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A STUDY ON THE ESTABLISHMENT AND IMPLEMENTATION OF CONSERVATION PROGRAM IN ARUN LNG PLANT

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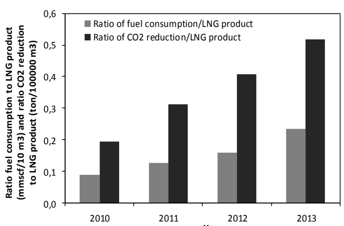
Graphical abstract



Abstract

Energy conservation is an important issue in all sectoral activities, especially in processing industries such as natural gas refinery and liquefaction plant, petrochemical and cement mill in which energy isused in large amount. This paper presents a discussion on the experience in establishment and implementation the energy conservation program, including the reduction of greenhouse gas (GHG) emission achieved in the last four years in Arun LNG Plant, a commercial natural gas liquefaction plant in Aceh, Indonesia with a capacity of 2.2 million ton LNG per year. In addition, an analysis on the specific energy consumption and CO_2 reduction is provided. The Energy Management Matrix was adopted in assessment of the energy management implementation in theArun LNG Plant. It was found that the efficiency of the plant tended to decrease from year to year, which was represented by the specificity of fuel consumption (accounted based on the LNG product). In 2010 the specific fuel consumption was 0.0088 mmscf per m^3 LNG product; it was up to 0.0234 in 2013. Fortunately, it was observed that the specific CO_2 reduction (calculated on the LNG product basis) increased during tlast four years; in 2010 and 2013 the specific CO_2 reduction was 0.195 and 0.518 ton per 10^5 m^3 LNG produced, respectively.

Keywords: Energy conservation; greenhouse gas; specific of fuel consumption; specific of CO_2 reduction

1.0 INTRODUCTION

Energy conservation is an important issue in all manufacturing sectoral activities where energy used is in big amount. Energy conservation is an integrated and planned effort systematicallyfor energy resource sustainability by effective and efficient used of energy. Effective and efficient used of energy will provide some advantages, such as the reduction in production and operational costs.

In Arun Liquefied Natural Gas Plant (Arun LNG Plant), the energy conservation (or enerco) program has been established since 1997 by running the Marine Boil-off Gas (MaBOG) project. The MaBOG project was addressed to recover the boil-off gas during loading the LNG to the tanker. The MaBOG project can recover the gas about 1000 m^3LNG for each loading process, thatis equivalent to one tanker of LNG per year if number of loading is 125 tankers per year.

The enerco program was then continued by the Recovery of LNG Tank Boil-off Gas (ReBOG) project in 1998. That project was initiated for recovery tank boil-off gas (BOG) during storage. Since the capacity of plant decrease from year to year, in 2012 the management had stopped the operation of 2 units ofLNG tank and 1 unit of LNG Berth circulation.

Earlier, in 2002 the enerco program was also supported by implementing the Flared & Vented Gas Recovery (FVGR) project. The FVGR project was subjected to reuse boil-off gas as a fuel, both for normal condition and shutdown. That FVGR project was possible to reuse boil-off gas 3-10 mmscfd. In addition, in 2003 Arun LNG Plant installed 10 units of Heat Recovery Steam Generation (HRSG) system in order to recover the energy from turbine flue gas to produce steam. As a result, some conventional boilers were turned off, to save the fuel gas by about 35 mmscfd. In this article, the report is only provided for the MaBOG, ReBOG and HRSG projects. Meanwhile, the FVGR project will be published elsewhere.

Several studies on the BOG management have been done in the past [1-10]. Most of them worked on the software simulation and model calculation for handling the BOG during unloading, storage and transportation; optimizing LNG storage; and design of control system during re-liquefaction. Only a few worked on the real case [11]. Moreover, there are many articles deal with HRSG, especially on thermodynamic analysis, modeling, optimizing, design, experimental, etc. [12-26]. Most papers presented theoretical studies and laboratory scale experimental, while only a few reported the commercial scale HRSG projects. Herewith, the authors refer only to the articles published in last five years.

This paper starts with the discussion on an experience in establishment and implementing the enerco program including reduction of greenhouse gas (GHG) emission achieved in the last four years in Arun LNG Plant, a commercial LNG plant in Aceh, Indonesia with a capacity of 2.2 million ton LNG per year comprises six trains. At the end, analysis on the specifics energy consumption and CO_2 reduction is provided.

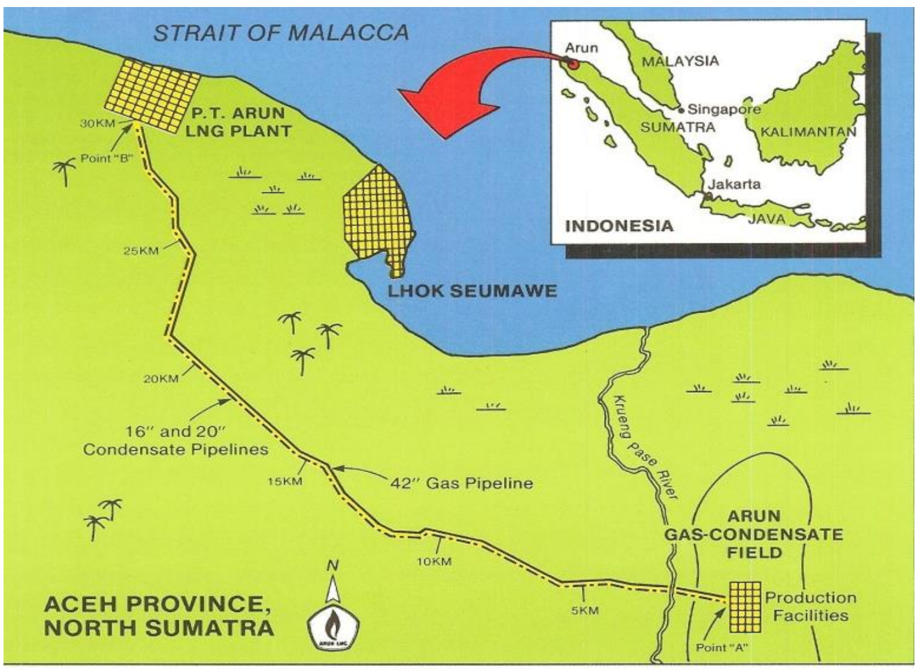


Figure 1 Map of Arun field and Arun LNG Plant

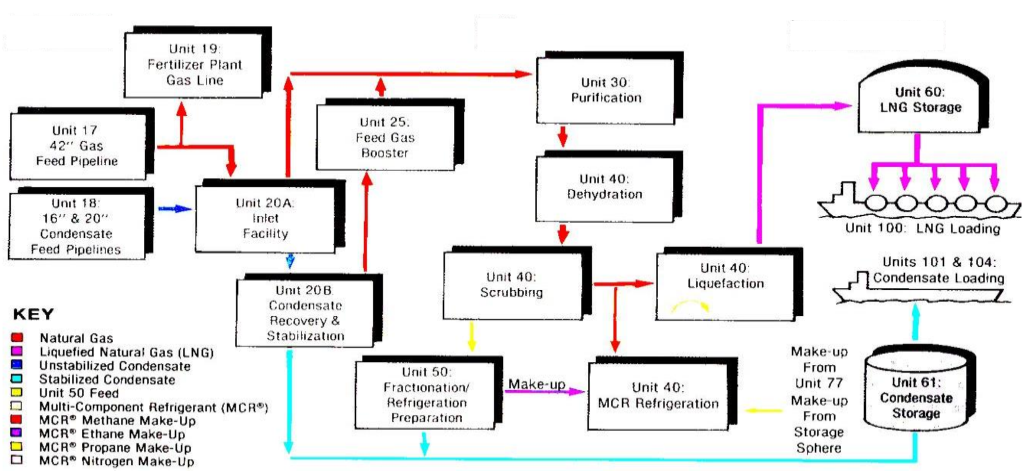


Figure 2 Block diagram of Arun LNG Plant

1.1 Description of Arun LNG Plant

Arun gas and condensate field (Arun field) was found and operated by Mobil Oil Indonesia (MOI), or recently known as ExxonMobil, which acts as a sharing contractor of Pertamina (Indonesia State Petroleum Company) since 1971. Arun field is located in the Block B area, Lhoksukon, Aceh Province, Northern Sumatra, Indonesia (Figure 1). Gas reserve in theArun field was predicted as much as 17 trillion cubic feet. Meanwhile, Arun LNG Plant (PT. Arun NGL Co.) placed in Blang Lancang, Lhokseumawe (±30 km from the Arun field), in the same province. PT. Arun NGL Co. is a joint venture company between Pertamina (55%), MOI (30%) and Japan-Indonesia LNG Company, JILCO (15%).

The LNG is produced through the cooling of natural gas below its condensing temperature of -153°C. In a liquid state, the gas volume is one six hundredth of its volume in gaseous form and therefore can be stored and transported efficiently in tanks and carriers. The production of LNG and condensate involves a number of processing steps that occurred at several different units (Figure 2). A short description for each unit is given as follows.

Inlet Facility: Gas and condensate from Arun field entered Arun LNG Plant in the inlet facilities which consisted of Flash Drums to separate gas from condensate. Condensate was directed to the Condensate Stabilization Unit and gas was treated in the LNG trains.

Purification Unit: In each LNG train, the gas firstly passed through the Mercury Absorber to absorb the mercury content in the gas. The outflow gas further flowed to the DEA Absorption Columns to remove carbon dioxide and trace quantities of hydrogen sulphide. These gas treating processes taken place in Purification Unit.

Dehydration Unit: The outlet gas from the Purification Unit was dried in the Molecular Sieve Dehydration Unit to reduce the moisture content. Regeneration of the molecular sieves was carried out by recirculation of hot, dry gas through the beds at a certain period.

Scrubbing Unit: The gas, along with condensed hydrocarbon liquids passed through a scrubber column where the LPG liquids were separated out and directed to the LPG fractionation train. Currently, the LPG was not produced anymore.

Liquefaction Unit: The main gas stream exited the top of the scrubber column and was cooled with propane to provide liquid reflux for the column, then passed to the main LNG heat exchanger for cooling to -153°C. Cooling was carried out in two stages using a multi component refrigerant (MCR) system consisting of nitrogen, methane, ethane and propane. The final temperature of product LNG was controlled by letting down the high pressure liquefied gas across a Joule-Thomson (J-T) valve to near atmospheric pressure. At this stage, a portion of the liquid flashed off and was used as fuel, with the remaining liquid was directed to storage. The amount of flash gas produced could be varied by changing the temperature of the gas stream exited the main exchanger (i.e. changing the load of the MCR refrigeration system). In this way, the fuel gas balance for the plant might be manipulated; with less fuel gas was produced at the expense of more refrigeration power required.

Storage and Loading Units: LNG was directed to storage in 6 insulated tanks. Self-refrigeration of the LNG was used to maintain a low temperature in the tanks. The BOG was recovered using four electric motors driven by centrifugal compressors and directed into the plant fuel gas system. Further, the BOG generated during loading process was directed to the same BOG recovery system as that used for the storage tanks. The same procedures were also provided for condensate out from the Condensate Stabilization Unit.

The first production and shipment for condensate were in May 1977 and 14 October 1977, respectively and the first production and shipment for LNG were 29 August 1978 and 4 October 1978, respectively.

2.0 EXPERIMENTAL

The study is focused on the acquisition and utilization of energy in the production and office activities effectively. Specific systems and energy end-use facilities were surveyed, included MaBOG recovery system, steam and electricity generation system, flare and vent gas recovery system as well as lighting and air conditioning system. In a two-component gel, it is easy to modify the molecular structure of either of the two components.

General works of investigation were preparation and coordination, survey and collecting the data, analysis and evaluation, and writing the recommendation. Before measuring and collecting the data, some agendas were provided i.e., the enerco team's consolidation, tools preparations, calculation method development, required data identification, as well as the coordination between the enerco team and the company top level management, and the detail schedule arrangement.

Initial survey was done in order to collect the secondary data such as production process data, installed equipment design data and their operation record, daily or monthly production data, raw gas data, LNG product data, energy and fuel consumption data, and the past modified process data.

In addition to data collection, observation and interview with the operators and company management were also provided during the survey in regard to have more detail data on energy consumption pattern and to deeply explore the opportunities in energy saving that possible to be implemented.

Further steps werethe review and verification of the secondary data. This step was to make sure that the data have high validity and reliabiliy. The verified data were used for initial estimation. Measurement and collecting the primary data wasperformed to complete the secondary datacollection. The measurements were performed at the potential points for higher energy saving so that the number of energy potency can precisely be known. In addition, the measurements were done to clarify the secondary data.

Analysis of energy balance was provided on the major equipment/unit that used large amounts of energy, such as gas turbine, flare gas, and lighting system. To develop the energy balance; raw gas, LNG product, fuel consumption and air flow rate data were used. The energy balance was evaluated to identify thermal losses and energy saving potential. The CO_2 emissions load and reduction in the main units were also predicted.

The Energy Management Matrix was adopted in assessment of the energy management implementation in the Arun LNG Plant. This effort was crucial to be done in order to prove the increase of energy efficiency through the integrated and sustainable improvement both in the management and all the operation levels.

3.0 RESULTS AND DISCUSSION

3.1 Production and Consumption Profile

Figures 3 and 4 described the production and consumption profiles of the ArunLNG Plant. It is evident that feed gas entered the plant and fuel gas consumption decreased gradually each year, except for the fuel consumption in 2013. The fuel consumption in that year was little higher than 2012. The pattern of feed gas was affected by the natural gas reserve in the Arun gas field that decreased as age of exploitation increased. Since the feed gas slowed down from year to year, therefore, the LNG product also slowed down (Figure 4). The same tendency presented by the ratio of LNG to feed gas. Based on those facts, the Plant has been turned off at October 10, 2014. During the 36 years of operation, the Plant has produced 4,269 tankers LNG.

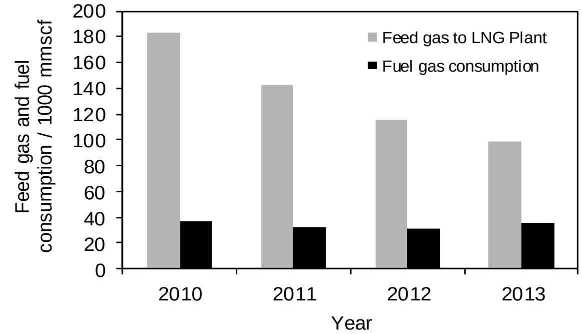


Figure 3 Profile of the feed gas and fuel consumption

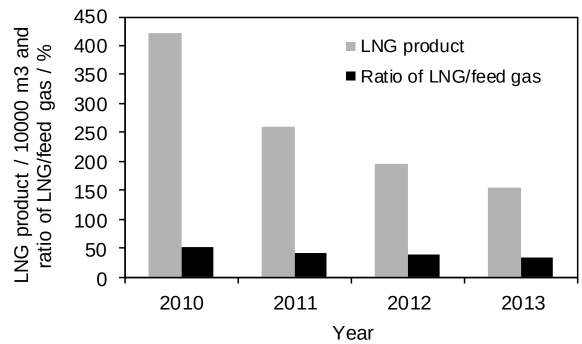


Figure 4 Profile of the LNG and the ratio of LNG to feed gas

Table 1 Estimation of the CO_2 emission load from the point source (ton)

Emission point source	Year			
	2010	2011	2012	2013
Feed gas	2,178,635	1,655,998	1,350,155	1,154,100
Fuel gas combustion	2,471,080	2,546,118	2,094,255	1,625,677
Flaring	4,187	4,139	3,632	3,533
Total	**4,653,902**	**4,206,255**	**3,448,042**	**2,783,310**

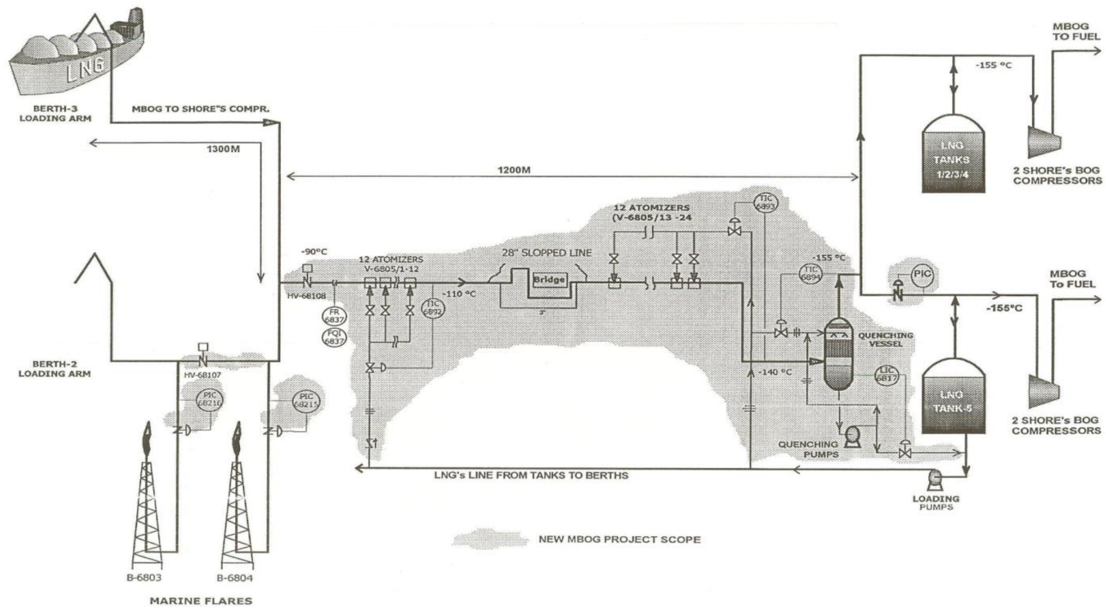


Figure 5 Scheme of the MaBOG recovery

On the other hand, the higher of fuel consumption in 2013 probably due to the following reasons: (1) lower in the MaBOG recovered (as seen in Table 2), and (2) lower in the turbines and plant efficiencies. The Plant efficiency in the 2013 was only about 70%, the lowest one compared to others three years of observation. In addition, the decrease of the LNG product was sharper compared to the feed gas to Plant (Figures 3 and 4). The data reflected that the conversion of feed gas to LNG significantly decreased from year to year.

The GHG emissions came from CO_2 in feed gas and flue gas (both as a point source) and CH_4 fugitive emission from the plant equipment such as flange, valve, compressor, pump, tank and pressure safety valve. In addition to the CH_4 fugitive, some others emission from flue gas (N_2O, SO_2 and NO_x) can be converted to the CO_2 emission by using Global Potential Warming (GWP) factor. The GHG (CO_2e) emission in Arun LNG Plant during the last four years is shown in Table 1. The tendency of emission from all sources decreased from year to year. Interesting fact exhibited by the fuel gas combustion source, even in Figure 3 the fuel consumption is higher in 2013 however the emission release was the lowest one. That data gains the argument that turbine (or fuel gas combustion) efficiency was low in the entire year.

3.2 MaBOG Project

Schematic diagram of the MaBOG recovery is shown in Figure 5. The MaBOG was caused by heat leak during delivery and loading, which was in initial design that BOG passed to the marine flare to keep the loading process work well. In this study, the Plant design model/configuration/layout was used as a baseline in the calculation process. Since 1997, the MaBOG was recovered and used as fuel for gas turbines. The fraction of recovery is evaluated as follows:

$$\%recovery = \frac{FQI\ 6837}{FQI\ 6804} x100\% \qquad (1)$$

where:

FQI 6837 = boil-off gas flow rate displayed/recorded at metering FQI 6837

FQI 6804 = boil-off gas flow rate displayed/recorded at metering FQI 6804

Profiles of the number of shipments, MaBOG recovery and number of CO_2 reduction are presented in Figure 6 and Table 2. It is clear that the number of shipments decreased from year to year, similar to the LNG product pattern (as shown in Figure 4). Thereafter, the average BOG recoveries (amount of the BOG recovered per tanker loaded) were more than 20 mmscf or 75%, except in 2013. In 2013 the MaBOG recovery system operated only for 3 months (January-March); this was the reason why the average recovery just up to 5.37 mmscf (quite small compared to those others three years). From April to December 2013, all the MaBOG sent to the marine flare. Moreover, the number of CO_2 reduced decreased as the total BOG recovered decreased (see Table 2). The ecreaseof the MaBOG recovered means increase the MaBOG to the flare. Consequently, release the GHG (CO_2) to the atmosphere slightly jumped up at least by doubling, evidently from flare and feed gas.

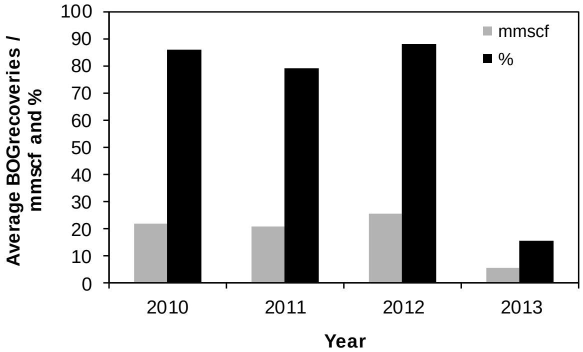


Figure 6 Profile of the average BOG recovery

Since the MaBOG recovered was used as the fuel for the turbine, when its number decreased, the volume of turbine fuel from the feed gas should be enhanced to ensure the fuel rate or energy produced constant. That is the reason to claim that CO_2 release might contributed by feed gas. As expected, the ratio of CO_2 reduction to fuel gas consumption for 2013 suddenly jumped down to level lower than 2011 (see Figure 10), which proved that the fuel consumption in that year higher than 2011 and 2012 (as presented in Figure 3).

3.3 ReBOG Project

Recently Arun LNG Plant operated four LNG Tanks and two LNG Berths. Installed tanks were fully contained system, tank inside a tank, which was designed to maintain the temperature of -153°C. Operating those numbers of tanks generated BOG about 5 mmscfd higher than that needed by the gas turbine. Surplus (un-consumed) BOG was then re-liquefied to LNG and pumped to the tank.

To avoid decrease the plant thermal efficiency, Arun LNG Plant has switched off the operation of 2 LNG Tank and 1 LNG Berth in 2012. By running that option, the Plant reduced BOG as much as 8.9 mmscfd. As a further result, two compressors (with the capacities of 5.5 MW and 3.3 MW) have also been switched off so that it might save the fuel about 3.5 mmscfd or equivalent to 43,800 m^3 LNG per year. The final benefit of that effort was suppressing the GHG emission about 63.78 ton CO_2e per year.

3.4 HRSG Project

Schematic diagram of gas turbine without and with HRSG is shown in Figures 7 and 8. Arun LNG Plant had 10 units HRSG boiler; six units were fired HRSG with burner and four units were unfired HRSG without burner.

As mentioned above, the HRSG was attached to utilize the energy in flue gas out from gas turbine with temperature quite higher of 515°C and mass flow rate 114 kg/sec. (Figure 7). The flue gas energy used to generate a saturation steam at 10 kg/cm^2 with the flow rate 60 ton per unit per hour. Since the energy content in flue gas was absorbed, flue gas temperature to stack decreased from 515°C to 165°C (Figure 8). By installing HRSG boiler, the Plant saved the fuel gas about 35 mmscfd and reduced the CO_2 emission about 721.97 ton per year.

The number of CO_2 reduced from those two projects did not depend on feed gas, fuel consumption and LNG product. It was fixed over the year of project implementation.

3.5 Specific Fuel Consumption and CO_2 Reduction

Figure 9 describes the ratios of fuel gas consumption and CO_2 reduction to LNG product. These two parameters explained the specifics fuel consumption and CO_2 reduction based on the LNG product. The amount of CO_2 reduction here is the total of CO_2 reduction from the three enerco projects, i.e. MaBOG, ReBOG and HRSG. Meanwhile, Figure 10 reflects the specific CO_2 reductions on the feed gas to Plant and fuel consumption. Hopefully, those four defined parameters more representative to discuss the profile of the specific fuel consumption and specific CO_2 reduction. Used the number of CO_2 reduction itself may cause erroneous discussion since feed gas to the Plant and fuel consumption decreased from year to year. Therefore, to avoid un-accurate interpretation of the data, introduced those new parameters are necessary.

It is clear from Figure 9 that the ratios of the fuel gas consumption and CO_2 reduction to LNG product tend to go up from 2010 to 2013. Increase in the specific fuel consumption means energy used in the LNG production process increase; consequently, LNG production cost increase. Inefficient in fuel consumption might be influenced by many factors such as the equipment/plant aging; used of energy in office and housing; leak in the steam piping; used of energy for maintenance; etc. Meanwhile, the specific CO_2 reduction reflected the opposite pattern, which significantly increased. That means that the suppressing of the CO_2 emission was successfully achieved. The increase in the specific CO_2 reduction described that the enerco projects in Arun LNG Plant worked effectively in reducing the GHS emissions but was not so for reducing the specific fuel consumption.

Table 2 Profile of the MaBOG recovery

Observed parameter	Year			
	2010	2011	2012	2013
Number of shipment (tanker)	34	20	16	13
Total BOG recovered (mmscf)	711.3	391.3	252.9	64.4
Average BOG recovery (mmscf)	21.55	20.59	25.29	5.37
Average BOG recovery (%)	85.8	78.9	88.0	15.26
Number of CO_2 reduction (ton)	34.82	19.155	12.38	10.96

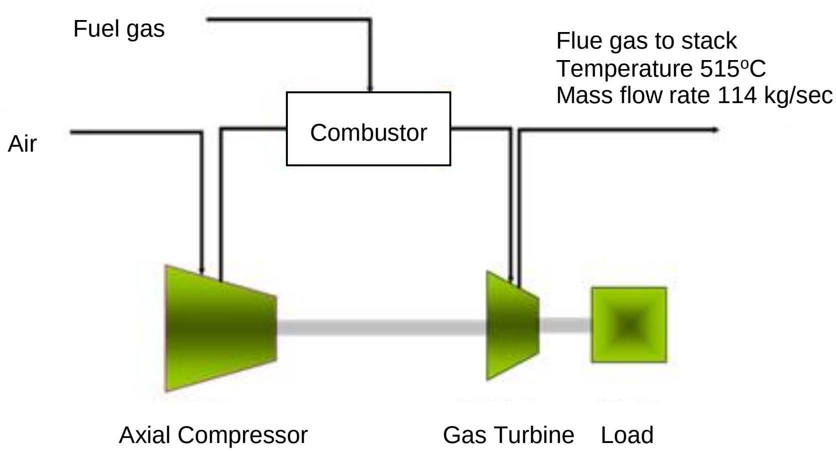


Figure 7 Block diagram of gas turbine without HRSG

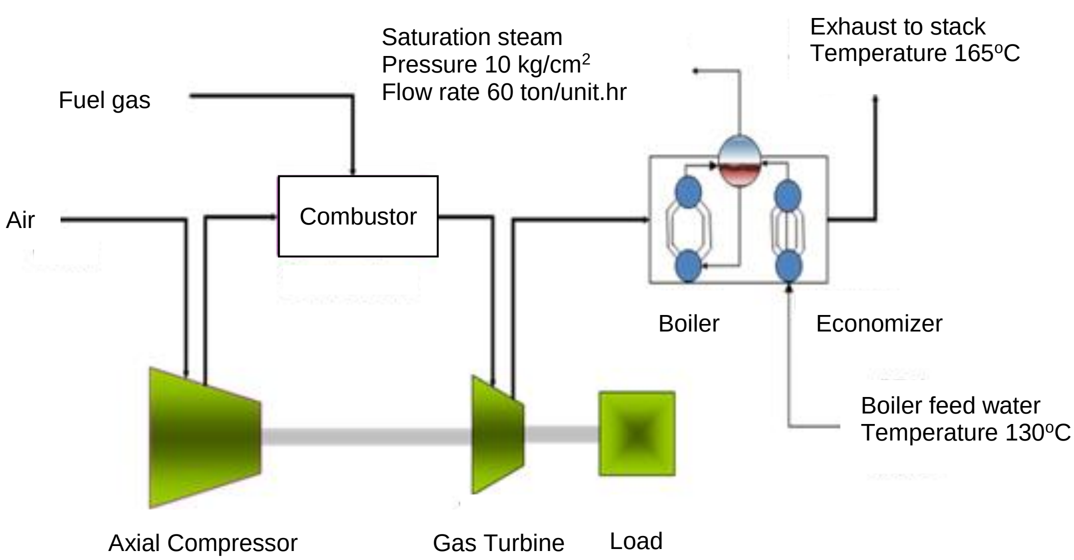


Figure 8 Block diagram of gas turbine with HRSG

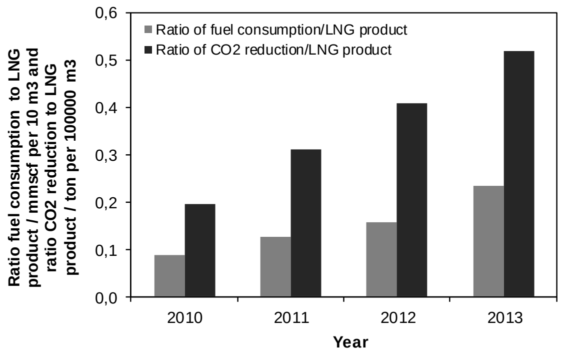


Figure 9 Ratios of the fuel used and CO_2 reduction to LNG product

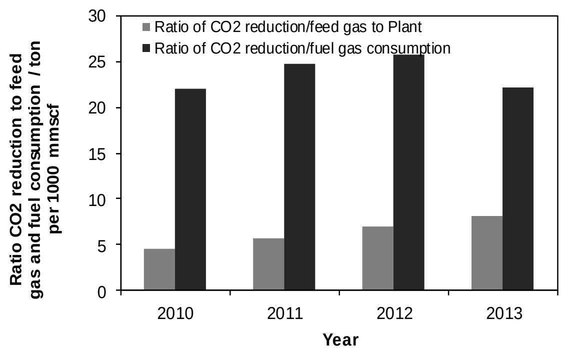


Figure 10 Ratios of the CO_2 reduction to feed gas and fuel consumption

In Figure 10, the specific CO_2 reduction on feed gas to Plant follows the pattern of specific CO_2 reduction on the LNG product as shown in Figure 9, although the increase occurred slowly from year to year. Those two specific CO_2 reductions were in good agreement with the feed gas and LNG product data plotted in Figures 3 and 4. Moreover, from Figure 10 it can be read that the ratio of CO_2 to fuel gas consumption in 2013 departed from usual pattern. That fact was affected by the fuel gas consumption in the same year as presented in Figure 3. Higher in fuel consumption might lowered the ratio of CO_2 to fuel consumption. Those phenomena off course did not desire in the plant operation.

4.0 CONCLUSION

Some conclusions can be listed here based on the results and discussion.

1. LNG product decreased from year to year during four year evaluation as the feed gas to Plant decreased.
2. Fuel gas consumption also decreased from 2010 to 2012, in 2013 it significantly increased.
3. CO_2 emission load from all point source tended to go down as year of operation increased.
4. Specific fuel consumption on the LNG product increased by year.
5. Enerco project in Arun LNG Plant was successfully run and effectively reduced the CO_2 emission.

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