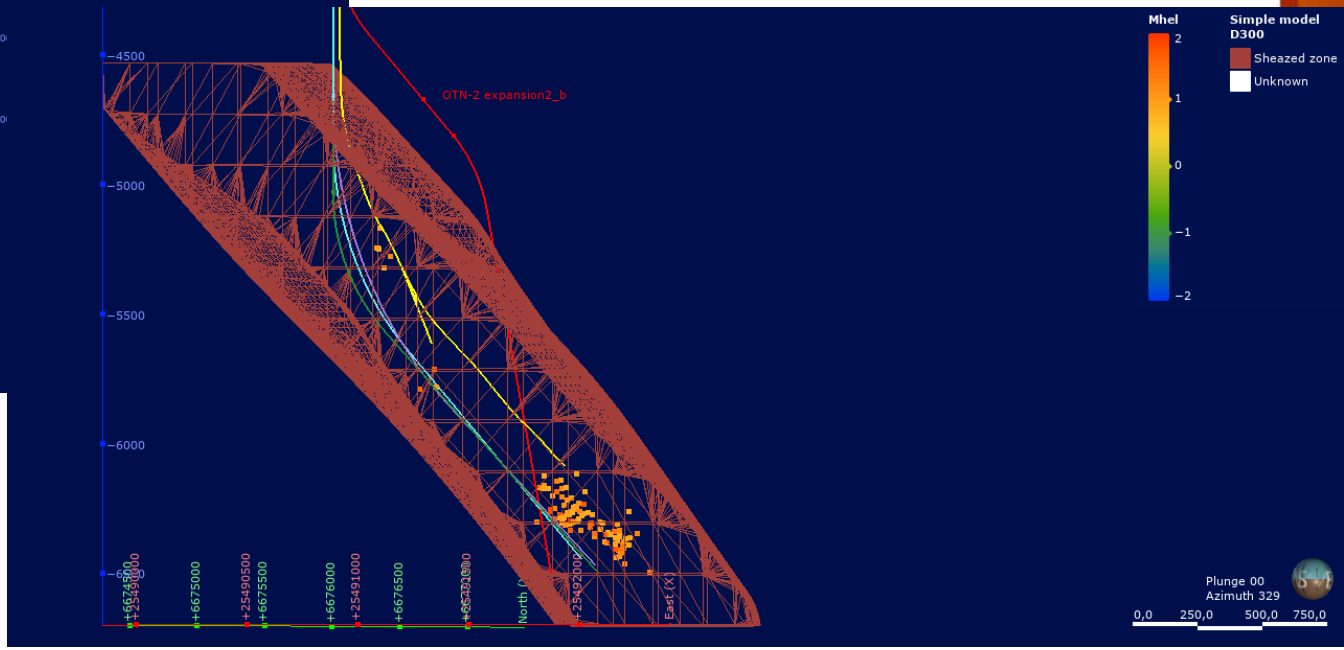
Stimulation Control



St1 Deep Heat Oy

Modelling the Reservoir and the Flow

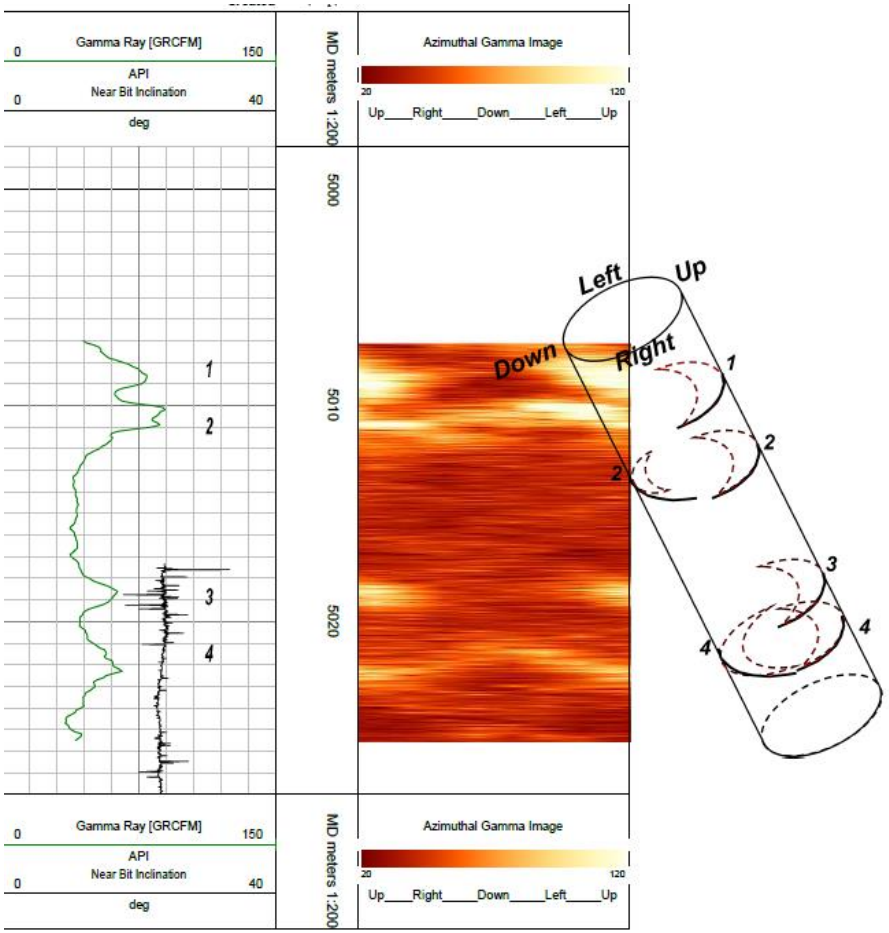





Back Up: Lessons Learned

Being Persistent

How to stabilize a crystalline rock borehole more than 5km deep?



Being Innovative
Six ways to destroy a hammer