

NG²

BOG management strategy

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New Generation, Natural Gas,



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NG² BOG STRATEGY



Reduce storage tank BOG

Monetize jetty BOG into power during loading

Reduce LNGC excess BOG

Monetize desaturation & transfer BOG into power
Reduce emission during unloading

Reduce storage tank BOG

Objectives

Technologies

Argon insulation

6600V power line

Argon Insulation

6600V power line

Argon Insulation

Gains

Increased liquefaction plant output
3 to 5 % of tank capacity
extra export LNG per year

Use DF/DE engines power to recompress BOG return lines
Reduced CAPEX /OPEX for BOG return lines & compressors
Monetize BOG

Increased shipping efficiency : 5 to 9 000m³ of extra unloaded LNG per ship per year
Lower emissions

Increased shipping and terminal efficiency
Zero emission unloading
Capability
Export power to terminal
Monetize BOG

Increased terminal efficiency
Reduced CAPEX /OPEX for BOG compressors



What is



?

- “NG²Tank” is an acronym for **New Generation, Natural Gas, Tank**
- It proposes an innovative solution to reduce the BOG rates of existing or new built LNG storage tanks

Benefits

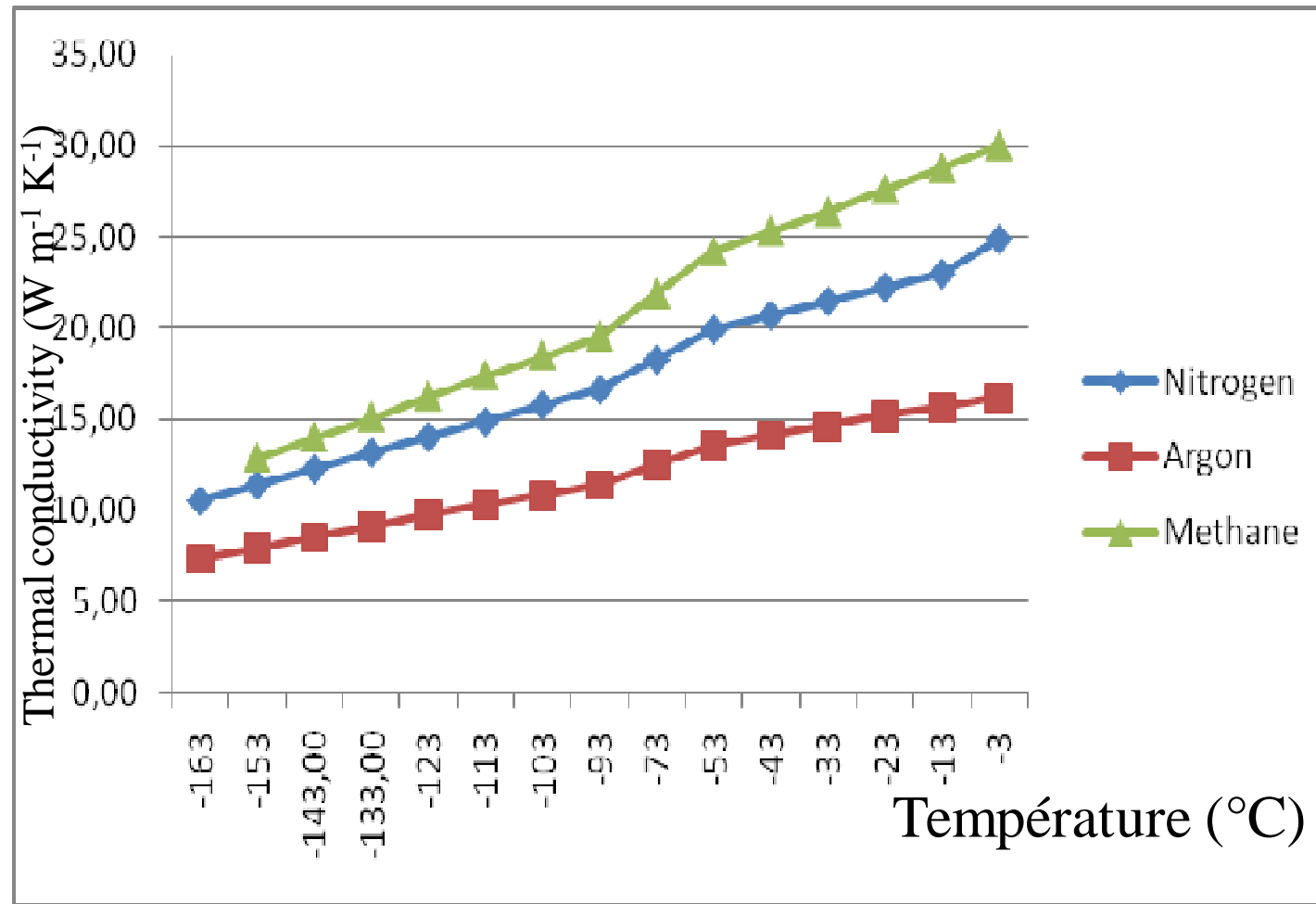
- Reduce OPEX /CAPEX of BOG compressors and piping
- Increase LNG output of liquefaction plants
- Replace methane leaks by argon leaks, which has no GHG effect in the atmosphere
- Increase safety by providing a inert envelope around the LNG tank

What is Argon gas?

- Most common (0.934 %) « rare » gas in air
- Widely used as an industrial gas for its :
 - Inerting properties : welding....
 - Electrical properties : lights
 - Thermal properties : double glass windows, skin divers suits...
- World production : 750 000 tons /year
- Typical bulk price, delivered by truck, liquefied : 800 \$/ton
- Virtually inexhaustible supply...

Argon/Methane/Nitrogen Thermal properties

30 % less thermal conductivity than methane
20 % less than nitrogen



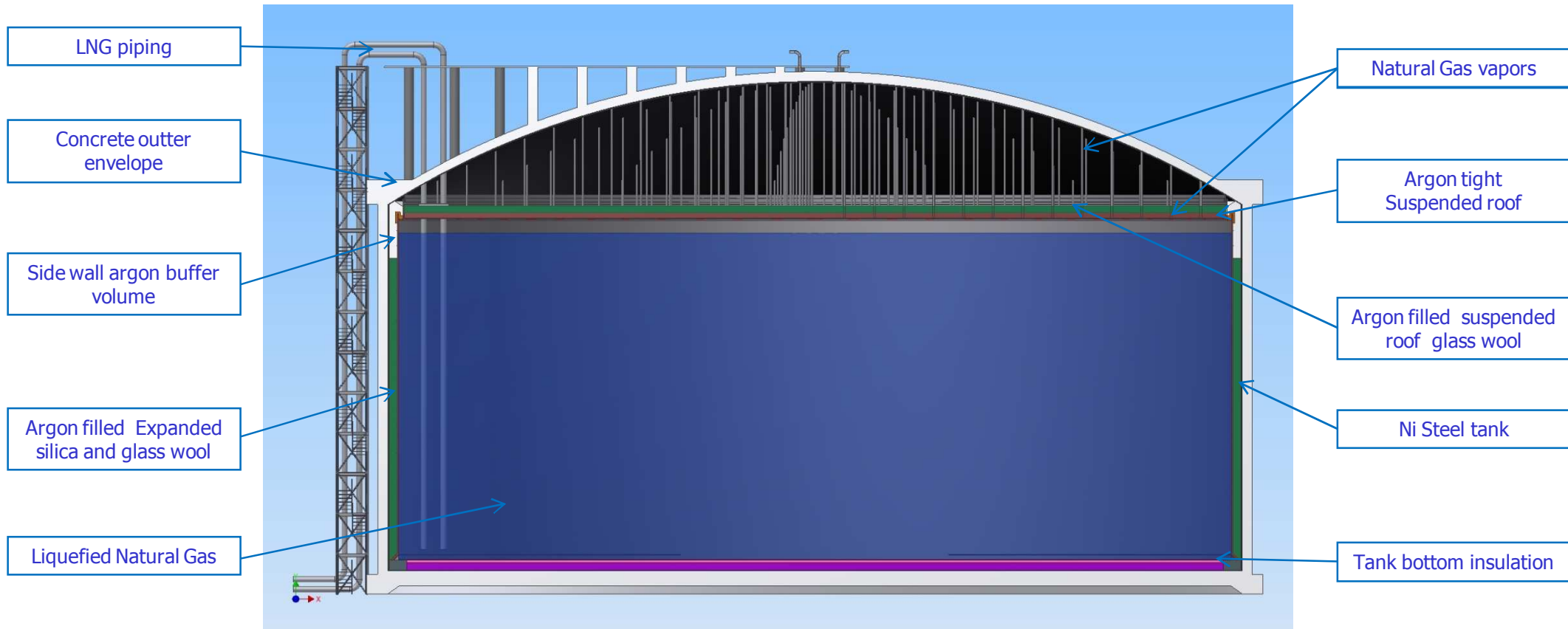
→ Argon is widely used for these reasons in double glass windows, why not for LNG terminals and carriers ?

Technical features (patented)

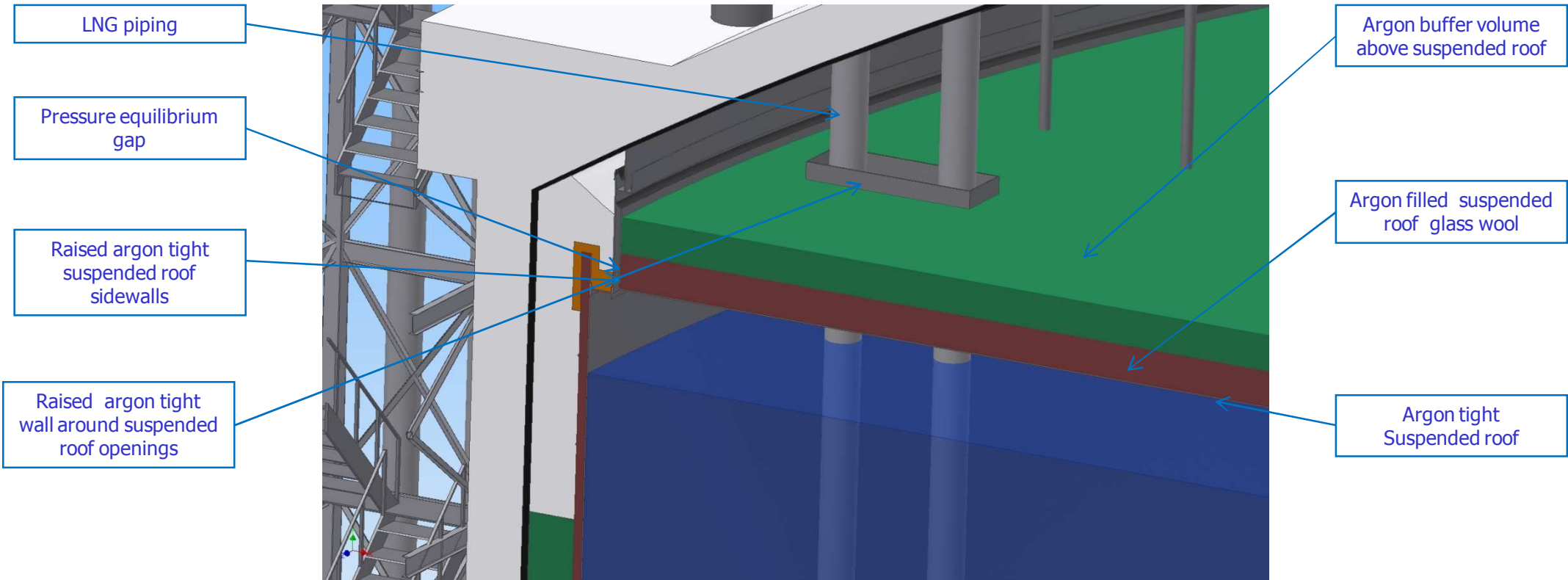
- Argon gas is trapped by gravity below nitrogen and methane vapors
- Upper part of the volumes used as buffer
- Reduced argon consumption
- On new built, specific modification of suspended roof to make it gas tight and trap argon above the LNG cargo...while keeping pressure equilibrium...

For more details, see LNG 16 paper..

Implementation



Implementation



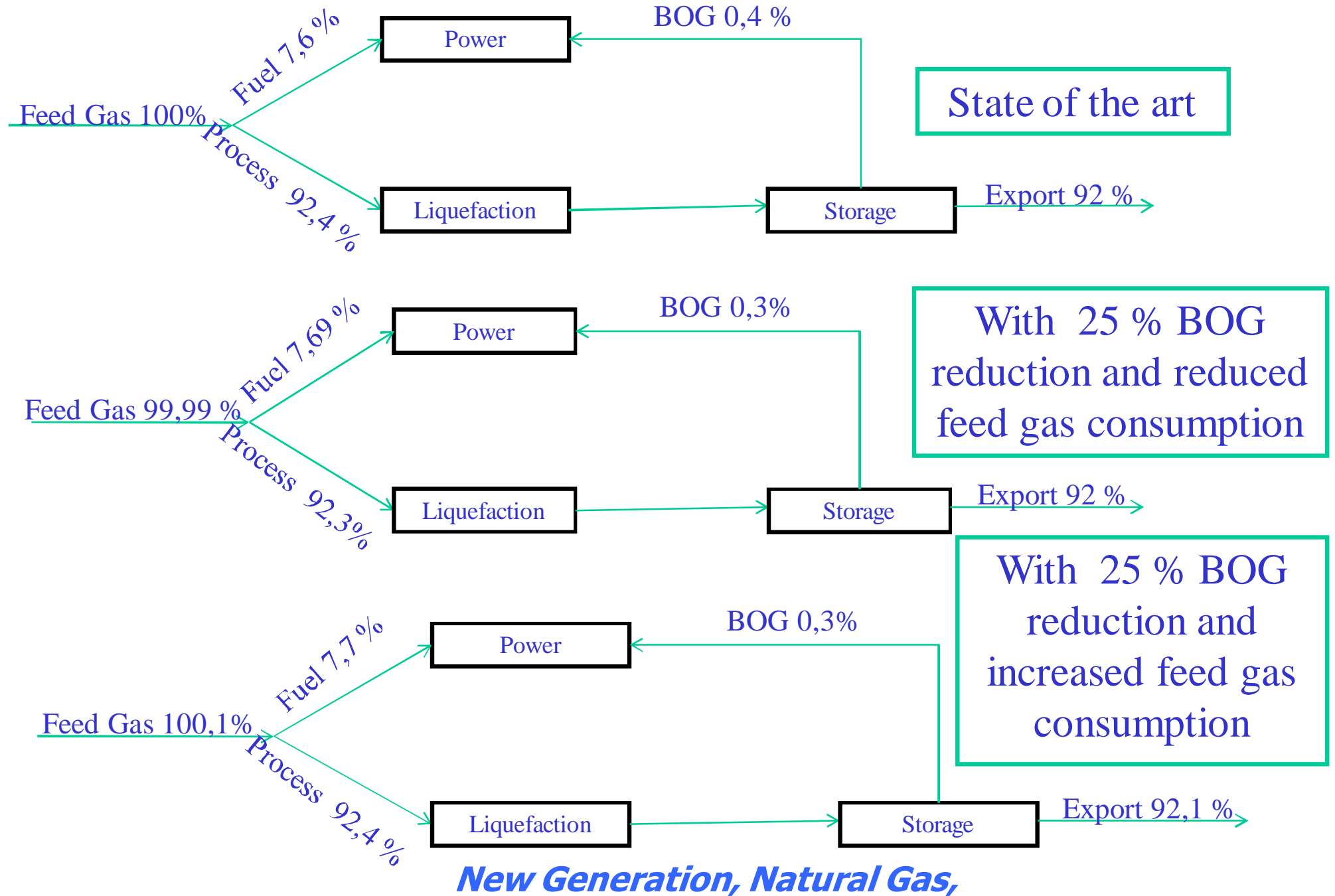
Benefits(retrofit) (side walls only)

- Assuming heat leaks are split into three thirds:
 - Suspended roof : 33 % → unchanged
 - Side walls : 33% → 20 %
 - Bottom : 33 % → unchanged
- Overall BOG reduction : 14% (100 % → 86 %)

Benefits (new built) (side walls + suspended roof)

- Assuming heat leaks are split into three thirds:
 - Suspended roof : 33 % → 20 %
 - Side walls : 33% → 20 %
 - Bottom : 33 % → unchanged
- Overall BOG reduction : 27% (100 % → 73 %)

Liquefaction plant case



Business model (1)

Hypothesis	New Built Case	
LNG Storage tank	capacity	175 840 m3
	density	450 kg/m3
Insulation volume :		
	Side wall	
	Height	35 m
	Inner Diameter	80 m
	Outer diameter	82 m
	Volume	8 792 m3
	Roof	
	Surface	5 024 m2
	Thickness	0 m
	Volume	2 010 m3
total insulation volume		10 802 m3
Average side insulation temperature		200 K
Average roof insulation temperature		200 K
Average Argon vapor density		3,50 kg/m3
Average Methane vapor density		0,33 kg/m3
Quantity of required argon		37 806 kg
Quantity of displaced methane		3 601 kg
Argon cost :		800 USD/ton
Methane value :		200 USD/ton

Hypothesis	Retrofit case	
LNG Storage tank	capacity	175 840 m3
	density	450 kg/m3
Insulation volume :		
	Side wall	
	Height	35 m
	Inner Diameter	80 m
	Outer diameter	82 m
	Volume	8 792 m3
	Roof	
	Surface	0 m2
	Thickness	0 m
	Volume	0 m3
total insulation volume		8 792 m3
Average side insulation temperature		200 K
Average roof insulation temperature		200 K
Average Argon vapor density		3,50 kg/m3
Average Methane vapor density		0,33 kg/m3
Quantity of required argon		30 772 kg
Quantity of displaced methane		2 931 kg
Argon cost :		800 USD/ton
Methane value :		200 USD/ton

Business Model (2)

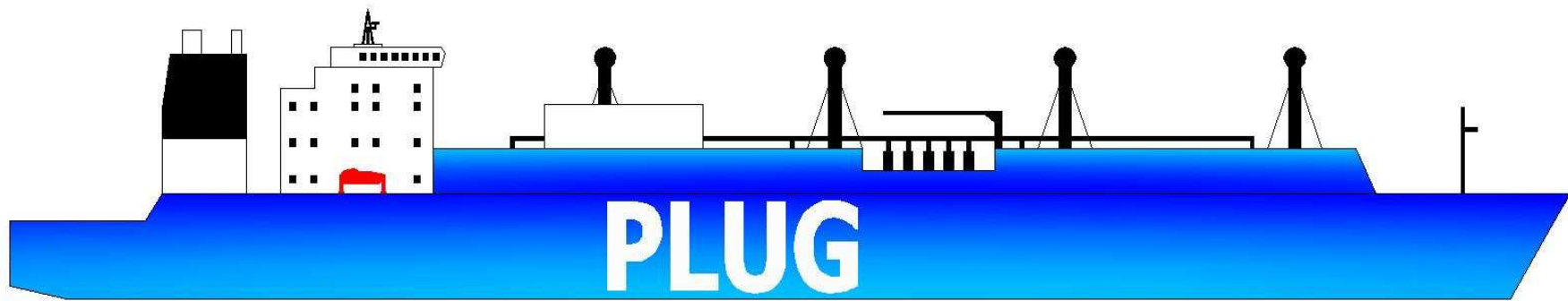
CAPEX	
Argon unit CapEX	\$100 000
Argon instrumentation	\$100 000
Engineering	\$50 000
Royalties	\$50 000
Argon cost	\$30 244
CH4 Saving	-\$720
TOTAL CAPEX	\$329 524
OPEX	
Maintenance (5% of CapEX)	\$16 476
Royalties	\$50 000
TOTAL OPEX	\$66 476
Gains	
Initial BOG	0,050%/day
BOG reduction	25%
New BOG	0,038%/day
Reduced BOG per Year	3 610 tons/year
% of extra LNGper year vs tank capacity	5%
Feed Gas value	50 USD/ton
LNG Value	200 USD/ton
Extra Value of Exported LNG	\$541 532/year
Net Value	\$475 056/year
ROI	8,3 months

CAPEX	
Argon unit CapEX	\$80 000
Argon instrumentation	\$80 000
Engineering	\$30 000
Royalties	\$50 000
Argon cost	\$24 618
CH4 Saving	-\$586
TOTAL CAPEX	\$264 031
OPEX	
Maintenance (5% of CapEX)	\$13 202
Royalties	\$50 000
TOTAL OPEX	\$63 202
Gains	
Initial BOG	0,050%/day
BOG reduction	15%
New BOG	0,043%/day
Reduced BOG per Year	2 166 tons/year
% of extra LNGper year vs tank capacity	3%
Feed Gas value	50 USD/ton
LNG Value	200 USD/ton
Extra Value of Exported LNG	\$324 919/year
Net Value	\$261 718/year
ROI	12,1 months

New Generation, Natural Gas,

Benchmarking

- Capex Yemen LNG : 4 Billions \$ for 6,7 MPTA :
→ 597 \$/TA
 - Capex NG2TANK : 370 000 \$ for 3600 TA :
→ 103 \$/TA
- ...NG2TANK is 6 times more efficient than the initial liquefaction plant investment...without considering that there is no need of extra fuel gas OpEx to get this extra LNG export!

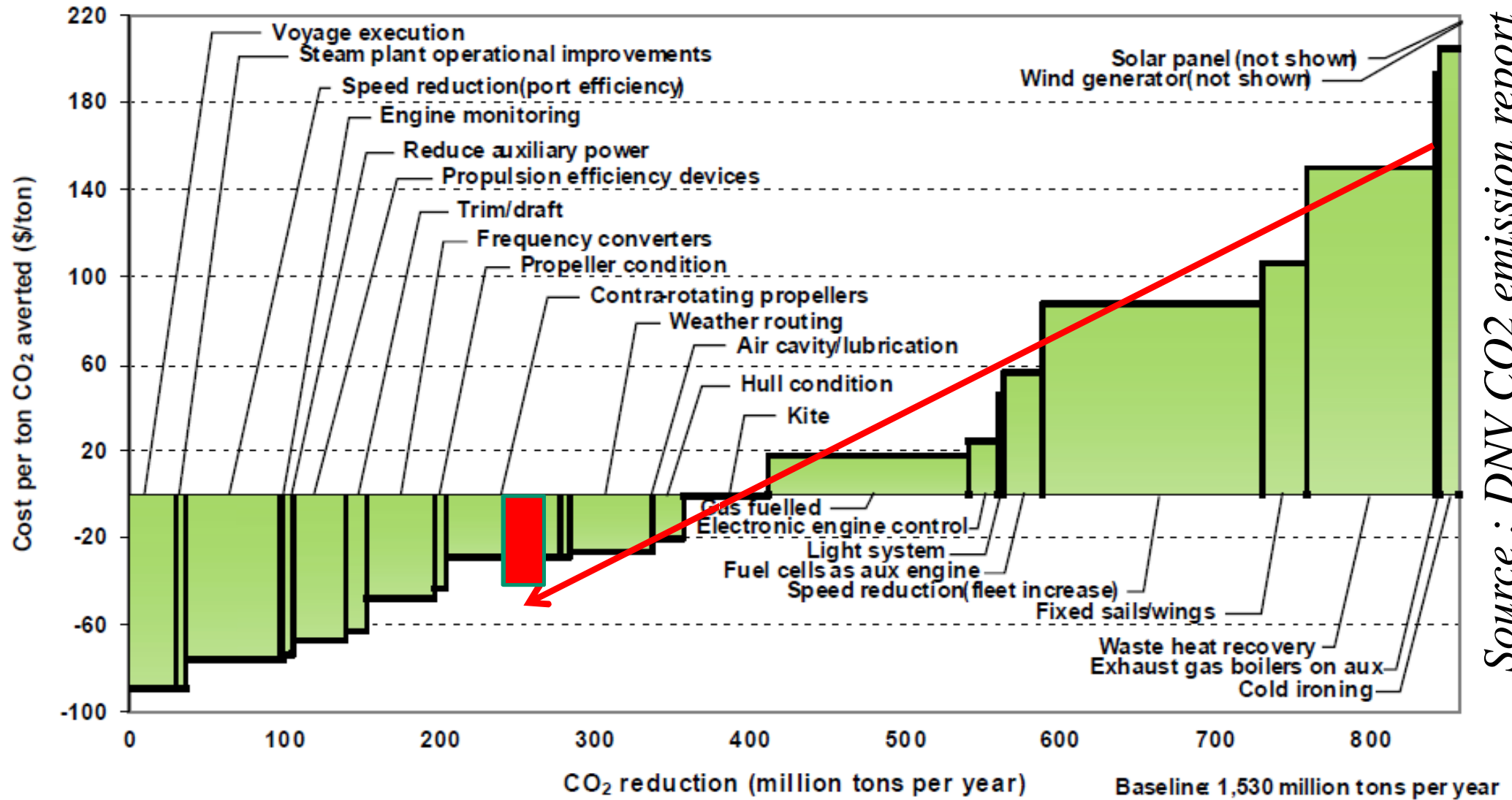


What is ?

- “PLUG” is an acronym for **P**ower **G**eneration during **L**oading & **U**nloading
- It proposes a game changing solution to connect LNG carriers to the shore^power network

**PLUG is the world first shore power providing a multi MW, High Voltage connection....
...within a minute!**

Objective



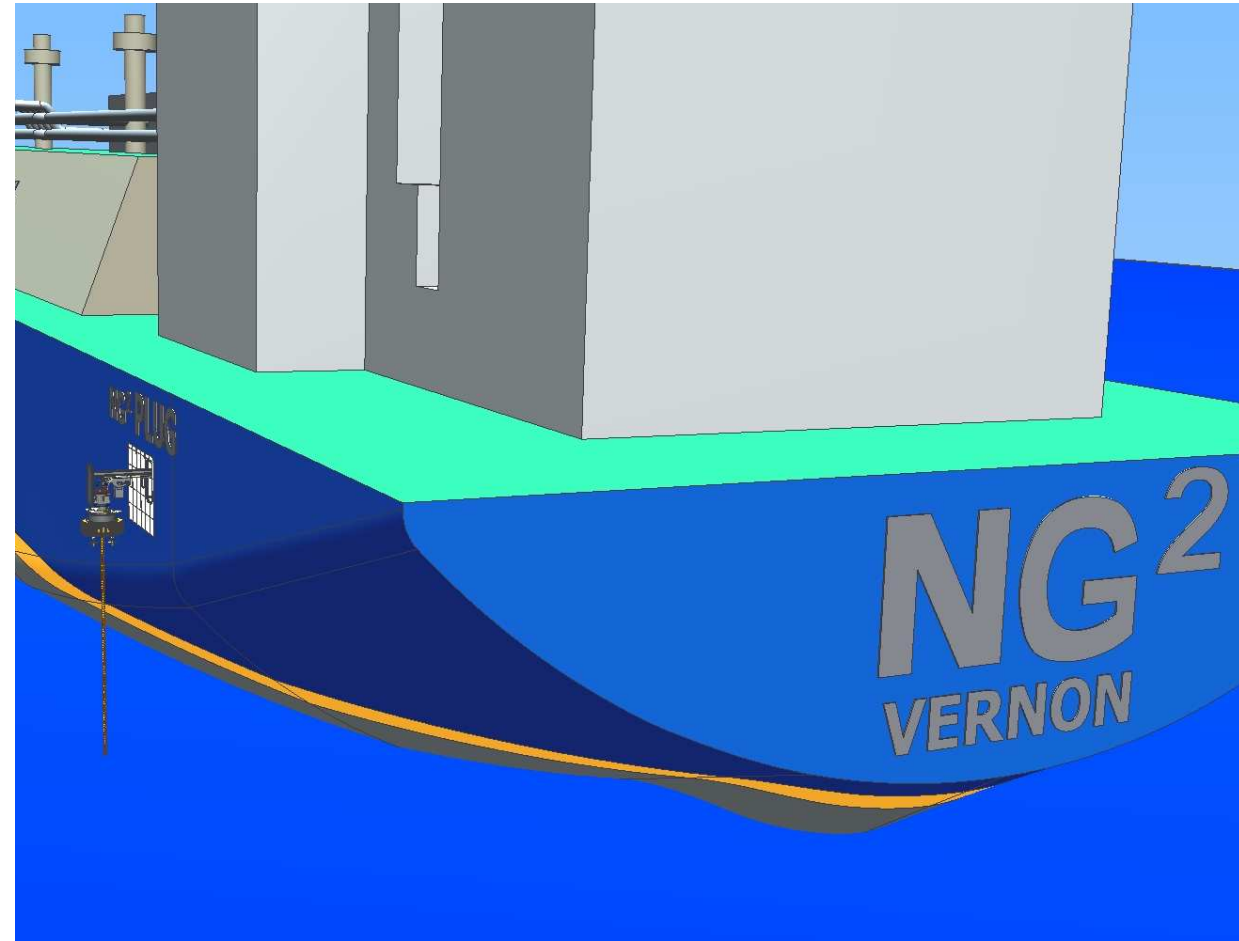
Objective is to reduce drastically shore power costs...and make it profitable!



for LNG carriers

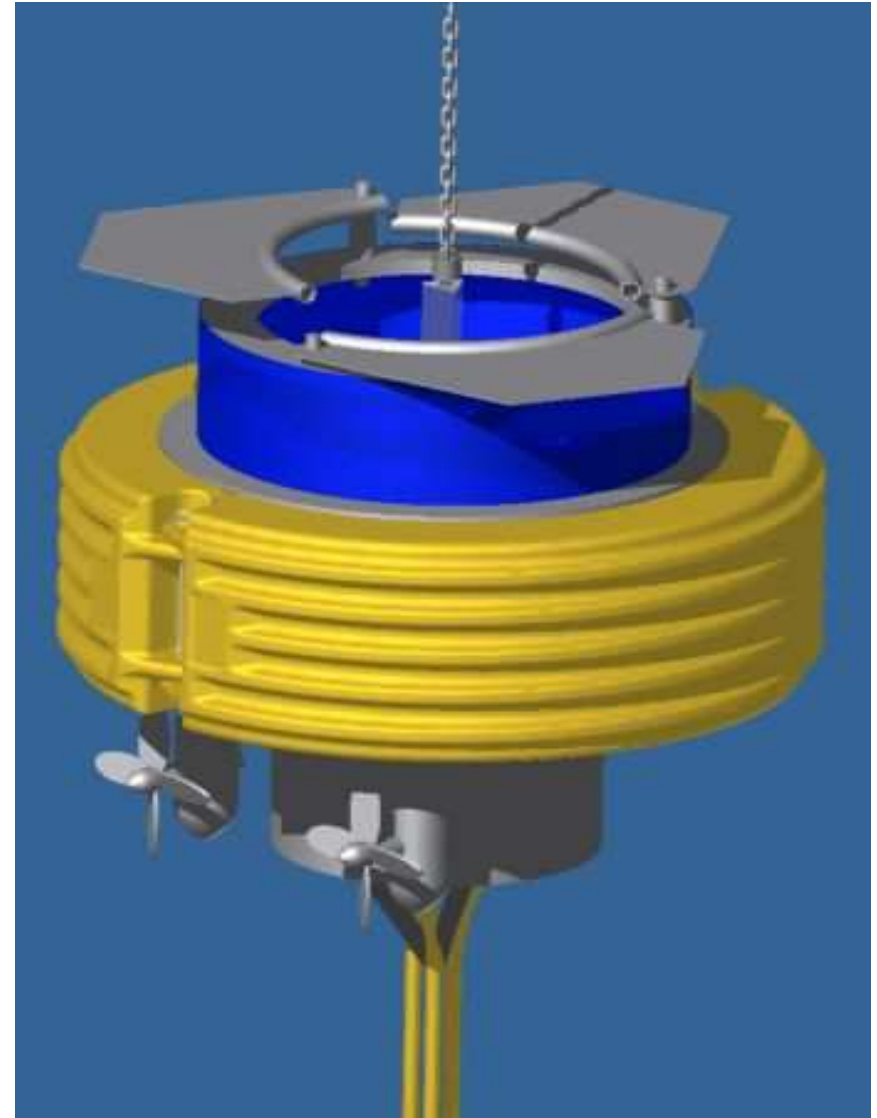
Main challenges :

- Intrinsically safe
- Versatility : variable power port location depending on engine room location with regard to loading /unloading piping interface
- No direct access to the ship engine room side
- Emergency Release capability



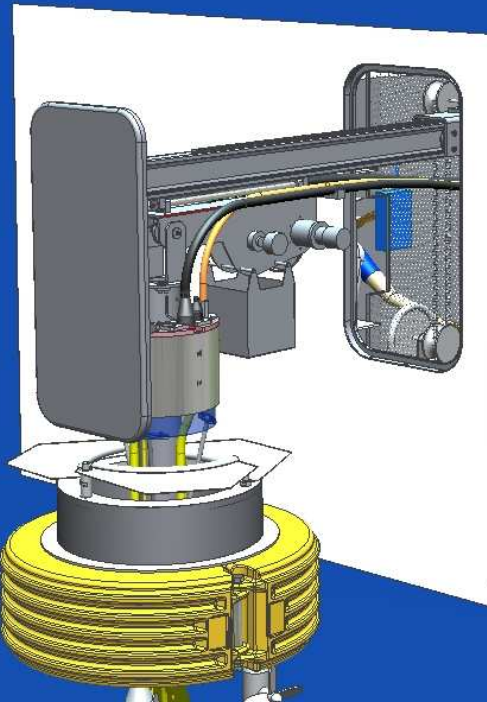
Solutions

- Self sealing gas tight / watertight connector
- Self mating /demating connector
- Implementation of 8 MVA PLUG power port within E/R side
- Floating power line
- Floating and self propelled connector
- Connection of up to three 8 MVA units, in parallel to allow DF/DE LNGCs to export power to the shore
- Emergency Release capability by letting the hoisting chain go...



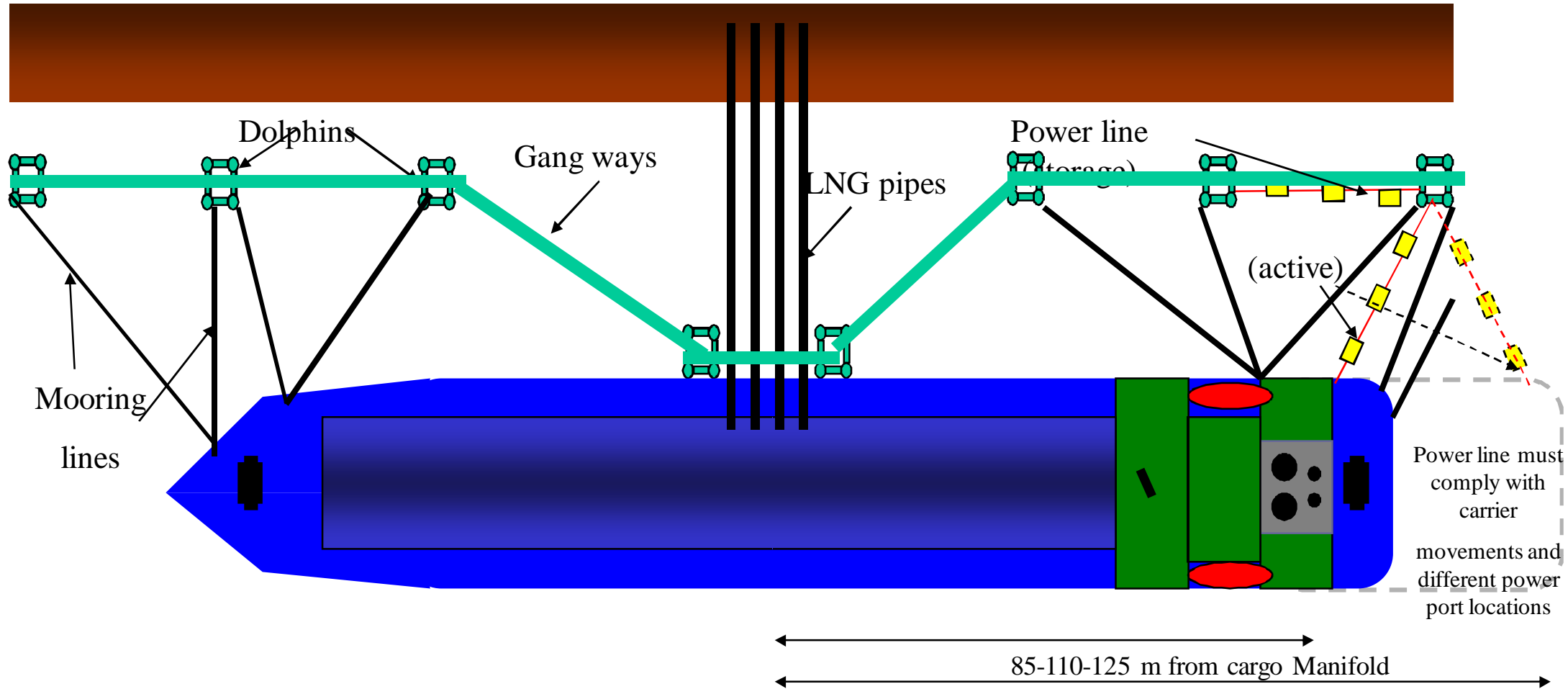
Solutions

NG² PLUG

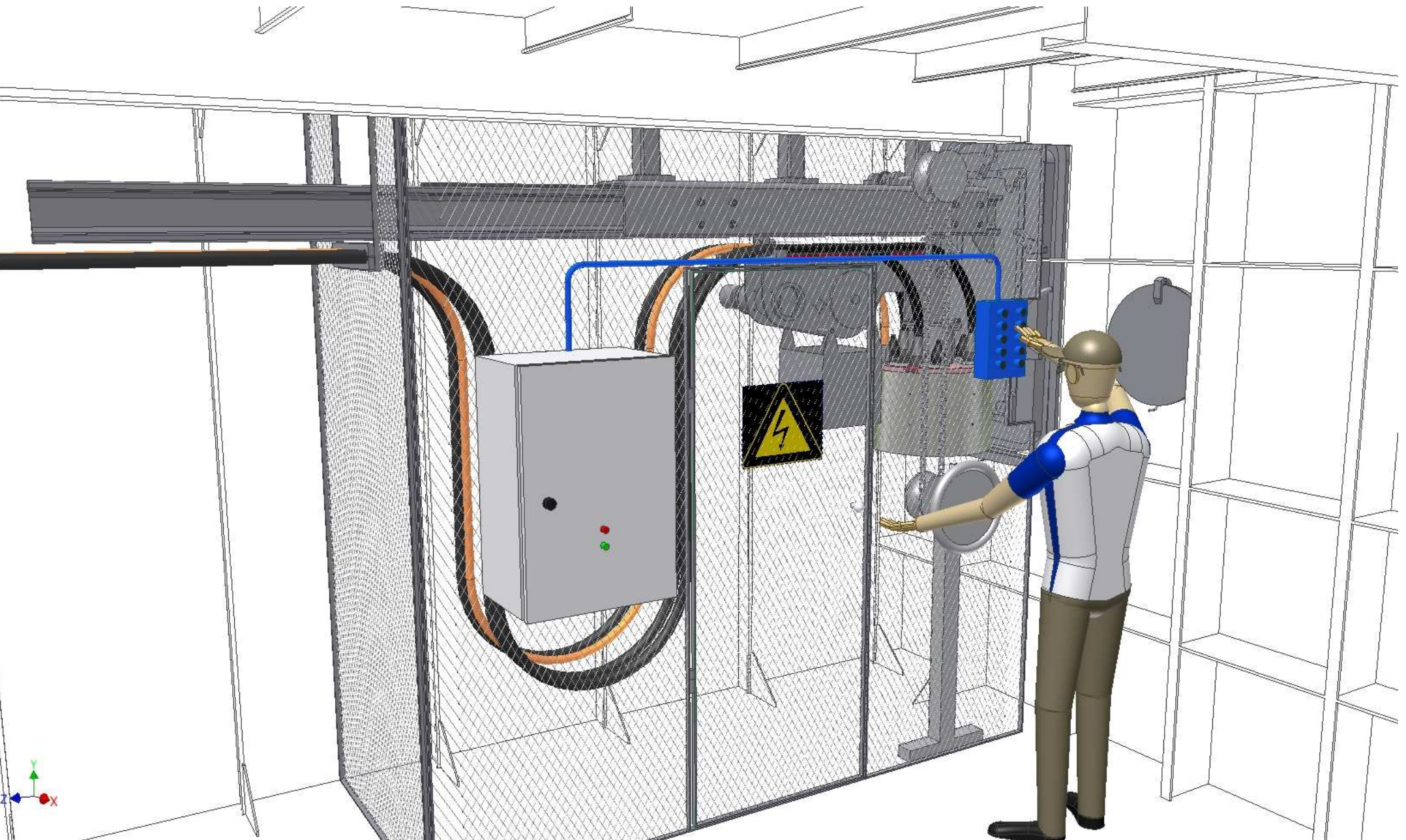


New Generation, Natural Gas,

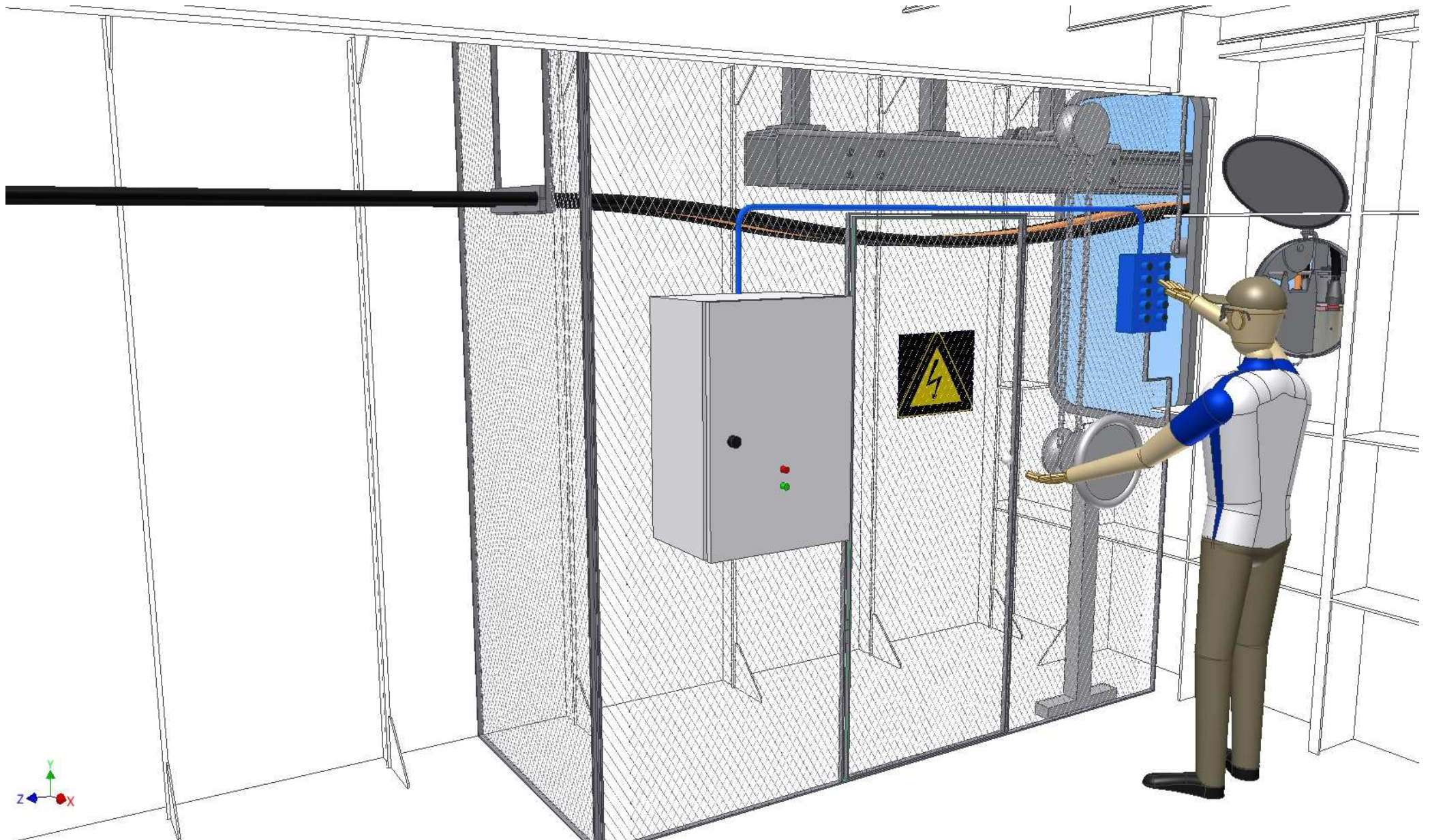
Implementation strategy



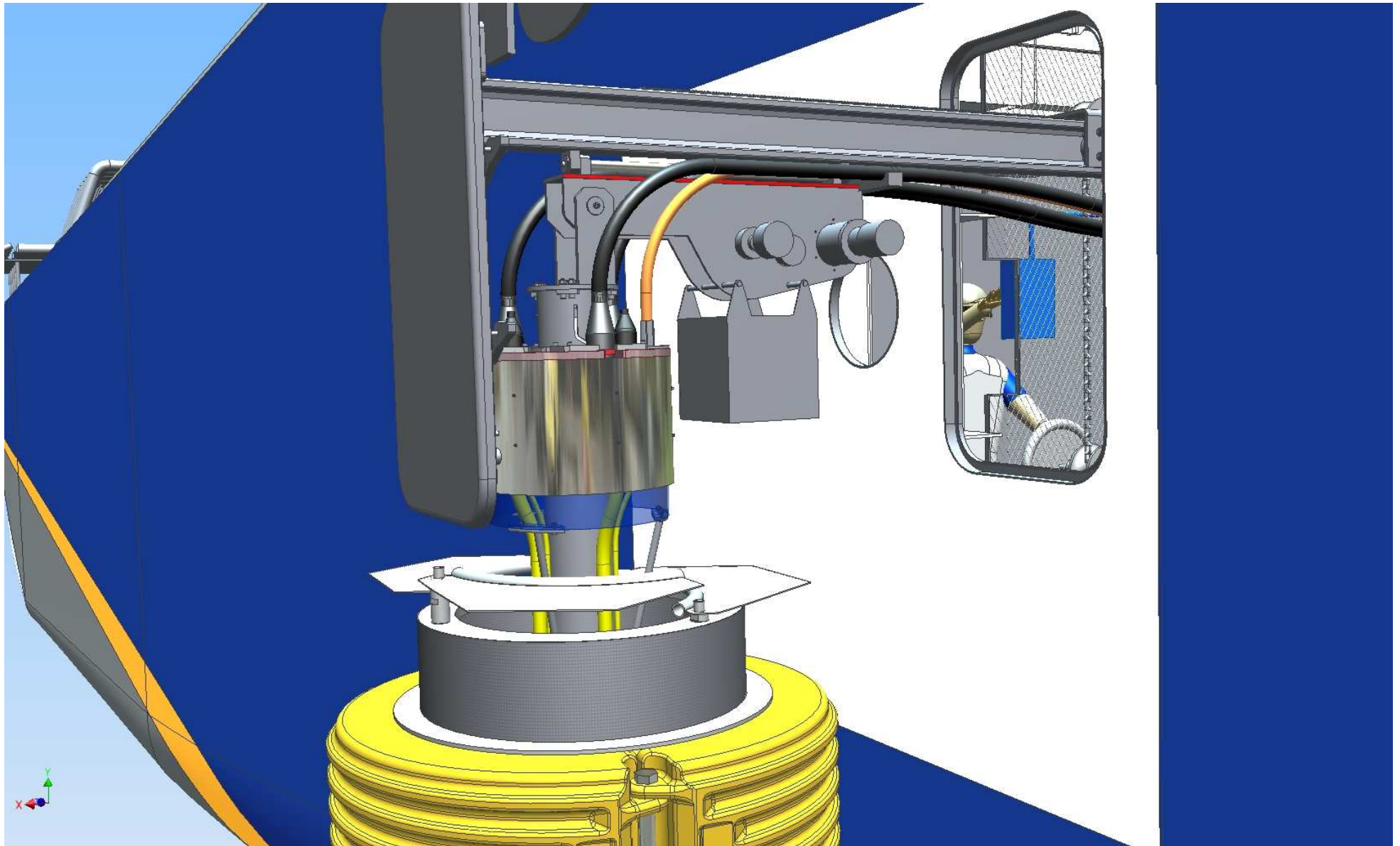
Inside view at sea



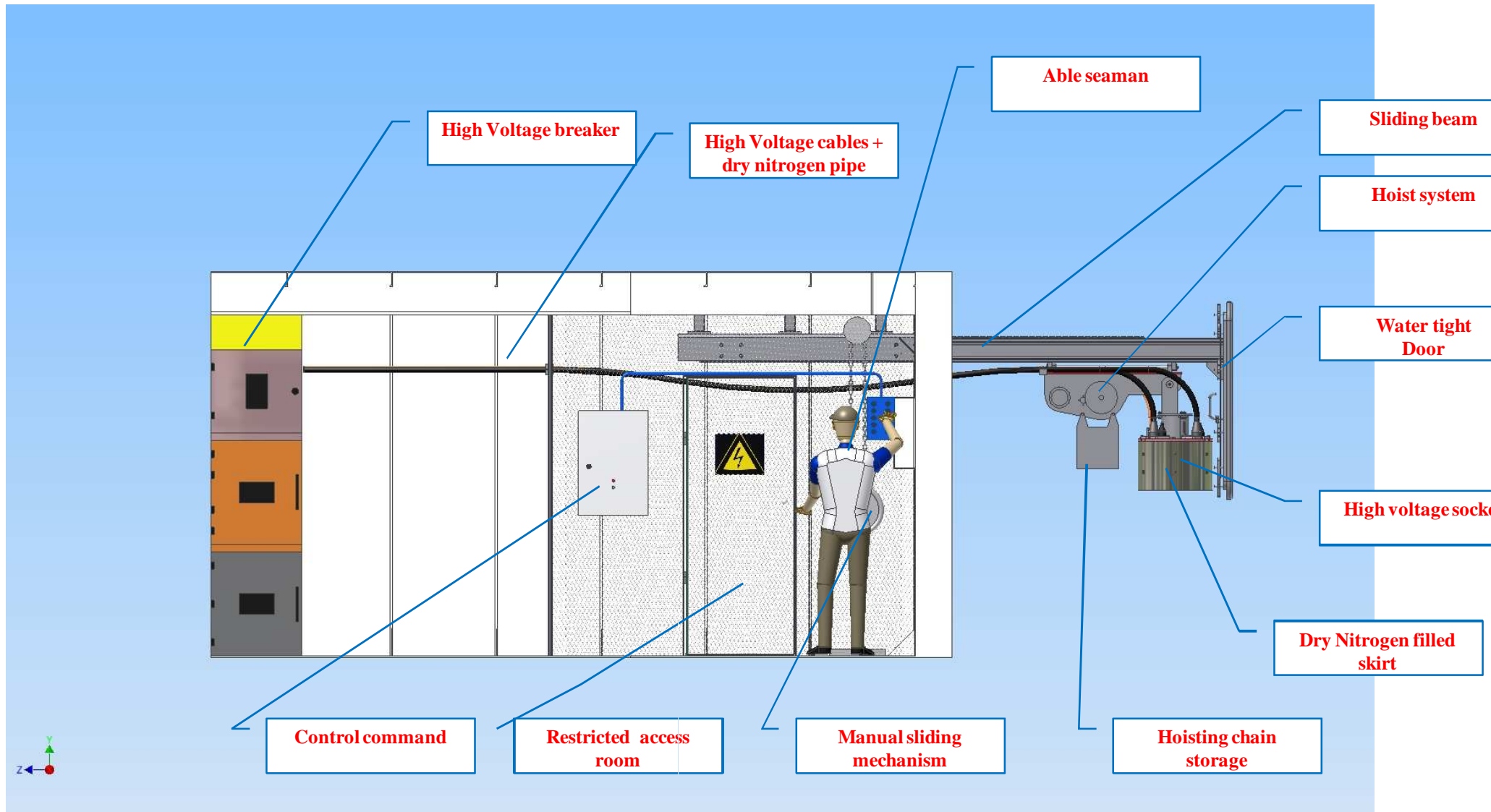
Inside view in operations



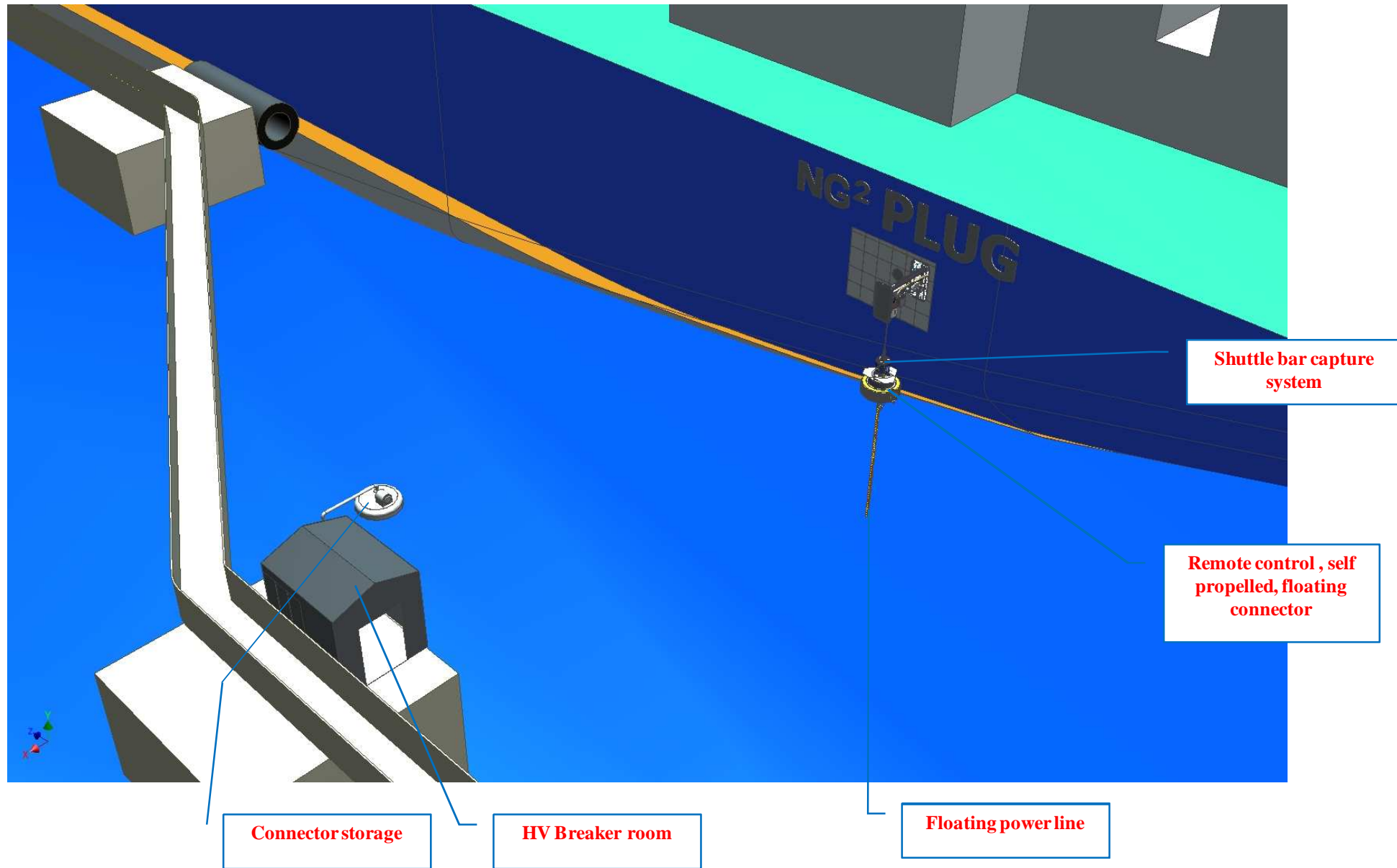
Outside view in operations



On board components



Shore side components

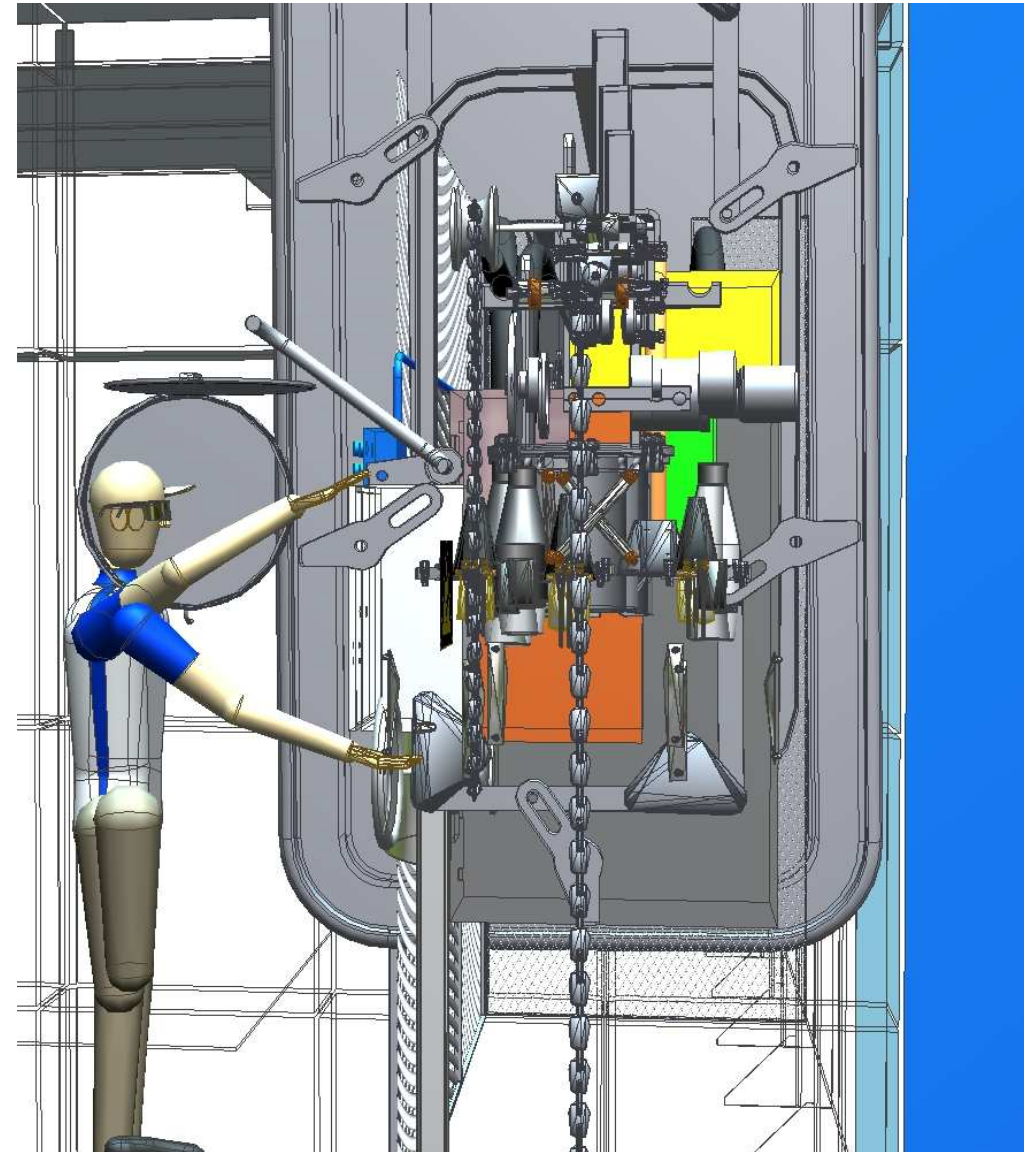


New Generation, Natural Gas,

PLUG innovation makes simple, cost effective shore power exchange operations

Project status :

- Manufacturing and test of first unit : June 2010
- PLUG is short listed for :
 - LDA / Le Havre Ferry
 - Color Line / Oslo Ferrys
 - SNCM & CMN / Marseille Ferrys
 - RCCL Oasis of the Sea / Fort Lauderdale...



New Generation, Natural Gas,



What is ?

- “**NG²Tank**” is an acronym for **New Generation Natural Gas, Tank**
- It proposes an innovation to improve significantly the environmental and economical performance of membrane LNGCs...

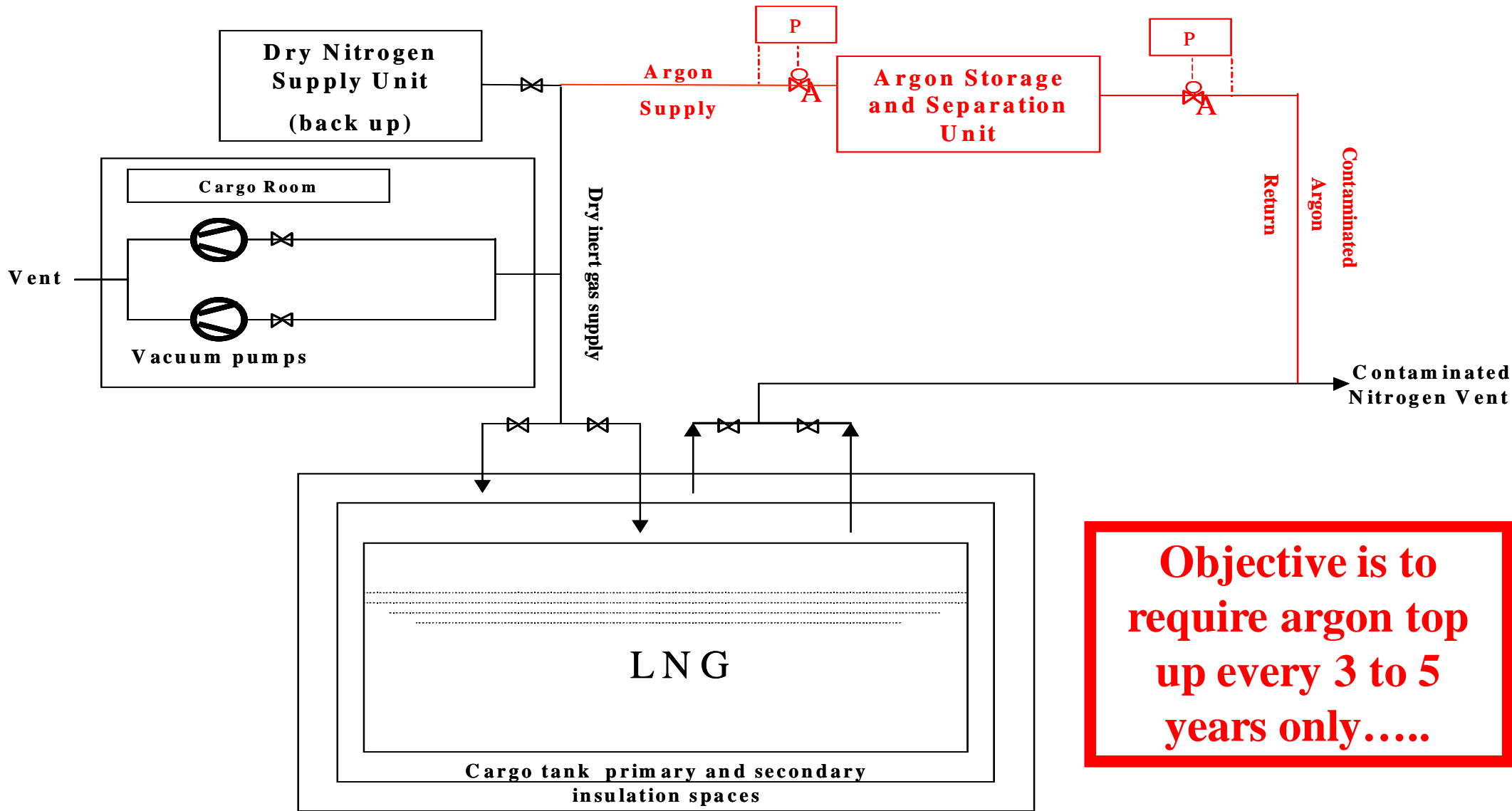
→ Proposal : replace nitrogen gas in the insulation spaces by another gas with a lower thermal conductivity : ARGON



For Membrane LNGCs

- Main features :
 - on board **Argon Storage and Separation Unit (ASSU)** which aims at improving the performance of NO type membrane LNG carriers
 - increase thermal insulation performance by 10 % compared to nitrogen filled insulation
 - reduce by 10 % boil off gas flaring if retro fitted on existing carriers;

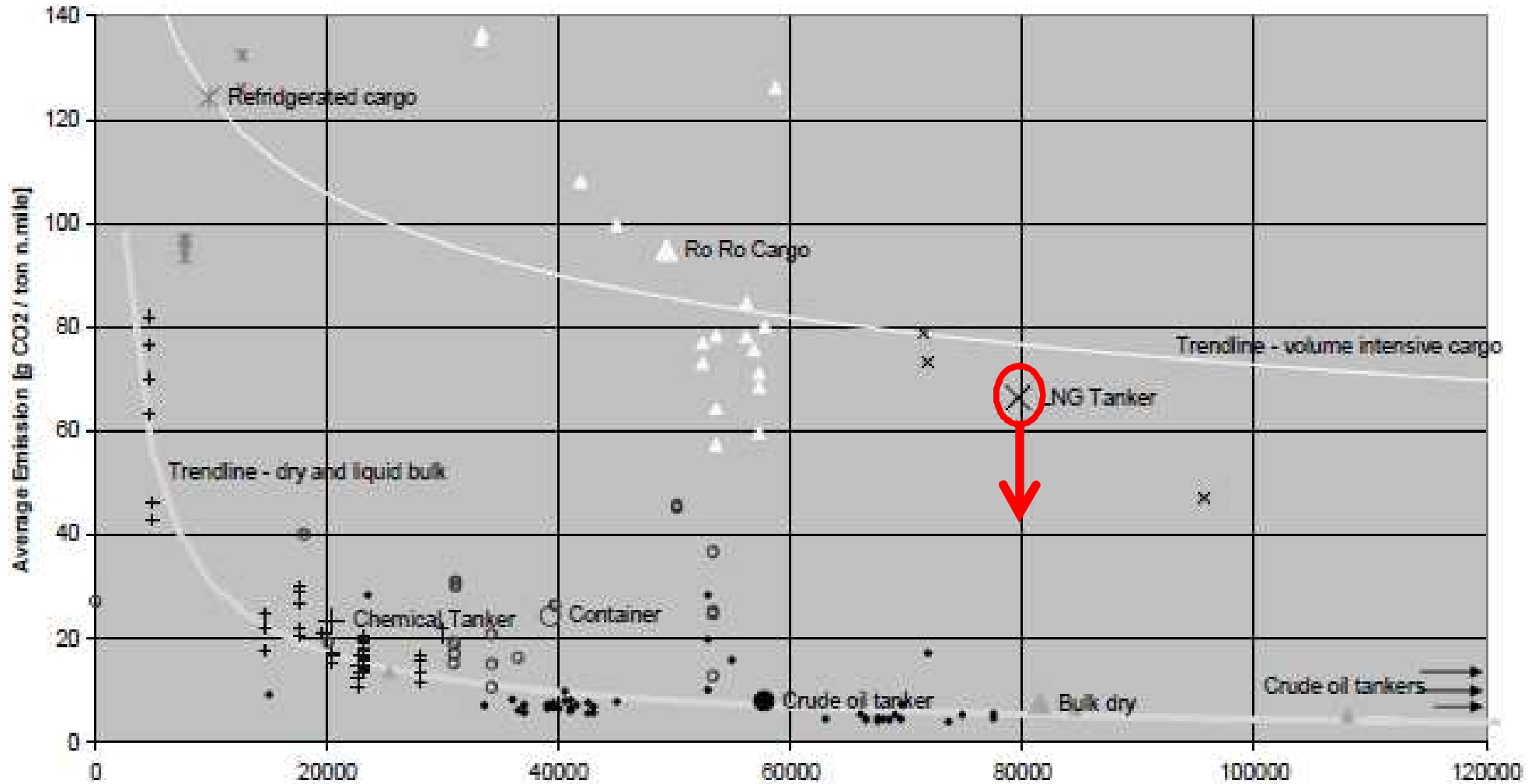
ASSU Implementation



Objective is to require argon top up every 3 to 5 years only.....

Why ?

Average CO2 index and Average gross tonnage for ship groups and individual observations



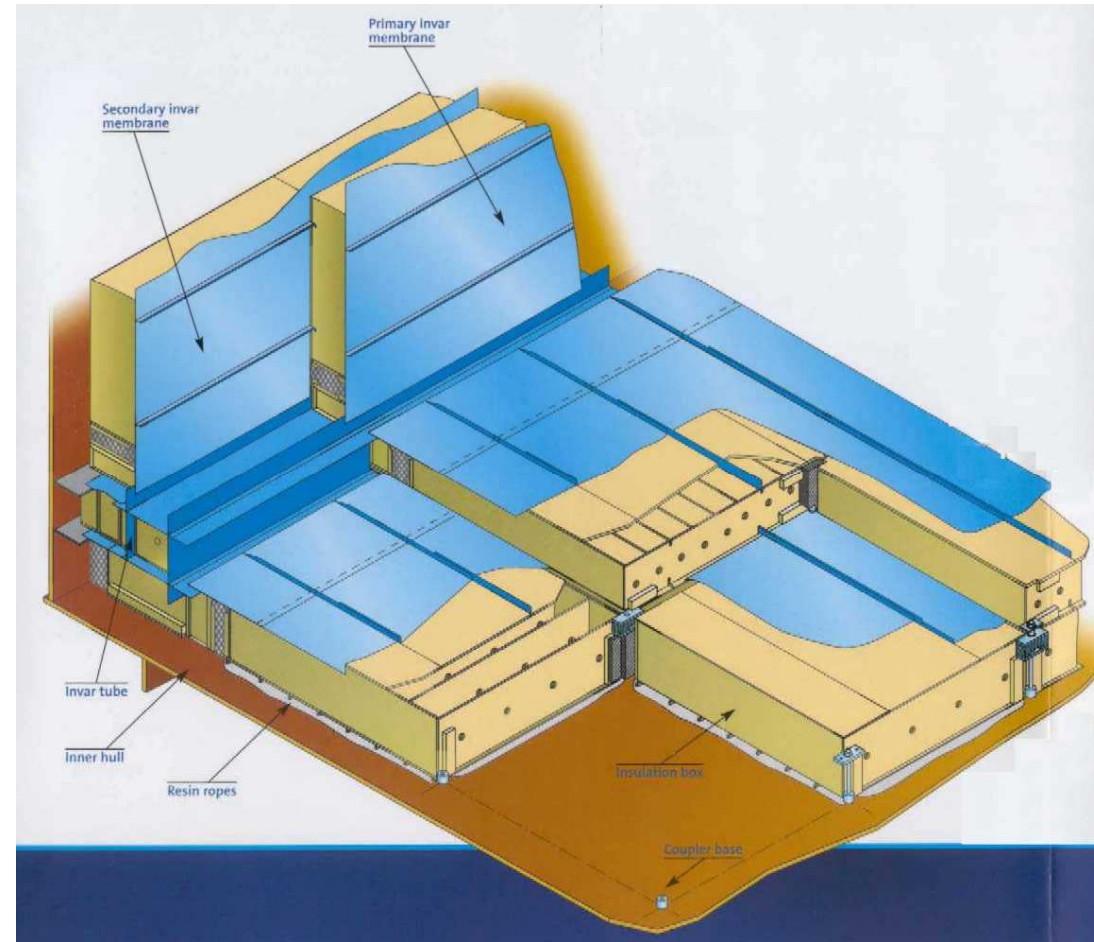
Objective is to reduce LNGCs footprint by reducing speed.....

Membrane tank State of the art

Same insulation technology for slow speed Diesel & re liquefaction or Diesel Electric than for Steam Driven LNGC although :

- BOG not used as fuel for slow speed Diesel
- Dual Fuel Diesel are more efficient than steam turbine...

Performance of insulation (thickness) optimised with the size and power consumption of the re liquefaction unit or Dual fuel Diesel reduced consumption against ... the shipping capacity

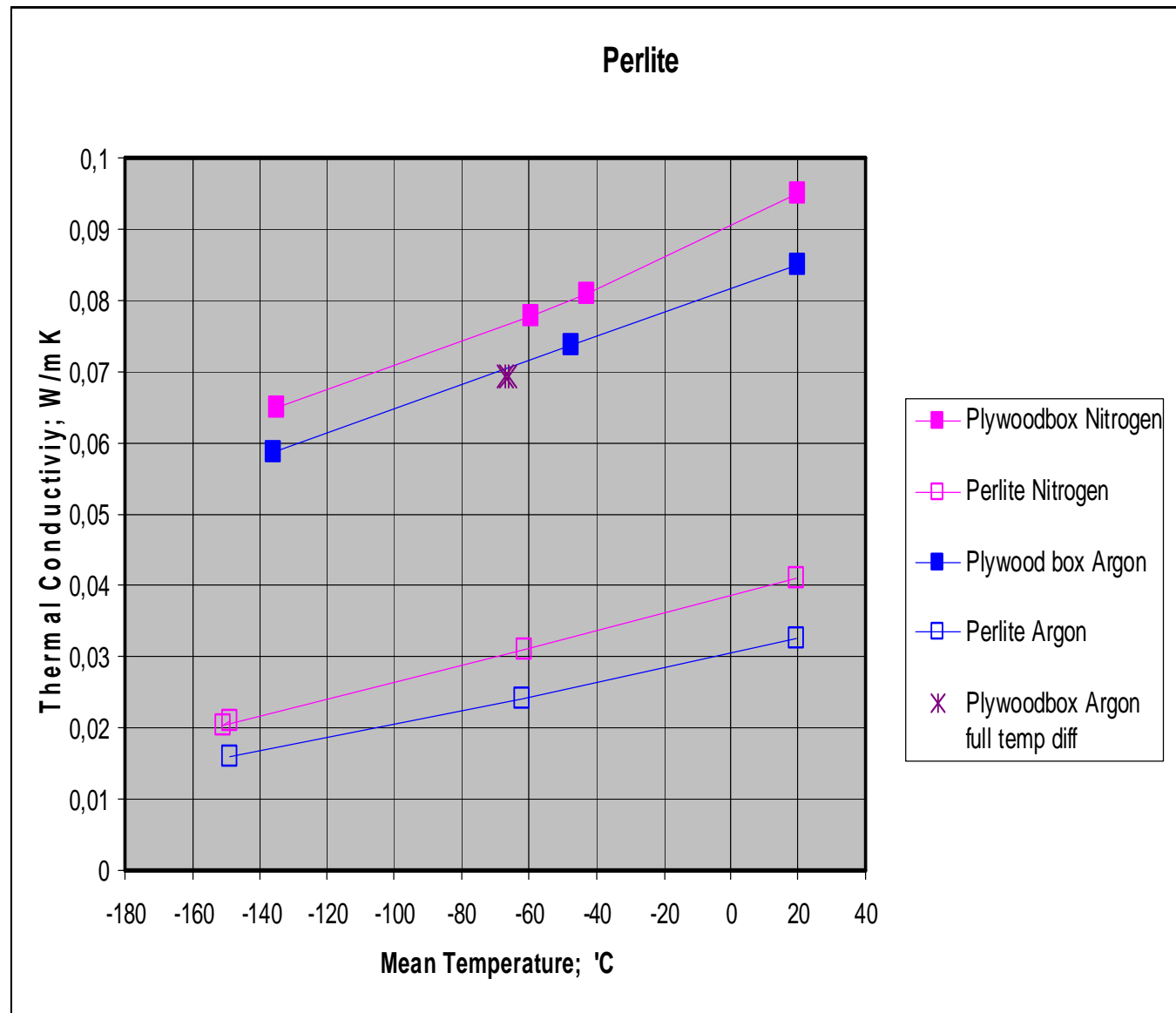


→ In some cases, the insulation performance prevents from "cashing in" all the potential benefits of new propulsion schemes...

→ Typical BOG rate for LNGCs : 0.15 %, i.e 225 m³ per day for a 150 000 m³ LNGC..

Test results

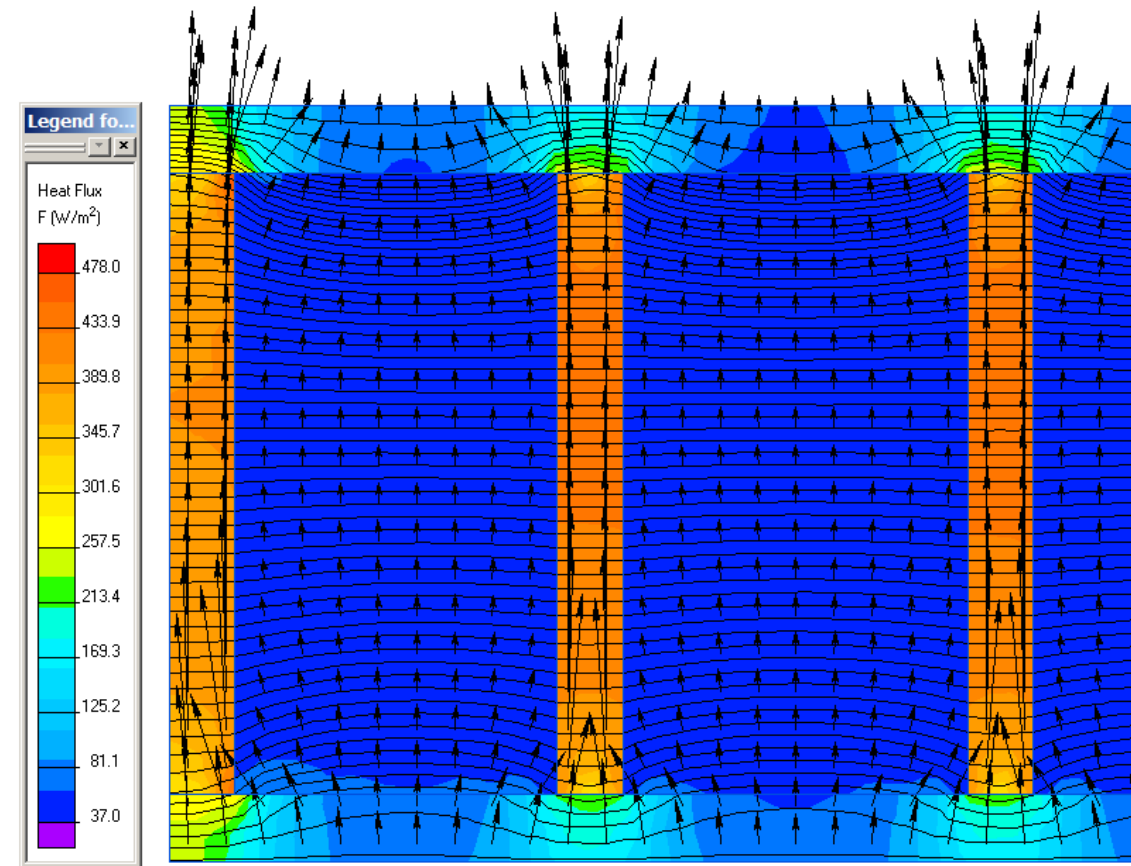
- Test results confirmed expectations...
- ...and confirmed a 10% gain of NO 96 overall thermal performance, including heat fluxes through plywood...



Thermal modeling

2D thermal modeling of the NO 96 box have been performed and validated with the test results

in particular they confirmed 10 % overall gain, taking into account the contribution of the plywood to the total heat flux



Safety aspects

- *IGC : "Interbarrier and hold spaces associated with cargo containment systems for flammable gas requiring full secondary barriers should be inerted with a suitable dry inert gas and kept inerted with a suitable dry inert gas provided by a shipboard inert gas generation system, or by a shipboard storage which should be sufficient for normal consumption for at least 30 days."*
- *Gas Encyclopedia for Nitrogen and Argon : "Physiologically, inert, non toxic gas. By displacing the oxygen in the air, it may have harmful effect on the organism, by reducing the partial pressure of oxygen and acting as an asphyxiant."*
- *NG leak carrying capacity : argon is 2,4 times heavier than methane compared to nitrogen which is only 1,8 times heavier, generating a 30 % increase in buoyancy effect which should speed up detection and collection of any natural gas leaks through the membrane, increasing the safety of the cargo containment system.*

→ From safety point of view, use of argon is clearly feasible

Potential gains

Dual Fuel

Hypothesis			
LNG value	4 \$/mmBtu	mmBTU/m3	
	94 \$/m3	23,6	
	207,68 \$/ton	m3/t	
Nominal BOG rate	0,0015 /day		2,2
Nominal loaded Speed	19,5 knots		
BOG reduction	10 %		
Reduced BOG rate	0,00135 %/day		
Modified loaded Nominal	18,8 knots		
Nominal Ballast speed	19,5 knots		
Route Length	10 000 nautical miles		
Cargo tank capacity	210 000 m3		
Nominal transit duration	42,7 days		
Loading/unloading period	2,0 days		
Flaring periods	0,5 days		
Rotation duration	44,7 days		
Modified transit duration	43,5 days		
Modified rotation duration	45,5 days		
Operating days	350 days/year		
Number of rotations	7,8 per year		
Modified number of rotations	7,7 per year		
Nominal Unloaded LNG	1 536 454 m3/year		
Modified unloaded LNG	1 545 415 m3/year		
Extra Unloaded LNG	8 961 m3		
Extra Unloaded LNG value	845 942 \$/year/vessel		
LNG shipping efficiency improvement	0,58 %		
CO2 emission savings	11 202 tons/year		
CO2 emission permit value	30 \$/ton		
CO2 emission permits gain	336 047 \$/year		
Total extra profit	1 181 989 \$/year		

Qflex & Qmax

Hypothesis	Qflex	Qmax	
Cargo tank capacity	210 000	260 000	m ³
Reliq plant ballast voyage input power	5	6	MW
Reliq plant loaded voyage input power	5,5	7	MW
Operating days		350	days/year
Ballast voyage		175	days/year
Loaded voyage		175	days/year
Reliq plan Power consumption	44 100	54 600	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	7 497	9282	tons/year
Reliq plant CO2 emissions	25578	31668	tons/year
BOG reduction	10 %		
Modified Reliq Plant Power consumption	39 690	49 140	MWh/year
Modified Reliq plant HFO consumption	6 747	8 354	tons/year
Modified Reliq plant CO2 emissions	23 020	28 501	tons/year
HFO value	400 \$/ton		
CO2 value	30 \$/ton		
	Qflex	Qmax	
HFO savings	299 880	371 280	\$/year
CO2 emissions savings	76 734	95 004	\$/year
Total Savings	376 614	466 284	\$/year

Benchmarking

NG2TANK
is one of the
best solutions
to reduce
emissions!!

