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MONITORING AND EVALUATION FRAMEWORK FOR GEOTHERMAL PROJECTS: OLKARIA I UNIT 6, KENYA

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ABSTRACT

A monitoring and evaluation framework serves as a guide in project management and is a tool that ensures control in all the phases of a project. For capital intensive geothermal projects, a framework has proven to be beneficial in their management. The development of the framework borrows concepts and ideas from public management systems that have been and are being developed.

A framework was developed for management of geothermal projects through the use of a project being implemented in Kenya (Olkaria I unit 6). A description is given on management of phases staged in geothermal projects. Different tools and methodologies were applied to develop the framework from the initiation, execution and completion phases. Time and scope management through the use of decomposition and critical path is utilised. In cost management earned value analysis was used as a means of cost control. A profitability model was also developed that gives the economic viability of the project and is essential at the project initiation.

A reporting method with the use of performance indicators for project monitoring is discussed and guidance on reporting of the indicators as well as reporting frequency. A dashboard report for the Olkaria I unit 6 project was developed and is presented with assumed data.

1. INTRODUCTION

1.1 Development strategy

The geothermal activity in Kenya lies within the East African Rift system. Fourteen geothermal sites, shown in Figure 1, have been identified within the Kenyan rift with potential power of over 10,000 MWe while the current installed geothermal capacity stands at about 623 MWe. It is expected that the installed capacity will grow to 5,500 MWe by 2030 (MoEP, 2015). Overall power generation in Kenya is expected to grow to 19,200 MWe by 2030 from the 2,200 MWe in 2015. The growth will be necessitated by a long-term development policy, Vision 2030, which is geared towards improving living conditions in Kenya and ensuring energy sustainability. The aim of the policy is transforming the country to an industrialised middle income economy with a high quality of life, and a clean and secure environment.

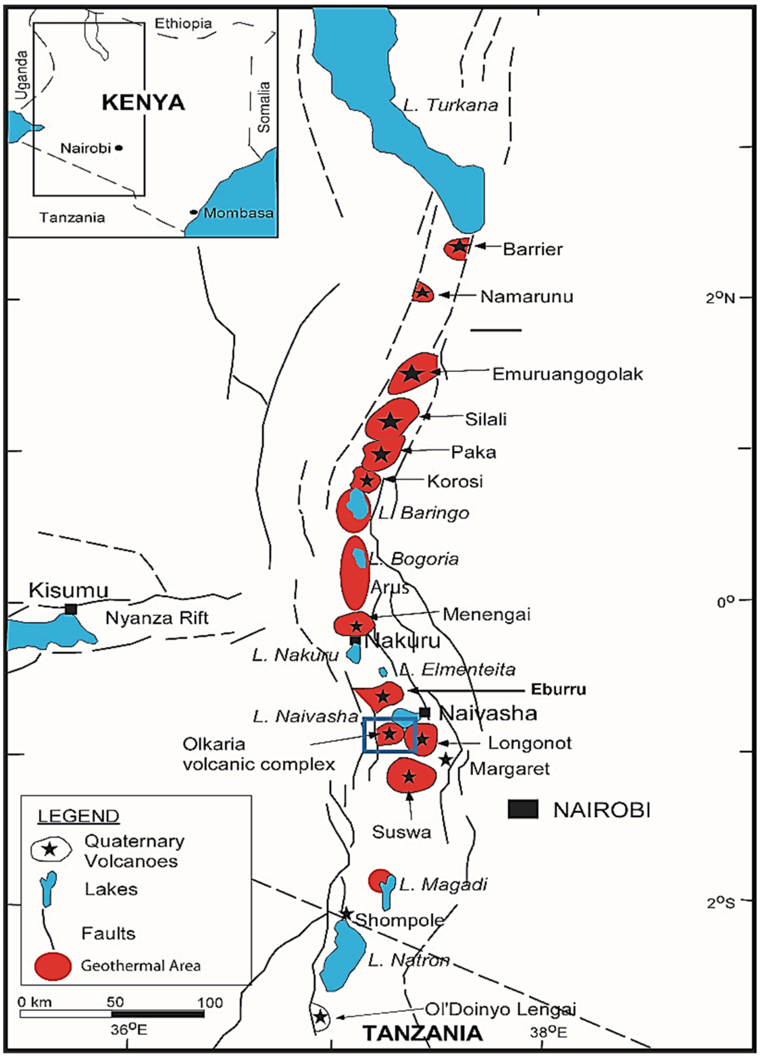


FIGURE 1: Geothermal sites along the Kenyan rift

One key pillar of the strategy is growth in electricity generation, especially from geothermal power. The government is ensuring the injection of 5000+ MWe power by 2018. This is a plan to inject an energy mix of about 5000 MWe, mostly green energy, through enhancement of various forms of energy while exploiting the current resources in the country. Prominent on this plan is the exploitation of geothermal energy and it is expected that 1,746 MWe will be injected by 2018. The plan has resulted in fast-tracking implementation of power projects in the country to ensure the attainment of this ambitious plan. Under this plan, 280 MWe was added into the grid in 2015 from Olkaria I Unit 4 &5 and Olkaria IV projects. The government has been in the forefront to encourage the development of geothermal power for electricity generation and direct use. Favourable legislations and policies supporting geothermal development are amongst the initiatives made to ensure achievement of the plan. The government has also encouraged the involvement of Independent Power Producers (IPPs) to invest in the sector.

1.2 Management of geothermal projects

Geothermal projects are capital intensive and require keen management to ensure appropriate dispensation of resources and efficient management of time for the intended results to be attained. This creates the need to have proper mechanisms of planning, monitoring and evaluation. A good monitoring and evaluation framework ensures that the project intended goals and objectives are met, while ensuring at the same time learning opportunity, traceability and that decision making is done with good and reliable information.

The Monitoring and Evaluation framework (M&E framework) described in this work seeks to address how geothermal projects can be evaluated/monitored at the Olkaria Geothermal field and serves as a link between the resource and products. It provides the basis for evaluation and decision-making and links all processes inherent in geothermal utilisation and weighs the project risks. The framework depicts a reporting method through the use of dashboards. This gives highlights on the implementation and status of projects at a given time. The elements in the framework serve as a means of evaluation and project reporting in terms of:

i. Economic viability and return on investment over a given period;
ii. Giving clear indicators of areas of improvement in technology;
iii. Defining the progress of plants and wells over a period of time;
iv. Enabling management of resources earmarked for the different projects:
v. Raising alarm on fields or areas that require monitoring.

2. DEVELOPMENT OF MONITORING AND EVALUATION SYSTEMS

Monitoring is the continuous analysis of information regarding implementation of a project with the aim of reaching set targets. It can be defined as the ongoing process through which stakeholders obtain regular feedback on progress made towards achieving goals and objectives (UNDP, 2009). It entails reviewing progress made in implementing actions or activities against goals.

Evaluation is the assessment of either completed or ongoing activities to determine the extent to which they are achieving stated objectives and contributing to decision making (UNDP, 2009). Evaluation involves analysis of projects with the aim of establishing fulfilment of objectives, efficiency, effectiveness impact and sustainability (OECD, 2009). The benefits of project evaluation include:

- Providing feedback on the project performance;
- Measuring failure or success with regard to set goals and objectives;
- Establishing a learning platform through documented experience.

A monitoring and evaluation framework is a guide to manage projects during implementation. According to the Project Management Body of Knowledge (PM BOK) this could be equated to the project monitoring and control phase, which is defined as the process of comparing project progress against the planned progress. The process is replicated throughout the project life cycle.

Various approaches of developing M&E frameworks have been established. A critical element in their development is the use of mixed methods. Mixed methods involve the use of both quantitative and qualitative data for evaluation of attributes influencing the project. This eventually gives real-time feedback on implementation and on how well a project worked (Bamberger et.al, 2010).

Development of M&E frameworks have been within the public sector management systems where accountability, performance feedback and impact assessment is critical (Hailey and Sorgenfrei, 2004). M&E frameworks have been continuously developed within public sector management systems. The evolution of management systems has taken place over a period of time. In the 1960s emphasis was put on financial and cost accounting through the Planning, Programming and Budgeting Systems (PPBS) while Programme Management by activities emphasised schedule management in the 1970s. Later, there was the development of Management by Objectives and Logical Framework Approach which introduced setting of objectives and identification of performance indicators (Meier, 2003). Commonly adopted strategies, results-based management, managing for development results and the log frame approach are discussed.

2.1 Results-based management (RBM)

RBM is a management strategy based on the use of results oriented tools aimed at improving performance (Meier, 2003). RBM targets to track progress and performance with the goal of demonstrating outcome and impact. It places emphasis on outcomes and impacts as opposed to inputs and outputs (Kusek and Rist, 2004). It was one of the principles adopted during a series of UN conferences for developing countries in the 1990s. During the conferences, various development priorities such as: education and environment, social development and women rights were discussed and targets for development set. In 2000, the Millennium Development Goals (MDGs) were adopted during the United Nations Millennium Summit. The developing countries were encouraged to adopt RBM as a means of promoting good governance and results oriented public sector management (Meier, 2003).

As portrayed in the RBM life-cycle, Figure 2, the strategy ensures that all contribution to a project is geared towards the achievement of set results. According to the RBM Handbook by UNDG (2011) monitoring involves regular and systematic assessment based on actual performance and regular reporting. Monitoring results in RBM is a process that commences from the planning stage where a results framework and theory of change (toc) are developed. The results framework can be in the form of a matrix with targets, baselines and verification terms set. During the implementation stage monitoring and evaluation provides information for decision making and platform for documentation of lessons learnt.

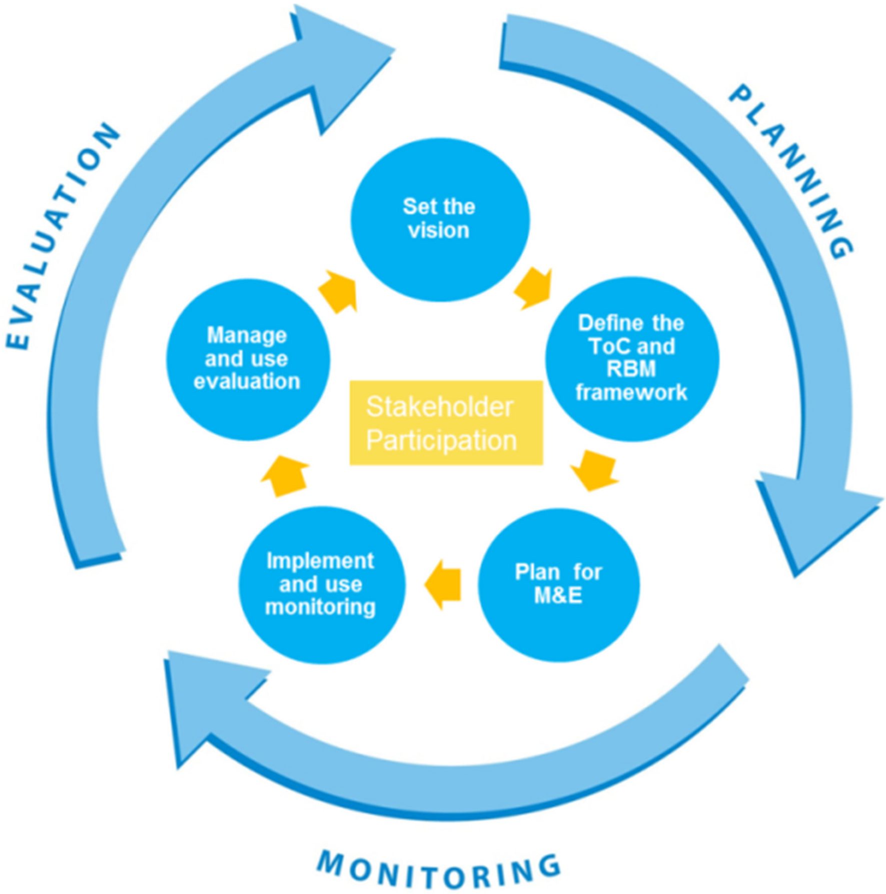


FIGURE 2: RBM life-cycle (UNDG, 2011)

In RBM, evaluation is defined as systematic assessment of a project, strategy or policy, focusing on accomplishments while examining results (UNEG, 2005). Evaluation in this context has three functions as defined in the RBM Handbook (UNDG, 2011); programme improvement, accountability and organisational learning. Key principles defined for RBM according to RBM Handbook are: accountability, ownership and inclusiveness.

2.2 Managing for development results

Managing for Development Results (MfDR) focuses on development performance and on sustainable improvement. It provides a framework for development efficiency in which performance information is used to improve decision making (OECD, 2009). The MfDR concept is based on effective global development through enhancing ownership, aligning assistance with priorities, harmonizing agencies, policies and procedures, focusing on achievement of development outcomes. The principles of MfDR are (MfDR, 2015):

- Focusing on results at all phases of the development process;
- Aligning programming, monitoring and evaluation with results;
- Keeping measurement and reporting simple;
- Managing for achievement of results;
- Using results information for learning and decision making.

MfDR is commonly used by national governments and development agencies to measure effectiveness of projects relating to poverty reduction and economic sustainability. It is based on four main features: shared goals and strategies, performance-based budgets, evidence-based decision making and public accountability. For success of MfDR, there is a need for credible data and procedures to enhance development of performance monitoring and evaluation systems.

2.3 Logical frame approach

The LFA has been used as a project appraisal document by the World Bank. It was created in 1969 for the U.S Agency for International Development. It has been used for design, implementation, monitoring and evaluation (Team Technologies, 2005). The Logical Framework Approach (LFA) is an objective-oriented instrument for project management.

LFA is used to develop the design, improve implementation, monitor and evaluate projects. It is an engaging instrument used for problem identification, setting priorities, planning and implementing projects, follow up and evaluating progress. (Örtengren, 2003). The LFA tool (Logframe) is developed as a matrix (Table 1) which is interrelated with changes in one item resulting in changes in another.

TABLE 1: Structure of LogFrame matrix (EuropeAid, 2004)

Project description	Indicators	Source of verification	Assumptions
Overall objective – The project's contribution to policy or programme objectives (impact)	How the OO is to be measured including quantity, quality, time.	How will the information be collected, when and by whom	
Purpose – Direct benefits to the target group(s)	How the purpose is to be measured incl. quantity, quality, time.	As above	If the purpose is achieved, what assumptions must hold true to achieve the OO
Results – Tangible products or services delivered by the project	How the results are to be measured incl. quantity, quality, time.	As above	If results are achieved, what assumptions must hold true to achieve the Purpose
Activities – Tasks that have to be undertaken to deliver the desired results			If activities are completed, what assumptions must hold true to deliver the results

The first column in the matrix describes the project; the strategy or goal, impact and deliverables or output. The indicators column outlines the performance indicators and target for the levels while the third column gives the sources of data during implementation either reporting or effects of an activity.

The fourth column describes the conditions for project success i.e. the assumptions and risks are outline in the fourth column.

The process of development of the logframe is a two-stage process that involves:

i. The first stage is the analysis. This involves stakeholder analysis, problems, objectives and strategy analysis. This process requires constant review and is refined throughout the project.
ii. The second stage is the planning which involves the practical operation of the plan. The project structure is developed, activities and resource scheduling is also done.

A major problem with implementation of the LFA is that the process should be done prior to project documents preparation and requires stakeholder participation.

2.4 Dashboard development

The process of reporting for M&E frameworks can be inherent in the tool that is used, however there is a shift in reporting methods to dashboard reporting. Dashboard reporting involves the summing and integration of key performance indicators to communicate performance (Wind, 2005). Dashboards have been defined as a collection of interconnected key performance metrics and underlying performance drivers that reflect both short and long-term interests to be viewed in common throughout the organization (Pauwels et al., 2009). Dashboards are visual and attuned to give specific and precise information on a subject.

3. GEOTHERMAL PROJECT IMPLEMENTATION – MANAGEMENT OVERVIEW

Geothermal projects take the course of a project cycle; initiation, planning, execution and closing. However, at each stage of development one or more process groups may be part of the phase. The phases are as classified in Table 2 and nine key steps outlined:

TABLE 2: Phases of geothermal development (Ngugi, 2008)

Resource exploration	Resource assessment	Power plant construction	Operations
Review of existing information	Appraisal drilling	Production drilling	Reservoir & steam field management
Detailed surface exploration	Feasibility study and Environmental Assessment	Power plant design and construction	Power plant operations
Exploration drilling			

i. *Resource exploration* entails review of existing data on the field from previous studies as well as geological and geophysical mapping and geochemical sampling of the area. It also involves exploratory drilling to confirm availability of a resource.
ii. *Resource assessment*: involves appraisal drilling which helps in approximating the size of the resource, approximate the cost of production and ascertain chemical composition of the geothermal fluid. A feasibility study of the project is done to verify the viability of the project, environmental impact and power plant technologies available.
iii. Power plant construction
   a. Production drilling focuses on provision of sufficient steam for the sized plant;
   b. Power plant construction entails, design, construction of the steam gathering system, the power plant and the electrical substation and transmission lines.

iv. *Operations*

a. Reservoir management involves monitoring the steam field to ensure that steam quality to the plant is maintained and drilling for make-up wells due to drawdown;
b. Operations and maintenance of the power plant to ensure continuous power generation.

3.1 Profile of the Olkaria I Unit 6 project

Olkaria I Unit 6 is on the east side of the Olkaria field. The plant is an additional unit to the first geothermal plant in Kenya, Olkaria I containing three 15 MWe units. The plant was commissioned between 1981 and 1985 and is due for upgrade. In 2015, additional units 4 and 5 were commissioned, each 70 MWe. The new unit (unit 6) is expected to be commissioned in December 2018. Through the development of the framework and reporting, dashboard performance indicators and measures are established at various stages of development. Economic and cost analysis is done and a visual reporting mechanism generated.

3.2 Initiation and project planning

The concept of the project as discussed in the previous chapter is based on the country´s geothermal growth strategy. This forms the basis of development of the geothermal expansion programme and the execution plan. Development of Olkaria I unit 6 was incorporated as part of the projects in the Olkaria geothermal programme. The steps in the planning process are described as:

i. *Review of existing information:* Throughout the development of a geothermal field it is a practice to study the subsurface and gain information on the resource. Continued drilling in the field gives more information on the extent and the characteristics of the field. Conceptual and numerical models give information on the resource extent, the characteristics and estimate the energy content and capacity. This phase gives the basis for developing planning inputs. The Olkaria field has been studied over the years and currently the conceptual and numerical models are being updated.

ii. *Master programme* defines the planned projects, the expected commissioning dates and the number of wells to be drilled for both production and re-injection based on optimisation studies carried out for the field. The number of production wells depends on the planning assumptions developed from studies on the field:
   a. Average expected output for each production well in the field is 5 MWe
   b. Two hot re-injection wells are required for every 35 MWe. Cold and shallow re-injection wells depend on brine productivity in the field.

iii. *The drilling programme* outlines resources (drilling rigs) and a drilling schedule with tentative dates for the entire drilling process, including procurement/contracting, rig mobilisation and move, actual drilling periods and well testing. Different resource optimisation scenarios are developed with time and cost as major factors for consideration.
The wells for the project were drilled and managed through various drilling contracts, run consecutively, as well as with the company owned rigs. The average depth of the existing holes in the field is about 3000 m. The master plan and the programme are defined in Table 3.

iv. *Profitability models* are developed at the onset of a project. They form part of the economic analysis and provide an overview of project performance in terms of return on investment. The models assist in deciding whether a project is worthwhile and the best means of financing the project. The profitability model for the Olkaria I unit 6 is based on an Excel model by Páll Jensson (2016). It defines the expected cost of development and expected return on operation. The model includes drilling, power plant construction and operational costs. Assumptions made include that the cost of drilling is distributed within 2014 and 2015, thirty years of operation from 2019 and that costs associated with taxes and depreciation are accounted for based on Kenyan laws. The model predicts that the project will be profitable within the time frame with a net present value of 8.2 of total capital and 10% internal rate of return.

TABLE 3: Project master plan and resource allocation

Olkaria I unit 6	**Number of wells required**	**2009/10**	**2010/12**	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**2015/16**
Planned	25			9	9	7		comm
Actual	28	1	1	4	4	11	7	
Number of rigs required		1	1	3	3	3	2	
Rig allocation	Rig-1		1	1	0	4	0	
	Rig-2	1		0	3	3	3	
	Rig-3			3	1	4	4	
	Total	**1**	**1**	**4**	**4**	**11**	**7**	

Resource allocation								**Total per rig**
Estimated cost per Rig/Year (MUSD)	Rig-1	0	4.5	4.5	0	18	0	**27**
	Rig-2	5.52	0	0	16.56	16.56	16.56	**55.2**
	Rig-3	0	0	10.56	3.52	14.08	14.08	**42.24**
	Total per year	**5.52**	**4.5**	**15.06**	**20.08**	**48.64**	**30.64**	**124.44**

The model can be used in comparison with the actual performance of the plant once it starts operating for readjustment on financial position of the company. Figure 3 shows the net present value of the project equity by 2017 and of total investment 2042.

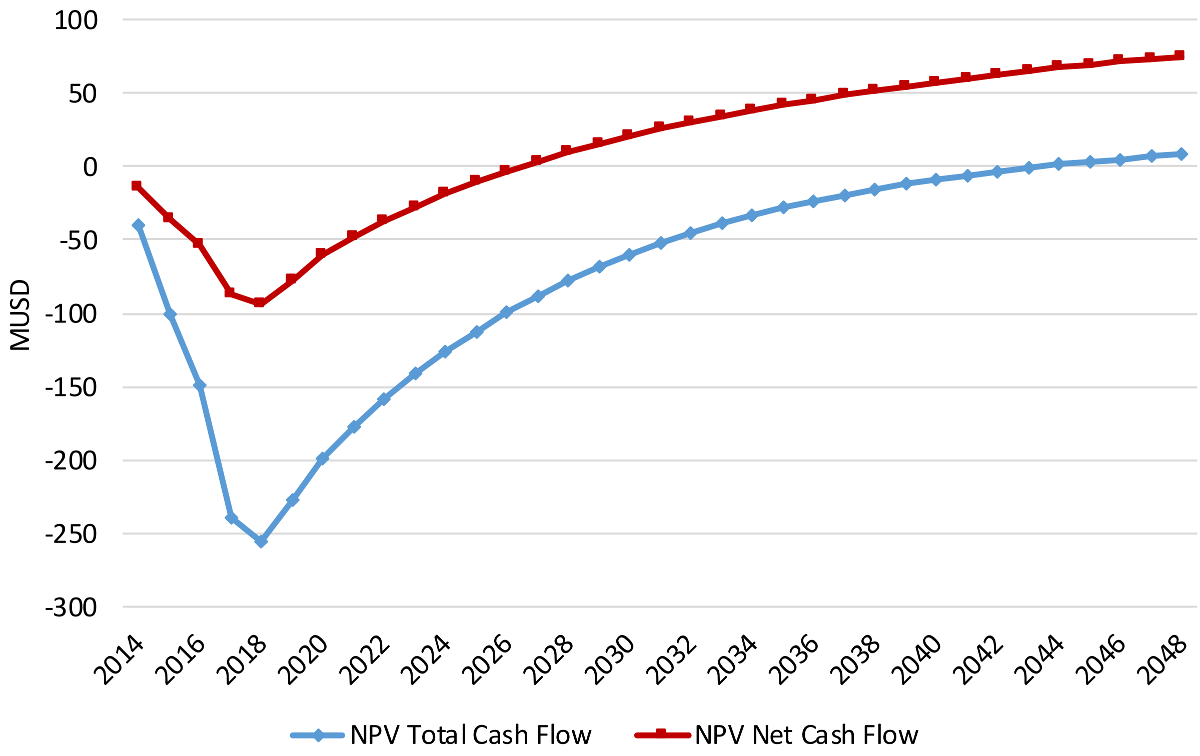


FIGURE 3: Accumulated net present value

3.3 Execution

3.3.1 Phase definition – drilling

The process of drilling can be divided into three phases (Kipsang, 2013): the pre-spud phase, the drilling phase and the completion phase, Figure 4.

i. *Pre-spud.* The pre-spud phase mainly entails well siting (identification of the preferred location of the wells), review of the drilling programme and development of infrastructural works plan. The well design, infrastructural works, such as roads, waterlines and cellar, and rig mobilisation is done. Figure 4 depicts all the phases in the development of geothermal.
ii. *Drilling* process involves getting to target depth with the design of the well that has been approved. A drilling schedule gives progress of overall drilling in terms of schedule and cost. This includes: delays, critical path and effects on the entire project completion and cost indices. Drilling software enhances the drilling process through data collection during the drilling period. The software can be used for materials management, control of directional drilling and obtaining geological data on the well profile.
iii. *Completion*. This involves completion and discharge testing. Completion tests take about 2-3 days and consist of running water loss surveys, injectivity tests and transient pressure tests to confirm the results of drilling. Discharge tests take about 2-3 months depending on the characteristics of the well and persist until the equilibrium of the well is attained. During the test, steam/water flow, pressure, temperature and chemical content of the well are measured and analysed.

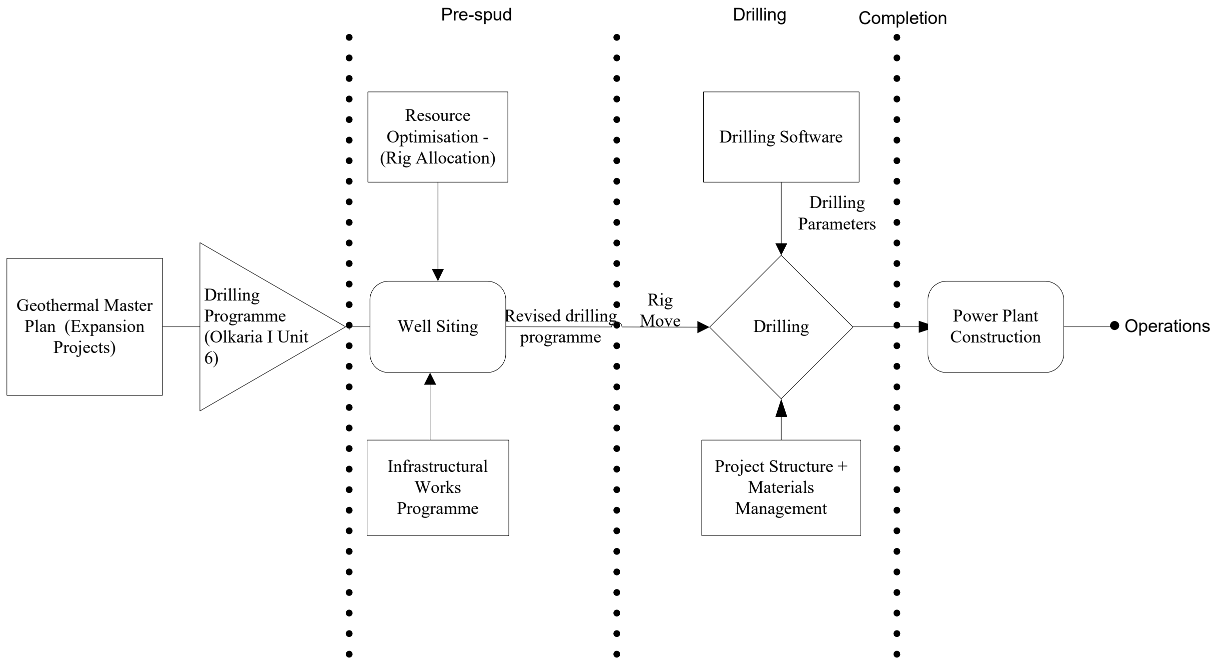


FIGURE 4: Geothermal development phases

3.3.2 Time and scope management

Time and scope management can be managed in a similar way as described below. The scenario described depicts the power plant construction phase. The construction phase of a geothermal power plant comprises the design, construction, installation and commissioning. These phases involve a large scope of various works, commonly managed through EPC (Engineering, Procurement and Construction) contracts. EPC contracts have been used in KenGen's previous geothermal projects in Kenya, such as Olkaria IV and Olkaria I units 4 & 5. The contracts are based on dividing the works into sizable lots, award them to different contractors and manage them through a consultant. Some of the methods used are:

i. *Decomposition technique*, this is the breaking down of the project to manageable parts based on the project. WBS system is integrated in the scope, time and cost management. Figure 5 depicts a level 1 schedule for the power plant construction. The breakdown shows major activities of individual contracts for:
   1. Construction of steam gathering system;
   2. Construction of power plant;
   3. Construction of switch yard and transmission line.

ii. *The Critical Path Method* estimates the longest path of planned activities to the end of a project and reflects the shortest time to complete a project. Delays on activities on the critical path directly impact the planned project completion date. The method analyses the earliest and latest dates that each activity can start and finish without affecting the overall progress of the project. Critical activities within the project are highlighted in Figure 5. This shows areas where flexibility in scheduling can be exercised.

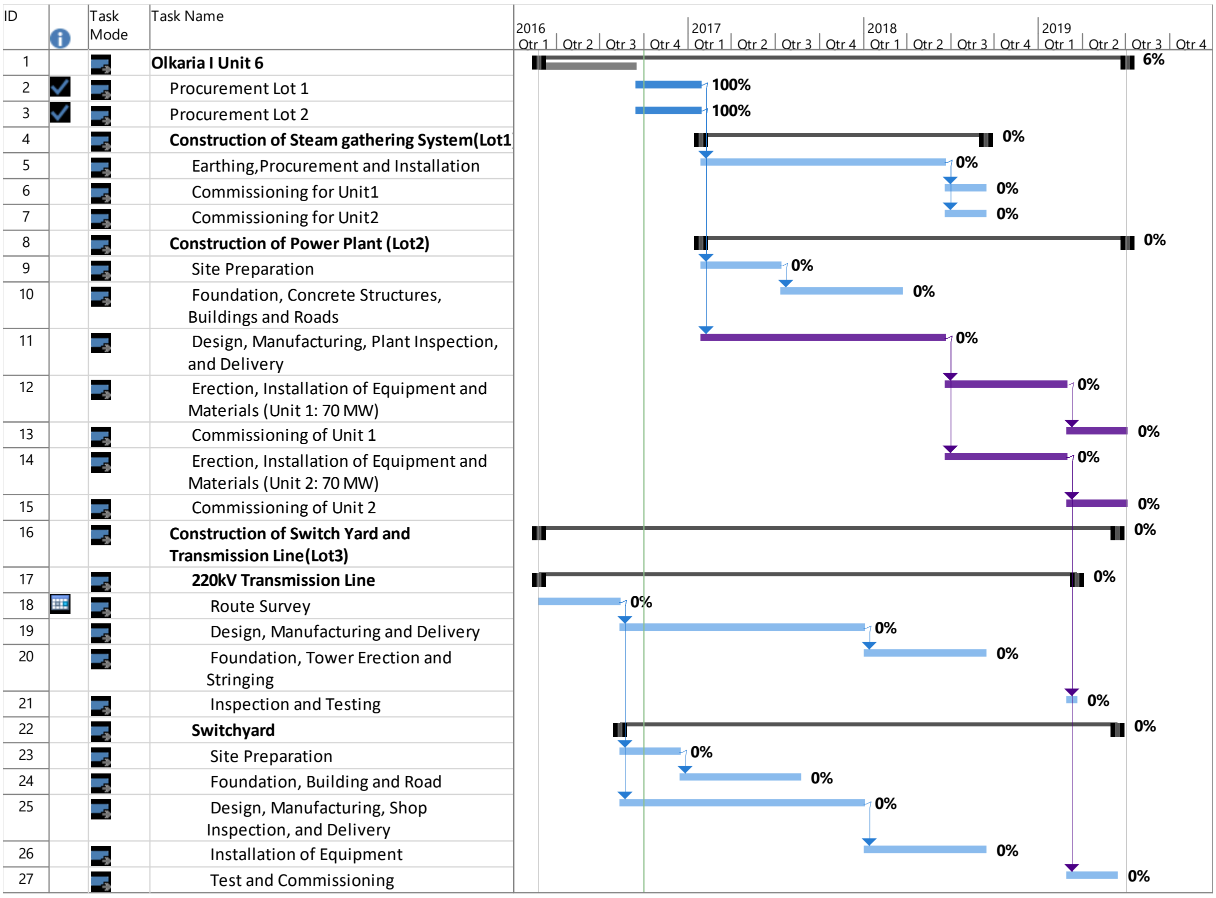


FIGURE 5: High level power plant construction project schedule

3.3.3 Cost management:

Cost management varies within the project with regard to the stage of development. Below is the means of cost management during implementation and analysis after implementation.

i. *Earned Value Management (EVM)*
   This is a method combining scope, schedule, and resource cost measurements to assess project performance and progress (PMI, 2013). Three dimensions of performance measure established are:

a. *Planned Value,* or performance measurement baseline; this is the budget assigned to scheduled work either for an activity or to a specific WBS item. Total planned value for a project is referred to as budget at completion.
b. *Earned Value*; this is the measure of progress of work performed based on the budget. It is the budget associated with work performed. (PMI, 2013). Progress measurements for each WBS enables a measurement of the overall progress of the work.
c. *Actual Cost*; this is the cost incurred for work performed. It is related directly to actual work that has been performed.
d. *Schedule Variance*: this is one of the indicators of performance. It gives progress of a project at a particular time expressed in terms of cost. It indicates progress that is behind or ahead of schedule.

$$SV = EV - PV$$

where SV = Schedule variance;
EV = Earned value;
PV = Planned value.

e. *Cost Variance:* This is a cost measure of budget surplus or deficit at a given time.

$$CV = EV - AC$$

where AC = Actual cost.

The cost variance at the end of the project is the difference between the *Budget at Completion* (*BAC*) and the actual amount spent and indicates the relationship of physical performance to the cost.

Efficiency indicators include the schedule performance index and the cost performance index. The *Schedule Performance Indicator (SPI*) is a measure of time efficiency. It is a ratio of earned value to planned value. $SPI < 1.0$ implies that less work was completed than was planned while $SPI > 1.0$ indicates that more work was completed than was planned.

$$SPI = EV/PV$$

where SPI = Schedule performance index.

Cost Performance Index (*CPI*) is a measure of the cost efficiency of budgeted resources.

$CPI < 1.0$ indicates cost overrun for work completed.
$CPI > 1.0$ indicates a cost underrun of performance

$$CPI = EV/AC$$

where CPI = Cost performance index.

The *EVM* analysis for the construction phase is depicted in Figure 6

ii. *Cost Analysis*

Cost analysis involves interpreting the results of the actual costs. The process gives a basis of future project costs. It also indicates areas of improvement in terms of higher efficiency where the costs are higher than anticipated. The cost of drilling for Olkaria I unit 6 is analysed in Figure 7. The cost analysis is based on the major activities during the drilling process and includes the cost of equipment hire. Similar analysis for power plant construction can be undertaken.

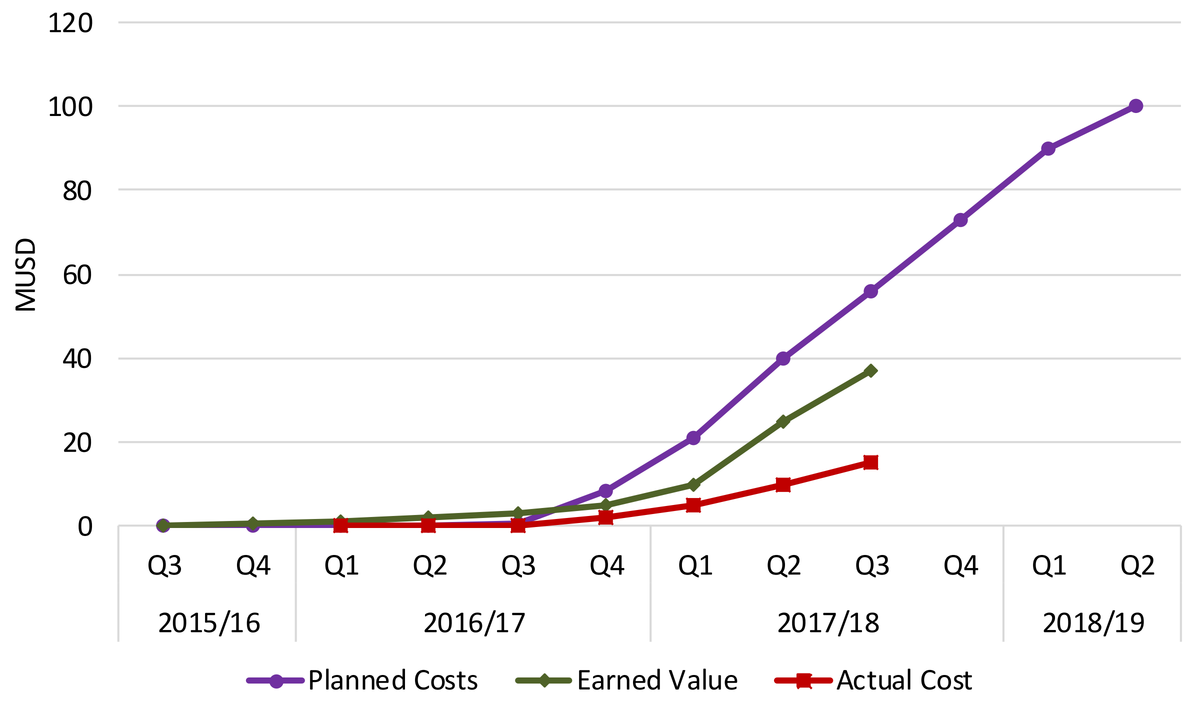


FIGURE 6: Assumed EVM analysis for Olkaria I unit 6 power plant construction

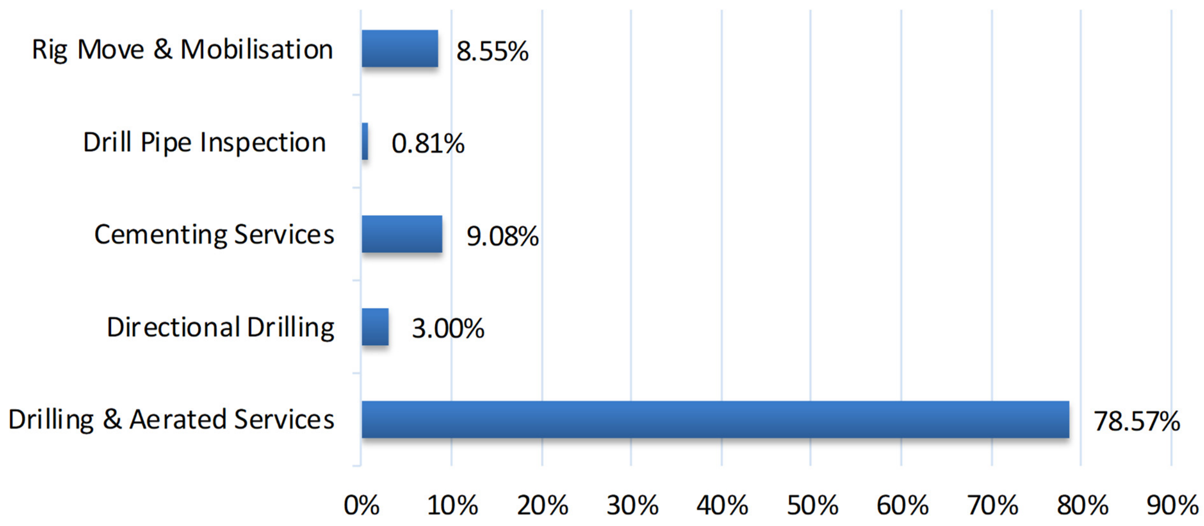


FIGURE 7: Drilling cost analysis

3.4 Reporting

Reporting for the analysed project indicators through a dashboard gives an overall overview of the project status and forecast. However, for the purpose of enhancing and providing adequate information on the project, various reports and reporting procedures are deemed important. Table 4 gives procedure and performance indicators that could be adapted for different phases of development.

TABLE 4: Reporting template

	Olkaria I unit 6 reporting	Unit of measure	Target	Reporting duration	Status	Notes
1	Drilling			Project duration		
	a. No. of wells drilled	No.	25		28	13 wells to be connected
	b. Success rate of drilling	%	100%		96.4%	Total depth: 3000 m
	c. Schedule progress	SPI	>1		1.05	
	d. Budget management	CPI	>1		0.62	
2	Power plant			Project duration		
	a. Timeliness	SPI	100%			Consultant hired
	b. Cost efficiency	CPI	100%			–
	c. Completion rate	%	100%			
	d. Delays	%	100%			
3	Operation			Monthly		
	Efficiency					Overhaul schedule
	a. Availability	%	100%			Planned outages schedule
	b. Total units sent out	MWe	100%			–
	c. Units used on works	MWe	100%			
4	Reservoir management	MWe	85.2			
	a. Steam availability 84 MW			Project duration	85.2	
	b. Success rate		1.42	Project duration	75.6 MWe	3 wells WHP <5 Bar, 13 wells to be connected
	c. Reinjection strategy	Volume	T/hr	Bi-annual		No. of wells for reinjection
	d. Field performance			Bi-annual		Wellhead pressure and temperature
	e. Make-up connection	No.		Annual		Dependent on drawdown

4. GEOTHERMAL MANAGEMENT DASHBOARD

The consecutive dashboards highlight the different information that could be incorporated for complete reporting. The first part of the dashboard as in Figure 8 gives the planning parameters an extent to which the goals have been achieved. An overall success rate in reference to drilling is also given. This is with regard to expected depth of the wells drilled, that is 3000 m. In Olkaria I unit 6, one well was abandoned after an obstruction was encountered. The drilling project costs given are evaluated through EVM analysis, the activities in drilling and the time analysis for the twenty-eight wells drilled.

The second part of the dashboard gives details on the power plant construction, the wells to be connected to the plant giving a success rate of 1.42 since only 13 wells are to be used for the connection. Further evaluation is required to ascertain the success rate of both the East and Northeast fields, where the wells are located, individually. A depiction of the EVM analysis to be used during construction and the progress schedule is also shown, this, however, is based on invented data.

Various parameters will be monitored during operation of the plant. A graphical analysis of these has been developed. The dashboard gives a view of the phases of development and numbers used are assumed. The dashboard should give details at each stage of the geothermal project development/progress and may change according of information required.

PROJECT : **Olkaria I unit 6**

Capacity	70MWe
Wells	
Production Wells	17
Reinjection	
Hot	4
Cold	1
Shallow	3
Total	25
Assumptions	
1 Well	5MWe
20% Reserve	

a) Project Plan

Year	Total	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Planned Wells	**25**	0	02	9	93	7	Commissioning
Actual Wells	**28**	1	1	4	4	11	7
Plugged	**1**		1				

Drilling Sucess Rate	**96%**

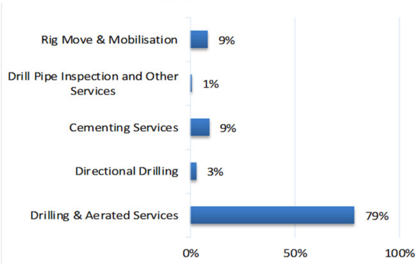
RAG STATUS

Red	Not Acceptable
Amber	Moderate
Green	Acceptable

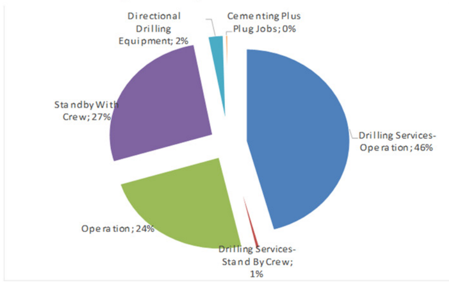
b) Drilling

Project Cost	
Budgeted Cost of the Project	USD 155.75
Actual Cost of Work Performed	USD 143.63
Budgeted Cost of Work S	USD 84.83
Budgeted Cost of Work P	USD 89.19
Cost Variance	-54.44
Cost Performance Index(C	0.62

Drilling Operations Total Cost



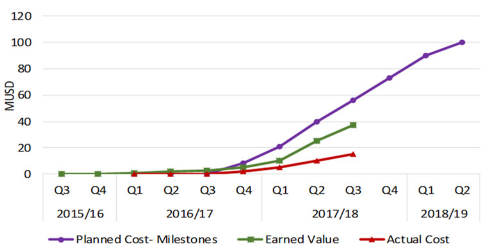
Drilling Time Analysis



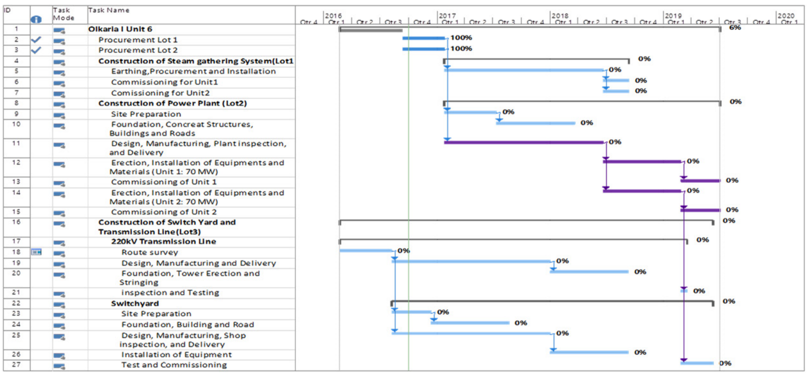
c) Plant Design

	No.	Capacity
Wells for Production	12	85.2
Wells for Re-injection	1	
Field Success Rate		**142%**

d) Power Plant Construction
Schedule and Scope Management



Power plant construction% Progress



e) Operation

Power Plant Assumed Parameters

Months	Jan	Feb	Mar	Apr	May	Jun	Jul
Sent Out Units	68	60	70	70	65.000	65.000	65.000
Used Units on Work	3.29	3.27	3.69	3.43	3.35	3.00	2.52
Availability	97.14%	85.71%	100.00%	100.00%	92.86%	92.86%	92.86%

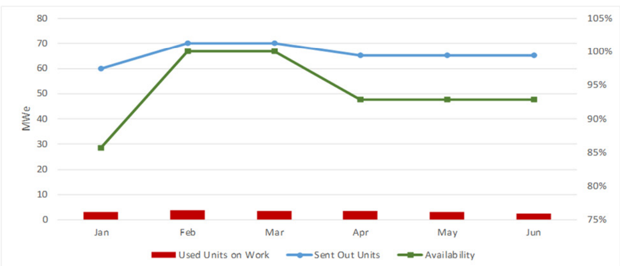


FIGURE 8: Dashboard

5. CONCLUSIONS

Olkaria I unit 6 framework is a model of how geothermal projects can be developed and managed through the different project phases. A combination of management tools has been utilised to give a comprehensive and flexible framework. The framework can be used for geothermal projects and has reporting parameters that are observed within the geothermal development and operation lifecycle.

The paper mainly presents management of scope, time and cost in the project, nevertheless details pertaining risk and quality amongst others can be incorporated into the dashboard. Qualitative measures can be developed to have these areas also represented. The reporting template defines some of the performance indicators that can be measured during and after project completion. The dashboards can be modified to give different information with regard to the process or the stage of development.

Reporting can be enhanced through the use of business objects to give live data. This requires integration of systems used within the organisation for automatic updates. Materials management, drilling software and financial and schedule management software can be integrated to feed and provide data. It is also essential to have properly managed databases that can be queried to provide the different information required for the reporting.

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APPENDIX I: Financial model parameters

TABLE 1: Investment

Assumptions and results					Discounting rate (MARR)		10%		Planning horizon		35	Years
Assumptions:												
		2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Investment:	**MUSD**											
Buildings		39.60	59.40	47.64	95.29	15.88						
Equipment	100%		8.15	9.28	20.38	5.21						
Other				0.73	4.38	2.19						
Total investment		**39.60**	**67.55**	**57.66**	**120.05**	**23.28**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Financing:												
Working capital (Inv from Op)		0.67	1.33	3.33	4.96	8.37						
Total financing		**40.27**	**68.88**	**60.98**	**125.01**	**31.65**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Equity	100%	0.35										
Loan repayments	100%	20.00	years									
Loan interest	100%	0.04										
Operations:		**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Sales quantity	1.000						564.14	564.14	564.14	564.14	564.14	564.14
Sales price	100%						0.09	0.09	0.09	0.09	0.09	0.09
Variable cost	100%	0.04	MUSD/MWh									
Fixed cost	100%	0.235	MUSD/MWh									
Inventory build-up (MUSD)		0.000		0.000		0.000						
Other assumptions:					**Main Results:**							
Debtors	8.33%	of turnover					**Total Cap.**	**Equity**				
Creditors	8.33%	of variable cost			**NPV of cash flow**		**8.22**	**74.35**				
Dividend	0%	of profit			**Internal rate**		**10%**	**16%**				
Income tax	30.00%	of taxable profit			**Internal value of shares**			**2.74**				
Depreciation buildings	4.00%				**after 10 years**							
Depreciation equipment	6.70%											
Depreciation other	6.70%											
Loan management fee	1.00%											

APPENDIX II: Drilling dashboard

Drilling

Cost of one well 6.23 MUSD

Planning Parameters

	Total	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Planned Wells	25.00	0	0	9	9	7	
Actual Drilling	28.00	1	1	4	4.00	11.00	7
	0.00						
Plugged	1.00		1				
Obstruction	0.00			0	0	0	0
Drilling Success Rate	96%						

Drilling Schedule

Planned Start Date	01-Jul-11
Actual Start Date	28-Jul-09
Actual Finish Date	09-Dec-14
Planned Finish Date	30-Jun-14
Expected Wells to be Drilled	25
Project Duration (Days)	1960
Schedule Progress - Time Based	NA
Physical Work Progress- Physical Scope	
% Delay	
Physical Work Delays (Days)	
Schedule Variance	USD 4.37
Schedule Performance Index (SPI)	1.05

Cummulative Budget Absorption

	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	
Planned Cost	0	0	28.038	33.295	23.493	0	0
Earned Value	3.581	3.229	10.129	14.210	37.585	20.459	0.000
Actual Cost	7.065	4.756	14.656	17.774	61.889	37.488	0.000
Schedule Progress	30%	0%	0%	20%	0%	0%	20%
Physical Progress No. of Wells %	0%	0%		0%	41%		

Drilling Time Analysis

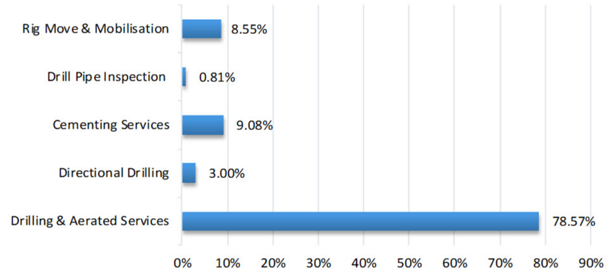
Description	Total	Percentages
Drilling Services-Operation	21,958.50	45.76%
Drilling Services-Stand By Crew	330.50	0.69%
Operation	11,430.24	23.82%
Standby with Crew	12,869.26	26.82%
Directional Drilling Equipment	1,187.33	2.47%
Cementing Plus Plug Jobs	208.13	0.43%

Project Cost

Budgeted Cost of the Project	USD 155.75
Net Contract Value	
Contigency Amount	USD 0.00
Work Value	USD 0.00
Actual Cost of Work Performed	USD 143.63
Budgeted Cost of Work Scheduled (PV)	USD 84.83
Budgeted Cost of Work Performed (Earned Value)	USD 89.19
Cost Variance	-54.44
Cost Performance Index (CPI)	0.62
NOTES	

Over the estimated budget

Drilling Operations Total Cost	5,264,277.80	3,205,453.06	8,809,233.22	11,374,185.66	45,703,918.76	25,372,344.20	99,729,412.70	Percentage
Drilling & Aerated Services	4,278,944.47	2,952,760.75	7332950.993	8225720.547	34478133.5	21088110.38	78,356,620.64	78.57%
Directional Drilling	0.00	0.00	195200	526559.1445	1839749.651	426649.3269	2,988,158.12	3.00%
Cementing Services	0.00	0.00	583389.92	1381905.968	5291367.376	1800676.26	9,057,339.52	9.08%
Drill Pipe Inspection	0.00	252,692.31	252692.3077	300000	0	0	805,384.62	0.81%
Rig Move & Mobilisation	985,333.33	0.00	445000	940000	4094668.236	2056908.236	8,521,909.80	8.55%
								100%



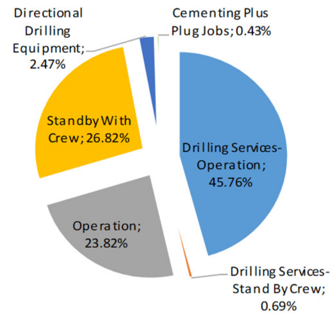


FIGURE 1: Drilling dashboard