Summary: UK's onshore geothermal energy potential and how to progress it

The child pages in this part of the website show the geology of around 20 locations in northern onshore UK basins where, in our opinion, groundwater in the temperature range 70-100 degrees Centigrade can be brought to surface at rates adequate to run through an ORC turbine system, giving commercial electricity generation. ORC (Organic Rankine Cycle) turbine technology wasn't available in previous decades, it is now a proven enabler for low-temperature geothermal developments, with projects running in USA, Canada, India, Germany.

But not yet in the UK. Successive UK governments have been convinced that wind turbines and solar farms were the preferred commitment for UK renewables policy, with gas turbines becoming a declining back-up and future nuclear projects only now beginning to see the necessary reforms which will allow reactor approvals and construction to resume on a commercial basis. Ambitious targets have been set for wind energy (especially offshore) and Government envisages up to 50GW by 2030. Wind has problems. A 2.6 MW onshore wind turbine might have a payback period of approximately 6-7 years, and that is with large subsidy for the owners. With interest in wind declining, and the shortcomings of reliance on wind and solar for Britain's electricity supply recently exposed by 2024-5 cold weather, it is clear that UK energy policy is in need of a complete overhaul. Here is opportunity for geothermal, it's an obvious area for investment.

Technically, we show here that there is substantial potential in UK for low-temperature geothermal projects. In our own work we have focussed to date on East Midlands, the Craven (Bowland) basin from Preston area through Clitheroe to Skipton, the Northumberland basin from Carlisle to Bewcastle, and the Grangemouth, Falkirk area of the Scottish Midland Valley. Our approach based on targeting fractured rock trends in the Carboniferous sequences of these areas, has not been applied hitherto by any other group, so far as we know. We'll be expanding our review to southern England and South Wales, this year, and we'll hope to see the confused UK energy scene clarify as the World transforms.

Binary-Turbine and Power Plant

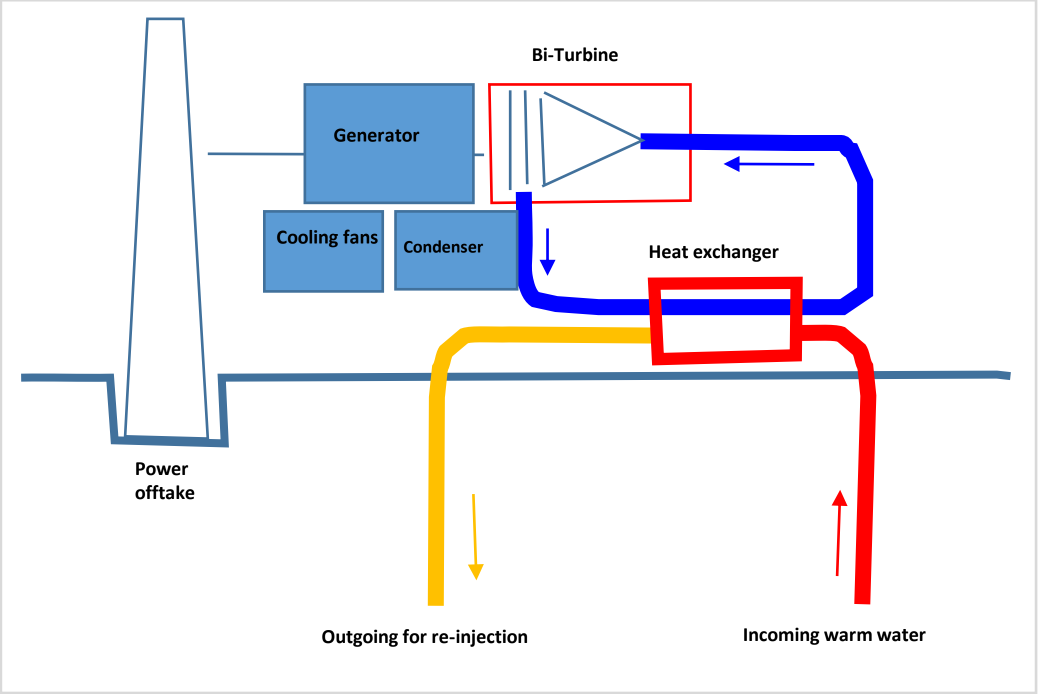
ORC, meaning Organic Rankine Cycle, is a thermodynamic process which bi-turbines use to convert low-temperature heat sources into electricity. ORC systems employ organic fluids which have lower boiling points than water, and that lets them extract energy from geothermal heat sources like groundwater reservoirs below 100 degrees C. The key components of an ORC bi-turbine are these:

The working fluids include pentane, butane, R245fa. They have boiling points lower than water and vaporise at lower temperatures, which allows efficient extraction from geothermal fluids around 100 degrees Centigrade. The geothermal fluid arriving at surface is going to be close to 100 degrees, it is pumped into a heat exchanger where it transfers heat to the organic working fluid, which vaporises. The exchanger is set up for optimal transfer efficiency whilst minimising pressure drop. The vaporised working fluid, now at high pressure, enters the first, high-pressure turbine which extracts the initial energy and converts it to drive an electric generator.

After it has gone through the first turbine the working fluid is part-expanded and still has some energy. It can be pre-heated before it goes into the second, low-pressure turbine, to improve process efficiency. This further converts the remaining thermal energy into mechanical work, the output from this second turbine also drives an electric generator.

When the working fluid has passed the second turbine it is condensed to liquid state, ready to recirculate in the cycle. The condensed liquid is pressurised by a feed pump and goes back into the exchanger. The pump is important, it must operate across a range of temperatures and pressures for system stability.

So, the bi-turbine design allows energy extraction over a broader range of pressure and temperature than a single turbine can, resulting in more electricity generation than a single ORC system can deliver. If temperatures and flow rates of the produced geothermal fluids vary, the bi-turbine can be tuned to match varying conditions. ORCs are specifically designed to run at lower temperatures than traditional steam turbines, and are particularly well-suited for geothermal plays with fluids in range 70-100 degrees Centigrade.



ORC bi-turbines also have a small footprint, having minimal emissions. The geothermal fluids never come into contact with the power plant's turbine unit. This means high-salinity ground water, any hydrocarbons traces, or corrosive/poisonous gas in solution in the fluid stream go back downhole in an injector well to safe depth. With small land-use demand, they can run off-grid and provide stable, continuous power supplies to areas which have limited access to electricity. They continue to see design development: efficiency will get still better.

So what do the costs of an ORC geothermal project look like?

The economics of low-temperature geothermal projects based on producer wells drilled to around 2000-3000 metres and return injectors to around half that depth order, are perfectly feasible, provided they are drilled into zones which deliver fluids at reasonably high rates. From a geological point of view, it's straightforward to identify onshore locations and assemble a UK portfolio of quality targets for drilling geothermal wells. Modern pressure-pulse drilling connects and enhances natural fracture systems. There is plenty of onshore acreage which is not licensed for oil and gas exploration (and thus is much less likely to automatically attract objections and serious delays in getting permissions), and it is serviced very cheaply by available seismic data. How one can apply for rights to drill geothermal plays and assert ownerships in open acreage investments, when no regulatory legislation for this form of activity yet exists, is presently unclear. Misdirected historical advice led to this situation.

Drilling say 5 producer wells from one pad gives big savings on site prep, well and turbine maintenance, we might need only 3 injectors to get cooled brine back to formation, and those wells are cheaper as they only need go to say 1000 metres. The wells should be separated to minimise interference with the thermal capacity around each other, that means some element of deviation is necessary, maybe spudding at least some of them inclined: a couple could go to different formations.

Lets consider the case for one large pad, and drill wells in sequence, skidding the rig, 1 producer well vertical to 2500m, 4 producers radially inclined to 2500m; 3 injectors to 1000m (cover any intermittent build-ups of cooled water for re-injection by building a large holding tank). How many heat exchangers and turbines do we need, if the production is all off one site? Here we presume each well needs its own turbine to produce 2MW, but we might find higher input water temperatures are possible with exchanger boosters.

Drilling/completions	£14 million
Turbines/generators	£5 million
Exchangers	£2 million
Condensers	£1 million
Installation	£1 million
Pumps, systems	£1 million
Connect to grid	?£1 million
Sundry	£1 million

With these uncertain and approximated figures, Capex is £26mm for 5 producer wells, 3 injectors, and 5 turbines. A rig is only on site for the drilling. For operating cost set a bare minimum £7.5 million for 25-year life.

For Levelised Cost Of Electricity we exclude off-site manpower costs and eventual site clearance/restoration. Given the amount of power produced over 25 years (2 MW x 5 wells x 0.85 capacity factor x 8750 hrs per well per year x 25 years = 1,859,375 MWh), the LCOE = (26,000,000 + 7,500,000/ 1,859,375) which is levelised at £18 per MWh. That is about 65 percent of the present cost of onshore wind turbine power.

Unlike wind power generation, we don't need to turn off the plant when there's no wind, or too much wind. Geothermal is reliable, is environmentally preferable as pads are small and can be made inconspicuous, and the plant has longer life than wind turbines. Like wind, geothermal will see reduced costs as the technology advances.

Next step

In April 2022 UK Parliament POSTbrief 46 addressed the status and potential of geothermal energy. "Geothermal projects have high capital expenditure (CAPEX), most of which is spent on drilling and materials. In addition, there is geological and financial uncertainty over the subsurface conditions and volume of revenue that will be delivered. High upfront costs and drilling risks are considered a main barrier to wider uptake of geothermal energy in the UK as they make it difficult to obtain project finance under current technology awareness and market conditions. Projects currently need financial support to improve their commercial viability and reduce risks to developers and investors".

No they don't. Not now. Compare this out-of-date analysis with the US Energy Department projection for cost of geothermal energy on www.energy.gov/eere/geothermal/enhanced-geothermal-shot . They think that the cost of next-generation geothermal energy in the USA is going to reduce to $45 per megawatt hour by 2035 and that the geothermal industry could become a powerhouse of U.S. economic growth, with particular benefits for rural communities. The same could go for UK. Closing down key components of UK manufacturing could stop.

We have a complete game-changer in low-temperature geothermal. This approach applies also to other basins, world-wide. It has radical implications for future energy development policy – it becomes feasible to control and even reverse the rise of carbon levels, if enough onshore drilling resource became available, and with that the transition to zero carbon need not entail any material decline in UK manufacturing output as we presently know it. It would have the opposite effect!

UK Government needs to be aware of the low-temperature geothermal option and include it in short-term planning. Read what America is doing. Add license terms to encourage UK projects. Offer some tax breaks to help investors. The risk is small. The reward is economic growth and energy supply security.

We should be delighted to discuss this analysis, on request.

Dr John Nicholson

www.highlandgeology.com

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