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PROJECT MANAGEMENT PLAN FOR UPRATING THE 280 MW GEOTHERMAL POWER PLANTS IN OLKARIA, KENYA

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ABSTRACT

This project seeks to describe the uprate of the 280 MW geothermal power plants in Olkaria, Kenya, by 40 MW due to the presence of additional resources. The advantages of uprating outweigh the development of new top-up plants which are capital intensive and cumbersome to implement. There are considerations that need heeding when uprating existing power plants such as scope, cost, quality, resource, communication, procurement and stakeholders. Additionally, risk and time management are crucial for delivering the project successfully. This is because the uprating process interferes with current production, which can be minimized by adopting strict time schedules to implement changes. This study provides guidance on how to approach similar uprating projects based on the 6th edition of the Project Management Body of Knowledge (PMBoK) and definitions in the ISO 21500 guide to project management. The study concluded that success in such projects is not guaranteed but developing a project plan increases the probability of success.

1. INTRODUCTION

1.1 Project overview

The Kenyan government has been astute in promoting geothermal energy development since it has recognized it as a critical enabler for sustained economic growth and transformation. Furthermore, the government has made it the preferred choice for the future, considering that it is clean, reliable, and affordable and can be utilized as a baseload. The Kenya Electricity Generating Company PLC (KenGen), and its predecessors, which is the leading geothermal developer in Africa, has been involved in initiating and developing projects in the Olkaria geothermal field since the 1950s. Primarily, the focus has been on developing and delivering new geothermal projects within the seven segments of the Olkaria geothermal field as shown in Figure 1 in Appendix I.

In 1981, KenGen commissioned the Olkaria I power plant with an installed capacity of 45 MW. Since then, an array of other conventional power plant projects have been commissioned including Olkaria II (105 MW), Olkaria IV (150 MW), Olkaria 1AU (additional units) (150 MW) and Olkaria V (172.3 MW). Similarly, KenGen has an installed capacity of 83.5 MW from wellhead technology which was pioneered in 2012. To date, KenGen has an installed capacity in Olkaria of 706 MW from geothermal resources and based on the performance of existing installations, utilization has been satisfactory. Furthermore, the resource performance and the estimated potential of 10,000 MWe in Kenya has motivated plans for additional geothermal projects (Ouma, 2009; Omenda, 2014).

In line with these considerations, it is worth noting that many geothermal projects worldwide experience changing resource characteristics over time. Often, these changes are in the form of resource decline, changing fluid characteristics or, in some cases, the resource potential exceeds expectations. Decline leads to production losses and is, in most cases, mitigated by investment in fluid reinjection. Change in fluid characteristics does not necessarily mean a reduction in the resource but can have negative impacts on production. On the other hand, the resource being larger than expected usually results in further expansion of the plant. Depending on the changes experienced by geothermal industries, they must develop appropriate methodologies, take advantage of opportunities and protect themselves against threats. For instance, current operational parameters in the 280 MW geothermal power plant, which is a combination of Olkaria IV and Olkaria IAU, indicate the existence of an additional resource of 40 MW. Recognition and utilization of such additional resource is vital in ensuring sustainable growth and development. As such, KenGen recognizes continual improvement as a strategic organizational goal that promotes opportunities which lie in optimizing the geothermal resources.

To support this strategic goal, this study develops a meticulous and exhaustive project management plan for uprating existing equipment, which are turbines, generators, scrubbers, steam control valves and associated control components. This uprating plan, as presented in Appendix II, details necessary preparatory requirements such as regulatory approvals and procurements and offers guidelines for equipment modifications. This study adopts the approach proposed by the 6th edition of the Project Management Body of Knowledge (PMBoK) (PMI, 2013) and definitions in the ISO 21500-2012 guide (ISO, 2012) to project management by focusing on elements such as scope, schedule, cost, quality, resource, communication, risk, procurement, and stakeholders. Ultimately, this uprating approach is important because it averts the development of new top-up plants that are capital intensive and cumbersome to implement. Nevertheless, the scope of this study is limited to uprating existing equipment and does not consider other viable alternatives, such as introducing conventional topping plants or binary systems.

1.2 Project description

KenGen adopts the Engineering Procurement and Construction (EPC) form of contracting in most of its geothermal development projects. Primarily, the project manager assumes overall responsibility in such projects with the support of a Project Implementation Team (PIT). Due to project complexity, the services of a consultant are required, especially when affirming project design requirements and developing tender documents. In this context, specific design requirements include re-rating generators, steam path design, confirming the integrity of existing steam lines, modifying scrubber internals, confirming condenser and cooling tower heat loads and assessment of integration with existing control and electrical systems. Engaging such consultants before their commitment to projects is also encouraged by the Development Finance Institutions (DFI).

The consultant and contractor are procured based on the Public Procurement and Asset Disposal (PPAD) Act of 2015, which requires public institutions to tender their requirements publicly to allow for non-exclusive, impartial or unbiased competition among those who may wish to partake in the procurement transactions. To satisfy relevant social and environmental regulations, KenGen will update the existing Environmental and Social Impact Assessment (ESIA) by capturing the envisioned modifications in an audit report and submit it to the National Environmental Management Authority (NEMA) for approval. Based upon the obtained design specifications and consent by NEMA, KenGen will conduct negotiations of the Power Purchase Agreements (PPA) with the Power Offtaker (Kenya Power) and the regulator (Energy and Petroleum Regulatory Authority). This negotiated agreement will provide information to the financier on decision-making and modalities of disbursing funds. The consultant, in cooperation with the PIT, will develop tender specifications. As a legal requirement, KenGen will advertise the tender and upon successful evaluations and negotiations, select a contractor. The contractor, who reports to the KenGen project manager, is responsible for all project procurements, execution of uprates and commissioning.

The uprating process is divided into four phases, as shown in Figure 1. The 1st and 2nd phases represent Units 4 and 5 of Olkaria 1AU, while the 3rd and 4th phases represent Units 1 and 2 of Olkaria IV. Similarly, the process includes onshore and offshore operations. The contractor will follow through these phases to de-risk the project from failure. The contractor will commence the works on the 1st and 2nd phase by procuring two fully bladed rotors, journal bearings, condenser banks, circuit breakers and diaphragms. Acquiring the two fully bladed rotors is a strategic decision that aims at reducing the expected number of production stops by avoiding on-site modifications that are lengthy and laborious. The 3rd and 4th phases will utilize similar components, excluding the fully bladed rotors and use rotor blades instead. Works on the 1st phase will commence after shutting down the Unit. The contractor will proceed to remove the existing pressure let down valves, the Unit 4 old rotor and diaphragms. This rotor will be shipped to the contractor's premises for re-blading and balancing. This is an offshore activity and will require utmost precision since the same rotor will be installed in the 3rd phase at Olkaria IV.

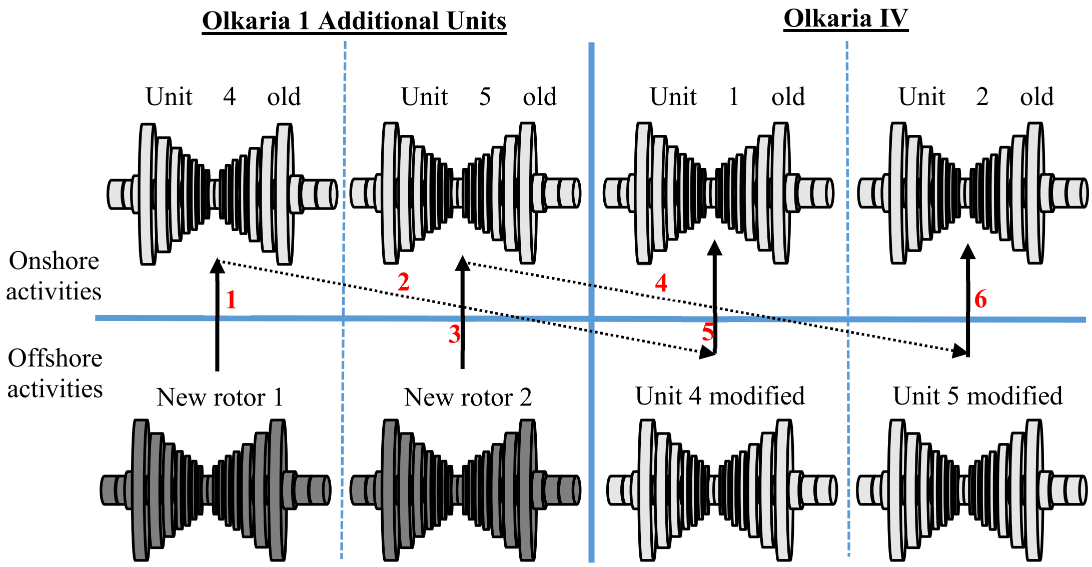

FIGURE 1: Turbine uprating sequence

The contractor will then perform modifications on the Unit 4 generator to match the existing step-up transformers. The contractor will concurrently modify the steam control valves and scrubber internals, followed by the installation of an additional circuit breaker and condenser banks for production of reactive power. Once all modifications are complete, the operations team will restart the Unit, followed by a performance test to confirm that the uprating process meets the requirements. Successful performance tests will initiate the 2nd phase. This phase will follow a similar sequence as its predecessor. The re-bladed rotors from the 1st and 2nd phases will be utilized for the 3rd and 4th phases. Once these rotors are delivered on-site, the uprating process at Olkaria IV will replicate that of Units 4 and 5. To carry out this project successfully, all roles, responsibilities and elements such as scope, schedule, cost, quality, resource, communication, risk, procurement, and stakeholders, will be presented in the form of a project management plan.

1.3 Project justification

Conducting the uprating process successfully will require the development of a rigorous and exhaustive project management plan. Developing this plan is paramount for several reasons. Firstly, this project is the first of its kind in Kenya; hence, there is limited available literature or lessons learned from similar or relevant undertakings within the geothermal industry. Therefore, the project management plan will contain activity estimates concerning costs, schedule and work effort. Secondly, KenGen's inexperience in similar projects makes this a risky venture, given the current reliance on geothermal energy sources in Kenya. To put this in perspective, thorough planning averts all challenges of integrating the uprated project with the existing systems, failure to which there may be severe consequences. Furthermore, a development plan decomposes the work into manageable and comprehensible components. Thirdly, the uprating process is a unique and complex undertaking since it interferes with existing generating units as opposed to completely new projects that focus on additional installations. Executing this process is only possible when the generating units are offline, which translates to losses in production. This aspect underlines the time-constrained nature of the project and high-level planning with particular emphasis on schedule management, which must be employed to keep the losses of production at a minimum. This will be achieved by generating realistic time and schedule estimates. This scheduling will also guide the sequential implementation of tasks and avoid scope creep. Additionally, utilizing a project management plan counters any unforeseen challenges through critical risk assessment and analysis.

2. LITERATURE REVIEW

2.1 Foundations of project management planning

Projects are undertaken at all organizational levels to fulfil objectives by producing deliverables. However, they have an uncertain characteristic in that, in the beginning, the amount of time required or precise costs are unknown (PMI, 2017). That said, it is important to develop project plans which decrease the rate of uncertainty. According to Dvir et al. (2003), planning is considered a crucial aspect in modern project management, and although it does not guarantee project success, lack of it may lead to failure. Effective planning requires the involvement of stakeholders and leads to the generation of project management plans. A project management plan is a formal, approved document that explains in summary or detail when and how to fulfil the project objectives by presenting the products, milestones, resources and activities. In comprehensible terms, a project management plan indicates what is being done and how it will be done (Litman, 2013). Additionally, it establishes business and resource requirements such as costs, delivery dates, resource utilization and schedules. Updates progressively elaborate project plans throughout the course of the project, depending on its complexity.

There are various common accepted guides and standards to project management. For example, the Guide to Project Management Body of Knowledge (PMBoK) by the Project Management Institute (PMI) stresses the need for capitalizing processes and procedures that support planning (PMI, 2017). However, this position assumes that project planning lessens uncertainty and increases the likelihood of success (Dvir et al., 2003). According to this global standard, project planning involves various processes, as shown in Table 1.

The ISO 21500:2012 is an international standard which provides guidance on concepts and processes of project management that are important for, and have an impact on, the performance of projects (ISO, 2012). This standard cross-references project management processes to process and subject groups. The subject groups are integration, stakeholder, scope, resource, time, cost, risk, quality, procurement and communication. The process groups are initiating, planning, implementing, controlling and closing. Similarly, this standard indicates that the planning process group consists of activities, as shown in Table 2. This standard further clarifies that there is no chronological order for carrying out the activities.

TABLE 1: Planning process group components as adapted from PMI (2017)

Process group	Components	
Planning	Develop project management plan Plan scope management Collect requirements Define scope Create work breakdown structure Plan schedule management Define activities Sequence activities Estimate activity durations Develop schedule Plan cost management Estimate costs	Determine budget Plan quality management Plan resource management Estimate activity resources Plan communications management Plan risk management Identify risks Perform qualitative risk analysis Perform quantitative risk analysis Plan risk responses Plan procurement management Plan stakeholder engagement

TABLE 2: Planning process group actvities as adapted from ISO (2012)

Process group	Activities	
Planning	Develop project plan Define scope Create work breakdown structure Define activities Estimate resources Define project organization Sequence activities Estimate activity durations	Develop schedule Estimate costs Develop budget Identify risks Assess risks Plan quality Plan procurements Plan communications

2.2 Planning geothermal projects

Typically, geothermal energy projects progress through stages of study, design, construction and field development with resolutions along the way. These stages can be categorized into four phases, namely exploration, resource development, construction, and commissioning, and operation and maintenance (Serdjuk et al., 2013). They can also be classified as preliminary survey, exploration, test drilling, project review and planning, field development, construction, start-up and commissioning (Gehringer and Loksha, 2012). Geothermal resource development is based on rigorous scientific studies, surveys, models and assumptions due to its risky and capital-intensive nature. These comprehensive studies provide valuable insights that reduce risks associated with geothermal development such as resource existence and size, sustainability and utilization challenges (Ngugi, 2014).

Geothermal power projects entail the development of complex infrastructure undertakings ranging from steam field pipelines and wellheads to powerhouses and substations. Such developments involve interrelated activities in different project phases; hence, they require high-level planning and integration to be successful (Zegordi, 2012). Mostly, national governments initiate such projects depending on their strategic outlay and alignment. Meeting implementation deadlines, within planned costs and varying resource, binds such projects. For example, countries utilizing geothermal energy such as Peru, Iceland, Netherlands, Nicaragua and Kenya have come up with master plans that provide a road map for development. These master plans guide decision making and offer strategic direction for identifying, ranking and executing geothermal projects sustainably (Matsuda and Lima, 2015). Sometimes, geothermal projects change beforehand due to the fast-paced changes in technology, political structures and markets. Such changes call for regular and elaborate updates in the planning process to avert budget variances, time overruns or scope creep.

2.3 Fundamentals of planning time-constrained projects

As discussed previously, project planning is pivotal to the development of successful projects. However, constraints characterize these projects which affect them throughout the life cycle. PMI distinctively indicates that there are three project constraints, namely time, cost and scope. Occasionally, they also include quality as a substitute for scope or as an added constraint. PRINCE2 (PRojects IN Controlled Environments), which is a process-based method for managing active projects, further indicates that there are six project constraints, namely time, cost, scope, quality, benefits and risks. Regardless of the approach to project constraints, they are considered core to decision making in all project backgrounds (Mokoena et al., 2013).

It is worth noting that the failure of one constraint affects the outcome of the others negatively since they are interlinked. Typically, when a project manager realizes that there is going to be a slippage in project timelines, they either provide extensions or accelerate work effort. The consequence of such strategies is the use of additional resources. Considering that time is the only constraint that we have no control over, it is the primary duty of the project manager to ensure that it is planned accordingly and favourable reactions to slippages are adopted. In managing general projects, the project client or external stakeholders can instigate time deadlines. The push for stricter deadlines can also be a priority of contractors or suppliers in a project.

These considerations are no different when developing geothermal energy projects. Consequences of time constraints in geothermal projects can be severe, and it is imperative to define requirement priorities before commencement for purposes of concurrence and enhancement of collaboration between vendors. These approaches can guarantee delivery of crucial deliverables or requirements by the deadline. For example, during the installation of the additional Unit 3 at Ulubelu geothermal power plant in Indonesia, the client requested a work period of 23 months. This was shorter than the time for the previous units that had taken 28 months to install. To meet these requirements, the contractor adopted and applied stricter plans such as designing the turbine, generator and chemical equipment as a package and following delivery schedules promptly. The project was delivered 3 weeks ahead of schedule. Progressive and elaborate planning of activities also ensured that the initial project phase was not marred by ambiguity, since it was possible to deliver equipment and conduct the construction safely.

For the development of Units 5 and 6 of Lahendong power plants, a similar scenario was adopted as in the Ulubelu case where the client requested a delivery time of 22 months. In comparison, a similar Unit of the Kamojang power plant had required 23 months to install. These timelines for Units 5 and 6 were met 1 month and 3 months ahead of schedule, respectively (Murakami and Takamiya, 2017). In New Zealand, Fuji Electric delivered Kawerau geothermal power plant successfully by satisfying contractual performance criteria through advanced project planning. Construction and commissioning work achieved the required quality standards, and the plant was put into commercial operation 1 month ahead of the contractual time limit (Horie, 2009). These studies clearly indicate that delivering auspicious time-constrained projects hinges on developing clear plans and reporting priorities before the commencement of work.

2.4 Outline of a project plan

As depicted earlier, geothermal projects can adopt various phases of development, depending on their complexity. Simple projects will assume modest plans while the complex ones will have detailed progressive plans. Cognizant to the fact that this study aims at uprating two existing power plants, integrating the new systems through detailed progressive planning is necessary to guarantee that it meets all or the majority of project deliverables. The main deliverable is a project management plan that constitutes sub-plans on scope, schedule, cost, quality, resource, communication, risk, procurement, and stakeholders. The approach proposed by the Project Management Body of Knowledge (PMBoK) and definitions in the ISO 21500 guide to project management formulate the steps followed in this project plan.

2.4.1 Scope

Scope is one of the triple constraints in project management, as indicated by the Project Management Institute (PMI). Scope refers to what the project is expected to accomplish and specifies the budget requirement allocated to create project deliverables (Zilicus Solutions, 2012). The consequence of defining project scope is the formulation of a scope management plan that in turn, documents how to define, develop, control and validate scope (PMI, 2017). It also focuses on describing the project and sets boundaries. These boundaries show the project contents and exclusions. Apt scope management advocates for constant monitoring to avoid infringing stakeholder expectations. Ultimately, scope management leads to the formation of a work breakdown structure (WBS) that segments deliverables into manageable parts.

2.4.2 Schedule

A schedule represents the time distribution of all tasks of a project. Time is the only constraint that is not recoverable, and therefore adept planning is crucial to ensure successful project delivery. According to PMI (2017), schedule management involves outlining and sequencing activities, estimating their durations and ultimately formulating a schedule. Outlining and sequencing activities ensures the logical creation of project work estimates, thus leading to efficient and effective outcomes. Estimating activity durations helps to foresee the actual amount of time required to complete a particular task. The result of this process is a schedule management plan. Managing time is a crucial part of any successful project, and without careful planning, projects are bound to fail. Monitoring progress and revising the schedule management plan is vital in enhancing the chances of project success.

2.4.3 Cost

PMI (2017) outlines cost as one of the triple constraints of project management. Cost planning entails articulating the financial and human resources required to deliver a project successfully, with the ultimate formulation of a cost management plan. This process generally involves the estimation of activity costs and determination of the overall project budget. Monetary estimates required for the completion of project work are determined. These estimates further lead to the development of a project budget that determines the cost baseline against which project performance is tracked and managed. Cost estimation involves utilizing various tools and techniques such as analogous estimating, parametric estimating, three-point estimating, bottom-up estimating and reserve analysis (PMI, 2017).

2.4.4 Quality

According to PMI (2017), quality planning involves identifying the quality standards that are key to the project and formulating ways and means to satisfy them. Performing quality planning requires the incorporation of other planning processes such as time and risk since quality changes will most likely affect them. Planning quality facilitates the development of a quality plan with all the required metrics in place. Proper quality planning ensures successful project delivery and better productivity; hence, increased stakeholder satisfaction.

2.4.5 Resource

Resources include project enablers or means such as people, facilities, equipment, materials, infrastructure and tools (ISO, 2012). Planning resources leads to the formation of a resource management plan that documents how to estimate, acquire and manage physical and human resources. It is imperative to develop resource plans since they indicate the level of effort required for the successful delivery of any project.

2.4.6 Communication

Effective communication is a recipe for conducting successful projects. Planning communication helps identify an appropriate approach for interaction and collaboration with project stakeholders. It also serves as a guide and creates a communication framework during the course of the project life. In project development, planning communications is conducted early, which allows appropriate allocation of resources to communication activities. This translates to the provision of relevant information in the right format, time and audience, which culminates to the development of a communications management plan (ISO, 2012). This plan provides a documented approach of engaging stakeholders by presenting pertinent information to them promptly.

2.4.7 Risk

Risk is an uncertainty that could affect or influence project activities positively or negatively. Such uncertainties have considerable scope in projects, and therefore it is prudent to manage them from inception (Chapman and Ward, 2003). Risks tend to occur throughout the cycle, and it is essential to manage them iteratively. Geothermal energy projects are risky due to the uncertain nature of resources which prompts the need for risk planning and management. To enhance project success, risk-planning leads to the generation of a risk management plan that instigates the required measures such as mitigating, exploiting, avoiding, transferring or accepting (PMI, 2017). Risk assessment entails two phases, namely assessment and formulating responses. Risk assessment is further split into identification and analysis. One of the methods used in identifying and analyzing risks is the development of a risk register.

2.4.8 Procurement

Procurement entails purchasing all required resources of a project. Such resources include workers, equipment, consultancy services, materials or results. Planning procurement leads to the formation of a procurement management plan that indicates decisions such as whether to make or buy, from within or externally, as well as when to do it. Procurement plans include documents such as invitations to tender or requests for proposal.

2.4.9 Stakeholders

According to the ISO 21500 guide to project management, a stakeholder is as a person or entity that is interested in or can affect or be affected by or perceive itself to be affected by, any project feature. Predominantly, stakeholders can orchestrate the success or failure of a project by influencing the outcomes since they affect them directly or indirectly. To achieve success and prevent opposing expectations, it is vital to carry out an analysis of their needs, interests, potential impact and engagement levels. This process ultimately leads to the formation of a stakeholder management plan.

3. DEVELOPING THE GEOTHERMAL ENERGY PROJECT PLAN

3.1 Plan scope management

The project manager is responsible for scope management which is an integral part of a project management plan. The process of scope management planning describes all uprating requirements, boundaries and concludes with the development of a work breakdown structure as described below.

3.1.1 Collecting requirements and set project boundaries

According to PMI (2017), requirements are conditions that are necessary for a service or product to satisfy the present conditions of the practising organization or active stakeholders. They are the foundations of formulating a work breakdown structure and require iterative analyses once the project execution commences. Project boundaries are defined in the project initiation stages so that it is clear from the start what the project aims to achieve or not. Besides providing a clear description of the project, this process also presents assumptions and exclusions that may apply.

Project boundaries
The scope of this uprating project includes modification of turbines, generators, scrubbers, steam control valves and associated control components at Olkaria 1AU and Olkaria IV geothermal power plants in Kenya. The project deliverable is a project management plan detailing sub-plans of scope, schedule, cost, resource, communication, risk, procurement, and stakeholders. The acceptance criterion for this project is the successful addition of 20 MW per power plant within 795 days from the execution approval date. The project adopts an Engineering Procurement and Construction (EPC) form of contracting where planning for resources is the responsibility of the contractor, who reports to the project manager. The estimated budget is USD 80 million.

Project exclusions
Project exclusions explicitly state actions outside the uprating boundaries. Such exclusions include:

- Development of the project charter
- Analysis of all execution, monitoring, control, and closing process group elements as stated in the 6th edition of the Project Management Body of Knowledge (PMBoK)
- Design calculations justifying the existence of additional geothermal resources equivalent to 40 MW
- In-depth analysis and discussion of alternative utilization methods such as installing topping plants

Project constraints
The six constraints as prescribed in PRINCE2, namely time, cost, scope, quality, benefits and risks, affect this project. However, particular emphasis is laid on schedule management and risk assessment. This is because of the risky nature of the project and the expected disruption in normal operations which are minimized through high level, progressive and dedicated schedule management.

Project assumptions
This project makes several assumptions:

- Development of project description and deliverables is based on reliable input from subject matter experts in geothermal energy project planning.
- The project limits the possible gross power increase to 40 MW as guided by the current operational limitations.
- The financial risks are lower compared to entirely new conventional power plants that entail high costs of drilling and infrastructural developments.
- Negotiations and all necessary approvals are agreeable within the timelines allocated in the project schedule.
- The contractor performs all tasks within the required safety and quality requirements and standards.
- The sequential project plan provided in this study will promote energy recovery specific not only to Olkaria but also for other power plant projects seeking to uprate.

3.1.2 Developing Work Breakdown Structure (WBS)

The work breakdown structure (WBS) indicates the hierarchical decomposition of the work to be executed during the uprating of the power plants. This project's WBS entails two first sectional phases, namely preparation and execution. These phases contain sub-sections with multi-levels in the second and third-order, as shown in Table 3. The benefit of this is that costs and timelines can be allocated to specific actions in the WBS. It also enhances easy tracking of the project issues and areas requiring corrective actions as it executes. The overall project WBS is documented in Appendix II.

TABLE 3: Sample work breakdown structure

WBS level	Phase/activity name
0	UPRATING THE 280 MW GPPs IN OLKARIA, KENYA
1	PHASE 1: PREPARATION
1.1	Uprating programme
1.1.1	Procure consultancy services
1.2	Negotiations
1.2.1	Negotiate PPA with off taker and regulator
2	PHASE 2: EXECUTION
2.1	Olkaria 1AU Units 4 and 5 components
2.1.1	Manufacture deliver 2 fully bladed rotors, journal bearings and diaphragms

3.2 Plan schedule management

Initial steps of planning in a project generate a schedule. It reflects the total work, resources and specific timeframes required to complete the project successfully. Simply put, a schedule chronologically sequences events in the order they are likely to take place. According to PMI (2017), this planning process encompasses defining and sequencing activities and estimating resources and activity durations. The key benefit of a schedule plan is that it provides direction and guidance on how to manage a project throughout its lifecycle (PMI, 2013). Lack of it thereof will pose a significant challenge to the project as the manager may be unable to comprehend and communicate the resources required to deliver the project successfully.

Planning schedule management culminates to the development of a project schedule. Schedules can be generated using project management software such as Microsoft Office Project, Excel or Primavera. Such software assists in the tabulation of estimated project activity resources which are labour, material, equipment and supplies. Proper estimation of project timelines is critical in delivering this project successfully due to the anticipated disruption of normal power plant operations. This, together with strict follow up on project schedule activities, minimizes the anticipated losses in production. Different activities, as detailed in the project work breakdown structure (WBS), will adopt the bottom-up estimation method coupled with judgement from experts in the geothermal industry (PMI, 2017). The project schedule is displayed by use of a Gantt chart generated using Microsoft Office Project software, as shown in Appendix II. Figure 2 indicates the critical tasks necessary to ensure that the project completion date does not slip.

3.3 Plan cost management

This project utilizes the bottom-up estimation technique, where the work packages in the WBS are aggregated. The contractor is responsible for carrying out these work packages in accordance with the project budget and financial requirements. The total project investment is estimated at 80 MUSD including equipment, EPC payments and calculated generation losses. The project assumes a 12.5% interest rate of return on equity. 70% of the project investment will be financed through a commercial

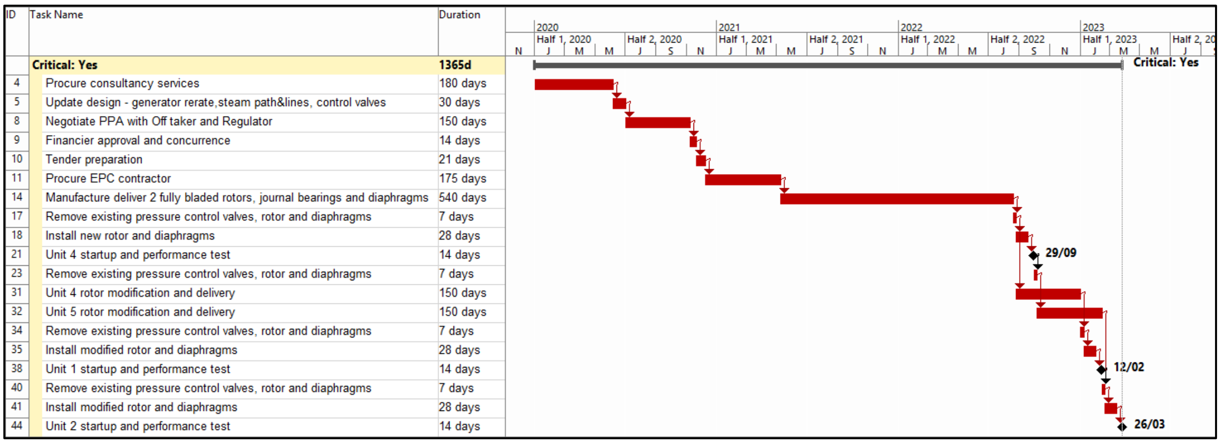

FIGURE 2: Critical tasks for the uprating project

loan from a development finance institution (DFI) while KenGen through the Government of Kenya will fund 30%. The loan assumes an interest rate of 8% with a repayment tenure of 15 years. This is a financially viable project with a recoverable investment within 6 years. The internal rate of return (IRR) of this project is 25% which is above the assumed 12.5%. The accuracy of these estimates is based on expert judgement and is expected to be reviewed and refined during the project. The project costs will be tracked through project timesheets to determine where potential problems exist. In the end, this will assist in identifying necessary reports and metrics.

3.4 Plan resource management

Project managers are tasked with the significant role of planning, scheduling and allocating resources in a project. In resource planning, four essential resources that need to be identified are materials, people, equipment and time (Kumar et al., 2014). For this project, the project manager provides overall insight and is responsible for project outcomes. On the other hand, the contractor is responsible for all project resources. Such resources include material, equipment, planning and scheduling daily staffing levels and timelines. The project resource management plan details the roles and responsibilities depending on the WBS elements as shown by the sample in Table 4.

TABLE 4: Sample resource management plan

WBS level	Phase / activity name	Resource type
1.1.2	Update design - generator rerate, steam path, heat load	Consultant/KenGen
1.1.3	Update ESIA and submit to NEMA	KenGen
1.2.1	Negotiate PPA with Off taker and Regulator	KenGen
1.1.4	Procure EPC contractor	KenGen
2.1.1	Manufacture and deliver 2 fully bladed rotors	Contractor
2.1.2	Procure circuit breaker and condenser banks	Contractor
2.2.1	Remove existing pressure control valves, rotor and diaphragms	Contractor
2.2.2	Install new rotor and diaphragms	Contractor
2.2.5	Unit 4 start-up and performance test	KenGen /Contractor

3.5 Plan communication management

There is an interrelation between this plan and the stakeholder management plan. This is because informing them of the project progress is a recipe for successful implementation. Based on stakeholder needs, the communication plan guides the project manager and team on ways of averting misrepresentation, delays in delivery or insufficient communication to stakeholders (PMI, 2013). The communications plan should be within reach by the appropriate stakeholders throughout the project. To ensure effectiveness, it is important to review and revise this plan continually. This uprating project involves several stakeholders such as contractors and government bodies as detailed in the stakeholder planning section. The sample in Table 5 illustrates the integration of various communication methods used such as emails, team meeting minutes, phone calls and status reports when communicating with different stakeholders. Such communication assures that all the stakeholders are in accord with project progress.

TABLE 5: Sample communication management plan

Communication type	Objective	Medium	Frequency	Audience	Deliverable
Monthly project status meetings	Report on the status of the project to management	Face to face	Monthly	Project manager Contractor	Slide updates Project schedule
Technical design review meetings	Review designs of the project	Face to face	As and when required	Project team Contractor Operations	Technical design reviews

3.6 Plan risk management

There is a solid relationship between project success and planning risk management (Elkington and Smallman, 2002). That said, it is imperative to conduct thorough iterative risk management for geothermal projects. Their complexity, uniqueness and uncertainty require high-level risk assessment and management. In this uprating project, understanding potential risks and their corrective actions is crucial for increasing the chances of success. Further, building the risk process into the decision-making process ensures that potential risks are managed well. The process of planning risk management involves risk identification, performing qualitative risk analysis, performing quantitative risk analysis and planning risk responses (PMI, 2017).

3.6.1 Risk identification

The most critical phases of risk management are risk identification and analysis (Chapman and Ward, 2003). However, analysis can only be managed when the identification of such risks has been completed. Risk identification is an iterative process as risks may change with the progression of a project. Further, risk identification is an all-inclusive process, thereby involving multiple stakeholders since each stakeholder may have a different perspective on the risks the project is facing. An integrative part of this process is that categorizing presents risks in a structured format. There are numerous ways of classifying risks with the most pragmatic approach being the identification of relevant risk categories based on particular project objectives (Krane et al., 2010). This categorization is also dependent on the project set up and environment. It is, therefore, the duty of the project manager and team to brainstorm and document all possible risk sources based on the existing situation. Based on this premise, this study categorizes risks as political, environmental, financial, operational, technical, legal and regulatory, and social.

Political risks

The political atmosphere of a country greatly influences investor decisions in getting involved in geothermal development projects. High levels of bureaucracy at national and county levels in Kenya is increasing avenues for corrupt dealings. This, coupled with the extensive period of development, makes investors and financiers shy away from taking part in such projects (Johnson and Ogeya, 2018). With the government administration in Kenya changing every 5 years, politicians may formulate new policies which may not be in line with furthering geothermal resource optimization. Considering that this project envisages taking 3.8 years, the necessary approvals through the national and county governments will have to be prepared and presented before commencement. The bureaucracies in negotiations and approvals, which take an unnecessarily long time can be reduced by promoting transparency in policy and decision making (Ngugi, 2014).

Environmental risks

The geothermal power plants are in Hells Gate National Park, which is run and operated by Kenya Wildlife Service (KWS). Due to the sensitivity to environmental issues, KenGen and KWS have a Memorandum of Understanding (MoU) on how to utilize resources optimally within the park. Environmental risks that are considered, especially when developing geothermal resources, include air emissions, noise, wastewater and depletion of vegetation cover (Ogola, 2005). Bearing in mind that this uprating project will mainly involve the replacement of physical equipment in the power plants, the outstanding environmental risks include air pollution due to increased traffic when moving equipment and noise emanating from machines and vented steam. However, before commencement, the modifications will be captured in the annual statutory environmental audit report and submitted to the National Environmental Management Authority (NEMA) for approval. This is also a requirement to be able to receive funding from financiers.

Financial risks

Financial risk encompasses the possibility that external sources of finance, such as loans may not be available when needed (Toma and Alexa, 2012). During the development of conventional geothermal power plants, financial risks revolve around high exploration costs and power plant infrastructure costs (Johnson and Ogeya, 2018). These risks become significant once financiers have committed to the development of a project and spread out through the commercial operation period. For this uprating project, the financial risks are presumed to be lower compared to entirely new conventional power plants that entail high costs of drilling and infrastructural developments. This uprating project will require 70% financing in the form of a loan from an investor. Before commitment of loans, it is expected that the investor undertakes risk identification and evaluation. Some of the anticipated aspects affecting financial risks include delayed financial disbursement, matching a project with lending criteria, fluctuations in interest and exchange rates and reduction of the annual allocation of budget by the government (Ngugi, 2014; Okwiri, 2017).

Operational risks

Operational risks occur when there is a possibility that the organization will fail to meet contractual obligations due to operational reasons. They are also as a result of internal failures in the business which are brought about by factors such as poor operator training, inadequate planning, unclear lines of communication between operations and project teams or changes in project scope (Toma and Alexa, 2012). Recalling that this project may lead to losses in production because modifications have to be carried out on offline equipment, makes this risk category critical. It is therefore imperative to involve the operations team from the project initiation and handover the project when all deliverables have been met.

Technical risks

The uprating process involves modification of existing systems which is rarely done in the geothermal industry. This means that there is a technical risk due to untested technology. In such cases, financiers are cautious when lending due to their risk-averse nature. Such risks can be mitigated by conducting a technical risk assessment to address issues such as when technology is expected to mature and whether there are any system integration issues to be expected.

Legal and regulatory risks

Of late, the legislative environment in Kenya has become favourable to investors undertaking geothermal development or expansion. However, strict considerations must be made to ensure that the multiple and often complex frameworks through which developers need to operate are streamlined even further. This project will involve negotiating an existing Power Purchase Agreement (PPA) with the

Kenya Power (KP), who are the sole purchasers of power in Kenya, and the electricity regulator referred to as Energy and Petroleum Regulatory Authority (EPRA). Some of the legal and regulatory risks in this project include breach of contract by either party or failure to obtain a Best Alternative to Negotiated Agreement (BATNA) during PPA negotiations.

Social risks
Geothermal resources are localized in areas of high potential. Nevertheless, their development affects the livelihood of existing communities, both positively negatively. The organization has to ensure that the project does not result in a decreased quality of life of surrounding communities by proposing and implementing complimenting value-added services and activities such as expropriation and compensation of affected people.

3.6.2 Risk analysis

After categorizing risks in the identification process, they are prioritized and evaluated to recognize the relative significance of risks compared to each other (Habegger, 2008). This culminates in the development of a risk register, as shown in Table 6. The risk register entails aspects such as risk category, name, probability, impact and severity. The categories are as described in the subsequent section of risk identification while the others are discussed later in this section. Since there are many ways of developing risk registers, relevant project information is filtered before prioritization (Maytorena et al., 2004).

TABLE 6: Sample risk register

Risk identification and analysis				
Category	**Risk name**	**Probability score (A)**	**Impact score (B)**	**Severity (A*B=S)**
Political	Project acceptance and consent by Ministry	4	4	16
Environmental	Noise emanating from construction equipment	3	3	9
Financial	Financial disbursement	5	2	10
Operational	Significant losses in production	5	5	25
Social	Negatively affect quality of life of locals	1	2	2

Risk analysis employs qualitative, semi-quantitative and quantitative methods. Qualitative methods evaluate individual risks by considering a wide range of characteristics such as probability or likelihood of occurrence while quantitative methods numerically analyze the effect of project risks on objectives. However, purely qualitative risk assessment is too general and subjective since it prohibits the determination of probabilities and results using numerical methods. Quantitative assessments that utilize techniques such as Monte Carlo simulation or decision analysis are burdensome and complex. This study adopts a semi-quantitative risk analysis which categorizes risks by comparative scores rather than by explicit probability measures (Radu, 2009). This approach avoids the bias in qualitative assessment and the rigorous criteria of quantitative analysis. Semi-quantitative risk assessment utilizes numerical scales such as impact and probability. The two aspects are then combined, either linearly or logarithmically, to form a scale of risk priority. This study combines the two elements using the formula below:

$$\text{Severity } (S) = \text{Probability score } (A) \times \text{Impact score } (B)$$

Impact is described in qualitative terms that are critical, high, medium, low and insignificant and are assigned a score of 1-5. Probability is described by qualitative terms that are very unlikely, unlikely, possible, likely and almost certain with a score of 1-5. Further, it adopts a quantitative risk probability scale from 0-100% with increments of 20%. This is depicted in the risk-scoring matrix shown in Figure 3.

Impact	Critical	5	5	10	15	20	25
	High	4	4	8	12	16	20
	Medium	3	3	6	9	12	15
	Low	2	2	4	6	8	10
	Insignificant	1	1	2	3	4	5
			1	2	3	4	5
			Very unlikely *(0-20%)*	Unlikely *(21-40%)*	Possible *(41-60%)*	Likely *(61-80%)*	Almost certain *(81-100%)*
				Probability			

Critical risks
High risks
Medium risks
Low risks
Insignificant risks

FIGURE 3: Risk scoring matrix

From the scoring matrix in Figure 3 above, the impact evaluation scheme for the various identified risk categories is as indicated in Table 7.

TABLE 7: Impact evaluation scheme

	1: Insignificant	2: Low	3: Medium	4: High	5: Critical
Political	No delays in project approval	Approval delayed by 1 week	Approval delayed by 2 weeks	Approval delayed by a month	Approval delayed by > 1 month
Operational	Project schedule slip by <10%	Project schedule slip by 10-20%	Project schedule slip by 20-40%	Project schedule slip by 40-70%	Project schedule slip >70%
Financial	<1% of capital investment	1-3% of capital investment	3-5% of capital investment	5-7% of capital investment	>7% of capital investment
Environment	No damage within confined area	Minor damage within confined area	Temporary damage within confined area	Significant damage in a limited area	Long term damages in wide area
Social	Community not affected by project	10-20% of community affected by project	20-40% of community affected by project	40-60% of community affected by project	>60% of community affected by project
Legal and regulatory	No effect on contract performance	Results in meeting between parties to raise issues	Verbal advice given due to breach of contract	Written notice given due to breach of contract	Termination of contract
Technical	No integration issues with existing system	<2 integration issues with existing system	<5 integration issues with existing system	<7 integration issues with existing system	>7 integration issues with existing system

3.6.3 Plan risk responses

This process entails determining measures such as contingency actions or preventive actions if the identified risk occurs. It is an iterative process and concludes when an optimal set of responses is developed. This process leads to the development of residual risks which remain after undertaking planned responses (PMI, 2017). The response plan, which is a provision made from the risk register and an output of this process, can include different parameters depending on the nature and size of the project as shown in Table 8.

TABLE 8: Sample risk responses

Action plan – residual risks				
Risk treatment/ Response plan	**Risk owner**	**Risk probability (RP)**	**Risk impact (RI)**	**Residual risk (RP*RI)**
Meeting with government officials from the Ministry and justifying project	KenGen project manager	3	3	9
Condone off areas and use PPE	Contractor/KenGen project manager	1	2	2
Involvement and support from national government in financial negotiations	KenGen project manager	3	2	6
Strict adherence to schedule to avoid extended delays	Contractor/KenGen project manager	5	3	15
Introduce a social engagement plan to indicate project benefits	KenGen project manager	1	1	1

3.7 Plan procurement management

KenGen is a state corporation, and as such, the Public Procurement and Asset Disposal (PPAD) Act of 2015 guides all procurements. This Act buttresses the need for tendering requirements publicly to allow for non-exclusive, impartial or unbiased competition among those who may wish to partake in the procurement transactions. The project will adopt an EPC form of contract, and therefore the contractor engaged will be responsible for engineering design, procurement of services and products, construction and commissioning. This method is preferred due to the relatively limited internal capacity and experience in developing such projects. The project manager will oversee and generally manage all project activities and play a crucial role in integrating the contractor and operations team to ensure successful implementation.

3.8 Plan stakeholder engagement

Stakeholder management adopts a structured, iterative approach. In such an approach, stakeholders are identified, categorized and engaged throughout the lifecycle of the project. Stakeholder identification leads to the development of a stakeholder register which is developed in the early stages of project planning. The register details information regarding their interests, influence, involvement, the preferred channel of communication and potential impact on a project (Riahi, 2017). Stakeholder categorization helps in building strong relationships between the project team and the identified stakeholders. Stakeholders are categorized based on power/influence, power/interest, impact/influence, salience model, the direction of influence or prioritization. Prioritization is useful where the stakeholder communities change frequently while the power/influence, power/interest or impact/influence models are useful for projects with simple relationships. The salience model classifies stakeholders based on power, urgency and legitimacy and is useful where the stakeholder communities adopt complex relationship networks (PMI, 2017). These three attributes define relations between KenGen and the identified stakeholders. This study therefore adopts a salience model-based stakeholder register and proposes actions based on the power/influence/interest models as shown in Table 9.

This model proposes that a binary combination of power, legitimacy and urgency will help to classify and rank the stakeholders further as either non-stakeholders, demanding, discretionary, dependent, dormant, dangerous, dominant and definitive. Proposed actions include keeping stakeholders informed, managing them closely, monitoring or keeping them satisfied, as indicated in Table 10.

TABLE 9: Sample stakeholder register adopting the salience model

Name	Role	Preferred communication channel	Power	Legitimacy	Urgency	Stakeholder classification	Proposed action	Priority Rank
National government	Facilitate project approvals	Face to face, emails, phone calls or memos	1	1	0	Dominant	Keep informed	2
KenGen project team	Project coordination	Face to face, emails, phone calls or memos	1	1	1	Definitive	Manage closely	3
EPRA (regulator)	Approve PPA	Memos, face to face or email	1	0	1	Dangerous	Keep informed	2
Local community	Provide labour services	Print media or social comm-unity gatherings	0	0	1	Demanding	Monitor	1

TABLE 10: Matrix for the salience model stakeholder register

Power	Legitimacy	Urgency	Priority rank	Proposed action	Classification
0	0	0	0	Don't manage	Non-stakeholder
0	0	1	1	Keep informed	Demanding
0	1	0	1	Monitor	Discretionary
0	1	1	2.5	Manage closely	Dependent
1	0	0	1	Monitor	Dormant
1	0	1	2	Keep satisfied	Dangerous
1	1	0	2	Keep informed	Dominant
1	1	1	3	Manage closely	Definitive

This study identifies stakeholders as either internal or external. The internal stakeholder is KenGen, who is the project client and includes top management, project manager, project team and staff. The external stakeholders include the national government, politicians, the KenGen project team, the KenGen operations team, Kenya Power (Offtaker), the Energy and Petroleum Regulatory Authority (EPRA), the local community as well as other energy developers, suppliers, contractor, financial institutions, Kenya Wildlife Service (KWS) and the general public. Their specific interest, influence and involvement are discussed below:

National government
KenGen is parastatal, which is owned to 70% by the government. The national government, through the Cabinet Secretary in charge of Energy and Petroleum, needs to be involved during the planning phases of the project to facilitate financing from DFIs. Again, consultation with the government is vital in getting the necessary approvals and obtain final decisions.

Political
Government administrations in Kenya change every 5 years. To some extent, these administrations develop new development agendas that may or may not favour the development of geothermal energy projects. Similarly, geothermal power projects take long development periods which may differ between administrations. It is on this premise that the political stakeholders are considered. As a matter of fact, the leadership where these power plants are located, influence the outcome of the project, and therefore, their contribution needs to be considered.

KenGen project team
KenGen is the project developer that owns and runs Olkaria 1AU and Olkaria IV power plants. The project manager spearheads the project team that entails staff from operations and project execution departments. Of great importance is the role of the project manager in integrating the operations and the EPC contractor during project implementation.

KenGen operations team
The operations team, also known as the project occupier, runs and operates the existing power plants. They are critical stakeholders in this project since it requires the shutdown of the operational power plants, which they currently operate. Any plant modifications must be brought to their attention to ensure continuity in production after project implementation.

Kenya Power (Offtaker)
KenGen adopts a single buyer model where all the generated power is sold to one buyer, the Kenya Power company. Therefore, before the development of projects or any other system changes in the plants, KenGen must negotiate a new power purchase agreement. Since this project entails uprating an existing power plant, re-negotiations with Kenya Power are vital in order to satisfy this requirement.

Energy and Petroleum Regulatory Authority (EPRA)
After negotiations with Kenya Power (KP) on the additional capacity, the energy regulator, that is the Energy and Petroleum Regulatory Authority (EPRA), approves the agreement.

Local community
Initial development and expansion of the power plants involved expropriation. However, this project will not lead to such occurrences since all activities affect existing equipment only. KenGen has established close ties to the local community, which benefits from transport infrastructure and employment opportunities. To avoid conflict of interests and promote synergism, it is imperative to inform the local community, especially their leadership, about changes in the existing power plants.

Other energy developers
Other developers may want to use this study as a yardstick since only very limited projects of a similar nature have been carried out in the past. The approach and lessons learned after project implementation are vital for any upcoming project to enable informed decision-making.

Suppliers
The project will involve the procurement of resources such as consultancy services, equipment, workforce, materials and services. Timely and correct deliveries, such as equipment from external suppliers, will affect the outcome of the project. To avoid inconveniences due to product or service delay, it is vital to engage supplier regularly during project execution.

Contractor
The contractor will conduct the actual project work and as such plays a critical role in the completion of the project. The quality of work is dependent on the contractor workmanship and effort.

Financial institutions
These institutions are banks or investors. The existing power plants were co-financed by DFIs, and it is imperative to involve them before conducting any modifications since these institutions will support the project by financing 70% of the loan.

Kenya Wildlife Service
The power plants are in Hells Gate National Park, which is operated by Kenya Wildlife Services (KWS). In 2008, KenGen and Kenya Wildlife Services (KWS) signed a Memorandum of Understanding (MoU) to promote harmonized use of resources, promote environmental conservation measures and mitigate negative impacts when developing geothermal resources. Based on the measures mentioned above,

KenGen can only conduct development activities after obtaining consent from KWS. Furthermore, all equipment and personnel assigned to the project have to access one entry point operated by both KenGen and KWS officials.

Public
As indicated earlier, KenGen is a parastatal company of which the government owns 70%. It is also listed in the National Stock Exchange market which means that 30% of this stake is privately owned. It is on this premise that the public needs to be informed about changes in existing project set-ups.

4. IMPLEMENTING THE GEOTHERMAL ENERGY PROJECT PLAN

4.1 Execution

Execution follows the planning phase in the project life cycle. In this phase, the deliverables identified in the planning phase are met and managed. It is considered the most extensive phase in the lifecycle, and it consumes the majority of project resources and effort. Executing the project management plan entails various processes which include directing and managing project work and knowledge, quality, teams, procurement, communication with stakeholders and implementing risks response (PMI, 2017). As indicated previously, this uprating project will be undertaken while utilizing an EPC form of contracting. The KenGen team, led by the project manager, in cooperation with the consultant, will lead in project supervision. The project manager will assume overall project authority and accountability with inputs from a project implementation team that includes members of the power plant operations team. These teams will support decision-making and general supervision of processes as the project progresses.

All communication, especially to external stakeholders, will be through the KenGen project manager. Effective communication will ensure that all project stakeholders receive the relevant information to provide a positive outcome of the project. Not only does effective communication enable productive dialogue within teams, but it also creates influence and helps build positive relationships. On the other hand, the contractor will execute the assigned activities as stipulated in the work breakdown structure, including procurement of material, labour and equipment. The contractor will conduct all purchases in line with KenGen's specifications to ensure the guaranteed quality of the outcomes after completion of the project. The contractor will also ensure that all uprating works are conducted safely, within schedule and planned costs. The contractor will primarily focus on the time constraint to avoid unnecessary plant outages which result in losses in production. High-level planning and follow up of activities will ensure that the overall project objectives are met within the planned period of 3.8 years. This will also optimize profits. All risk responses identified will be implemented in this phase of the project to prevent recurrence.

4.2 Monitoring and control

Monitoring and control is an iterative phase in the project management life cycle since it interacts with all the other project phases (ISO, 2012). This phase entails processes such as controlling integrated changes, scope, quality, procurement and monitoring risks, communication and stakeholder engagement (PMI, 2017). Primarily, these processes focus on monitoring, measuring and controlling project performance in accordance with the project management plan. To meet objectives while executing this uprating project, monitoring and controlling phase will track the progress of work, carry out preventive and corrective actions or make change requests when necessary. One method that is used by project managers to track progress is earned value management (EVM). This method measures performance by reporting variances based on work done and work planned. It is also applied in forecasting project timelines and cost control.

For instance, in order to measure cost and schedule performance, the schedule performance index (SPI) and cost performance index (CPI) are reported to the project manager by the contractor as shown in Table 11.

TABLE 11: Sample project monitoring and control metrics

Metric	Report timeline	Favourable	Unfavourable
Schedule performance index (SPI)	Monthly	$0.9 \leq SPI \leq 1.0$	SPI>1.0 or SPI<0.9
Cost performance index (CPI)	Monthly	$0.9 \leq CPI \leq 1.2$	CPI<0.9 or CPI>1.2

Table 11 lists the acceptable thresholds of the project, which, in case of failure, require corrective action to steer the project back on course. For scope control, the project manager is responsible for monitoring all contractor related activities to ensure that the work is in accordance with the envisioned plan. The project manager may utilize regular meetings with project stakeholders to enforce the need to assimilate the work with the objectives. Any scope change requests submitted will be reviewed and implemented where necessary.

During project implementation, all anomalies will be recorded, resolved and reported in consultative meetings. Corrective actions will be identified and communicated to the project teams. Quality analysis of data will be done continuously to eliminate recurrence of problems and promote desired levels of performance. Conducting the performance tests on uprated equipment will be vital in ensuring that the acceptance criterion of an additional 40 MW is realized.

4.3 Closure

Closure is the last phase of the project management life cycle, and it formalizes acceptance. In this project, the contractor will provide the uprated power plants to KenGen. The KenGen project manager will evaluate the success of the project by submitting a completion report summary and handover the power plants to the operations team. The completion report may include lessons learned, safety aspects, cost variances, schedule variances, project sustainability, follow up actions and recommendations. The contractor will release project resources and demobilize from the site after successfully conducting equipment performance tests.

5. CONCLUSIONS

This project seeks to uprate the 280 MW geothermal power plants in Olkaria, Kenya by 40 MW exploiting additional available resources. The advantages of this approach outweigh the development of new top-up plants which may be capital intensive and cumbersome to implement. A project plan for uprating the power plants was developed based on the approach proposed by the 6th edition of the Project Management Body of Knowledge (PMBoK) and definitions in the ISO 21500 – 2012 guide to project management. This study noted that there are special considerations that need heeding when uprating existing power plants such as scope, cost, quality, resource, communication, procurement and stakeholders. Of the factors and constraints stipulated in these standards, risks and time management were identified as the key elements to ensure that the uprating project is delivered successfully. This is because undertaking the uprating project meant shutting down operational units; hence, culminating in losses in production. Such losses are minimized by adopting strict time schedules and allowing significant resource for project planning. Again, no projects of a similar nature have been conducted within the geothermal industry in Kenya, which makes it a risky venture due to the technicalities involved in replacing and integrating equipment.

This project assumes that the limit gross power increase is 40 MW due to current operational limitations. The plan envisions an implementation period of 3.8 years based on inputs and estimates provided by subject matter experts when developing the WBS. The project forecasts a 15-year period to repay the overall investment cost, which is 80 MUSD in the form of a loan from an investor. The outstanding risks in this project are operational, technical, legal and regulatory. The main stakeholders are the KenGen operations team, the project team, Energy and Petroleum Regulatory Authority, Kenya Power (Offtaker) and the contractor. One lesson emanating from this study is that success in such projects is not guaranteed but developing a project plan provides a higher probability of success. In conclusion, the various aspects as stipulated in this study can be customized to suit projects of a similar nature, thus, assisting investors or owners seeking to uprate in the future.

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APPENDIX I: The different segments of the Olkaria geothermal system

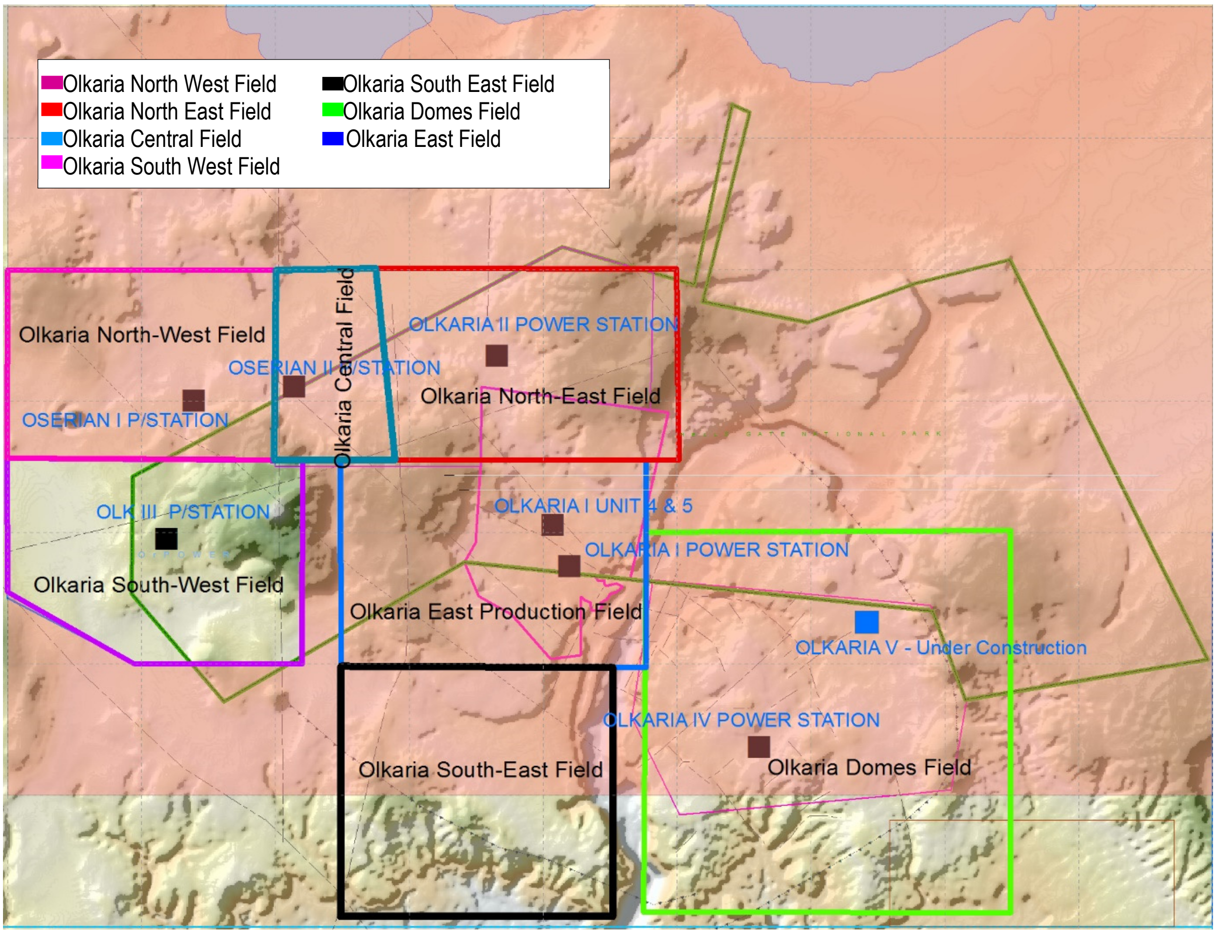

FIGURE 1: Location map showing the Olkaria geothermal area in Kenya

APPENDIX II: Project management plan for uprating the 280 MW geothermal power plants in Olkaria, Kenya

Project perspective

This plan highlights background information about the uprating project and integrates all components in the planning process group as proposed by the 6th edition of the Project Management Body of Knowledge (PMBoK) and definitions in the ISO 21500 guide to project management. The critical components outlined include scope, schedule, budget, resources, communication, risks and stakeholder engagement.

Background information

Current operational parameters indicate that the resource for the 280 MW geothermal power plants in Olkaria, Kenya, can be optimized by an additional 40 MW. One of the strategic initiatives of KenGen is to improve its processes continuously. This project is in line with this initiative as the resources will be optimized without necessarily conducting well drilling for additional steam which is considered capital intensive. This project is also in line with the governments' agenda of increasing renewable sources of energy, thus, decreasing reliance on expensive fossil fuels.

Project scope

The main deliverable is a project management plan that constitutes sub-plans on scope, schedule, cost, quality, resource, communication, risk, procurement, and stakeholders. The plan focuses on uprating Olkaria 1AU and Olkaria IV geothermal power plants in Olkaria, Kenya by 40 MW. This project adopts an EPC form of contracting where a contractor is engaged to carry out the uprating works. This contractor will report to the KenGen project manager. The project will be partially financed by a Development Finance Institution (DFI) and the Government of Kenya through a loan with a debt to equity ratio of 70/30. The project envisions a period of 3.8 years to complete.

Content

In this project, KenGen will procure a consultant who will guide in tender development and defining specific design requirements. During this time, KenGen will update the existing ESIA by capturing the envisioned modifications in an audit report before submission to the National Environment Management Authority (NEMA). KenGen will then negotiate the existing PPA with Kenya Power (KP) and Energy and Petroleum Regulatory Authority (EPRA) to capture the new requirements. These new requirements will require approval and concurrence from the financier before tender preparation and procurement of the EPC contractor.

The EPC contractor will commence the actual works at Olkaria IAU by procuring and delivering two fully bladed rotors, journal bearings, diaphragms, circuit breakers and condenser banks. The operations team will shut down Unit 4, where the contractor will remove the existing pressure control valves, rotor and diaphragms prior to the installation with new components. The contractor will also modify the generators to match the current step-up transformers. Again, the contractor will modify the control valves and scrubber internals, followed by the installation of an additional circuit breaker and condenser banks for production of reactive power when needed. The operations team will bring the Unit back to service, followed by a performance test to confirm that the process meets the requirements. Unit 5 modifications will commence after completion of performance tests on Unit 4. Unit 5 modifications will follow the procedures conducted on Unit 4.

In order to modify Units at Olkaria IV, the contractor will ship the rotors removed from Olkaria I AU to their premises for re-blading and balancing. This offshore activity requires to be conducted with utmost precision. After delivery of the modified rotors on-site, the uprating process will replicate that of Units 4 and 5 above.

Exclusions

Project exclusions explicitly state actions outside the uprating boundaries or the project scope. Such exclusions include:

- Development of the project charter.
- Analysis of all execution, monitoring, control, and closing process group actions, as stated in the sixth edition of the Project Management Body of Knowledge (PMBoK).
- Design calculations justifying the existence of additional geothermal resources equivalent to 40 MW
- In-depth analysis and discussion of utilization methods such as installing topping plants.

Constraints
Project constraints are limits of the resources time, money, workforce or equipment. This project is affected by the six project constraints, namely time, cost, scope, quality, benefits and risks. Specifically, more emphasis is laid on risk and time because uprating can only be conducted when the equipment is offline, which disrupts normal operations culminating in losses in production. To avert considerable losses in production, meticulous time management through high-level planning and risk assessment is vital.

Assumptions
This project makes the following assumptions:

- Project start date is 1st January 2020.
- There is reliable input from subject matter experts in geothermal energy project planning when developing the project description and deliverables.
- The possible gross power increase is limited to 40 MW as guided by the current operational limitations.
- Negotiations and all necessary approvals are agreeable within the timelines allocated in the generated project schedule.
- The sequential project plan provided in this study will promote energy recovery specific not only to Olkaria but also for other power plant projects seeking to uprate.

Work breakdown structure (WBS)
The work breakdown structure indicates the hierarchical decomposition of the work that has to be executed during the uprating process. This project entails three levels that are levels 1, 2 and 3, as shown in Table 1.

Project schedule
Project scheduling involves estimating time resources and developing a schedule. The activities identified in the WBS are used to determine the total project duration of 3.8 years using MS Project as indicated by the Gantt chart in Figure 1 in this Appendix.

TABLE 1: Work breakdown structure

WBS level	Phase / activity name
0	UPRATING THE 280 MW GPPs IN OLKARIA, KENYA
1	PHASE 1: PREPARATION
1.1	Uprating programme
1.1.1	Procure consultancy services
1.1.2	Update design - generator rerate, steam path and lines, control valves and heat load
1.1.3	Update ESIA by capturing modifications in audit report and submit to NEMA
1.2	Negotiations
1.2.1	Negotiate PPA with power offtaker and regulator
1.2.2	Financier approval and concurrence
1.2.3	Tender preparation
1.1.4	Procure EPC contractor
2	PHASE 2: EXECUTION
2.1	Olkaria 1AU Units 4 and 5 components
2.1.1	Manufacture deliver 2 fully bladed rotors, journal bearings and diaphragms
2.1.2	Procure circuit breaker and condenser banks
2.2	Unit 4 modifications, start-up and commissioning
2.2.1	Remove existing pressure control valves, rotor and diaphragms
2.2.2	Install new rotor and diaphragms
2.2.3	Modify generator, control valves and steam scrubber internals
2.2.4	Install additional circuit breaker and condenser banks for reactive power
2.2.5	Unit 4 startup and performance test
2.3	Unit 5 modifications, start-up and commissioning
2.3.1	Remove existing pressure control valves, rotor and diaphragms
2.3.2	Install new rotor and diaphragms
2.3.3	Modify generator, control valves and steam scrubber internals
2.3.4	Unit 5 startup and performance test
2.4	Olkaria IV Units 1 and 2 components
2.4.1	Procure rotor blades, nozzle diaphragms and journal bearings
2.5	Units 4 and 5 offshore works for use on Units 1 and 2
2.5.1	Unit 4 rotor modification and delivery
2.5.2	Unit 5 rotor modification and delivery
2.6	Unit 1 modifications, start-up and commissioning
2.6.1	Remove existing pressure control valves, rotor and diaphragms
2.6.2	Install modified rotor and diaphragms
2.6.3	Modify generator, control valves and steam scrubber internals
2.6.4	Install additional circuit breaker and condenser banks for reactive power
2.6.5	Unit 1 startup and performance test
2.7	Unit 2 modifications, start-up and commissioning
2.7.1	Remove existing pressure control valves, rotor and diaphragms
2.7.2	Install modified rotor and diaphragms
2.7.3	Modify generator, control valves and steam scrubber internals
2.7.4	Unit 2 start-up and performance test

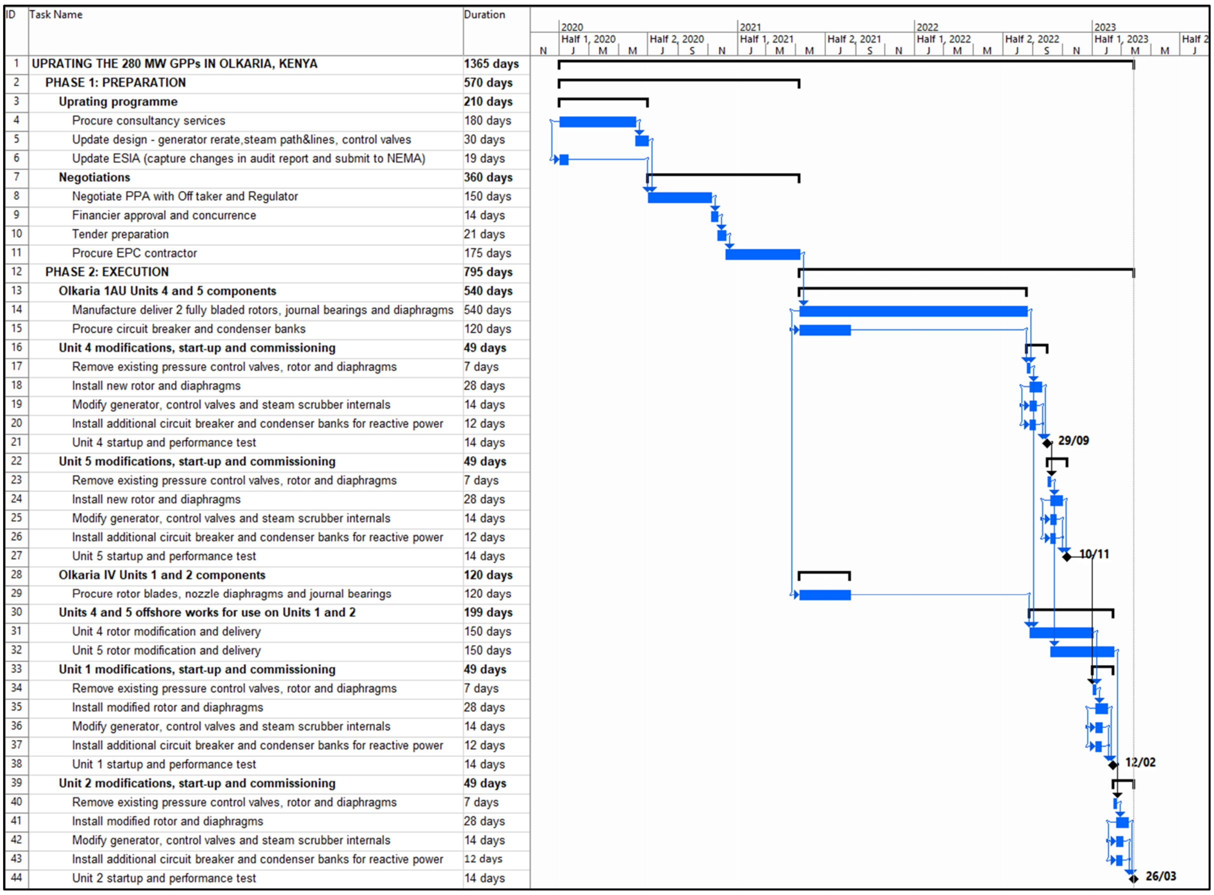

FIGURE 1: Gantt chart for the uprating project

Project budget

Cost estimates are based on the WBS. The total estimated costs for the project is 80 MUSD, as shown in Table 2.

TABLE 2: Budget breakdown

Item	Cost (MUSD)
Preparation (negotiations and tender documents)	0.075
Engineering and project management	3.0
Turbine and generator equipment	34.0
Cost of production due to stoppage	40.0
Contingency	2.925
Total cost estimate	**80**

Project resources, roles and responsibilities

Resource planning entails creating a plan for the workforce, material, equipment and budget that are required for a project. Though sometimes combined with the development of the schedule, tracking it individually helps identify actual roles and responsibilities of the people involved. The resource plan in Table 3 indicates the various roles and responsibilities of stakeholders based on the WBS.

TABLE 3: Project roles and responsibilities

WBS level	Phase / activity name	Resource type
1.1.1	Procure consultancy services	KenGen
1.1.2	Update design - generator rerate, steam path, steam lines, control valves and heat load	Consultant
1.1.3	Update ESIA by capturing modifications in audit report and submit to NEMA	KenGen
1.2.1	Negotiate PPA with Offtaker and Regulator	KenGen
1.2.2	Financier approval and concurrence	Financier
1.2.3	Tender preparation	Consultant/KenGen
1.1.4	Procure EPC contractor	KenGen
2.1.1	Manufacture deliver 2 fully bladed rotors, journal bearings and diaphragms	Contractor
2.1.2	Procure circuit breaker and condenser banks	Contractor
2.2.1	Remove existing pressure control valves, rotor and diaphragms	Contractor
2.2.2	Install new rotor and diaphragms	Contractor
2.2.3	Modify generator, control valves and steam scrubber internals	Contractor
2.2.4	Install additional circuit breaker and condenser banks for reactive power	Contractor
2.2.5	Unit 4 startup and performance test	KenGen/Contractor
2.3.1	Remove existing pressure control valves, rotor and diaphragms	Contractor
2.3.2	Install new rotor and diaphragms	Contractor
2.3.3	Modify generator, control valves and steam scrubber internals	Contractor
2.3.4	Unit 5 startup and performance test	KenGen/Contractor
2.4.1	Procure rotor blades, nozzle diaphragms and journal bearings	Contractor
2.5.1	Unit 4 rotor modification and delivery	Contractor
2.5.2	Unit 5 rotor modification and delivery	Contractor
2.6.1	Remove existing pressure control valves, rotor and diaphragms	Contractor
2.6.2	Install modified rotor and diaphragms	Contractor
2.6.3	Modify generator, control valves and steam scrubber internals	Contractor
2.6.4	Install additional circuit breaker and condenser banks for reactive power	Contractor
2.6.5	Unit 1 startup and performance test	KenGen/Contractor
2.7.1	Remove existing pressure control valves, rotor and diaphragms	Contractor
2.7.2	Install modified rotor and diaphragms	Contractor
2.7.3	Modify generator, control valves and steam scrubber internals	Contractor
2.7.4	Unit 2 startup and performance test	KenGen/Contractor

Project communication plan
Communication is a continuous activity of providing relevant information to stakeholders about a particular project. It can be constructed to include many aspects such as type of communication, objectives of communicating, frequency, audience and the required deliverable, as shown in Table 4. Proper communication ensures that all stakeholders are in harmony with the events of a project.

Project risk assessment
The risks identified in the project are categorized into political, environmental, financial, operational, technical, social and legal and regulatory. Each of these categories has several distinct risks whose probability, impact and severity scores are shown in Table 5.

TABLE 4: Project communication plan

Communication type	Objective	Medium	Frequency	Audience	Deliverable
Kickoff meeting	Introduce the project team and the project Review project objectives	Face to face	Once	DFI representative Project team Operations team Contractor KWS representative KP representative EPRA representative	Agenda Meeting minutes Way forward Ground rules
Project team meetings	Review status of project with the team	Face to face	Weekly	Project team Contractor Operations representative	Agenda Meeting minutes Project schedule
Adhoc project status meetings	Report on status of project to management	Face to face Conference calls Memos	As and when required	Project manager Contractor	Slide updates Project schedule
Monthly project status meetings	Report on the status of the project to management	Face to face	Monthly	Project manager Contractor	Slide updates Project schedule
Technical design review meetings	Review designs of project	Face to face	As and when required	Project team Contractor Operations representative	Technical design reviews
Project status reports	Report status of project including activities, progress, costs and issues	E-mail	Monthly	Ministry of Energy DFI representative Project team Operations team Contractor, suppliers KWS representative KP representative EPRA representative	Project status report Project schedule
Project general awareness	Report project status including gains or reported societal issues	Print and digital media	Bi-annual	The general public including local community	Project progress or status

TABLE 5: Risk matrix for the uprating project

RISK IDENTIFICATION AND ANALYSIS				
Category	**Risk name**	**Probability score (A)**	**Impact score (B)**	**Severity (A*B=S)**
Political	Project acceptance and consent by Ministry	4	4	16
	Delays in project approvals	5	5	25
Environmental	Noise emanating from construction equipment	3	3	9
	Increased air pollution due to increased traffic	3	2	6
	Difficulty in project approval by NEMA	2	3	6
Financial	Financial disbursement	5	2	10
	Fluctuations in interest and exchange rates	3	3	9
Operational	Significant losses in production	5	5	25
	Failure to involve operations team	1	5	5
Technical	Use of untested technology	3	3	9
	Issues with integration with current systems	3	4	12
Legal & regulatory	Failure to obtain best alternative to negotiated agreements	2	4	8
	Breach of contract by either party	2	5	10
Social	Negatively affect quality of life of locals	1	2	2
	Problems getting acceptance by the public	1	1	1

The risks with the highest severity score need to be prioritized and actioned where necessary. Risk responses entail determining measure such as preventive or contingency actions that need to be taken after risk identification. The specific risk responses for each of the identified risks are shown in Table 6.

TABLE 6: Risk responses for the uprating project

ACTION PLAN – RESIDUAL RISKS				
Risk treatment/ Response plan	**Risk owner**	**Risk probability (RP)**	**Risk impact (RI)**	**Residual risk (RP*RI)**
Meeting with government officials from the Ministry and justifying project	KenGen project manager	3	3	9
Start seeking for approval early at least 3 months in advance	KenGen project manager	3	4	12
Condone off areas and use PPE	Contractor/KenGen project manager	1	2	2
Permitting road worthy vehicles and equipment to carry out works	Contractor/KenGen project manager	2	1	2
Meeting with NEMA officials and heeding to environmental audit considerations	KenGen project manager	1	2	2
Involvement and support from national government in financial negotiations	KenGen project manager	3	2	6
Utilizing favorable interests and exchange rate margins	Contractor/KenGen project manager	2	2	4
Strict adherence to schedule to avoid extended delays	Contractor/KenGen project manager	5	3	15
Dedicated persons from operations in the project implementation team	KenGen project manager	1	4	4
Promote research through collaborations with market leaders in the industry	KenGen project manager	2	3	6
Adoption of sophisticated troubleshooting methods and tools	Contractor/KenGen project manager	2	3	6
Hire a legal consultant	Contractor/KenGen project manager	2	3	6
Arbitration	Contractor/KenGen project manager	2	4	8
Introduce a social engagement plan to indicate project benefits	KenGen project manager	1	1	1
Project discussion through available mass media streams such as print or social	KenGen project manager	1	1	1

Project stakeholder engagement

Based on the salience model, the stakeholders are identified and ranked in order to determine their priority score. This is shown in Table 7.

TABLE 7: Salience model-based stakeholder register
(P stands for power, L for legitimacy and U for urgency)

Name	Role	Preferred communication channel	P	L	U	Stakeholder classification	Proposed action	Priority rank
National government	Facilitate project approvals	Face to face, emails, phone calls or memos	1	1	0	Dominant	Keep informed	2
Political	Participate in legislations	Face to face or phone calls	1	0	0	Dominant	Keep satisfied	1
KenGen project team	Project coordination	Face to face, emails, phone calls or memos	1	1	1	Definitive	Manage closely	3
KenGen operations team	Machine shutdown, start-up and operation	Face to face, emails, phone calls or memos	1	1	1	Definitive	Manage closely	3
Kenya Power (Offtaker)	Negotiation of PPA	Memos, face to face or email	1	1	1	Definitive	Manage closely	3
EPRA (Regulator)	Approve PPA	Memos, face to face or email	1	0	1	Dangerous	Keep informed	2
Local community	Provide labour services	Print media or social community gatherings	0	0	1	Demanding	Monitor	1
Other developers	Adopt lessons learned	Print media	0	0	1	Demanding	Monitor	1
Suppliers	Provision of project equipment and material	Email, telephone or face to face	1	0	1	Dangerous	Keep informed	2
Contractor	Project implementation	Face to face	1	1	1	Definitive	Manage closely	3
Financier	Financing project	Face to face, emails, phone calls or memos	1	1	1	Definitive	Manage closely	3
Kenya Wildlife Service	Facilitate project commencement	Memos, face to face or email	1	1	1	Definitive	Manage closely	3
General public	Support government through funding	Print media	0	0	1	Demanding	Monitor	1
National Environment Management Authority	Approve ESIA	Memos, face to face or email	0	1	0	Discretionary	Monitor	1