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# Optimizing Power Generation in Patuha Geothermal Field: An Integrated Approaches to Field Management for Optimum Capacity and Reliability

Ilen Kardani, Budi Santoso, Andisyah Purdanto, (PT Geo Dipa Energi)

Aldevco Octagon 2nd floor, warung jati street no.75 South Jakarta, Indonesia

ilen.kardani@geodipa.co.id,budi.s@geodipa.co.id,andisyah@geodipa.co.id

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## ABSTRACT

The Patuha geothermal field, located in Bandung, Indonesia, plays a pivotal role in the nation's renewable energy portfolio. This article discusses holistic approach of field management, with a primary focus on strategies tailored to maximize geothermal resource utilization, address operational challenges, and ensure the Patuha Geothermal Power Plant operates at optimum Capacity and Reliability.

This comprehensive approach covers the entire spectrum of geothermal field management, encompassing both subsurface and surface facilities, and is structured into four key areas:

**1. Idle Well Utilization:** As the drilling of 12 wells on progress and construction of a power plant still ongoing, the strategic utilization of idle wells takes center stage. This study investigates innovative approaches to tap into the latent potential of these wells during the interim period, ensuring a continuous supply of available steam to the existing power plant unit. The tangible impact of idle well utilization is evident in the remarkable enhancement of the Power Plant's Capacity and Availability Factor, surpassing 95%, a benchmark that surpasses industry standards in Indonesia.

**2**. **Scale Removal in Wellbores**: Addressing scale deposition within wellbores is critical to maintaining optimal geothermal resource extraction and, consequently, the Power Plant's Capacity Factor. This section meticulously explores a spectrum of cutting-edge technologies and methodologies for efficient scale removal, guaranteeing the unimpeded integrity and longevity of wellbores, while concurrently maximizing plant efficiency.

**3. De-bottlenecking Power Plant Facilities**: The operational efficiency and reliability of power plant facilities serve as enabler in overall production optimization and contribute significantly to the Availability Factor. Our rigorous approach to enhancing condenser performance, optimizing cooling tower systems, and streamlining water treatment processes has effectively minimized bottlenecks, ensuring a consistent and sustainable power generation process.

**4. Preventive and Predictive Maintenance:** The enduring operational life of production facilities hinges on the implementation of proactive maintenance practices. We firmly advocate that preventive and predictive maintenance supersedes corrective actions in importance. This maintenance philosophy enables us to proactively identify and address equipment issues, thereby reducing downtime and optimizing the lifecycle of all production facilities, ultimately resulting in a substantially higher Availability Factor for the Patuha Power Plant.

**5. Minimizing Own Use of Electricity**: In line with sustainability goals, we have prioritized minimizing our own use of electric power across all facilities and equipment. By implementing energy-efficient practices and technologies, we aim to not only reduce operational costs but also generate surplus electricity for sale, contributing to increased revenue and sustainability.

The strategies detailed in this article not only contribute to the ongoing success of the Patuha geothermal field but also bear substantial implications for geothermal energy endeavors in Indonesia or even worldwide.

## 1. INTRODUCTION

Geo Dipa Energi Patuha Geothermal Field is located in West Java, Indonesia. It has a potential around 400 MW and right now already running one unit with installed capacity 60 MW from September 2014. The second 60 MW unit is still under development, the drilling operations almost complete for the last well from 12 wells, and the powerplant construction is planned complete at the end of 2026. The characteristics of the geothermal reservoir are vapor dominated (97%), reservoir pressure 1000 psi, reservoir temperature $225^0$ C, low NCG (0.7%), and low pH (around 4). Annual reservoir decline estimated 1.6%, and it has wellbore calcite scaling problem at one of its wells (PPL-7). Twelve production wells, include two wells from Unit 2, are now operated to supply the steam, while only one injection well needed for condensate injection. The depth of the wells vary from 900 to 2500 m.


**Figure 1: Patuha Geothermal Field Location at Indonesia**

Patuha Geothermal Powerplant is dry steam simple cycle type. Figure below describe the process of Patuha Field

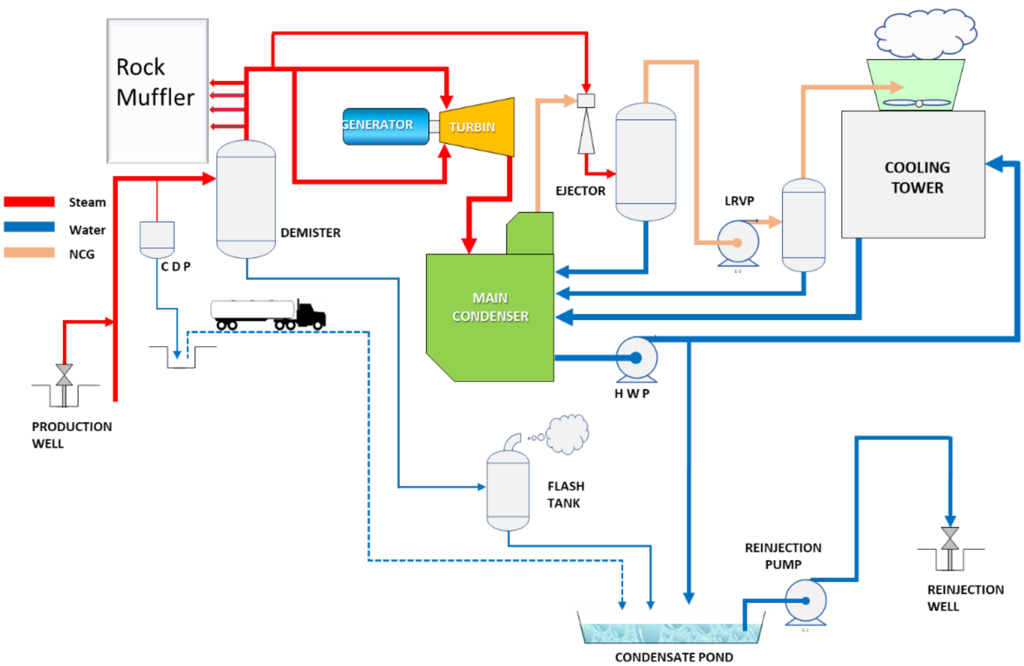


**Figure 2: Process Diagram of Patuha Geothermal Field**

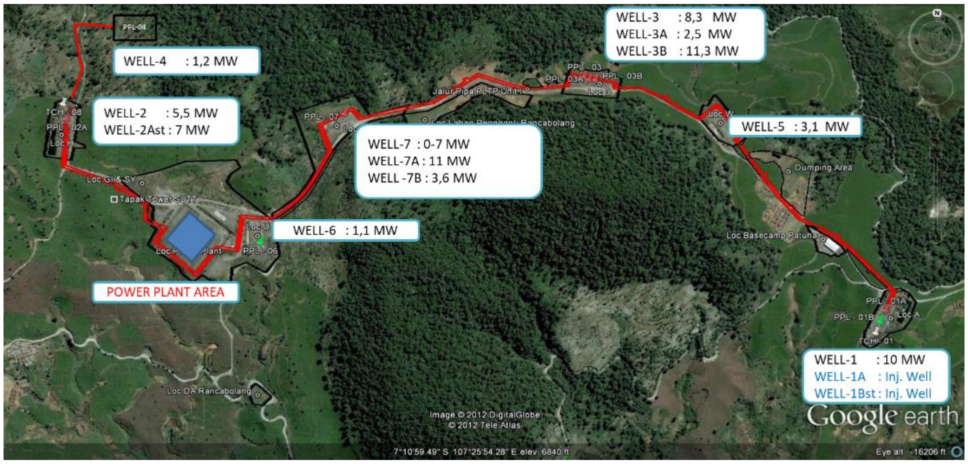


**Figure 3: Aerial view of Patuha Geothermal Field**

## 2. POWER GENERATION OPTIMIZATION APPROACHS

Electrical generation from geothermal powerplant naturally decline due to steam supply decline and loss of powerplant efficiency due to wear in the turbine components. In order to maintain optimum generation, routine powerplant maintenance and drilling make up wells or well intervention programs are common practices in geothermal industries. Good maintenance strategy will maintain the efficiency in the acceptable range with reasonable cost. And to battle with steam decline, well intervention usually the first choice, if there are problems in the wellbore. In the case no problem in the wellbore, and steam decline purely related to reservoir decline, make up well is more suitable. In Patuha, only one well has scaling problem, others do not have. So, work over only suitable to for PPL-7 and the most suitable option to get extra steam is drilling make up wells. Make up wells are very costly, one well needs 5 – 7 million dollars depend on the operational drilling days. Due to financial limitation, Patuha still not drill make up well yet. Patuha management decide to make different approaches to maintain stable electrical generation. Figure below show the historical electrical generation from first year until now.

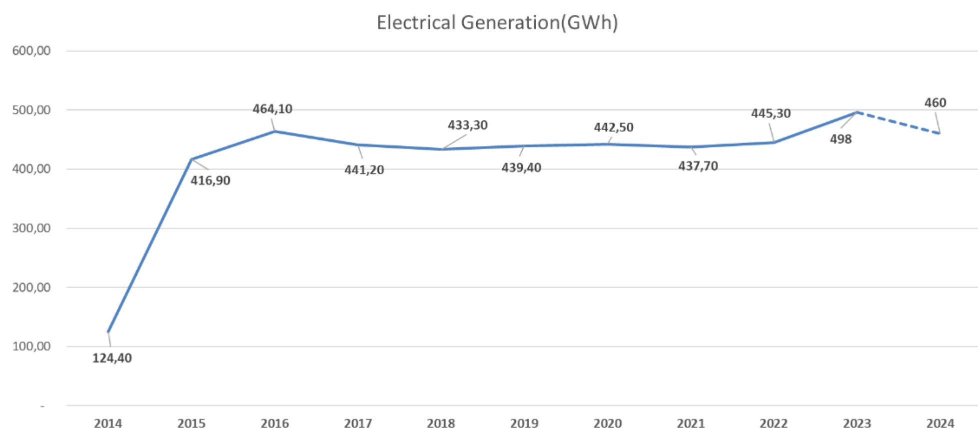


**Figure 4: Patuha Geothermal Field electrical generation record from 2014 until 2023 and target for 2024**

Geodipa Patuha Geothermal Field can maintain its power generation as above figure by comprehensive approaches to battle two major issues as follow:

Steam supply decline:

- Idle Well Utilization
- Scale Removal in Wellbores

Operational efficiency improvement:

- De-bottlenecking Power Plant Facilities
- Preventive and Predictive Maintenance
- Minimizing Own Use of Electricity

### 2.1 Idle Well Utilization

In the beginning of Patuha Geothermal Field Operation at 2014, seven production wells are enough to produce steam to generate 60 MW powerplant full capacity. After operation for a year, the steam supply was short and needed another steam source. So, idle well utilization become the best choices compared to drilling make up wells. Figure below show the idle well utilization strategy take place at Patuha up to now.

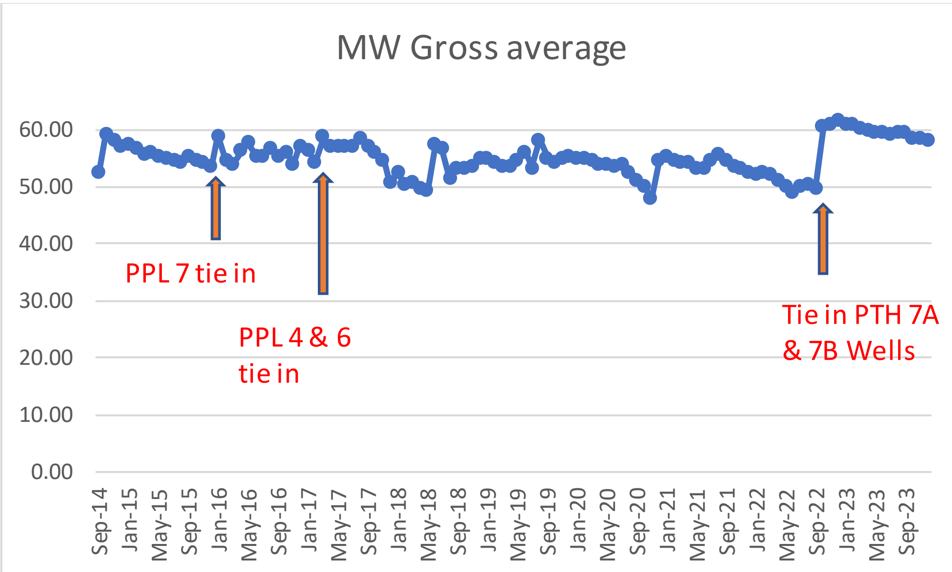


**Figure 5: Patuha Idle Well Utilization from Sept 2014 - now**

#### 2.1.1 PPL-7 tie in at 2015

The Patuha powerplant can achieve 59.88 MW gross during commissioning at September 2014. After operated for one year, in the end of 2015, the load decrease to around 54 MW. Patuha still have three idle wells, PPL-4, and PPL-6, and PPL-7. Management choose to utilize PPL-7 because this well has biggest steam production as per well test record, up to 7 MW. Before online, logging is conducted and found restriction in the well bore, so work over reaming is required. After completing the work over job, the PPL-7 is connected and contributed in increasing the electricity generation at January 2016, 60 MW load can be achieved again.

#### 2.1.2 PPL-4 and PPL-6 tie in at 2017

After PPL-7 tie in, the powerplant running normally at full load, and gradually decrease again due to steam supply decline. Utilization the last two idle wells, PPL-4 and PPL-6 was chosen due to it has lowest project cost. Each well contributed 1 MW, and the gross load of the Turbine Generator back to 60 MW.

#### 2.1.3 PTH-7A and PTH-7B tie in at 2022 <Heading 3 Style>

There is no idle wells anymore after PPL-4 and PPL-6 already connected to steam gathering line, so well intervention on PPL-7 wellbore problem is the only option. It will be explained in the next approach. Luckily, the Patuha 2 project commenced from 2021 and the drilling of new wells (12 production wells) on progress, and the construction of the powerplant needs around three years to be completed, the idle wells utilization strategy is resurfaced again. With approval from the lender, PTH-7A and PTH-7B hook up project commenced. The project is completed at October 2022 and the power generation surpass initial commissioning and achieve 61 MW turbine generator gross load. This year, another well (PTH-2C) is planned to be hooked up and contribute to Patuha. Of course, make up well will be needed to replace these wells if Patuha 2 powerplant construction is complete (estimated at the end of 2026). Still, this strategy is very important for buying time for make up well completion, while maintaining optimum electrical generation for Patuha Unit 1.

### 2.2 Scale Removal in Wellbores

PPL-7 production well is the only one well in Patuha that has scaling problem. This problem greatly influences the production rate of PPL-7, if the wellbore is clean, 7 MW equivalent steam can be produced, and gradually decrease until zero with the scale formation growing and blocking the steam path. The scaling type is calcite (calcium carbonate). It is predicted that ground water channeling through cement imperfection and enter the wellbore in the upper section of the liner. When the ground water is heated by the steam, most of them evaporated and leave the mineral that form solid calcite scale. It is very difficult to prevent the ground water intrusion to the wellbore, the only possible option is to treat the intrusion area by scale inhibitor, or cleaning the scale periodically. Inhibitor option still under study and not implemented yet due to high installation cost and also prone to plugging and tubing failure. Patuha already use Work Over rig 750 HP, Hydraulic Workover Unit (HWU) equivalent to 550 HP rig, and the newest method is using coil tubing unit (CTU). Work over rig is most powerful tools for scaling removal, but expensive. The cost for this job is more than 1 million dollars. This method is used for the first well intervention at 2015, and the used again at 2020 for reaming, fishing, and milling job at PPL-7. By this method, the well production time approximately 1 year without well washing. The Hydraulic Workover Unit (HWU) method is a little cheaper than work over rig, but with less capability. This method used for fishing and milling but unsuccessful, so Patuha need to redo the jobs with work over rig later. The newest method used at PPL-7 is Coil Tubing Unit (CTU) at 2022, unfortunately, the pump and water jetting device (roto jet) cannot run properly, and the job continue with milling 3.7" path maker milling tool. The production time only last for two months and continue with well washing program. Next CTU job is scheduled on March 2024 with roto jet cleaning. The last method that complement all above methods is well washing. It is simply a process of killing the well and continue with quenching until 4000 $m^3$ condensate water enter the well, this process is the main process to reduce the scaling in the wellbore, make the hole bigger, so the steam path also bigger. Then shut in the well for pressure build up, this process needs around 2 and a half days. Then discharge the well for cleaning purpose, and back to online. This method is the cheapest, and no need special equipment, only existing pumps and pipelines. Yet, it is very useful complementary program between well intervention with rig, or CTU intervals that need high budget. The biggest drawback of well washing is reduced well integrity, so monitoring by Metal Thickness Detector (MTD) with logging truck is required periodically to make sure the well still in good integrity

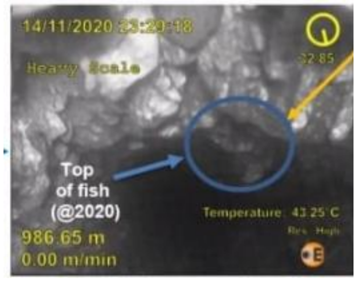


**Figure 6: PPL-7 wellbore condition at upper section of liner, massive calcite scaling spotted by DHV**

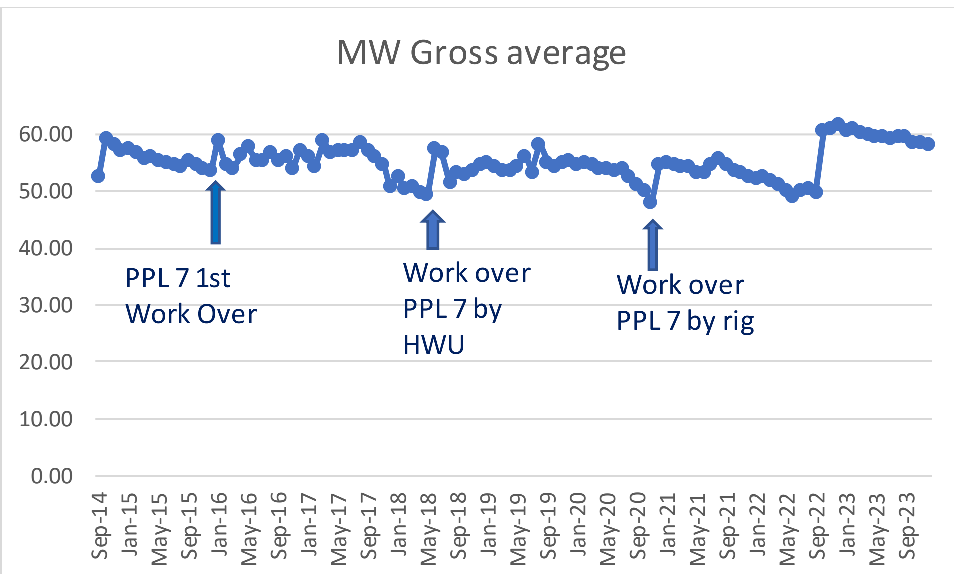


**Figure 7: PPL-7 Work Over**

### 2.3 De-bottlenecking Powerplant Facilities

After make sure the steam supply is sufficient, it is important to prevent bottlenecking in powerplant process, especially in the main cooling water system that greatly influence the overall powerplant efficiency. Condenser, hot well pumps, and cooling towers are the main components of main cooling water system. Rigorous study and approaches are conducted, mainly to ensure the effective cooling and lower condenser vacuum, significantly improve the gross output of the turbine. Monitoring the condenser heat transfer efficiency and cooling tower efficiency, and observing trending data, can lead to early warning of performance decrease of the cooling water system. This event will lead to maintenance jobs i.e. cleaning the nozzle, fan blade inspection or water treatment improvement discussion with chemical vendors. Patuha also decide to replace all the fill pack to maintain top performance of the cooling tower after 8 years of operation. All above efforts has effectively minimized bottlenecks, ensuring a consistent and sustainable power generation process.


**Figure 8: Sulfur deposit in the main cooling water system, mainly in cooling tower equipments**

### 2.4 Preventive and Predictive Maintenance

Good maintenance is the enabler key of success to reach high availability and reliability factor.

Preventive and predictive maintenance are the two main strategies of the Maintenance Division at PT.GDE Patuha. In the year 2023, a total of 3784 Work Orders (WO) were executed, which 91% of it are preventive and predictive maintenance. This illustrates that the Maintenance Division's primary focus is on these strategies. Details of WO per maintenance strategy along with their respective precentages can be seen in table below.

**Table 1 : Maintenance work order and maintenance mix**

| Maintenance Strategy | Work Order | Maintenance Mix |
|---|---|---|
| Preventive | 2428 | 64% |
| Predictive | 1075 | 28% |
| Corrective | 234 | 6% |
| Emenrgency | 1 | 0% |
| Modification | 46 | 1% |
| **Total** | **3784** | **100%** |

Before executing maintenance strategy, identifying equipment is crucial so that maintenance mapping can be carried out. In the GDE Unit Patuha, there are currently 430 equipment being maintained, such as turbines, generators, transformers, pumps, gearboxes, and electrical equipment, etc. These items are registered in the asset list in our CMMS and will continue to be updated in case of changes or new equipment addition.

Once all equipment is registered, a System Equipmment Reliability Prioritization (SERP) is performed to determine the criticality of the equipment. This assessment is based on production throughput, safety factors, regulatory compliance, plant efficiency, and recovery time. The output of the SERP is the Maintenance Priority Index (MPI).

After determining the SERP, the next step is to conduct Failure Mode & Effect Analysis (FMEA) and generate the Failure Defence Task (FDT), which includes several maintenance strategies such as Preventive Maintenance, Predictive Maintenance, Overhaul, Proactive, and First Line Maintenance. The priority for creating FDT is for equipment that falls within the top 30% of the MPI values. After obtaining the FDT, the task is transformed into a Work Order and scheduled for execution by the Maintenance Planner.

In recent years, GDE Unit Patuha has been focusing on development of predictive maintenance because by implementing predictive maintenance, maintenance can be performed without equipment shutdown and will reduce downtime. The replacement of spare parts is not based on time but on the condition of the equipment. With reduced downtime for maintenance work, costs can be minimized, therefore maintenance optimization schedule can be achieved.

The implementation of predictive maintenance at GDE Unit Patuha begins by determining the predictive maintenance methods. Investment of predictive maintenance tools have also been made, such as vibration analyzers, ultrasound analyzers, IR thermography cameras, and UT thickness tools. To complete this implementation, a predictive maintenance team also established. This team is well trained and hold several predictive maintenance certificates.

**Table 2: Predictive maintenance methode and application**

| Method | Application |
|---|---|
| Vibration analysis | Turbine, generator, pump, motor, gearbox, fan |
| Ultrasound | Pump, motor, electrical & mechanical connection |
| IR thermography | Pump, motor, electrical & mechanical connection |
| Corona discharge inspection | Main & Auxiliary transformer |
| Used Oil Analysis | Turbine, gearbox |
| Dissolve Gas Anlysis | Main & auxiliary transformer |
| UT Thickness Inspection | Pipe & vessel |

GDE Unit Patuha also develop predictive maintenance report called "Equipment Health Index". In this report shows equipment status based on predictive maintenance and equipment severity level. Therefore, if there is any equipment issues, it will quickly indentified and enabling prompt corrective action.

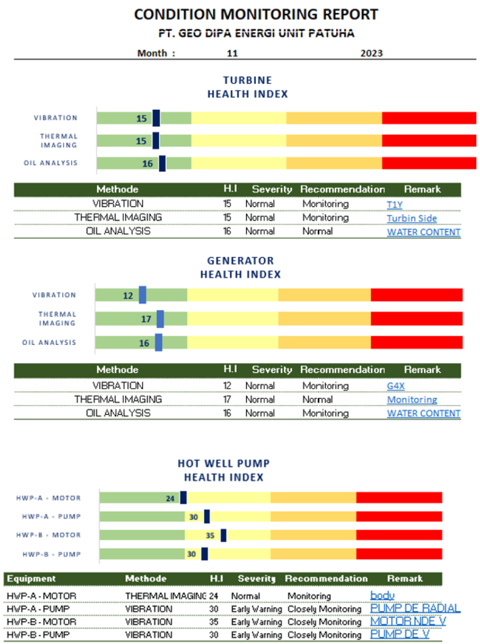


**Figure 9: Equipment Health Index**

The result of preventive and predictive maintenance at GDE Unit Patuha can be seen that over the past four years : plant availability is maintained over 90%, no internal caused force outages occurred and maintenance operating expenses have been well maintained around 10 billion rupiah.

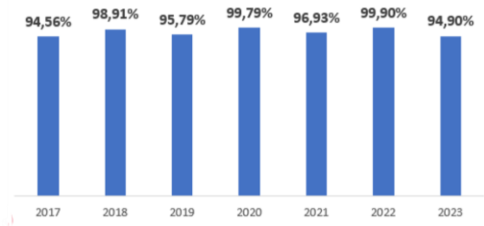


**Figure 10: Plant Availability Factor**

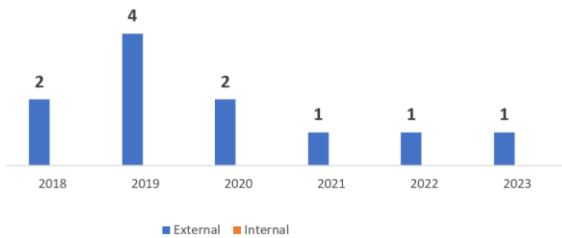


**Figure 11: Forced Outage**

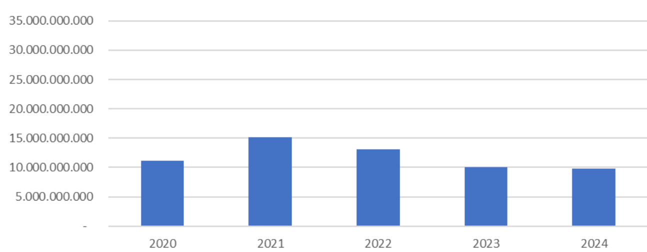


**Figure 12: Maintenance Opex**

### 2.5 Minimizing Own Use of Electricity

The last approach to optimize the power generation is minimizing own use of electricity. The biggest success in this program is by optimizing the Gas Removal System (GRS). Originally, Patuha GRS's is designed enough to extract 3% of NCG from the design steam rate. Actual NCG at Patuha only 0.7%. By design, one 60% ejector and 40% ejector, and two 65% Liquid Ring Vacuum Pumps (LRVP) are all running. Production and maintenance department working together to find the best combination of ejector and LRVP needed by the process. Finally, the most efficient way is running only one ejector 60 % and one 65% Liquid Ring Vacuum Pump. The steam for 40% ejector can be diverted to turbine for MW gain, and reduce the own use of one LRVP motor 0.5 MW. Total 1.5 MW gain is reached by this GRS optimization. Patuha also replace almost all bulb lamps with energy saving lamps (LED), and also install solar panel in the administration building roof. We also install solar powered street lighting. Behavior based energy saving also encourage to employee, i.e. switch electrical equipment when leaving workplace, etc.

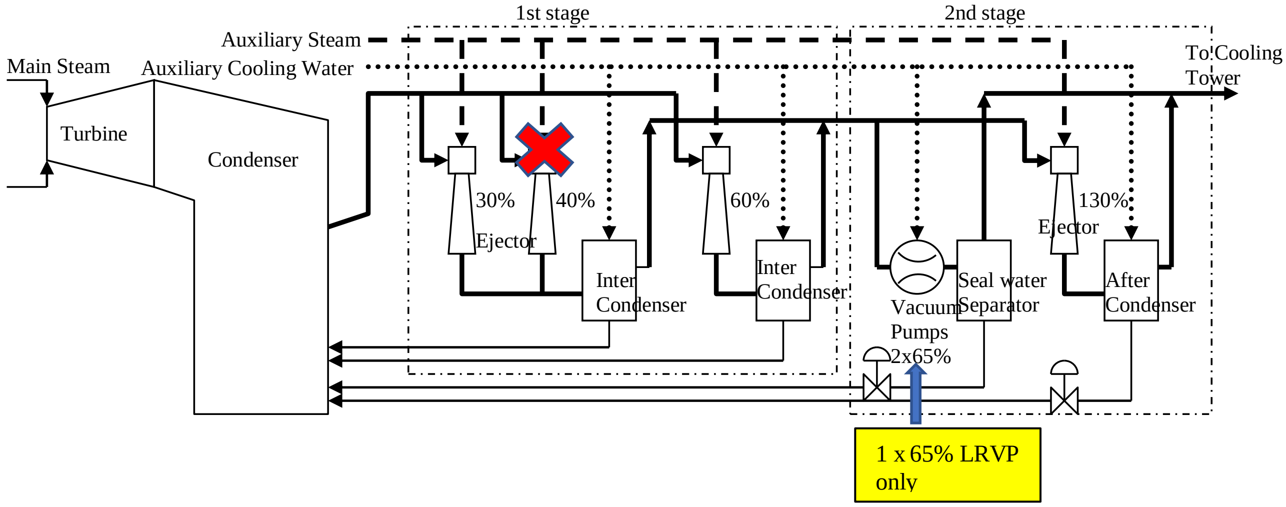


**Figure 12: Gas Removal System optimization**

**Figure 13: Solar powered street lighting**

## 3. CONCLUSION

Patuha Geothermal Field successfully optimizing electricity generation by comprehensive approaches start from upstream process which is steam supply sustainability by idle well utilization and wellbore scale removal programs, and continue to downstream process by minimizing bottleneck at powerplant facilities mainly main cooling water system, minimizing electricity own use, and finally implementing modern maintenance strategy mixed of preventive and predictive maintenance technology.

## 4. RECOMMENDATION

Collaboration with academician, researcher, and similar industries to get new idea for further optimization of electricity generation.

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