Techno-Economic of Waste Energy Utilization from LNG Terminal for Emission Reduction in Map-Ta-Pud Industrial Estate

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ABSTRACT

Liquefied Natural Gas (LNG) terminal is one of new construction in Map-Ta-Pud (MTP) during 2007-2011. With the process of regasification, LNG will be heated by seawater and change phase from liquid to vapor. The energy for phase changing was lost by seawater to sea. Therefore the objective of this study is to design the integrated process for all plants in MTP to reducing the emission with the utilization of lost energy in LNG regasification process. The simulation result shows that this integrated process with LNG energy utilization can reduce the toxic and emission in MTP atmospheric. The total toxic recovery = 99.2-99.4 %. The BTEX recovery and VOC recovery = 100 % and sulfur compound recovery = 95-97%. In addition, the preliminary of economic evaluation and sensitivity analysis show that the payback period of this gas treatment process can be possible in 2-8 years.

Keywords: Energy utilization, LNG terminal, Liquefied Natural Gas, Emission reduction

1 INTRODUCTION

Currently, there are many industrial plants; refinery plant, petrochemical plants, etc., are established in Thailand, especially in Map-Ta-Pud industrial estate (MTPIE). Map-Ta-Pud is the most famous industrial estate in Thailand. It locates in Rayong province in Eastern part of Thailand. There are 58 companies in this industrial estate [1]. The most business of these companies involve to natural gas separation, refinery, petrochemical intermediate stream product (e.g. aromatic and olefin) and downstream product (e.g.

monomer), electricity and steam generation.

After passes 10 years (1995) in operation, there are many cases of safety, health and environment occurred more frequent, especially for surrounding villagers. The main root cause certainly comes from improper treating or lack of proper flare gas treatment or leakage gas from the process. With this root cause, the LNG receiving terminal, which has excess cold energy from the 5 MTPA (Metric Ton Per Annual) vaporization process [2] – [3], can be applied for improving the gas quality before flaring. Therefore, in this study, the utilization of excess energy from 5 MTPA LNG for waste gas treatment in MTP industrial estate is focused.

2 RESEARCH AND METHODOLOGY

2.1 Apparatus

There are 2 major software relate in the study, ASPEN PLUS V.7.2 [4] and Google Earth [5]. ASPEN PLUS is used as the process simulator software for process design and Google Earth is used to indicate the coordinator of the source of emission gas and also used for estimated the distance of pipe route in emission pipeline network. The input of the simulation model was acquired from the actual gas capacity, actual waste gas composition from air pollution measurement and the design data for LNG terminal capacity.

All plant positionsare retrieved from Google Earth library. In addition, the distance of local flare stack of each plant to pipeline network, distance of each plant along the route of pipeline network and the distance of pipeline network to gas treatment plant are estimated by this software. The pipeline network route refers to the existing pipeline network that show in the software also. (*Fig.1*)

The equipment cost database [6] based on year 2007 with gulf coast of USA FOB basis [7]. For the remaining equipment e.g. separator, the price based on the calculation reference in the Aspen software. The price of pipeline network in simulation referred to average actual cost from local consultant.

Fig. 1 *Estimate distance of flare location, route of pipeline network and sampling point of emission gas.*

2.2 Input data

2.2.1 Emission gas composition

According to report from Green Peace [8], it shows that there were toxic components, cancer predominate components and volatile hydrocarbon components in the sampling of air pollution measurement in MTP area (Fig. 1). It means that there are some portion of gas is mainly not combusted at flare stack, completely. So it's the reason that toxic components remain in MTP atmosphere. However, the exact number of each component in waste gas (Feed local flare stack) has not been reported and only air pollution analysis result can be referred as remaining gas in atmospheric (after burnt), therefore, each component of waste gas must be assumed to the higher number of the remaining quantity in MTP atmospheric. In the study, there are 2 cases for gas composition: High toxic case and Low toxic case. The first case, toxic gas is assumed to be 1% for all toxic gases and also more than low case 1-10 times (Depending on composition). With this estimation, the toxic level in gas is believed to be more severe than the actual from real source. The second case, toxic gas level is assumed from actual sampling data in MTP surrounding area (AQC-MTP001/004/005) [4]. With high case and low case, the real waste gas composition should be located in between of the range of these cases.

For the other gases (except toxic gas), they are assumed as hydrocarbon fuel gas which is normally contained in the real waste gas. In general, C_1-C_6 alkane component (e.g. Methane, Ethane, etc.) and Hydrogen (H_2) are the base component for fuel gas. Moreover, some of inert gas (e.g. Nitrogen (N_2) and Carbon dioxide (CO_2)) are contain in the fuel gas as well. With the combination of the references above, the composition of each case are shown in Table 1.

2.2.2 Feed gas flow rate

In the study, the number of waste gas source is identified as 6 sources in MTP area. The location is identified and coordinated by Google Earth software. The criteria for prospect gas source is the location where is in the radius of air sampling point. Since these plants are located in the surrounding area of air pollution sampling, therefore, they are chosen as a represented plant. For the waste gas flow rate to flare of each plant, it shall be calculated with assumption that there is no plant in MTP performed continuous excess gas flaring and only purge gas for flaring is operated.

The calculation of waste gas flow rate from each plant is deployed from the simple equations. In these equations, the purge gas is function of stack diameter, gas molecular weight and flow factor. If there is air ingress protector equipped with flare stack (1), the requirement of purge gas would be less than the "without air ingress protector" case (2).

$$\text{Purge gas flow} = 0.5K \times D^3 \times MW^{-0.565} \qquad (1)$$

$$\text{Purge gas flow} = K \times D^3 \times MW^{-0.565} \qquad (2)$$

Where   Purge gas flow rate in Sm^3/h
         K = Flow factor (-)
         D = Stack diameter (in)
         MW = Purge gas molecular weight

2.2.3 Operating condition

In general, the pressure of flare system of each plant depend on the facility design and many others factor. However, the range of operation of flare header is 0.5-3.5 barg, approximately. In case, this flare gas has to be routed to waste gas network and deliver to gas treatment plant, 0.5 barg should be the minimum value for pressure supply to the gas treatment plant. If there is the source plant operated at the higher pressure, it would not impact to the design because the inlet of gas treatment plant pressure is designed to handle the waste gas since 0.01 – 0.5 barg and it also has its flare to prevent over pressure of gas inlet.

***Table 1** Waste gas composition (Dry condition), the quantity level and their chemical property*

Component name	Formula	Molecular Weight	Mol fraction (High Scenario)	Mol fraction (Low scenario)	Scenario Diff ratio
METHANE	CH_4	16.04	0.25	0.2529	0.988
ETHANE	C_2H_6	30.07	0.15	0.1518	0.988
PROPANE	C_3H_8	44.10	0.06	0.0607	0.988
ISOBUTANE	C_4H_{10}	58.12	0.02	0.0202	0.988
N-BUTANE	C_4H_{10}	58.12	0.01	0.0101	0.988
2-METHYL-BUTANE (i-C_5)	C_5H_{12}	72.15	0.01	0.0101	0.988
N-PENTANE	C_5H_{12}	72.15	0.01	0.0101	0.988
N-HEXANE	C_6H_{14}	86.18	0.01	0.0101	0.988
HYDROGEN	H_2	2.02	0.1	0.1012	0.988
HYDROGEN-SULFIDE	H_2S	34.08	0.01	0.0103	0.968
NITROGEN	N_2	28.01	0.02	0.0202	0.988
CARBON-DIOXIDE	CO_2	44.01	0.1	0.1012	0.988
CARBON-MONOXIDE	CO	28.01	0.05	0.0506[8]	0.988
BENZENE	C_6H_6	78.11	0.01	0.0044[8]	2.293
TOLUENE	C_7H_8	92.14	0.01	0.0468[8]	0.214
P-XYLENE	C_8H_{10}	106.17	0.01	0.0071[8]	1.417
M-XYLENE	C_8H_{10}	106.17	0.01	0.0071[8]	1.417
O-XYLENE	C_8H_{10}	106.17	0.01	0.0051[8]	1.948
VINYL-CHLORIDE	C_2H_3Cl	62.49	0.01	0.0069[8]	1.448
1,2-DICHLOROETHANE	$C_2H_4Cl_2$	98.96	0.01	0.0574[8]	0.174
CHLOROFORM	$CHCl_3$	119.38	0.01	0.0019[8]	5.256
CARBONYL-SULFIDE	COS	60.07	0.01	0.0080[8]	1.248
METHYL-TERT-BUTYL-ETHER (MTBE)	$C_5H_{12}O$	88.15	0.01	0.0046[8]	2.156
METHYL-ETHYL-KETONE (MEK)	C_4H_8O	72.11	0.01	0.0026[8]	3.825
METHYL-ISOBUTYL-KETONE (MIK)	$C_6H_{12}O$	100.16	0.01	0.0045[8]	2.205
ACETONE	C_3H_6O	58.08	0.01	0.0145[8]	0.691
CARBON-DISULFIDE	CS_2	76.13	0.01	0.0042[8]	2.394
ETHYL-CHLORIDE	C_2H_5Cl	64.51	0.01	0.0030[8]	3.342
ETHYLBENZENE	C_8H_{10}	106.17	0.01	0.0045[8]	2.226
DICHLOROMETHANE	CH_2Cl_2	84.93	0.01	0.0026[8]	3.816
STYRENE	C_8H_8	104.15	0.01	0.0024[8]	4.169
TETRACHLOROETHYLENE	C_2Cl_4	165.83	0.01	0.0009[8]	10.738
TRICHLOROETHYLENE	C_2HCl_3	131.39	0.01	0.0019[8]	5.259
WATER	H_2O	18.02	0.00	0.00	0.000

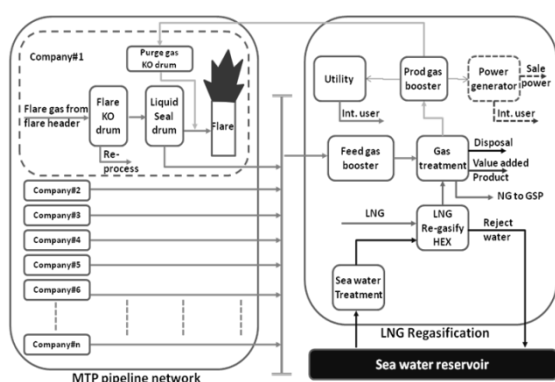## 3 RESULT AND DISCUSSION

3.1 Process design concept

***Fig. 2** Overview process schematic between each plant to gastreatment plant*

The concept of the design is to centralize the waste gas from each source to treat in specific location. Considering to Fig.2, there are n source of waste gas and route to waste gas network system then deliver to gas treatment. In each source, the flare system of each source comprises of flare Knock-Out Drum (KO drum), liquid seal drum and flare stack. In company No.1, gas from flare gas header shall be fed to KO drum for separating the liquid droplet, which is entrained in flare gas, from gas phase. The separated liquid shall be delivered to closed drain system for reprocess again (depending on the each process). Gas from this drum shall feed to liquid seal drum/ staging drum. In the study, the function of this drum is to stage or divert the flow of flare gas to another direction. It's not design to be seal drum for preventing backflow from flare tip. Liquid in staging drum shall control the flow of gas by hydraulic pressure of the liquid height inside the drum. During normal operation, flare gas shall divert to waste gas network and send to waste gas treatment plant (via

orange line in Fig.2) and the concept of flare system of all companies in this study are the same. In case of emergency such as blowdown case, the large flow rate of blowdown gas from whole process shall route flare gas header as normal route. However, the pressure of gas due to back pressure from network lead the hydraulic pressure of liquid seal is broken, then gas shall route to local flare as plant design.

In view of purge gas requirement, during any operation scenario, purge gas is still required. Since the concerned of toxic gas in fuel gas of each plant so treat gas shall supply from treatment gas plant with backup of natural gas from distribution network of PTT Gas Separation Plant (GSP). Moreover, in case of loss of clean purge gas from both sources, the local fuel gas from process can be used as the last priority.

After gas is routed to the treatment plant, gas shall be treated with the cryogenic concept. The cold energy from cooled natural gas from LNG vaporizer shall be utilized. The liquid products from the cryogenic process are fuel liquid and sulfur compound. They shall be sent for disposal with specific waste treatment system, especially for sulfur and VOC content or utilize as fuel for further propose. Treat gas can be used for purge gas of source plant, utilization for power generation for internal process facility, then sell the excess to main power grid. Since the composition of waste gas from all source compose with hydrocarbon e.g. methane, ethane, etc., it can be used source of energy for electricity production.
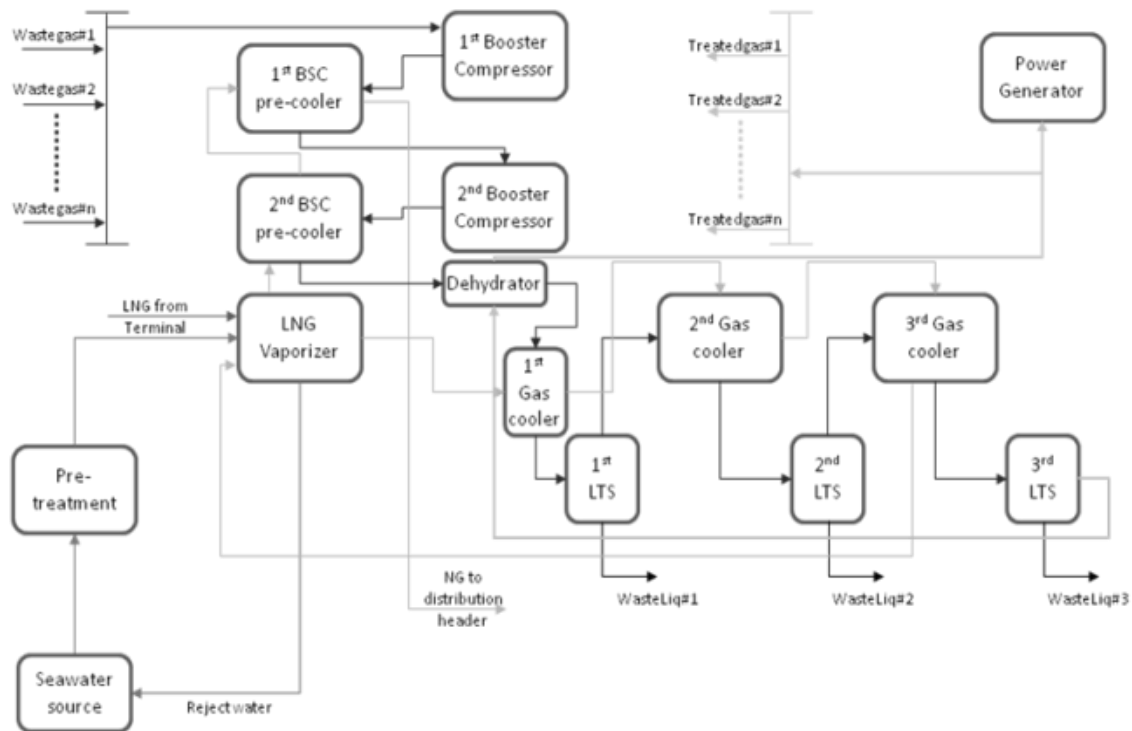
3.2 Process design description

Fig. 3 *Process flow diagram of gas treatment process*

In the process of gas treatment, it can be divided in 3 sub-processes; Gas pressure booster, Dehydration and Cryogenic separation as shown in Fig.3. Waste gas from pipeline network routed to gas treatment plant (Red line). The design pressure of inlet gas of the system is 0.5-1.0 barg. The limitation depends on the design inlet pressure of 1st booster. In case of over pressure gas is relieve to flare system of treatment gas process. Gas is compressed from 0.5 barg to 1 barg by this stage and it shall be increased to 14 barg by 2nd stage compressor in

next stage. The design pressure shall not be more than 14 barg because of the investment cost. This pressure is the maximum working pressure under pressure rating ASME class 150 and it also enough for toxic removal process including gas dehydration. The cooling of compressed gas is done by using of recycle treated gas from cryogenic process before further utilization. The control temperature of outlet gas of each stage is 20°C.

After gas compression, high pressure gas feed to dehydration unit for saturated water removal. The

objective of this unit is to prevent gas hydration or ice formation which may be occurred in the low temperature process. In this design, cryogenic separation is used, so the dehydration unit is strongly recommended. In general, water content in outlet gas of dehydration unit should be 1-2 lb per MMSCF (Million Standard Cubic Foot) if the downstream process is the cryogenic relevant. In the design, minimum temperature of downstream process is -80°C, and ice formation/ gas hydration shall not occur at -80°C

Gas from dehydration unit feeds to "Feed-Product cooler" for pre-cooling cryogenic inlet gas and heating-up product treated gas vice versa. Feed gas temperature decreases to 4°C for heavy components removal e.g. BTEX (Benzene, Toluene, Ethyl Benzene and Xylene), VOC and CS$_2$. Low Temperature Separation (LTS) technique is selected for this process because the composition of feed gas from waste gas network is not constant as specification; therefore, this method is suitable for wide range of composition type and fluctuation of composition content in feed gas. In addition, this method also easy for design, installation, operation and maintenance if compare to other low temperature technique. In view of investment, CAPEX (Capital Expenditure) of this method is also lower than other method. However, the disadvantage of this method is the product purity. Since the objective of the design does not aim to get the purified specific component but it aim separate the toxic component from the waste gas with the opportunity to utilize the treated gas as much as possible. Therefore, other low temperature methods such as low temperature distillation may not require. Cold side stream of this heat exchanger is the treated gas from the 3rdstage LTS. The inlet temperature of cold side is -80°C and the outlet of cold side is designed to have the temperature less than -29°C. The temperature shall not be specified on this stream because the downstream of this gas is gas generator or recycling gas as purge gas. Therefore, ambient air temperature is adequate for heating up this gas stream.

Gas from F-P cooler (Hot side) feed to F-P LTS for liquid removal as above explanation. Gas carries to 1ststage cooler and decrease gas temperature from 4°C to -45°C. The objective of this stage is to remove the Liquefied Petroleum Gas (LPG) portion and Vinyl Chloride is presented. The liquid product of this stage is removed by 1stLTS. The liquid product aims to use as fuel for any purpose if there is high VOC content. Therefore the use of this product must be used with carefully. After 1st stage, gas feed to 2ndstage cooler and 3rdstage, consequently. The design temperature of 2ndstage is -65°C. The objective of this stage is to remove the sulfur component such as COS and H$_2$S. Therefore the liquid product of this stage must be sent

out as disposal for further specific handling. In addition, another objective of this stage is to use as variable stage separation. Actually the concept of the gas treatment in this study is to separate liquid product in to 4 groups such as Heavy component & VOC, LPG, Sulfur compound and Liquid CO$_2$ (LCO$_2$) at atmospheric condition. The waste product group is the first and the third group. The cut point temperature of the first group and the second group is too narrow for adjustment, therefore the setting temperature has to be fixed at -45 ^{o}C but the third group is different. In case there is the waste gas which has boiling point less than the setting temperature (-65°C), it can be adjusted (Decreasing) for remove that gas, however, the range of operation must be in the range of -65 to -73°C.

In the last stage (3rdstage), gas from the 2ndstage delivers to the 3rdstage cooling with the objective of CO$_2$ removal as liquid for LCO$_2$ production. Since the CO$_2$ can be used as feedstock for downstream industry and it also reduces heating value of treat gas and leads to difficulty in engine combustion, so these are the reason for CO$_2$ removal at the last stage in process. At this stage, the temperature shall be reduced to -80°C. After the 3rdstage, the main composition in gas is CH$_4$, C$_2$H$_8$, N$_2$ and H$_2$ therefore; gas can be used for combustion without toxic component. Gas from the 3rdstage shall be fed to F-P cooler again (as described above). Gas shall be heated-up and fed to gas distribution network system for further utilization.

3.2 Toxic Removal Performance

According to Table2, the heavy component including C$_{5+}$, BTEX, VOC and Sulfur compound are removed with 100 % efficiency. For the sulfur compound, the removal efficiency cannot reach 100% because of H$_2$S. In the treated gas, H$_2$S content is approximate 0.2-0.3% mol for all scenarios. As the same to CO$_2$, although the temperature shall reach the boiling temperature of CO$_2$ but it cannot be condensed to liquid totally. The reason is because of the use of conventional separator. However, the CO$_2$ content in treat gas is approximate 9-10%mol. At this CO$_2$ content level, treated gas can be used as fuel for gas engine. The performance of the engine may drop by this CO$_2$ level but if comparing the CO$_2$ in treated gas and NG for vehicle in Thailand which has 23% CO$_2$ content in gas. The quality of treated gas is better than Thailand NGV (Natural Gas for Vehicle). For the LPG portion, the most of LPG is removed to liquid product. However, it is distributed to all liquid products, so the quantity of LPG shall less than the expectation in 1stLTS product. Although the result shows that there is other substances (e.g. H$_2$S or other gas) contaminate in this product, it can be treated by

reducing the pressure to the standard condition and keep the temperature at -45°C. At that condition, there are only LPG and VOC content in liquid product. Therefore, if the use of this product as fuel was required, the concerned of VOC level must be considered. For the total toxic removal, the efficiency is more than 99.0%. With this efficiency, it shows that this process can perform with the good result of gas treatment with low cost of operation.

The value in Table3 is the level of toxic and VOC which are content in the treated gas. In addition, they are also compared to the international standard for screening level of toxic in air pollution. There are 4 standards for this comparison; EPA Region 6 Screening Level, Short-term/Long-term Texas Effects Screening Levels, Acute/Intermediate/Chronic ATSDR Minimal Risk Levels and Louisiana Toxic Air Pollution Ambient Air Standards [4]. The result shows that the quantity of all toxic substance in all scenarios are lower than the lowest screening level value and also reach to zero in any referred international standard

Table 2 Recovery efficiency of the treatment process between feed waste gas and treated gas for all scenarios

Composition	Recovery efficiency (%)			
	Normal flow		Emergency flow	
	High Toxic	Low Toxic	High Toxic	Low Toxic
C_1	11.89	11.89	11.89	11.89
C_2	76.58	76.65	76.58	76.65
C_3	99.43	99.43	99.43	99.43
C_4	99.99	99.99	99.99	99.99
C_{5+}	100.00	100.00	100.00	100.00
BTEX	100.00	100.00	100.00	100.00
VOC	100.00	100.00	100.00	100.00
Sulfur compound	96.56	95.03	96.60	95.03
CO_2	55.90	55.62	55.91	55.62
Total Toxic gas	99.34	99.26	99.37	99.26

Table 3 The comparison result of standard screening level of air pollution to treat gas from treatment process for all scenarios.

Composition	Min. Screening level	Quantity level (µg/m3)							
		Treated gas				Deviation under screening level			
		Normal flow		Emergency flow		Normal flow		Emergency flow	
		High Toxic	Low Toxic	High Toxic	Low Toxic	High Toxic	Low Toxic	High Toxic	Low Toxic
BENZENE	0.25	1.75E-15	1.15E-15	1.76E-15	1.14E-15	0.25	0.25	0.25	0.25
TOLUENE	95.8	0	0	0	0	95.8	95.8	95.8	95.8
P&M-XYLENE	208	0	0	0	0	208	208	208	208
O-XYLENE	730	0	0	0	0	730	730	730	730
VINYL-CHLORIDE	0.22	1.51E-08	1.12E-08	1.51E-08	1.12E-08	0.22	0.22	0.22	0.22
1,2-DICHLOROETHANE	0.074	0	0	0	2.38E-16	0.074	0.074	0.074	0.074
CHLOROFORM	0.084	4.92E-14	1.35E-14	4.93E-14	1.35E-14	0.084	0.084	0.084	0.084
CARBONYL-SULFIDE	0.8	2.09E-06	1.67E-06	2.09E-06	1.67E-06	0.8	0.8	0.8	0.8
MTBE	3.7	2.81E-14	1.92E-14	2.82E-14	1.92E-14	3.7	3.7	3.7	3.7
MEK	390	0	0	0	0	390	390	390	390
MIK	205	0	0	0	0	205	205	205	205
ACETONE	370	1.57E-13	3.23E-13	1.58E-13	3.23E-13	370	370	370	370
CARBON-DISULFIDE	3	7.98E-12	4.34E-12	8.02E-12	4.36E-12	3	3	3	3
ETHYL-CHLORIDE	4.1	1.61E-10	5.70E-11	1.61E-10	5.70E-11	4.1	4.1	4.1	4.1
ETHYLBENZENE	200	0	0	0	0	200	200	200	200
DICHLOROMETHANE	2.3	4.38E-12	1.51E-12	4.38E-12	1.51E-12	2.3	2.3	2.3	2.3
STYRENE	11	0	0	0	0	11	11	11	11
TETRACHLOROETHYLENE	0.33	0	0	0	0	0.33	0.33	0.33	0.33
TRICHLOROETHYLENE	0.017	0	0	0	0	0.017	0.017	0.017	0.017
HYDROGEN-SULFIDE	1	7.91E-06	8.20E-06	7.91E-06	8.20E-06	1	1	1	1

3.3 Recovered product

As per *Table4*, the results show that the quantity of liquid product is very large number and the portion of production from 1st stage, 3rd stage, 2nd stage and pre-cooling stage, respectively. However, it depends on the composition at actual condition. In real operation, if waste gas or excess gas is routed to the waste gas network the composition may change. The HHV (High Heating Value) of the pre-cooling stage is more than other product because the component in that stage is heavy hydrocarbon base e.g. BTEX but it's not suitable to use the product as liquid fuel directly because there are other substance such styrene and VOC contained in this product. The reprocess of this product or blending with fuel oil for further application is more suitable than

disposal because the number of this product is quite large number, so the cost of transportable shall be expensive and the storage with the wrong handling procedure may be a new issue in disposal area.

Since the process of gas treatment is to compress the gas before sending gas to cryogenic process, therefore, the pressure of liquid product is 14 barg as well. At this pressure, gas or light gas shall be compressed in liquid product, once the pressure is release to atmospheric condition, only the expected product shall be kept as liquid phase in the product. Therefore, all liquid products must reduce the pressure before using. For the 1st stage product, H_2S shall release out from LPG portion. For 2nd stage product, the most of LPG shall release from liquid sulfur compound. Therefore, the monitoring of liquid sulfur must be considered as dangerous flammable substance. The 3rd stage substance, light hydrocarbon e.g. ethane shall release from the liquid CO_2. However, some H_2S may contaminate in the product as well, the monitoring is required for this product. After decreasing the pressure, some liquid product can be used as fuel or some lighter gas can be used as fuel gas e.g. lighter gas from 3rd stage product because the HHV of the liquid product is high enough for combustion.

3.4 Preliminary cost estimation and economic evaluation

According to the design process, the cost estimation base on the max capacity scenario (purge gas base on emergency flow capacity). Investment cost; CAPEX (Capital Expenditure) and OPEX (Operation Expenditure) are included in the model for payback period calculation also.

The assumption of cost estimation of process side is waste gas price and electricity price. The estimated price bases on the average current Thailand sale gas price for waste gas and electricity price.

Waste gas from each company shall be buy to gas treatment plant at rate = 10 THB/MMscf. All treated gas is assumed to produce as electricity and use internal for process operation. The rest of electricity shall be sold to PEA (Provincial Electricity Authority) at rate = 3 THB/kWh. In view of CAPEX, land cost and civil work are included in the calculation. The location of the process based on the worse scenario; there is no area for facilities installation and required land expansion into the sea.For OPEX, major cost is salary of company staffs. The maintenance cost is not too high because the system is designed as conventional technology and less of rotating equipment. So 10 MMTHB/yr is possible. From the cost estimation, the result of preliminary economic evaluation shows that the payback period of

normal flow case is more than 8 year and emergency flow case is only 1.32 year.

Table 4 Liquid product characteristic of Pre-cooling stage, $1^{st}LTS$, 2nd stage LTS and 3rd stage LTS for all scenarios.

Prod. type	Parameter	Unit	Scenario			
			Normal flow		Emergency flow	
			High Toxic	Low Toxic	High Toxic	Low Toxic
			Value	Value	Value	Value
Pre-cooling stage product	Flow rate	kg/h	136.9	97.43	1313.4	934.9
	Temperature	°C	4	4	4	4
	Pressure	Barg	14	14	14	14
	Density	kg/m³	738.6	681.3	2.684	681.5
	HC Dew Pt.	°C	119.8	126.3	120	126.3
	HHV	BTU/scf	3172.5	3210.1	3172.5	3210.1
1st stage product	Flow rate	kg/h	725.2	734.6	6955.1	7050
	Temperature	°C	-45	-45	-45	-45
	Pressure	Barg	14	14	14	14
	Density	kg/m3	652.1	633	1.827	633
	HC Dew Pt.	°C	52.17	52.52	52.18	52.52
	HHV	BTU/scf	74.96	2024.5	2011.9	2024.5
2nd stage product	Flow rate	kg/h	275.8	285.9	2646.62	2744
	Temperature	°C	-65	-65	-65	-65
	Pressure	Barg	14	14	14	14
	Density	kg/m3	632	627.7	1.509	627.7
	HC Dew Pt.	°C	3.112	2.691	3.111	2.691
	HHV	BTU/scf	1434.6	1439.7	1434.6	1439.7
	Wobbe Index	BTU/scf	1292.9	1300.7	1179.5	1300.7
3 rd stage product	Flow rate	kg/h	293.1	301.6	2813.1	2894
	Temperature	°C	-80	-80	-80	-80
	Pressure	Barg	14	14	14	14
	Density	kg/m3	666.4	667.1	1.419	667.1
	HC DewPt.	°C	-26.14	-26.47	-26.14	-26.47
	HHV	BTU/scf	1065.8	1060.7	1065.8	1060.7
	Wobbe Index	BTU/scf	990.4	985.8	903.6	985.8

When performing the sensitivity analysis on the treated gas flow rate variation (Table 6), the result shows the treated gas flow rate which can give the project return in 8 year should be more than 5 MMscfd or it means the feed of waste gas should be more than 10 MMscfd, approximately.

7 CONCLUSIONS

According to the process design in the study, toxic in gas can be removed to liquid form with nearly 100%. Moreover these liquid products can be used fuel for combustion as well. In some product, it must be taken care as waste material for further disposal handing. For the treated gas, the HHV and composition content is gas

is possible to utilize as fuel gas for combustion engine which is same as NGV. The advantage of this process for MTP is to centralize all emission in MTP area and handling with single source. With this concept is help to reduce the overall investment and the preliminary economic evaluation shows that the payback period of this project is possible in 8 years at 5.0 MMscfd. However, the actual number of company in MTP is 58 companies which are also 6 times, approximately, to this study. Therefore, the payback period on this project should be less than 8 years; however, in case of implementation, the detail study is also required for additional detail e.g. gas composition, by-product composition, etc.

Table 5 *Costestimation and total investment cost for process facility construction.*

Parameter	Normal Flow	Emergency Flow
Treated gas flow rate; MMscfd	1.12	10.78
HHV; BTU/scf	715.6	715.6
Mass density; kg/m3	0.784	0.784
SG (60/60)	0.654	0.654
Calculated Wobbe Index;BTU/scf	885.0	885.0
Calculated SG	0.641	0.641
Estimatedgenerated power; MW	3.98	38.16
Internal usage		
GT Plant-Blower; MW	0.03	0.33
GT Plant-BSC; MW	0.25	2.35
Desalination Plant-Pump; MW	0.15	0.15
Total internal usage; MW	0.43	2.83
Miscellaneous power; MW	1.0	1.0
Margin power; MW	1.0	1.0
Grand Total power usage; MW	2.43	4.83
Remain power for sale; MW	1.55	33.33
Benefit from power selling;MMTHB/yr	38.46	827.93
Waste gas purchasing cost from local company; MMTHB/yr	0.29	2.77
Benefit; MMTHB/yr	38.17	825.16
Estimated CAPEX; MMTHB		
Total equipment cost	706.72	706.72
Total Land cost	78.13	78.13
Total soil work cost	280.00	280.00
Total concrete cost	112.50	112.50
Total CAPEX	1,177.35	1,177.35
Margin 10%	117.73	117.73
Grand Total CAPEX	1,295.08	1,295.08
Estimated OPEX; THB/yr		
Employee salary	240.00	240.00
Maintenance cost	10.00	10.00
Miscellaneous	10.00	10.00
Total OPEX	260.00	260.00
Margin 10%	26.00	26.00
Grand Total OPEX	286.00	286.00

Table 6 *The sensitivity analysis with treated gas variation and payback period of gas treatment process.*

Product flow; MMscfd	Pay Back period; year
1.12	<8
2.00	<8
4.00	<8
4.50	<8
5.00	7.92
5.50	4.93
6.00	3.81
8.00	1.82
10.78	1.32

In view of emission, the problem of health from toxic in emission gas can be solved with the great result. However, the policy and regulation of emission control in Thailand must be changed to get more strictly and serious than the present such as emission tax implementation, etc. In addition, the health and safety of the surrounding area must be the first consideration before project sanction.

5. ACKNOWLEDGEMENTS

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