INFRASTRUCTURE DEVELOPMENT IN GEOTHERMAL FIELDS: A CASE STUDY FOR MENENGAI GEOTHERMAL PROSPECT, KENYA

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ABSTRACT

The world over is gearing towards exploring and harnessing of renewable energy. This is because green energy development is the theme towards reduction of green house gases and hence reduce global warming. Geothermal energy is one of the green energy and Kenya in particular has a potential over 7,000 MWe along in the Kenya Rift. Kenya is therefore exploring and harnessing this renewable and promising geothermal energy. To develop this immense potential, a lot of infrastructure development is required. Geothermal fields are naturally located in very steep and rugged terrains with no meaningful, or none at all and therefore logistical arrangements are required in the development of infrastructure in a geothermal field. Normally accessibility of geothermal potential areas is difficult until these fields are opened up to ease mobility into and within the prospects. There are various infrastructural development that are required in a geothermal field before actual drilling can be undertaken. These include; Access roads network, water supply connections, well pads and circulation ponds construction, electricity connections and provision of lay down areas. This paper therefore discusses these critical infrastructural development and an approximate cost of each task. It also describes the challenges encountered from access road provision until the drilling phases of geothermal wells.

INTRODUCTION

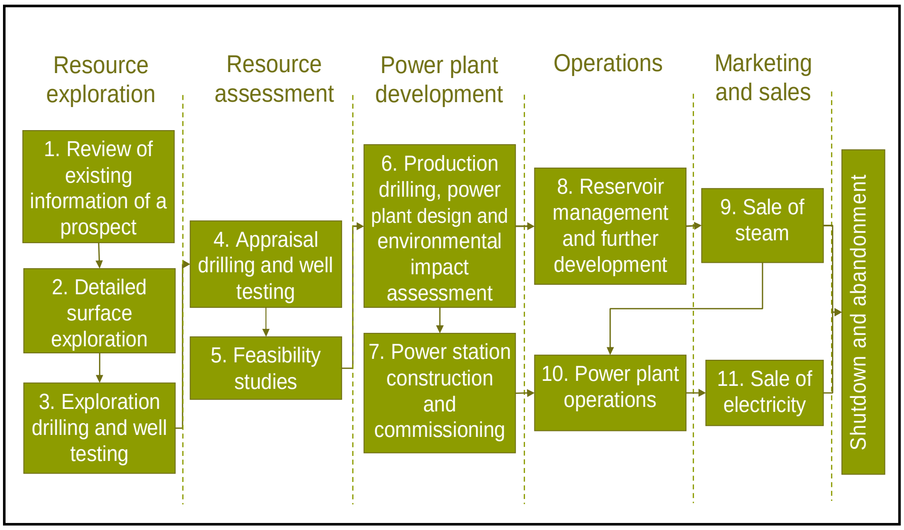
Geothermal resource development comprise the following principal activities

Stage 1: Geothermal Resources Assessment

Stage 2: Resource Development

Stage 3: Electric Power Generation

Figure 1 shows the stages of geothermal development in details. After the surface exploration is completed and the exploration wells are sited, a lot of infrastructure work is normally carried out for drilling of the first well to be realised. In Kenya like elsewhere in the world, geothermal prospects are located on remote areas and therefore the whole work is done form scratch. The chapters that follow expound on the infrastructural work that is carried out in a geothermal prospect, taking into consideration Menengai geothermal prospect as a practical case.



INFRASTRUCTURE WORK

Access roads network.

In order to ease mobility within a geothermal field, access roads network is vital. Due to the lugged nature of these geothermal fields, cutting of these access roads take quite a lot of time, money and machine power. Strong earth moving equipment are required to cut and flatten these roads. Bulldozers are the initial earthmoving equipment that require to be engaged to clear the bushes and remove surface rocks and soil. After the bulldozer has finished that, graders are used to grade the roads to final finish, cut mitre drains and give the roads required slope. Tipper trucks are then used to dump murram along the roads while a grader follows to spread it uniformly along the entire road. Vibratory roller compactor then follows to compact the spread murram while water bowsers move along to water the murram for better bonding. These roads sometime may pass very steep gullies and culverts are therefore constructed at the bottom of the gully to allow storm water pass without washouts.

As the access road enters Menengai caldera, a hard base rock was encountered which could not be cut using a bulldozer. This made us to engage a licensed qualified company to do blasting of this section of the road. After blasting, bulldozers were engaged to remove the rocks fragments and hence the steep gradient was drastically reduced.

Water supply connection

Drilling of geothermal steam cannot be achieved if water is not available in plenty. One drilling Rig consumes as much as 2000 litres per minute of water. Menengai geothermal prospect, which GDC is geared to developing from initial stages possess a lot of challenges as far as water is concerned. Unlike areas like Olkaria and Eburru, whose proximity to lake Naivasha give the two fields a very big advantage as far as geothermal development is concerned, Menengai geothermal field is very different. In this field, there are no streams neither is there fresh water lake.

GDC had to look for other ways of getting water in Menengai. One option was to drill water boreholes in order to get adequate water for drilling needs. Seven boreholes were drilled and commissioned and very impressing results indicated that water yield is in the range of 12-60 m^3 per hr in these boreholes. When the six (6) boreholes will be connected, we expect a total output of 264 m^3 per hr. This translates to 4400 litres per minute. Table 1 below shows the details of the six boreholes.

Table 1: Parameter of the 6 boreholes drilled in Menengai caldera

	Borehole 1	Borehole 2	Borehole 3	Borehole 4	Borehole 5	Borehole 6
Drilled Depth- Mtrs	200	105	135	50	50	55
Cased Depth- Mtrs	155	105	130	48	48	52
Water Rest Level- Mtrs	22.6	56.2	43.7	18.2	19.7	18.1
Proposed Pump setting level- Mtrs	100	86	115	40	38	40
Flow rate- m^3/hr	60	12	12	60	60	60
Pump size	6"	4"	4"	6"	6"	6"

GDC approached Nakuru Water and Sanitation Services Company (NAWASSCO) and was allowed to connect into their main using 4 inch GI pipes. From this connection NAWASSCO committed to supply a minimum of between 80-100 m^3 per hr. This again translate to 1500 litres per minute.

With these two sources of water on our reach, were are assured of about 5900 litres of water per minute and therefore we are confident that with the two Rigs drilling in Menengai, the GDC can confidently proceeds with the projects of putting up storage reservoirs tanks, water pump stations and electric sub-station as we anticipate power line connection into the caldera by Kenya Power & Lighting Company (KPLC)

A contract to supply, construct and commission five reservoir tanks each of capacity 4 million litres is underway. This will give us a total installed capacity of 20 million litres. To illustrate what this mean to two anticipated rigs; Two Rigs consume 4000 litres per minute, it will therefore take 5000 minutes to drain all the tanks assuming no inflow. This will translate to 83.3 hrs or 3.5 days. That is how big the tanks capacity we boast of! Atypical tank is shown in figure 2.

Figure 2: A typical steel panels bolted tank

Use of brine water from discharging wells is our future option when excavating of cooling ponds/pans is complete. Due to the porous nature of Menengai field, lining of these ponds is very critical on the inner part to stop water percolation. Plans are underway to procure pond liners. A contract for water pump station is also underway whereby a pump house will be build, three massive booster pumps will be supplied, one running, one on standby and one spare. Five submersible pumps will also be installed. Each booster pump will have a capacity to pump 270 m^3 per hr (4500 litres per minute) of water. That means we require 14.8 hrs to fill one reservoir tank. It also implies that one booster pump can feed the two rigs with water requirement even when there is total loss in circulation.

Well pads and circulation ponds.

A wellpad is a well prepared flat area where a drilling rig and accessories are placed during drilling process. There are different sizes of wellpads depending on the number of cellars that needs to be constructed onto it and the size of a rig. Generally, common standard size rig requires a pad measuring 110 m long by 70 m wide for one cellar. For any additional cellar, 35meters are added to the pad length. Therefore a pad of three cellars require 180m length, i.e 80 m by 180 m. This is just a general guideline and it's not cast on stone. It should be noted that rigs are of different sizes meaning that pads may vary from rig to rig. Cellars are constructed concrete pit where drilling mad is retained during spud-in process. In normal drilling process, drilling fluid from the well return back to the cellar and is drained through the cellar drain into the circulation pond.

Table 2: Typical cost estimate and infrastructural requirements for a 140 MW power plnt

MAIN ACTIVITIES	OPTIONS	REQUIREMENTS	QTY	UNIT	HRS/FUEL REQUIRED	UNIT COST (KShs)	TOTAL COST (KShs)	RECURRENT COSTS (KShs)
WATER SUPPLY	OPTION 1A (Usage of brine)	Excavation of 12,000 M^3 holding ponds	2	pc	600 Hrs	12,000	7,200,000	
		EPDM material & Accessories and installation	12	pc		1,805,137	21,661,644	
		Hardcore to cover EPDM	1,200	ton		1,500	1,800,000	
		Victaulic water pipes	450	pc		21,060	9,477,000	9,477,000
		Victaulic couplings	450	set		3,198	1,439,100	1,439,100
		Sub-mersible pumps	2	pc		250,000	500,000	
		Booster pumps	2	pc		1,000,000	2,000,000	
		Diesel Generators	2	pc		2,000,000	4,000,000	
		Diesel consumption	10	lts	1440 litres	75	1,080,000	1,080,000
		Transport cost for 30 days	9000	km		30	270,000	270,000
		Supervisors allowances	2	each	30 days	3,000	180,000	180,000
		Engineer's allowances	1	each	30 days	4,000	120,000	120,000
		Hire of Casuals	20	each	240 Hrs	135	648,000	648,000
	Sub-Total						**50,375,744**	**13,214,100**
	Option 2A (Metered)	Victaulic water pipes	450			21,060	9,477,000	9,477,000
		Victaulic couplings	450			3,198	1,439,100	1,439,100
		Metered cost of water(lts)	4,000		1440 litrs	0.0750	432,000	432,000
		Transport cost for 30 days	9000	km		30	270,000	270,000
		Supervisors allowances	2	each	30 days	3,000	180,000	180,000
		Engineer's allowances	1	each	30 days	4,000	120,000	120,000

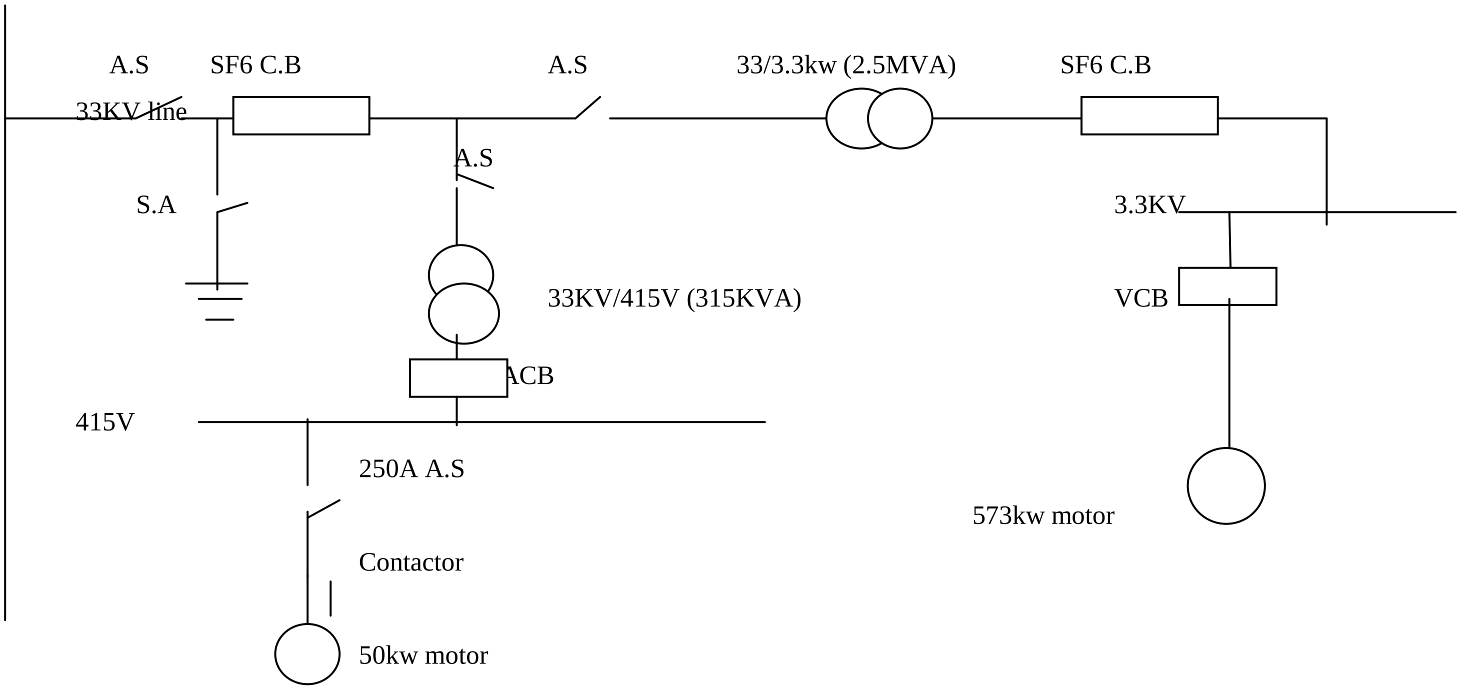
		Hire of Casuals	10		240 Hrs	135	324,000	324,000
	Sub-Total						**12,242,100**	**12,242,100**
	Option 3A (Drill boreholes)	Purchase of 5 acres land	5			1,500,000	7,500,000	
		Drill boreholes	5			2,500,000	12,500,000	
		Victaulic water pipes & fittings	50	Km		4,360,966	21,804,829	21,804,829
		Pump Station	1			57,000,000	57,000,000	
		Reservoir tanks	5			35,000,000	175,000,000	
		Electricity connection (33kv)	1			24,000,000	24,000,000	
		Sub-Station	1			26,000,000	26,000,000	
		Control & switching room	1			1,200,000	1,200,000	
		Transport cost for 30 days	9000	km		30	270,000	270,000
		Supervisors allowances	2	each	30 days	3,000	180,000	180,000
		Engineer's allowances	1	each	30days	4,000	120,000	120,000
		Hire of Casuals	10		240 Hrs	135	324,000	324,000
							522,142,287	**894,000**
CONSTRUCTION OF ACCES	Option 1B (Using own equipment)	D8 Bull Dozer	1		500 litres	75	37,500	37,500
		Motor Grader	1		200litres	75	15,000	15,000
		Vibratory Roller	1		100 litres	75	7,500	7,500
		Water Bowser	1		140 litres	75	10,500	10,500
		Tipper Trucks	2		140 litres	75	10,500	10,500
		Wheel loader	1		70 litres	75	5,250	5,250
		Hire of Casuals	3		120 litres	135	48,600	48,600
	Sub-Total						**134,850**	**134,850**
	Option 2B (Using hired equipment)	D8 Bull Dozer	1		40 Hrs	12,000	480,000	480,000
		Motor Grader	1		40 Hrs	7,500	300,000	300,000
		Vibratory Roller	1		40 Hrs	6,000	240,000	240,000
		Water Bowser	1		40 Hrs	1,289	51,560	51,560
		Tipper Trucks	2		40 Hrs	1,678	67,120	67,120

		Wheel loader	1		40 Hrs	10,500	420,000	420,000
		Hire of Casuals	3		120 Hrs	135	48,600	48,600
Sub-Total							**1,607,280**	**1,607,280**
CONSTRUCTION OF DRILL SITES AND CIRCULATIONS PONDS	Option 1C (Own equipment)	Back Hoe Excavator	1		50 litres	75	3,750	3,750
		D8 Bull Dozer	1		500 litres	75	37,500	37,500
		Motor Grader	1		200 litres	75	15,000	15,000
		Vibratory Roller	1		100 litres	75	7,500	7,500
		Water Bowser	1		140 litres	75	10,500	10,500
		Tipper Trucks	2		140 litres	75	10,500	10,500
		Wheel loader	1		70 litres	75	5,250	5,250
		Fencing of well pad & pond and landscaping	1	each			100,000	100,000
		Hire of Casuals	10		120 hrs	135	162,000	162,000
	Sub-Total						**352,000**	**352,000**
	Option 2C (Hired equipment)	Back Hoe Excavator	1		20 Hrs	7,000	140,000	140,000
		D8 Bull Dozer	1		160 Hrs	12,000	1,920,000	1,920,000
		Motor Grader	1		120 Hrs	7,500	300,000	300,000
		Vibratory Roller	1		120 Hrs	6,000	240,000	240,000
		Water Bowser	1		120 Hrs	1,289	51,560	51,560
		Tipper Trucks	2		120 Hrs	1,678	67,120	67,120
		Wheel loader	1		120 Hrs	10,500	420,000	420,000
		Fencing of well pad & pond and landscaping	1	each			100,000	100,000
		Hire of Casuals	10		120 Hrs	135	162,000	162,000
Sub-Total							**3,260,680**	**3,400,680**
GRAND TOTAL FOR MOST VIABLE OPTIONS FOR INITIAL ONE SITE(3A+2B+2C)							**330,906,789 (US$4,136,335)**	
GRAND TOTAL FOR MOST VIABLE OPTIONS FOR EACH ADDITIONAL SITE (1A+2B+2C)								**18,222,060 (US$227,776)**
COST ESTIMATE FOR INFRASTRUCTURE DEVELOPMENT FOR 30 WELLS							877,568,589 **(US$10,969,608)**	**877,568,589**

(ENOUGH FOR 140MW PLANT)

Electricity connections

With the anticipated contracts for putting up of water pumps station and supply of booster pumps and sub-mersible pumps, electricity connection is vital because these pumps require power to run them. Two contracts has already been given for electricity connection. One of them is to connect a high voltage (HT) line of 33 KV into the caldera. This was given to the only power company authorized to distribute power, the Kenya Power & Lighting Company. This company will establish wayleaves thereafter connect the HT line. The second contract involves construction of a transformation and switching power sub-station. This sub-station will transform the voltage from 33 KV to 3.3 KV and to 415 V. This is because booster pumps motors are rated at 3.3 KV while sub-mersible pumps are rated at 415 V. Power is also required for lighting and workshop jobs (Figure 4). GDC will however construct metering and switching control room for KPLC and also GDC use. GDC will carry out all civil works required in the sub-station and also do fencing of the entire sub-station, which is a requirement by KPLC.



Key:

A.S – Air break switch, S.A – Surge arrestor, VCB - Vacuum Circuit Breaker, ACB – Air Circuit breaker. C.B – Circuit Breaker

Figure 4: Line Diagram for the Substation

Provision of laydown areas

There are so many materials and equipment in a geothermal field that require to be secured in a save area. Laydown areas or storage yards are made for storage of these materials and equipment. These areas are leveled and murram is applied then compacted so that heavy equipment and trucks can be able to deliver materials inside the yard. Perimeter chain link fencing is thereafter constructed around these areas, to secure the materials and equipment. The cost of construction of laydown areas is above the cost indicated in the table above. After all these are said and down is when you may expect to see something like a land rig below;

Figure 5: A land Rig in operation on a well pad.