Three innovative ways to reduce LNG carriers and terminals environmental footprint

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INTRODUCTION

Environmental and economical pressure is growing on the whole LNG industry and, especially LNG shipping.

To meet the need to further reduce LNG carriers and terminals environmental footprints, three innovations are investigated :

1) the replacement of nitrogen by argon in the insulation spaces of GTT (Gaz Transport et Technigaz) NO Type membrane LNGCs ,taking advantage of the lower thermal conductivity of this gas, to either :

- reduce, on existing vessels, equipped with re liquefaction plants, by 10 % the natural BOG rate and reduce the corresponding power consumption and emissions;
- reduce, on existing vessels, equipped with dual fuel power plants, by 10 % the natural BOG rate and reduce their BOG fuel consumption and emission by both :
  - operating at a lower nominal speed when using BOG as fuel;
  - reducing their BOG flaring during waiting time or low speed operations.

2) the implementation of a ship to shore "PLUG" high voltage and high power interface (typically 8 MW / 6600 V) in order to use local network power supply to meet the vessel power needs when loading or unloading, taking advantage of potentially « greener » and less expansive on shore energy sources such as wind power than the vessel on board generator sets…

3) the use, on the return voyage, whenever the LNG importing country has sufficient supplies, of the vessel ballast tanks to bring back to the LNG exporting country fresh water instead of sea ballast water, reducing this way :

the risk of transport of unwanted species from one ocean to the other ;

the emissions of desalinisation plant in arid LNG exporting countries.

The potential benefits of each of these innovations on the global environmental footprint, even outside the LNG carriers and terminal domain , are considered and documented in this paper, taking as a special case their potential implementation on Qatari LNGCs..

REPLACEMENT OF NITROGEN BY ARGON IN THE INSULATION SPACES OF NO TYPE MEMBRANE LNGCS

The interest of replacing nitrogen by argon in the insulation spaces of membrane LNGCs, has been first mentioned and presented at the 2005 Doha Natural Gas Conference, see reference 1. This paper not only confirmed the feasibility but also identified the potential gains which could be provided by this patented innovation, from both environmental and economical point of view.

To demonstrate the gains, specific test have been performed at the Sintef thermal research laboratory in Norway (as part of the NG2shipI/F European research initiative) on a perlite filled box (used for GTT NO 96 cargo containment system), under argon and nitrogen atmosphere.

These tests) demonstrated that gains were around 10 %.

Based on this, ***New Generation, Natural Gas,Natural Growth*** (***NG3***), a start up company created to provide innovative equipments improving the economical and environmental performances of LNG carriers and terminals, is developing an Argon Storage and Separation Unit (ASSU) which would allow to flush the insulation spaces in closed cycle (see figure 1) in order to reduce drastically the argon consumption and the associated Capex (large liquefied argon storage tank) and Opex (cost of the argon replacement in an open cycle).

In this figure, one will note that, beyond the ASSU itself, its implementation on board has a limited impact on the vessel cargo containment system :

- no modification are required on the cargo containment membrane system;
- the same network is used to feed the insulation spaces with inert gas, which may be either argon coming from the ASSU either, as a safety back up , nitrogen coming from the existing on board nitrogen generators;
- the existing cargo room vacuum pumps can be used to empty the insulation spaces before filling them with argon;
- only extra piping are required to collect the contaminated argon back towards the ASSU to recycle it.

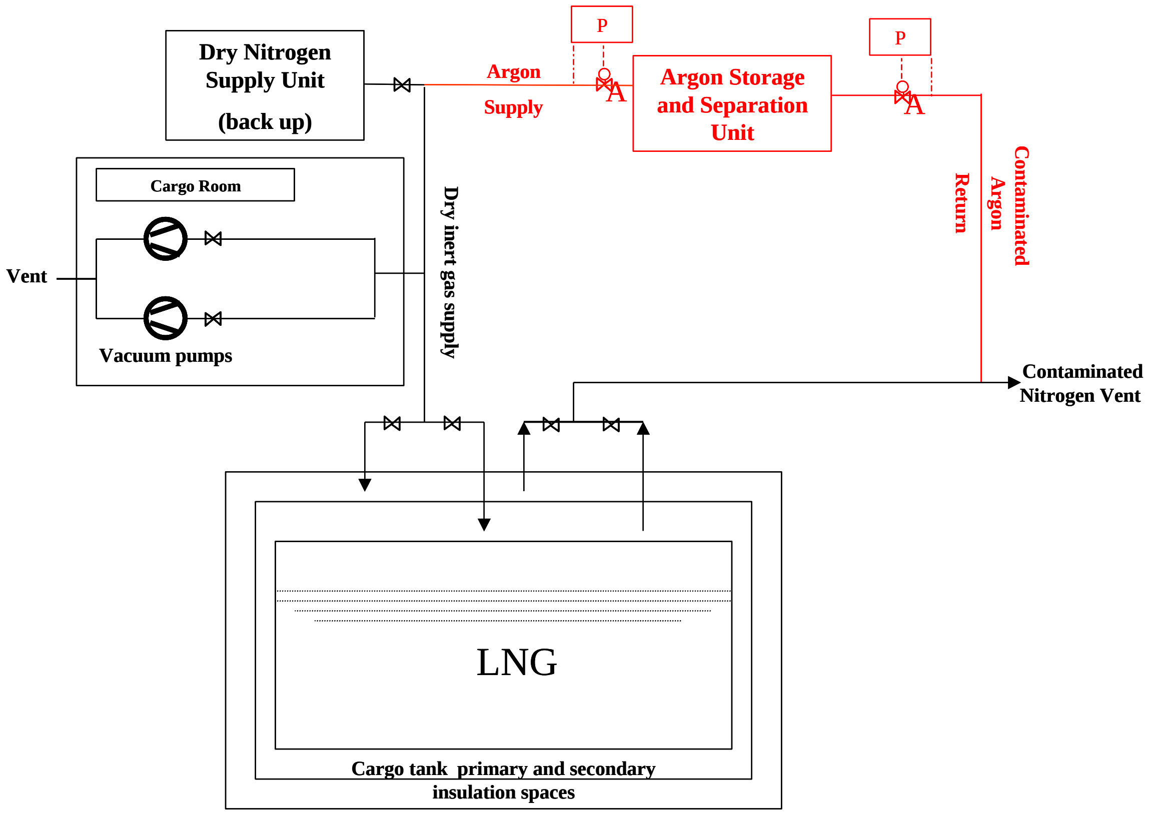

Figure 1 : Typical Implementation of the ASSU Argon closed loop system

Focusing on NO type membrane, LNGCs used to export LNG from Qatar, two strategies can be implemented to take benefit of this 10 % the natural BOG rate reduction[1]:

- reduce operating speed , flaring and increase unloaded LNG quantities in case of steam of DF/DE driven carriers ;
- reduce re liquefaction plant power consumption and related emissions in case of the Qflex-Qmax carriers.

Table 1 gives an example of spread sheet calculation estimating the environmental and ***economical*** gain one may expect from this innovation for a typical Dual fuel LNG.

Hypothesis					
LNG value	400	$/ton			
	180	$/m3	LNG density	0,45	tons/m3
Nominal BOG rate	0,0015	/day			
Nominal loaded Speed	19,5	knots			
BOG reduction	10	%			
Reduced BOG rate	0,00135	%/day			
Modified loaded Nominal spe	18,8	knots			
Nominal Ballast speed	19,5	knots			
Route Length	2 000	nautical miles			
Cargo tank capacity	150 000	m3			
Nominal transit duration	8,5	days			
Loading/unloading periods	2,0	days			
Flaring periods	0,5	days			
Rotation duration	10,5	days			
Modified transit duration	8,7	days			
Modified rotation duration	10,7	days			
Operating days	350	days/year			
Number of rotations		33,2	per year		
Modified number of rotations		32,7	per year		
Nominal Unloaded LNG		4 910 165	m3/year		
Modified unloaded LNG		4 915 893	m3/year		
Extra Unloaded LNG		**5 729**	**m3**		
Extra Unloaded LNG value		1 031 135	$/year/vessel		
LNG shipping efficiency improvement		0,12	%		
CO2 emission savings		**7 089**	**tons/year**		
CO2 emission permit value		30	$/ton		

Table 1 : Typical Environmental and economical gains by replacement of Nitrogen by argon in insulation spaces for dual fuel LNGC

In this case study, the gains brought by the BOG reduction are due to :

- a slower speed, more energy efficient, shipping during loaded voyage at nominal speed;
- a reduce flaring of excess BOG when the vessel is operating at lower speed, for example during port manoeuvring, heavy weather or crossing of the Suez canal…

One of the apparent paradox of this computation is that, for a given carrier, if lower operating speed leads , as expected, to lower CO_2 emissions, at the end of the year, it leads as well to a larger quantity of unloaded LNG…The reason is that, although the number of rotations per year is reduced, less cargo is fuel is used to propel the vessel…

Table 2 gives an example of spread sheet calculation, estimating the environmental and ***economical*** gain one may expect from this innovation for a Qflex and Qmax LNGCs which use a combination of slow speed propulsion and a on board BOG reliquefaction plant .

In this case study, the gains brought by the BOG reduction are due to the reduction of the re liquefaction plant power consumption which reduce accordingly the vessel Heavy Fuel Oil consumption and CO_2 Emissions…

Hypothesis			
	Qflex	**Qmax**	
Cargo tank capacity	210 000	260 000	m^3
Reliq plant ballast voyage input power	2	3	MW
Reliq plant loaded voyage input power	5	6	MW
Operating days		350	days/year
Ballast voyage		175	days/year
Loaded voyage		175	days/year
Reliq plan Power comsumption	29 400	37 800	MWh/year
Power generation HFO consumption ratio	0,17	tons/MWH	
Power generation CO2 emission ratio	0,58	tons/MWH	
	Qflex	**Qmax**	
Reliq plant HFO consumption	4 998	6426	tons/year
Reliq plant CO2 emissions	17052	21924	tons/year
BOG reduction	10	%	
Modified Reliq Plant Power consumption	26 460	34 020	MWh/year
Modified Reliq plant HFO consumption	4 498	5 783	tons/year
Modified Reliq plant CO2 emissions	15 347	19 732	tons/year
HFO value	250	$/ton	
CO2 value	30	$/ton	
	Qflex	**Qmax**	
HFO savings	124 950	160 650	$/year
CO2 emissions savings	51 156	65 772	$/year
Total Savings	**176 106**	**226 422**	$/year

Table 2 : Typical Environmental and economical gains by replacement of Nitrogen by argon in insulation spaces for Qflex /Qmax LNGCs

IMPLEMENTATION OF A SHIP TO SHORE "PLUG" HIGH VOLTAGE AND HIGH POWER INTERFACE

"PLUG" is a acronym which stands for "**P**ower **G**eneration during **L**oading and **U**nloading" and is a European research initiatives focused on the development of a high performance ship/shore power interface for LNGCs, see reference 2.

Figure 2 gives an overview of the "hand out" PLUG concept , which requires a single person to establish a 8 MW, high voltage / high power interface between LNGC carriers and terminals and meets among others, the emergency release capability required for the safety LNG carriers and terminals…

PLUG allows to connect the vessel with the shore local power network, as soon as they are at the liquefaction plant or re gasification terminal pier. Once the connection is established, the vessel can import, or even export, power to and from the shore, allowing to perform an optimization strategy which will depend on the relative, on board / versus local shore power generation cost and emissions performances.

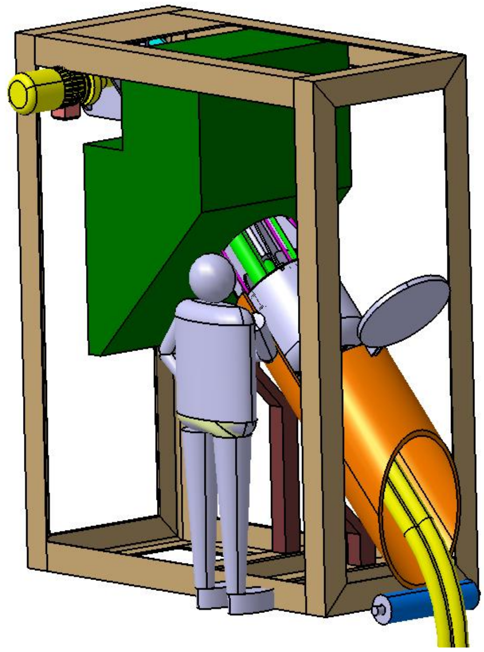

Figure 2 : PLUG ship/shore power interface concept for LNGCs

Table 3 gives an example of spread sheet calculation , estimating the environmental and ***economical*** gain one may expect from this innovation for a Qflex and Qmax LNGCs, which use HFO for on board power generation .

On the re gaseification plant side, analysis will have to be performed on a case by case basis, depending on :

- with regard to cost , the local power market conditions (which varies not only depends on location butare as well time dependant on a hourly basis, see figure 3);
- with regard to emissions, the local energy mix characteristics.

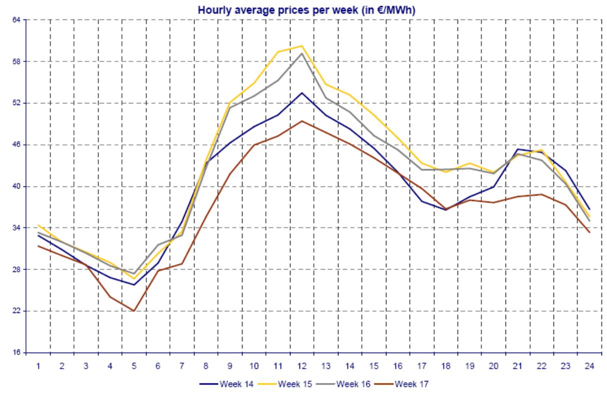

Figure 3 : Example on power market cost fluctuation on a hourly and weekly basis: French market case (source : Power Next)

Hypothesis			
Number of rotations		33	per year
	Qflex	**Qmax**	
Average power consumption at loading terminal	120	140	MWh per rotation
Average power consumption at unloading terminal	120	140	MWh per rotation
Power comption at loading terminal	3 960	4 620	MWh/year
Power consumption at unloading terminal	3 960	4 620	MWh/year
Power generation HFO consumption ratio	0,17	tons/MWh	
Power generation CO2 emission ratio with HFO	0,58	tons/MWh	
HFO value	250	$/ton	
On board power generation cost with HFO	145	$/MWh	
On board power generation case	**Qflex**	**Qmax**	
HFO consumption	1 346	1 571	tons/year
CO2 emissions	4 594	5 359	tons/year
Cost	1 148 400	1 339 800	$/year
Local Qatar Power generation value	70	$/MWh	
Local Qatar Power generation CO2 emission ratio	0,43	tons/MWh	
Local importing terminal Power generation value	120	$/MWh	
Local Importing terminal Power generation CO2 emission ratio	0,5	tons/MWh	
CO2 value	30	$/ton	
Power import with PLUG case			
	Qflex	**Qmax**	
CO2 emissions	3 683	4 297	tons/year
Cost	752 400	877 800	$/year
	Qflex	**Qmax**	
Power generation cost	396 000	462 000	$/year
CO2 emissions savings	27 324	31 878	$/year
Total Savings	**423 324**	**493 878**	$/year

Table 3 : Typical Environmental and economical gains by importing power with PLUG interface for Qflex /Qmax LNGCs

USE OF LNGCS AS FRESH WATER CARRIERS

Figure 3 : View of the inside of an LNGC ballast tank

LNGCs have to ballast in order to keep their sea worthiness (proper immersion of the propeller(s), reduction of the slamming effects on the bow plates…) on their return voyage back to LNG exporting countries.

Presently, the ballast used is water directly pumped from the sea at the unloading terminal, which is pumped out of the ballast tanks, at the other end of the voyage, at the LNG exporting terminal.

This approach, based on the use of sea water to ballast LNGCs present the following drawbacks :

- In some cases, unloading terminals are located not in open sea, but in estuaries where the sea (or river) water is heavily loaded with silt. When the ship will empty its ballast at the loading terminal, most of the silt will have already settled down in the ballast tanks and will remain there, adding weight to the ship (several thousands tons in a few years for the worst cases!) and requiring periodic removal ;
- The ballast water may transport, under the generic acronym of ANS (Aquatic Nuisance Species), unwelcome species (bacteria, algae's, fishes, etc…) from one ocean to the other , with the corresponding environmental hazards, to the point that the International Maritime Organisation is issuing guidance and initiating legislation to the effect that all the ballast water shall be progressively replaced and/or treated during the ballast voyage to reduce this risks (see reference 3);
- The ballast tanks (see figure 3) being periodically exposed to sea water are an area prone to corrosion problems, which may generate at best, extra maintenance or, at worst, excessive hull weakness and structural failures;
- This transportation of sea water around the globe does not bring any economical and environmental benefits to the LNG chain…

The volumes of sea water transported this way for ballast is quite significant, typically for a given LNGCs, around 1/3rd of the cargo tank volume, whereas at the same time :

- Qatar, like most Middle East LNG exporting countries, is facing a chronic lack of fresh water supplies, and has to produce it with giant desalination plants with the corresponding environmental consequences : high power consumption, high CO_2 emissions, as well as the

release of large quantities of brine water into the Gulf , with the correspond stress on the Gulf marine life;
- A significant share of Qatar LNG customers are located in areas where ample fresh water supplies, as indicated by the fact that a significant shares of their LNG receiving terminals are located close to or within the estuaries of large rivers…

Technically speaking, using ballast tank to carry fresh water does not present any significant technical challenge and is not even innovative : use LNGCs as fresh water carriers on their ballast voyage has been already considered decades ago by Gaz de France between the Montoir de Bretagne LNG receiving terminal and Algeria.

One of the major incentive, at this time, to consider this solution was to avoid to fill up the ballast tank with the very muddy Loire estuary water…But this initiative was eventually (and is still?) discarded by operators, mostly because it would bring extra constraints on LNG shipping operations which are the main purpose of the business….

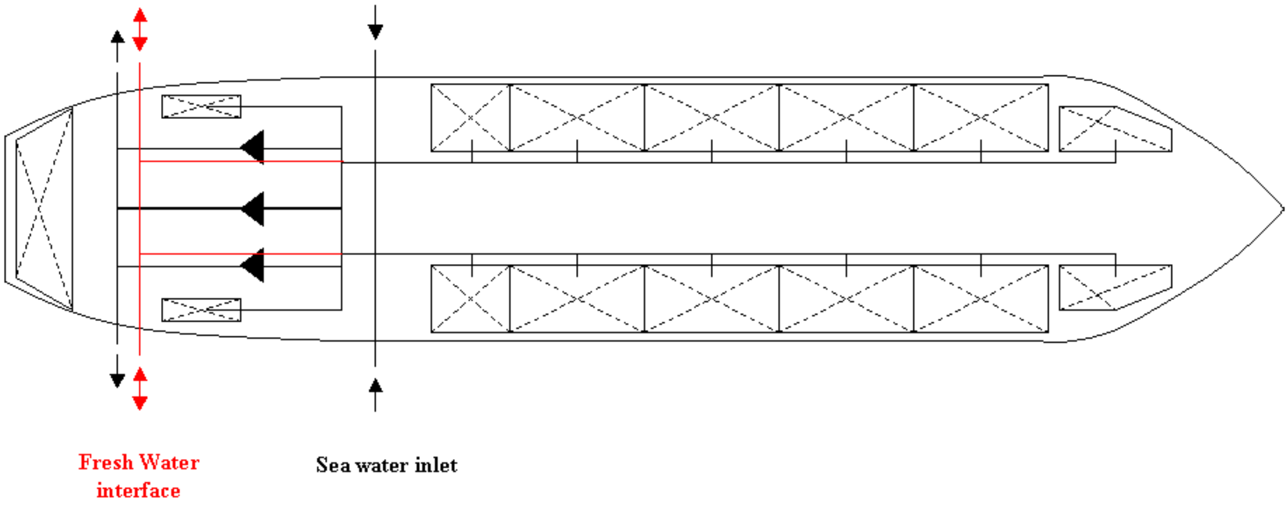

Figure 4 : Typical Implementation of a fresh water ballast system

The existing pumps and piping used for ballast with sea water could be used to load and unload fresh water and should be kept available, as a back up, if the vessel destination cannot provide the required fresh water.

The only extra hardware would be some additional piping in the engine room to connect the ballast system to a ship/shore fresh water interface, either in the engine room area, at the aft of the vessel, as indicated in figure 4, either at mid ship, to benefit from the availability of the LNG loading arms pier and reduce the cost of the flexible water line to be connected to the vessel.

Environmental gain could be very significant as the required energy to deliver this fresh water to Qatar could be limited to the energy to collect, pump aboard and discharge this water.

Operational Expenses are expected to be very low due, among others, to :

- the reduction of the maintenance of ballast tank (no silt deposit, less corrosion);
- the energy saving, as water ballast renewal to avoid transportation of unwanted species will no more be required during transit, (in reference 3, the corresponding cost is estimated at $ 2 000 000 per year …)

From emissions point of view, this solution has to be compared with Qatar fresh water supply by desalination plants. As a guidance, reference 4 may be used, which gives for the emissions ratios of the most efficient desalination technologies :

- MSF (Multi Stage Flash) : 5.56 Kg.CO_2 / m^3 (Combined with Gas power plants)
- MED (Multi Effect Evaporation) : 4.38 Kg.CO_2 / m^3 (Combined with Gas power plants)
- RO (Reverse Osmosis) : 3.08 Kg.CO_2 / m^3 (Considering that Qatar Renewable Source power contents is similar than the Portugese case mentioned in this reference))

Considering, as an average, for fresh water desalination production in Qatar a ratio of 4. Kg.CO_2 / m^3 , table 4 gives an example of a spread sheet calculation to estimate environmental and ***economical*** gain one may expect from this innovation for the same LNG carrier as in table 1.

For this case study, the cost of fresh water on the importing LNG terminal side was estimated at 0,2 \$/m^3. (typical French Normandy region case) and 1 \$/m^3 for the cost of desalination plant in Qatar.

In this case study, the gains brought by fresh water ballasting are due to :

- a lower cost of fresh water supply;
- emissions credits;
- lower ballast maintenance cost.

From a more global point of view, if one considers that Qatar is on the way to produce around 80 MTPA of LNG, and, to be conservative, that one fifth of the exporting LNG routes could be towards LNG importing terminals with large fresh water supplies, Qatar could get this way around 10 MTPA of practically emission free fresh water, at, furthermore, a competitive price.

This 10 MTPA of ballast fresh water is to be compared to the 2008 Qatar desalination plant production which is estimated at 600 MTPA.

Qatar could therefore reduce by more than 1 % its emissions related to fresh water production by desalination...

Hypothesis			
Modified number of rotations		38,0	per year
Desalination Fresh water cost		1,2	$/m3
Desalination plant CO2 emissions		4	kg/m3
LNG Import terminal Fresh water cost		0,2	$/m3
CO2 emission permit value		30	$/ton
	Qflex	**Qmax**	
Cargo tank capacity	210 000	260 000	m3
Ballast water capacity	70 000	86 667	m3
Unloaded fresh water	**2 660 000**	**3 293 333**	**m3/year**
Fresh water revenue	**2 660 000**	**3 293 333**	**$/year**
Lower ballast tank maintenance	**50 000**	**50 000**	**$/year**
CO2 emission savings	**10 640**	**13 173**	**tons/year**
CO2 emission permits gain	**319 200**	**395 200**	**$/year**
Total extra profit	**3 029 200**	**3 738 533**	**$/year**

Table 4 : Typical Environmental and economical gains by use of LNGCs as fresh water carriers

CONCLUSION

A first conclusion on these possible innovative ways of reducing the environmental footprint of LNG carriers and terminals :

- replacement of nitrogen by argon in the NO type membrane LNGC is expected to be a sure winner as it directly improve the efficiency of the vessels, whatever their route;
- importing shore power with PLUG shall be very sensitive on local power characteristics on both sides of the LNG trade as well on the value given to CO_2 emissions…
- use of LNGC as fresh water shall be implemented on a case by case basis, depending on fresh water cost and availability on the importing terminal side.

To take a “bird eye” point of view on the challenge of improving the environmental performance of LNG carriers and terminals, one may extract the following general thoughts from this three potential innovation :

- In many cases, these improvements shall be considered as an option, keeping previous solutions as back up, in order to avoid any risk on the safety and reliability of the core LNG shipping business;
- Beyond the Qatar innovative Qflex and Qmax approach approach of increasing the size of LNGCs, further significant improvement can be achieved at a lower scale and on a retrofit basis ;
- In many cases, significant gains can be achieved by just looking for a more cooperative approach not only between LNG carriers and terminals, but even outside the LNG shipping world : the main challenge is, in these case to open our mind to detect opportunities and potential co operations;

- In many cases, environmental friendliness does not conflict with economics but on the contrary, generate extra profit, especially if the CO_2 emission market becomes a reality for shipping.

These are significant challenges, but the author has no doubt that the Qatar LNG community will be able to tackle them successfully!

NOTES :

(1) One will note that, for future new built, another strategy could be considered to take benefit of improved NO 96 thermal insulation : reducing by 10 % the insulation thickness, keeping the same BOG rate : this would reduce significantly the quantity of insulation materials (saving up to 300 tons of plywood!), but most importantly, would increase, within the same hull size, the cargo tanks capacity by several thousands m^3, two aspects which would be beneficial both from environmental and economical point of view, but are not documented in the present paper.

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