

Deep Geothermal Energy

Photonics for Harvesting

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ABOUT

Drilling for Geothermal Energy

”...where we are and where we go...”

THE EPB STORY

THE SITUATION 2012



GEOHERMAL ENERGY

***ONLY WHERE ELEVATED TEMP GRADIENTS
ARE PRESENT***

REASON?

ACCESS (= drilling) COST TOO MUCH.

***= 60-80% OF GEOHERMAL DEVELOPMENT COST
acc to independant accessment***

SOLUTION?

- ***Government SUBSIDIES***

***GOVERNMENTS GUARANTEE 18-28 EU CENTS PER KILOWATTHOUR FOR NEW ENERGY
- which stalls development of new technology***

- ***New, cheap drilling methods***

WHAT THIS PRESENTATION IS ABOUT

THE SITUATION 2012 II



GEOHERMAL ENERGY

OVER-FOCUS ON ELECTRICITY

WHICH ELEVATES SKY-HIGH THE DEMANDS ON TECHNOLOGY

DEEPER WELLS, HIGHER TEMPERATURES*

****Strengthens image of geothermal energy only for the geologically privileged***

***While the fact is that
the biggest energy demand is on
heating and cooling;
perfectly served
by
hot water energy****

****which will in turn relieve demand on other electricity for it to serve higher purposes***

Now, then



***WHAT DRILLING TECHNOLOGY
CAN DO***

STATE OF THE ART

Well cost US\$ 1500-3000 /m

6000m DEPTH RANGE; sedimentary lowest, HDR highest; STANDARD FINAL DIAMETER*

****Oilfield Standard = 8½" open - 7" cased borehole; 4 CASINGS*****

*****LARGER COST MUCH MORE***



ENERGY PRICE* ?

10 - 20 EU¢ / kWh

****Model calculation for a specific well configuration;
hot water energy at wellhead at average HDR geological conditions***

THE GOOD NEWS:



***There is
IMPROVEMENT POTENTIAL
LOOK TO THE CONCEPT OF***

ADAPTED CONVENTIONAL TECHNOLOGY

****ACT***

ACT ? WHERE DO WE LOOK ?



Not the oil industry*

****Neither motif nor need.***

ACT
EXAMPLES
HOW WELLS CAN BECOME CHEAPER



- **INNOVATIVE BREAKAGE**
- **GRAVITY INDEPENDANCE BY WELL TRACTOR**
- **BuoyPipe**
- **CONTINUOUS LINER**
- **HOSE RETURN**

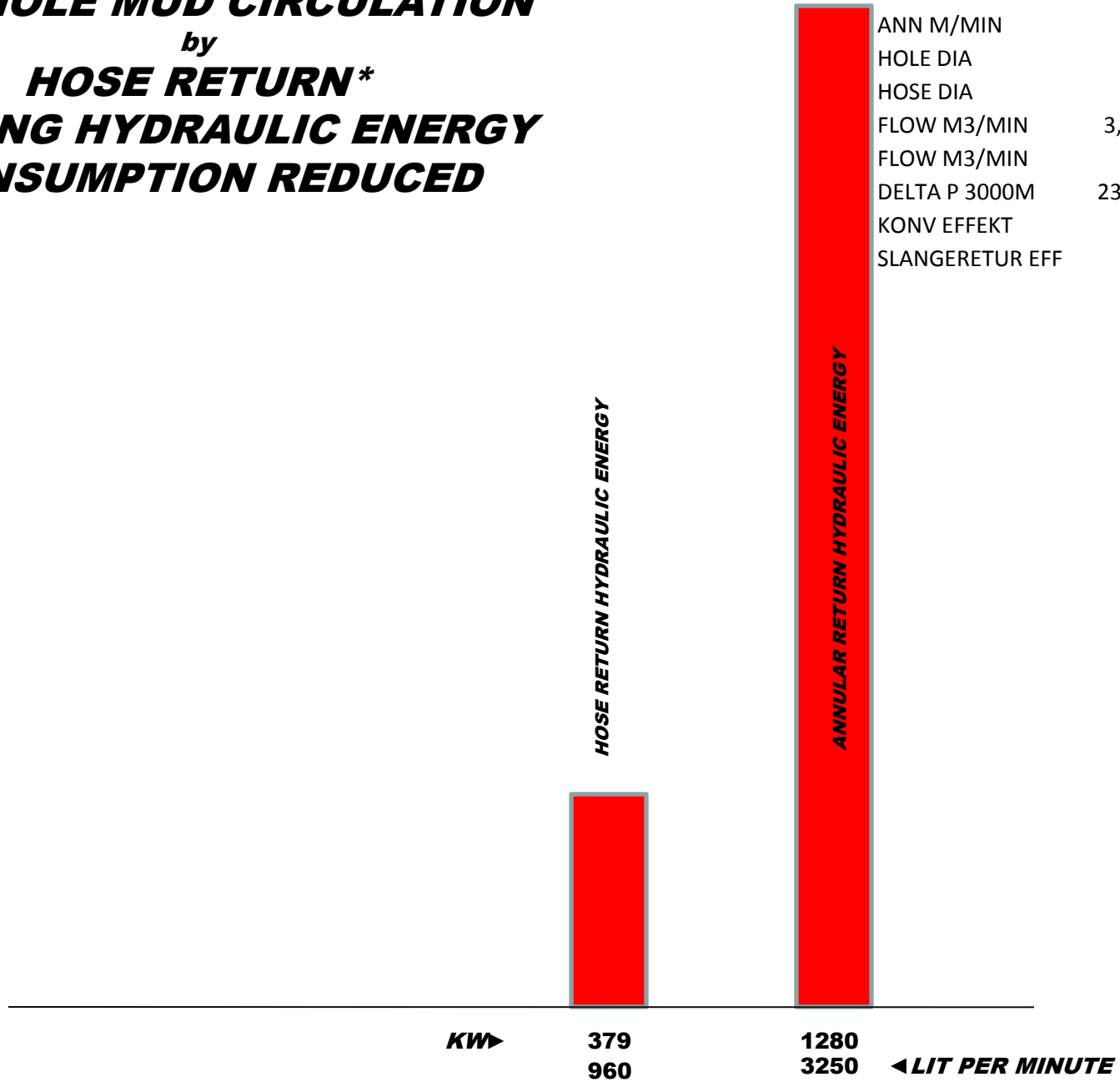


KOLIBROMAC
THE DRILLING MACHINE

LET'S TAKE A LOOK
WHAT ONLY
HOSE RETURN
MAY ACHIEVE

BOREHOLE MUD CIRCULATION
by
HOSE RETURN*
DRILLING HYDRAULIC ENERGY
CONSUMPTION REDUCED

ANN M/MIN	32	
HOLE DIA	15	
HOSE DIA	5	
FLOW M3/MIN	3,242928	KONV RETUR
FLOW M3/MIN	0,96	SLANGERETUR
DELTA P 3000M	23679310n/M2	3500PSI
KONV EFFEKT	1280KW	
SLANGERETUR EFF	379KW	



70% REDUCED

**Tested and tried*

In Summary

WHAT ACT CAN DO

Adapted Conventional Technology



1000-1500 US\$ / m

=

< 10 EU¢ / KWh*

i.e. not an unacceptable energy price in our times

****Model calculation for a specific well configuration;
hot water energy at wellhead at average HDR geological conditions***

DRILLING TECHNOLOGY

Novel Methods 2012

- ❖ ***Flame Spallation and Fusion Drilling (1998) ****
- ❖ ***Chemically Enhanced Drilling (2000) ****
- ❖ ***Electro Pulse Drilling (EPB) (2005) ****
- ❖ ***Metal Shot Abrasive-Assisted Drilling (2006) ****

THIS PRESENTATION CONCERNS EPB

EPB

Electro Pulse Boring

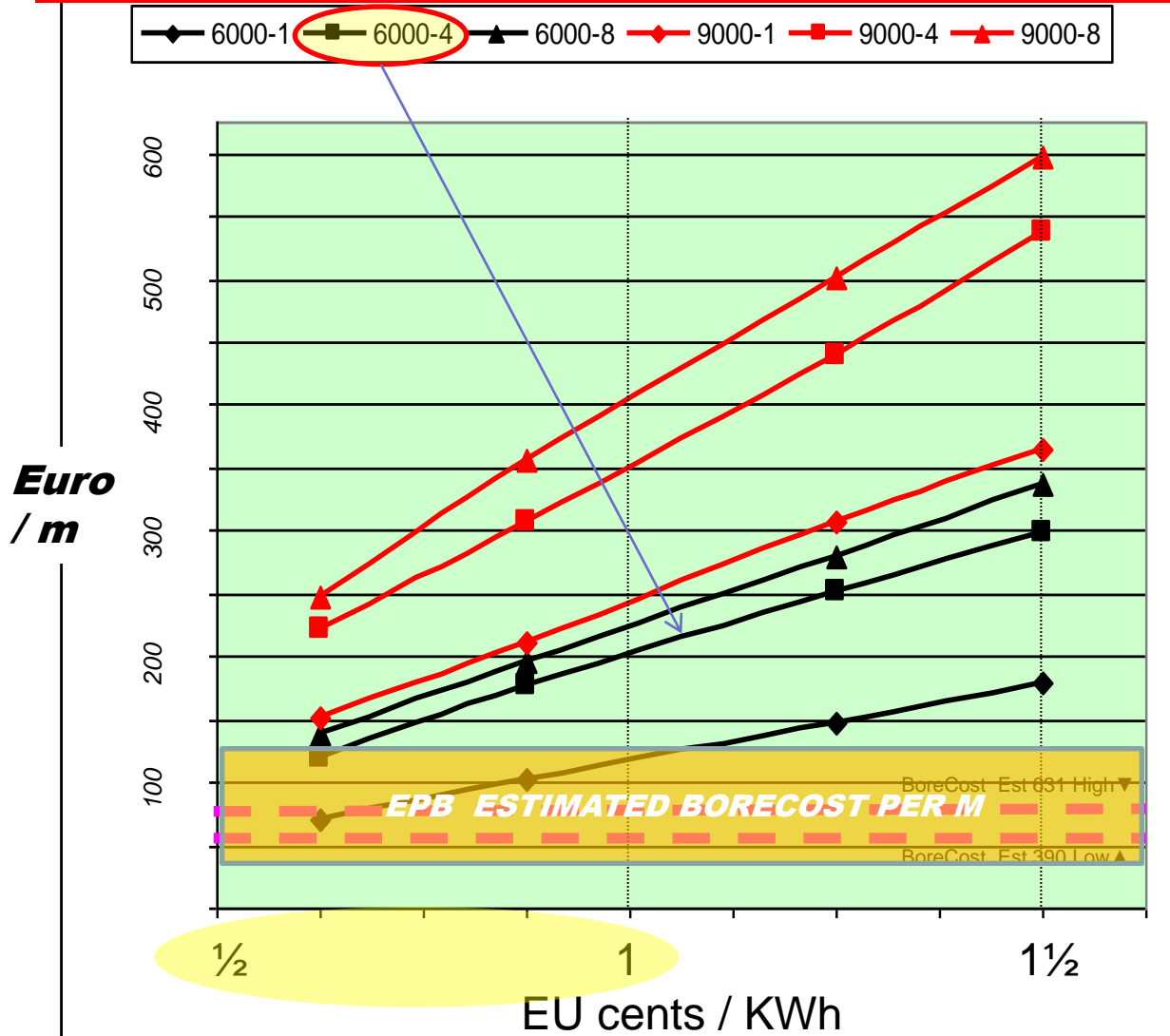
What can it do?

EPB

ENERGY-PRICE (WELLHEAD) VS BORECOST

DEVIATED BRANCH HOLE ENERGY COLLECTOR

Energy unit in one hole



NOTE THE DIAMETER

Example Geothermal HDR
Heat Exchanger:
6000m & 4 Branches

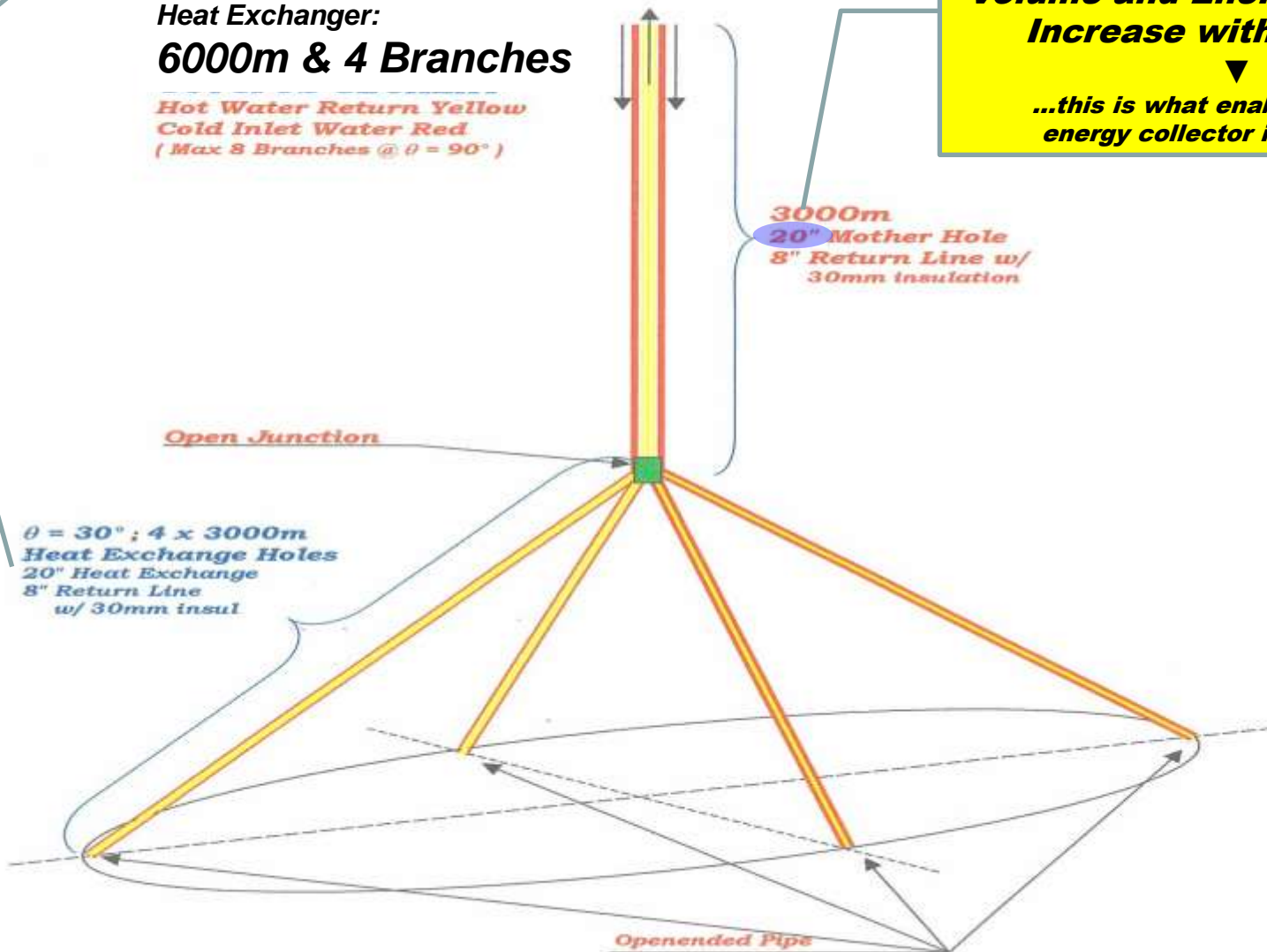
Hot Water Return Yellow
Cold Inlet Water Red
(Max 8 Branches @ $\theta = 90^\circ$)

20" HOLE DIAMETER

EPB:

**Volume and Energy Efficiency
Increase with Diameter**

...this is what enables complete
energy collector in one hole....



Open Junction

3000m
20" Mother Hole
8" Return Line w/
30mm insulation

$\theta = 30^\circ$; 4 x 3000m
Heat Exchange Holes
20" Heat Exchange
8" Return Line
w/ 30mm insul

Openended Pipes

CLOSED LOOP HEAT EXCHANGER IN ONE HDR HOLE

***-a concept for guaranteed
GEOHERMAL ENERGY***

***availability
EVERYWHERE***

***-no groundshaking
(guaranteed)***

EPB

Electro Pulse Boring

How can that be?

EPB

***It is
HARD ROCK EXCAVATION TECHNOLOGY
by***

***Electric Pulses
discharged between***

***fluid submerged electrodes
in contact with
the Rock Matrix***



***IT EXCAVATES ROCK
IN AMAZING VOLUMES
AT A MINIMUM OF APPLIED ENERGY
WHEN PROPERLY FORMATTED AND APPLIED***

EPB

Pulse Characteristics

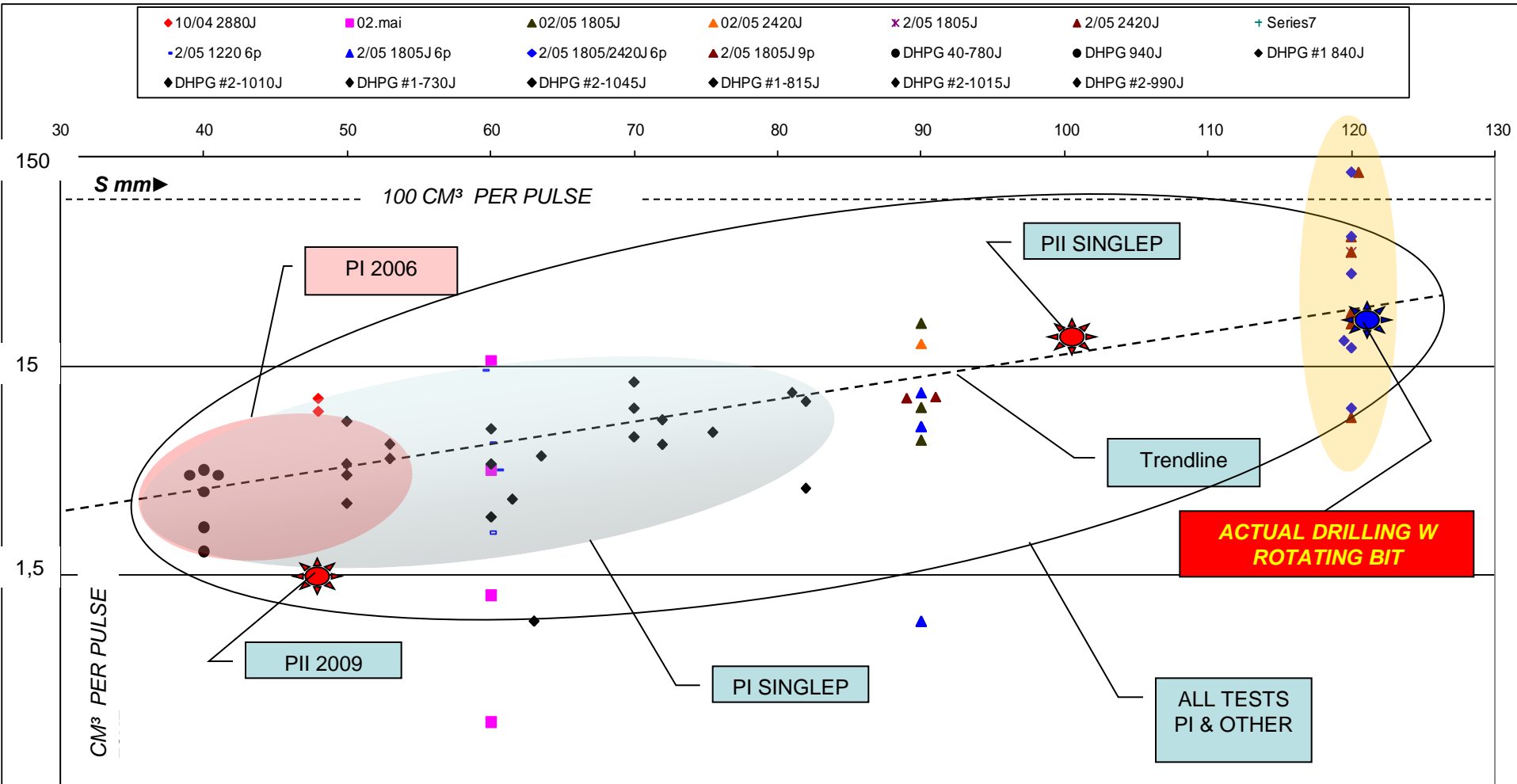
EXAMPLE (magnitudes)

PULSE:	Value	Unit
VOLTAGE	500	KV
AMPS	10	KA
PEAK POWER	5	GW
AVG POWER CONSUMPTION	25	KW
DURATION	300	nSec
REPETITION FREQUENCY	10	Hz
DURATION; of TOT TIME	0,001	%o

EPB FACT BASE

S30-S120 SUMMERIZED SEPT 2011

VOLUME PER PULSE; FUNCTION OF ELECTRODE GAPS (all singlepuls exp, varierende ladN, virg & non-virg locations)



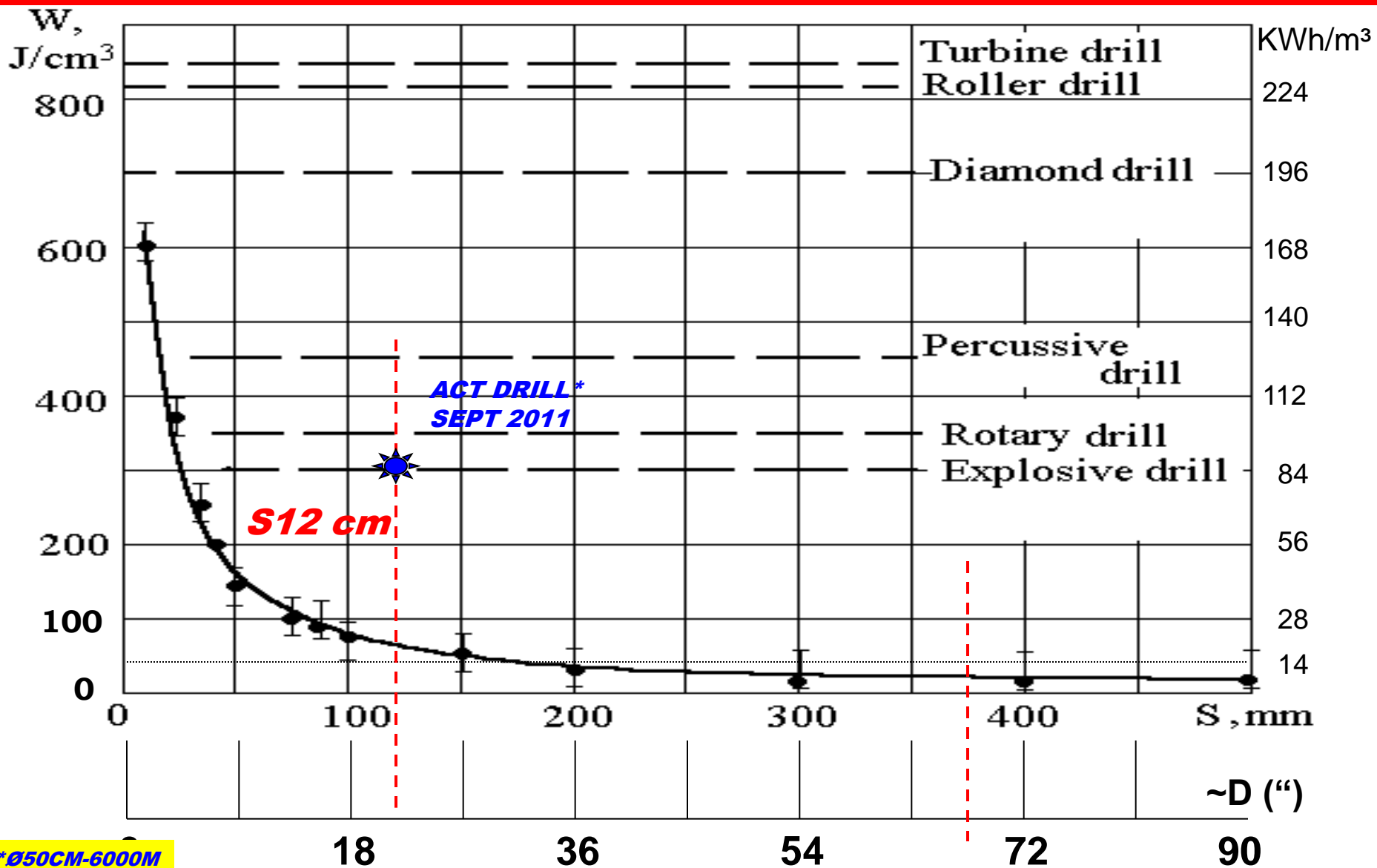
VOLUME EXCAVATOR

Example relevant for Granite

➤ EXAMPLES

Distance S <i>Electrode Gap cm</i>	Excavated <i>Per Pulse</i>	Excavated <i>Per Hour</i>	= Drill Speed <i>Mtr Per Hour Ø20" Borehole</i>
➤ S = 10	20 cm³	1,4 m³	7
➤ S = 15	100 cm³	7 m³	35
➤ S = 50	1000 cm³	70 m³	na

EPB Breaking Energy



*Ø50CM-6000M
= 31500 kwh

ENERGY EFFICIENT EXCAVATOR

Examples

➤ **EXAMPLES** **Granite**

**Excavated
Per Pulse**

**Energy
per m³**

➤ **S = 12 cm:**

100 cm³

20 KWH

➤ **S = 50 cm:**

1000 cm³

5 KWH



Epb is:
**VOLUME EXCAVATOR + ENERGY EFFICIENT
& COST EFFECTIVE**

SOME OTHER FAVOURABLE CHARACTERISTICS

Details yes, but important ones

➤ ***EPB favours LARGE DIAMETER BOREHOLES;
faster, more energy efficient and cheaper;***

more and more so as the diameter increases

➤ ***An EPB borehole diameter is bigger than the bit
which made it;***

***it allows the option open
to protect the hole as it is being drilled***

in Summary:

EPB : An Emerging Technology

and

The Established Fact Base

indicates

20'' HDR GEOTHERMAL WELL*

@ €100 /m (or less)

i.e.

geothermal energy

at

€1 per 100 KWh (or less)

...general availability...

REALLY; NOT EPB ALONE, BUT



+ EPB

= 20 KWH / m³ BREAKAGE*
= 70% REDUCED HYDRAULIC ENERGY*
= ONE DIAMETER CASING TOP TO BOTTOM *

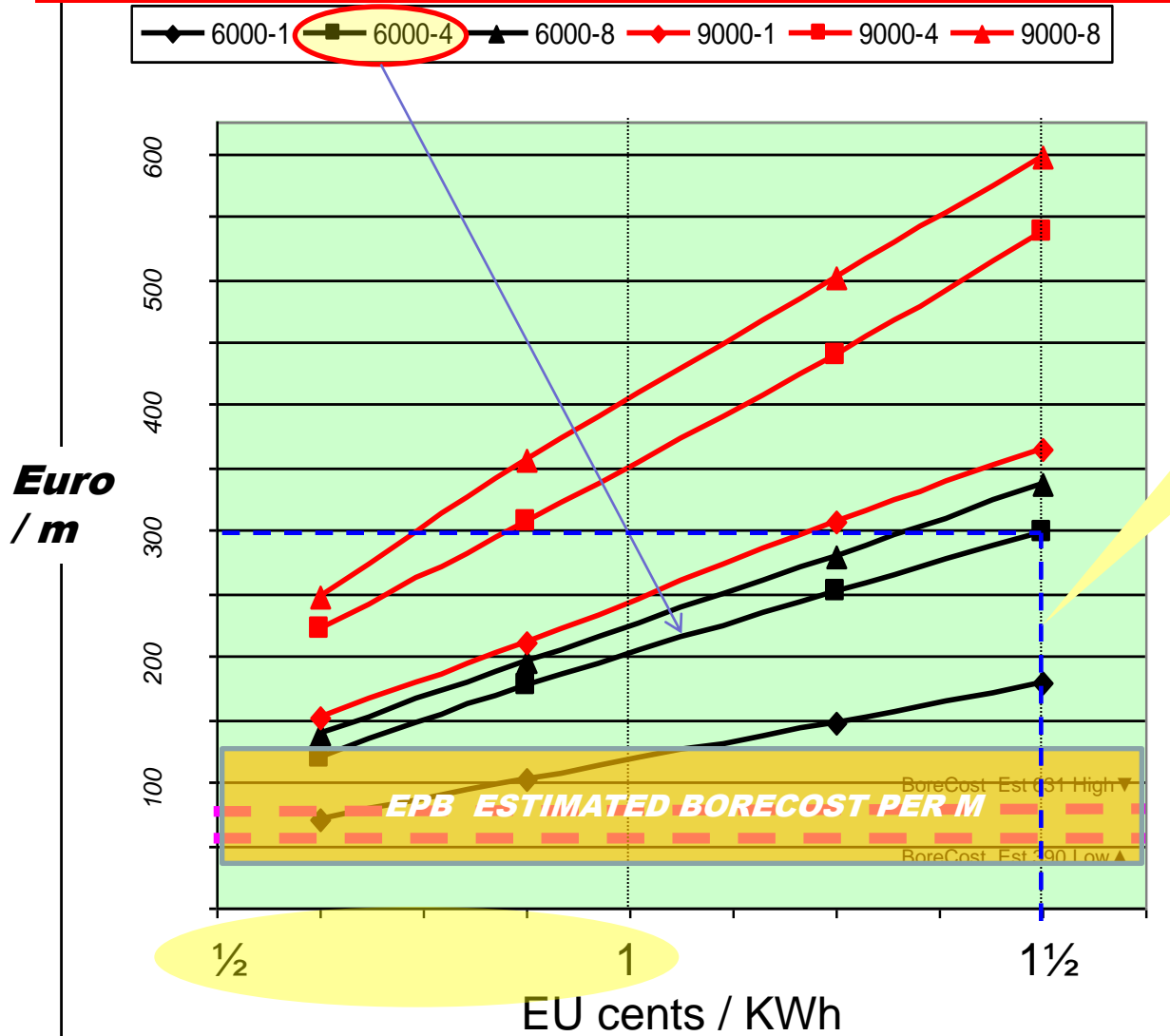
≈ 100 € / m
20" HDR D6000m

EPB

ENERGY-PRICE (WELLHEAD) VS BORECOST

DEVIATED BRANCH HOLE ENERGY COLLECTOR

Energy unit in one hole

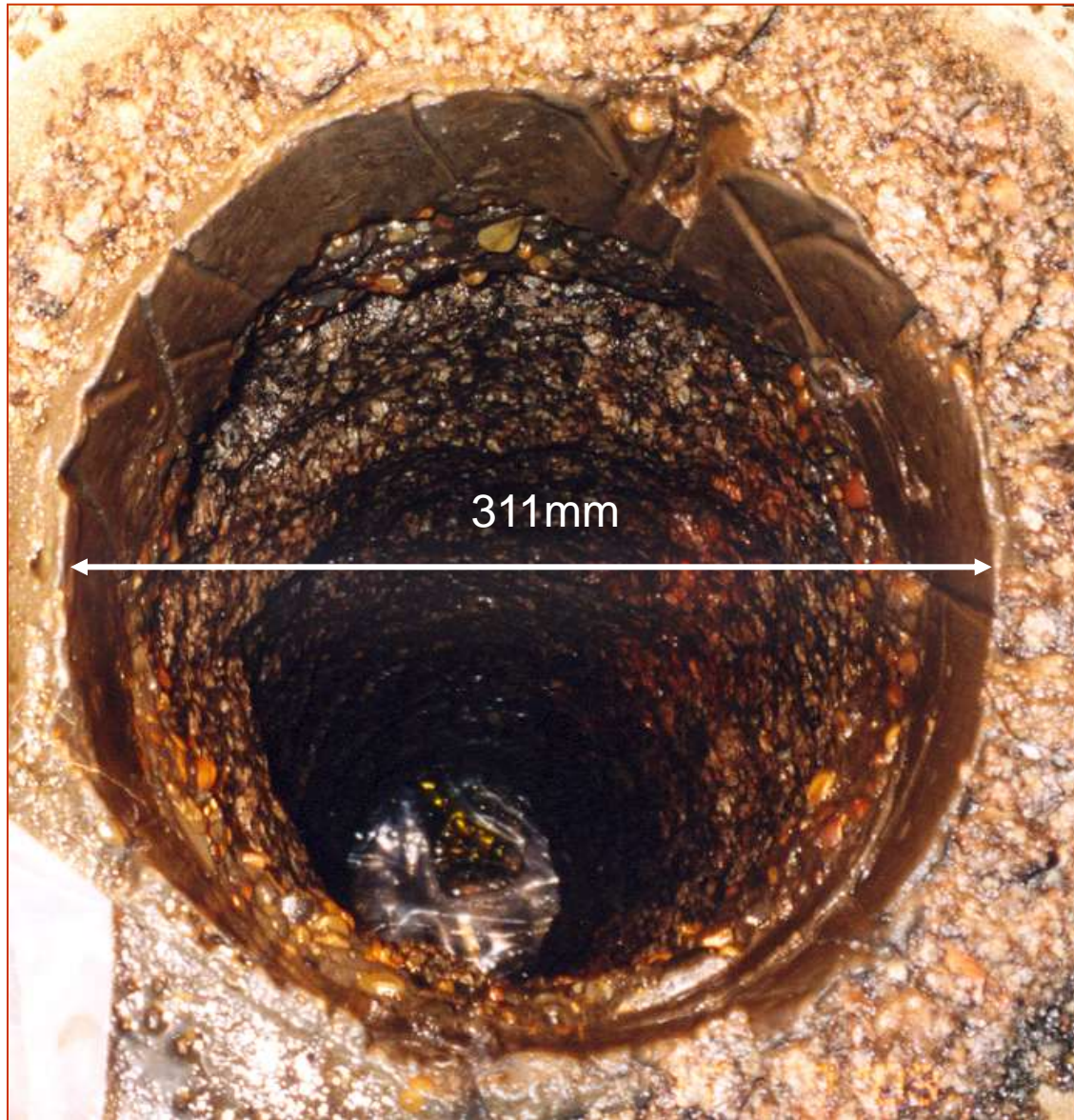


NOTE
THE SENSITIVITY
3x COST ► +50% PRICE!

EPB

Pictures from 15 years of R&D

EPB 2003: Drilling Full Scale in Granite



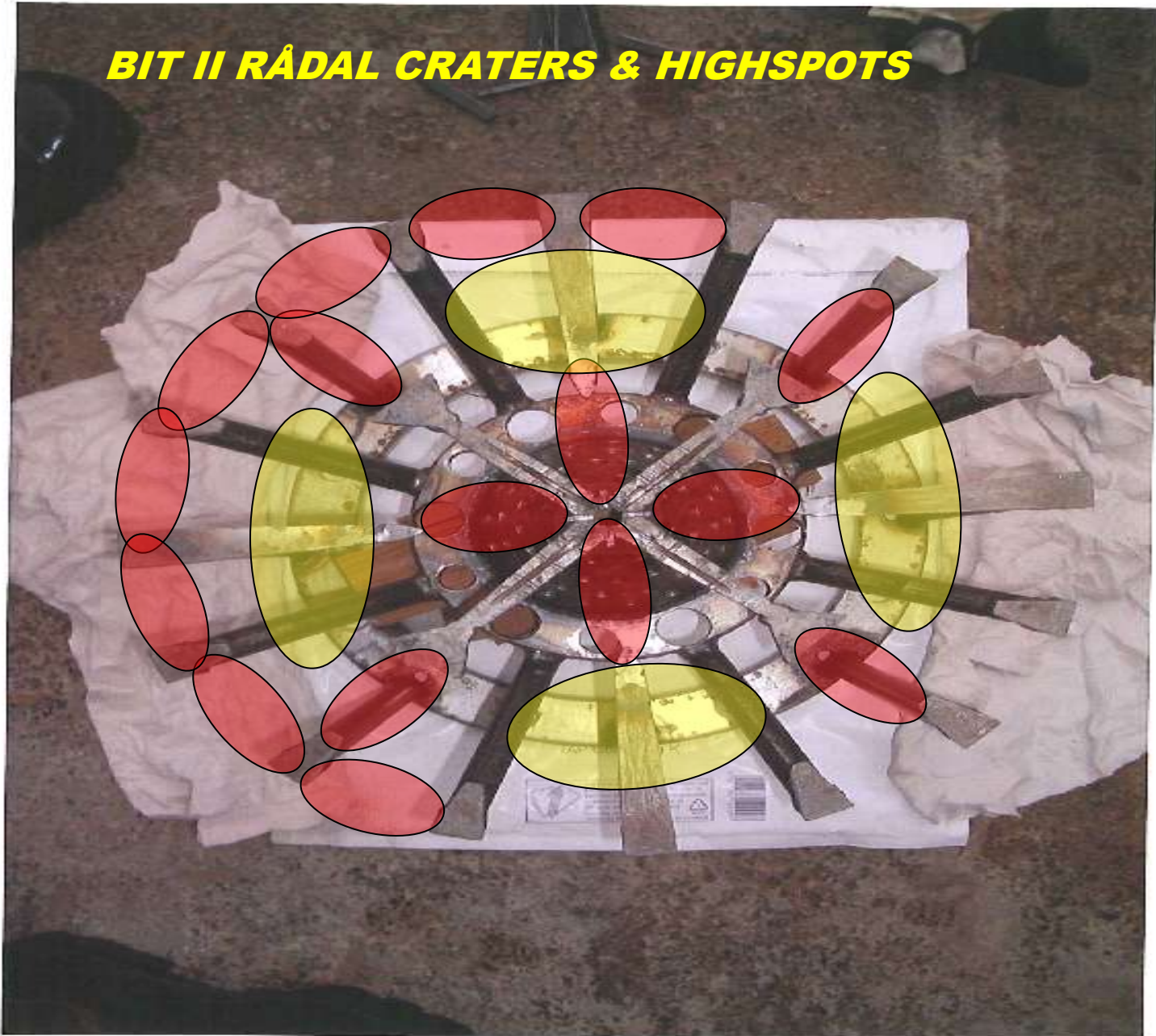
A LATER BIT DESIGN

PROTOTYPE I **MULTIELECTRODE BIT**

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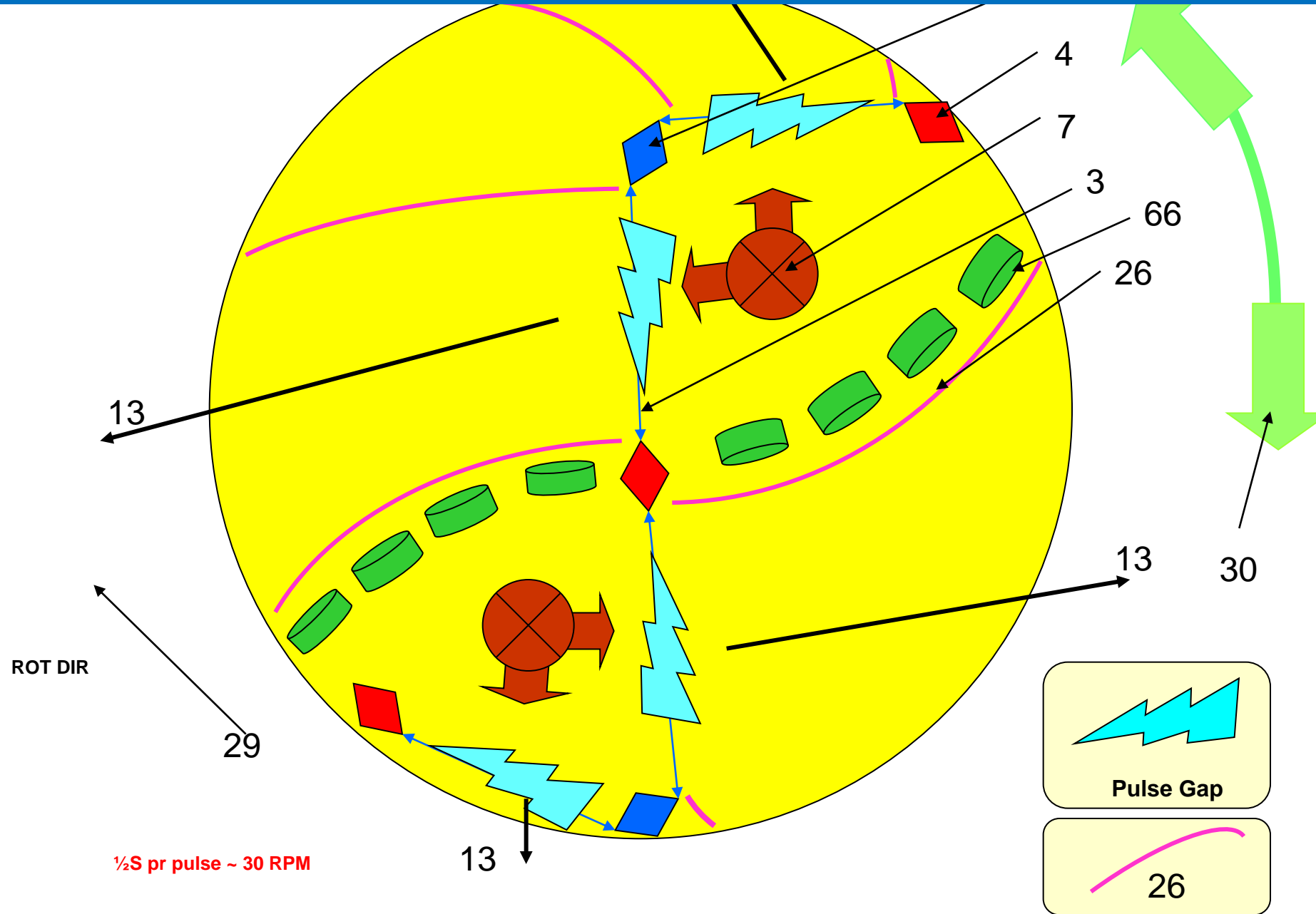


BIT II RÅDAL CRATERS & HIGHSPOTS



HOLE DIAMETER AND ELECTRODE DISTANCE

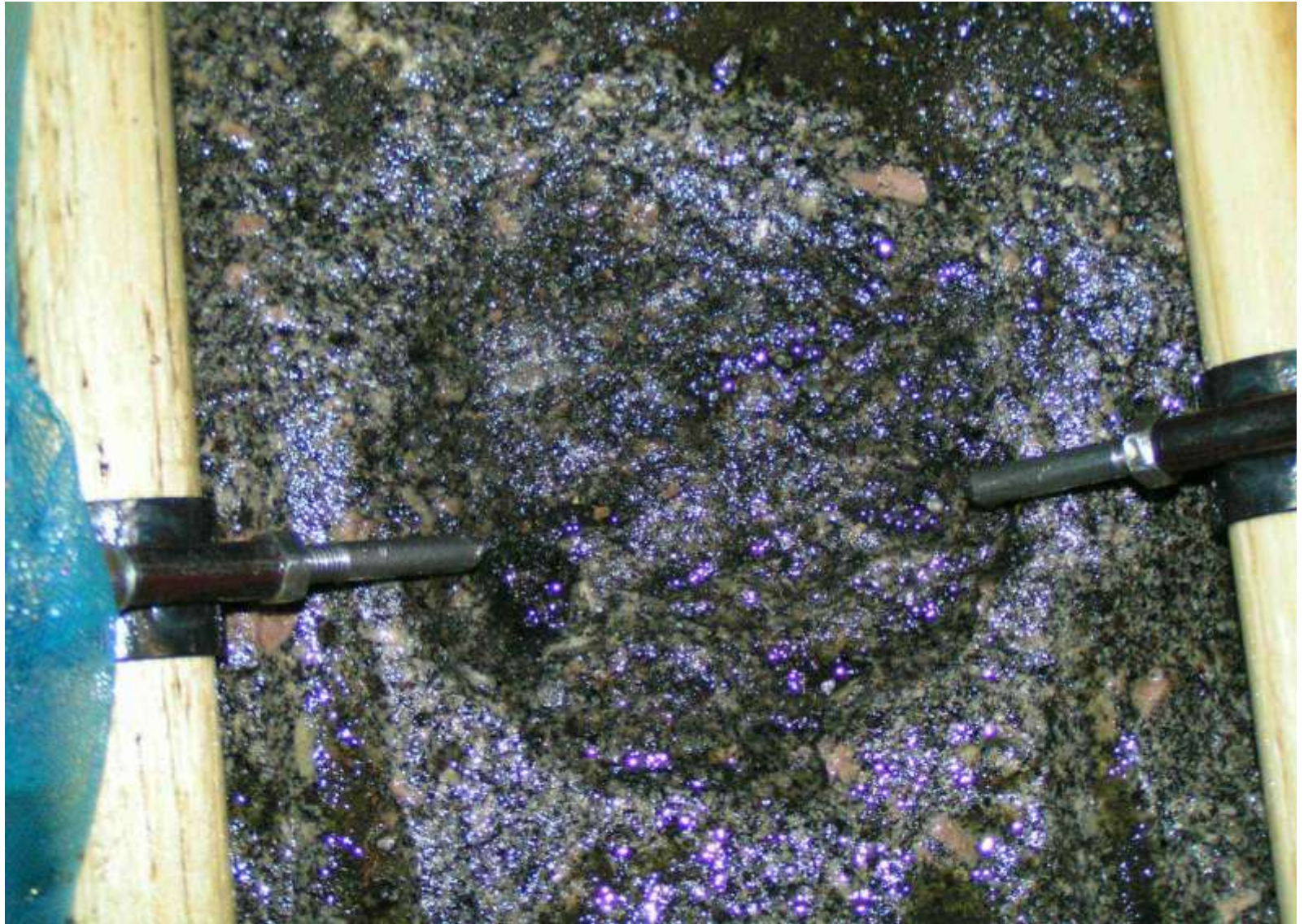
Example: S15 fits D38



EPB 2005 CRATER : 376 cm³ 12cm gap 3 pulses



Fig Exp feb 2005: Crater at 12cm gap-3 pulses



2009 BOREHOLE FOOTPRINT



2009 CUTTINGS SELECTION



2009 EPB TESTRIGG BERGEN-NORWAY



EPB

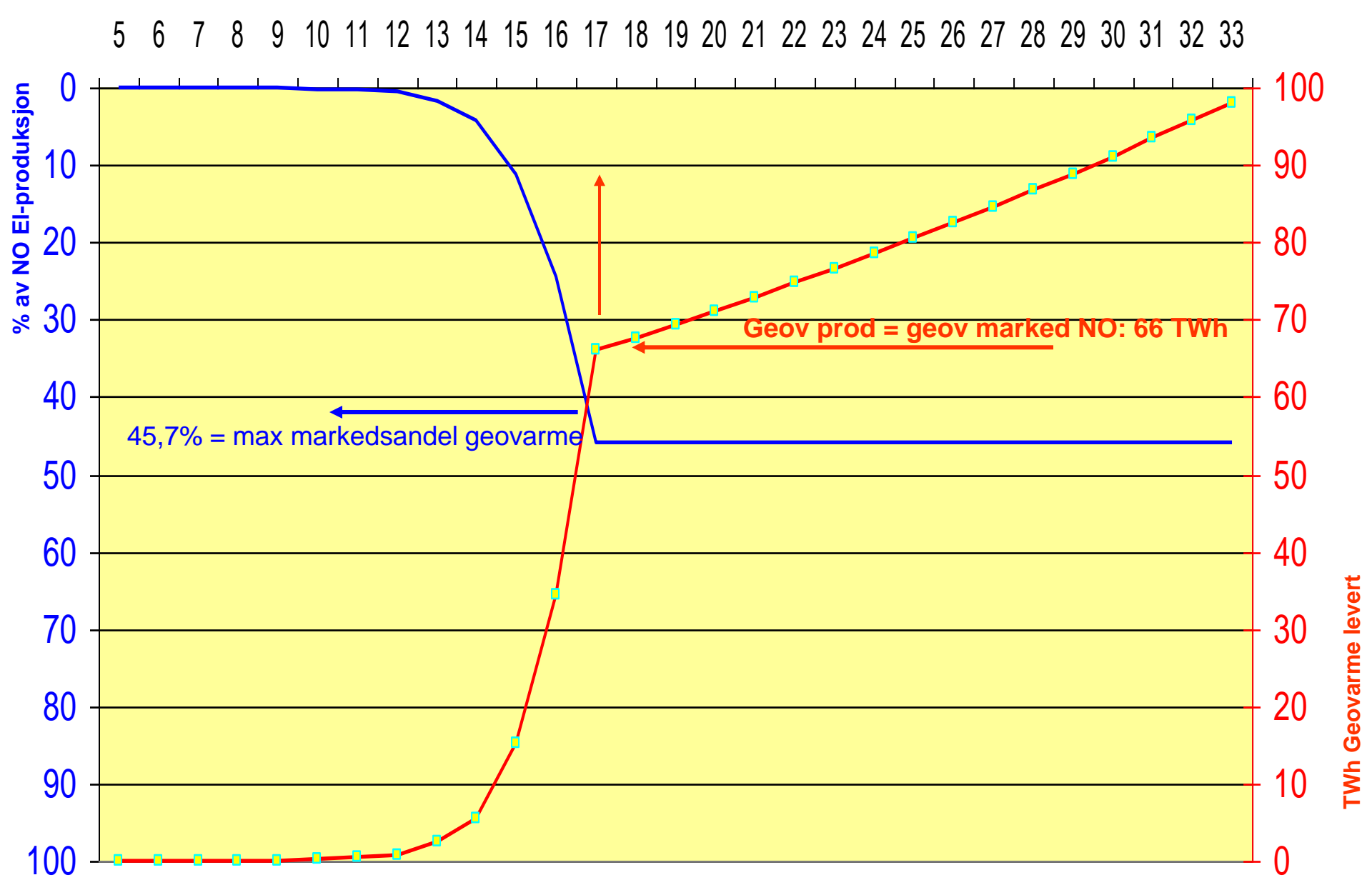
Electro Pulse Boring

Where do we go from here?

NORWAY PERSPECTIVE

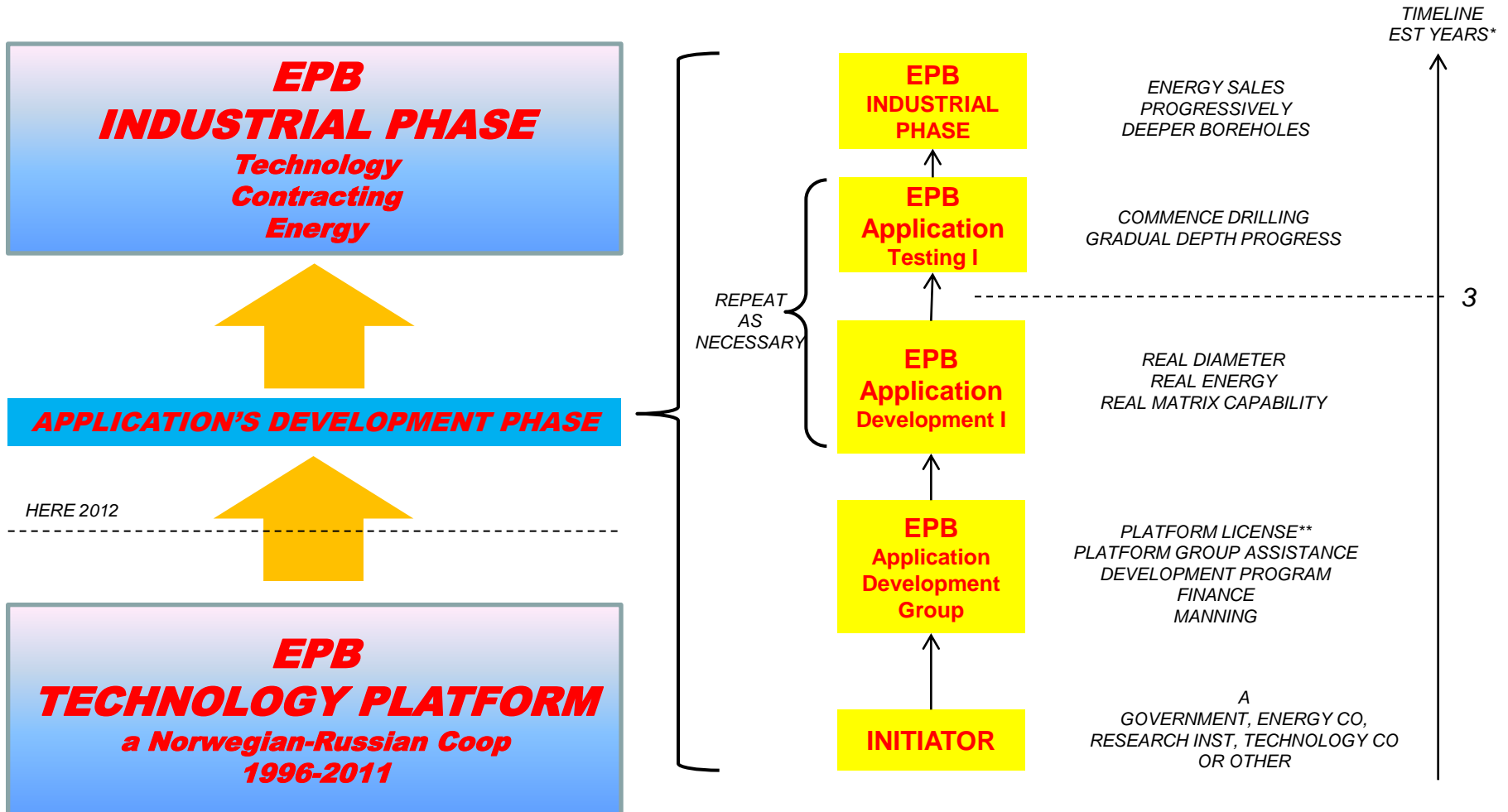
Årstall; 2005-2033

— % av EI-NO — TWh NO



A GEOTHERMAL EPB APPLICATION: HOW CAN WE GET TO IT* ?

*AN APPLICATION = AN EPB LARGE DIAMETER DEEP DRILLING RIG

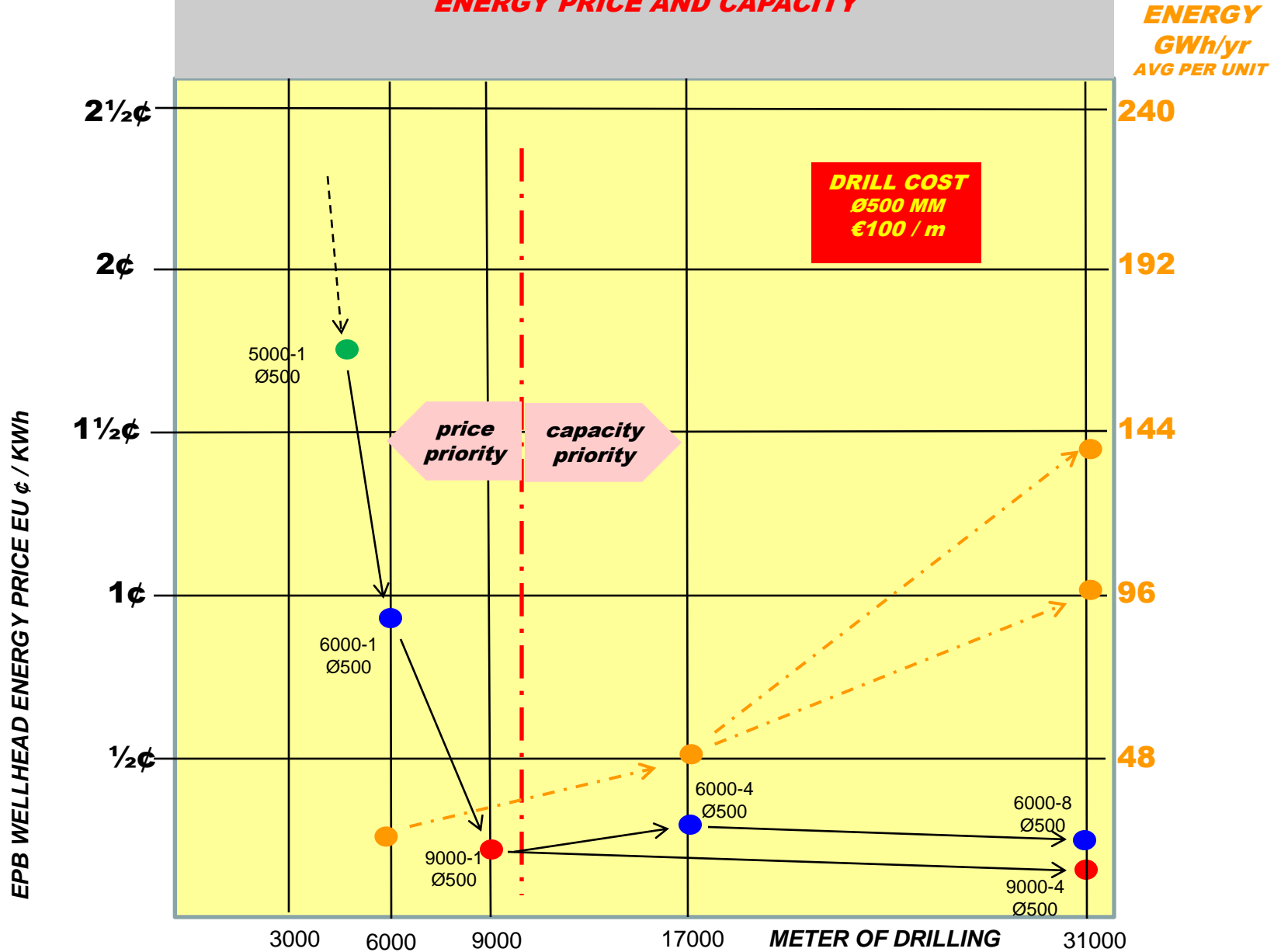


*Nominal values. Applications are different. **A one-time fee ≈ 6-7% of platform cost

EPB

ENERGY COLLECTOR IN ONE HDR HOLE

DEVELOPMENT PATH 2010 ONWARDS
ENERGY PRICE AND CAPACITY



Where do we go from here, cont'd:

OR

FULL STOP

THE SITUATION 2012 III



EPB

COUNTER-FORCES HAVE MOBILIZED

- 1 OIL COMPANIES PROTECT GAS: THE SHALE GAS INITIATED PRICE COLLAPS:***
They need no cheap geothermal competitor
- 2 UTILITY COMPANIES PROTECT ELECTRICITY: MARKET WORRIES:***
They need no 1¢ /Kilowatthour geothermal energy competition
- 3 SUBSIDY TAKERS PROTECT SUBSIDIES: POLITICAL WORRIES:***
The politicians must not learn about 1¢ /Kilowatthour drilling technology
- 4 TECHNOLOGY COMPANIES PROTECT MARKET POSITIONS:***
PROGRESS GOOD ONLY WHEN INVENTED HERE

***THE OLD LESSON IS HERE AGAIN:
PROGRESS DON'T COME EASY***

VOUCH

from a drilling professor

who

guarded his chair with diligence for 35 years:

***Inventions in multitude came past my desk.
Never I saw an as promising one as EPB.
True, many a bridge shall have to be crossed
before fly like a 747 it does
but fly it will, it already does
Wilbur & Orville
are thoroughly past***

THIS ENDS
the
PRESENTATION

Thank You for the Attention