

LNG IMPORT FACILITY CONSISTING OF EXISTING LNG MOSS TYPE VESSEL INTO FLOATING TERMINAL WITH REGASIFICATION UNIT

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Abstract – In this paper we want to present you a project that can boost both transport and economy sector of Central European countries by introducing a less expensive fuel, more environmental friendly and with a good perspective in the future. The paper is structured in six parts. In the first part is evoked the importance of the topic and basic definitions. In the second part are presented the Floating Storage and Regasification Unit(FSRU) particulars for LNG. In part three are presented the conversion overview. In part four are presented aspects of regasification process and forward machinery space. In part five we present operations aspects. In the last part we present LNG import terminal Constanta project like a solution for integration into the national energy system .

Keywords: conversion, ship, terminal, LNG, integration, energy system, regasification.

1. INTRODUCTION

A new technology has developed the LNG(liquefied natural gas) companies to converted LNG carrier for floating storage and regasification unit(FSRU).

The FSRU is now the first floating LNG regasification terminal based on conversion of an existing LNG carrier. The FSRU must receive LNG from offloading LNG carriers, and the onboard regasification system will provide gas send-out through flexible risers and pipeline to shore. The FSRU will be designed in compliance with DNV class rules and relevant international standards.

The LNG terminal is a steel mono hull with LNG tanks arranged in the middle, regasification plant in the forward end (port side) and crew facilities, control room and utility machinery in the aft end(Figure1). The terminal is permanently moored to seabed with a turret mooring arrangement mounted fwd(front-wheel-drive), and the gas send-out line is arranged through the turret down to the seabed and to shore via a seabed pipeline.

The LNG tankers offloading to the floating terminal will be moored in a side-by-side configuration. Berthing, loading and de-berthing will take approximately 24 hours. Process and utility systems have been chosen and designed for simplicity and least retrofit as well as for ease of operation and maintenance.

LNG regasification project key components are:

- Marine facilities; offshore gas unloading jetty, mooring dolphins and breasting dolphins
- FSRU – permanently moored alongside the jetty
- Export gas pipeline (approximately 1.2km) running subsea from the jetty to the onshore gas distribution network including a gas metering station
- LNG carriers will moor alongside the FSRU and unload LNG into the unit for storage prior to regasification and export to the onshore gas distribution pipeline.



Fig. 1. Location and mooring of FSRU

2. FLOATING STORAGE AND REGASIFICATION UNIT PARTICULARS

The FSRU will be permanently moored approximately 600m from port side and crew facilities.

FSRU functional requirements are:

- **Gas send out rates:**

	Nominal	
	400MMscf/d (~LNG:	
	790m ³ /h or ~3.1MMtons/yr)	
	Peak	
	480MMscf/d (~LNG:	
	940m ³ /h	or
~3.8MMtons/yr)		
	Minimum	
	100MMscf/d (~LNG:	
	200m ³ /h	or
~0.8MMtons/yr)		
- **Gas send out pressure:**

	Maximum-66	barg
	Minimum-30	barg
	Nominal -60	barg

- **MSO Compressor:** 4500kg/hr (4,8MMscfd ~LNG: 10m³/h), 45bar.
- (1MMscf/d-1 million cubic foot/day = 28,316.847 cubic meter/day[13]; BarG(Gauge Pressure)-pressure reading relative to current atmospheric pressure. BarA(Absolute Pressure)-pressure reading relative to absolute vacuum) [14].
- **Gas temperature** above 0° C at 25 barg at the Gas Control Station
- **LNG storage capacity** (unchanged) 125,000m³
- **LNG loading capacity**(unchanged) 10,000m³/hr
- **Ship's mooring** designed to accommodate the FSRU permanently moored with LNG carriers ranging from 77,710 – 217,000m³ moored alongside

The components of FSRU are presented in the Figure 2[7],[8],[9].

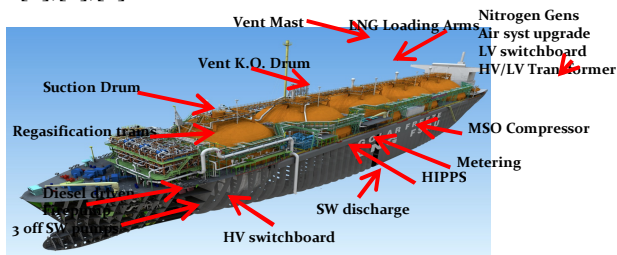


Figure 2. Components of FSRU

FSRU description:

- **Turret mooring-** The turret to be connected in front of the bow and causes a need for modification of the bow of the ship. The turret shall be configured to provide an essential non-rotating platform for supporting the anchor lines, flexible risers and associated control/service lines. The turret shall be equipped with a turntable which allows 360° continuous rotation of the FSRU[9].
- **Side-by-side mooring system** - The terminal shall allow safe berthing of standard LNG carriers. There is no need for modification of the berthed LNG carriers. The side-by-side mooring system shall consist of a number of fenders (typically six) and a suitable number of mooring lines. The FSRU must be equipped with quick release hooks with adjustable release load, and roller fairleads as required. The terminal must be fitted with an azimuth thruster, for control of the terminal during LNG carrier berthing/de-berthing[9].
- **Loading arms** - The FSRU will be provided with standard loading arms to allow side-by-side transfer of LNG and vapor return. The FSRU shall be equipped with three 16 inch LNG loading arms; two for liquid and one for vapor return. The loading arms will be quite similar to the type that is used on onshore terminals, however modified to account for relative motions between carrier and FSRU. The FSRU will also be fitted with equipment for guiding the arms onto the carrier's connection flanges. This pre-coupling guide operation will be necessary to compensate for relative motion during coupling when the relative motion exceeds +/- 0.5m[10].
- **LNG regasification-** LNG is sent from the tanks to the regasification skid fwd. The regasification skid essentially comprises booster pumps and vaporizers. The booster pumps will increase the pressure to about

90 bar, before the high pressure LNG is vaporized, after which the gas passes a fiscal metering unit and is sent to the sub sea pipeline via the gas swivel and flexible risers. The regasification system shall have the following key design data: maximum gas send-out pressure- 85 bar; maximum gas send-out flow-240 tonnes/hr;gas send-out temperature (min.)- 0 °C[10].

- **Bog handling** - Maximum boil-off from the storage tanks is 0.25%/day, as per original design requirements. The boil-off gas is removed from the tanks and used as fuel for steam generation in the FSRU boilers. The terminal will operate at a higher pressure than the offloading LNG carriers, and thus avoiding excessive BOG handling equipment[10].
- **Onboard power generation** - The existing equipment shall be used for onboard power generation. There are two existing steam driven turbo generators onboard, and one more of similar type will be installed. In addition there is a diesel driven generator as well as a diesel driven emergency generator. The boilers will run on natural gas only, partly covered by suction of BOG from the vapor header, and partly by additional fuel supplied by the LNG vaporizers[10].

3. CONVERSION OVERVIEW

3.1. Conversion overview

Main LNG and Regas items are the following :

- Installation of a regasification plant on FWD deck
- Installation of suction drum on FWD deck.
- Replacement of one of the two cargo pumps in 3 storage tanks with new pumps with capacity matching the FSRU send-out capacity
- Installation of 2 LNG loading and 1 Vapour return arms in place of STB loading station.
- New gas vent knock out drum and vent mast on tank 2
- Minimum Send Out Compressor
- Gas metering station
- Ship to shore and ship to ship link.

3.2. Main new utility systems

These are:

- 2x 100% Nitrogen Generators and driers in engine room
- One new control air compressor and driers in engine room
- Replacing main switchboard in engine control room
- New 6.6kV/440V transformer in engine room
- New Emerson control system for existing ship's- and utility systems in cargo control room.
- Fire and Gas system upgrade
- New FWD machinery space for:3 new 6MW TG's;3 Seawater pumps, 4400m³/h; Diesel driven Firewater pump -1200m³/h; utilities.

3.3. Hydro-structures and adjacent constructions

Besides the FSRU there are also fixed structures that consists in :

1. Jetty

2. Mooring dolphins
3. Truck Loading platform
4. Pipeline for LNG
5. Pipeline for natural Gas

The LNG Carriers that supply the LNG will moor alongside the jetty and within 20 hours will fully unload a charging up to 125.000 cm of LNG. The FSRU will be moored permanently to the jetty through the mooring dolphins for its useful life (up to 30 years). The pipeline for LNG will be build from the FSRU to the truck loading platform onshore. The pipeline for natural gas will be built up to the connection to the national gas network(Figure 3).

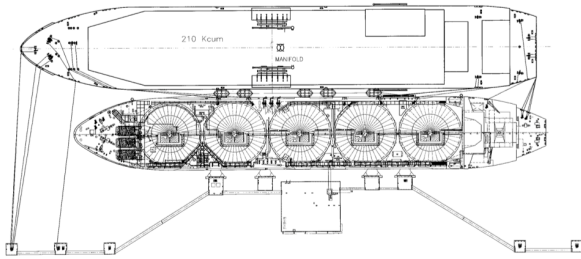


Figure 3. Hydro-structures and adjacent constructions

For transiting the LNG towards the central European countries a LNG transport barge will be needed. In order to determine the exact capacity of the barge an elaborated study will be issued to predict the demand in LNG upstream on Danube. The barge will load the necessary quantity of LNG and deliver it upstream Danube up to Germany(Figure 4).

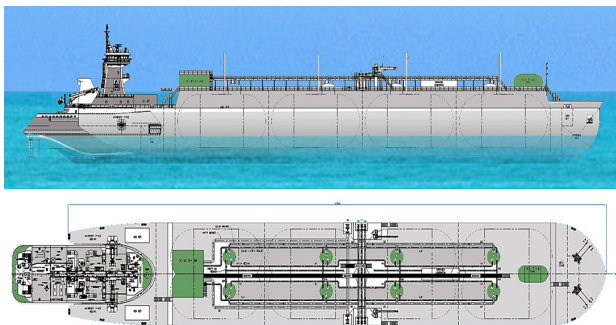


Fig. 4. LNG transport barge

4. REGASIFICATION-PROCESS OVERVIEW

The regasification equipment is arranged in parallel trains, assembled as separate modules, or the whole plant can be built in one module to fit to the available space. Each train consists of one or two LNG booster pumps and one shell and tube heat exchanger.

The booster pumps are fed by a common LNG buffer tank. The regasification system can be designed for open or closed loop operation, and the heating medium for LNG vaporization can either be sea water or steam. The system can be designed to match any requirements to flow and pressure. The regasification diagram is presented in Figure 5.

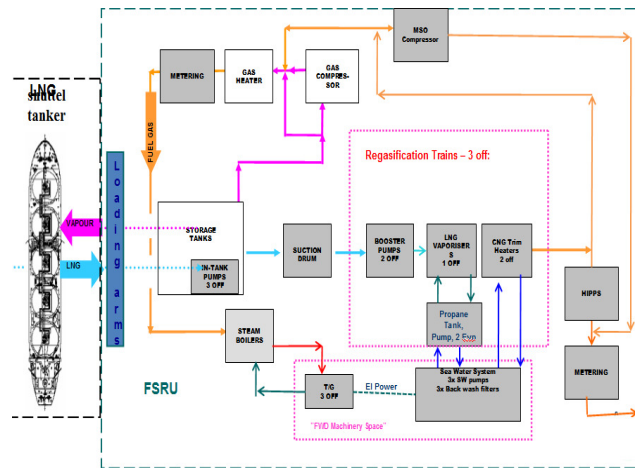


Figure 5. The regasification diagram

4.1. LNG storage as FSRU

Cargo tank operating pressure (vapour pressure):

- Normal: 0.2 - 0.5 barG
- SRV set point: 0.7 barG

Hold Space pressure:

- Pressure set point relative to atmosphere is unchanged
- Hold space pressure set point relative to cargo tank pressure is unchanged.

In-tank Pump configuration :

- Cargo Tank 1, 2 and 3 with one new 500m³/h LNG transfer pump installed in place of one of the existing LNG cargo transfer pumps.
- No change to pumps in Cargo Tank 4 and 5(Figure 6).

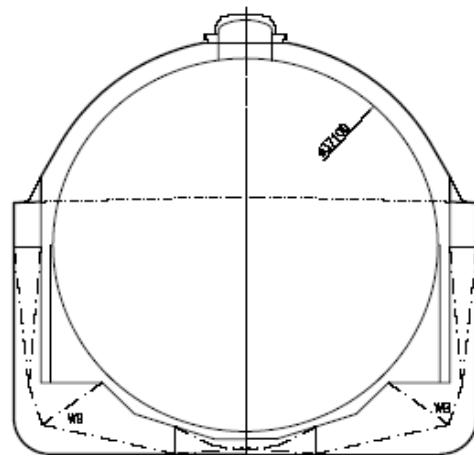


Fig. 6. LNG storage as FSRU

4.2. Regasification Plant – In-Tank Pump

Purpose: Supply of LNG to the booster pump suction drum via a new independent liquid header.

Location: Replaces one cargo pump in tanks 1, 2 and 3(Figure 7).

Redundancy: 3 x 50%, but existing cargo pumps may also be used.

Rated Flow : 500m³.

Rated head: 150m.

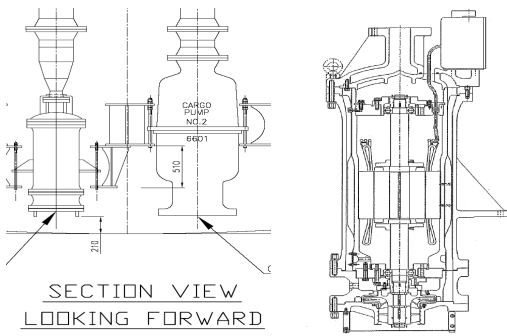


Fig. 7. Regasification plant-in tank pump

4.3. Regasification plant- Booster Pumps Suction Drum

Purpose: Acts as a buffer volume during start-up, unexpected shut downs and capacity changes Heat sink for the booster pumps during start-up.

Location: On fwd deck, stbd of regas modules.

Technical Data: Volume 14m³, Design Pressure 10barg(Figure 8).

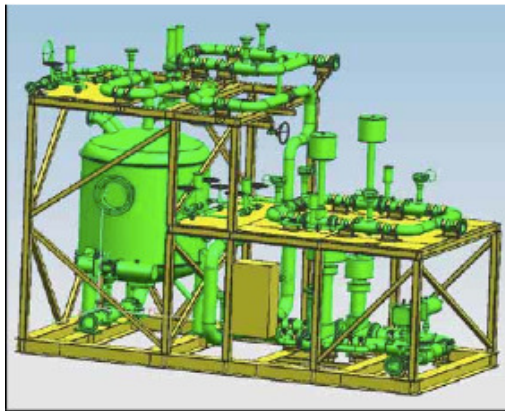


Fig. 8. Booster Pumps Suction Drum

4.4. Regasification Trains

The following equipment is essential for each of the 3 regasification trains: 2x50% *Booster pumps*, rated to 245m³/h each at head 1660m; 1 *off LNG vaporizer*, Printed Circuit Heat Exchanger – Propane, LNG heated from (-160)°C to approx (-15)°C; 2x100% *Trim heaters*, Shell / Tube -sea water; *Propane Loop:* 1xPropane tank, 5.9m³, 1xPropane circulation pump, 820m³/h ,head 58 m, 2xPropane evaporators, semi welded titanium plates(Figure 9).



Fig. 9. Regasification trains

4.4. Regasification process

The simplified process of regasification is presented in Figure 10.

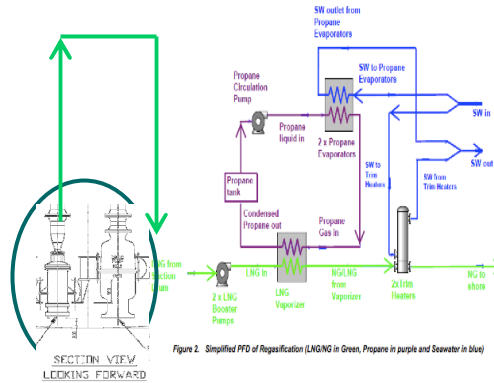


Figure 2. Simplified PFD of Regasification (LNG in Green, Propane in purple and Seawater in blue)

Fig. 10. Regasification process

4.5. Forward Machinery Space

The components of machinery space are:*seawater cooling system*(2 seachests and hypochlorite system, 3 SW pumps 4400 m³/h each, 6.6kV motors with SW cooling); *3 Shinko TG's 6MW each*(Power supply for SW pumps, regas and ship);*freshwater cooling system*(2 FW cooling pumps-350m³/h each); *Diesel Firewater Pump, 1200m³/h* (For new spray and firewater system); *Electrical equipment room*(HV and LV distribution boards); *ventilation, bilge and CO₂ firefighting*(Figure 11).

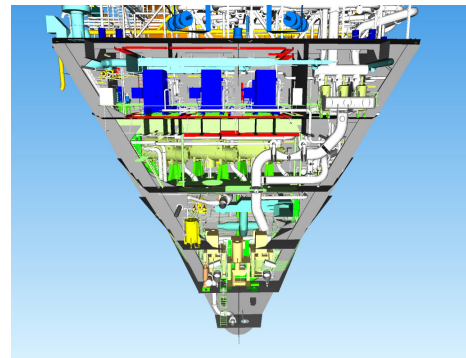


Fig. 11. The components of machinery space

5. OPERATIONS ASPECTS

- a)The FSRU will be permanently moored, thus turbine will be blanked off and preserved (dehumidified).
 - b)The FSRU is intended to supply gas to Constanta during the summer months (6 – 8 months/year).
 - c)Two winter modes; cold or warm . The FSRU shall be able to take spot LNG also in winter months, but time will be allowed for cooling down when/if required.
- Key environmental considerations for operations: no excessive heat dumping – MSO compressor installed to export BOG;max 9° C ΔT from seawater inlet to

seawater discharge;no overboard bilge etc (pump to holding tank for barge transfer).

6. LNG IMPORT TERMINAL IN CONSTANTA

The project consists in building a LNG import terminal in Constanta, harbor from where the merchandise (LNG in this situation) can easily be delivered on Danube's basin and reach central European countries.

Up to now there was little or none import and use of LNG in countries like: Germany, Austria, Slovakia, Hungary, Serbia, Bulgaria, unlike other European countries that have over 20 Years of using LNG. The reason these countries didn't profit from the benefits of LNG usage is that there was little access to import LNG and if there was, it was very expensive. In order to deliver LNG to Austria a railway or truck transport should have been organized in special containers from the LNG terminal near a sea to Austria.

Through the terminal built in Constanta specialized vessels could transport LNG at lower prices to all countries upstream Danube.

Advantages:

- o Cost reduction for European transport sector
- o Maritime access in Constanta port
- o Strategic location: Danube inland waterway access .

The project is in accordance with EUROPEAN TRANSPORT STRATEGY TEN-T INTEGRATION (AXIS NO. 18) and is built in the context of similar functional LNG terminals in EU: SPAIN (6), FRANCE (3), UNITED KINGDOM (3), ITALY (2), PORTUGAL (1), BELGIUM (1), SWEDEN (1), GREECE (1). As we can observe, Constanta LNG terminal is the only one in the Black sea, and except the one in Greece, the only one in Central-Eastern Europe[17,18,19,20](Figure 12).

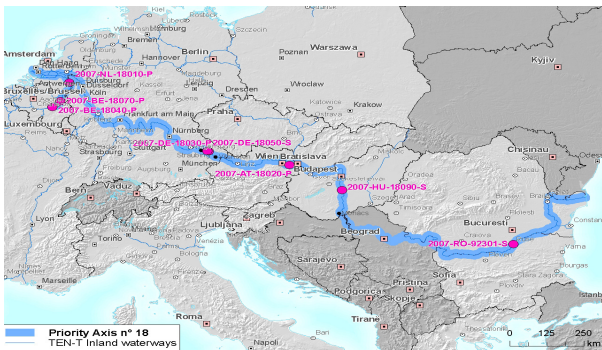


Fig. 12. The European transport strategy TEN-T integration

The objectives of this project are:

GENERAL: Extension of energy sources for a sustainable European transport.

SPECIFIC: Improved European water transport by means of cost reduction; Complementary energy source for an efficient European transport.

Why LNG?

- LNG is an efficient fuel for many means of transport (e.g.. used as barge/vessel, truck or locomotive fuel);
- LNG is less expensive than other Petrol fuels

- LNG is GREENER than other petrol fuels , this means cleaner environment ;
- Libya and Algeria closest existing LNG Export terminals.

With a conversion of the engine, any vehicle can function on LNG. There are developed trucks, locomotives, vessels and even public transportation busses that run on LNG.

By turning towards LNG powered engines a massive cost reduction is occurred as the price for 1.8 l of LNG (0.61 euro) is less with more than 40% than the price for 1 l of diesel (1.46 euro).

Burning LNG is not so pollutant as burning conventional gas: no SO_x, Particle emissions, insignificant NO_x emissions and lower CO₂ emissions, in this way highlighting the contribution of LNG usage to a sustainable environment.

LNG can be imported from Libya and Algeria, countries from which the vessels reach relatively fast Constanta Harbor through Bosphorus.

The main project component, for *Floating Storage Regasification Unit* (FSRU) consists in a special type of ship which is used for LNG transfer (LNG carrier) and a vital component required while transiting and transferring Liquefied Natural Gas (LNG) through the oceanic channels. This ship is converted to an independent FSRU. The conversion consists mainly in installing the regasification unit, the mooring system, loading arms, regasification system and pipes.

The FSRU will be moored to a jetty and fixed in order not to move.

Its function is to take the cargo from the LNG carriers, store it in special LNG tanks at -162^o C. From here it can:

1. load the LNG to smaller vessels for transport upstream Danube, or
2. load LNG through the LNG pipeline towards the loading platform in order to deliver LNG via road/rail way, or
3. pushes LNG into the regasification unit and than through the pipeline in the national gas network.

6.1. Project components' costs

The project components costs are estimated to reach a total amount of 175.525.000 euro but can vary depending on the capacities and structure of the investment. After the elaboration of the feasibility study a more accurate cost will be provided (Table 1).

Table 1. Project components' costs

No.	Item	Value (euro)	Value (roni)
1.	Project preparation- Fesiability study and technical details	875,000.00	3816,850.00
2.	FSRU	132,000,000.00	575,678,400.00

3.	Marine facilities: mooring facilities- mooring dolphins, jetty etc-, Jetty and terminal access from land; trucks loading platform	25,000,000.00	109,030,000.00
4.	Pipe network: LNG and natural gas, other necessary pipelines	10,000,000.00	43,612,000.00
5.	LNG transport barge	8,000,000.00	34,889,600.00
TOTAL		175,875,000.00	767,026,050.00

- LNG is cost reduction
- Open a door to large scale LNG imports through Constanta
- A project to introduce LNG to central Europe at low prices
- A way for developing a sustainable environment.

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5. CONCLUSION

This project is of European importance and helps develop not only one but many other countries because:

- LNG is a much cleaner form of fuel that can power industries, transports and also can be converted into natural gas for domestic consumption
- LNG is less expensive than conventional fuels, half the price of diesel
- Central and eastern Europe does not have acces to LNG import, or has limited access to very expensive LNG due to a long chain of intermediaries and limited transport capacities that hold back the possibility of developing this industry
- By building an LNG Terminal in Constanta, Romania, LNG can be delivered upstream Danube to Linz or even Nuremberg. Constanta is the door for large scale imports (from the sea) to Central Europe
- By using LNG instead of traditional fuels economies of scale can be created from a micro persepctive (lower utilities invoices) to a macro scale perspective (environmental qulity improvement and lower operation prices in industries and transports).
- LNG is cleaner energy