Badak LNG
A World Class Energy Company

MEMORANDUM

To : Production Vice President
From : Technical Senior Manager

No. 272/BP30/2015-935
Bontang, 22 May 2015

Subject : **2015 INTERNAL ENERGY AUDIT REPORT – BADAK LNG**

Please find attached the 2015 Internal Energy Audit Report – Badak LNG. Five potential opportunities for improvement have been identified in this internal audit, consists of 2 items in Boilers, 1 item in steam distribution system and 2 items in electricity.

Thank you and regards,

Ibnu Milan Prajoga
Act. Technical Senior Manager

CC:

1) Business Support Vice President
2) SHE-Q Senior Manager
3) Operation Senior Manager
4) Maintenance Senior Manager
5) Prod. Planning & Energy Conservation Manager
6) Process & SHE Engineering Manager
7) Facilities & Project Engineering Manager
8) Inspection Manager

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2015 INTERNAL ENERGY AUDIT REPORT - BADAK LNG

1. EXECUTIVE SUMMARY

Badak LNG commits to perform continuously energy management system in order to sustain efficient Plant performance through systematic, measurable, applicable and realistic energy conservation programs. To materialize the commitment, Badak LNG established several plant energy assessments since 2009, assisted by Performance Improvement (PI) in 2009 and Himpunan Ahli Konservasi Energi (HAKE) in 2013. In addition, annual energy audit/review is performed by internal Badak LNG to ensure all programs can be conducted as planned.

Five potential opportunities for improvement have been identified in this internal audit, consists of 2 items in Boilers, 1 item in steam distribution system and 2 item in electricity. Those programs potentially can improve 99.7 GJoule of fuel saving annually.

2. CONCLUSIONS & RECOMMENDATIONS

2.1. Year 2015 Internal audit has been completed at Badak LNG Boilers, steam trap as well as electricity consumption in offices and community (employee housing).

2.2. Refer to evaluation; it is observed that most of the time the O2 excess of observed Boilers is higher than the design value which indicates to lower Boilers' efficiency. By improving Boilers operation and monitoring system through increasing operators' awareness in Boiler operation and adding O2 excess profile in MCR (Main Control Room), it is expected that 0.5% of O2 excess reduction can be achieved. This approximately corresponds to 2.1 GJoule/year of fuel reduction or $1.2 million of annual saving.

2.3. It is also observed that the actual flue gas temperature of Boilers is significantly higher, between 20 - 30°C, than the design figures. Improvements should be addressed to Economizers, either is tube's external cleaning or replacing the economizers' tubes. The external tube cleaning is expected to improve flue gas temperature by 5°C lower than current figures. It equals to approximately 3.5 GJoule/year of fuel reduction or $2 million of annual saving.

2.4. According to Stream Trap Survey held in 2013, a total of 339 out of 1,405 steam traps are failed and should be repaired or replaced. The significant energy loss contributes from 69 pieces of failed High Pressure (HP) steam traps (excluding at Trains A/B). By combination of HP stream trap repair and replacement, an amount of 28,037 tons per annum of HP steam loss can be reduced and contributes to approximately $0.84 million of annual fuel saving.

2.5. Potential saving from electricity are from water heater replacement at PC-3A/3B housing with smaller capacity and modification of the electrical distribution panel & lighting controllers at PSF area. The electricity power reduction is estimated around 409 MWH/year or $0.38 million of annual saving.

3. SCOPE OF WORKS

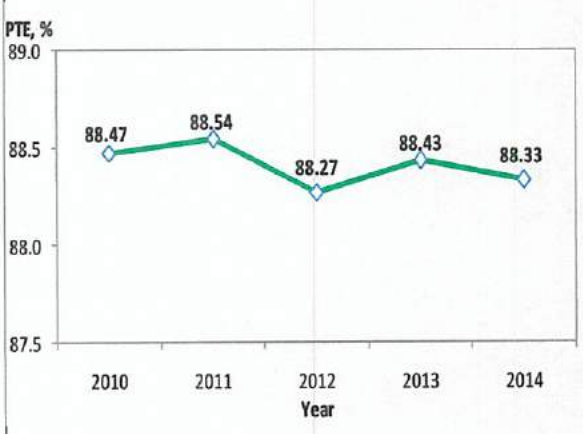
The audit is focused on excess combustion air and flue gas temperature of Boilers, steam trap of High Pressure steam as well as electricity consumption of Badak LNG offices building and community (employee housing).

Audit was conducted by internal Badak LNG team, as follow:

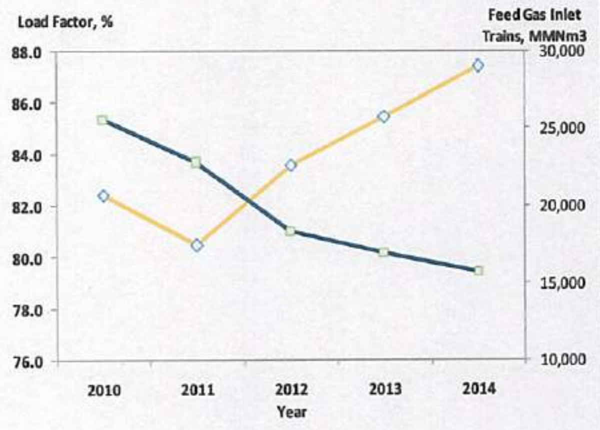
- Rizqy Fajar Arifianto (Certified Energy Auditor)
- Fany Arfianto
- Norvan Hery Kusnandar
- Ertanto Vetra
- Fauzan Fitra
- Bambang Irawan
- Yoga Dwi Utomo

4. BADAK LNG PLANT ENERGY PERFORMANCE

Feed gas delivered to Badak LNG tends to decline and impacts to Plant energy performance. Number of Trains in service has to be aligned in accordance to provide high Plant load factor which contributes to maintain high Plant Thermal Efficiency (PTE) at lower feed gas rate. See profile of PTE, feed gas delivered and Plant load factor in following figures. Refer to the figures, it is concluded that by improving Trains load factor, PTE can be maintained even at lower feed gas rate.



Plant Thermal Efficiency (PTE)



Feed Gas Delivered and Plant Load Factor

Figure 1. Trendings of Badak LNG PTE, Load Factor and Feed Gas Delivery

Feed gas received by Badak LNG Trains are processed to produce LNG, LPG (C3 & C4) and hydrocarbon condensate (C_5^+) as known as BRC (Badak Return Condensate). Some feed gas is also utilized as Boiler fuel. The remaining is loss in entire Plant system, such as Process flare, Marine flare, LPG boil off gas flare and gas venting. To maintain high Plant Thermal Efficiency (PTE), therefore fuel gas and losses must be managed in low regime.

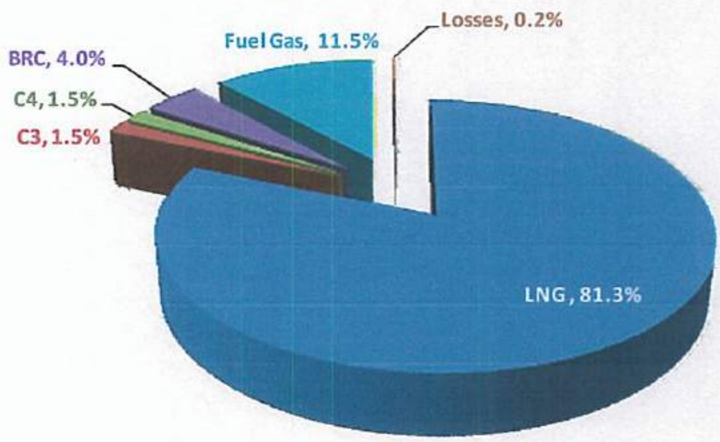


Figure 2. Badak LNG Energy Distributions

The trending of fuel consumption and loss are shown in the following graphs (in % of energy distribution). It is observed that loss tends to decrease, however the fuel consumption has tendency to be higher. In Badak LNG system, most of fuel is used for steam generation system (Boilers) with small portion for gas turbine generator (31PG-15).

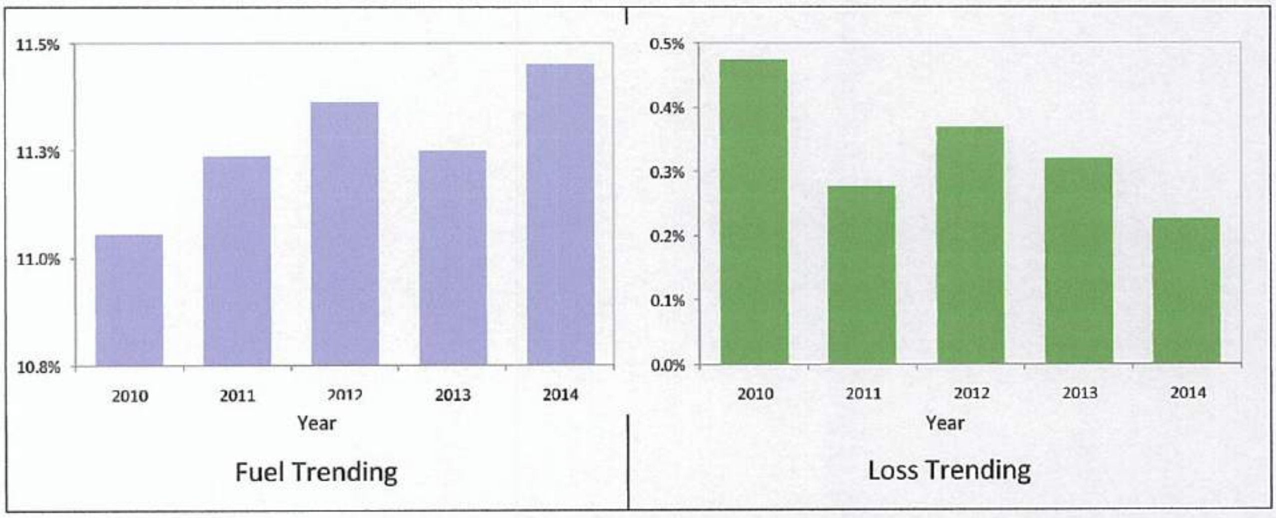


Figure 3. Trending of Fuel Consumption and Plant Losses

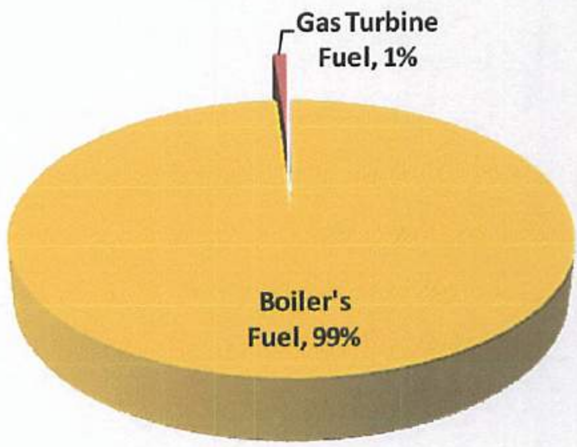


Figure 4. Badak LNG Fuel Distributions

5. AUDIT ENERGY

5.1. Boilers (Steam Generation)

According to ASME PTC 4-2008, Badak LNG uses indirect method for evaluating boiler efficiency which is calculated from:

Efficiency = [1 – (Losses – Credits)}/Input] x 100

- Input: the total chemical energy available from the fuel. Input is based on the higher heating value.
- Losses: the energy that exits the steam generator envelope other than the energy in the output stream(s).
- Credits: energy entering the steam generator envelope other than the chemical energy in the as-fired fuel. In Badak LNG's Boiler, this value is zero.

The energy from fuel is distributed to be Boiler efficiency and losses at typical respective figures of 84% and 16%. The energy losses components with typical figures are tabulated in following table and chart:

Table 1. Losses Components in Operating Boiler

No.	Boiler Loss	Loss Figure	Respective Operating Parameters
1.	Dry Gas	4.4%	O2 Excess
2.	Moisture in air	0.1%	Flue Gas Temperature
3.	Moisture combustion	10.8%	Fuel Gas Composition/Heating Value
4.	Radiation	0.4%	Fuel Gas Flow

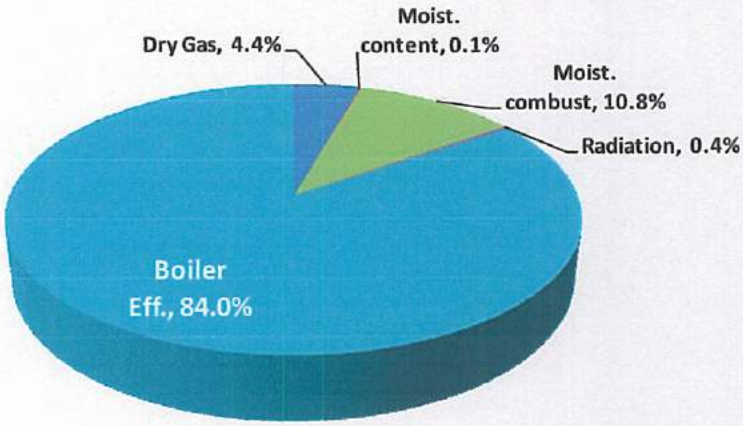


Figure 5. Boilers Energy Distributions

Refer to above, Dry Gas and Moisture Combustion losses share the biggest portion of Boiler losses. Taking into consideration that fuel gas composition is dictated by overall plant fuel gas balance and fuel gas flow is related directly to combustion/steam production rate, therefore this report focuses to the Boiler operating variables that can be technically manipulated, those are O_2 excess and flue gas temperature factors. See simplified correlation among loss parameters and Boiler operating variables in following figure.

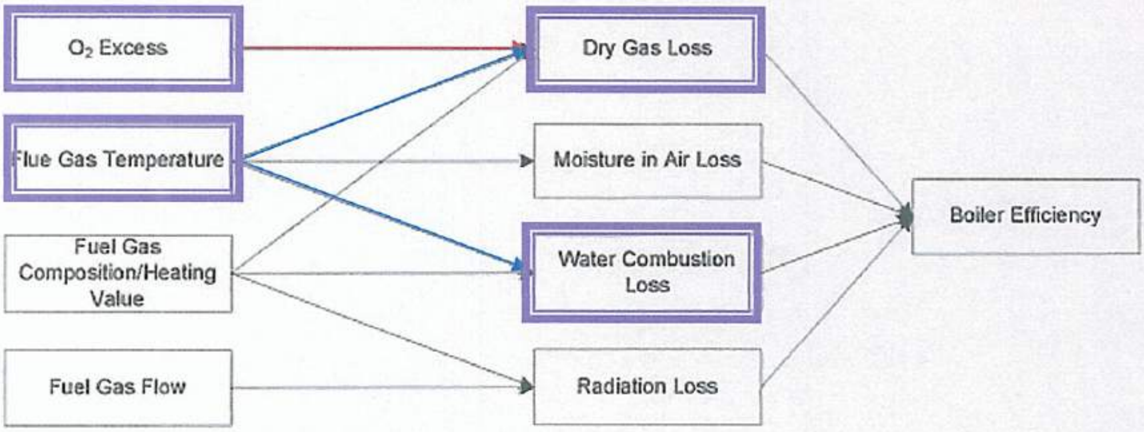


Figure 6. Correlation of Boilers Loss and Operating Variables

A. O_2 Excess

Following are the graphs showing the O_2 excess in flue gas of several Boilers, both the actual and design.

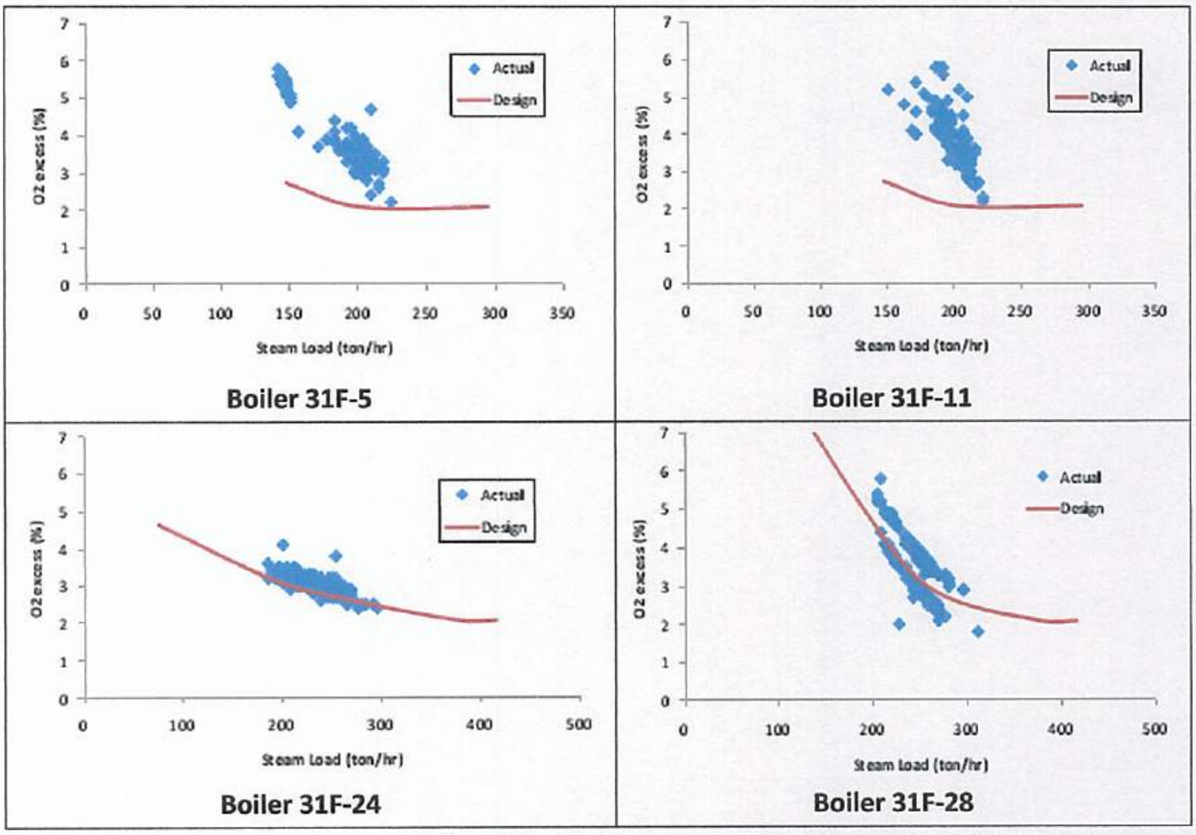


Figure 7. Comparison of O_2 Excess in Flue Gas Boilers, Actual and Design

According to above figures, it is observed that most of the time the O2 excess is still higher than the design value which later translates to lower efficiency.

Refer to evaluation; it is observed that most of the time the O2 excess of observed Boilers is higher than the design value which indicates to lower Boilers' efficiency. By improving Boilers operation and monitoring system through increasing operators' awareness in Boiler operation and adding O2 excess profile in MCR (Main Control Room), it is expected that 0.5% of O2 excess reduction can be achieved. This approximately corresponds to 2.1 GJoule/year of fuel reduction or $1.2 million of annual saving.

See detail evaluation in P&SHEE memorandum no. 065/BP31/2015-122 entitled "Study for Boiler Energy Efficiency Improvement Program" dated on 16 April 2015.

B. Flue Gas Temperature

Following are the graphs showing comparison of stack temperature of several Boilers, both actual and design.

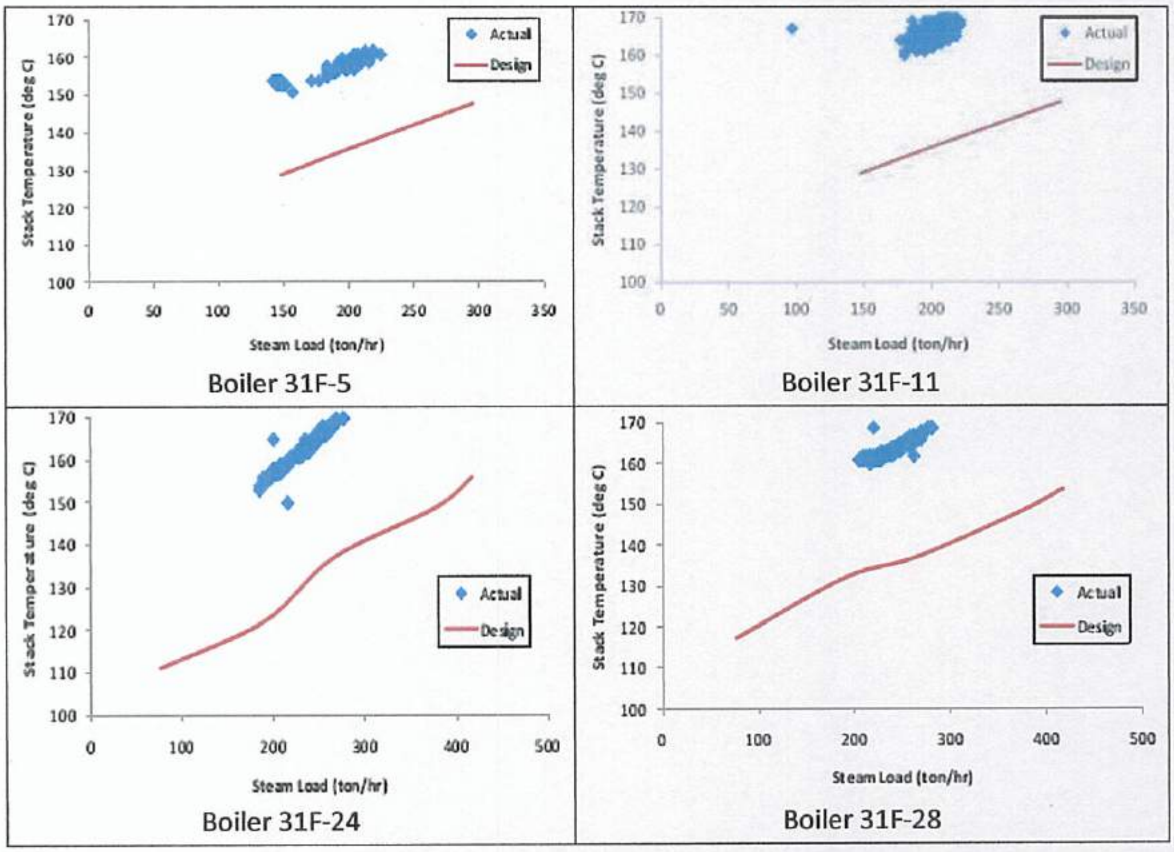


Figure 8. Comparison of Stack Temperature of Boilers, Actual and Design

It is also observed that the actual flue gas temperature of Boilers is significantly higher, between 20 - 30°C, than the design figures. Improvements should be addressed to Economizers, either by conducting tube's external cleaning or replacing the economizers' tubes. The external tube cleaning is expected to improve flue gas temperature by 5°C lower than current figures. It equals to approximately 3.5 GJoule/year of fuel reduction or $2 million of annual saving.

See detail evaluation in P&SHEE memorandum no. 065/BP31/2015-122 entitled "Study for Boiler Energy Efficiency Improvement Program" dated on 16 April 2015.

5.2. Steam Trap

According to Steam Trap Survey held in 2013, the failed steam traps are tabulated in following table:

Table 2. Result of Steam Trap Survey in 2013

Steam Pressure	Total Est.Steam Loss (Kg/Hour)	Number of Failed Steam Traps
Low Pressure (3.5 kg/cm^2)	1,047.29	104
Medium-Low Pressure (10.3 kg/cm^2)	511.81	38
Medium Pressure (17.2 kg/cm^2)	1,829.31	119
High Pressure (58.6 kg/cm^2)	3,688.15	78
Grand Total	**7,076.56**	**339**

Steam loss distribution can be plotted in following figure, which can be concluded that High Pressure (HP) steam loss contributes more than a half of total steam loss caused by steam trap failure. In addition, considering that HP steam contains the highest energy, therefore repair/replacement program for failed steam traps in HP steam system should be prioritized.

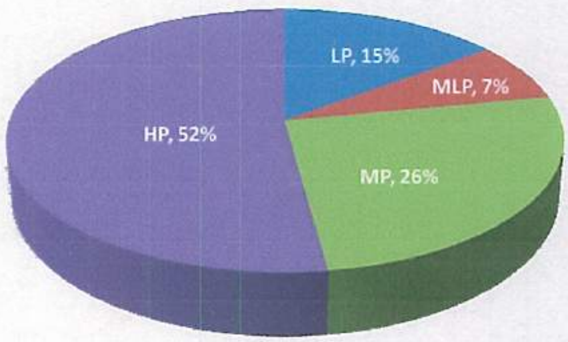


Figure 9. Distribution of Steam Loss from Failed Steam Traps

Taking into account that Trains A/B are under long term idle (LTI) and extended short term idle (ESTI), therefore High Pressure (HP) steam trap broken are corrected from 78 to 69 ea, which corresponds to 3,2 tons/hour of HP steam loss or 92.58 GJoule per year of energy saving. Based on $30/ton of HP steam generation cost, therefore recondition (repair/replacement) of 69 of HP steam traps will potentially save $0.841 million annually.

5.3. Electricity in Offices Building

5.3.1 Existing Condition

A survey on electrical power consumption has been conducted for all areas in Badak LNG. It includes power consumption profile during daytime and night-time (see **Figure 10** and **Figure 11**).

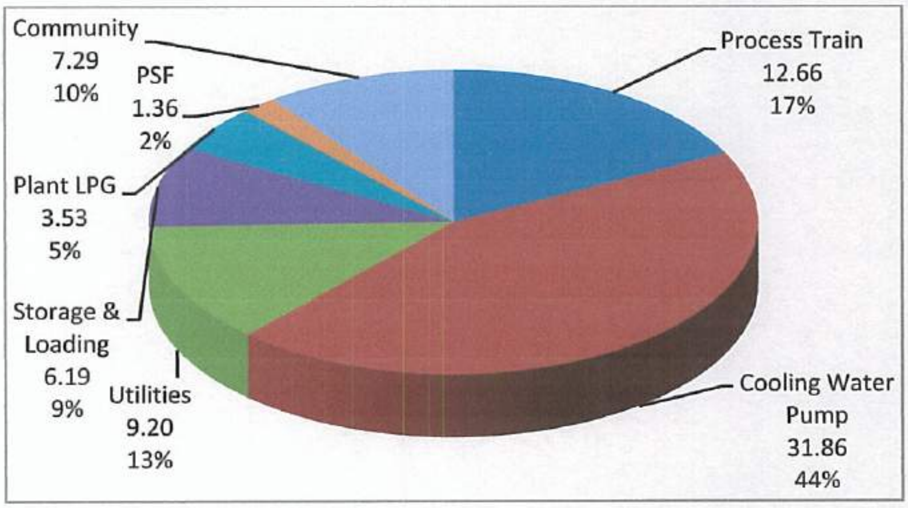


Figure 10. Power consumption distribution during daytime (in MW; %)

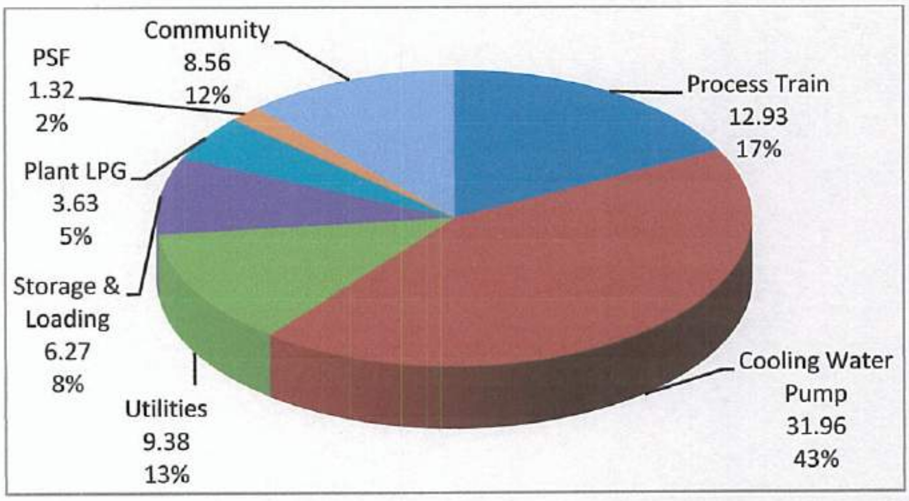


Figure 11. Power consumption distribution during night-time (in MW; %)

Refer to the load profiles above, CWP motors, Process Trains and Utilities area still become the major consumers of electric power. The loads for those areas are dominated by motors (pump and compressor drivers). Considering the characteristic of process handled by those motors which does not need variable speed, the use of *variable speed drive* to make the power consumption more efficient is not applicable. On the other side, most of plant area has implemented photocell to automatically turn on-off the lighting. Therefore, the **focus of this audit will be at Community and PSF area.**

5.3.2 Community Area

There is opportunity for power efficiency without reducing the resident comfort i.e. by replacing the water heater at PC-3A and PC-3B housing from water heater with capacity of 80 USG (300 Litre) to capacity of 40 USG (150 Litre); same type as found at PC 3 housing. This change is still possible to be done considering the number of occupant at PC3A/B house is similar with PC 3. If the replacement water heater could be done, in the end we will save around 409,530 kWH/year or $40,530 of annual saving.

Power Saving Potential per unit	5,500 Watt
Quantity of PC-3A and PC-3B	17 units (excluding house utilized as Apartment)
Energy Saving Potential per Year	**409,530 kWH***

*Utilization factor 50% per day (12 hours)

5.3.3 PSF Area

Power consumption at PSF during daytime is bigger that night; 1.36 MW versus 1.32 MW. However base on site survey at night, many lights are still ON even though there is no activity in the building. It means, there is possibility to make power efficiency at PSF area, specifically in lighting operation. The current operating mode of lighting at TOP, maintenance office area, maintenance workshop, and warehouse is **24 HOURS ON**. There is a possibility for energy saving at PSF Areas. The proposed design of new lighting system for each area is different, depend on the activities characteristic of each area.

❖ **TOP Building and Maintenance Office Area**

The proposed new lighting system at TOP building and maintenance office area, as follows:

- The lights are automatically ON at 06.00 AM – 06.00 PM.
- If someone is working overtime (06.00 PM – 06.00 AM), the lights must automatically turned ON.

To run the lighting scheme, some technologies should be used: Vacancy sensor using dual technology, Occupancy sensor using dual technology or Programmable Logic Controller (PLC).

❖ **Maintenance Workshop**

The proposed lighting operation modes for Maintenance Workshops area are as follows:

- The high bay lights are automatically turned ON/OFF.
- Number of high bay lights which are ON at daytime is less than at existing condition.

To run the lighting scheme, it utilizes: Vacancy sensor using dual technology or Programmable Logic Controller (PLC).

❖ **Warehouse**

There is a possibility for energy saving at Warehouse area by using proposed operating mode of high bay lights as follows:

- The high bay lights are automatically turned ON/OFF.
- Number of high bay lights which are ON at daytime is less than at existing condition.
- For outdoor area, such as lay down "J" area, the high bay lights are OFF in sunny day using photocell.

To run the new lighting system design at Warehouse, some technologies should be installed in these building like Vacancy sensor using dual technology, Programmable Logic Controller (PLC) or Photocell.

Current energy consumption and potential energy saving by implemented new lighting system above can be seen in table below.

Table 3. Potential Saving of Electrical Consumption in Plant Support Facilities

No.	Plant Support Facilities	Total Energy Consumption for Lighting per Year (kWH)		Potential Energy Reduced per Year (kWH)
		Current Condition	Proposed New Lighting System	
1	Office area	3,161,703	1,580,851	1,580,852
2	Maintenance Workshop	1,783,536	934,608	848,928
3	Warehouse	1,582,056	607,686	974,370
Total Energy (kWH)		**6,527,295**	**3,123,145**	**3,404,150**

By using the new lighting system, the energy consumption of PSF area can be reduced up to 3,404,150 kWH/Year or approximately $340,415 of annual saving.

Prepared by

Fany Arfianto
Rizqy Fajar Arifianto
Ertanto Vetra
Fauzan Fitra
Bambang Irawan
Yoga Dwi Utomo