Document Title: **EXECUTIVE SUMMARY**
ENERGY ASSESSMENT / AUDIT
FOR OFFSHORE - KAKAP FIELD

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EXECUTIVE SUMMARY

The energy audit was started on end of January 2015 which walkthrough survey, and continue for inspection, test and measurement till May end 2015. The draft report was issued on early June 2015 and the final report hopefully will be finalized on early July 2015.

System which included in the energy audit are: Gas Process system, Oil process system, water cooling & RO water system, electrical system, HVAC system and Lighting system. Equipment which included in the energy audit are: Gas Turbine and Gas Engine Generator, Gas Turbine and Gas Engine Compressor, Motor Control Center (MCC), Pumps, Electrical Motors, Gas Engine Generator & Compressor, Boiler, Heating Ventilation Air Conditioner (HVAC), Lighting, Air Compressor.

The methodology of the inspection, test and measurement is use special methods such as: combustion analysis, heat analysis/infrared thermography, power quality analysis, vibration, discharge loss, suction loss, liquid flow measurement, air flow measurement, refrigerant COP analysis, lux/lumen analysis, etc. Especially on KF platform, we doing simulate gas process to get optimize process can taken to process good performance.

Equipment under tests and assess including generators, gas compressor, boiler, pumps and their MCC, air compressor, coolers, lighting, and HVAC. Visual check, power quality analysis, Thermography, Vibration and Input output gap analysis are some of our methods to know exactly efficiency of each equipment and their contribution to total energy consumption.

At the end of our tasks, we issue final report containing our data during preliminary survey, document review, visual inspection, test and measurement. In some way, writing this report is an expression of our responsibility to inform you the technical conclusion and analysis based on actual condition as well as recommendation for improvement. Within this report, we also give some basic maintenance and procedure with an example how to measure and tests of main energy user equipment.

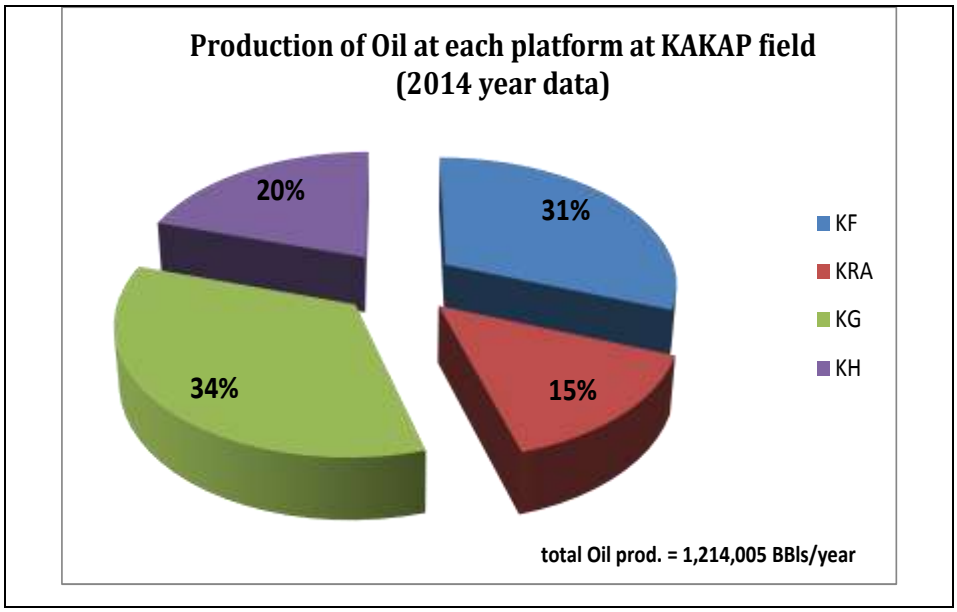
- **Production & Energy Overview of KAKAP Field**

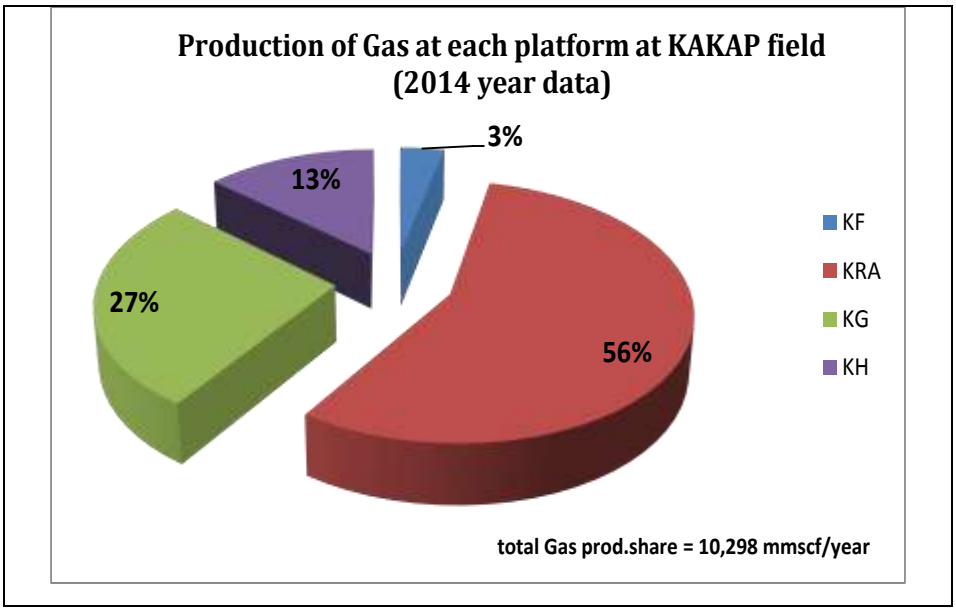
On 2014 year, production capacity of KAKAP field (LTD.) reach of average daily is 3,316 bopd crude oil and 26.637 mmscfd of gas export. The highest Gas export is at 39.203 mscfd and the highest of Crude Oil production reach on 4,472 bopd. While minimum gas export is zero, and minimum Crude oil produce is 1,301 bopd.

Oil & Gas production of KAKAP Field (Ltd.) can summarizes as table below:

Production on KAKAP	OIL PRODUCE	GAS EXPORT
YEARLY		
Total 1 year (oil, barrel)	1,210,177	
(gas, mmscfd)		9,723
DAILY		
Minimum (Oil, bopd)	1,301	
(gas, mmscfd)		-
Maximum (Oil, bopd)	4,472	
(gas, mmscfd)		39,203
Average (Oil, bopd)	3,316	
(gas, mmscfd)		26,637

Oil & gas yearly production on each platform can seen on graphs below:

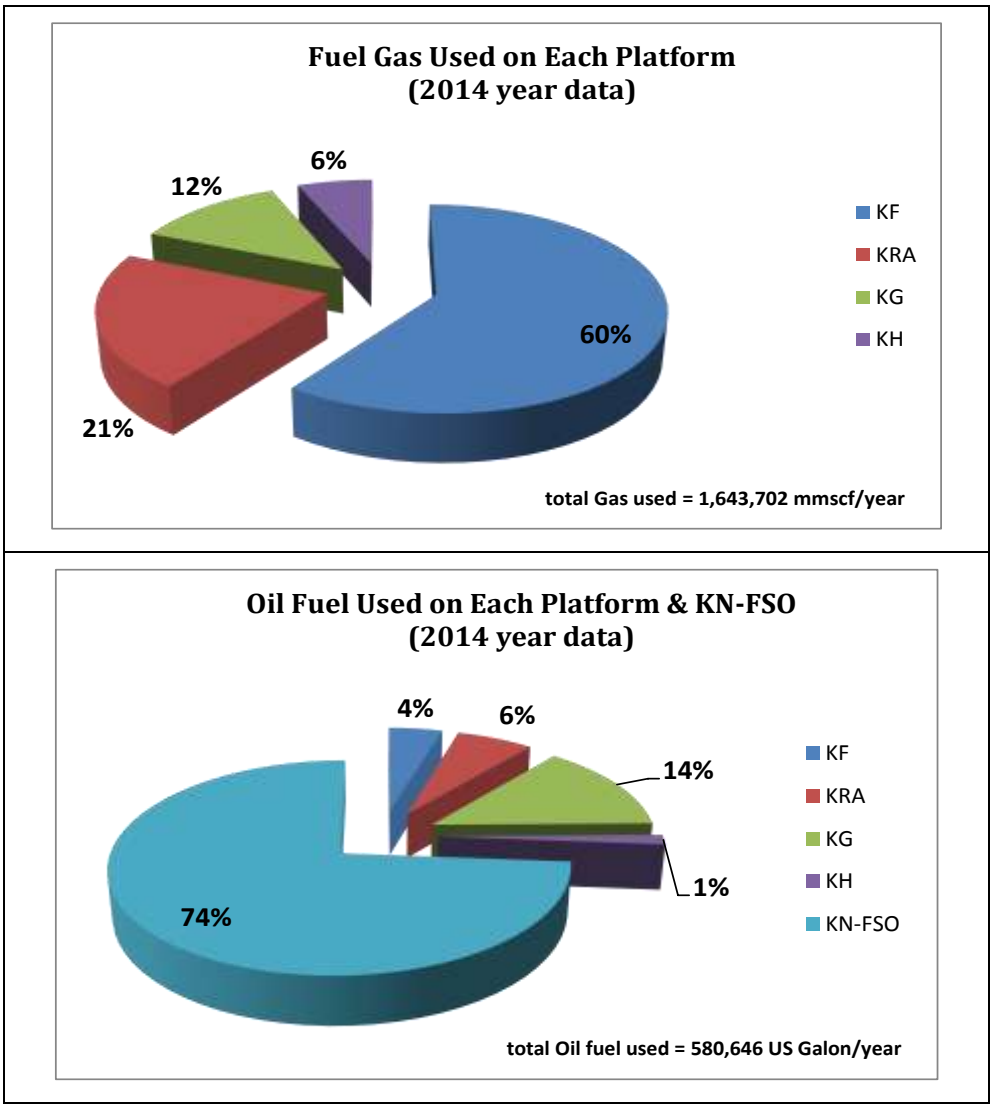




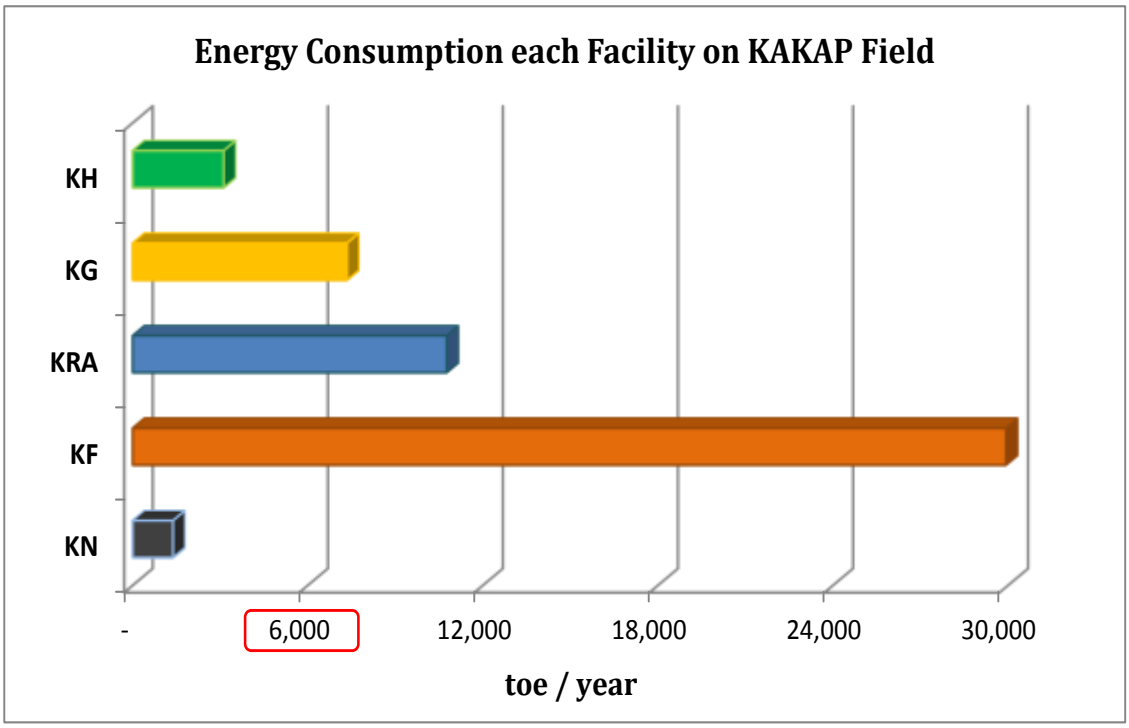
Energy source at KAKAP Field (LTD.) consist of type: fuel gas and fuel oil (HSD and MFO type). Fuel gas obtained from won used of gas producing on each field/platform, while fuel oil is backup energy at platform, but it is primary sources energy for KN-FSO activity. Totaly, energy used (gas and oil fuel) at KAKAP Field (LTD.) can brief as table below:

Energy Used on KAKAP	FUEL GAS USED		DIESEL OIL Used	
YEARLY				
Total 1 Year	mscf	mmbtu	Gallons	mmbtu
Fuel Gas	1,643,702	1,976,653		
Diesel Oil			580,321	55,812
DAILY				
Minimum (Fuel Gas)	1,528	1,838		
(Diesel Oil)			558	65
Maximum (Fuel gas)	5,313	6,400		
(Diesel Oil)			12,574	1,511
Average (Fuel Oil)	4,503	5,415		
(Diesel Oil)			1,590	153

Energy yearly consumption on each platform can seen on graphs below:



Government of Indonesia (GoI) have regulation about Energy ie.: PP No.70/2009 that regulate about energy management implementation which implemented to the industry where have energy consumption above 6000 toe (tonne oil equivalent)per year. So, platform and KN-FSO facilities can brief energy consumption with limitation of 6000 toe/year can see on figure below:



From figure above, platform which have meet energy > 6000 toe/year are: KF, KRA and KG platform, where these facility must implemented Energy Management as requirement GoI Regulation No. PP/70/2009.

♦ **Energy Performance Indicator's (EnPI's)**

Energy Performance Indicator (EnPI) that will review is:

- Driver of Energy Consumption
- Baseline & Baseload of Energy
- Specific Energy Consumption (SEC)

a. Driver

Energy consumption driver for each facility at KAKAP field (LTD.) can descibe on table below:

No	FACILITY	Energy Consumption Factor (Driver)
1	KF p/f	Driver : Gas export to WNTS and Net-Crude Oil ship to KN Energy used : Fuel Gas and Gas lift
2	KRA p/f	Driver : Gas export to KF and Gross-Crude Oil ship to KF Energy used : Fuel Gas and Gas lift

3	KG p/f	Driver : Gas export to KF and Gross-Crude Oil ship to KN Energy used : Fuel Gas, Gas lift and Flare
4	KH p/f	Driver : Gas export to KF and Gross-Crude Oil ship to KN Energy used : Fuel Gas, Gas lift and Flare
5	KN-FSO	Driver : Oil Lifting (During lift period) Energy used : Total Diesel Oil Consumption

b. Baseline & Baseload of Energy Used

Baseline & Baseload formula for each paltform and KN-FSO can see on describe below:

1. KF platform

Energy Used = 4.158 x O&G export (boepd) + 2576.7 ..... [mscfd]

Where,

Fuel Gas used = Energy used – (Gas Lift + Flare) .....[mscfd]

Note: 1 mscfd equivalent energy with 1200 mbtu
1 mmbtu equivalent with 1.055 GJ

Baseline parameter is : 4.158 x export of Oil & Gas ; and
Baseload is : 2576.7 mscfd.

2. KRA platform

Total Energy Used = 0.1627 x O&G export (boepd) + 1099.5 ..... [mscfd]

Where,

Fuel Gas used = Total Energy used – (Gas Lift) ..... [mscfd]

Note: 1 mscfd equivalent energy with 1200 mbtu
1 mmbtu equivalent with 1.055 GJ

Baseline parameter is : 0.1627 x export of Oil & Gas ;and
Baseload is : 1099.5 mscfd.

3. KG platform

Total Energy Used = 1.0195 x O&G export (boepd) + 132.84 ..... [mscfd]

Where,

Fuel Gas used = Total Energy used – (Gas Lift + Flare) ..... [mscfd]

Note: 1 mscfd equivalent energy with 1200 mbtu
1 mmbtu equivalent with 1.055 GJ

Baseline parameter is : 1.1095 x export of Oil & Gas ; and

Baseload is : 132.84 mscfd.

4. KH platform

Total Energy Used = 0.4243 x O&G export (boepd) + 117.63 ..... [mscfd]

Where,

Fuel Gas used = Total Energy used – (Gas Lift + Flare) ..... [mscfd]

Note: 1 mscfd equivalent energy with 1200 mbtu
1 mmbtu equivalent with 1.055 GJ

Baseline parameter is : 0.4243 x export of Oil & Gas ; and

Baseload is : 117.63 mscfd.

5. KN - FSO

Total Energy Used = 0.3365 x Vol. Oil Lifting + 3071 ..... [Liter Fuel Oil]

Where,

Fuel Oil (HSD & MFO) in Liters unit.

Baseline parameter is : 0.3365 x volume Oil Lifting ; and

Baseload is : 3071 Liter of HSD.

c. Specific Energy Used (SEC)

SEC at KAKAP Field (accumulated) can calculate as table below:

Energy used	2,032,464	mmbtu/y
Product Gas	9,723	mmscf/y *
	2,182,158	boe/y
Product Oil	1,210,177	bbls/y
Total O & G product	3,392,335	boe/y
SEC KAKAP field=	**599.13**	**mbtu/boe**

*) 1 mmscf Gas at KAKAP field eq.with 224.44 boe crude

SEC average for each platform and KN facilty at KAKAP Field can see on table below:

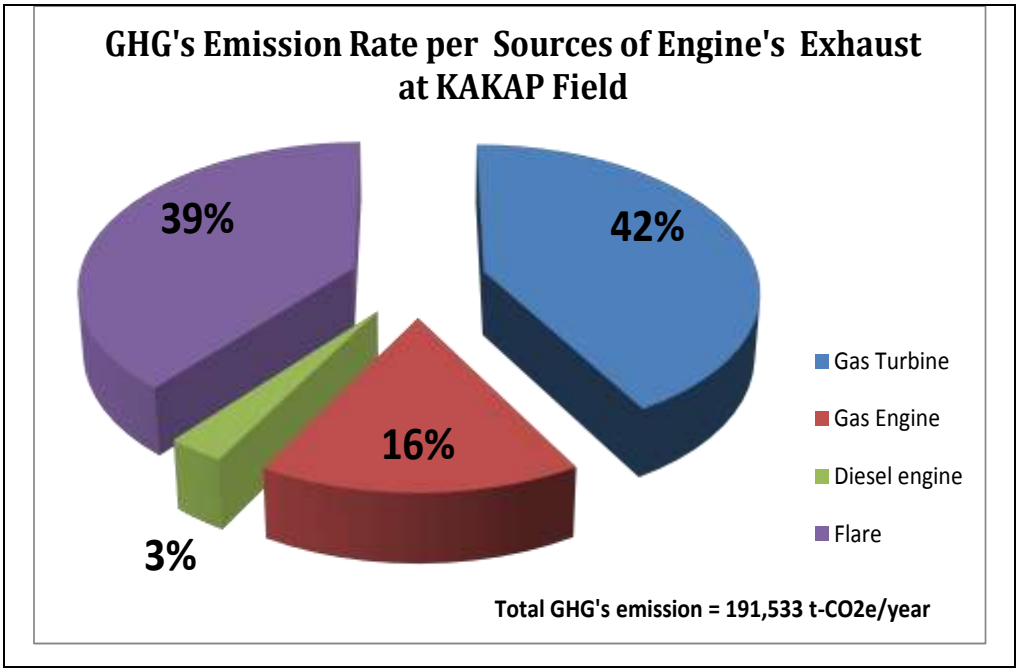
Facility	SEC (mbtu/boe)
KF	423.9
KRA	217.87

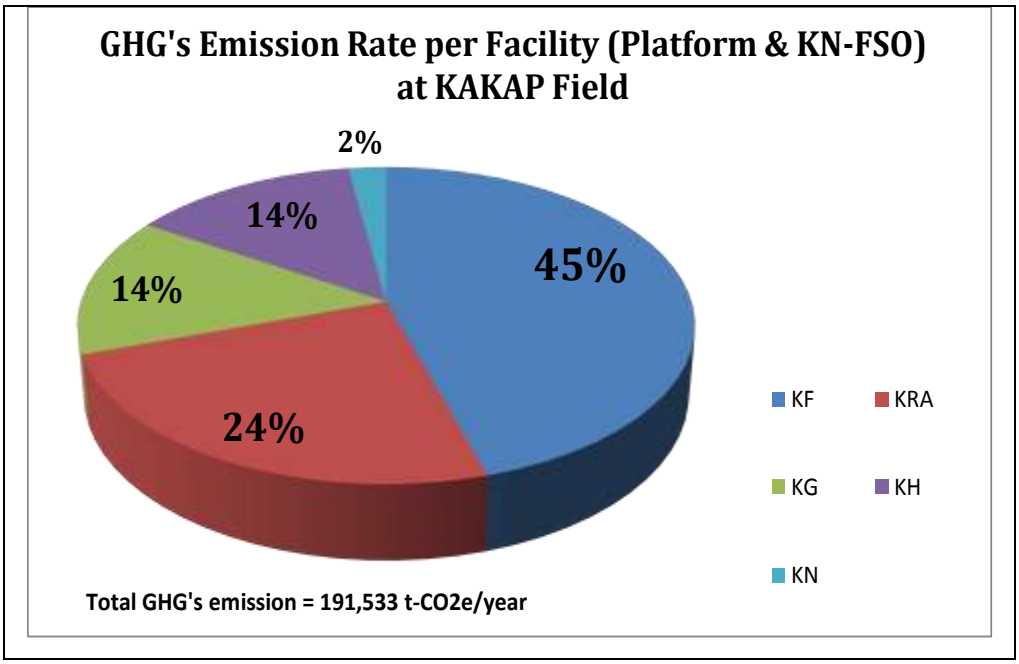
KG	201.89
KH	132.34
KN *	11.82

*) SEC of KN is only for storage/received & oil lifting activity (no Oil & Gas production)

- **Green House Gases (GHG's) at Kakap LTD Facilities**

Greenhouse Gases (GHGs) emission come from the combustion of primary energy source (gas & diesel oil) cause emission of exhaust gasses (CO_2) to atmosfer. The calculated of GHGs of Kakap LTD have been calculated around **191,533 t-CO_2e per year**. Here the GHG's profile on each sources of engine and paltform/KN shared at KAKAP Field:





♦ **Energy Saving Opportunities**

As the final output of the energy audit activities, energy saving opportunities which can derived from the measurement and analysis each system & equipment at each platform and KN can be described as table below:

a. KF platform

Description	Saving Opportunities		Estimate of Investation	Estimate Periode of Implemented
	Energy	Cost		
1. Electro motor of P-101 A/B operate at 60% load, but work of pump only 15% of design, so it good to install Variable speed driver (VSD) on electric Motor	933,319 kWh per year	IDR. 1,866,637,000 per year	IDR. 2,250,000,000 **Saving Category: Low Cost**	1 -2 year
2. HVAC (Chiller) performance COP now is very closed to minimum of standart, it chalange to replace with modern chiller to get maximum COP so can reduce electricity used.	586,631 kWh-electric per year (2 unit Chiller)	IDR. 1,173,261,840 per year	IDR. 1,200,000,000 **Saving Category: Low Cost**	1 – 2 year
3. Majority of Lamp at KF platform still using TL/CFL type, and it opportunity to replace with LED type to reduce energy (electric) consumption.	74,679 kWh-electric per year	IDR. 149,358,000 per year	IDR. 102,300,000 **Saving Category: Low Cost**	< 1 year

4. Replace Electric heater at LQ with utilize energy of Hot Oil Thermal system.	132,942 kWh-electric per year	IDR. 265,883,520 per year	IDR. 700,000,000 **Saving Category: Low Cost**	1 - 2 year
Total Saving	**Energy Saving**	**Cost Saving**	**Invest estimate**	**Implemetation planning**
	1,727,571 kWh-electric per year or eq.with **35,614 mmbtu of fuel gas** per year	**IDR. 3,455,240,360** per year	**IDR. 4,252,300,000**	1 - 2 year period

b. KRA platform

Description	**Saving Opportunities**		**Estimate of Investation**	**Estimate Periode of Implemented**
	Energy	**Cost**		
1. There is problem on gas compression GT Compressor Centaur CAS-3600 due to HPC scution get debris (problem on 3rd stage compressor), so make worse eficiency of GTC.	57320.39 mmbtu per year	IDR. 5,502,757,000 per year	IDR. 10 – 20 billion **Saving Category: Medium Cost**	2 year (maximal)
2. There is still no-optimal air combustion of GLC engine (%O2 at stack at low 0.2%, so need to setting air fuel ratio of combustion (trimming control), so %O2 at stack near 3% - 4%.	8774.57 mmbtu per year	IDR. 842,359,000 per year	0 **Saving Category: No Cost**	1 year (maximal)
3. There is still cooling losses at Generator slightly higher than reference (design is 30%, and actual is 37%), so it have opprtunity to make better eficiency.	4011.50 mmbtu per year	IDR. 385,103,500 per year	IDR. 20 – 30 Million **Saving Category: Low Cost**	1 year (maximal)
4. HVAC (Chiller) performance No. 1 have COP lower than No. 2, caused by air flowrate of condenser (radiator) worse than No. 2. Maybe rpm of fan motor No. 1 Chiler have de-rating or dusting. Need to repair fan motor and cleaning schedule.	50519.50 kWh-electric per year	IDR. 60,623,000 per year	IDR. 40 – 50 Million **Saving Category: Low Cost**	1 year (maximal)
Total Saving	**Energy Saving**	**Cost Saving**	**Invest estimate**	**Implemetation planning**
	70,702 mmbtu of fuel gas per year	**IDR. 6,790,844,500** per year	**IDR. 10,060,000,000** up to **20,080,000,000**	1 - 2 year period

c. KG platform

Description	Saving Opportunities		Estimate of Investation	Estimate Periode of Implemented
	Energy	Cost		
1. There is still no-optimal air combustion of GLC engine (%O2 at stack is high 8.9%, so need to setting air fuel ratio of combustion (trimming control), so %O2 at stack near 3% - 4%.	1991.09 mmbtu per year	IDR. 191,144,400 per year	0 **Saving Category: No Cost**	1 year (maximal)
2. There is still cooling losses at Generator is higher than reference (design is 30%, and actual is 42%), so it have opprtunity to make better eficiency with better cooling system.	2208.91 mmbtu per year	IDR. 212,054,900 per year	IDR. 50 – 100 Million **Saving Category: Low Cost**	1 year (maximal)
3. Result performance evaluate of HVAC (Chiller) of KG very closed at minimum COP (value 2.71 with reference minimum is 2.7) and phisicaly the unit of Chiller was old-machine (de-rating eficient), so with replaced new one can save energy & cost operation.	46219.16 kWh-electric per year	IDR. 55,463,000 per year	IDR. 200 Million **Saving Category: Medium Cost** (PBP 3.6 years)	2 year
Total Saving	**Energy Saving**	**Cost Saving**	**Invest estimate**	**Implemetation planning**
	4,736 mmbtu of fuel gas per year	**IDR. 458,662,300** per year	**IDR. 250,000,000 up to IDR. 300,000,000**	1 - 2 year period

d. KH platform

Description	Saving Opportunities		Estimate of Investation	Estimate Periode of Implemented
	Energy	Cost		
1. There is still cooling losses at Generator slightly higher than reference (design is 30%, and actual is 40%), so it have opprtunity to make better eficiency.	1688.92 mmbtu per year	IDR. 162,136,600 per year	IDR. 20 - 30 million **Saving Category: Low Cost**	1 year (maximal)
2. %Flare at KH platform is 8.8%. It higher than standart reference of "Permen ESDM No. 31/2012", where maximum value is 3%. Optimize flare	206,784 Mmbtu per year	IDR. 19,851,000,000 per year	IDR. 15 – 20 Billion **Saving Category:**	2 year

(reduction) is minimize GLC breakdown (shutdown) by best maintenance (PdM & PM) and install online engine monitoring, so avoid gas to flare.			**Medium Cost**	
Total Saving	**Energy Saving**	**Cost Saving**	**Invest estimate**	**Implemetation planning**
	208,472 **mmbtu** of fuel gas per year	**IDR. 20 billion** per year	**IDR. 15 billion up to IDR. 20 billion**	1 - 2 year period

e. KN facility

Description	**Saving Opportunities**		**Estimate of Investation**	**Estimate Periode of Implemented**
	Energy	**Cost**		
1. There is still non-optimal air combustion of Boiler (%O2 at stack still 8-10%, so need to setting air trimming control so %O2 at stack near 4%.	21264 Liter/year or 128435.98 mmbtu/year	Rp. 191,376,000 per year	- **Saving Category: No Cost**	1 year (maximal)
2. There are some pipe and flange/valve of steam distribution have leak (open), so energy can losses at this point of leakage (see chapter 4 at Boiler evaluation)	92,917 kWh/year or 19,6 ton steam per lifting	Rp. 96,300,000 per year	Rp. 200,000,000 **Saving Category: Low Cost**	1 year
3. Operation of Chiller at KN still manualy, but there is finding at survey no control of temp evaporator follow load of demand (AHU/ room temperatur)	105,120 kWh-electric/year	Rp. 409.900.000 per year	Rp. 1,000,000,000 **Saving Category: Medium Cost**	2 year
4. There is leakage at AHU of Chiller, so temperatur of air supply to room increase (energy losses)	121,472 kWh-electric/year	Rp. 473,740,800 per year	Rp. 500,000,000 **Saving Category: Low Cost**	1 year
5. There is leakage at steam pipe and turbine system of COP pump	68,253 kWh steam/ year or eq. with 11,57 ton per lifting	Rp. 67,502,000 per year	Rp. 150,000,000 **Saving Category: Medium Cost**	1 – 2 year
6. Majority of Lamp at KN still using TL/CFL type, and it oppoetunity to replace with LED type to reduce energy (electric) consumption.	48,320 kWh-electric/ year	Rp. 188,488,000 per year	Rp. 78,800,000 **Saving Category: Low Cost**	1 year
Total Saving	**Energy Saving**	**Cost Saving**	**Invest estimate**	**Implemetation**

				planning
	165,171 **Liters** of Oil Fuel per year or equivalent with **6,423 mmbtu** per year	**IDR. 1,427,306,800** per year	**IDR. 1,928,800,000**	1 - 2 year period

Note: *saving category refer to GoI Regulation of "Peraturan Menteri ESDM No. 14 tahun 2012".*

Totally, Energy & Cost saving oppertunities at KAKAP Field (LTD.) can describe as table below:

Description	mmbtu of Fuel Gas saving	mmbtu of Oil Fuel saving	Total energy saving mmbtu	Ton oil equivalen (toe) saving per year
Energy Saving Opportunities (annualy)	319,524	6,423	325,947	8,063
Cost Saving Opportunities (annualy)	**IDR. 30,674,304,000 per year** of Fuel Gas consumption (with refer price of gas is USD 8/mmbtu)		**IDR. 1,427,306,800 per year** of Fuel Oil (HSD & MFO) refer to HSD price = IDR. 12,000/liter anf MFO price = IDR. 8,000/liter	
	Total Cost Saving opportunity is **IDR. 32,101,610,800** per year			
Percentage energy saving	Total energy consumption at KAKAP Field = 52,517 toe/year Energy saving opportunity = 8,063 toe/ year % Energy can be saved opportunity = **15.35%**			

♦ Recommendation for Energy Used Reduction

As the result of audit energy, the recommendation can be implemented by KAKAP Field (LTD) to aim energy reduction target next periode can be listed below:

A.	KF Platform
1).	Instal variable speed driver (VSD) on electric motor for COS pump P-101 A/B, because pump operated too low of load (only 15% but motor operated still at 60% of load).
2).	Should replace HVAC (Chiller) for LQ at KF platform with modern /latest technology to get maximum COP so can reduce electricity consumptiuon (refer to low COP at assest).
3).	Should replace majority of lamp type at KF p/f with LED type technology lamp to reduce electric consumption on platform.
4).	Potential to replace electric heater at LQ with utilize energy of hot thermal oil system at KF platform.

B.	**KRA Platform**
1).	Repair of probem at HPC of Centaur Compressor immedietly becuase it the biggest potential to reduce energy (fuel gas) consumption on KRA platform (better eficiency GT Compressor can reduce fuel gas consumption at same load operate condition).
2).	Need to setting air fuel ratio of combustion (trimming control) at GLC CAS-2140 of KRA, so %O2 at stack near 3% - 4% and it can make engine operated at optimum eficiency condition (reduce fuel gas consumption).
3).	Need to cleaning programm at Gas Engine Generator cooling water pipeline of LAN-4470/ LAN-4480 (it maybe maybe have bad fouling on tubes of cooler so can reduce eficiency of engine)
4).	Need to repair fan motor and cleaning schedule for HVAC No.1 at KRA platform, so can make better eficiency of chiller
C.	**KG Platform**
1).	Need to setting air fuel ratio of combustion (trimming control) at GLC engine CAS-1640 of KG, so %O2 at stack near 3% - 4% and it can make engine operated at optimum eficiency condition (reduce fuel gas consumption).
2).	Need to cleaning programm at Gas Engine Generator cooling water pipeline of LAN-1510 (it maybe maybe have bad fouling on tubes of cooler so can reduce eficiency of engine)
3).	Should replace HVAC (Chiller) for LQ at KG platform with modern /latest technology to get maximum COP so can reduce electricity consumptiuon (refer to low COP and physicaly old machine during assest).
D.	**KH Platform**
1).	Need to cleaning programm at Gas Engine Generator cooling water pipeline of GX-130X of KH platform (it maybe maybe have bad fouling on tubes of cooler so can reduce eficiency of engine)
2).	Flare procentage at KH platform is 8.8% at now. It higher than standart reference of “Permen ESDM No. 31/2012”, where maximum value is 3%. So, need to optimize flare (reduction) with minimize GLC breakdown (shutdown) at operation by best maintenance (PdM & PM) and install online engine monitoring, so avoid gas to flare. Because flare at KH p/f caused from GLC shutdown, so gas should be alocated for injected to well and export to KF p/f will be flared.
E.	**KN-FSO**
1).	There is still non-optimal air combustion of Boiler (%O2 at stack still 8-10%, so need to setting air trimming control so %O2 at stack near 4%, so it can reduce fuel consumption during lifting period.
2).	There are some pipe and flange/valve of steam distribution have leak (open), so energy can losses at this point of leakage (see chapter 4 at Boiler evaluation of KN-FSO report). With repair it can reduce load of boiler so can reduce fuel consumption during lifting period.
3).	Operation of Chiller at KN still manualy, but there is finding at survey no control of temp

	evaporator follow load of demand (AHU/ room temperatur). With instal automatic load control of chiller and AHU can minimized energy losses at chiller so can reduce electric used.
4).	There is leakage at AHU of Chiller, so temperatur of air supply to room increase (energy losses). With repair of leakage at AHU can reduce load of compressor at chiller so can reduce electric used.
5).	There is leakage at steam pipe and turbine system of COP pump during operate. With repair leakage of steam pipe can reduce steam consumption for COP pump and can reduce load of boiler so fuel consumption can be minimized.
6).	Should replace majority of lamp type at KN-FSO with LED type technology lamp to reduce electric consumption on platform.

♦ **Energy Management System Review**

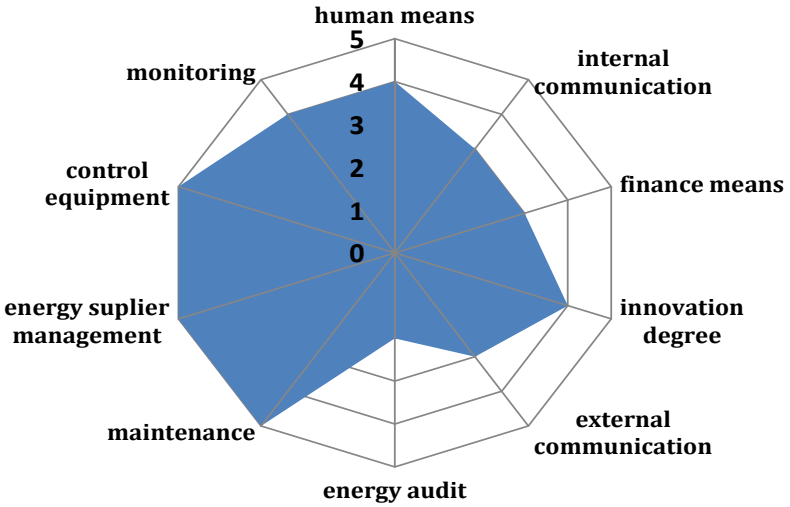
In order that the aims and objectives the goal of energy efficiency, the energy management system is necessary build at Kakap LTD field, considering the pattern of energy utilization without monitored generally always happens such as:

- Snob Effect, And;
- The pattern of engine operation will be derating

Snob effect is a phenomenon where a level / energy efficiency targets have been achieved then arises a sense of proud / arrogant and feel has been reached, so no need to pursue the target (program) energy efficiency.

Engine operation pattern, gradually (depending on the pattern of operation / loading equipment) will have the name derating / decrease in performance (performance), this will impact on energy consumption patterns will increase without output so that the efficiency of the equipment will down (energy consumption will lead waste to energy). To avoid that condition, it is necessary to develop a strategy that is get into the Energy Management System (EnMS). It is also an attempt to obtain an optimal achievement in the implementation of energy conservation.

Here, the result of Energy Management System (EnMS) based matrix ISO 50001 tools at KAKAP Field (LTD.) can explained at graph below:



From the pictures on a review of the energy management system, first impression is the company's commitment to energy management that the value is good enough, that is the human means with scale value is 4. It is seen that the strong of company Energy Star KAKAP Field in conducting energy management program is on the elements that have been very good (scale 5), such as: control equipment , energy supply management, and maintenance. While it is already quite good but needs to be improved, such as: commitment of funding for energy saving programs (finance means), energy audit program, internal communications and energy saving innovations.

By improving system energy metering and recording data and implemented energy saving opportunities have been recommended above, it can be made an analysis of the performance (KPI) each unit of energy centers (such as panels or MCC, main engines or equipmentys and electric distribution) and the end it optimize that KAKAP Field have better energy performace for next year.

Final Report in Jakarta in July 2015

Project Manager
PT TÜV SÜD Indonesia