Electro Pulse Boring (EPB): An Experimental Rock-breaking Technology for Low-cost Access to Ubiquitous, Inexhaustible, Autonomous, Ultra-deep (5-10 km) Geothermal Heat for Electricity and DHS

W. Leighty
Alaska Applied Sciences, Inc. (AASI)
Box 20993, Juneau, AK 99802-0993 USA wleighty@earthlink.net

ABSTRACT

The answer to Humanity's energy emergency, anywhere on Earth, is beneath our feet, if only we could afford to bore deep enough to reach it. Deep geothermal heat is Humanity's only potential benign, baseload, dispatchable, inexhaustible, equitable, and affordable energy source for all purposes, anywhere on Earth, generating electricity and district heating and cooling systems (DHCS). But we cannot afford to bore deep enough with today's prevailing rotary, abrasive drilling technology. "Electro Pulse Boring" (EPB), a novel rock-breaking technology, uses very high voltage, high power, short electric pulses (500-700 kV, 10 ns, ~1,500 J, 10-20 pps, average power ~ 25 kW) to fracture rock, to enable low-cost, deep (5-10 km) geothermal heat harvest anywhere on Earth, without the twin boreholes and deep rock fracturing (fracking) required of Enhanced Geothermal Systems (EGS). Increased energy capture, via increased contact area, is via slanting thermosiphon holes bored from the on the "mother hole", also by EPB. Our total global energy supply may now be from autonomous local electric and thermal mini-grids, each supplied by a single, or multiple, deep, closed-system, geothermal boreholes. Our need for national and continental grids and for energy storage is greatly reduced.
Keywords: Electro-Pulse-Boring, deep geothermal energy, geothermal, ubiquitous, benign, baseload, autnomous

1 EPB TECHNOLOGY

See Figure 1. EPB uses high-power electric pulses to fracture rock at 5-10 km depth at far lower cost than rotary abrasive drilling ubiquitous today. If this technology can be commercialized, it could disrupt and replace present attempts to solve humanity's "climate change" emergency via harvesting supra-terrestrial RE sources like wind and solar. EPB equipment is smaller and more transportable than rotary drilling rigs and requires less energy. It allows a single, simple or branched borehole to extract up to 50 MWt (thermal) energy continuously, as baseload energy, is a closed thermosiphon system. Hot water, from large, deep rock contact area rises through an insulated center pipe from full borehole depth, via thermosiphon convection.

To increase borehole power production (MWh per hour) the hot rock contact area must me increased. EGS uses at-depth fracking, which often causes earthquakes, causing EGS exclusion from a geothermal resource area. EPB should prove amenable to directional drilling, allowing many branches, below ~ 5 km, to contribute heat energy to the nominal 50 cm diameter motherhole flow. This assumes that EPB may be used for directional drilling at an adequate acute angle to the vertical motherhole: a major research aspect.

The average geothermal gradient, anywhere on Earth, is about 30 C per km depth. At 9 km, at almost 300 C, with enough contact area, abundant energy may be extracted, forever, if the borehole system is managed well. Brought to the surface by water or other working fluid, in a closed system, electricity generation via steam Rankine or Organic Rankine Cycle (ORC) generators plus district heating and / or cooling continuously available. Affordable access to deep geothermal heat eliminates the prospecting risk of finding geothermal fluids and / or "hot spots" in Earth's shallow crust, and is amenable to Enhanced Geothermal Systems (EGS) requiring two or more boreholes.

Because the EPB borehole is a constant, typically 50 cm, diameter from Earth's surface to full depth, casing depth and cost is minimized. Casing depth will vary: overburden soil depth and type and encountered aquifers increase depth and cost. Thus, EPB's cost advantage over conventional, rotary, abrasive drilling will vary.

2 EPB HISTORY AND STATUS

Since 2005 a collaboration among Norwegian University of Science and Technology (NTNU, Trondheim, NO), Technical University of Tomsk (RU) and SwissGeoPower (CH) has been investigating EPB, a novel rock-breaking process using very high voltage, high power, short pulses of electricity, (500-700 kV, 10 ns, 10 pps; average power ~ 25 kW) applied to an electrode array on the borehead. Both overlying sedimentary and crystalline basement rock is fractured to chips, which are removed to the surface with conventional mud-driven "hose return".

These parties have advanced EPB to ~TRL3; IP value and status is unknown:

- Professor Arild Rodland, retired from NTNU, Trondheim, NO. Owner of Unodrill AS, NO, which owns some key EPB IP. Boring technology consultant, O&G industry, including HDD, in USA, NO
- Dr. Hans-Olivier Schiegg, CEO, SwissGeoPower, CH
- Tomsk Polytechnic University (TPU), High Voltage Institute, Tomsk, RU
- China University of Geosciences, Wuhan (CUG), CN

• VITO Belgium, BE

EPB technology languishes, lacking three essentials:

a. A Down Hole Pulse Generator (DHPG) capable of operation at 9 km depth at the minimum boring rate of 30 m, 15 m^3 per hour required to achieve the cost target of € 100 per meter for a 50 cm diam hole, 6 to 10 km deep;

b. Funding and a site for low-cost, deep boring geothermal R&D and Demonstration to 6 - 10 km depth;

c. Building a pilot-scale deep-geothermal power plant providing electricity plus DHCS thermal energy for a baseload microgrid.

The DHPG must be situated directly above the borehead, suspended from the surface via a power and controls umbilical, and must survive 250-300 C and the pressure at 6-10 km depth. This is a pulsed-power challenge that must be met before deep boring testing may proceed and succeed. Military directed energy weapons (DEW) technology could be adapted. High-T power semi-conductors are becoming available.

3 COMMERCIALIZATION

If this technology can be commercialized, it could disrupt and replace present attempts to solve humanity's "climate change" emergency via harvesting supra-terrestrial, time-varying RE sources like wind and solar, because no minimal gathering, transmission, and energy storage would be required. Deployed worldwide, it would accelerate humanity's necessary and urgent conversion of the world's largest industry from ~ 80 % fossil to ~ 100 % renewable, CO2-emission-free sources, as quickly as we prudently and profitably can.

EPB should be especially valuable in remote locations like Alaska's 150 small communities of a few hundred to a few thousand prople, where imported diesel fuel is costly; where deploying a conventional drilling rig is far too costly.

We must now design, demonstrate, and bring to TRL 8-9 "pre-commercialization", a deep (5-10km), large-diameter (50cm) boring technology so low in cost that electricity and hot water for DHS may be delivered, almost anywhere on Earth, for <$0.04/kWh by distributed geothermal energy plants fed by deep boreholes. We have considered several nascent deep-boring technologies, including some funded by USDOE ARPA-E, generally at TRL 2-4, concluding that EPB is the most technically and economically promising. Several European EPB researchers have made encouraging technical progress, but have not adequately collaborated; have not reached an adequate and critical funding level. The magnitude and prestige of the MacArthur grant should motivate needed collaboration and provide adequate R&D&D capital to advance EPB to TRL 8-9, pre-commercialization, at which private enterprise must invest for global proliferation.

Research, Development, and Demonstration (R&D&D) investments required will be approximately:

- Proof of concept: $ 25 million; 18 months
- Pre commercialization: $ 150 million; 24 months

European researchers have demonstrated 50cm diameter EPB boring to 200m with a surface-mounted pulse generator. Now, the critical component, the Down Hole Pulse Generator (DHPG), able to function at full borehole depth, temperature, pressure, must be designed and tested: the salient EPB technology risk. Progressively-deeper boreholes will reveal necessary equipment design improvement iterations. Finally, a MW-scale demonstration energy plant will be built, delivering baseload electricity and hot water from the deep borehole.

Impact: If EPB achieves its cost goal of € 100 per meter for a 50 cm diam hole, 6 to 9 km deep, for sites easily-accessible to the compact EPB system (costs are higher for remote systems: Alaska villages), then:

a. Baseload geothermal energy at 90 C out - 20 C return can be produced for < $ 0.01 / kWht;

b. Baseload ORC generators can produce electricity at < $ 0.02 / kWhe from branched holes; < $ 0.05 / kWhe from single holes;

c. Boring costs will be lower for conventional two-borehole EGS, for lower long-term COE;

d. Thermal and electrical micro- and macro-grids may be established in remote areas, serving several communities and many people from a single branched or unbranched borehole;

e. The abundant associated lower-grade heat may be used for DHS and DHW, crop-drying, greenhouses

Timeline and key milestones:

• Form collaboration: Europe, USA, China

• Commission design + build DHPG and other critical components

• Locate and commit to boring test sites for preliminary (to 1-2 km) and ultimate (5-10 km) borings

• Identify customers for preliminary and ultimate boreholes, as they become obsolete for EPB technology advancement

• Assemble field testing personnel and equipment for future testing program

• Milestone 1: Equipment and field test team ready for deployment

• Bore progressively-deeper boreholes, logging performance data and design weaknesses, at one or more boring test sites

• Revise DHPG and other equipment designs, from field experience. Build and deploy Generation 2 equipment

• Milestone 2: 50 cm diameter borehole to 1-2 km

• Milestone 3: Continuous penetration rate maintained at > 2m per hour, uninterrupted

• Revise DHPG and other equipment designs, from field experience. Build and deploy Generation 3 equipment

• Bore progressively-deeper boreholes, logging performance data and design weaknesses, at one or more boring test sites

• Milestone 2: 50 cm diameter borehole to 6-7 km

• Milestone 3: Continuous penetration rate maintained at > 5m/hour, uninterrupted

• Milestone 4: 50 cm diam borehole to 8-10 km depth

• Milestone 5: MW-scale energy plant built, for electricity generation and hot water distribution

• Milestone 6: Equipment designs matured for pilot-scale production, for lease to geothermal developers

• Milestone 7: Business plan to propagate technology equitably and profitably; qualified customers identified

• Milestone 8: MW-scale energy plant commissioned and sold

• Final report. Prepare papers for presentation at scientific and industry conferences, and for publication

Impact: If EPB achieves its cost goal of € 100 per meter for a 50 cm diam hole, 6 to 9 km deep, for sites easily-accessible to the compact EPB system (costs are higher for remote systems like Alaska villages), then:

a. Baseload geothermal energy at 90 C out - 20 C return can be produced for < $ 0.01 / kWht (kWh thermal);

b. Baseload ORC generators can produce electricity at < $ 0.02 / kWhe from branched holes; < $ 0.05 / kWhe from single holes;

c. Boring costs will be lower for conventional two-borehole EGS, for lower long-term COE;

d. Thermal and electrical micro- and macro-grids may be established in remote areas, serving several communities and many people from a single branched or unbranched borehole;

e. The abundant associated lower-grade heat may be used for DHS and DHW, crop-drying, greenhouses;

f. The electricity grid is relieved of potentially-suboptimal large investments in upgrading the electricity Grid, as it would otherwise be forced to accept ever-higher fractions of time-varying wind + solar, thus controlling electricity and energy prices for all ratepayers and citizens.

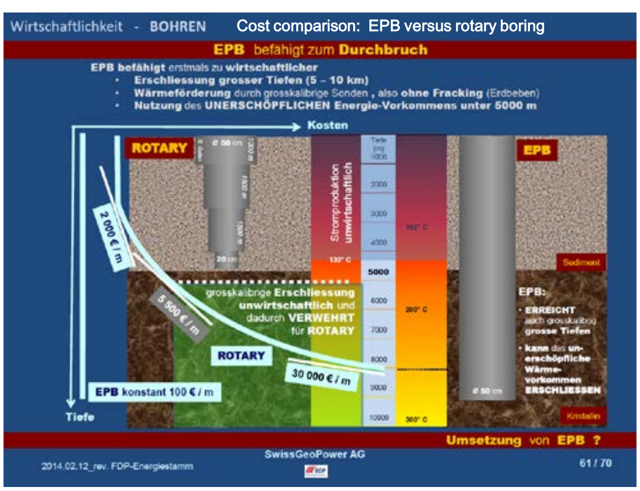

Figure 1. Compare EPB with conventional "rotary" drilling.

4 IP STATUS

International IP status is unknown. AASI now owns no rights to, nor IP related to, EPB. AASI has no experience with pulsed power, nor with DHPG design. We haven't the economic resources to launch any credible expert investigation such as that proposed here. But, after failing The rock-breaking and boring aspects, in granite, equivalent to crystalline basement rocks, has been demonstrated at NTNU in NO, and at TPU in RU, but perhaps without adequate IP protection. This project could advance EPB from ~TRL 3 to ~TRL 6-7. AASI will engage contractors to advance this project's success toward further investment and deployment, respecting any IP established in Europe. AASI will use project success results to establish new IP, and to attract interest to, and investment in, commercializing EPB, while respecting all extant IP.

5 FIT WITH USDOE, GRC, GEA

USDOE has invested heavily in novel geothermal technologies, via ARPA-E and "FORGE" programs, without the "transformative" success needed for geothermal-generated electricity to compete with natural gas turbine generation. Maturing EPB to ~ TRL 6 may best be accomplished by integrating our proposed, independently-funded R&D&D steps with other projects at a "FORGE" site. The Geothermal Resource Council (GRC) and Geothermal Energy Asociation (GEA) wish to help advance lower-cost access to deep geothermal, and could bring more resources to both "proof of concept" and "pre-commercialization" phases.

6 SINTEF MODELING RESULTS

A confidential performance study by SINTEF, in NO, commissioned by the EPB research team at NTNU, shows annual energy output, for a single borehole, closed thermosiphon system, optimized for maximum annual thermal energy delivery, assuming water temperatures 90 C output - 20 C return:

- Single 50 cm borehole to 6 km: 8 GWht / year
- Single 50 cm borehole to 9 km: 28 GWht / year
- 4-branch array at 4 km to 9 km from mother hole: 449 GWht / year

Deep heat reservoir depletion is ~ 23 % reduction in annual thermal energy output after 20 years.

All thermal modeling is based on derivatives of the seminal sustainable geothermal extraction study by Jeff tester, MIT, now Cornell. [1]

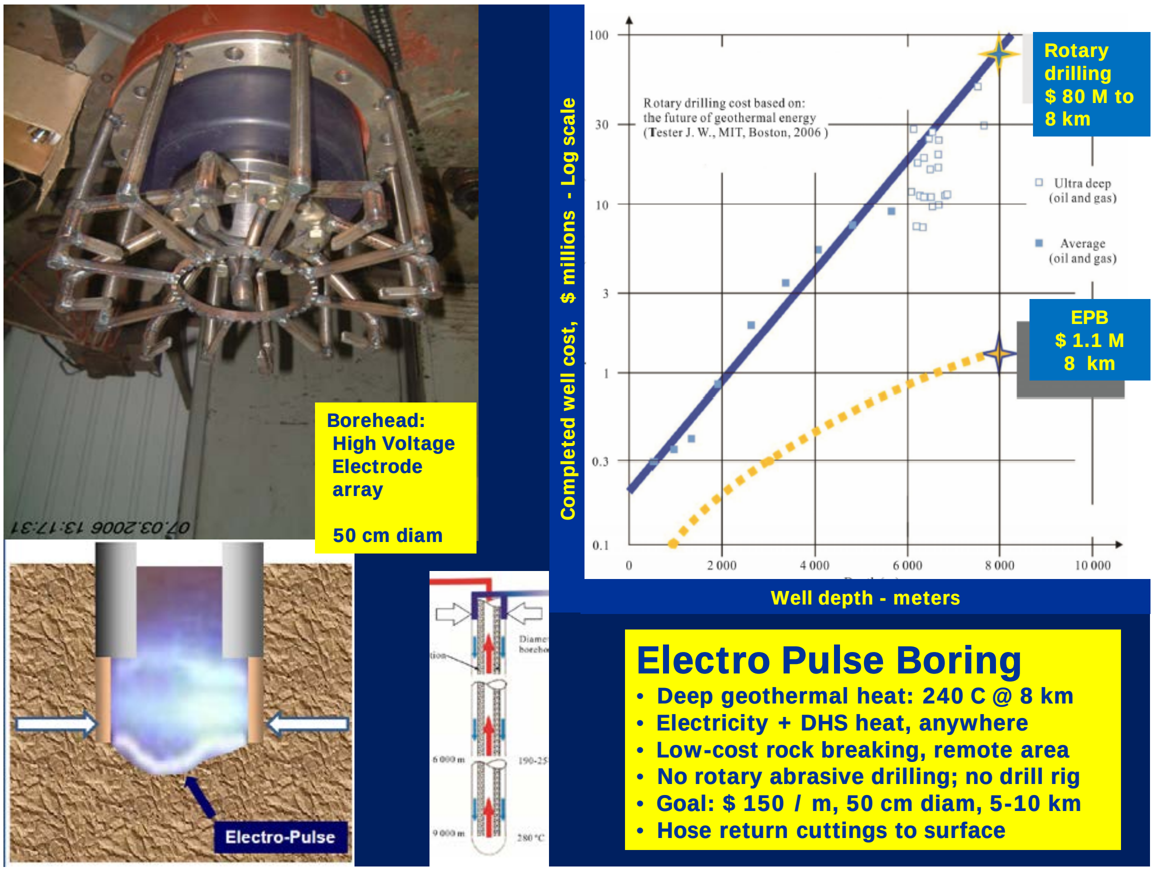

Figure 2. EPB uses high-power electric pulses to fracture rock at 5-10 km depth at far lower cost than rotary drilling.

7 CONCLUSION

Alaska Applied Sciences, Inc. (AASI) now has the opportunity to introduce, in the USA, Electro Pulse Boring (EPB), a new rock-fracturing technology to access ubiquitous, deep, geothermal heat at low cost, by pioneering design concepts, devices, and packaging for the key technology: the Down Hole Pulse Generator (DHPG). This will be a new company effort, to attract USA's advanced pulsed power and power modulation industry to EPB. In the USA we now find little awareness of nor interest in EPB; all attention is on EGS via costly boring technologies with only marginal improvements in costs for deep (6-10 km) boring to access the benign, baseload, unlimited, autonomous thermal energy available there.

Costs for a competent R&D&D program for EPB are $ 25 million for proof of concept, TRL 4-5 plus another $ 125 million to pre-commercialization, TRL 7-8.

If EPB achieves its cost goal of € 100 per meter for a 50 cm diam hole, 6 to 9 km deep, for sites easily-accessible to the compact EPB system (costs are higher for remote systems: Alaska villages), then:

a. Baseload geothermal energy at 90 C out - 20 C return can be produced for < $ 0.01 / kWht;

b. Baseload ORC generators can produce electricity at < $ 0.02 / kWhe from branched holes; < $ 0.05 / kWhe from single holes;

c. Boring costs will be lower for conventional two-borehole EGS, for lower long-term COE;

d. Thermal and electrical micro- and macro-grids may be established in remote areas, serving several communities and many people from a single branched or unbranched borehole;

e. The abundant associated lower-grade heat may be used for DHS and DHW, crop-drying, greenhouses

f. The electricity grid is relieved of potentially-suboptimal large investments in upgrading the electricity Grid, as it would otherwise be forced to accept ever-higher fractions of time-varying wind + solar.

REFERENCES

[1] Sustainable Energy: Choosing Among Options
By Jefferson W. Tester, Elisabeth M. Drake, Michael J. Driscoll, Michael W. Golay, William A. Peters, MIT Press