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Estimating the Optimal Levelized Geothermal Steam Tariff for Kenya

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ABSTRACT

Public Private Partnerships (PPP) models have become increasingly important drivers of promoting renewable energy growth in Kenya over the last decade with government facing increasingly constraint budgets. These PPP models are now gaining traction in Kenya's geothermal resource development with geothermal projects of over 2,000MWe already approved for implementation and with 245MW at advanced stages of implementation by Geothermal Development Company and Kenya Electricity Generating Company. These entities intend to sell the steam under PPP steam supply contracts, a separate business from steam conversion. Kenya's current geothermal Feed-In-Tariffs tariff for power plants capacity of between 35-70MW is US $ 0.088 kWh, with 20% Percentage escalable portion of the Tariff for the first 12 years and 15% thereafter, while for geothermal plants larger than 70MW is subject to power purchase agreements negotiations between the off-taker, and Energy and Petroleum Regulatory Authority (EPRA). However, the policy considers consolidated tariff at the off-take delivery point for both the energy conversion and steam payment with no explicit steam tariff rate for steam payment. With expected growth of PPP projects, computation of steam tariff charge rate that is cost reflective and consider PPP entry point would provide better basis for investment decision. The objective of this paper therefore is to estimate the costs and propose an appropriate optimal levelized Steam charge tariff for hypothetical 70MW geothermal project plants under PPP framework using a simplified MS excel-based financial model using concessionary debt under three *Cases: 1.* Steam tariff at the well (considers drilling costs and O&M well costs only; *Case 2.* Steam tariff at the well wellhead point considering all the costs at the well (drilling costs including drilling of 15% excess steam, and infrastructure costs (roads and water system), early development costs, operations and maintenance costs and decommissioning costs and of all full size but excluding interconnection the fluid collection and reinjection system cost. *Case 3*. Steam tariff at the power plant boundary (all drilling costs in case *1* and *2* and including the fluid collection and reinjection system costs). The analysis found the estimated optimal levelized geothermal steam tariff range of between 1.94 - 5.45 US cents/kWh depending on the PPP development model adopted. Sensitivity analysis carried out to determine the effects of commercial debt rate on the steam tariff found that the cost of debt, return on equity, drilling costs have a direct relationship on the steam tariff while power plant size have indirect effect. The level of sensitivity of the steam tariff varies with most parameters. From this analysis, the levelized steam tariff can be optimized by utilizing concessionary funding and self-drilling using own rigs.

1. INTRODUCTION

Kenya ranks ninth globally and tops Africa in geothermal power generation with installed capacity of 692.2 MWe contributing to about 26% of country's total installed electricity capacity and approximately 47% of electricity consumption in 2018 (Omenda et al, 2019).

The Government of Kenya has been the primary financier of drilling for geothermal steam for electricity generation. Due to the requirement for rapid expansion of electricity generation from geothermal sources, the government of Kenya faces substantial and expanding gap between the public investment needs and available resources with the government estimating that the country's infrastructure funding gap is approximately US$ 2-3 billion per year.

As part of the strategy to raise part of the required investment, the Government of Kenya (GOK) formed the Geothermal Development Company (GDC) with the mandate of accelerating geothermal development in the country by de-risking geothermal projects through undertaking the steam field development and inviting the private sector for power plant development, Mwai (2016). The Government also enacted the Public Private Partnership Act No.15 of 2013 that established a structured, methodical and staged development of Public Private Projects in the country Kenya. Private players (Independent Power Producers) (IPPs) such as Orpower have also been engaged in the development of geothermal resources.

With the new strategy, it is apparent that steam supply business could be a separate business from steam conversion as more private investors are involved in geothermal power development through Public private Partnerships arrangements. Already a couple number of projects including GDC's steam supply contracts for the 105MW Menengai Phase I geothermal power plant project and 280MW Olkaria I & IV, as well as Kengen's Olkaria well heads geothermal power plant base case examples.

The standard revised geothermal Feed-In-Tariff of US $ 0.088 per kWh for plants of between 35-70MW only provides tariff at the off-taker point. The steam tariffs between the steam supplier and steam converter is subject to agreements between the steam supplier and the power plant developer with approval by the Government and Energy and Petroleum Regulatory Authority (EPRA). An indicative fully cost reflective geothermal steam charge rate to guide private investors is therefore required. This is the objective of this paper; to establish the estimated costs and propose an appropriate optimal levelized steam tariff for geothermal power plants under PPP framework considering the different stages of entry for the private investors.

2. KENYA'S GEOTHERMAL PUBLIC PRIVATE PARTNERSHIP

Public Private Partnership Act No.15 of 2013 recognizes various PPP schemes in order of generally increased involvement and assumptions of risk by the private sector and their characteristics as shown below;

Table 1: PPP Schemes, Source: Public Private Partnership Act No.15 of 2013,

PPP Arrangement	Main Variants	Ownership of Capital Assets	Responsibility of Investment	Assumption of risk	Contract Duration
▪ Management contract	Management and performance	Public	Private	Private	≤ 10 Yrs
▪ Output Performance	operation, maintenance and management	Public	Private	Private	≤ 10 Yrs
▪ Lease	Lease, manages, operates and maintains and pays rent or royalties	contracting authority	Private	Private	≤ 30 Yrs
▪ Concession	operate, maintain, rehabilitate or upgrade an infrastructure facility-charge a user fee while paying a concession fee	contracting authority	Private	Private	≤ 30 Yrs
▪ Build-Own-Operate-Transfer	designs, constructs, finances, operates and maintains	Public/Private	Public/Private	Public/Private	≤ 30 Yrs
▪ Build-Own Operate	designs, finances, constructs, operates and maintains	Private	Private	Private	≤ 30 Yrs
▪ Build-Operate-and-Transfer	finances, constructs, operates and maintains and transfers	Public/Private	Public/Private	Public/Private	≤ 30 Yrs
▪ Build-Lease-and-Transfer	finance and construct, develop, lease & transfers	Public	Public	Public/Private	≤ 30 Yrs
▪ Build-Transfer-and-Operate	Constructs, transfers & operate	Public/Private	Public/Private	Public/Private	≤ 30 Yrs
▪ Develop-Operate-and-Transfer	Develop, transfers	Public/Private	Public/Private	Public/Private	≤ 30 Yrs
▪ Rehabilitate-Operate-and-Transfer	Refurbishes, operates and maintains	Public/Private	Public/Private	Public/Private	≤ 30 Yrs
▪ Rehabilitate-Own-and-Operate	Transfer, refurbish & operate	Public/Private	Public/Private	Public/Private	≤ 30 Yrs
▪ Land Swap	Transfers existing public land or asset				

While there exists a spectrum of models as shown in the table above, the Act recognizes that other combination types of more than one models can be implemented.

2.1 Models of Geothermal Development in International Practice

ESMAP Geothermal Handbook (2018) identifies eight different models that have been utilized in geothermal power development the international practice with international experience showing that there has been no single straight line model for development of geothermal resources as shown in Figure 1.

As shown in the figure 1, the upstream phases of geothermal project development rely heavily on public sector investments, while private developers tend to enter the project at more mature phases. The project development cycle (and sometimes the broader geothermal market structure) may be vertically integrated or separated (unbundled) into different phases of the supply chain. (ESMAP Geothermal Handbook, 2012). In the unbundled structure (Model 5, 6 & 7), more than one public entity or more than one private developer may be involved in the project at various stages, with the involvement of the private developers taking various PPP forms.

2.2 PPP Geothermal Projects in Kenya

The energy sector has been deliberate by way of policy to ensure that PPP is an alternative form of energy investment. As at November 2018, there are over seventy (70) approved projects in the PPP pipeline with the projects on diverse sectors and at various stages of the PPP Project style. The PPP Act, 2013 provides a straight forward process of implementing PPP Projects for quick execution with information on different stages of; Financial close (ready for financing); Commercial close (signed PPP Contracts); Contract Negotiations; and Tender/Procurement stages.

Nine geothermal power projects with development capacity of 2,405MW have been approved under the PPP arrangement and are at various stages as shown Table 2.

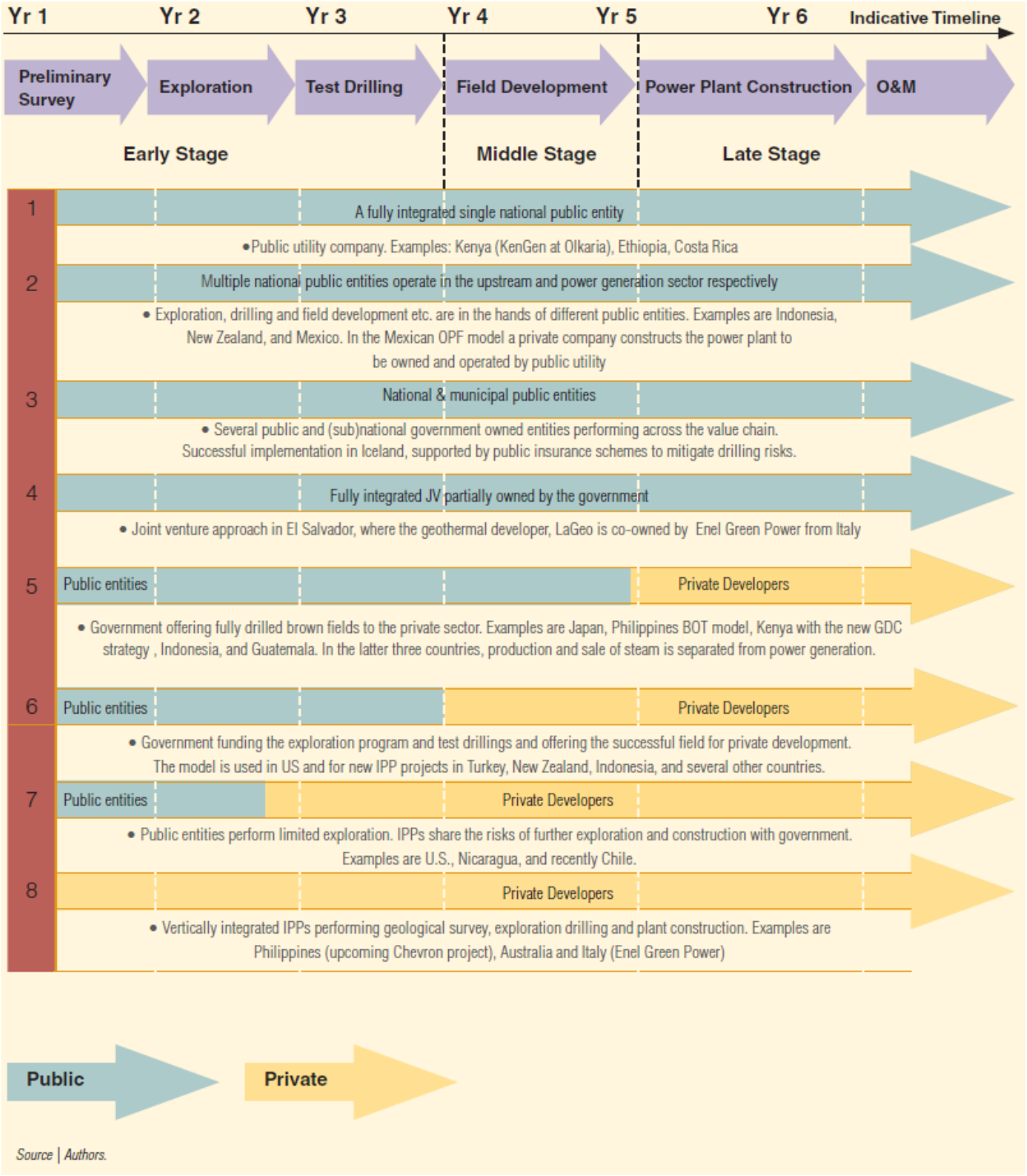

Figure 1: Models of geothermal power development in international practice (Source: Gehringer and Loksha (2012).

As shown in Table 2, three projects (BOO) in Menengai (35MWe Sosian Menengai Geothermal Power Plant Project, 35MWe Quantum Menengai Geothermal Power Plant Project, and 35MWe Ormat Orpower Geothermal Power Plant Project) and one project (BOOT) in Olkaria (140MWe Olkaria Geothermal PPP project - Phase 1) are at advanced stages. KenGen Master Lease Agreement (MLA) for leasing of 50MWe wellheads geothermal power generation units at Olkaria geothermal field on built, lease, operate and maintain basis for 15 years is also at Procurement stage. Under this arrangement the steam will be delivered at the Power Plant boundary

Menengai geothermal field is the first major project undertaken using the public-private partnership model 5.

Table 2: PPP approved geothermal projects (Source: PPP Unit website)

No	Project	Contracting Authority	Project Cost (M$)	PPP Model & Duration	Status
1.	50MWe Olkaria Wellheads Geothermal Projects	KenGen	-	Built, lease, operate & maintain	operational
2.	35MWe Sosian Menengai Geothermal Power Plant Project	GDC	79.15	BOO (25 yrs.)	Commercial/ financial close
3.	35MWe Quantum Menengai Geothermal Power Plant Project		79.15	BOO (25 yrs.)	Commercial/financial close
4.	35MWe Orpower Geothermal Power Plant Project		82.00	BOO (25 yrs.)	Commercial/financial close
5.	140MWe Olkaria Geothermal PPP project - Phase 1	KenGen	2,000	BOOT (25 yrs.)	Procurement
6.	420MWe Olkaria Geothermal PPP project - Phase 2			TBD	Proposal stage
7.	280MWe Olkaria VII & VIII		-	TBD	Drilling stage
8.	360MWe Menengai Phase 2	GDC	-	TBD	Drilling stage
9.	800MWe Baringo-Silali Phase 1		-	TBD	Drilling stage
10.	300MWe Suswa Geothermal Plant		-	TBD	Preliminary stages

N/B: BOO - Build-Own-Operate, BOOT - Build-Own-Operate-Transfer, BLOM – Built-Lease-Operate-Maintain, TBD: To be determined

2.3 The 105MW Menengai Phase I BOO Model

The structure of implementation of the 105MWe Menengai PPP Geothermal Project Model (shown in Figure 2 as model 5) consists of the need of de-risking of geothermal field development using public sector support and private sector capital mobilization at the power plant phase. The Menengai approach, sometimes referred to as the Project Implementation and Steam Supply Agreement (PISSA) model in reference to the agreement the IPP signs with GDC to purchase steam, allocates the high risk resource development activities to Government through GDC but involves private sector in the high capital intensive but low risk power generation phase.

In the 105MW Menengai model, the steam is charged on the basis of the kWh delivered to the three Contracted Independent Power Producers (IPP's) with the tariff capped at USD 0.085 per kWh (exclusive of value added tax) for 35MWe of power in line with the feed-in Tariff Policy.

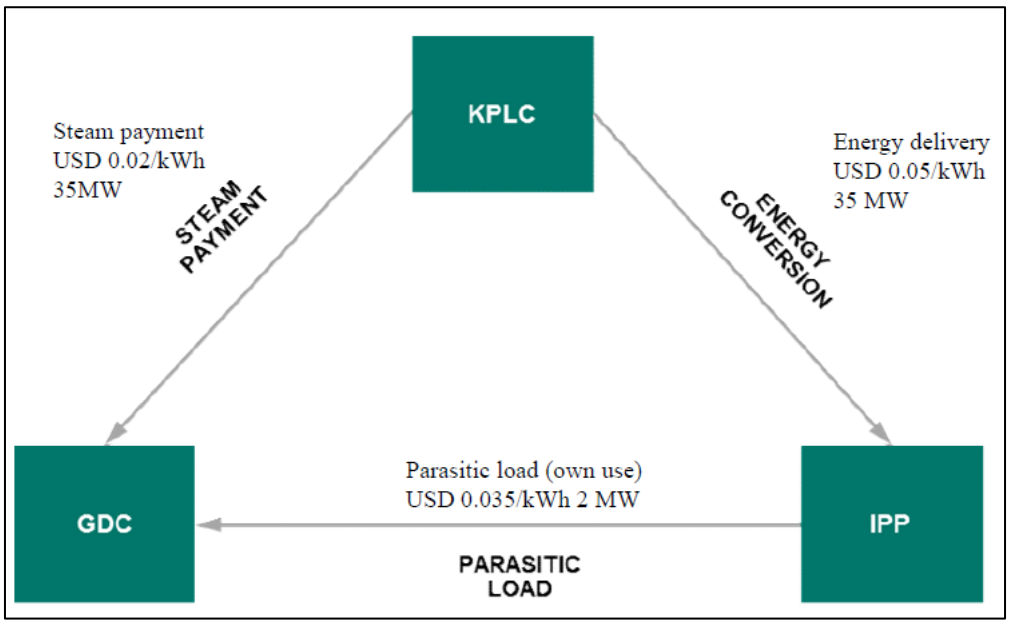

Figure 3: Payment Structure. Source: Akker (2018).

As shown in Figure 3, the generation component is capped at USD 0.05 per kWh while GDC is allocated US$ 0.02 /kWh for the steam component as a pass-through cost by KPLC for the net power delivered to the grid. The IPPs shall, from their revenue, pay

GDC for the steam consumed for generation of electricity for their own use (parasitic load) at the stated rate of steam, Akker (2018).

The geothermal steam tariff payment to GDC is expected to cover the steam field operations and maintenance costs, drilling of make-up wells, depreciation, profit and tax. In addition, this steam charge price takes into account the cost of undertaking the design, construction, installation, testing and commissioning of GDC connection facilities up to the power plant delivery point. Other factors considered in the steam charge calculations include the Governments interest of minimizing the electricity cost to the consumer, and the concessionary funding component of geothermal projects by the Government, Akker (2018).

The steam charge for the 280MW Olkaria I & IV project is similarly US $ 0.02 kWh. The subsidized tariff was arrived at in the interest of expediting the geothermal generation program and providing affordable cost of electricity to the consumer, and contribute towards lowering the energy costs to spur social economic growth especially industrialization. The steam charge price takes into account the cost recovery for drilling, well testing, and allow some component for the operations and maintenance of the wells, and steam delivery at the wellhead point and excludes the costs for the fluid collection and reinjection facilities, Standardmedia (2013).

As the Kenyan Government initiates the development of other geothermal fields through GDC, alternative public-private partnership models are being considered in which the private sector plays a bigger role in earlier stages as per the national geothermal strategy. These PPPs models will see IPPs fully be involved from the early stages of exploration and test drilling to the late stages of construction and development of power plant. The private sector contributions shall rise to 40 to 80 percent of investment for drilling production wells and steam field development.

Private sector investment in the early stages of geothermal project development cycles associated with higher risk will result in the PPP investor requiring; higher levelized tariff because of the longer lead time (>3 years), higher required rate of return on equity (Re) is higher (25%) due to high risk premium of early entry;, and the high cost of exploration, Simiyu (2013). Test drilling accounts for up to 15 % of the overall capital cost, which is required at a point when the risk of project failure is still high, Gehringer and Loksha (2012).

Hypothetically, if an IPP enters geothermal development at the early stage (before test drilling works) and take on higher risk associated with early geothermal project development risks, levelized geothermal tariff would need rise to between USD 0.14 and 0.17 per kWh as shown in Figure 4 (GDC, 2014; CPI 2015b). These tariffs rates are higher than the USD 0.088/kWh provided in the current policy and the true cost of geothermal development will be higher translating to higher pass-through geothermal steam tariff currently allocated to GDC, Simiyu (2013) and Akker (2018).

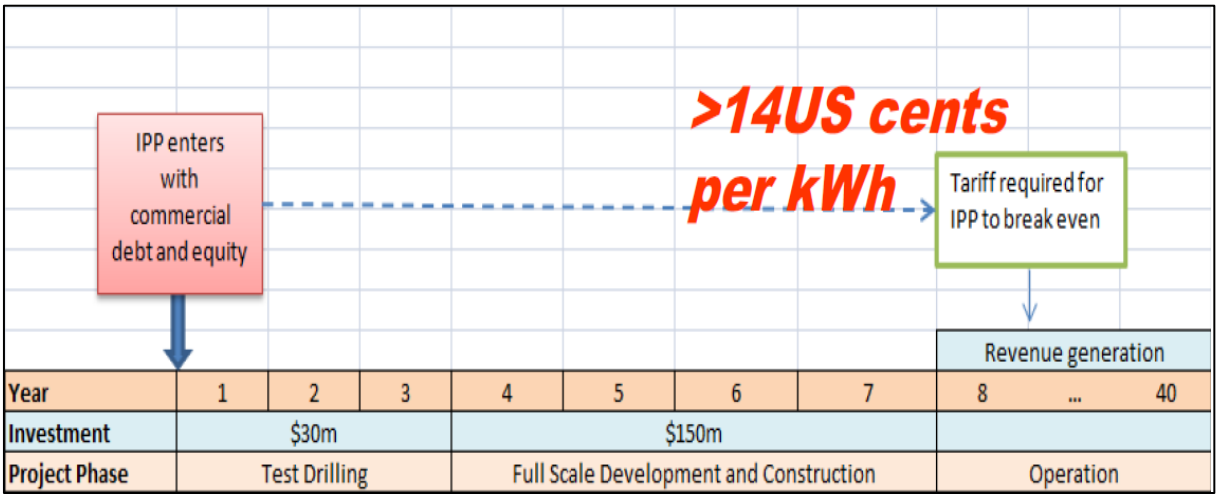

Figure 4: Hypothetical Testing drilling Investor entry point effects on geothermal Tariff. Source: Simiyu (2013).

2.4 Research Objective

Kenya's current geothermal electricity pricing mechanism is guided by the Government of Kenya's Ministry of Energy 'Feed-In-Tariffs Policy' of 2012. The standard revised Feed-In-Tariff for geothermal energy resource generated electricity connected to the grid for power plants capacity of between 35-70MW is US $ 0.088 kWh, with 20% Percentage escalable portion of the Tariff for the first 12 years and 15% thereafter. The tariffs for geothermal plants larger than 70MW is subject to Power Purchase Agreements negotiations between the developer and the Energy Regulatory Commission (ERC) MOEP (2015).

Geothermal power development is now recognized by the Government as part of the country's long term strategy, with the steam supply business projected to be a separate business from steam conversion in future as more private investors are involved in geothermal power development through Public private Partnerships arrangements. An indicative fully cost reflective geothermal steam charge rate to guide private investors is therefore required. This is the objective of this paper; to establish the indicative costs and propose an appropriate optimal leveled tariff for Steam for geothermal power plants under PPP framework considering the different stages of entry for the private investors.

Previous works in this research area have focused on estimating the leveled cost of generating geothermal electricity. Levelized cost of electricity (LCOE) represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. LCOE is often cited as a convenient summary measure of the overall competiveness of different generating technologies. The levelized cost for new geothermal projects on average, ranged from 6 to 8 US cents per kilowatt hour, Ngugi (2012), but it is recognized that the cost for individual geothermal projects can vary significantly based upon the various cost factors, and that costs for all power projects change over time with economic conditions. Kenya has fixed its feed in tariff for a geothermal plant of 70 MWe or less at 8.8 US cent per kWh, Ngugi (2012), U.S. Energy Information Administration (2013).

Most geothermal power projects have LCOEs between USD 0.05 and USD 0.08/kWh, which is at the lower end of the fossil-fuel cost range. Between 2013 and 2015, the weighted-average LCOE was around USD 0.06/kWh, rising to around USD 0.07/kWh during 2016–2018 Salvatore (2013).

3. METHODOLOGY

The research is based on a simplified MS excel-based financial model considering a hypothetical 70MW geothermal project. The model calculates optimal geothermal steam tariff charge taking into account investment costs, and the annual energy expected to be generated from the geothermal investment.

The model is based on the premise that steam supply shall be separate from power conversion with the government entity undertaking early exploration and drilling works, and operating and maintaining the wells while the private investors shall enter at different levels of PPP Models indicated in Figure 2 Model, 5, 6 & 7 for the conversion of steam. The model´s key input costs for the drilling, fluid collection and reinjection systems and steam field maintenance are based on hypothetical estimates from the geothermal industry estimates, ESMAP estimates and Kenya's energy planning reports. The estimates used in the modelling might not be the most optimal, but will nevertheless provide preliminary estimates of the indicative steam tariff with a probable accuracy sufficient for decision making purposes.

The key outputs from the model are the geothermal steam charge tariff for three (3) different the hypothetical project Cases. Risk assessment using sensitivity analysis was also carried out to evaluate and compare the effects of various parameters on the steam charge tariff.

The model specifically assesses whether the steam charge rate will generate viable financial returns for the three (3) investment Cases based considered below;

Case 1:

This Case calculates the Steam charge tariff at the wellhead point and considers only the recovery of the exploration, appraisal and production drilling costs and operations and maintenance costs for full-size wells only for a geothermal green field at concessionary rate. This Case assumes that the costs for the construction of the fluid collection and reinjection system and all other attendant infrastructure development costs will be recovered through the power plant tariff. The costs for preliminary surveys, permitting, market analysis, exploration studies, and drilling of excess steam have not been factored.

Case 2:

Calculates the steam charge tariff at the wellhead point considering all the costs at the well. This Case recovers all the costs related to drilling a green field (exploration, appraisal and production drilling costs and operations and maintenance costs of all full size wells, drilling of 15% excess steam), and infrastructure costs (roads and water system), early development costs and decommissioning costs at concessionary rate but excludes the costs for connection of the fluid collection and reinjection system to the power plant.

Case 3:

This Case assumes that the developer of a green field shall deliver the steam at the power plant boundary. Calculates the Steam charge tariff at the power plant delivery point recovers all costs in *Case 2* and including the costs for the fluid collection and reinjection system to the power plant boundary. This Case recovers costs using concessionary debt financing.

A sensitivity analysis is also carried out to determine the effects of commercial debt in financing, different rig rates and changes in the inputs parameters on the steam tariff.

This study does not consider the use of USD/tonne/hr of pricing steam based on the tones per hour delivered, a steam pricing model that protects the steam supplier from the inefficiency of the entity utilizing the steam.

3.1 Geothermal Steam Cost Modeling Assumptions

3.1.1 Technical Assumptions

The model uses the following broad assumptions across all the Cases

- Average output per well in Megawatts (MW) – 5MW
- Drilling cost per well ($M) – 6.5 MUSD
- Steam Buffer (%) – 15%
- Required access roads (Bitumen Standard) in kilometres – 50KM
- Access roads cost ($M/Km) – 0.3MUSD
- Fluid collection and reinjection system (M$/MW) – 0.MUSD
- Decommissioning of production wells at PPA end as a (%) – 50%

- Pre-Construction/early development costs as a percentage of the capex – 5%
- Net geothermal power plant capacity in MW – 70MW
- Geothermal power plant load factor – 90%
- PPA term in years is 25 years, also assumed as economic life of the well

3.1.2 Financial Assumptions

The following financial assumptions have been used in the modelling Cases

- A capital structuring (debt: equity) – 70: 30
- Return on Equity (after tax) – 12.5%
- Cost of debt – 4% for the Foreign concessionary rate and 8% for the commercial rate
- Weighted Average Cost of Capital – 7%

4. STEAM TARIFF MODEL RESULTS

The Steam charge tariff has been calculated using the annual revenue requirements (which takes into account the required rate of return based on the Weighted Average Cost of Capital (WACC)) and the annual energy expected to be generated from the investment.

4.1 Project capital requirements

Table 3: Model results of the analysis

Tariff Calculation		Case 1	Case 2	Case 3
Total Investment	**MUSD**	**91.00**	**142.12**	**182.60**
IDC	MUSD	0.00	19.90	25.56
Rate Base	**MUSD**	**91.00**	**162.01**	**208.16**
Annuity	MUSD	7.99	14.22	18.27
O&M costs	MUSD	2.73	4.86	6.24
Annual Revenue Requirement	MUSD			
Annual Energy	**kWhr**	**551,880,000**	**551,880,000**	**551,880,000**
Steam Charge Tariff	**USD/kWhr**	**1.942**	**3.457**	**4.441**

4.2 Steam charge tariffs

A comparison of the effects of various concessionary and commercial cost of debt rates was carried out with the results summarized below;

Table 4: Steam charge tariffs USD cents per kWh

Concession Rate	Case 1	Case 2	Case 3
2%	1.68	2.77	3.56
3%	1.77	2.99	3.84
4%	1.85	3.22	4.13
Commercial Rate			
5%	1.94	3.46	4.44
6%	2.03	3.71	4.76
7%	2.13	3.97	5.10
8%	2.22	4.25	5.46
10%	2.42	4.83	6.21

From the analysis above, **Table 4**, the steam charge tariff ranges between of 1.69 to 6.21 US cents/kWh depending on the development model adopted.

4.3 Risk Assessment Analysis

Impact Analysis: As part of the assessment, risk assessment using sensitivity analysis was carried out to determine the sensitivity of geothermal steam charge tariff relative to a given change in input parameters. The sensitivity and size of impact of drilling cost,

cost of debt, return on equity, on the project steam charge was carried out. One variable at a time was changed by a specified percentage, both above and below the most-likely value, and other variables held constant at the base case value. The output was then calculated for the new value; in this case the output being steam charge.

The results of the one-way sensitivity analysis f4.3 or all variables are as shown in Figure 5 below;

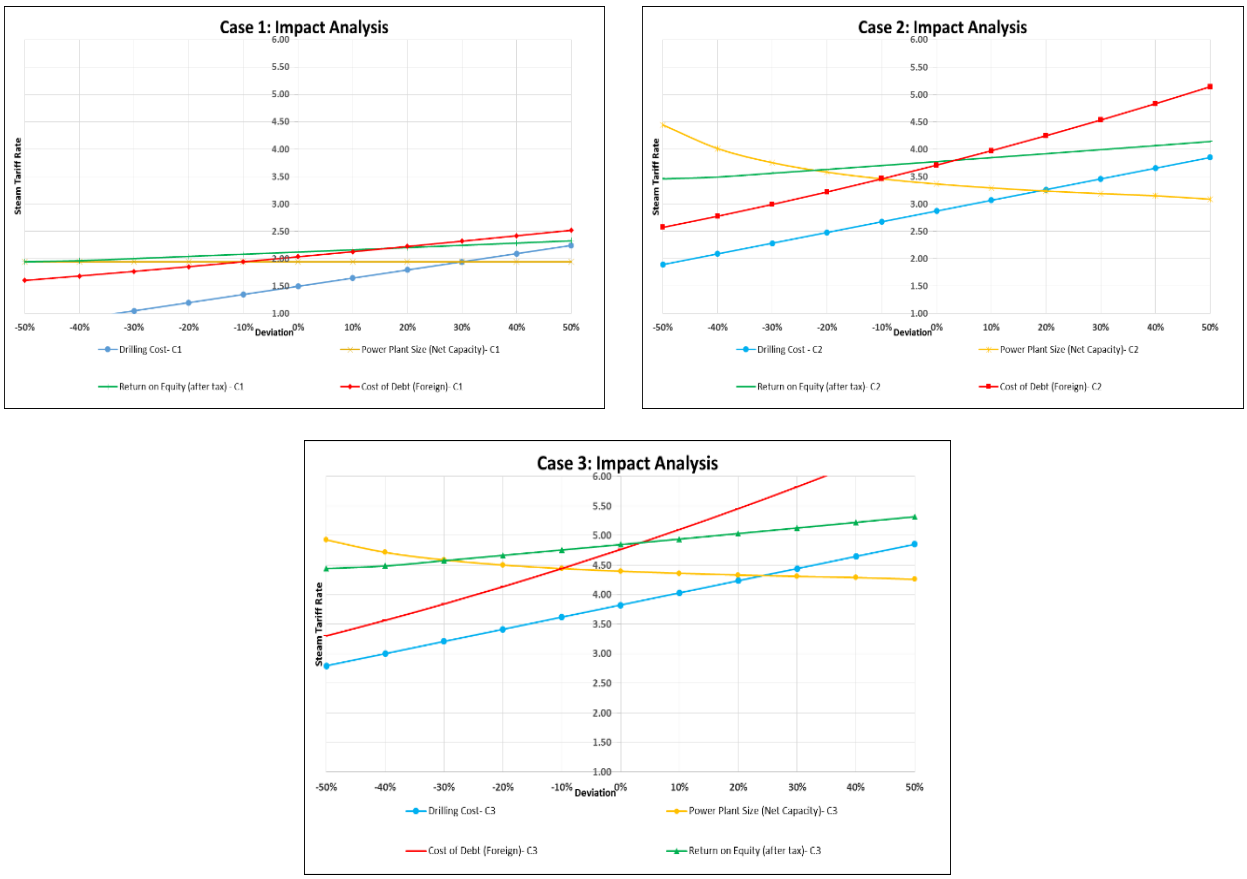

Figure 5: Impact analysis for parameters affecting the steam charge tariff for Cases 1, 2 and 3; drilling cost, cost of debt, return on equity and power plant size.

The trend line for cost of debt is the steepest compared to others parameters implying that the geothermal steam charge rates is very sensitive to the cost of debt in all the Cases, followed by returns on equity and cost of drilling of wells. An increase in the cost of debt for commercial rates from 5% to 8% (Case 3) has the biggest impact of increasing the steam tariff (US cents/kWhr) by 23% (1.01) compared to 14% (0.28) for Case 1. An increase in the cost of debt from 5% to 8% increases the steam tariff rate (US cents/kWhr) from 1.94 to 2.22 in Case 1, from 3.46 to 4.25 in Case 2 and from 4.44 to 5.46 in Case 3.

An increase in the after tax return on equity from 12.5% to 18% will increase the steam tariff rate (US cents/kWhr) by 11% in all the three Cases. Applying a 20 percent hurdle rate for the return on equity in case three renders the steam tariff of US$ 5.13 per kWh unnecessarily high compared to tariff of US$ 2.24 per kWh for Case 1.

An increase in the cost of drilling from USD 3.5 to 6.5 million, significantly increases the steam tariff by 86% for Case 1, 41% for Case 2,and by 38% in Case 3.

As the power plant size increases from 70MW to 140MW, the tariff reduces marginally by between 4% and 11% in the Case 2 & 3 respectively but have no effect on Case 1.

5. DISCUSSIONS

Case 1: From the analysis above, cost of debt of between 1% and 6% (for drilling costs only), the steam charge tariff ranges from 1.60 US cents/kWh to 2.03 US cents/kwh. However, the costs do not include the pre-construction, access roads, the fluid collection and reinjection system, 15% buffer steam, decommissioning of the wells after their economic life and the interest during construction (IDC). Sensitivity analysis for this case considering commercial loans ranging from 6% to 8% cost of debt under this case translates to an optimal steam tariff charge rate range of 2.03 to 2.22 US cents /kWh. This seems to be the applicable rate for the 280MW Olkaria I & IV geothermal power plants.

Case 2: At the well with all the costs included except the fluid collection and reinjection system, the calculated steam charge tariff range from 2.72 to 3.38 US cents/kWh. This reflects steam charge tariff assuming concessionary lending of between 1% and 4% for steam delivered at the wellhead. From the analysis, this estimated tariff reflects the steam tariff of 3 US cents/kWh by the Feed-in-

Tariffs for 50MW wellheads geothermal power generation units at Olkaria geothermal field on built, lease, operate and maintain basis, Chege (2017), Chege P.: et all, 2017). For commercial loans with interest ranging from 6% to 8%, it translates to higher tariff ranges from 3.71 to 4.25 US cents /kWh.

Case 3: Including all the costs for developing steam field delivered up to power plant boundary inclusive of fluid collection and reinjection system, the calculated steam charge tariff is in the range of 3.56 to 4.44 US cents/kWh assuming concessionary lending of between 2% and 5%. The tariff rises to ranges of between 4.76 to 5.46 US cents /kWh for commercial loans with interest ranging from 6% to 8%. This case is also the implementation model for 105MW Menengai PPP Geothermal Project whose tariff is 2.00 US cents /kWh. The subsidized steam tariff for the Menengai case is attributed to the financing structure of the Government budgetary support, grants and low interest rates of between 0.75% - 2%.

In Kenya, drilling wells using owned rigs cost about 3.5 million US$ and about 6.5 million using hired rigs (Ngugi, 2012). Keeping other parameters constant, an increase in the cost of drilling from USD 3.5 to 6.5 million, significantly increases the steam tariff by 86% for Case 1, 41% for Case 2,and by 38% in Case 3.

6. CONCLUSIONS

The analysis demonstrates the estimated optimal levelized geothermal steam tariff ranges from 1.94 - 5.45 US cents/kWh depending on the PPP development model adopted. A change in cost of other parameters including the cost of debt, cost of drilling (hired versus owned rig), power plant size, and return on equity can have a significant impact on the optimal tariff and ranges from 1.69 to 6.21 US cents/kWh.

This study indicates that the Government financial support and use of concessionary loans in the upstream phases of geothermal projects is principal to reduce the perceived risk and hence bring down the debt interest for commercial loans and improve the rate of return on equity and the overall steam tariff. This leveraging of government support will also translates to lower retail tariffs reduced tariffs.

This study also showed that drilling wells using owned rigs at a cost of US$ 3.5 Million compared to the use of hired rigs which cost about US$ 6.5 Million per well is a better strategy and will reduce the tariff significantly. The optimal actual optimal steam charge tariff should therefore be project specific and should consider the cost of debt, the financing structure and benchmarked project costs.

The calculated steam charge tariffs in the analysis do not consider inflation and inflationary pressure on both investments and O&M costs, and the Consumer Price Index (CPI) or periodic review is something to be a considered when approving the steam charge tariff.

7. REFERENCES

Akker, J.: Geothermal Energy Powering Kenya's Future: Menengai Geothermal Field Development Facilitated by Public Private Partnerships, Case Study, Climate Investment Funds (2018)

Chege P.: The 5MW Pilot Plant and 75.6MW Wellheads Projects - The KenGen Journey to World Class innovation, 2017

Chege P., Bardarson G., and Richter, A.: KenGen's Successful Implementation of a Modular Geothermal Wellhead Strategy, *Proceedings,* GRC Annual Meeting, Salt Lake City, Utah, USA (2017)

Gehringer, M., and Loksha, V.: Geothermal Handbook: Planning and Financing Power Generation, *Technical Report 002/12*, Energy Sector Management Assistance Program, World Bank (2012)

Ministry of Energy and Petroleum (MOEP): The Feed in Tariffs Policy Brochure. Kenya: Ministry of Energy and Petroleum (2015)

Mwai A.: Geothermal Development by Public Private Partnership- A Case Study Of Menengai 105 MW Project, *Proceedings*, 6th African Rift Geothermal Conference, Addis Ababa, Ethiopia (2016)

Ngugi, P. K.: What Does Geothermal Cost? – The Kenya Experience, Presented at Short Course VII on Exploration for Geothermal Resources, Lake Bogoria and Lake Naivasha, Kenya, Oct. 27 – Nov. 18, 2012, UNU-GTP, GDC and KenGen (2012)

Omenda, P.: Mangi, P.: Ofwona, C.: and Martin Mwangi, M.: Country Update Report for Kenya 2015-2019

Public Private Partnership Act No.15 of 2013

Simiyu S., M.: Public-Private Partnership Promoting Renewable Energy in Kenya: Case Study of Geothermal Development, presentation at the Irena Scholarship Programme, February 19th, 2013

U.S. Energy Information Administration. Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019, U.S. Energy Information Administration (2019)

https://www.standardmedia.co.ke/article/2000098054/cheap-power-in-sight-as-state-subsidises-energy-cost

Salvatore J.: World Energy Perspective: Cost of Energy Technologies, World Energy Council, Regency House 1–4 Warwick Street, London W1B 5LT, United Kingdom (2013)