Feasibility of Cold Energy Applications in LNG Import Terminals

[1]Ranjan Saxena, [2]Rohit Nayek
[1]MBA Candidate, [2]MBA Candidate
[1]Department of Oil & Gas,
[1]University of Petroleum and Energy Studies, Dehradun, India

***Abstract*— Energy to do work exists by virtue of temperature gradient. The temperature gradient can exist when the temperature of a body is either high or low as compare to the surrounding temperature. The temperature gradient existing because of lower temperature of body than the surrounding is known as "Cold Energy". LNG Import terminals are constantly under pressure to operate at higher efficiency and cut down on operation cost. Thus, the LNG import terminals can capitalize on the availability of cold energy and new sources for generating revenues. The various application of cold energy are- space cooling, desalination, elastomer crushing, power generation, Inlet Air cooling for turbines and production of gases by cryogenic air separation.**

***Index Terms*—LNG, Cold Energy, Regasification, Power Generation, Cryogenic and Desalination**

I. INTRODUCTION

Energy to do work exists by virtue of temperature gradient. The temperature gradient can exist when the temperature of a body is either high or low as compare to the surrounding temperature. The temperature gradient existing because of lower temperature of body than the surrounding is known as "Cold Energy".

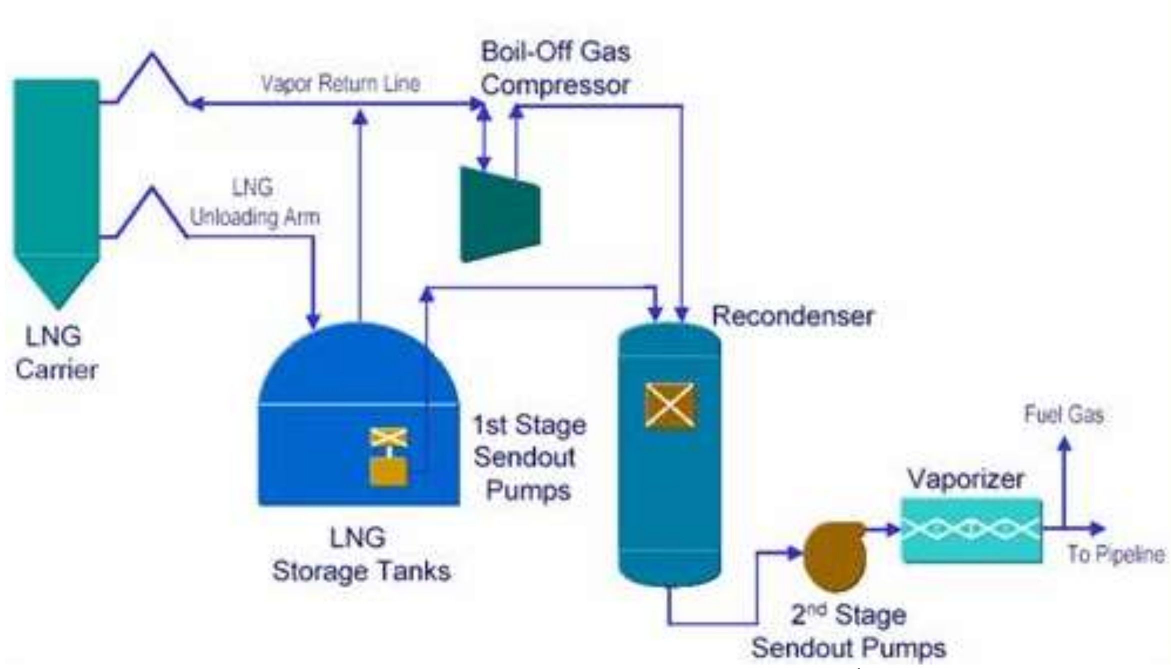


Figure1: Process Layout of LNG Import Terminal[1]

The natural gas which is transferred by Tankers is first liquefied at -161°C and supplied to the Liquefied Natural Gas (hereafter referred as LNG) Import Terminal, where it is regasified by using heat exchangers (ambient and combustion vaporizers). During this process of regasification of LNG, economically feasible amount of cold energy is liberated. The same opens new avenues for the optimum utilization of cold energy.

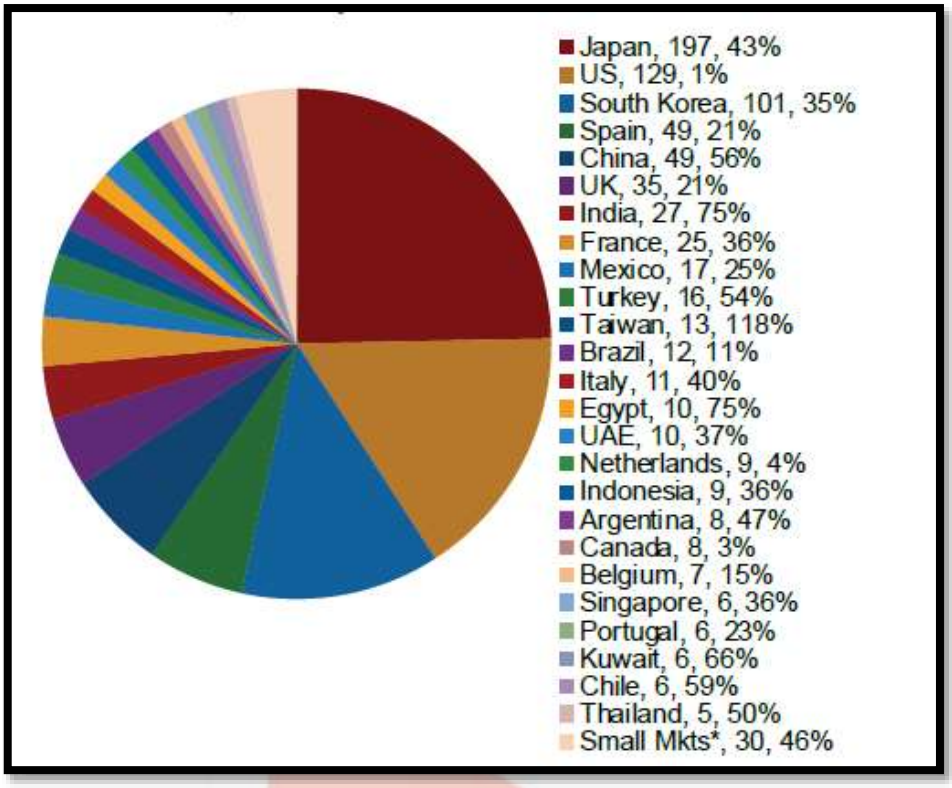


Figure2: LNG Regasification Capacity by Country (MTPA) and Utilization, January 2017 (Note: "Smaller Markets" includes Malaysia, Jordan, Pakistan, Poland, Greece, Lithuania, Israel, Dominican Republic, and Puerto Rico. Each of these markets had 4 MTPA or less of nominal capacity as of January 2017. Utilization figures are based on 2016 trade data. Sources: IHS Markit, IGU)

The global designed capacity of LNG Import Terminals is 795 MTPA[2]. The importing facilities grew by 22.4 MTPA, i, e; 3% growth (In 2016 over 2015). Japan remains to be the world's largest LNG importer with the total share of about 25% of the global regasification capacity with utilization rate of 43% in 2016. Poland became the new entrant in the regasification market. Russia (Kaliningrad), Bahrain and Philippines; all have regasification projects under construction in 2017. Taiwan imports approximately 13 MTPA of LNG and it proposes to expand its regasification capacity to 16 MTPA by the end of 2017. It remains to the only importer with more than 100% overall utilization. USA, has the lowest utilization rate (1%) due to the import demand off set by domestic shale gas production. Asian markets have most upcoming import terminals, countries like India are targeting 50 MTPA capacity in near future[3].

II. APPLICATIONS OF COLD ENERGY

LNG Import terminals are constantly under pressure to operate at higher efficiency and cut down on operation cost. Thus, the LNG import terminals can capitalize on the availability of cold energy and new sources for generating revenues. The various application of cold energy are- space cooling, desalination, elastomer crushing, power generation, Inlet Air cooling for turbines and production of gases by cryogenic air separation.

1. **Water Desalination (Cryo- Desalination)**

   Principle- Water desalination takes place naturally at polar icecaps, due to the fact that ice crystals are formed of pure water at certain sub-zero temperature range which separates the impurities from water. This freezing method utilises phase change of water from liquid to solid state. Theoretically, to freeze 1kg of water 80kcal of energy is required while to evaporate 1 kg of water 600kcal of energy is required.

Process-

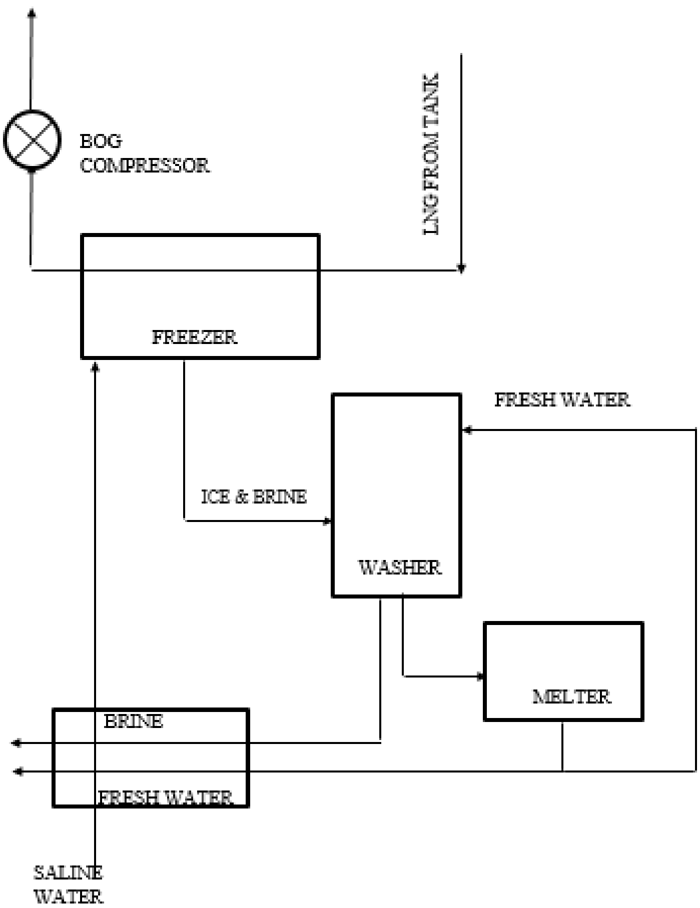


Figure3: Process Flow of Cryogenic Desalination

The process of cryogenic desalination involves three steps- freezing, washing and melting. In case of LNG Import Terminal; LNG can be utilised as refrigerant to freeze pure water. After freezing, the ice and brine solution is transferred to a washer with the help of gravity. The washer removes the brine by using fresh water. The ice is then transferred to Melter where it is melted at ambient temperature or by utilising the waste heat available in the plant. A small portion of fresh water is recirculated to the washer which is used to wash the pure water ice crystals. To enhance the efficiency of the process the saline feed water is cooled using heat exchanger by employing the cold brine solution and cold fresh water.

Benefits-

1. It reduces the problems like scale formation, fouling and corrosion, this provides the ease of material selection and process layout.
2. This process is insensitive to the changes in the concentration or the type of substances in the sea water.
3. This process is also suitable for Industrial and/or waste water which cannot be desalted by membrane process.

Countries which can utilise Cryo-Desalination-

China is projected to have water deficit of 201 Billion cubic metre by 2030[4]. The country has an increasing problem of pollution and has polluted many of the existing fresh water resources. It has designed capacity of 49 MTPA of LNG Import and currently utilises 56% of it. At current utilisation rate it has a potential of about 600 MW. Out of which 150 MW is usable looking at the global scenario of cold energy utilisation. This 150 MW is sufficient to produce approximately 1600 kg of water per hour. This is enough to suffice potable water demand of a community of 10,000 people (considering 3ltr water consumption per person).

Taiwan has the highest utilisation rate of 118%. It can utilise the cold energy to suffice the potable water demand of 5000 people. Its higher utilisation gives it an added advantage[5].

Egypt currently has a water deficit of 7 billion cubic metre. It is projected that by the year 2025 it will run out of water[6]. It is also predicted that Egypt will have spurt population growth till 2025. At current capacity and utilisation rate it can provide potable water for 3000 people.

2. Power Generation

Working principle and process-

At LNG Import terminals where the heat exchanging medium are gases; such as propane. The gaseous propane exchanges heat with the LNG and vaporises it. On exchanging heat with LNG, the propane liquefies. The liquefied propane is pumped to intermediate heating medium exchanger (IHM) where it is vaporised using sea water. Vaporised propane is fed to the gas turbine which generates power and it expands and heats it up to be again recirculated to LNG vaporiser. The vaporised natural gas is still at 0°C which is heated up further by exchanging heat with sea water.

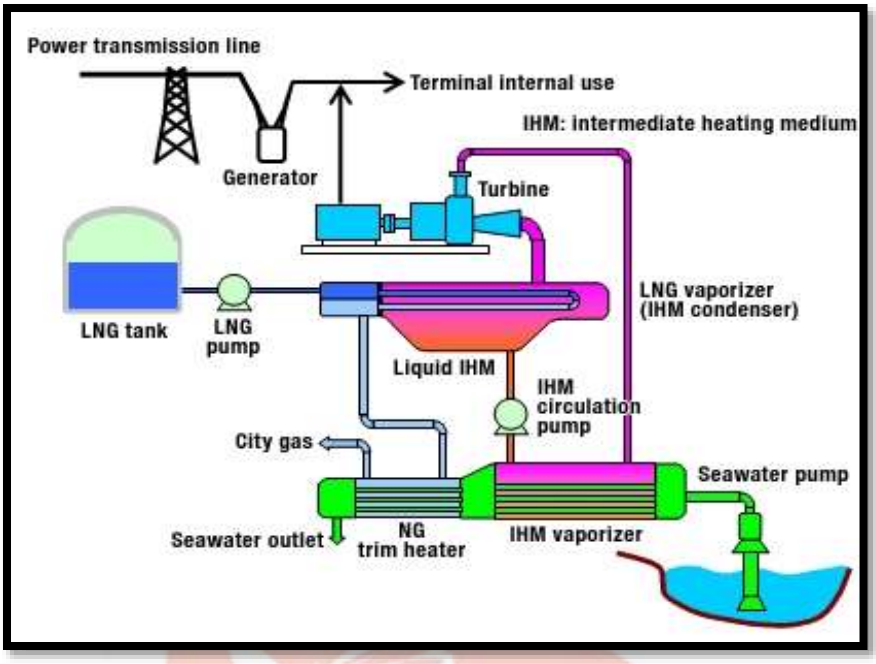


Figure4: Cryogenic Power generation using Rankine Cycle[7]

Benefits of Rankine cycle-

In the process of regasifying LNG at import terminal, cold energy is released from vaporisers can be utilised to generate power using Organic Rankine Cycle which can aid to the internal power consumption as captive and can be a source of revenue if it's feasible to sell the generated power to grid or a nearby industry.

i. Recovers the largest amount of heat with minimized losses.

ii. Compact Coil wound Heat Exchanger design results in easier evaporation process compared to conventional design.

iii. Ease of Operational Control. No risk of ingress liquid inside the turbine.

iv. High pressure operation reduces frame size of the turbine.

v. The source of heat required for Organic Rankine cycle is available for free, thus this falls in category of renewable energy.

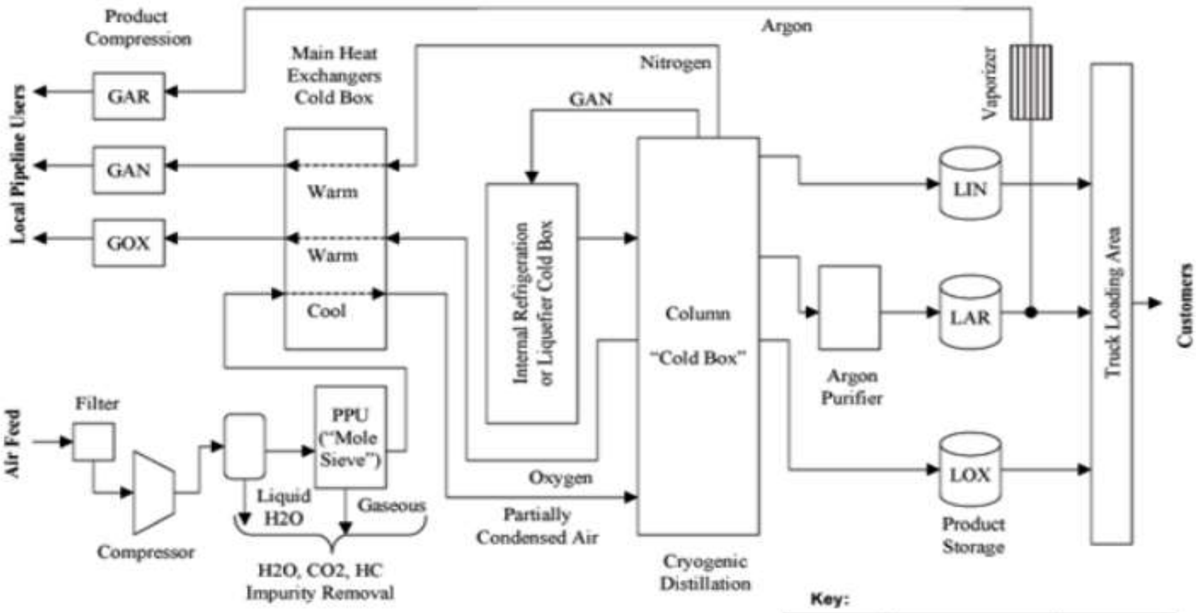
vi. The carbon-di-oxide generated by per kWh is 0.93 Kg by coal powered in India. Thus, every Megawatt of electricity generated by Organic Rankine Cycle will offset about 900 kg of Carbon-di-Oxide off the atmosphere.

3. Cryogenic Air Separation

Principle- Cryogenic separation of air is widely used process for medium to large scale plants. The separation is based on the fact that all the components of air (Nitrogen-78.08%, Oxygen- 20.95%, Argon- 0.93% and Other gases-0.04%) have different liquefaction temperatures thus can be separated out by freezing to their liquefaction temperatures.

Gases	Liquefaction Temp. (°C)
Oxygen	-182.95
Nitrogen	-195.79
Carbon Dioxide	-78.5
Argon	-186

Process-



Gaseous	Product	Liquid
GAN	Nitrogen	LIN
GAR	Argon	LAR
GOX	Oxygen	LOX
CO2	Carbon Dioxide	-
H2O	Water	H2O
HC	Hydrocarbons	-

Figure 5: Process flow of Cryogenic Air Separation[8]

Step 1- Compression of Air- Ambient air is drawn, filtered and compressed to 6 bar by a single stage compressor.

Step 2- Precooling of Air- For separation of components of air. It must be liquefied at an extremely low temperature, for achieving this the compressed air is precooled with chilled water. LNG can be utilised for chilling the water. If the LNG Import terminal uses Shell Tube Vaporiser (STV), the drain water from the air heater can also be used for the same.

Step 3- Purification of Air- By Using molecular sieve, carbon di oxide and water vapour can be removed. Zeolites, Porous Glass, Silicon Dioxide and Mesoporous silica can be used as molecular sieve which can be used to remove unwanted components.

Step 4- Cooling of Air- The purified air in the main heat exchanger is cooled down to -175°C. This process is carried out in two stages at LNG Import Terminal. In the first stage LNG is used as refrigerant to decrease the temperature of air. In the second stage, the temperature of air is further lowered to -175°C.

Step 5- Separation of Air- Oxygen and Nitrogen are separated capitalising on the fact that both have different boiling point. Oxygen liquefies at -183°C and Nitrogen liquefies at -196°C. Due to continuous evaporation and condensation produces pure nitrogen at top and pure oxygen at bottom.

Step 6- Withdrawal and Storage- Gaseous nitrogen and oxygen are fed to pipelines to transport to various buyers. The liquid nitrogen and oxygen can be bottled and supplied as well.

The obtained nitrogen is used in LNG Terminal for purging and providing inert atmosphere. The liquid nitrogen can be supplied to refineries, petrochemical plants, marine tankers and tyre industry. Cryogenic grinding is also utilised to produce medicines, spices, plastics and pigments. Many of the food industry utilise liquid nitrogen as a freezing agent as it is so cold that it often improves the quality of frozen food products.[8]

4. **Inlet Air Cooling (IAC)**

Principle- Inlet Air Cooling (IAC) increases power output because the cooled inlet air has higher density and thus, for a fixed volumetric flow a larger mass enters the air compressor of gas turbine. For every (°C) of temperature drop of the inlet air the power output from the GTG is increased by approximately 0.5%.

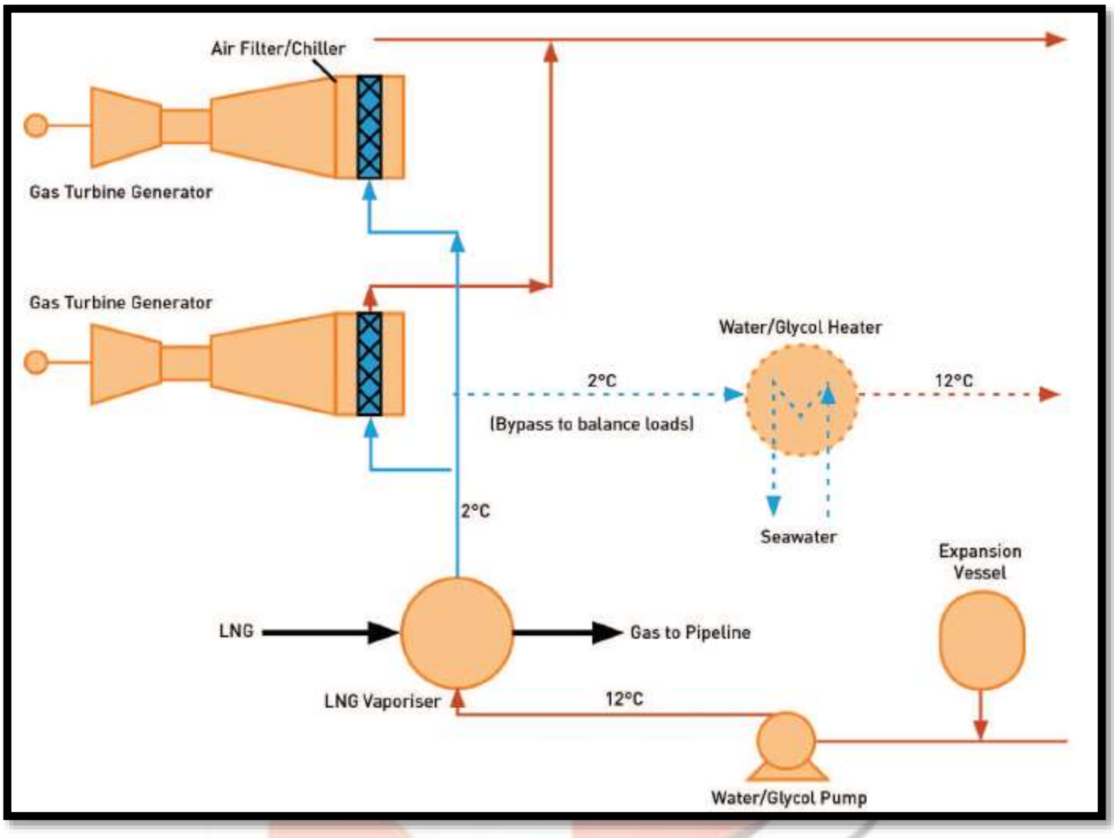


Figure 6: Process Flow of IAC Integration[9]

The extra power generated by IAC system is an additional cost head for both LNG import terminal and power plant. The economics of the integration will depend upon the cost of power generated. If the additional power generated can be sold, then it will be cheaper to produce then installing dedicated standalone equipment to generate the same power. During summer when the ambient temperature is high and humidity is low the largest power benefit happens.

III. CONCLUSION

In this era of scarce resources, it is important to harness all possible sources of energy. Cold Energy utilization is a step towards higher energy recovery, this contributes to the environment, economy and community. Every application of cold energy might not be feasible for every location. Thus, it is important to evaluate all the possible avenues.

REFERENCES

[1] Process Layout of LNG Import Terminal, *http://www.epd.gov.hk/eia/register/report/eiareport/eia_1252006/html/eiareport/Part1/Sec1_3_v2.html*
[2] IGU World LNG Report — 2017 Edition
[3] *http://www.lngworldnews.com/report-india-targets-50-mtpa-lng-import-capacity/*
[4] China faces water deficit, *www.chinadaily.com.cn/china/2010- 04/27/content_9777213-China faces water deficit*
[5] *www.bbc.com/news/world-asia-32200687- Taiwan rations water amid draught*
[6] Egypt's water crisis- Recipe for disaster, *www.ecomena.org/Egypt-water/- Egypt's water crisis- Recipe for disaster*
[7] Cryogenic power generation recovering LNG's cryogenic energy, *https://www.osakagas.co.jp/en/rd/technical/1198907_6995.html*
[8] Air Separation, *http://kchbi.chtf.stuba.sk/ODAOld/doc/Diploma%20work%20of%20Shershah%20Amarkhail.pdf.*
[9] LNG Journal March 2012-Article, LNG Terminal cold energy Integration opportunities offered by contractors.