D7.2: Comparative analysis of CNG-GASEVESSEL versus LNG and Pipeline

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Glossary, abbreviations and acronyms

bcm	billion cubic meters
bbl	barrel of crude oil
CAPEX	capital expenditures
CBA	cost-benefit analysis
FLNG	floating liquefied natural gas facility
FRSU	floating storage regasification unit
km	kilometre
knots/kn	nautical mile per hour
kWh	kilowatt hour
LNG	liquefied natural gas
MGO	marine gas oil
mmbtu	million British thermal unit
mmscmd	million standard cubic meter a day
mmscfd	million standard cubic feet a day
nm	nautical mile
Nm^3	normal cubic metre
NPV	net present value
OPEX	operating Expenses
Que$tor	software tool for capital and operating cost-estimation.
sm^3	standard cubic metre
VOLTA	optimization and cost calculation software developed by Esteco (WP2)
VOYEX	voyage expenses

1 Executive Summary

D7.2 presents the results of the comparative analysis carried out in T7.2. The GASVESSEL transport system is compared with alternatives pipeline and LNG to uncover the potential niche market for GASVESSEL and the volume/distance range for which GASVESSEL is cost competitive against pipeline and LNG options.

The work has consisted in:

- First, identifying GASVESSEL unit costs for each of the geo-logistic scenarios depicted in the project and input cost data from other WPs.
- Second, GASVESSEL cost curves for distance and volume ranges of 100-5000 km and 0,5-15 bcm/year were established, based on a GASVESSEL cost model. Variation in input parameters for GASVESSEL enables to highlight the cost sensitivity of the GASVESSEL to parameters like operating days, speed, fuel cost etc.
- Third, fixed and variable costs related to alternatives LNG and pipeline were calculated.
- Fourth, a comparison GASVESSEL-LNG-pipeline for each scenario was established.
- Fifth, cost curves for wider volume and distance ranges were established for pipeline and LNG based on the scenario specific figures.

This enables the setup of contour plots highlighting the volume/distance area for which GASVESSEL is cost competitive. Finally, a particular case for GASVESSEL was studied.

1.1.1 Alternative options (GASVESSEL scenarios)

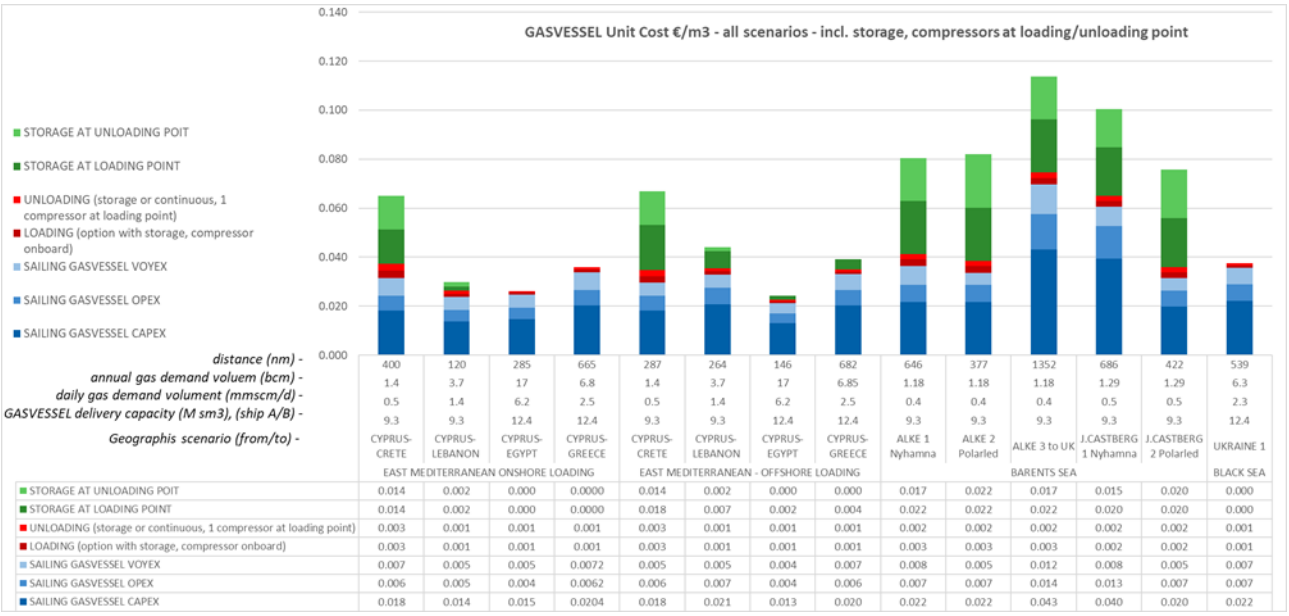
GASVESSEL is assessed and compared primarily based on the geo-logistic scenarios identified in WP2 covering three regions: East Mediterranean, Black Sea and Barents Sea.

Table 2: GASVESSEL scenarios (compiled from WP2, WP7)

REGION	SCENARIO	SOURCE	LOADING POINT	UNLOADING POINT	Volume mmscmd (bcm /yr)	Distance km (nm)	DESTINATION
BARENTS SEA	BARENT SEA Field - POLARLED	OFFSHORE GAS / ASSOCIATED GAS FIELD	OFFSHORE	OFFSHORE	1.18/1.29 (0.43/0.47)	697/781 (377/422)	Polarled => Langeled to UK
	BARENT SEA Field - NYHAMNA			ONSHORE	1.18/1.29	1195/1269 (646/686)	Langeled => UK
	FIELD - UK			ONSHORE	1.18	2501 (1352)	UK
MEDITER-ANNEAN SEA	CYPRUS - CRETE	OFFSHORE GAS FIELD => PIPELINE TO VASSILIKOS ENERGY HUB	ONSHORE	ONSHORE	1,41 (0,5)	740 (400)	Crete Power stations
	CYPRUS – LEBANON				3,67 (1.35)	222 (120)	Lebanon Power stations
	CYPRUS - EGYPT				17 (6.2)	527 (285)	Egypt Power stations
	CYPRUS - GREECE				6.85 (2.5)	1230 (665)	Greece mainland
	CYPRUS - CRETE	OFFSHORE GAS FIELD	OFFSHORE	ONSHORE	1,41 (0,5)	531 (287)	Crete Power stations
	CYPRUS – LEBANON				3,67 (1.35)	488 (264)	Lebanon Power stations
	CYPRUS - EGYPT				17 (6.2)	270 (146)	Egypt Power stations
	CYPRUS - GREECE				6.85 (2.5)	1262 (682)	Greece mainland
BLACK SEA	GEORGIA - UKRAINE	Shah-Deniz Gas fields, Azerbaijan	ONSHORE	ONSHORE	2.3 (6.3)	997 (539)	South Caucasus Gas Pipeline Gas pipeline

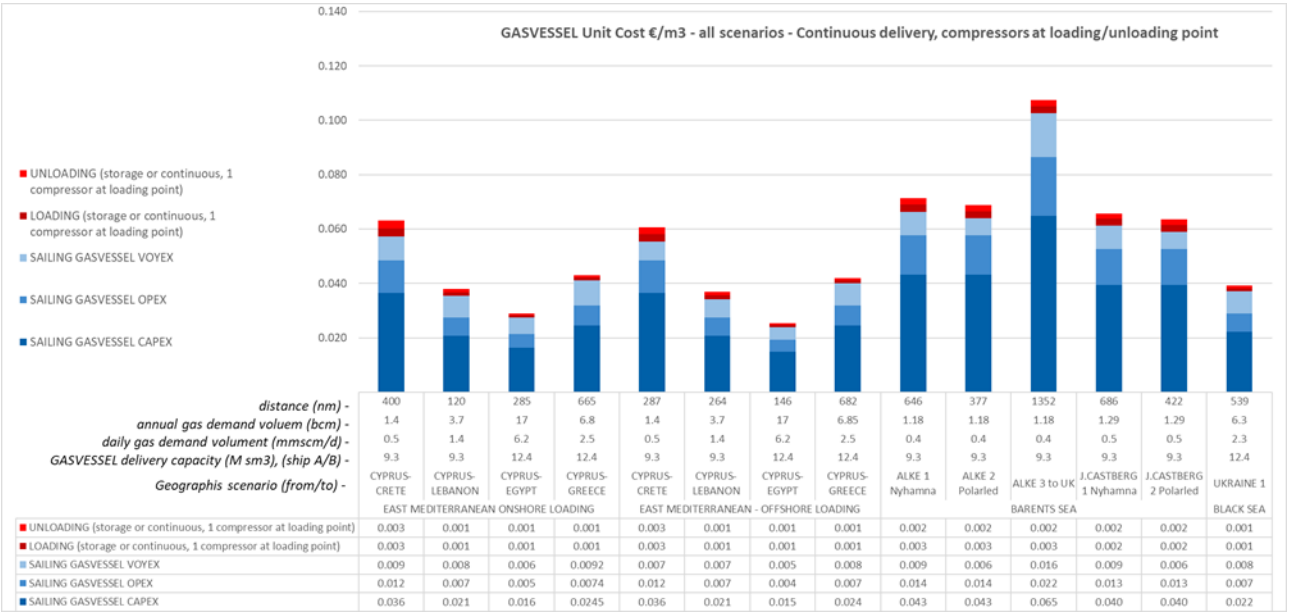
1.1.2 GASVESSEL costs

GASVESSEL unit costs, broken down into storage, loading/unloading and transport are displayed in the next two figures, first the option "with storage", then "continuous delivery".



distance (nm) -	400	120	285	665	287	264	146	682	646	377	1352	686	422	539
annual gas demand voluem (bcm) -	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3
daily gas demand volument (mmscm/d) -	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4
Geographis scenario (from/to) -	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1
	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING						BARENTS SEA			BLACK SEA
STORAGE AT UNLOADING POIT	0.014	0.002	0.000	0.0000	0.014	0.002	0.000	0.000	0.017	0.022	0.017	0.015	0.020	0.000
STORAGE AT LOADING POINT	0.014	0.002	0.000	0.0000	0.018	0.007	0.002	0.004	0.022	0.022	0.022	0.020	0.020	0.000
UNLOADING (storage or continuous, 1 compressor at loading point)	0.003	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.001
LOADING (option with storage, compressor onboard)	0.003	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.002	0.001
SAILING GASVESSEL VOYEX	0.007	0.005	0.005	0.0072	0.005	0.005	0.004	0.007	0.008	0.005	0.012	0.008	0.005	0.007
SAILING GASVESSEL OPEX	0.006	0.005	0.004	0.0062	0.006	0.007	0.004	0.006	0.007	0.007	0.014	0.013	0.007	0.007
SAILING GASVESSEL CAPEX	0.018	0.014	0.015	0.0204	0.018	0.021	0.013	0.020	0.022	0.022	0.043	0.040	0.020	0.022

Figure 7: GASVESSEL unit cost (€/Nm3) per scenario – strategy "storage", compressors at (un)loading point



distance (nm) -	400	120	285	665	287	264	146	682	646	377	1352	686	422	539
annual gas demand voluem (bcm) -	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3
daily gas demand volument (mmscm/d) -	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4
Geographis scenario (from/to) -	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1
	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING						BARENTS SEA			BLACK SEA
UNLOADING (storage or continuous, 1 compressor at loading point)	0.003	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.001
LOADING (storage or continuous, 1 compressor at loading point)	0.003	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.002	0.001
SAILING GASVESSEL VOYEX	0.009	0.008	0.006	0.0092	0.007	0.007	0.005	0.008	0.009	0.006	0.016	0.009	0.006	0.008
SAILING GASVESSEL OPEX	0.012	0.007	0.005	0.0074	0.012	0.007	0.004	0.007	0.014	0.014	0.022	0.013	0.013	0.007
SAILING GASVESSEL CAPEX	0.036	0.021	0.016	0.0245	0.036	0.021	0.015	0.024	0.043	0.043	0.065	0.040	0.040	0.022

Figure 9: GASVESSEL unit cost (€/Nm3) per scenario – strategy "continuous delivery", compressors at (un)loading point

1.1.3 Alternative options (GASVESSEL scenarios)

The GASVESSEL costs for the two options presented above (storage and continuous delivery) are further juxtaposed with pipeline and LNG unit costs for each scenario.

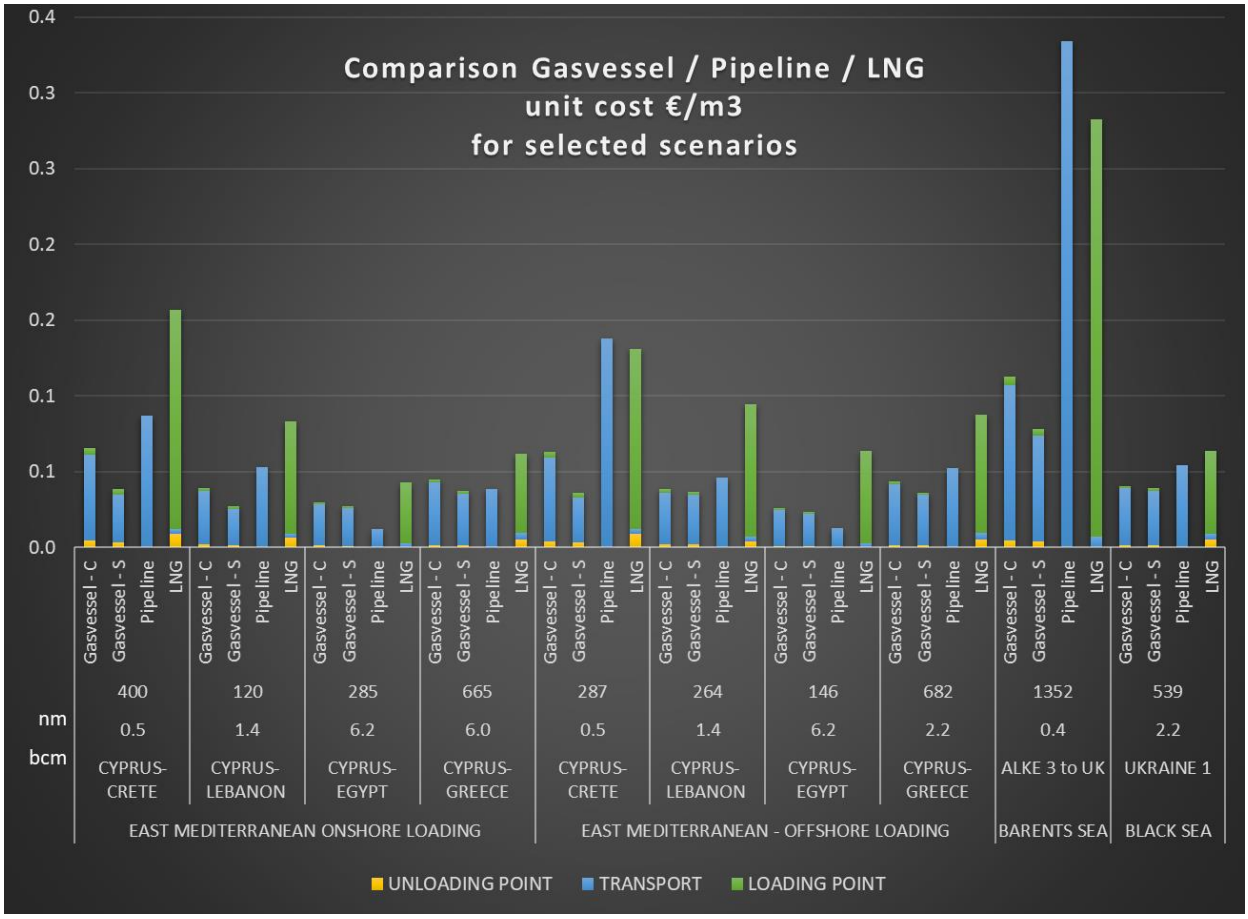


Figure 30: costs (€/Nm³) for GASVESSEL (storage and continuous delivery options), LNG and pipeline for each geo-logistic scenario.

1.1.4 Generalisation

Figure 15, Figure 31 and Figure 32 below present the cost curves established on the basis of the data from the geo-logistic scenarios, for GASVESSEL, pipeline and LNG respectively.

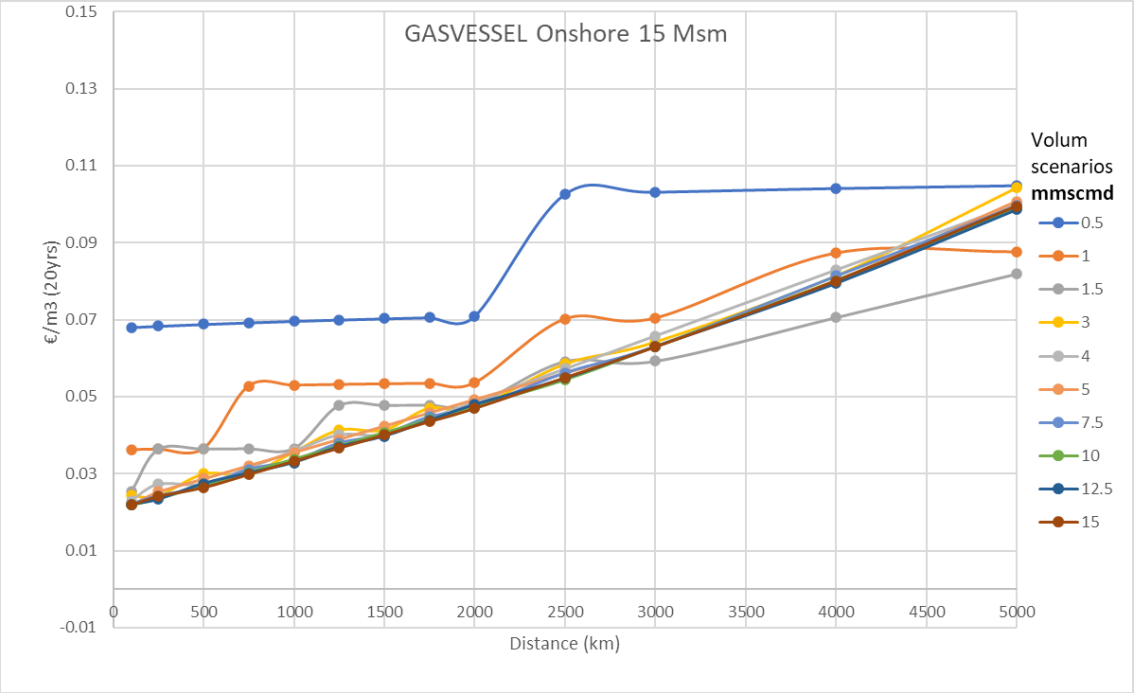


Figure 15: GASVESSEL unit cost per distance (100-5000km) and annual volume (0.5-15 bcm) , based on onshore-onshore case, Ship A (15M Nm3), compressor at (un)loading point, continuous delivery

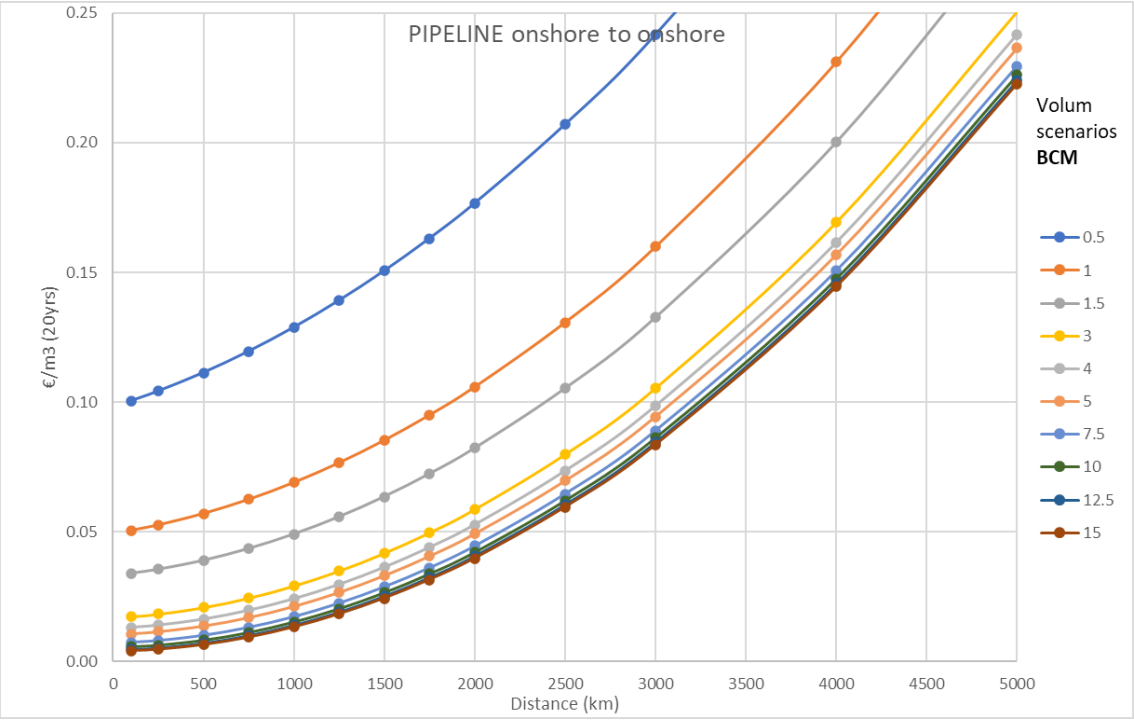


Figure 31 (a and b) Pipeline costs as funciton of distance (km) for distinct volume scenarios (bcm/year), based on (a) onshore scenarios, and (b) offshore scenarios

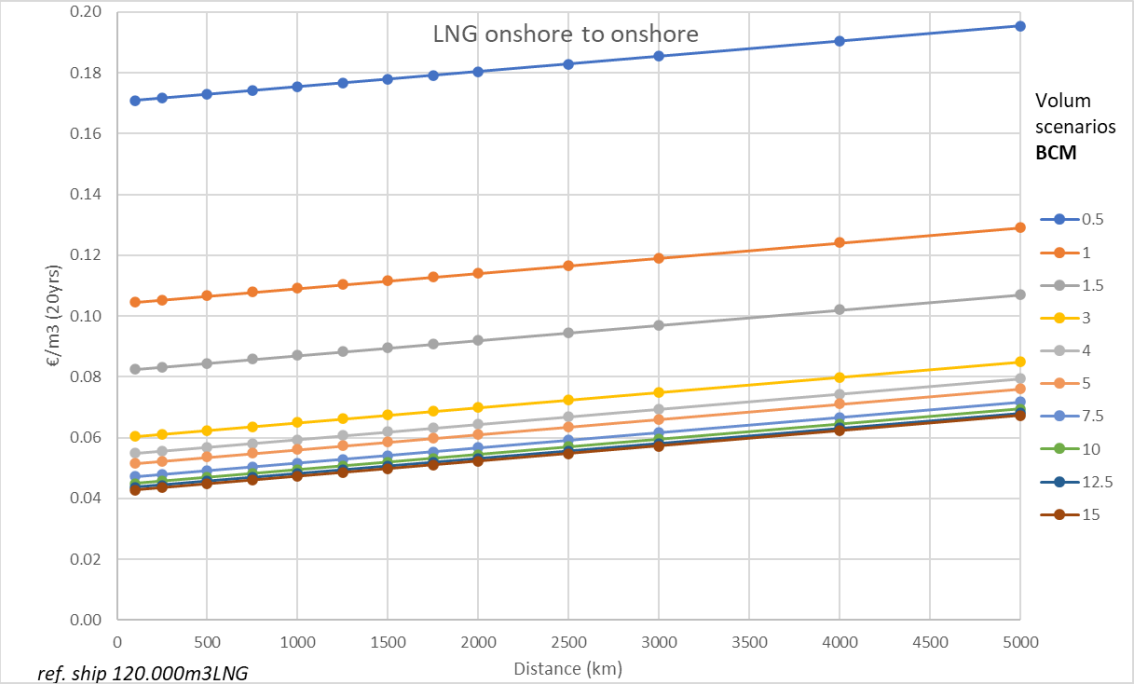


Figure 32 (a and b): LNG and FLNG costs as funciton of distance (km) for distinct volume scenarios (bcm/year), based on (a) onshore scenarios, and (b) offshore scenarios

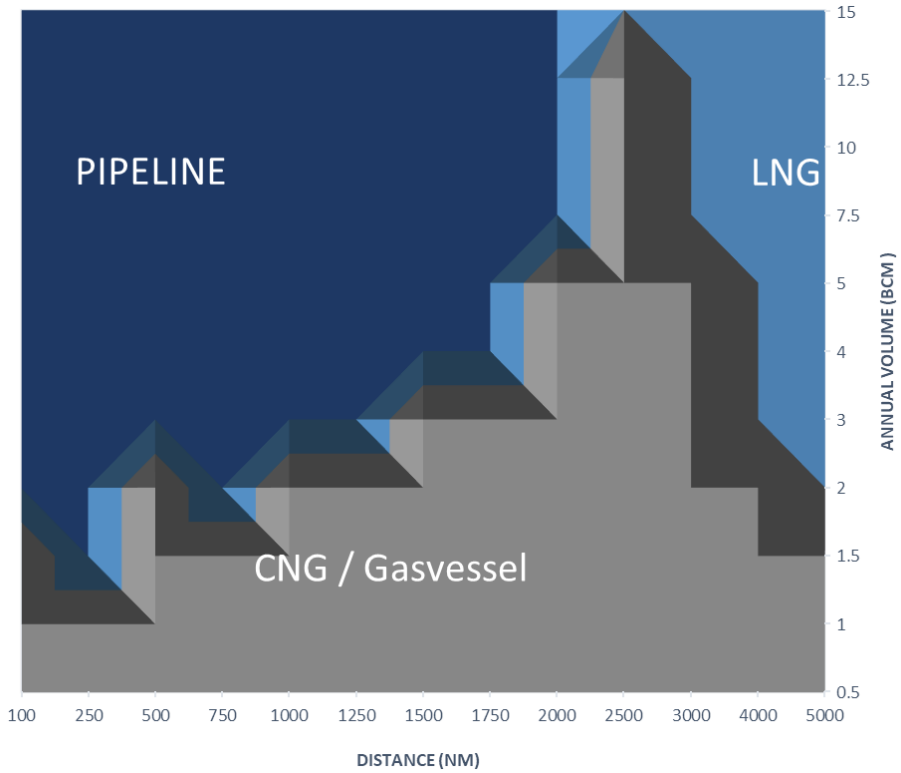
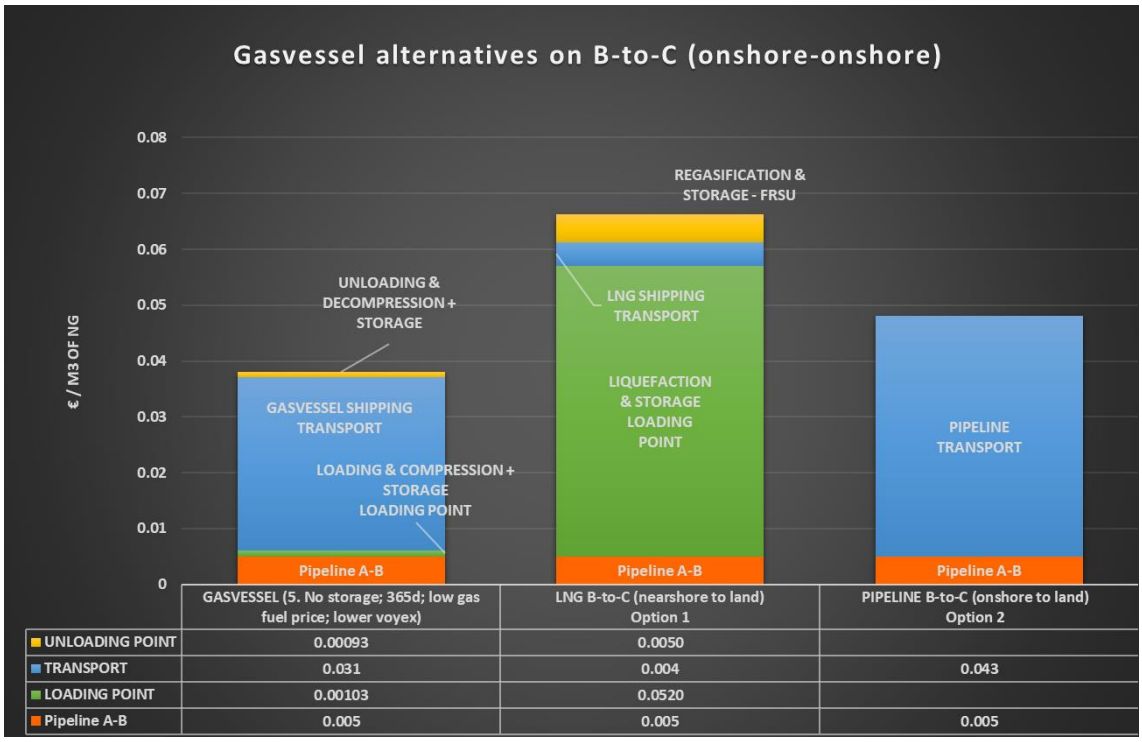


Figure 34 Contour plot unit cost for GASVESSEL (Ship A 15M Nm3), pipeline and LNG.

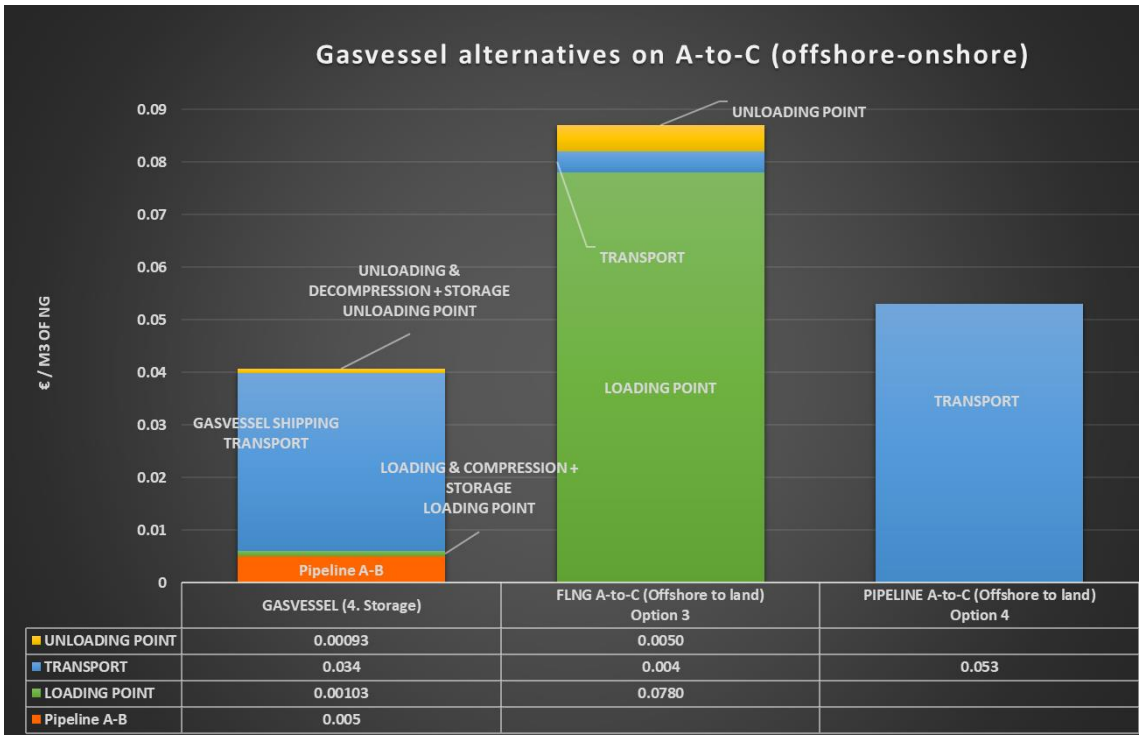
1.1.5 Cyprus-Greece

Finally, the GASVESSEL specific case Cyprus-Greece, starting at offshore field, ending at mainland Greece, through Vasiliko, is compared with pipeline and LNG options, both starting either onshore at Vasiliko, or at offshore field. The GASVESSEL fleet consists of 5 vessels, ensuring continuous delivery of 2.5 bcm/year (6.85 mmscmd). As summarised in Figure 39 and Figure 40, the GASVESSEL system (in combination with pipeline A to B) comes at 15-23% lower costs than pipeline onshore and offshore options, respectively (option 2 and 4), and at 38-53% lower costs than LNG and FLNG, respectively (option 1 and 3).



	GASVESSEL (5. No storage; 365d; low gas fuel price; lower voyex)	LNG B-to-C (nearshore to land) Option 1	PIPELINE B-to-C (onshore to land) Option 2
UNLOADING POINT	0.00093	0.0050	
TRANSPORT	0.031	0.004	0.043
LOADING POINT	0.00103	0.0520	
Pipeline A-B	0.005	0.005	0.005

Figure 39: Gasvessel vs. LNG and pipeline options,



	GASVESSEL (4. Storage)	FLNG A-to-C (Offshore to land) Option 3	PIPELINE A-to-C (Offshore to land) Option 4
UNLOADING POINT	0.00093	0.0050	
TRANSPORT	0.034	0.004	0.053
LOADING POINT	0.00103	0.0780	
Pipeline A-B	0.005		

Figure 40: Gasvessel vs. LNG and pipeline options, unit cost comparison on leg A-C offshore-onshore

2 Introduction

2.1 Purpose

The general objective of GASVESSEL is to prove the techno-economic feasibility of a new CNG transport concept enabled by novel patented Pressure Vessel manufacturing technology and a new conceptual ship design including safe on- and offloading solutions at 300 bar. The GASVESSEL project delivers a competitive cost-efficient CNG ship design and according safety standard verifications regarding ship, Pressure Vessel, loading and unloading facilities.

WP7 is part of the proof-of-concept phase of GASVESSEL and includes a full cost-benefit analysis and a quantitative and qualitative comparison to current systems.

This proof-of-concept is based on selected geo-logistic gas exploitation scenarios (WP2) and starts with benchmarking of the new CNG concept GASVESSEL with alternative gas transportation modes pipelines and FLNG (Current deliverable D7.2, T7.2), and further with profitability assessment in the form of financial plan and socio-economic impact analysis (T7.3, D7.3).

In the EU and the near-market offshore, gas transport today consists of two solutions: pipeline or LNG ships. For different areas and for different reason these traditional solutions are not always financially and/or politically viable. The construction of pipelines is expensive and often due to technical, environmental or political reason not possible. The alternative LNG transport requires considerable investments in liquefaction and regasification facilities. Europe's gas supply from third countries is suffering under a latent danger of disruption due to political disagreements. A more efficient waterborne transport concept that opens up unused gas supplies and that can respond fast and in a flexible manner to external circumstances is therefore necessary to ensure a sustainable and robust energy mix in Europe.

GASVESSEL represents a real opportunity to exploit stranded and associated gas volumes in Europe, which is now reliant on pipelines or the expensive LNG supply chain investments. GASVESSEL can contribute to realizing a new manufacturing industry and jobs in Europe while reinforcing the shipbuilding industry and improving security of energy supply.

Thanks to its flexibility in deployment and limited infrastructure requirement, GASVESSEL can serve as gas shuttle concept between isolated gas supply points (offshore fields) and isolated consumers (islands, poor access to gas network) providing a stable and flexible gas transport system. Liquefying plants and re-gasification are not required for the CNG solution because of the different process of compressing gas done by compressors installed on the ship. By compressing natural gas at the pressure of 300 bar the natural gas density increases hence increasing the quantity of gas to be transported compared to conventional solutions.

2.2 WP7 and T7.2

The main objective of WP7 (Cost-Benefit Analysis) is to provide cost benefit analysis of the GASVESSEL concept and determine for which circumstances the GASVESSEL concept is a competitive or preferred alternative to conventional technologies delivering gas to market.

This is done through two main analysis:

- Comparative analysis: comparing GASVESSEL transport solution with LNG/FLNG and pipeline alternatives (Task T7.2)
- Profitability analysis of GASVESSEL (financial, socio-economic, environmental cost and benefit) (Task T 7.3)

The comparative analysis consists of comparison of costs and emissions of each option (GASVESSEL, pipeline, LNG). The purpose of the task is to demonstrate effectiveness of GASVESSEL, and for which distance and volume range the GASVESSEL is cost competitive against alternative option, and in doing so identifying the niche market for CNG and GASVESSEL in particular.

To prepare and support this work, a database of all data, information, main parameters, cost, and technical specification, as well as analysis tools necessary for cost-benefit analysis has been gathered through Task T7.1.

T7.2 builds on previous work from the GASVESSEL project:

1. ship cost and technical information from WP5;
2. loading/unloading system technical information and costs from WP6;
3. geologistics scenarios from WP2, identified for each geographic regions East-Med, Black Sea and Barents Sea, and fine-tuned using optimisation tool VOLTA from Esteco;
4. identification of cost elements for alternative options (T7.2).

These input data are used in WP7 GASVESSEL fleet & transport system cost model from SINTEF, and compared to cost estimates for pipeline and LNG provided by CHC, for the entire set of transport scenarios. These scenario-specific estimations are further generalised into simplified volume-distance cost estimation curves for a distance range of 100-5000km and volume range of 0.5-15 mmscmd (million standard cubic meter a day).

The main deliverable of T7.2 is a contour plot indicating the combination volume/distance for which either CNG-GASVESSEL, LNG or pipeline is most cost competitive.

To be able to offer relevant comparisons CNG-LNG-pipeline, a distinction has been made between concepts involving offshore loading activity (loading near field) and onshore loading activity (scenarios assuming gas is loaded near an onshore terminal, as well as a distinction between maritime logistics enabling storage vs. strategies of continuous delivery.

2.3 Approach

T7.2 is building on data and data model developed in T7.1.

D7.1 CBA Database consists of the following elements (data flow illustrated in Figure 1):

1. **GASVESSEL market scenarios** (volume, distance, location) identified in **WP2** as potential deployment scenarios for GASVESSEL. These will serve as:
2. **Reference scenarios for the comparative analysis (T7.2)**, from which a set of distance/volume cases will be extrapolated to compare transport unit cost (€/Nm^3) between CNG, LNG and pipeline. The reference scenarios are based on market scenarios identified in WP2, and further completed through logistics optimization with the Esteco VOLTA tool (identifies the associated number of vessels, voyages, deliveries, storage etc).
3. **Technical characteristics, CAPEX and OPEX** of
    a. **Pressure vessels (WP3 and WP4):** used as input to logistics optimization and costs calculation (T7.2) and financial assessment (T7.3.1) and socio-economic analysis (T7.3.2).
    b. **Ship 15M and 12M (WP1, WP5):** used as input to logistics optimization and midstream costs calculation (T7.2).
    c. **Loading/unloading system and infrastructure (WP6)** used as input to logistics optimization and costs calculation (T7.2) and financial assessment (T7.3.1) and socio-economic analysis (T7.3.2).

d. **CNG storage units'** capacity and cost.

4. **Alternative gas distribution options (pipeline, LNG)** identified in **T7.2** used in comparative analysis for distinct volume/distance scenarios.

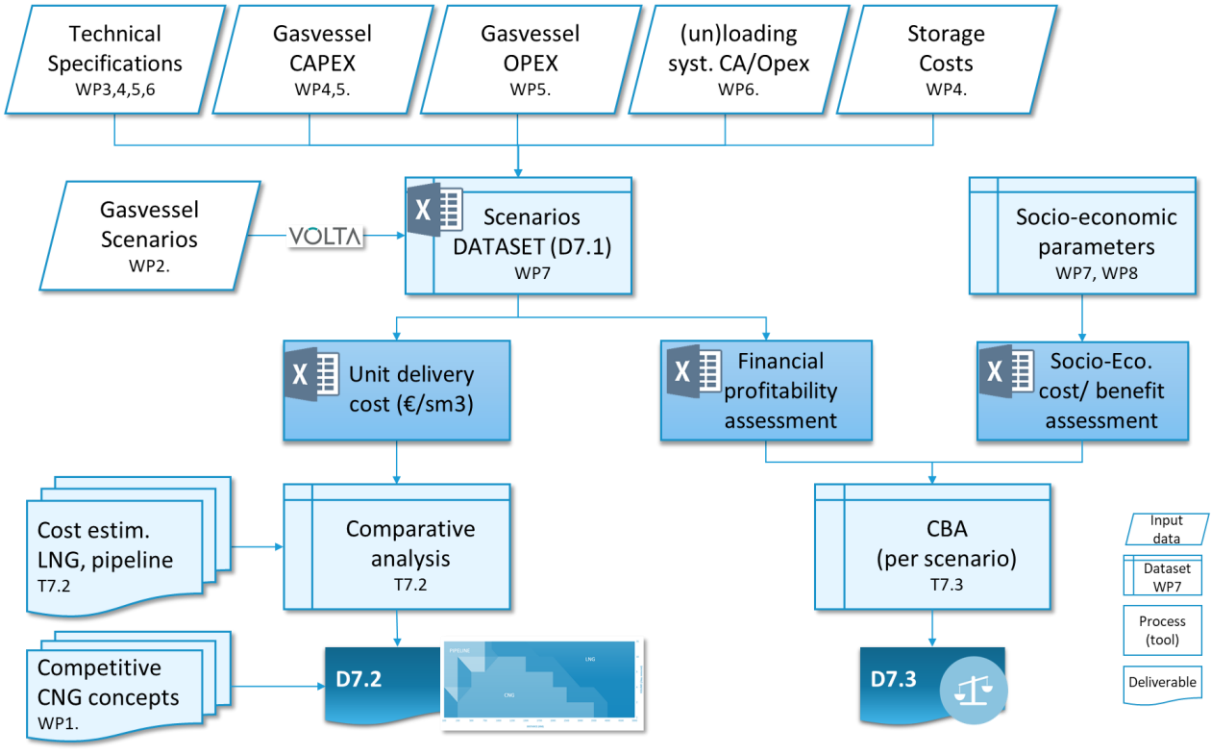


Figure 1: WP7 data process

The approach applied in T7.2 is reflected in the structure of the present Deliverable D7.2:

1. Established the cost structure and identified all cost parameters and data input to be used in GASVESSEL cost calculation, the scenarios used as foundation for the cost assessment, and the main assumptions and description of GASVESSEL fleet and transport system calculation - **Chap 3.**
2. Present the results of GASVESSEL cost calculation per scenario (unit cost for each scenario), as well as sensitivity to certain input variables - **Chap 3.4.1**.
3. Extend GASVESSEL scenarios into generic cases by setting up a GASVESSEL reference scenarios and a model for generalised GASVESSEL costs for volume range 0.5-15 bcm/year and distance range 100-5000km - **Chap 3.4.2**. The purpose is to establish a sufficient number of observations for comparison with LNG and pipeline.
4. Define the scope of the comparative analysis, based on methodology defined by SINTEF, ABS and CHC - **Chap 4.1.**
5. Identify alternatives for each scenario – LNG & Pipeline, and their associated cost - **Chap 4.2**
6. Present a GASVESSEL -LNG-pipeline comparison for each GASVESSEL scenario. Deduct a generic cost calculation from these scenarios. And identify cost estimated LNG / pipeline for further volume/distance cases, summarised in comparison plots highlighting most competitive options, for distinct volume and distance, in term of unit costs €/Nm^3 - **Chap 4.3**. (Tariff is not considered, to avoid discrepancy in calculation, across regions or across technological options.)
7. A specific GASVESSEL case is further explored, where a GASVESSEL based maritime CNG logistics chain is set up and compare with distinct pipeline and LNG options - **Chap 5**.

3 GASVESSEL Cost Calculation

3.1 Introduction

This chapter describes the cost structure of the GASVESSEL, i.e., the cost of the GASVESSEL fleet and transport system per unit of gas delivered, including data sources, main assumptions, and calculations.

The scope of the cost calculation is marked in yellow in the below figure:

3.1.1 Cost structure

The cost of GASVESSEL fleet and transport system consists of:

- The GASVESSEL cost, including ship, pressure vessels and compressor (CAPEX per ship).
- The compressor cost is handled separately in the calculation to enable consideration of moving the compressor at loading/unloading point rather than onboard. This to avoid the duplication of compressors onboard unnecessarily in the case of, for instance, large fleet.
- The GASVESSEL ship operating costs (OPEX per ship).
- The GASVESSEL transport system variable costs / voyage costs (VOYEX, per roundtrip per ship).
- The loading/unloading infrastructure acquisition cost and operating costs (CAPEX+OPEX per GASVESSEL transport system/scenario).
- The gas storage system acquisition cost and operating cost (CAPEX+OPEX per GASVESSEL transport system/scenario).

	CAPEX (per ship and per transport system)	OPEX (per ship)	VOYEX (per roundtrip per ship)
Ship & Pressure vessels	Vessel cost (WP5)	Estimated WP5	• Fuel consumption (DF engine gas mode) - Propulsion (transit, manoeuvring, berth) - Compressors (un+)loading • Port costs
Compressors	Separate cost (WP5)	Estimated WP5	
Loading/Unloading insfratructure	Option 1: Underwater pipeline & floating mooring buoy; Option 2: equiped jetty (WP6)	10% of fixed costs	
Gas storage and facility	Onshore: Cylinder Offshore: Gasvessel	10% of fixed costs	

Figure 2: GASVESSEL cost components, structure, main sources and principles applied.

CAPEX is estimated for vessels, storage options and loading/unloading facilities. For simplicatation purposes and to enable the generalisation of the calculation, a yearly CAPEX is calculated based on the estimated 20 years of operation for the GASVESSEL concept.

3.2 Data input and main assumptions

3.2.1 Vessel capacity

The two distinct vessels proposed in GASVESSEL and designed in WP5 differ only in term of carrying capacity. **Ship A** and **ship B** have a total gas cylinder capacity of **15M** and **12M** cubic meter of gas (Nm^3), respectively. From this, the available capacity which can be discharged at each voyage is **12,4M Nm^3** and **9,3M Nm^3** respectively for gas carriers Ship A and Ship B. This figure is applied as a fixed figure in the calculation of the fleet and transport system. The remaining cargo is used for:

(1) As fuel for propulsion during the entire roundtrip. A fixed figure of 200 tons of gas is applied (estimated earlier in the project based on a 5-day roundtrip), to identify the remaining cargo delivery capacity. However, in the cost calculation for each distance/volume scenario, the amount of gas fuel is calculated accounting for distance.

(2) Another part of the cargo is kept for running the compressors during loading and unloading. Estimated around 80 tons gas earlier in the project (WP5), the amount applied in the GASVESSEL cost calculation is 99 tons and 75 tons respectively for Ship A and B. This amount is estimated at 0,5% and 0,7% of cargo for loading and unloading, based on Taccani et al. (2020)[1]. These estimates remain unchanged also in scenarios when continuous delivery strategy is applied, and the vessel is kept longer at unloading point.

(3) Approximately 1,5 tons of gas remains in the cylinders to optimize the loading/unloading process (estimate from WP5).

The cargo volume breakdown is illustrated in Figure 3.

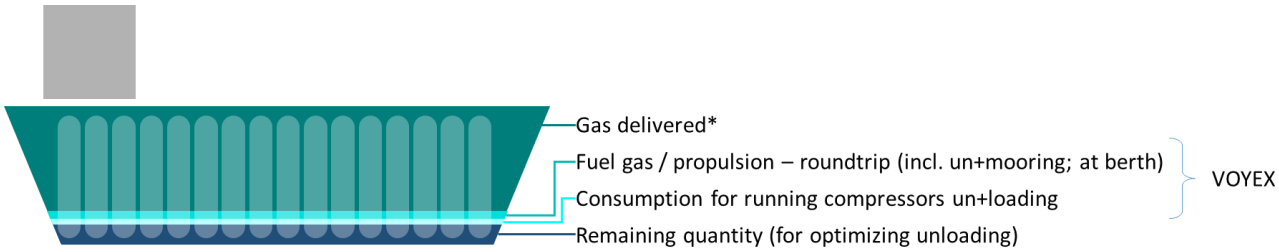


Figure 3: Schema of GASVESSEL carrying capacity

Table 1: Summary table gas carrying capacity breakdown – average figures

Figures in tons (t) and million Normal cubic meters (M Nm^3)	**Ship A**	**Ship B**
Ship total capacity	10 000 t (15 M Nm^3)	6 700 tons (12 M Nm^3)
-Gas unloaded / delivery capacity	8 250 t (12,4 M Nm^3)	6 200 tons (9,3 M Nm^3)
-Gas consumption for propulsion/manoeuvring/hotel	appr. 150 t	
-Gas consumption for running compressors (loading + unloading)	99 t	75t
-Remaining gas kept for optimizing unloading process	1 500 t (2,2 M Nm^3)	

3.2.2 Ship characteristics

The ship characteristics are depicted in WP5, D5.3. These cover the necessary input information for estimating the GASVESSEL fleet and transport system costs: design speed, cargo carrying capacity, installed power.

[1] Taccani et al., 2020: Taccani, Rodolfo; Maggiore, Gabriele; Micheli, Diego. 2020. "Development of a Process Simulation Model for the Analysis of the Loading and Unloading System of a CNG Carrier Equipped with Novel Lightweight Pressure Cylinders" Appl. Sci. 10, no. 21: 7555.

Length Overall	205.0	m
Length B.P.	190.9	m
Breadth moulded	36.0	m
Freeboard deck	15.5	m
Main Deck height / depth	22.0	m
Design Draught	7.5	m
Displacement @ design draught, abt.	40800	t
Speed @ design draught	16.5	kn
Cargo Cylinders carrying capacity, abt.	$15x10^6$	Nm^3

Table 2: A-Ship's main characteristics

ENGINE SYSTEMS:

- 4 generators Wartsila 8V31DF, 4070 kW at 720 rpm
- normal time 3 generators running at 85% load (last one in stand-by generator)
- average load: 3 x 0,85 x 4070 kW = 10380 kW

ITEM	LOCATION	DECK	Q.TY	DESCRIPTION	CHARACTERISTICS	SUPPLIER	TAG	REFERENCE DRAWING	REF. SHEET
1	Engine Rooms	3 at 9000 ABL	4	Main dual fuel generator set	Wartsila 8V31DF, 4070 kW at 720 rpm	Wartsila	-	WP5-D5.3-RV1-833-0-002-B01 General Arrangement	3

Figure 4: GASVESSEL ship main characteristics, engine system (extract from D5.3) and average load assumption (Source: GasVessel: WP5-D5.3-RV1-833-8-001-B01)

Power demand

The CNG ship is designed to have a maximum speed of 16,5 kn. An average speed of 16 kn is assumed in the fleet and power demand estimation.

The power demand for propulsion is based on an estimated average load of 3*4070kw*85%=10 379 kw (4 engines installed, but 3 running at 85% under normal conditions). This covers the phases sailing manoeuvring; for simplification purposes, no distinction is made.

The power demand for hotel during loading/unloading is roughly estimated around 500kw. This figure has little impact of the calculation, but for transparency purposes, the calculation applied is 1 engine and 12,5% load.

The same engine and power system configuration and consumption is applied for both Ship A and Ship B.

The SFOC in Gas mode for the 8V31DF Engine MCR 4070 kW is: fuel gas consumption 7130 kJ/kWh (144 g/kWh, based on gas fuel heating value 49,62 MJ/kg), and fuel oil consumption 2,3 g/kWh.

The fuel used for the loading/unloading process is calculated separately, as gas consumption for running compressors. This amount is estimated at 0,5% and 0,7% of cargo for loading and unloading, based on Taccani et al. (2020)[2]; 99 tons and 75 tons respectively for Ship A and B.

3.2.3 Operational profile

The operational phases of the vessels are divided into:

Sailing: duration time calculated based on constant speed and distance between loading and unloading points.

Mooring and unmooring phase: duration as fixed time amount estimated (WP5)

Loading and unloading time: duration time calculated based on flow rate: Loading 192 ton/hrs, unloading 135 ton/hr (source: Taccani et al., 2020): 43/32 hours for loading time and 61/46 hours for unloading, respectively for ship A/ship B. This is comparable to the figures originally estimated in the project loading/unloading ship A 30/70hrs and ship B 23/53hrs (NavalProgetti Midstream cost calculation interim

[2] Taccani et al., 2020: Taccani, Rodolfo; Maggiore, Gabriele; Micheli, Diego. 2020. "Development of a Process Simulation Model for the Analysis of the Loading and Unloading System of a CNG Carrier Equipped with Novel Lightweight Pressure Cylinders" Appl. Sci. 10, no. 21: 7555.

report, 2020). Extended unloading time is estimated under the "continuous delivery" strategy (calculation is depicted in Chapter 3.3 *GASVESSEL fleet and transport system*).

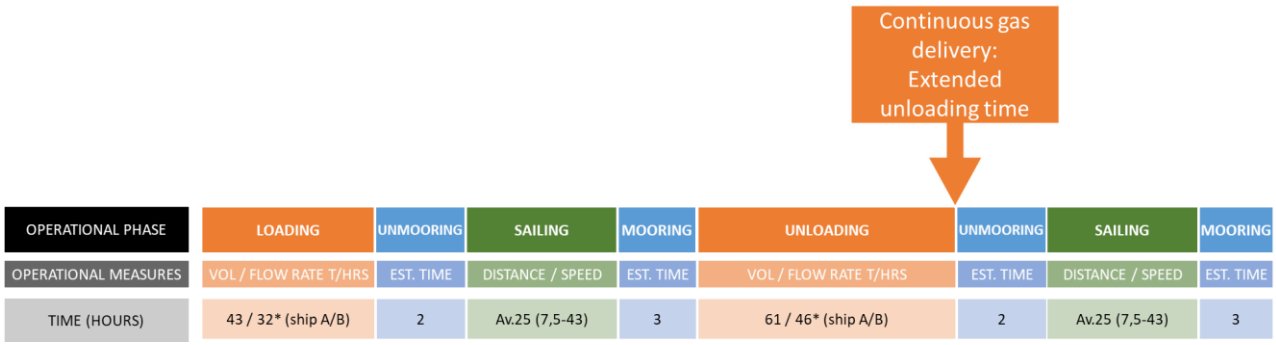


Figure 5: Schema of GASVESSEL operational profile

3.2.4 OPEX

OPEX is estimated in WP5 (HLL). The same OPEX is applied for Ship A (15 M Nm^3) and Ship B (12 M Nm^3).

OPEX for compressors is included in the estimation of the GASVESSEL ship OPEX. However, in the GASVESSEL fleet and transport cost estimation, the compressor costs are located under loading and unloading costs, to facilitate the comparison with LNG following a structure loading-shipping-unloading. Consequently, in the WP7 cost calculation, the estimated 300k€ for compressors S&R are moved from ship OPEX and treated separately as compressor OPEX. This also enables modularisation in the GASVESSEL transport system cost calculation: one configuration with compressors onboard the GASVESSEL and a second configuration with compressor set at loading and unloading port (in that configuration, the number of compressors at loading/unloading point corresponds to the number of ships simultaneously mooring for cargo handling operations).

The daily OPEX estimated for one 15 M Nm^3 vessel is 9320€, and 8498€ after removing the compressors' OPEX.

	15 M GASVESSEL Operational costs	
Vessel type	CNG Ship 15M	Vessel age: Newbuilding
Displacement:	41,000 mt	Maintenance condition: Good
Flag:	European	no major technical problems

Cost position	*Remarks*	*Annual costs*
CREW		
Crew wages	Crew of 22, European Officers, Asian Ratings	1 024 610 EUR
Training		17 857 EUR
Crew travelling overlapping		19 727 EUR
Travel costs	Trading area in Europe	40 000 EUR
Social contribution	Filipino requirement Filipino Social Security System	6 750 EUR
Crew management/ manning agency		28 333 EUR
ITF fees	Union fees for EU trading	8 000 EUR
Provisions	8.0 EUR/ person/ day	64 240 EUR
Fresh Water		5 000 EUR
	Total	***1 214 517 EUR***
LUBRICANTS/ CONSUMABLES		
Lubricants		70 000 EUR
Paint		15 000 EUR
Chemicals		12 000 EUR
	Total	***97 000 EUR***
STORES		
Dispensary		3 000 EUR
General Stores	Deck/ Engine stores	55 000 EUR
Wires/ Ropes		8 000 EUR
Nautical Publications	Sea charts, publications.	10 000 EUR
Security Equipment		2 000 EUR
	Total	***78 000 EUR***
SPARES AND REPAIRS		
S+R Deck		10 000 EUR
S+R Main Diesel Generators	Average costs per year. Engines are overhauled one-by-one in consecutive years	812 000 EUR
S+R Electrical Equipment		15 000 EUR
S+R Other Machinery		50 000 EUR
S+R Purifiers and Filters		3 000 EUR
S+R Pumps and Compressors		4 000 EUR
S+R CNG Compressors	Estimation	300 000 EUR
S+R Gas System onboard	Gas system for propulsion plant.	100 000 EUR
S+R Boiler/ Heater		4 000 EUR
S+R, Services bridge equipment/ navigational and communication equipment		10 000 EUR
S+R Provision plant/ AC		2 500 EUR
S+R, Services Safety Equipment		12 000 EUR
		1 322 500 EUR
INSURANCE		
H&M	incl. IV, total value 265,000 EUR, valid for fleet cover.	248 788 EUR
P&I		54 167 EUR
LoH	7.2 Mio EUR LoH limit, TEUR 40 daily rate 180/180	67 526 EUR
Other insurance		10 000 EUR
		380 481 EUR
Klassifizierungskosten		
Class	block fee costs of ABS	26 786 EUR
Flag State/ Tonnage Tax	Portugal: 15,000 EUR/ Liberia 10,000 EUR	10 000 EUR
Other certification		5 000 EUR
		41 786 EUR
OTHER OPERATIONAL COSTS		
ISM/ ISPS/ MLC/ ISO 9000	External costs of certification of management systems	10 000 EUR
Communication expenses		15 000 EUR
Transport/Freight		20 000 EUR
Travel costs inspection		4 000 EUR
Travel cost HSQE		3 500 EUR
Other sundries		15 000 EUR
		67 500 EUR

	OPEX	**EUR/ Year**
	Crew	1 214 517 EUR
	Insurance	380 481 EUR
	Stores, Spares, Repairs	1 497 500 EUR
	Flag/ Class/ Registration	41 786 EUR
	Other OPEX	67 500 EUR
	Total OPEX (EUR/ Year)	**3 201 784 EUR**
	Total OPEX (EUR/ day)	**8 772 EUR**
	Management fee (EUR/ year)	200 000 EUR
	Total OPEX including management(EUR/ day)	**9 320 EUR**

Removing Compressor S&R:

OPEX	EUR/ Year
Crew	1 214 517 EUR
Insurance	380 481 EUR
Stores, Spares, Repairs	1 197 500 EUR
Flag/ Class/ Registration	41 786 EUR
Other OPEX	67 500 EUR
Total OPEX (EUR/ Year)	**2 901 784 EUR**
Total OPEX (EUR/ day)	**7 950 EUR**
Management fee (EUR/ year)	200 000 EUR
Total OPEX including management(EUR/ day)	**8 498 EUR**

3.2.5 Scenarios

The GASVESSEL fleet and transport system costs are calculated for each of the scenarios identified in WP2. These scenarios cover three distinct geographical regions – East Mediterranean, Barents Sea/North Sea, and Black Sea. These scenarios are used in T7.2 to showcase the potential for GASVESSEL based on various logistics concepts, gas sources and destinations, distances, and volumes. Table 2 summarises the set of scenarios used in the present GASVESSEL cost calculation and the comparison study.

Table 2: GASVESSEL scenarios (compiled from WP2, WP7)

REGION	SCENARIO	SOURCE	LOADING POINT	UNLOADING POINT	Volume mmscmd (bcm /yr)	Distance km (nm)	DESTINATION
BARENTS SEA	BARENT SEA Field - POLARLED	OFFSHORE GAS / ASSOCIATED GAS FIELD	OFFSHORE	OFFSHORE	1.18/1.29 (0.43/0.47)	697/781 (377/422)	Polarled => Langeled to UK
	BARENT SEA Field - NYHAMNA			ONSHORE	1.18/1.29	1195/1269 (646/686)	Langeled => UK
	FIELD - UK			ONSHORE	1.18	2501 (1352)	UK
MEDITER-ANNEAN SEA	CYPRUS - CRETE	OFFSHORE GAS FIELD => PIPELINE TO VASSILIKOS ENERGY HUB	ONSHORE	ONSHORE	1,41 (0,5)	740 (400)	Crete Power stations
	CYPRUS – LEBANON				3,67 (1.35)	222 (120)	Lebanon Power stations
	CYPRUS - EGYPT				17 (6.2)	527 (285)	Egypt Power stations
	CYPRUS - GREECE				6.85 (2.5)	1230 (665)	Greece mainland
	CYPRUS - CRETE	OFFSHORE GAS FIELD	OFFSHORE	ONSHORE	1,41 (0,5)	531 (287)	Crete Power stations
	CYPRUS – LEBANON				3,67 (1.35)	488 (264)	Lebanon Power stations
	CYPRUS - EGYPT				17 (6.2)	270 (146)	Egypt Power stations
	CYPRUS - GREECE				6.85 (2.5)	1262 (682)	Greece mainland
BLACK SEA	GEORGIA - UKRAINE	Shah-Deniz Gas fields, Azerbaijan	ONSHORE	ONSHORE	2.3 (6.3)	997 (539)	South Caucasus Gas Pipeline Gas pipeline

From these scenarios, a generic scenario is set up to enable the calculation of a large set of cases within a volume and distance range of 0.5-15 mmscmd and 100-5000 km, applicable to Ship A and Ship B.

3.2.6 Loading/unloading

The loading and unloading system, infrastructure, and facilities for the GASVESSEL is defined in WP6. CAPEX figures are retrieved from D6.4 (March 2021), summarised in Table 3. The storage estimation is calculated separately, to enable scaling up and down the volume/distance scenarios, which means that the storage estimation costs from D6.4 is omitted. The OPEX is estimated as 10% of CAPEX.

The loading/unloading costs are specific for each scenario based on figures from WP6 and extrapolated based on WP6 figures for the generic scenarios, to enable the fixed costs to be indexed to the volume.

Table 3: CAPEX option comparative table from D6.4 rev 04 (WP4)

Region	Terminal type	Operation mode	Site	CAPEX (Option with bridges and berth), EURO	CAPEX (Option with underwater gas pipeline and floating buoy), EURO
Mediterranean Sea	Onshore	Loading	Vasilikos Energy hub, Total cost	**105 670 303,63**	**107 748 408,57**
			Direction to Crete	*23 542 717,18*	*23 772 246,90*
			Direction to Lebanon	*21 156 905,12*	*21 323 205,08*
			Direction to Egypt	*60 970 681,33*	*62 652 956,59*
	Onshore	Unloading	Port of Linoperamata, Crete	**138 713 964,66**	**138 748 226,50**
	Onshore	Unloading	Port of Zouk, Lebanon	**217 056 567,85**	**217 041 720,96**
	Onshore	Unloading	Port of Alexandria, Egypt	**223 658 477,54**	**228 198 393,47**
Barents Sea	Offshore	Loading	Alke gas production platform, Total cost	**32 778 275,98**	**32 778 275,98**
			Direction to Nyhamna	*16 389 137,99*	*16 389 137,99*
			Direction to Polarled	*16 389 137,99*	*16 389 137,99*
	Offshore	Loading	Johan Castberg gas production platform, Total cost	**32 240 275,98**	**32 509 275,98**
			Direction to Nyhamna	*16 120 137,99*	*16 389 137,99*
			Direction to Polarled	*16 120 137,99*	*16 120 137,99*
	Onshore	Unloading	Nyhamna gas treatment plant, Total cost	**237 079 155,14**	**238 365 956,44**
			Gas from Alke	*118 526 253,68*	*119 173 515,73*
			Gas from Johan Castberg	*118 552 901,46*	*119 192 440,71*
	Offshore	Unloading	Aasta Hansteen gas production platform, Total cost	**26 939 536,00**	**-**
			Gas from Alke	*13 548 518,00*	-
			Gas from Johan Castberg	*13 391 018,00*	-
Black Sea	Onshore	Loading	Port of Poti, Georgia	**29 756 956,58**	**30 544 820,03**
	Onshore	Unloading	Port of Yuzne, Ukraine	**83 416 541,96**	**84 113 782,44**

3.2.7 Storage

The storage system proposed for storage of gas at terminal are the FRA-CO container system, with a capacity of 12 400 Nm^3 each. Unit cost 150 000 €/piece, to which the cost of infrastructures (pipes, basements, safety, control plants etc.) is estimated as a cost index of 90 000 € per cylinder. The resulting total CAPEX for storage facility is 220 000 € per 12 400 Nm^3.

Floating storage is estimated as one GASVESSEL moored at loading point.

3.3 GASVESSEL fleet and transport system

The estimation of number of vessels and their associated fixed and variable costs is central to the cost model of the GASVESSEL transport system. The present chapter depicts the basic calculation to estimate the GASVESSEL fleet, the estimation of infrastructure costs for storage system, the GASVESSEL transport system cost in a strategy of continuous delivery, and the estimation VOYEX, i.e., variable costs associated with sailing a voyage.

3.3.1 Basis calculation

To estimate the number of vessels needed in the GASVESSEL fleet, the following input is used:

- Daily gas market demand (D)
- Delivery capacity of the vessels (C^V)
- Total sailing distance: From production site to market and return (d)
- Sailing speed, considered constant (s)
- Operational yearly time for the vessels, set to 350 days out of yearly 365 (O^V)
- Mooring time at both production and market sites (t^M)
- Unmooring time at both production and market sites (t^{UM})
- Loading time (t^L)
- Unloading time (t^{UL})

Based on the input, the roundtrip time for a vessel (r^V) is calculated as the sum of sailing time, mooring/unmooring time, and loading/unloading time, as follows:

$$r^V = \frac{d}{s} + t^M + t^{UM} + t^L + t^{UL}$$

The total number of roundtrips per year a vessel can sail (R^V) then becomes the operational yearly time for the vessels, divided by roundtrip time:

$$R^V = \frac{O^V}{r^V}$$

The required number of yearly vessel roundtrips to meet the market demand (R^D) is calculated as yearly gas market demand divided by the vessel delivery capacity:

$$R^D = \frac{D \times 365}{C^V}$$

Then the required number of vessels needed to meet the market demand (V) is the required number of yearly roundtrips to meet demand divided by the number of roundtrips a vessel can sail per year, rounded up to the nearest whole integer:

$$V = \left\lceil \frac{R^D}{R^V} \right\rceil$$

For each GASVESSEL reference scenario, only one vessel type is considered, and hence the delivery capacity of the vessels in the fleet will have one single value only. No adjustments have been made to the operational yearly time of the vessels or the sailing speed to see if the required number of vessels can be further optimized as these values are set quite high (350 days and 16 knots, respectively).

As a general rule, the number of vessels is rounded up to nearest whole integer. However, in some cases, the vessel needed to meet the yearly market demand may be just above a given number of vessels and hence the rounding up procedure may impose very high costs of vessels where the spare delivery capacity of the

vessel fleet is high. Therefore, it is also considered, for such instances, that the number of vessels is simply rounded to nearest integer, and the delivered annual amount of gas will be less than the actual market demand and this number will be used when calculating unit costs.

3.3.2 Storage vs continuous delivery

For the GASVESSEL reference scenarios, gas storage option (Strategy 1: Storage) is compared with the option of having continuous delivery (Strategy 2: Continuous delivery). With continuous delivery it is assumed that one or more vessel is always unloading the daily market demand for gas at the unloading port. With Strategy 1, the number of vessels is minimized and delivered demand that exceeds the market demand during time of delivery is stored in cylinders for the onshore unloading option, where each cylinder can store 12 400 m^3 gas at a unit cost of 0,15 M €, in addition there is infrastructure costs estimated at 0.09 M € per cylinder. Storage need is assumed similar for both loading and unloading ports/points. For the offshore unloading option, storage is assumed to be equivalent to a GASVESSEL, and hence the cost of a GASVESSEL is used. With Strategy 2, the number of vessels may have to be increased to account for continuously having a vessel that delivers the daily market demand at the unloading port/point. For some GASVESSEL reference scenarios the number of vessels will always account for continuous delivery and hence for these scenarios no storage options are calculated, and continuous delivery assumed.

Some assumptions are made for the calculation of needed storage and needed number of vessels for continuous delivery:

- Vessel utilization is spread evenly throughout the year.
- There is no time buffer between unmooring and mooring vessels at the unloading port/point, hence continuous delivery to meet market demand can be considered.

For Strategy 1, the theoretical storage autonomy needed (S) is calculated as number of days in the year divided by the required number of yearly vessel roundtrips to meet the market demand (R^D) minus the unloading time (t^{UL}), multiplied with the daily gas market demand (D):

$$S = \left(\frac{365}{R^D} - t^{UL}\right) \times D$$

This number will become less than zero for the GASVESSEL reference scenarios where the number of vessels accounts for continuous delivery without adjustments (daily total unloading capacity for all vessels in the scenario equals daily demand). A positive value means that the daily total unloading capacity for all vessels in the scenario is greater than daily demand and the storage is set to a size to cover the days between unmooring of a vessel until mooring of next vessel at the unloading port.

If Strategy 2, continuous delivery, is to be used, an adjustment in the number of vessels in the fleet may be needed. In the cases where S is less than zero, no adjustments are needed, and continuous delivery is always assumed. Otherwise, if the total unloaded quantity from the vessel exceeds the market demand during unloading time, the unloading time is extended (t^{UL*}) to match the daily market demand, and hence the roundtrip time for a vessel is adjusted (r^{V*}) as follows:

$$t^{UL*} = \frac{C^V}{D}$$

$$r^{V*} = \frac{d}{s} + t^M + t^{UM} + t^L + t^{UL*}$$

Following the calculations from Section 3.3.1, the adjusted total number of roundtrips per year for each vessel (R^{V*}) and the adjusted number of vessels needed for continuous delivery (V^*) becomes:

$$R^{V*} = \frac{O^V}{r^{V*}}$$

$$V^* = \left\lceil \frac{R^D}{R^{V*}} \right\rceil$$

3.3.3 VOYEX

The cost associated with each voyage covers fuel cost and port fees.

Fuel costs are based on estimated fuel consumption:

As explained in Chapter 3.2.2, the estimated fuel consumption of the vessel is simplified to two phases: (1) transit, estimated based on average power demand based on fixed speed; and (2) at loading/unloading point, divided into power demand for hotel and for cargo handling (gas fuel for running the compressors). The fuel oil price applied is 600€/t MGO. The fuel gas will be from the uploading cargo onboard the GASVESSEL. The upstream tariff of this gas is unknown, and highly depending on the location and scenario at hand. To enable the generalisation of the cost calculation and given that the fuel cost has low impact of the total shipping costs (compared to high CAPEX and OPEX), it is decided to simplify the fuel gas price estimation by indexing it on the fuel oil price (bunker price). The same approach is applied in Khalilpour & Karimi (2012)[3]. Factors of 25%, 50% and 75% of MGO are applied for the GASVESSEL fuel cost calculation.

The port fees for operation onshore/nearshore are estimated at 10 000€ for each port call as lumpsum costs for pilots, tugs, agency, services, potential carbon tax etc. No port fees apply for operations offshore.

3.3.4 Unit cost

The unit cost of the GASVESSEL is calculated based on total lifecycle cost (over 20 years) divided by the quantity of gas delivered. The main assumption is that the quantity of gas delivered corresponds to the gas demand indicated in each scenario. This is important to reflect the potential of GASVESSEL ships A and B, as well as the volume/distance cases where GASVESSEL is not exploiting its full capacity. This aims at enabling comparison with alternative options on the ranges predefined in the comparative analysis: volumes 0.5-15 bcm/year and distances 100-5000 km.

[3] Khalilpour, R., & Karimi, I. A. (2012). Evaluation of utilization alternatives for stranded natural gas. Energy, 40(1), 317-328.

3.4 GASVESSEL cost results

This chapter presents the results of the cost calculation of GASVESSEL transport system. First for each of the GASVESSEL scenarios specifically, then extrapolated to a range of volume/distance, based on a generalisation of the cost calculation.

The scenarios established in WP2 went through several rounds of cost estimations throughout the project. First the optimization tool from Esteco (VOLTA) was used to identify the scenarios with the best potential. These scenarios are defined as those which maximise load factor and minimize cost. Further, the scenario cost structure was expended in WP7's cost model by adding loading/unloading infrastructure cost, voyage costs, updated OPEX, both to fine-tune the GASVESSEL unit cost estimate, and to enable comparison with LNG and pipeline alternatives.

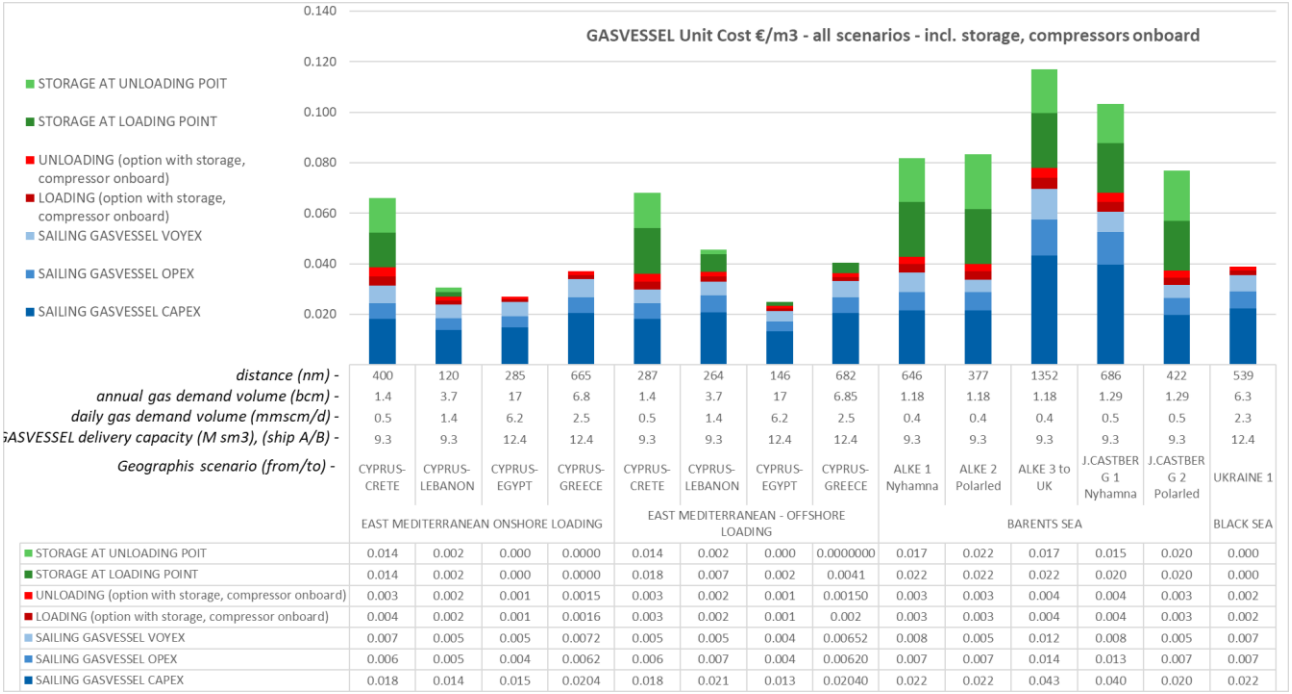
3.4.1 GASVESSEL costs: Scenarios

In the following diagrams, the GASVESSEL cost for each scenario is broken down in vessel costs (CAPEX, OPEX, VOYEX) in blue colour, loading/unloading costs (CAPEX, OPEX, including compressor related costs) in red colour, and storage costs in green.

3.4.1.1 GASVESSEL scenarios

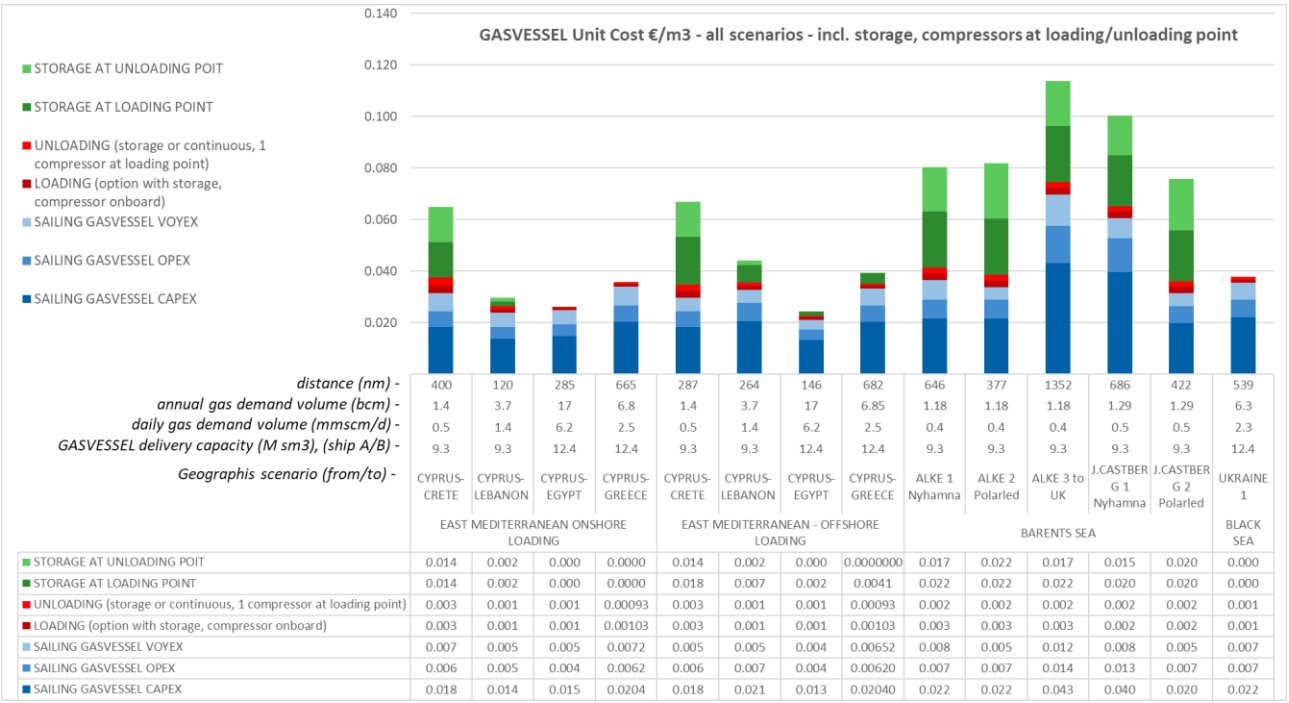
The main parameters for fleet estimation are constant speed of 16 knots, operational time 350 days, gas fuel cost at 50% of fuel oil price estimate. The volume and distances are those of GASVESSEL geo-logistic scenarios, and the ship A or B decided is specific to each case. These parameters are further explored through the generic scenarios (Chapter 3.4.2).

The results represent different strategies: including storage (Figure 6, Figure 7) vs continuous delivery (Figure 8, Figure 9), with compressors integrated onboard GASVESSEL (Figure 6, Figure 8) vs compressors located at loading/unloading point (Figure 7, Figure 9).



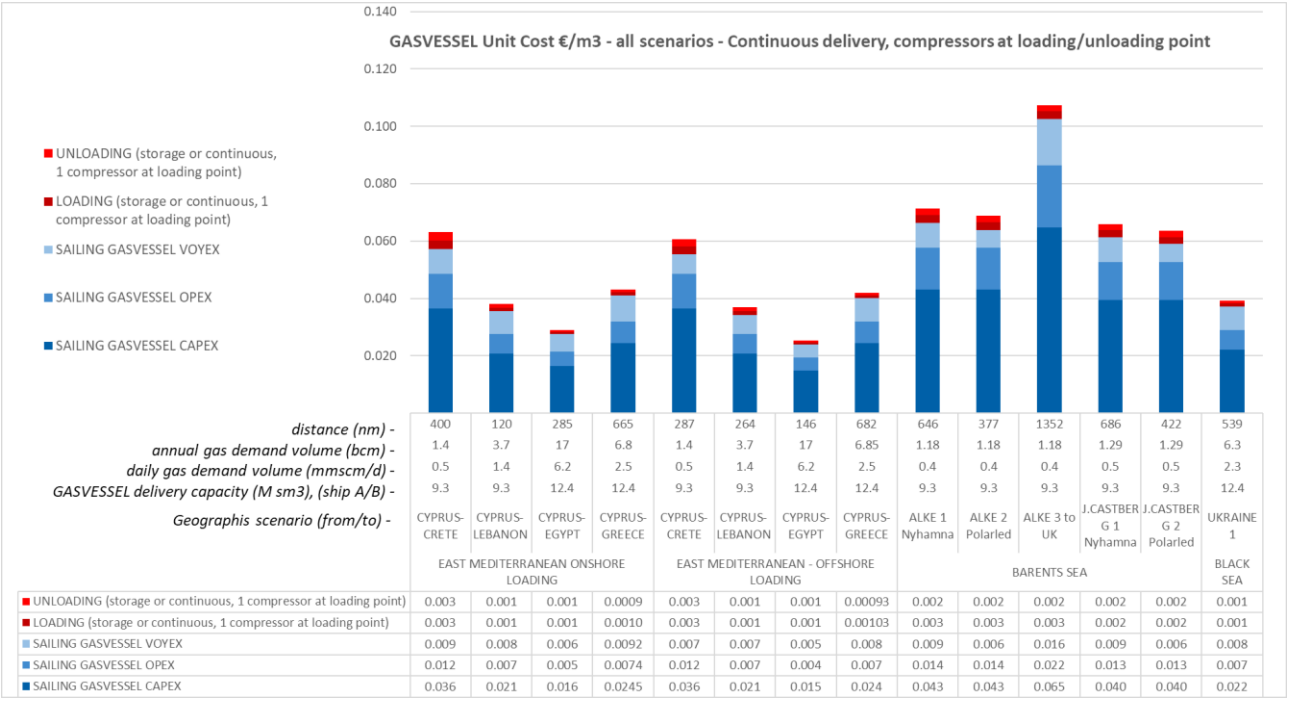
distance (nm) -	400	120	285	665	287	264	146	682	646	377	1352	686	422	539
annual gas demand volume (bcm) -	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3
daily gas demand volume (mmscm/d) -	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4
Geographis scenario (from/to) -	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1
	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING				BARENTS SEA					BLACK SEA
STORAGE AT UNLOADING POIT	0.014	0.002	0.000	0.0000	0.014	0.002	0.000	0.0000000	0.017	0.022	0.017	0.015	0.020	0.000
STORAGE AT LOADING POINT	0.014	0.002	0.000	0.0000	0.018	0.007	0.002	0.0041	0.022	0.022	0.022	0.020	0.020	0.000
UNLOADING (option with storage, compressor onboard)	0.003	0.002	0.001	0.0015	0.003	0.002	0.001	0.00150	0.003	0.003	0.004	0.004	0.003	0.002
LOADING (option with storage, compressor onboard)	0.004	0.002	0.001	0.0016	0.003	0.002	0.001	0.002	0.003	0.003	0.004	0.004	0.003	0.002
SAILING GASVESSEL VOYEX	0.007	0.005	0.005	0.0072	0.005	0.005	0.004	0.00652	0.008	0.005	0.012	0.008	0.005	0.007
SAILING GASVESSEL OPEX	0.006	0.005	0.004	0.0062	0.006	0.007	0.004	0.00620	0.007	0.007	0.014	0.013	0.007	0.007
SAILING GASVESSEL CAPEX	0.018	0.014	0.015	0.0204	0.018	0.021	0.013	0.02040	0.022	0.022	0.043	0.040	0.020	0.022

Figure 6: GASVESSEL unit cost (€/Nm³) per scenario – strategy "storage", compressors onboard



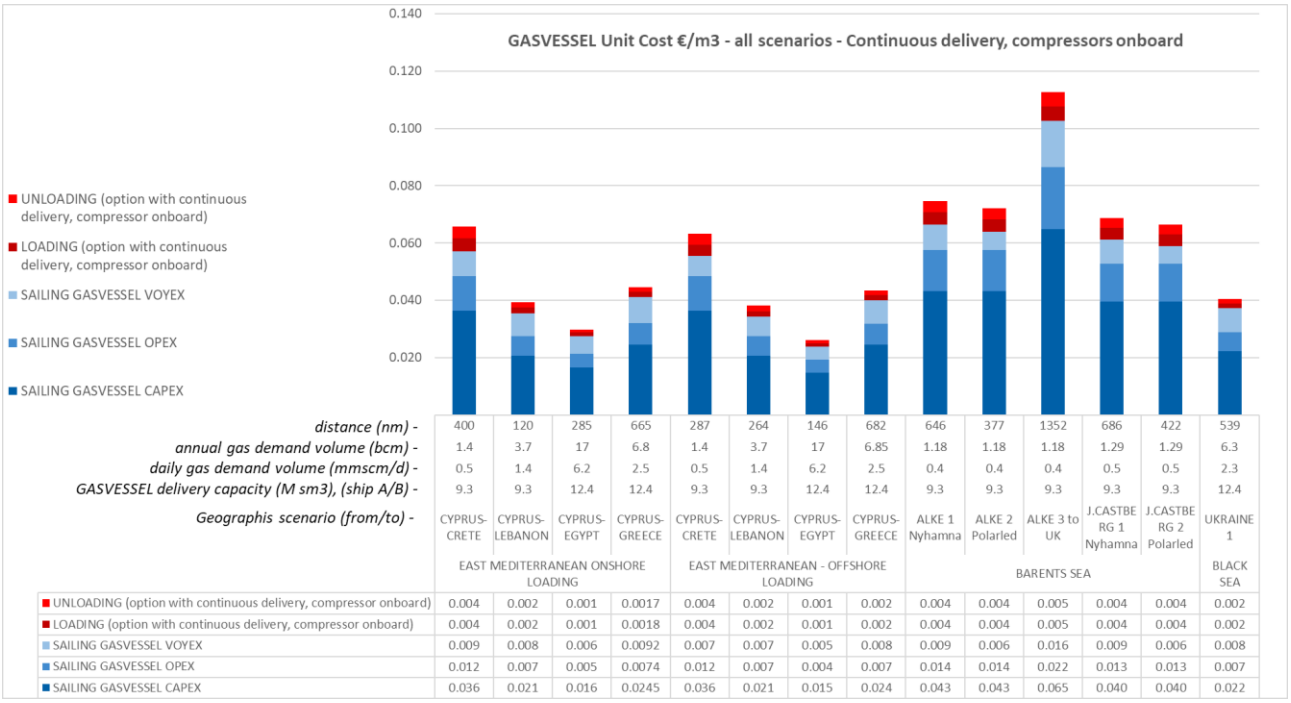
distance (nm) -	400	120	285	665	287	264	146	682	646	377	1352	686	422	539
annual gas demand volume (bcm) -	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3
daily gas demand volume (mmscm/d) -	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4
Geographis scenario (from/to) -	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1
	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING				BARENTS SEA					BLACK SEA
STORAGE AT UNLOADING POIT	0.014	0.002	0.000	0.0000	0.014	0.002	0.000	0.0000000	0.017	0.022	0.017	0.015	0.020	0.000
STORAGE AT LOADING POINT	0.014	0.002	0.000	0.0000	0.018	0.007	0.002	0.0041	0.022	0.022	0.022	0.020	0.020	0.000
UNLOADING (storage or continuous, 1 compressor at loading point)	0.003	0.001	0.001	0.00093	0.003	0.001	0.001	0.00093	0.002	0.002	0.002	0.002	0.002	0.001
LOADING (option with storage, compressor onboard)	0.003	0.001	0.001	0.00103	0.003	0.001	0.001	0.00103	0.003	0.003	0.003	0.002	0.002	0.001
SAILING GASVESSEL VOYEX	0.007	0.005	0.005	0.0072	0.005	0.005	0.004	0.00652	0.008	0.005	0.012	0.008	0.005	0.007
SAILING GASVESSEL OPEX	0.006	0.005	0.004	0.0062	0.006	0.007	0.004	0.00620	0.007	0.007	0.014	0.013	0.007	0.007
SAILING GASVESSEL CAPEX	0.018	0.014	0.015	0.0204	0.018	0.021	0.013	0.02040	0.022	0.022	0.043	0.040	0.020	0.022

Figure 7: GASVESSEL unit cost (€/Nm³) per scenario – strategy "storage", compressors at (un)loading point



distance (nm) -	400	120	285	665	287	264	146	682	646	377	1352	686	422	539
annual gas demand volume (bcm) -	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3
daily gas demand volume (mmscm/d) -	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4
Geographis scenario (from/to) -	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1
	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING				BARENTS SEA					BLACK SEA
UNLOADING (storage or continuous, 1 compressor at loading point)	0.003	0.001	0.001	0.0009	0.003	0.001	0.001	0.00093	0.002	0.002	0.002	0.002	0.002	0.001
LOADING (storage or continuous, 1 compressor at loading point)	0.003	0.001	0.001	0.0010	0.003	0.001	0.001	0.00103	0.003	0.003	0.003	0.002	0.002	0.001
SAILING GASVESSEL VOYEX	0.009	0.008	0.006	0.0092	0.007	0.007	0.005	0.008	0.009	0.006	0.016	0.009	0.006	0.008
SAILING GASVESSEL OPEX	0.012	0.007	0.005	0.0074	0.012	0.007	0.004	0.007	0.014	0.014	0.022	0.013	0.013	0.007
SAILING GASVESSEL CAPEX	0.036	0.021	0.016	0.0245	0.036	0.021	0.015	0.024	0.043	0.043	0.065	0.040	0.040	0.022

Figure 8: GASVESSEL unit cost (€/Nm³) per scenario – strategy "continuous delivery", compressors onboard



distance (nm) -	400	120	285	665	287	264	146	682	646	377	1352	686	422	539
annual gas demand volume (bcm) -	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3
daily gas demand volume (mmscm/d) -	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4
Geographis scenario (from/to) -	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1
	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING				BARENTS SEA					BLACK SEA
UNLOADING (option with continuous delivery, compressor onboard)	0.004	0.002	0.001	0.0017	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002
LOADING (option with continuous delivery, compressor onboard)	0.004	0.002	0.001	0.0018	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002
SAILING GASVESSEL VOYEX	0.009	0.008	0.006	0.0092	0.007	0.007	0.005	0.008	0.009	0.006	0.016	0.009	0.006	0.008
SAILING GASVESSEL OPEX	0.012	0.007	0.005	0.0074	0.012	0.007	0.004	0.007	0.014	0.014	0.022	0.013	0.013	0.007
SAILING GASVESSEL CAPEX	0.036	0.021	0.016	0.0245	0.036	0.021	0.015	0.024	0.043	0.043	0.065	0.040	0.040	0.022

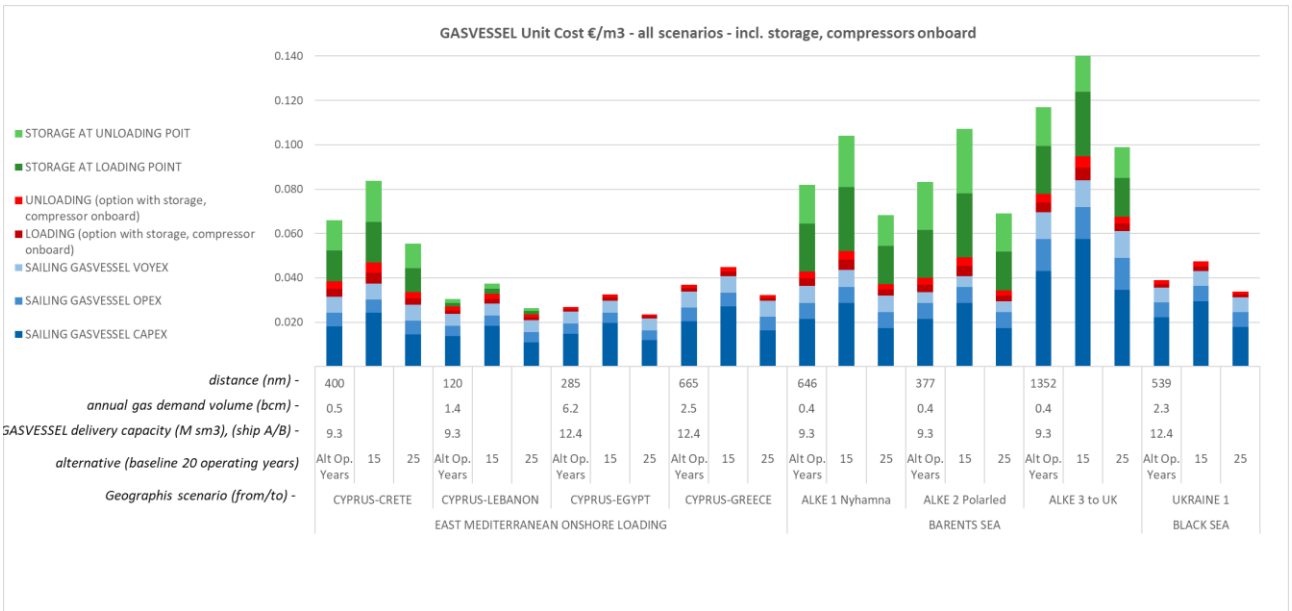
Figure 9: GASVESSEL unit cost (€/Nm³) per scenario – strategy "continuous delivery", compressors at (un)loading point

3.4.1.2 Sensitivity

To test the sensitivity of GASVESSEL scenarios, they are run with alternative years of operation, operational days, speed, and gas fuel price, to see the impact of the fleet size as well as total costs per m^3.

Number of years of operation considered:

Baseline is 20 years, and alternatives considered are 15 and 25 years. It is observed in Figure 10, as expected, an increase in unit cost per m^3 when years of operation is decreased to 15, and a decrease in unit cost per m^3 when years of operation is increased to 25 compared with the baseline of 20 years.



distance (nm) -	400			120			285			665			646			377			1352			539		
annual gas demand volume (bcm) -	0.5			1.4			6.2			2.5			0.4			0.4			0.4			2.3		
GASVESSEL delivery capacity (M sm3), (ship A/B) -	9.3			9.3			12.4			12.4			9.3			9.3			9.3			12.4		
alternative (baseline 20 operating years)	Alt Op. Years	15	25	Alt Op. Years	15	25	Alt Op. Years	15	25	Alt Op. Years	15	25	Alt Op. Years	15	25	Alt Op. Years	15	25	Alt Op. Years	15	25	Alt Op. Years	15	25
Geographis scenario (from/to) -	CYPRUS-CRETE			CYPRUS-LEBANON			CYPRUS-EGYPT			CYPRUS-GREECE			ALKE 1 Nyhamna			ALKE 2 Polarled			ALKE 3 to UK			UKRAINE 1		
	EAST MEDITERRANEAN ONSHORE LOADING												BARENTS SEA									BLACK SEA		

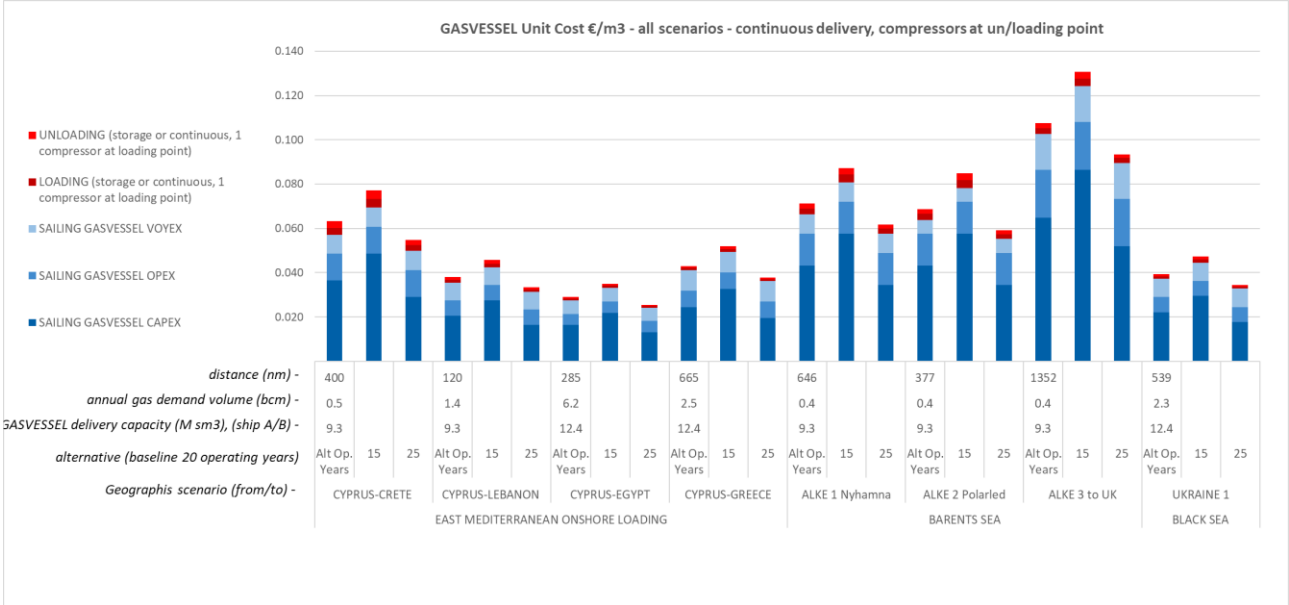
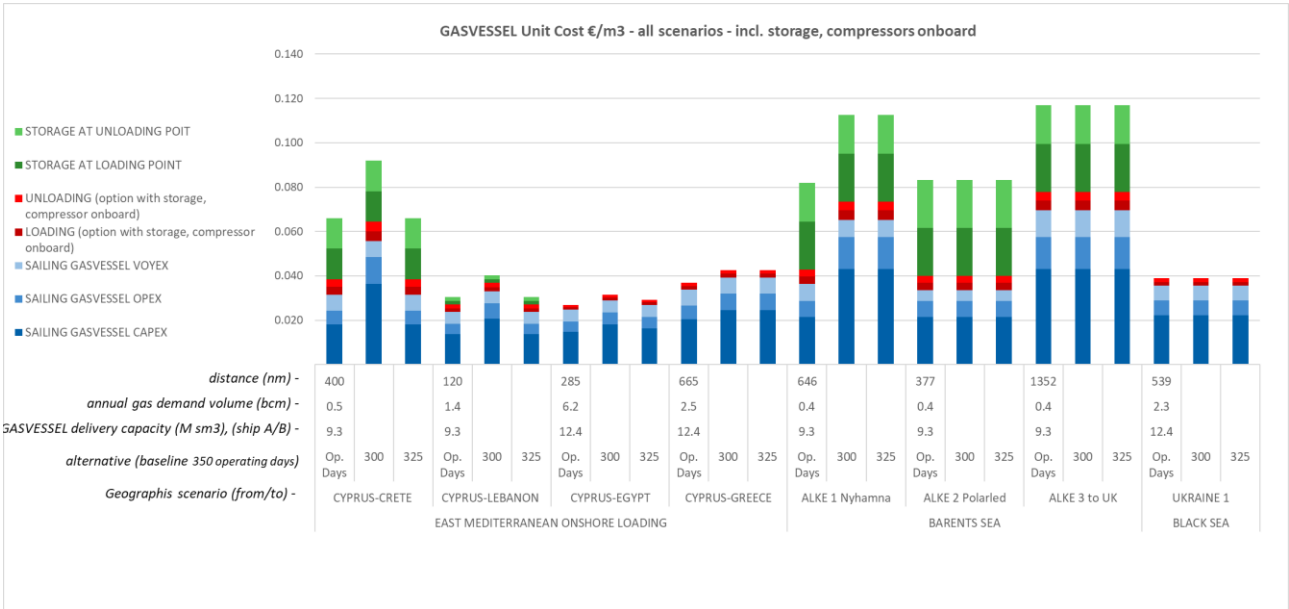


Figure 10 (a,b): Operating years 20, 15, 25 (a: with storage, b: continuous delivery)

Operational days:

Baseline is 350 operational days during a year for the vessels, and alternatives considered are 300 and 325 days. In Figure 11 it is observed that there is little change in unit cost per m^3 for continuous delivery for the scenarios (b) while for the case with storage (a) there are cost increases for some of the scenarios when reducing the number of operational days for the vessels. This is due to utilization of the vessels in the fleet: there are more vessels for the continuous case for the baseline of 350 operational days than there are when storage is used for these scenarios, and hence the vessels are not fully utilized, while for the storage case, there is a need to increase the vessel fleet with one (or more) vessels, and hence the jump in unit cost per delivered m^3.



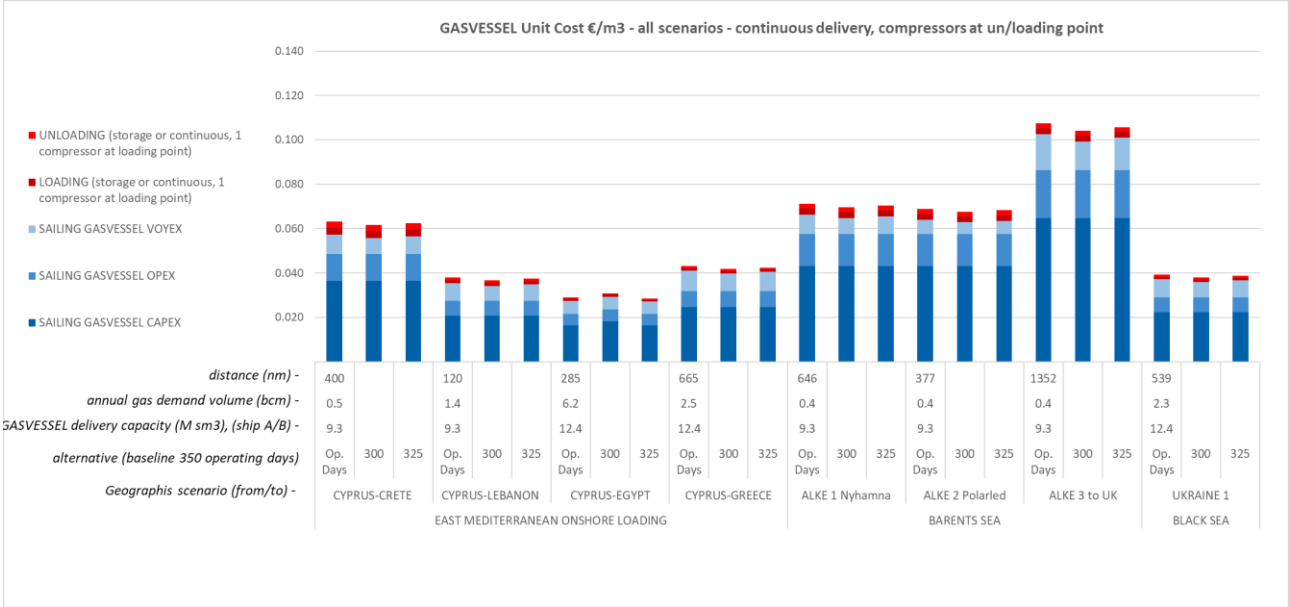
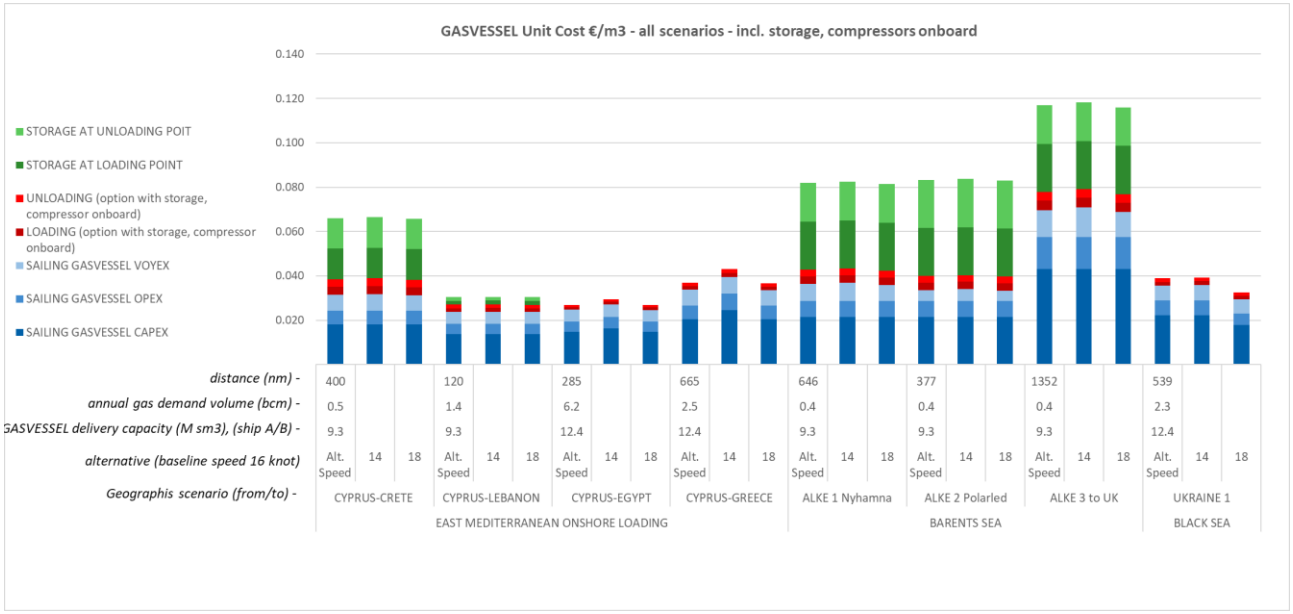


Figure 11 (a,b): operating days 350, 300, 325 (a: with storage, b: continuous delivery)

Speed:

Baseline is a sailing speed of 16 knots, and alternatives considered are 14 and 18 knots. It is observed little change in cost per m^3 for the alternatives in Figure 12, but there are some scenarios where there is need for one more vessel when sailing at 14 knots, and one less vessel when sailing at 18 knots which can be observed from the increase/decrease in CAPEX.



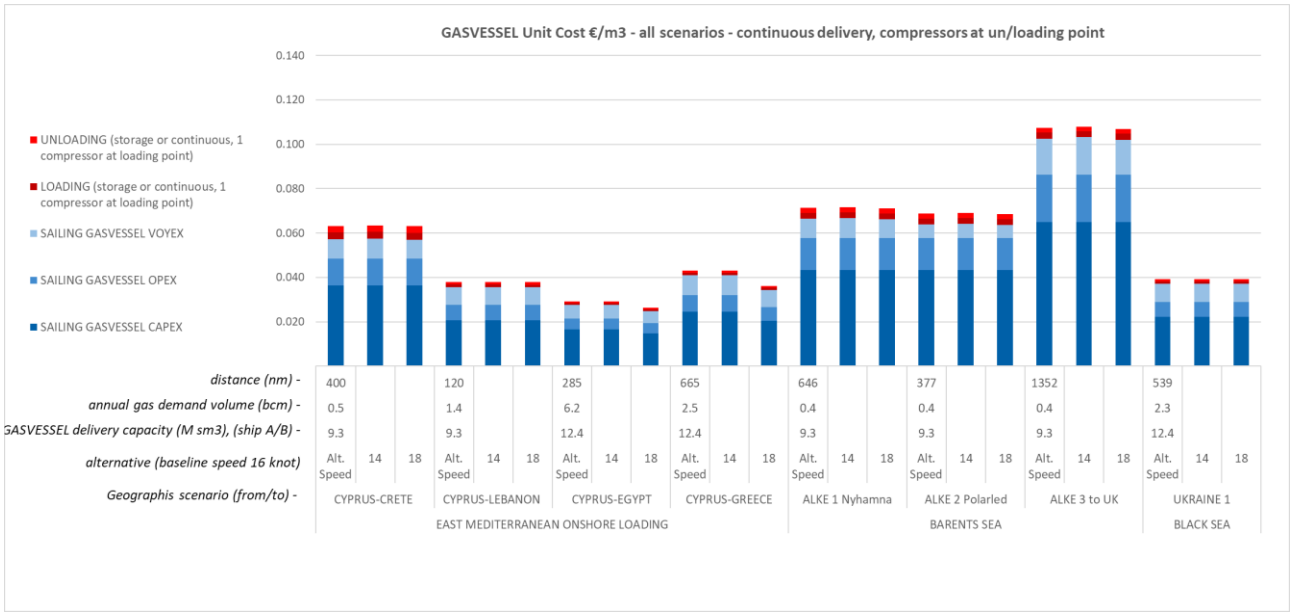
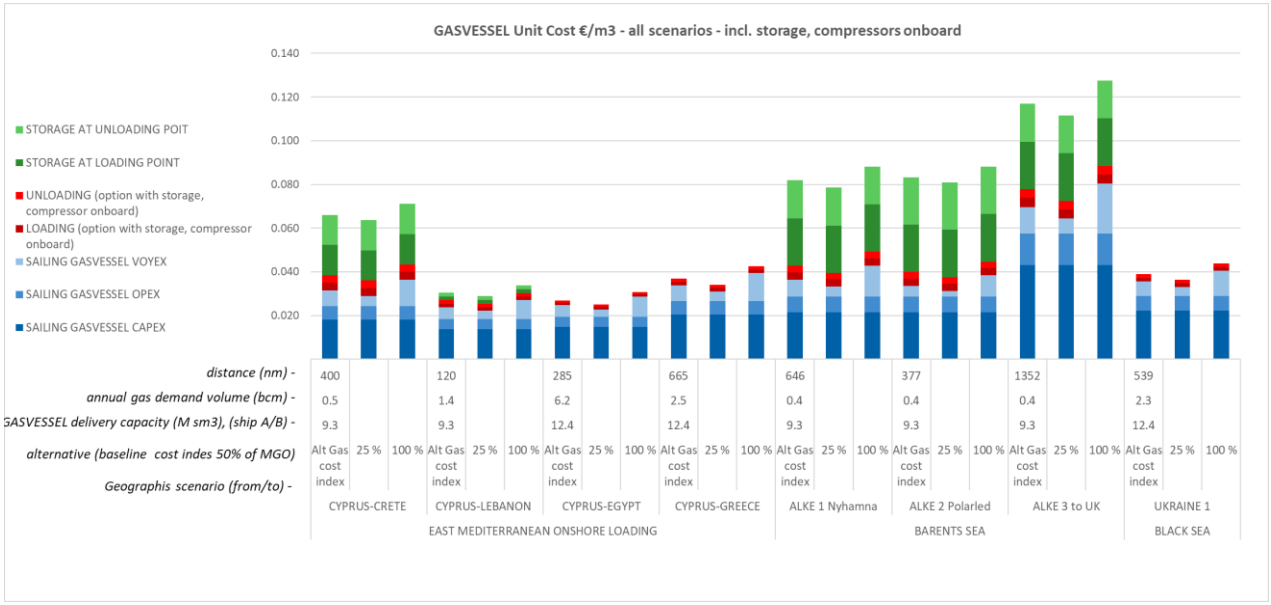


Figure 12 (a,b): .speed 16, 14, 18 (a: with storage, b: continuous delivery)

Gas price:

Baseline cost of gas is 50% of MGO, while alternatives 25% and 100% are considered. From Figure 13, it can be seen, as expected, that there is a change in VOYEX when the gas price is decreased and increased.



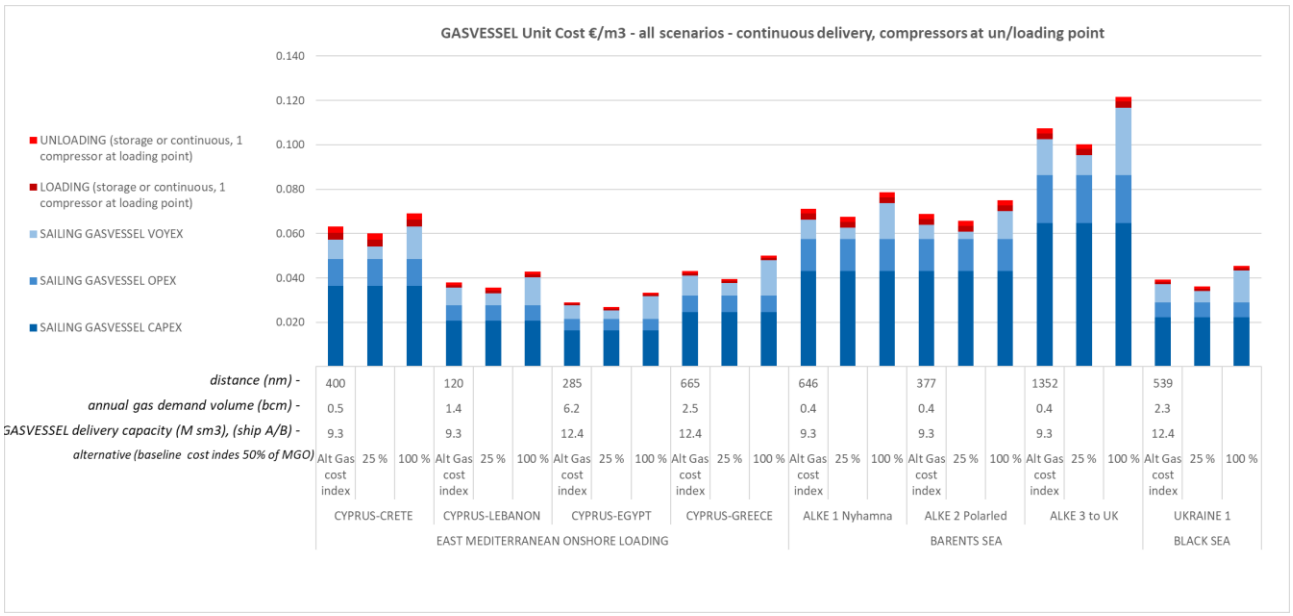


Figure 13 (a,b): fuel price 50%, 25%, 100% (a: with storage, b: continuous delivery)

3.4.2 GASVESSEL costs: Generalisation

To test various strategies and see their impact for various distance/volume cases, a generic scenario is set up in the GASVESSEL cost model.

Reference cases consist of:

- GASVESSEL Ship A (15M Nm^3, 12.4M Nm^3 delivery capacity) and Ship B (12M Nm^3, 9.3M Nm^3 delivery capacity)
- Compressor located at loading/unloading point, and alternative with compressors installed onboard
- Onshore – onshore pick-up and delivery
- Loading/unloading: more conservating approach, highest costs: equivalent to equipped jetty 34.5M€ for two ships
- Sailing speed of 16 knots on average (then varied 14-18)
- 350 operating days for vessels during the year (then varied 300-325)
- 20 years of operation (then varied 15-25)
- Fixed CAPEX (annual) and OPEX. No increase, no inflation. This due to comparison will be on costs only
- Fuel cost: gas fuel cost index of 50% of MGO (then varied from 20% to 100%)

Assumptions:

1. Based on demand

Important factor: the purpose is to spot a cost for a specific volume/distance, not to optimise volume/distance for a given fleet of GASVESSELs. The reason for this is that we want to compare with other option on the same volume/distance basis. This means that the cost curves generated by the cost model represent the costs of a GASVESSEL fleet and transport system for a given scenario, rather than for their max capacity.

2. Theoretical figures

Theoretical, meaning that for large volumes, requiring a large fleet, the necessary accommodation at loading/unloading point becomes unrealistic. The model does not spot the "non-feasible scenarios", but only calculated costs based on input from GASVESSEL original scenarios. However, the purpose of this exercise is to identify the potential for GASVESSEL when compared with alternative options; this phase, presented in Chapter 4, will reveal the infeasibility of GASVESSEL for such cases.

Continuous delivery, compressors at un/loading point.

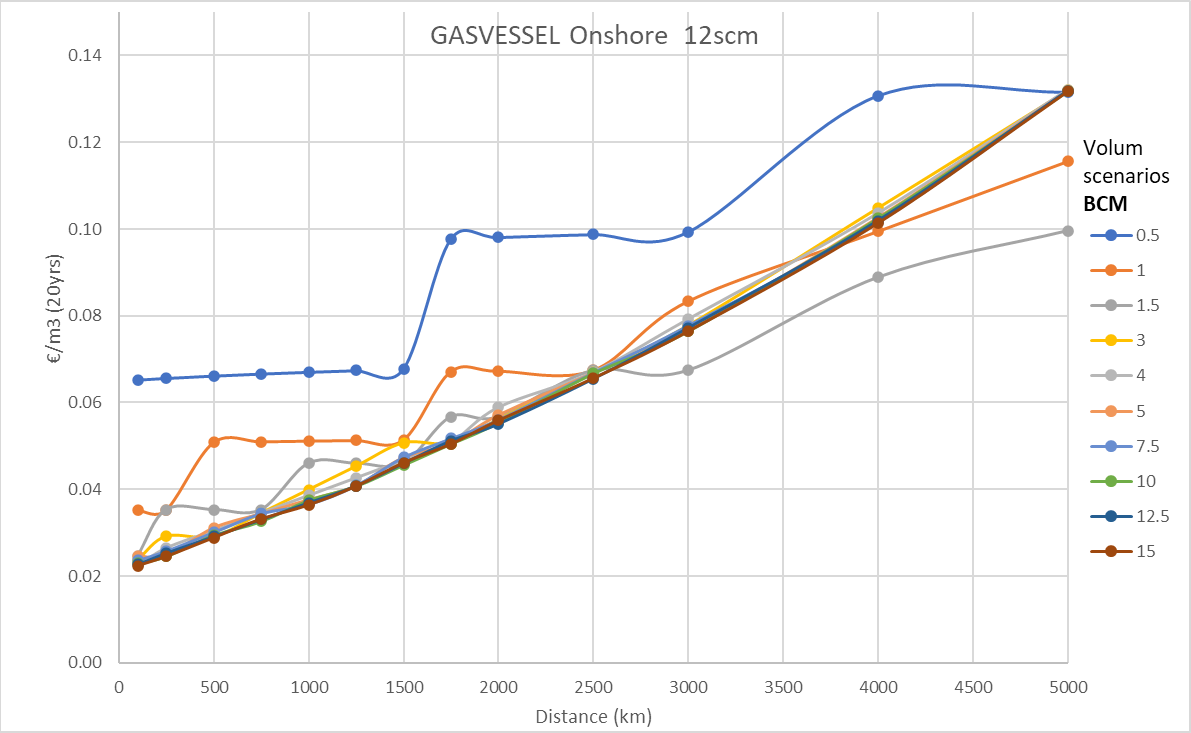


Figure 14: GASVESSEL unit cost per distance (100-5000km) and annual volume (0.5-15 bcm) , based on onshore-onshore case, Ship B (12M Nm³), compressor at (un)loading point, continuous delivery

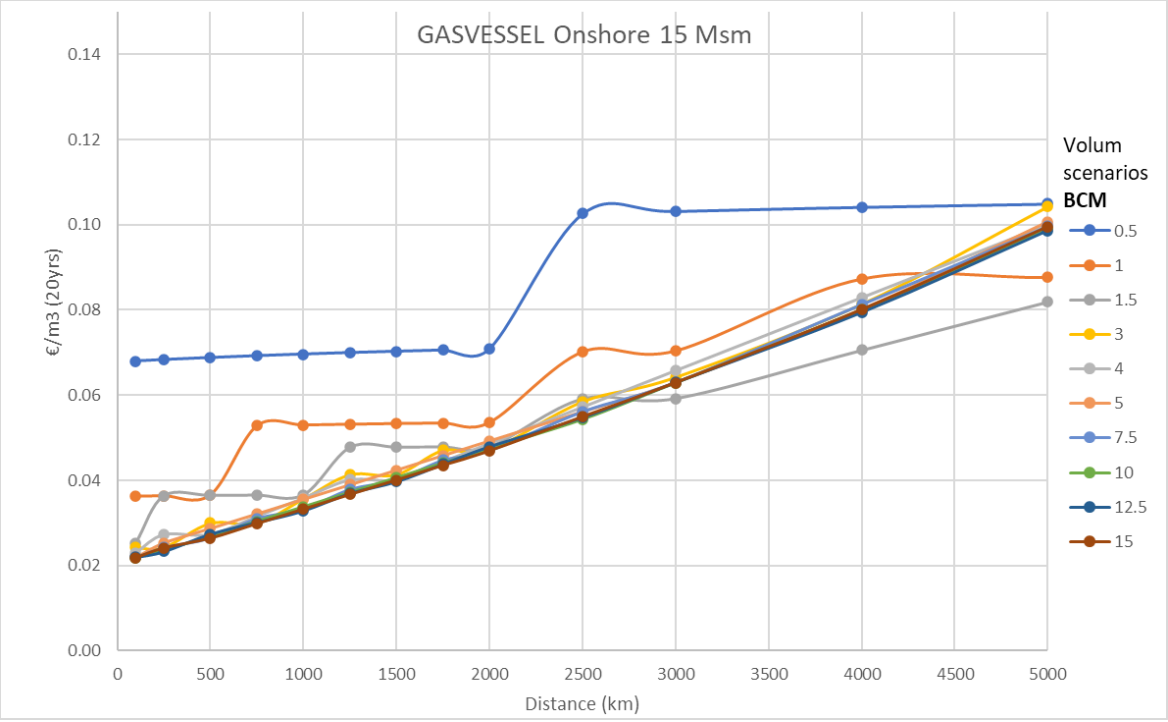


Figure 15: GASVESSEL unit cost per distance (100-5000km) and annual volume (0.5-15 bcm) , based on onshore-onshore case, Ship A (15M Nm³), compressor at (un)loading point, continuous delivery

Storage; compressors onboard.

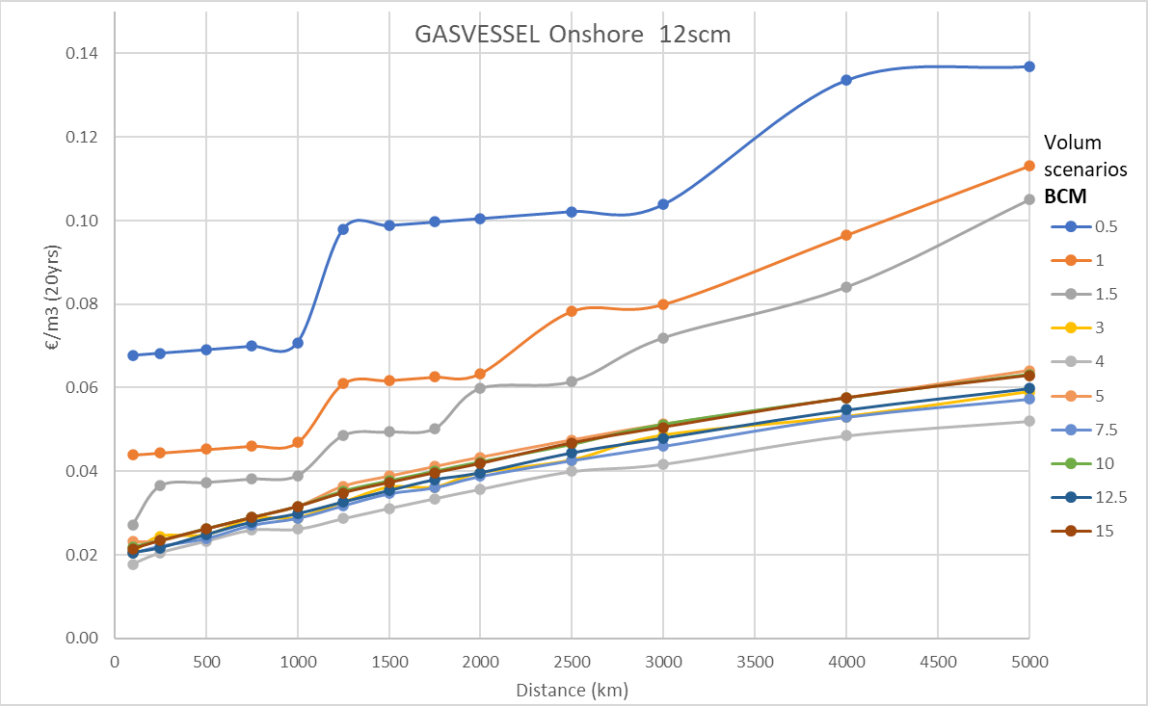


Figure 16: Onshore Ship B (12M Nm³), storage, compressor onboard

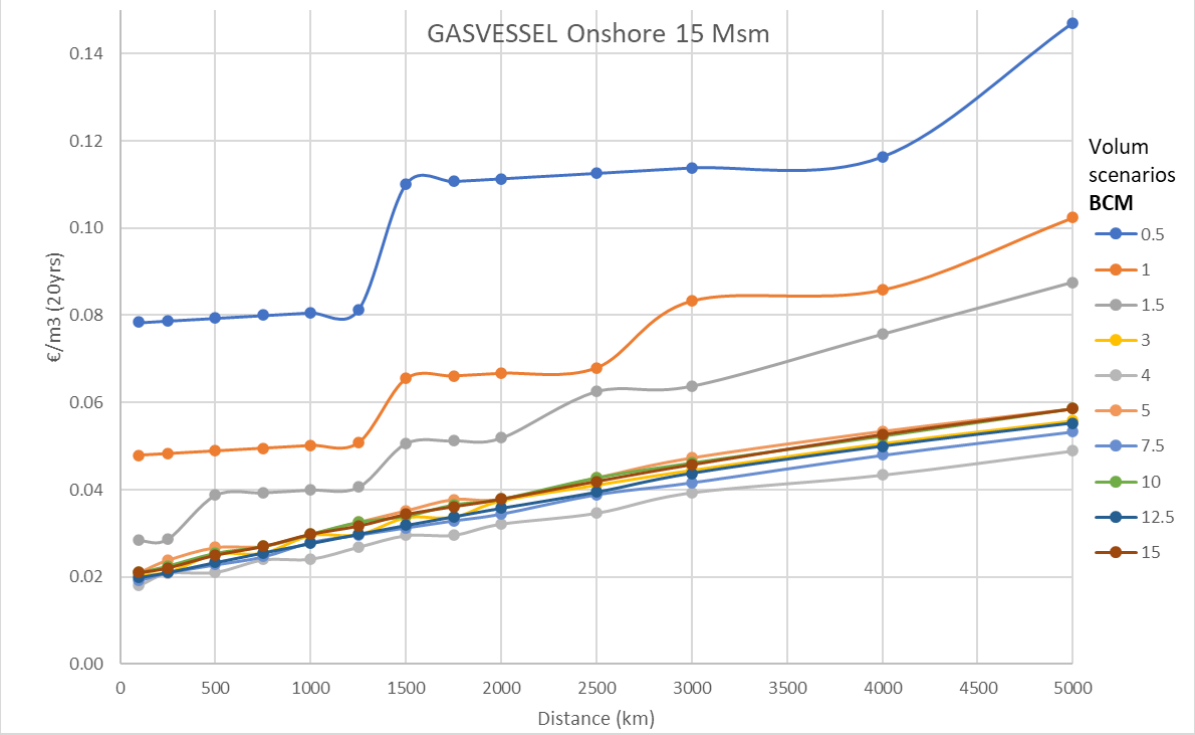


Figure 17: Onshore Ship A (15M Nm³), storage, compressor onboard

Storage; compressors at un/loading point

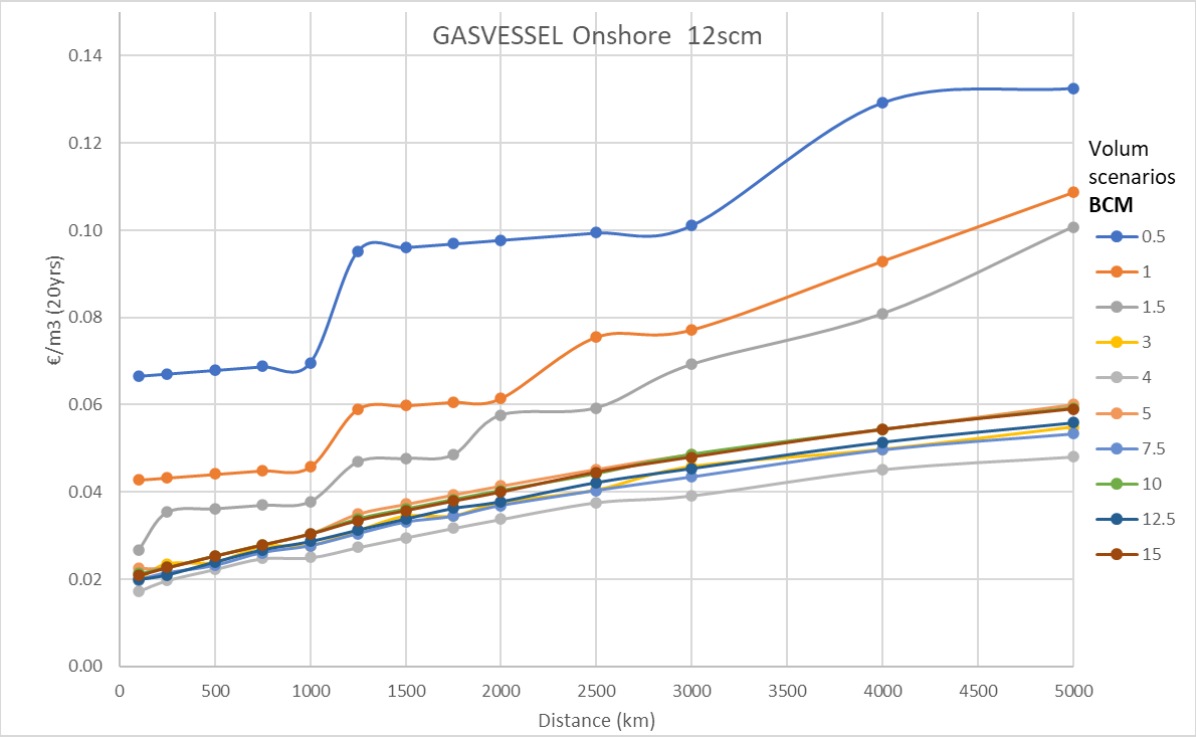


Figure 18: Loading onshore Ship B (12M Nm³), storage, compressor at (un)loading point

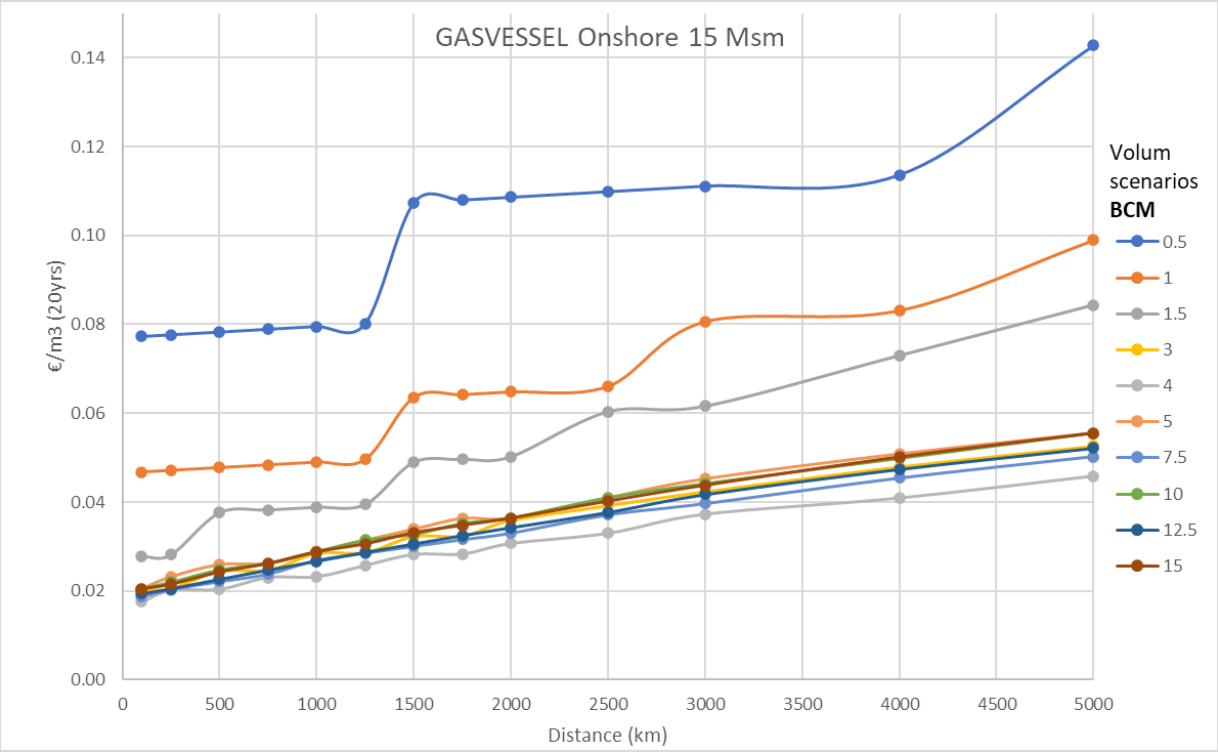


Figure 19: Loading onshore Ship A (15M Nm³), storage, compressor at (un)loading point

Storage; compressors onboard. with gas fuel cost 100% of MGO bunker price

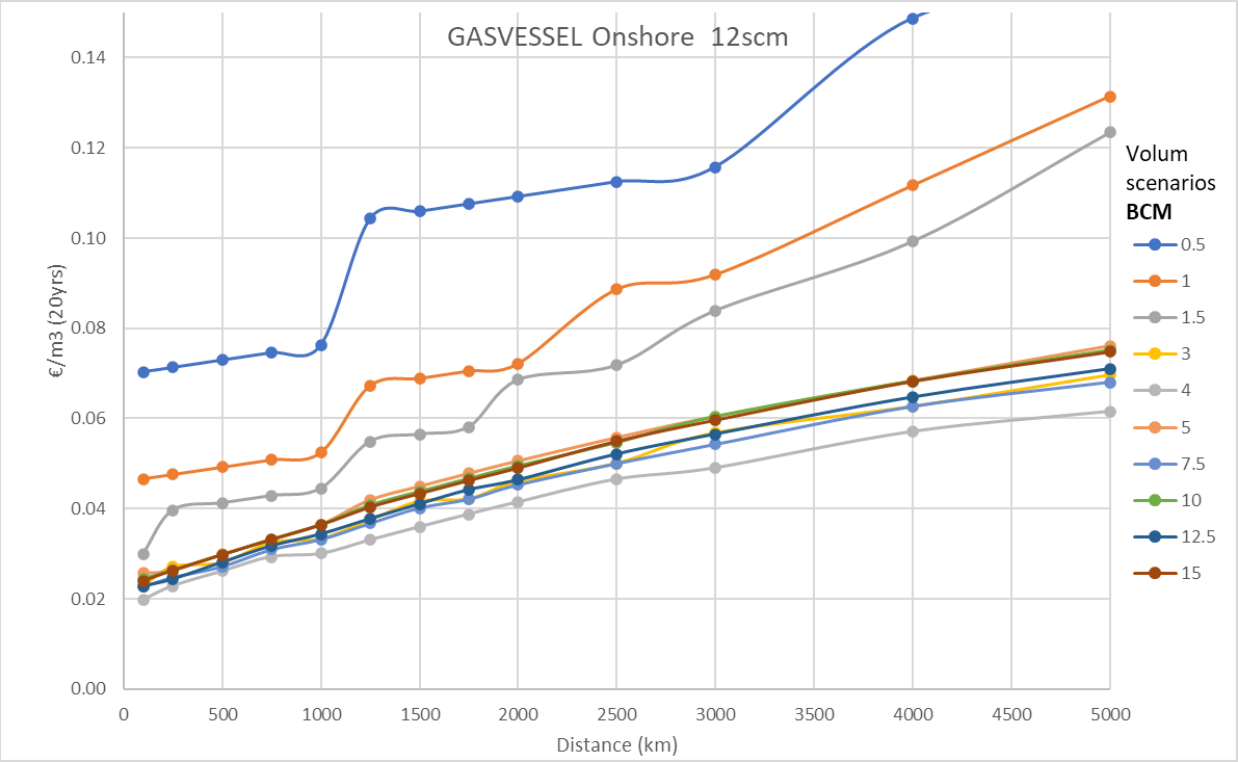


Figure 20: Onshore Ship B (12M Nm³), storage, compressor onboard, gas fuel cost 100% of MGO price

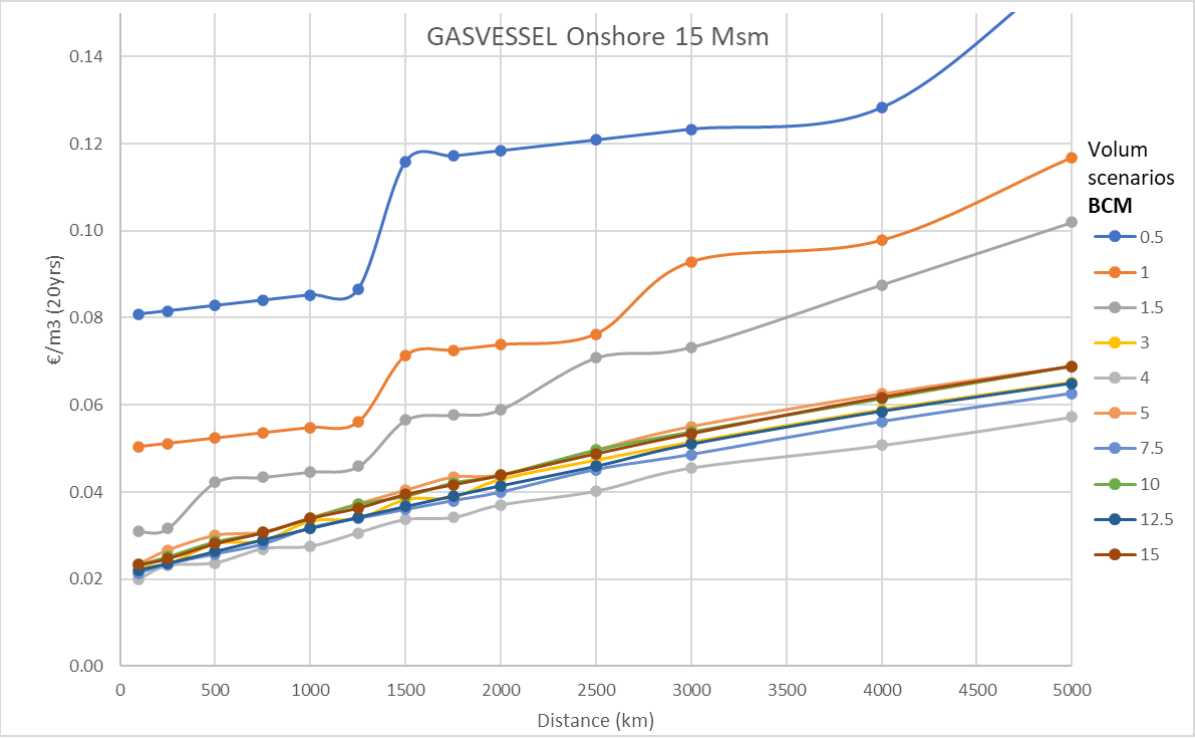


Figure 21: Onshore Ship A (15M Nm³), storage, compressor onboard, gas fuel cost 100% of MGO price

Storage, compressors at un/loading point, with gas fuel cost 100% of MGO bunker price

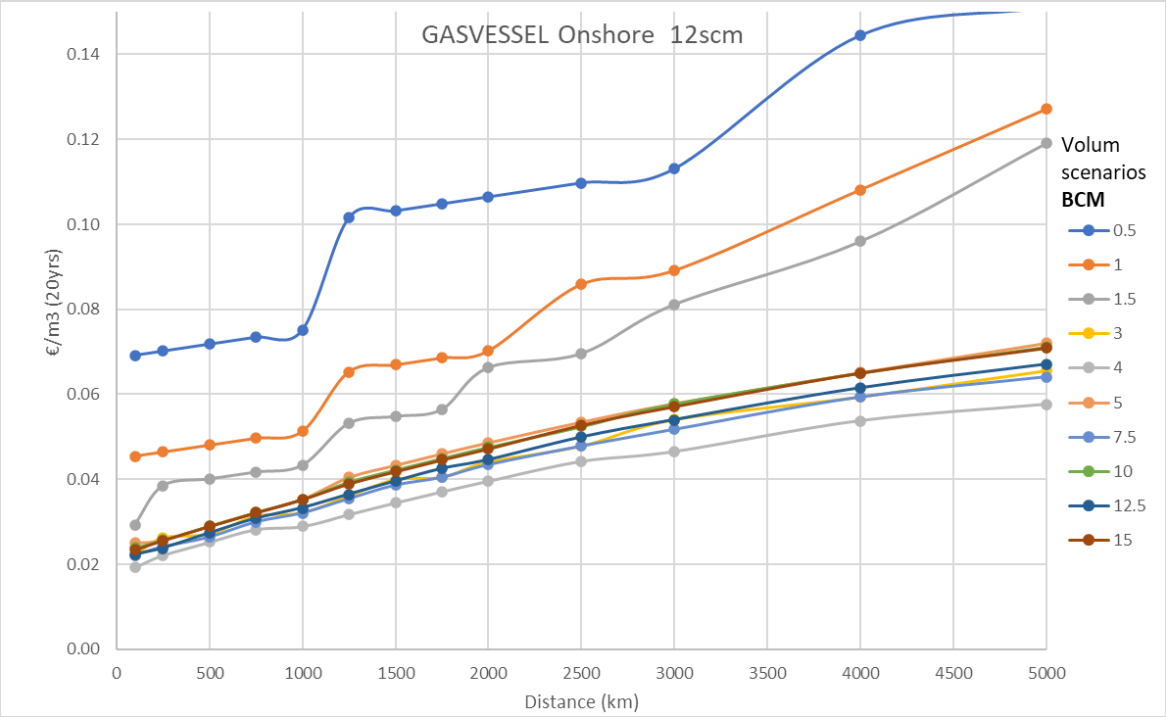


Figure 22: Onshore Ship B (12M Nm³), storage, compressor onshore at (un)loading point, gas fuel cost 100% of MGO price

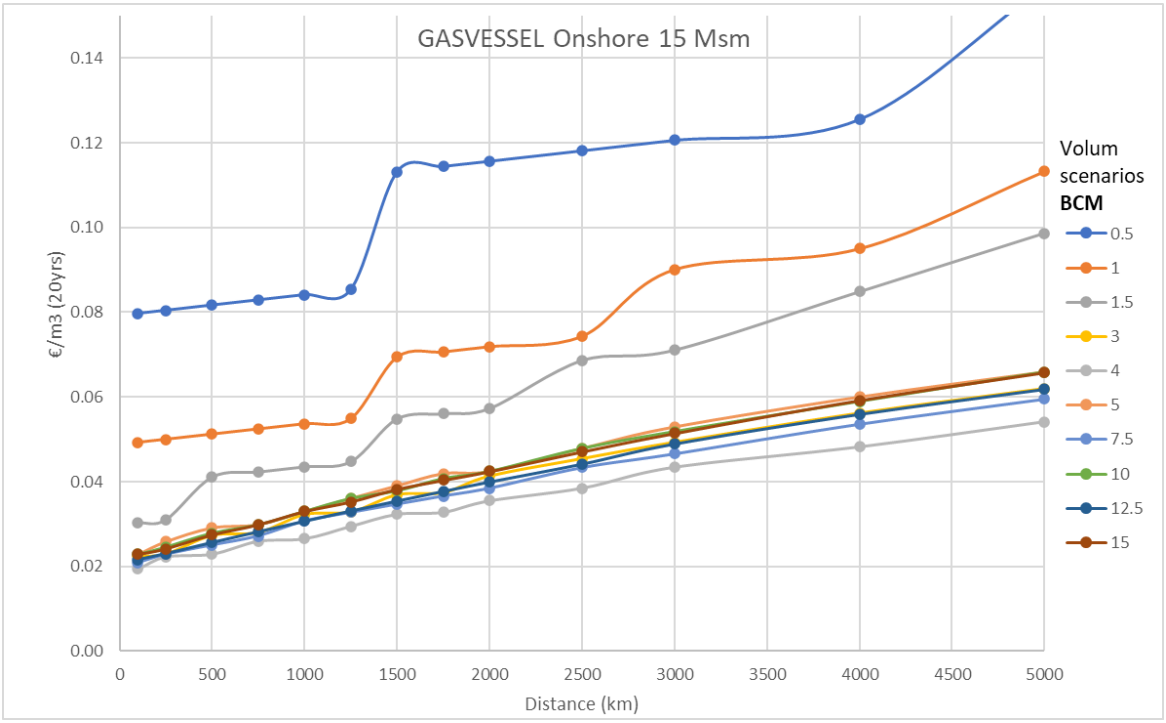


Figure 23: Onshore Ship A (15M Nm³), storage, compressor onshore at (un)loading point, gas fuel cost 100% of MGO price

Continuous delivery; compressors at un/loading point, with gas fuel cost 100% of MGO bunker price

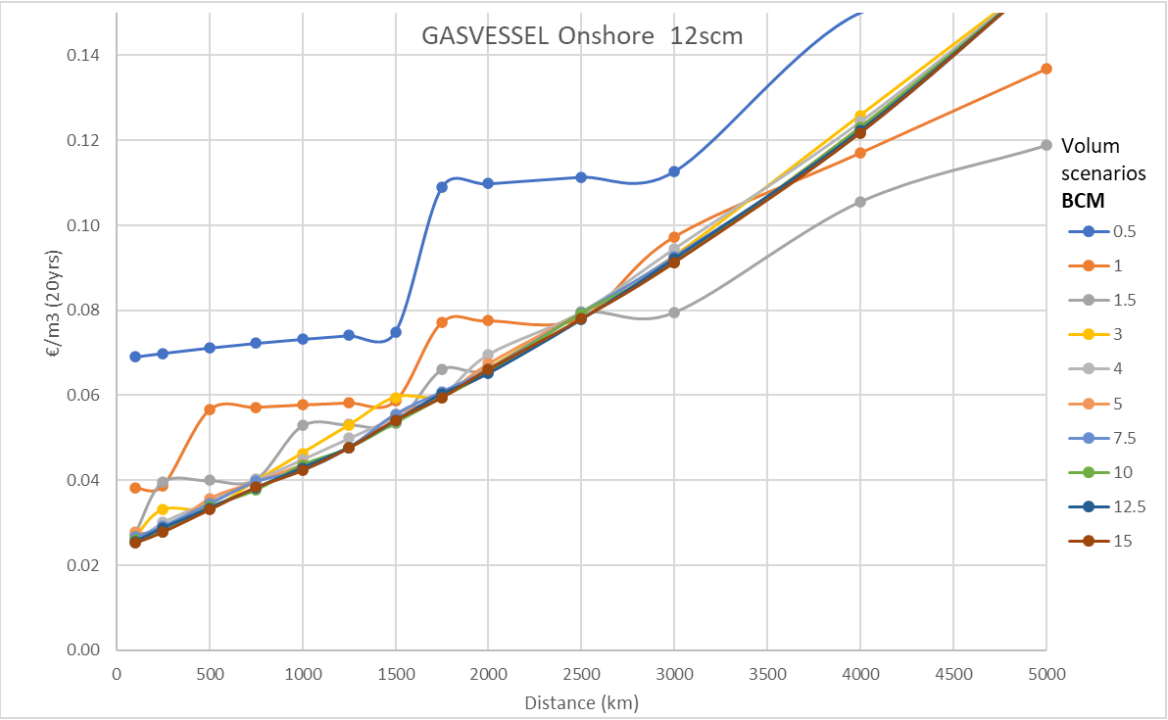


Figure 24: Onshore Ship B (12M Nm³), continuous delivery, compressor onshore at (un)loading point, gas fuel cost 100% of MGO price

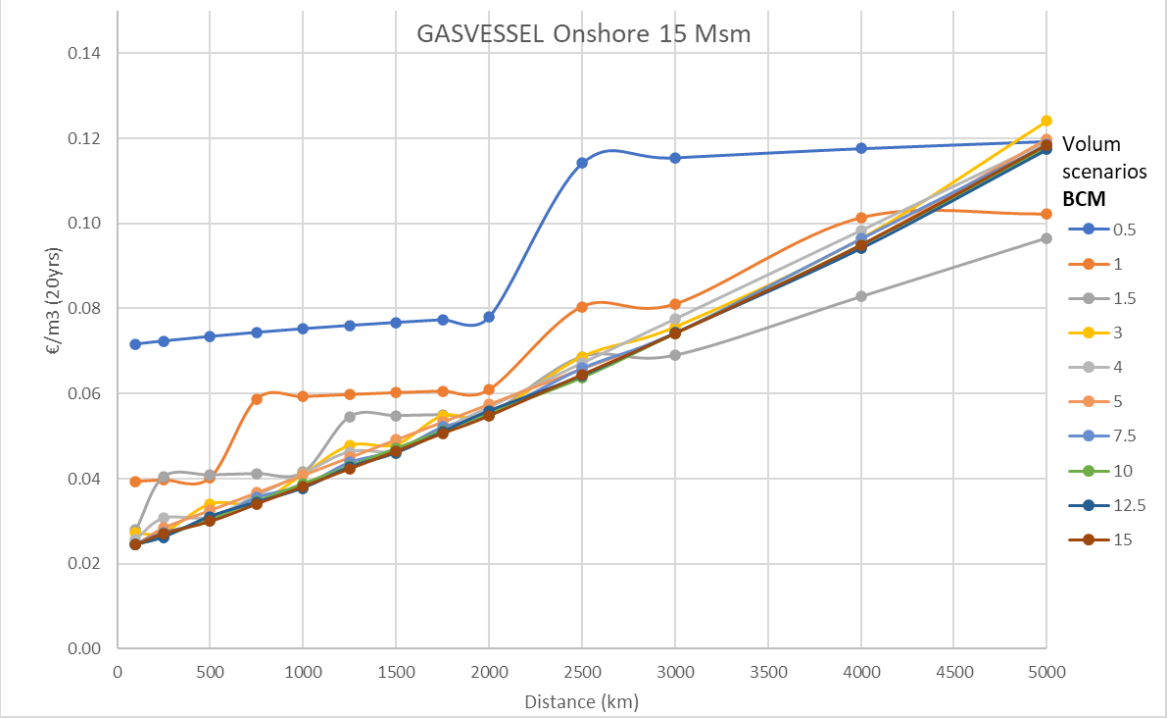


Figure 25: Onshore Ship A (15M Nm³), Continuous delivery, compressor onshore at (un)loading point, gas fuel cost 100% of MGO price

4 Comparative Analysis

The purpose of the comparative study is to identify the conditions for which GASVESSEL is cost competitive against alternatives pipeline and LNG. The comparison GASVESSEL-LNG-PIPELINE consists of two parts: Scenario specific comparison and Generic comparison for a wider range of distance/volume, based on extrapolation of the scenario specific data.

4.1 Method

The method for building the comparison consists of:

1. Scenario specific costs:
    a. For each GASVESSEL scenario, GASVESSEL unit costs are identified - **Chap 3.4.1**
    b. LNG and PIPELINE related cost for the same scenarios are estimated - **Chap 4.2.1 and 4.2.2**
    c. Comparison diagrams for specific scenarios are generated - **Chap 4.3.1**
2. Generic comparison:
    a. Based on the data from GASVESSEL scenarios, LNG and pipeline costs corresponding to a wider range of distance/volume are extrapolated - **Chap 4.3.2.1**
    b. These are compared to GASVESSEL generic cost curves. The cost comparison for volume/distance ranges of 0.5-15 bcm/year and 100-5000 km is established to visualise the niche of competitiveness for GASVESSEL - **Chap 4.3.2.2**

The generic scenario assumes no utilization of existing infrastructure for LNG, pipeline or GASVESSEL to ensure fair comparison and facilitate the generalisation of the cases to a wider range of distance/volumes. The comparison is based exclusively on cost. No "stranded" or "economically unfeasible" range is highlighted in the comparison plots.

The scope of the comparison is from loading point to unloading point. Necessary facility for storage and infrastructure for loading/unloading are included in the comparison, but no upstream costs related to production or upstream logistics, nor downstream distribution to end customer is considered.

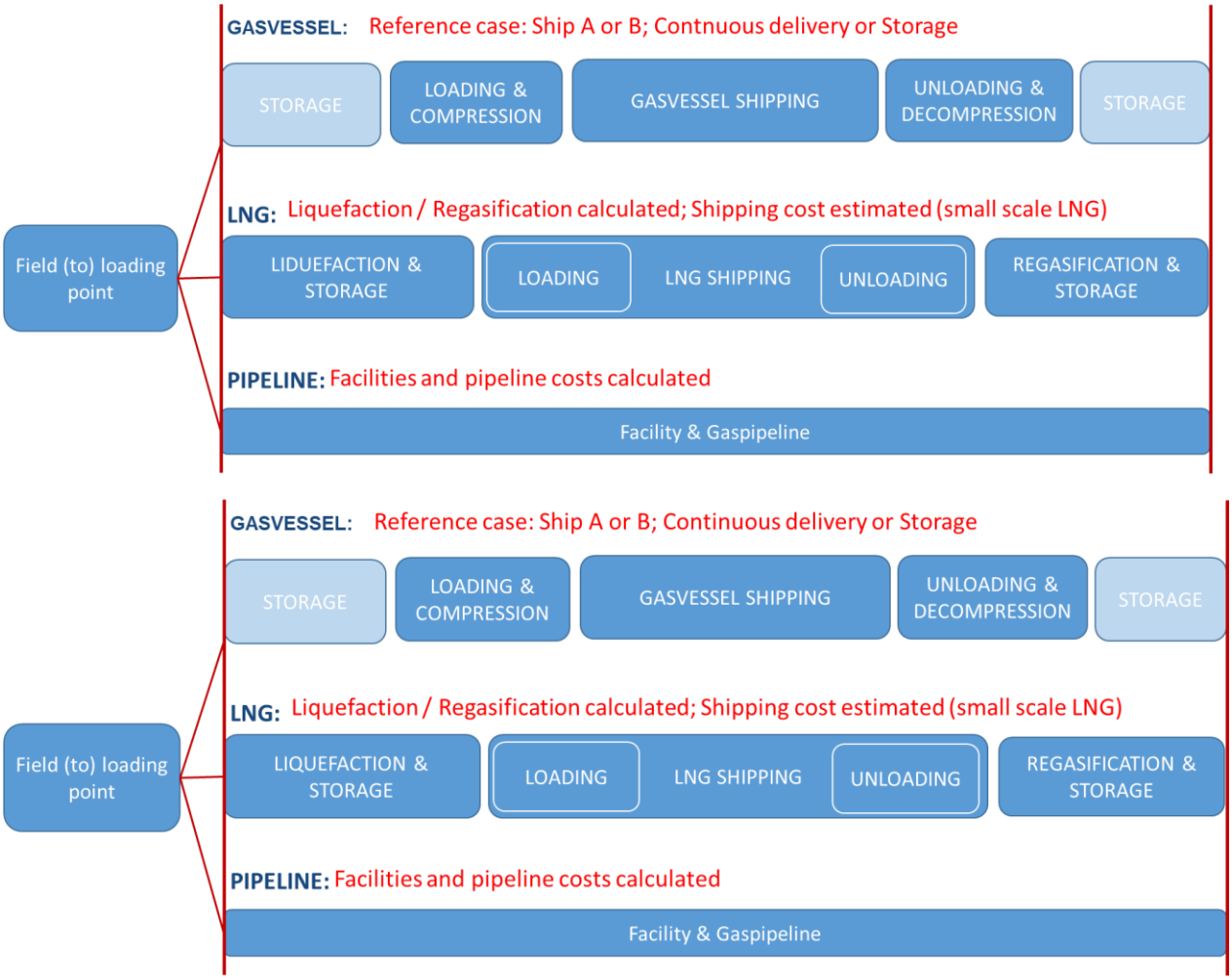


Figure 26: Schema of the scope of comparison GASVESSEL – Pipeline - LNG.

- For LNG, costs for liquefaction and regasification are calculated by CHC for each scenario. The LNG shipping costs are based on previous studies of small-scale LNG.
- For pipeline, fixed and variable costs for facilities and pipelines are calculated by CHC for each scenario.

The scenarios and the specific elements included in the comparison are summarised in Figure 27.

Region	East-Med	Est-Med	East-Med	Est-Med	East-Med	Est-Med	East-Med	Est-Med	Barents/ North sea	Barents/ North sea	Barents/ North sea	Barents/ North sea	black Sea
SCENARIO	CYPRUS-CRETE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-GREECE	ALKE Nyhamna	ALKE Polarled	ALKE - UK	J.CASTBERG - Polarled	UKRAINE 1
Start	Cyprus gas field	Cyprus gas field	Cyprus gas field	Cyprus gas field	Cyprus gas field	Cyprus gas field	Cyprus gas field	Cyprus gas field	Alke	Alke	Alke	J.Castberg	Shah Deniz
End	Crete	Crete	Lebanon	Lebanon	Egypt	Egypt	Greece	Greece	Nyhamna	Polarled	UK	Polarled	SHDKRI network
Gasvessel Loading point	Vassiliko	Field	Vassiliko	Field	Vassiliko	Field	Vassiliko	Field	Alke	Alke	Alke	J.Castberg	Poti
Type	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore	Offshore	Offshore	Offshore	Offshore	Onshore
Gasvessel configuration	Pipeline to Vassiliko > Gasvessel Vassiliko to Crete	Gasvessel from Field to Crete	Pipeline to Vassiliko > Gasvessel Vassiliko to Lebanon	Gasvessel from Field to Lebanon	Pipeline to Vassiliko > Gasvessel Vassiliko to Egypt	Gasvessel from Field to Egypt	Pipeline to Vassiliko > Gasvessel Vassiliko to Greece	Gasvessel from Field to Greece	Gasvessel from Alke field to Nyhamna	Gasvessel from Alke field to Polarled	Gasvessel from Alke field to UK	Gasvessel from Castberg field to Polarled	Pipeline ShahDeniz to Yuzhne > Gasvessel Yuzhne to Poti > Pipeline Poti to SHDKRI
Pipeline Alternative	Pipeline to Vassiliko > Pipeline Vassiliko to Crete	Pipeline Field > Crete	Pipeline to Vassiliko > Pipeline Vassiliko to Lebanon	Pipeline Field > Lebanon	Pipeline to Vassiliko > Pipeline Vassiliko to Egypt	Pipeline Field > Egypt	Pipeline to Vassiliko > Pipeline Vassiliko to Greece	Pipeline Field > Greece	Pipeline from Alke field to Nyhamna	Pipeline from Alke field to Polarled	Pipeline from Alke field to UK	Pipeline from Castberg field to Polarled	Pipeline ShahDeniz to Yuzhne > Offshore Pipeline Yuzhne to Poti > Pipeline Poti to SHDKRI
LNG alternative	Pipeline to Vassiliko > LNG vessel Vassiliko to Crete	LNG vessel from Field to Crete	Pipeline to Vassiliko > LNG vessel Vassiliko to Lebanon	LNG vessel from Field to Lebanon	Pipeline to Vassiliko > LNG vessel Vassiliko to Egypt	LNG vessel from Field to Egypt	Pipeline to Vassiliko > LNG vessel Vassiliko to Greece	LNG vessel from Field to Greece	LNG vessel from Alke field to Nyhamna	LNG vessel from Alke field to Polarled	LNG vessel from Alke field to UK	LNG vessel from Castberg field to Polarled	Pipeline ShahDeniz to Yuzhne > LNG vessel Yuzhne to Poti > Pipeline Poti to SHDKRI
Total daily gas demand/ delivery [MMSCM]	1.4	1.4	3.7	3.7	17	17	2,5	2,5	1.18	1.18	1.18	1.29	6.3
Annual delivery [bcm]	0.5	0.5	1.4	1.4	6.2	6.2	2.5	2.5	0.4	0.4	0.4	0.5	2.3
Transport distance [nm]	400	287	120	264	285	146	665	682	645	377	1352	422	578

Figure 27: GASVESSEL scenarios included in the comparison study.

4.2 LNG and pipeline alternatives

4.2.1 LNG

4.2.1.1 FLNG and FSRU

LNG/FLNG/FRSU CAPEX / OPEX calculation are from CHC. See cost tables from CHC in Appendix.

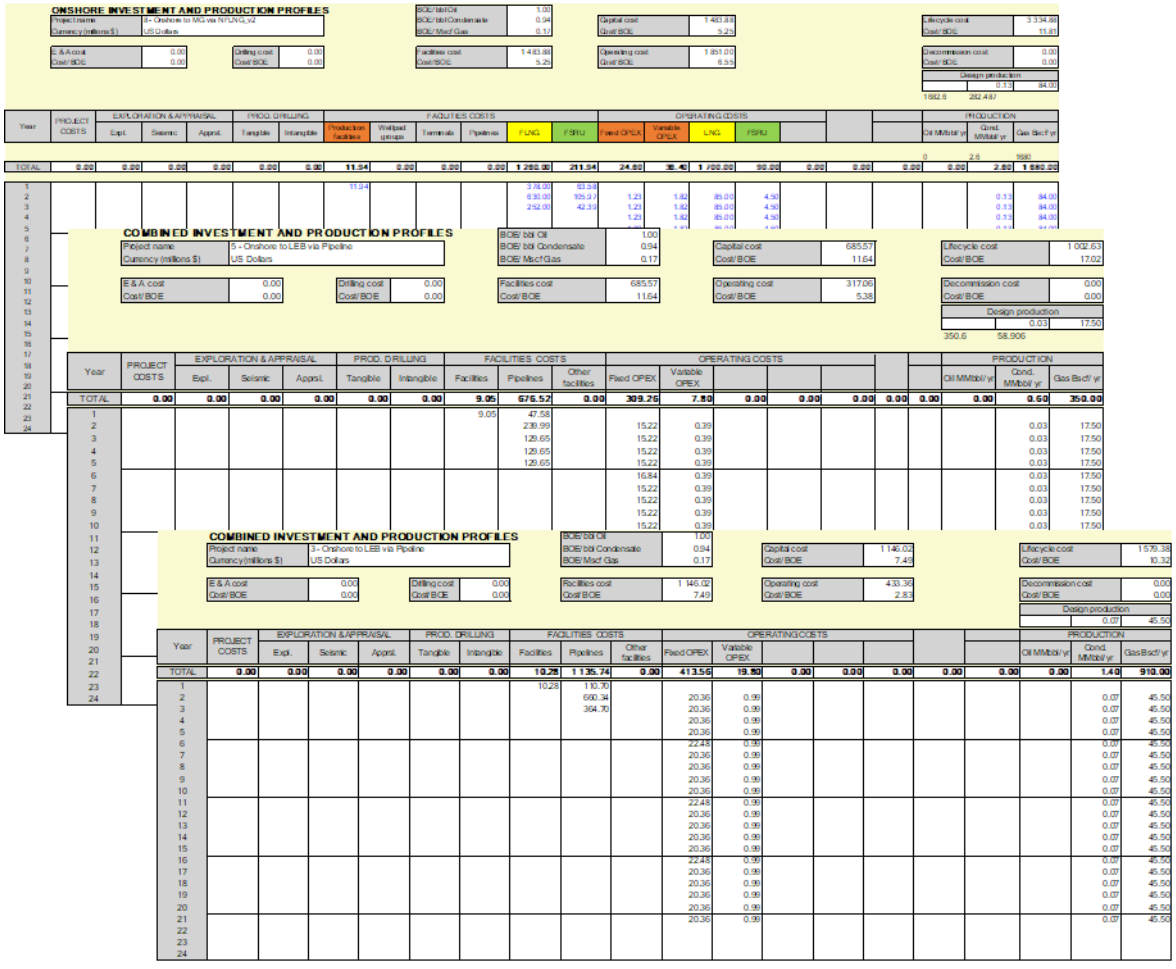
High level assumptions

1. All costs are in USD
2. Contingency, design costs, insurance and certification are all set to 0%
3. Upstream costs (drilling, wells, subsea equipment, separation, gas compression to 240 bar) are not included in the estimated costs, as these will be common to GASVESSEL and alternative gas transportation; 240 bar is the typical compressor design limit for an offshore installation and was also used as a limit in WP 2
4. Production life of 20 years @ plateau for all scenarios

FLNG and FSRU:

- FSRU and FLNG costs are generated using IHS Markit database
- CAPEX estimates generated by using power law relationship between liquefaction capacity and cost derived from database of comparable projects
- OPEX estimates generated by using linear relationship between gas delivery capability and cost derived from database of comparable projects
- Egypt scenario does not include FSRU, as FSRUs are already operating and available to receive LNG in that country

- For the LNG cases, an onshore LNG terminal is included at Vasilkos for the Egypt case, and nearshore FLNG moored at Vasilkos Port for the other cases
    - For the lower production cases nearshore, FLNG is a better comparison to the GASVESSEL option, and is more cost-effective than for land-based LNG
    - Nearshore FLNG vessels are limited to about 2.5 mtpa, so cannot be used for cases larger than this
- NFLNG cases include the costs of a jetty and offloading equipment
- Onshore costs for the processing facility include equipment required to process gas to required GASVESSEL/pipeline/FLNG specification, i.e., dew pointing, dehydration, etc.



4.2.1.2 *LNG Shipping*

LNG shipping costs are estimated based on secondary sources. As benchmark:

(1) LNG rate for a 155 000 m^3 LNG carrier, with long term charter rates, boil off gas priced at $6/mmbtu and return voyage is approximately $0.22/mmbtu (Source CHC, based om market data). Corresponding to appr. 0.007€/Nm^3.

(2) A study of small-scale LNG from Regan (2017)[4] estimated shipping tariff around 1,1$/mmbtu (0.033€/Nm^3).
(3) A comparative study of LNG/pipeline/CNG in the East Med region by Muhammad and Osiadacz (2015)[5] estimated LNG shipping cost at 0,35$/mmbtu (0.011€/Nm^3).
(4) MARINTEK[6] study of small-scale coastal LNG distribution with a 5000m^3 LNG carrier, based on a 1000km straight and an annual volume of 0.8 bcm, estimated shipping cost around 0.049€/Nm^3.

To be able to build a simplified cost curve taking into account both distance and volume transported, we use the data from small-scale studies used in Bittante et al. (2018)[7] optimization study, to build volume/distance cost curves (presented in Figure 29).

Ship type	Capacity	Speed	Fuel cost	Renting cost	Color
	m^3	km/h	$/km	$/month	
Type 1	7500	28	26	600,000	Yellow
Type 2	15,000	30	42	900,000	Green
Type 3	30,000	32	60	1200,000	Blue
Type 4	60,000	34	80	1500,000	Red
Type 5	120,000	35	100	2250,000	Magenta

Figure 28: Ship type and capacity, speed, fuel cost and renting cost for 5 LNG carriers (Source: Bittante et al. Table 2 (2018:82)

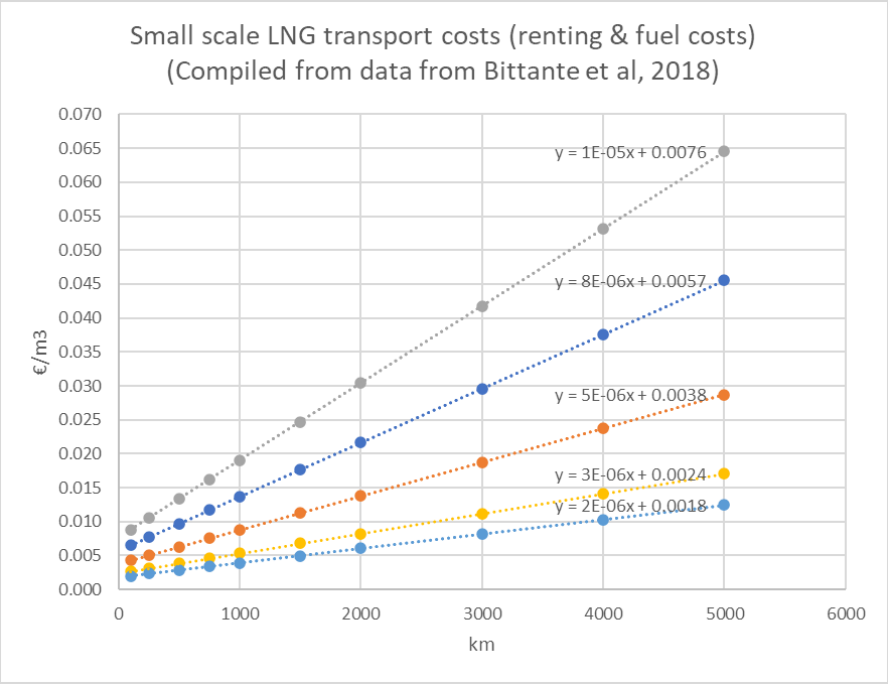


Figure 29: LNG shipping costs for distince vessel capacity (compiled with data from Bittante et al. (2018))

[4] Regan, T. (2017). Small scale LNG: Emerging technologies for small scale grids. Presentation to ESI Think-tank Roundtable, Singapore International Energy Week, 27.
[5] Muhammad, A. K., & Osiadacz, A. (2016). The Technical and Economical comparison between marine CNG and LNG Transportation. Современные научные исследования и инновации, (3), 182-188.
[6] MARINTEK (2005). Framtidsbilde for norsk naturgassdistribusjon, 2015-2025, ENOVA studie, rapport MT28 F088
[7] Bittante, A., Pettersson, F., & Saxén, H. (2018). Optimization of a small-scale LNG supply chain. Energy, 148, 79-89.

4.2.2 Pipeline

Topsides and pipelines CAPEX/OPEX calculation are from CHC. See cost tables from CHC in Appendix.

Main assumptions:

- Topsides and pipeline costs generated using Que$tor
- Topsides cost account for equipment on offshore platform required to process gas to required GASVESSEL/pipeline/FLNG specification, i.e., dew pointing, dehydration etc.
- In FLNG cases, pipeline costs refer to a flexible hose connecting the offshore platform with a loading buoy
- Pipeline routes assume straight lines between points
- Pipeline design accounts for maximum water depth along each route, as per Google Earth data
- Pipeline arrival pressure of 70 barg assumed at delivery point
- A condensate-to-gas ratio of 1.5 bbl/mmscfd is assumed and accounted for in the pipeline design

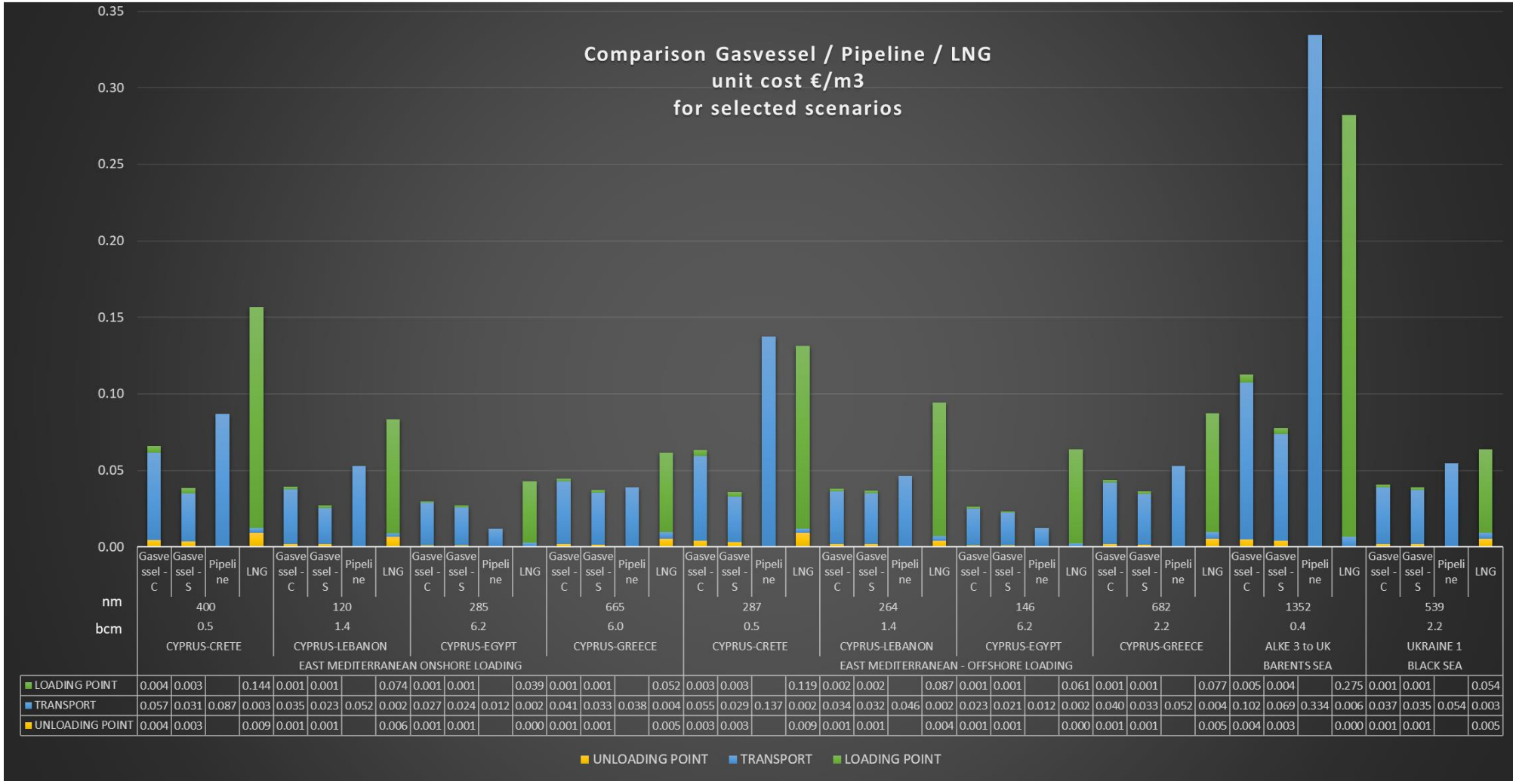
As a benchmark, the figure applied in the specific GASVESSEL scenario Cyprus-Greece (see Chapter 4.4) the cost estimated based on market information is 300 M€ for a 215 km long pipeline, starting offshore, handling 3 bcm of gas annually. Higher cost to be expected with high water depth. A second benchmark is Muhammad and Osiadacz (2015)[8], assuming a subsea pipeline CAPEX of $ 5 million per km for deep water case and a volume of 8 bcm/year.

[8] Muhammad, A. K., and Osiadacz, A. (2016). The Technical and Economical comparison between marine CNG and LNG Transportation. Современные научные исследования и инновации, (3), 182-188.

4.3 Results (Comparative analysis)

4.3.1 GASVESSEL vs LNG vs pipeline: All scenarios

Two GASVESSEL options are used in the comparison. Vessel size will be the one decided after optimization through VOLTA software; the speed is kept constant at 16 knots, the compressors are onboard the vessel, option 1 "Gasvessel – C" for Continuous delivery, and "Gasvessel – S" for option including storage.



	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG	Gasvessel - C	Gasvessel - S	Pipeline	LNG
nm	400				120				285				665				287				264				146				682				1352				539			
bcm	0.5				1.4				6.2				6.0				0.5				1.4				6.2				2.2				0.4				2.2			
	CYPRUS-CRETE				CYPRUS-LEBANON				CYPRUS-EGYPT				CYPRUS-GREECE				CYPRUS-CRETE				CYPRUS-LEBANON				CYPRUS-EGYPT				CYPRUS-GREECE				ALKE 3 to UK				UKRAINE 1			
	EAST MEDITERRANEAN ONSHORE LOADING																EAST MEDITERRANEAN - OFFSHORE LOADING																BARENTS SEA				BLACK SEA			
LOADING POINT	0.004	0.003		0.144	0.001	0.001		0.074	0.001	0.001		0.039	0.001	0.001		0.052	0.003	0.003		0.119	0.002	0.002		0.087	0.001	0.001		0.061	0.001	0.001		0.077	0.005	0.004		0.275	0.001	0.001		0.054
TRANSPORT	0.057	0.031	0.087	0.003	0.035	0.023	0.052	0.002	0.027	0.024	0.012	0.002	0.041	0.033	0.038	0.004	0.055	0.029	0.137	0.002	0.034	0.032	0.046	0.002	0.023	0.021	0.012	0.002	0.040	0.033	0.052	0.004	0.102	0.069	0.334	0.006	0.037	0.035	0.054	0.003
UNLOADING POINT	0.004	0.003		0.009	0.001	0.001		0.006	0.001	0.001		0.000	0.001	0.001		0.005	0.003	0.003		0.009	0.001	0.001		0.004	0.001	0.001		0.000	0.001	0.001		0.005	0.004	0.003		0.000	0.001	0.001		0.005

Figure 30: Comparision GASVESSEL (continuous and storage options), LNG and pipeline for the selected scenarios.

4.3.2 GASVESSEL vs pipeline vs LNG: Generalisation

4.3.2.1 Pipeline and LNG cost curves

To enable the extrapolation of the cost to a wider range of distance/volume, simplified models for the pipeline cost estimation are derived from the few cases studied in WP7. This model is aimed for the GASVESSEL T7.2 comparison study only, not statistically representative, nor to be used as a generic model. The estimation is based on the cost structure breakdown (facilities and pipeline CAPEX, OPEX) of the scenario-related costs established by CHC. Distinction is made between onshore and offshore options. The resulting cost/distance curves for distinct volumes scenarios are presented in Figure 31.

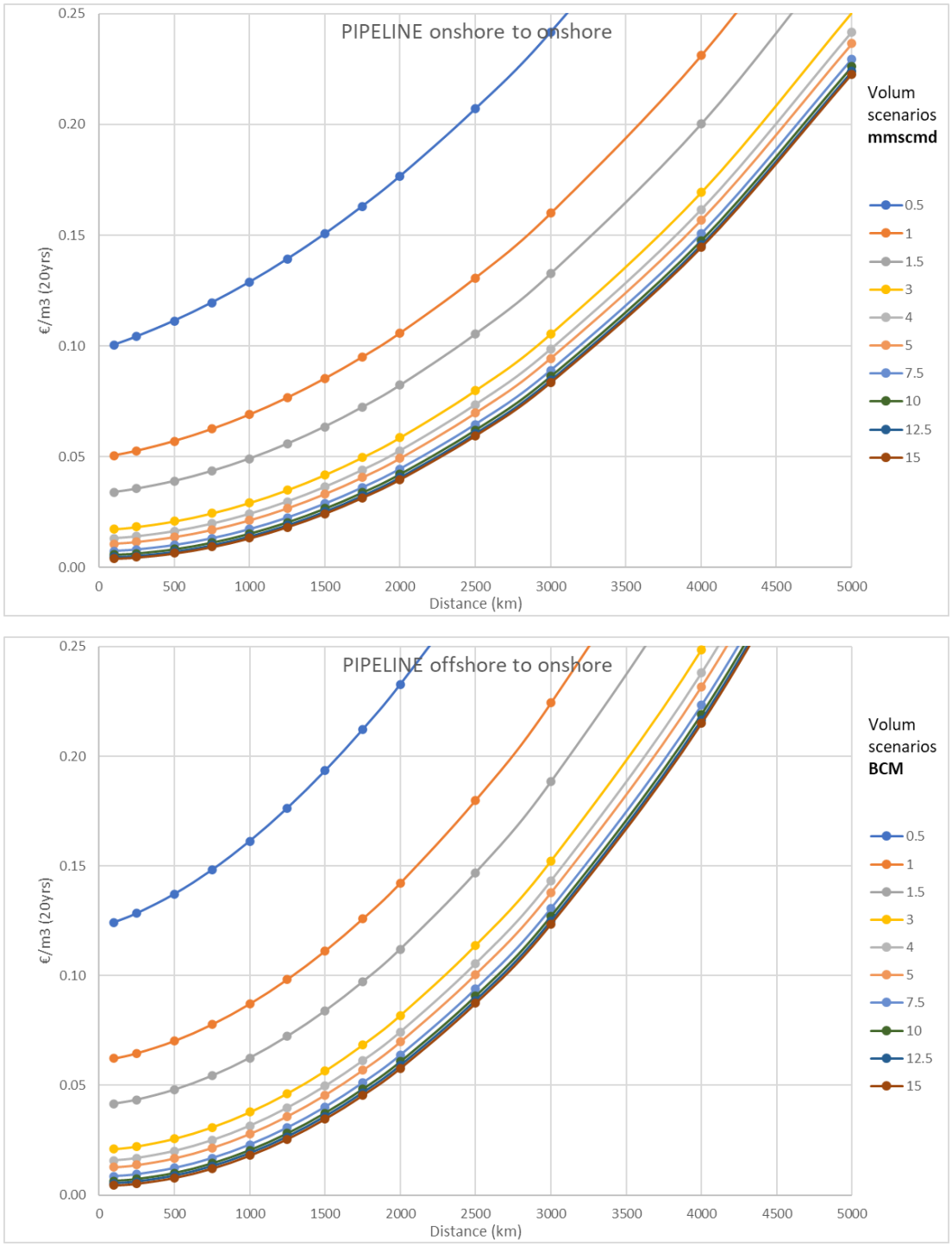


Figure 31 (a and b) Pipeline costs as funciton of distance (km) for distinct volume scenarios (bcm/year), based on (a) onshore scenarios, and (b) offshore scenarios

The same approach is used for FLNG and FRSU costs, deriving cost functions from the few scenarios treated, based on a cost breakdown in fixed and variable costs, FLNG and FRSU. The shipping cost figures are based on LNG shipping costs for LNG vessel of comparable delivery capacity to GASVESSEL. The resulting cost/distance curves for distinct volumes scenarios, including the shipping cost identified in Chap 4.2.1.2, are presented in Figure 32.

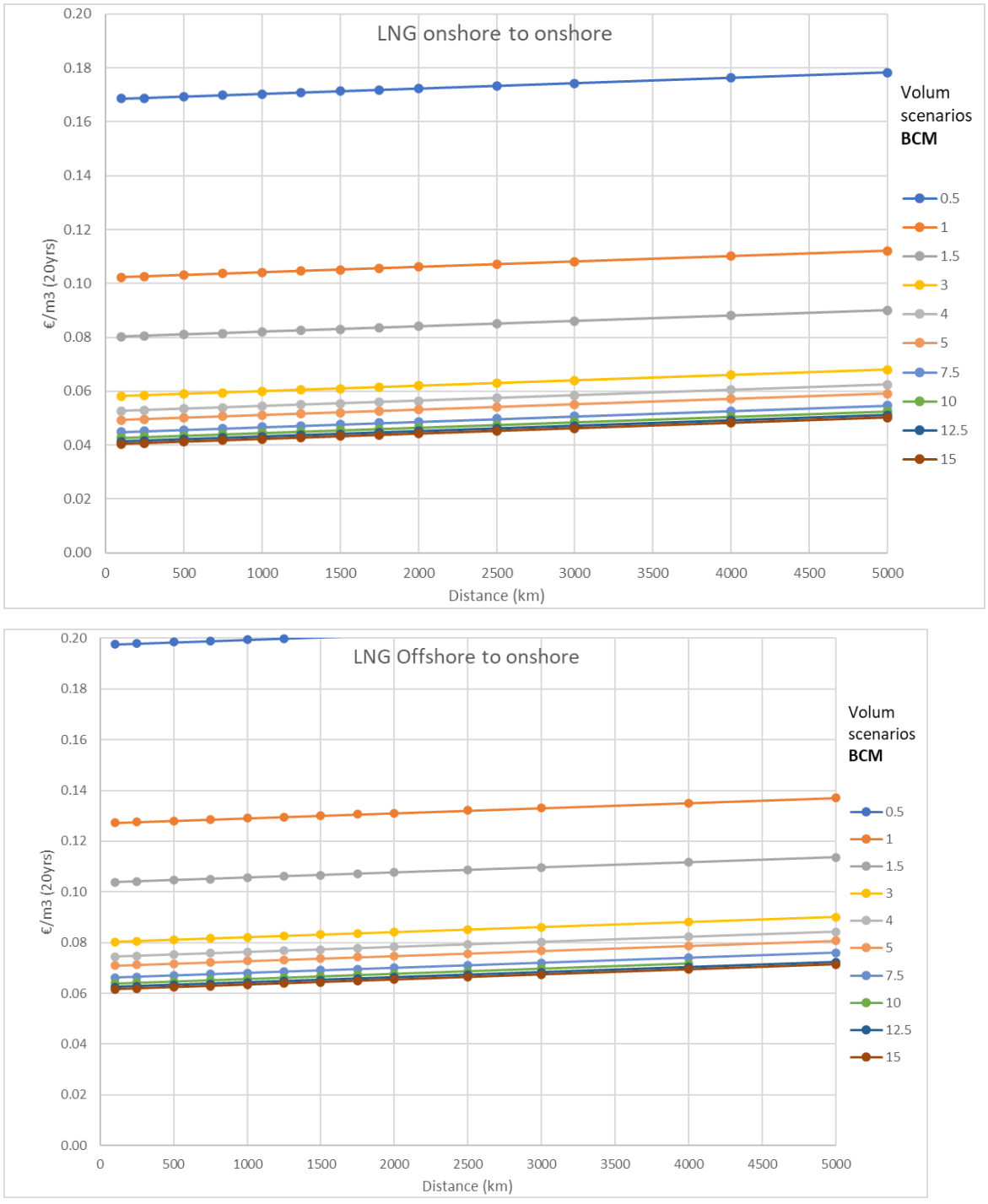


Figure 32 (a and b): LNG and FLNG costs as funciton of distance (km) for distinct volume scenarios (bcm/year), based on (a) onshore scenarios, and (b) offshore scenarios (ref ship LNG carrier 120 000m³)

4.3.2.2 Pipeline – LNG – GASVESSEL cost comparison

Based on the generalised cost model for GASVESSEL and the cost curves identified above for pipeline and LNG, comparison diagram are set up using Excel contour plots. These highlight for each volume/distance combination, which of GASVESSEL, pipeline or LNG option displays the lowest unit cost for transport (€/Nm^3). The two following plots are representing comparison with GASVESSEL ship B (12 M Nm^3) and A (15 M Nm^3). The GASVESSEL base case is onshore-onshore, continuous delivery, compressors at loading and unloading points (not onboard the ship), 16 knots sailing speed, operating days 350 per year, gas fuel cost index 50% of MGO, 20 years of operation. In the following contour plots, the dark blue colour is used for pipeline, grey for GASVESSEL and light blue for LNG.

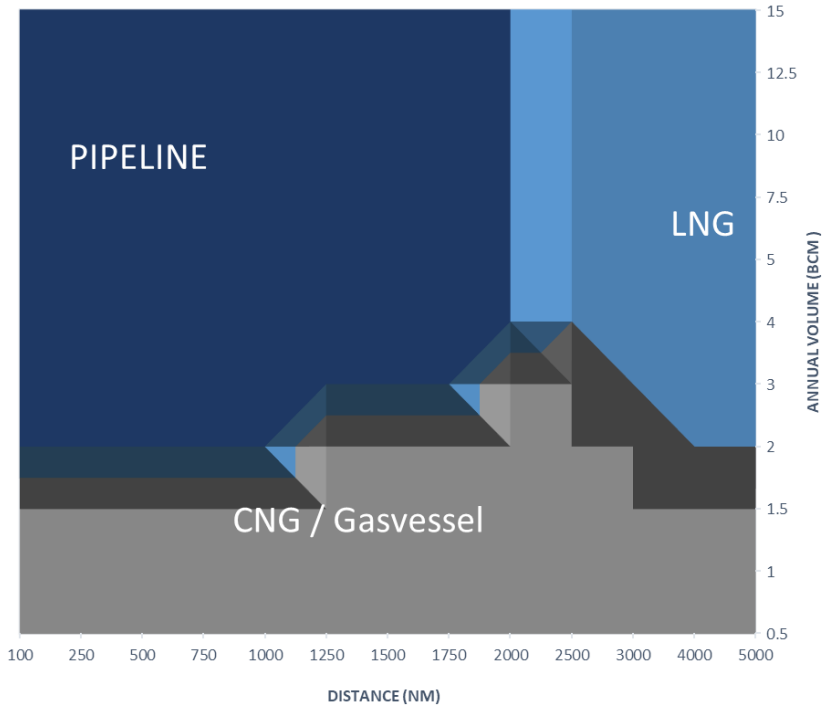


Figure 33: Contour plot unit cost for GASVESSEL (Ship B 12M Nm^3), pipeline and LNG.

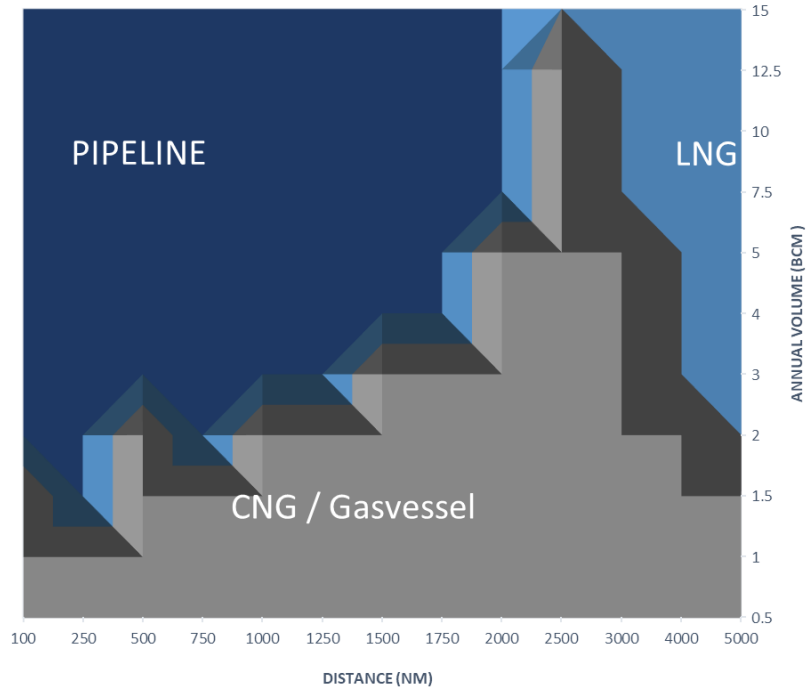


Figure 34 Contour plot unit cost for GASVESSEL (Ship A 15M Nm^3), pipeline and LNG.

To illustrate further the volume/distance range of competitiveness between GASVESSEL, pipeline and LNG, a cost curve diagram is generated, showing cost curves for small volumes (0.5 to 3) for which GASVESSEL is most interesting. The plain lines represent pipeline, the dashed lines GASVESSEL and the dotted lines LNG.

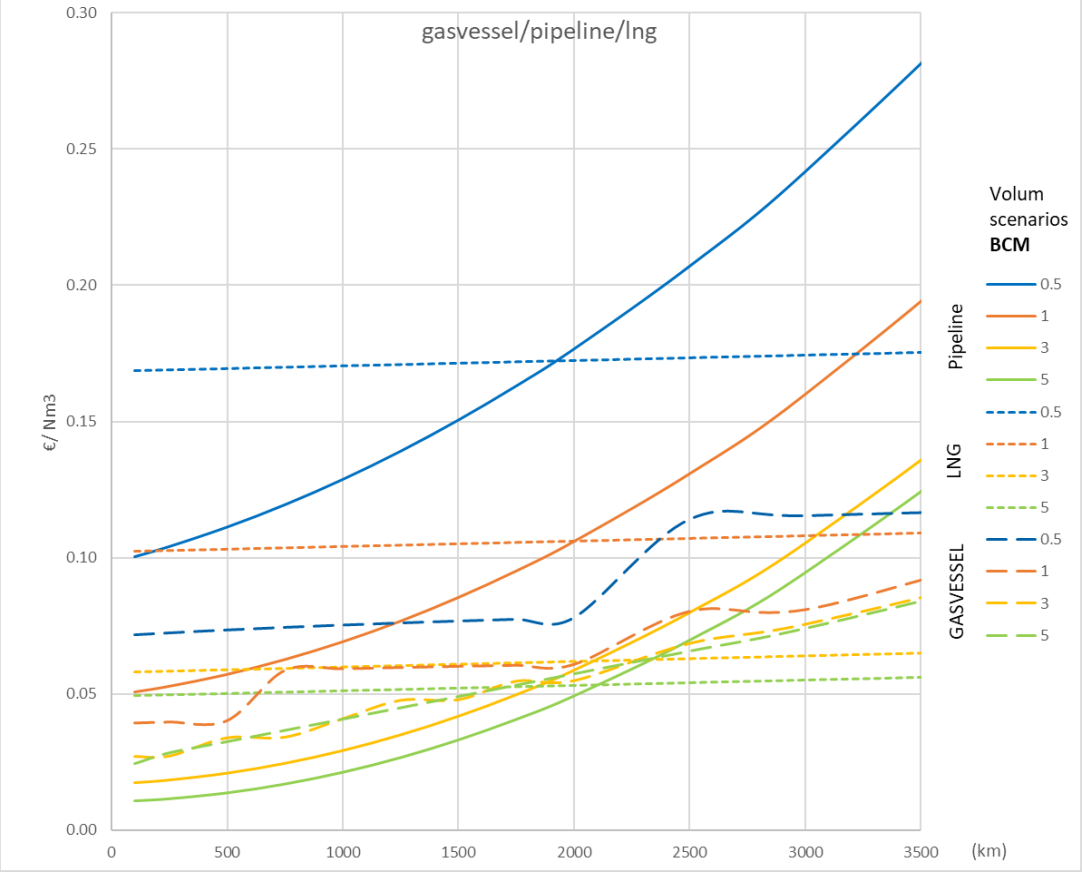


Figure 35: Unit cost comparison GASVESSEL (Ship A)/LNG/pipeline for volume range 0.5 – 5 bcm/year

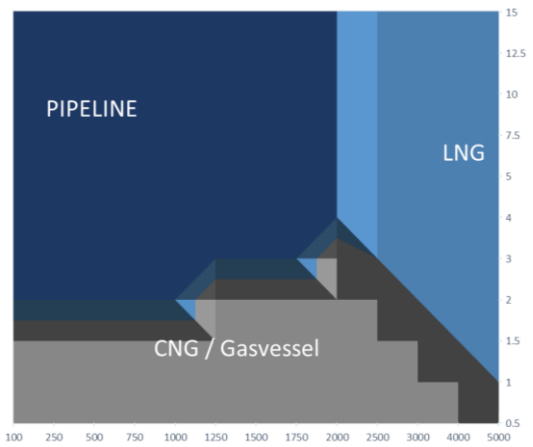
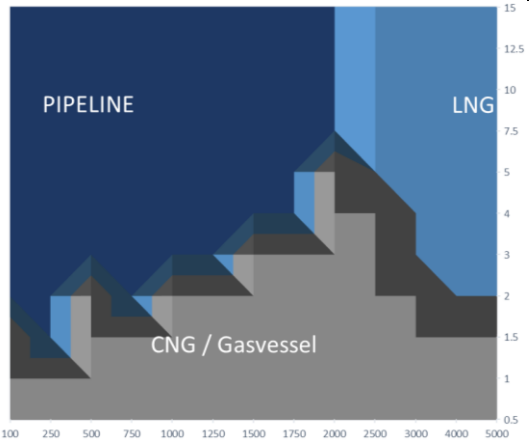
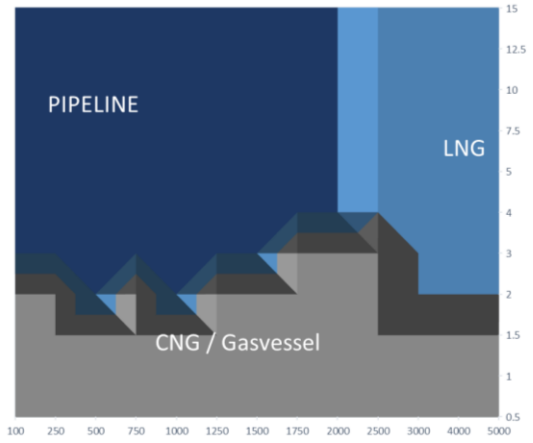
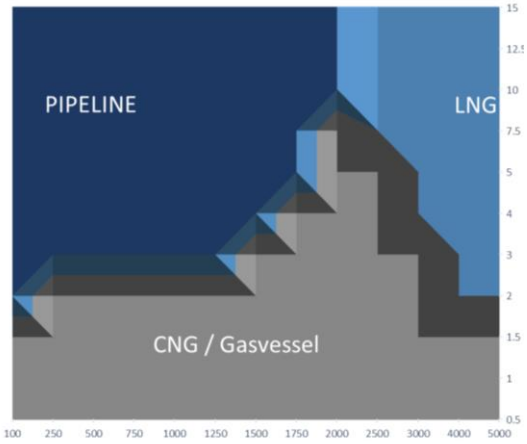
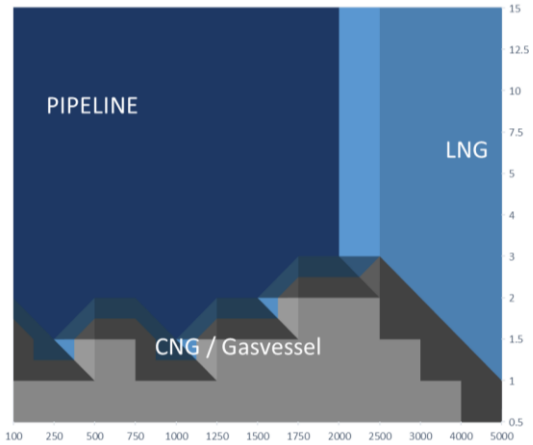
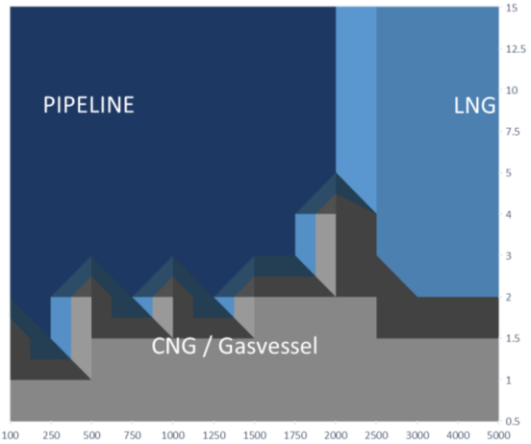
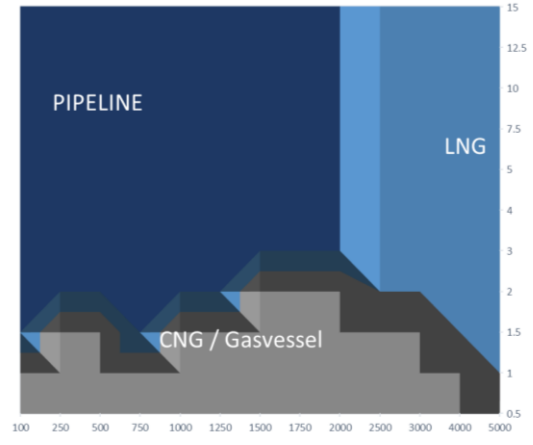
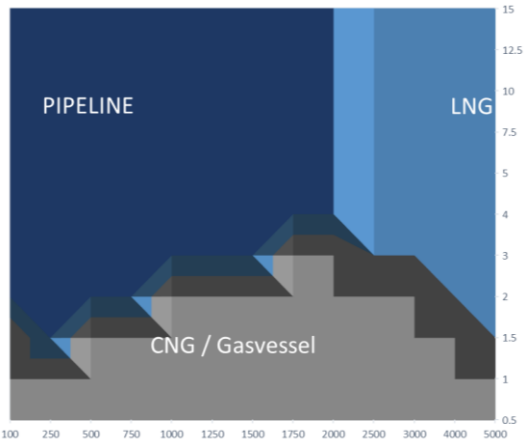
To explore the effect of distinct input parameters on the unit cost, the following set of contour plots displays distinct comparison cases. The baseline case in the GASVESSEL ship A with continuous delivery and compressor at loading/unloading points, average sailing speed of 16 knots, operating days 350 per year and fuel gas cost index 50% of MGO. The reference cost for LNG shipping is that of a ship with similar carrying capacity as GASVESSEL. The alternative cases presented in the following plots are summarised in the left column.

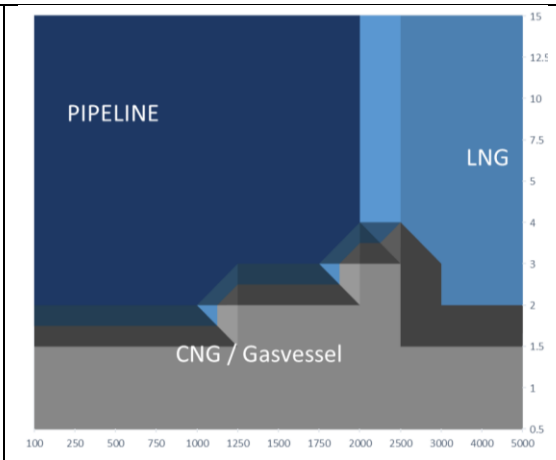
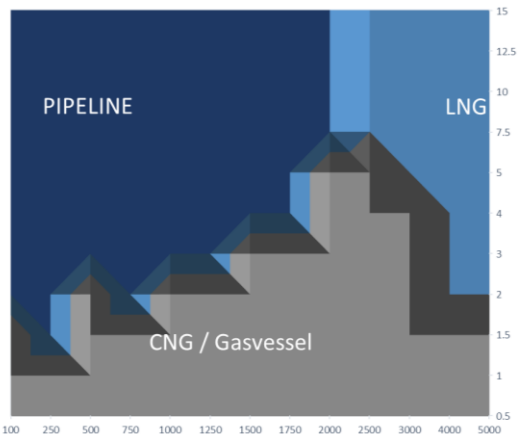
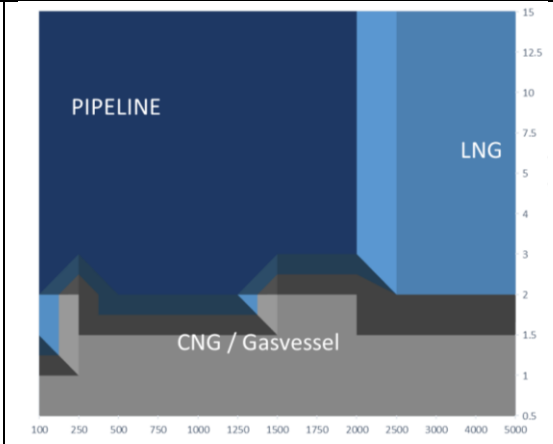
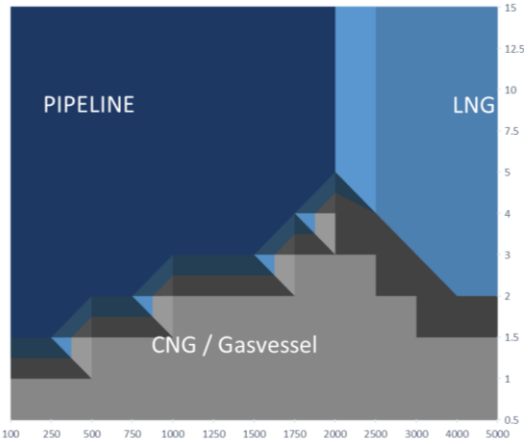
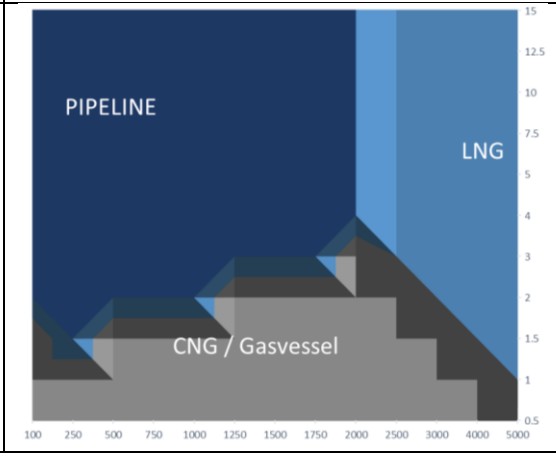
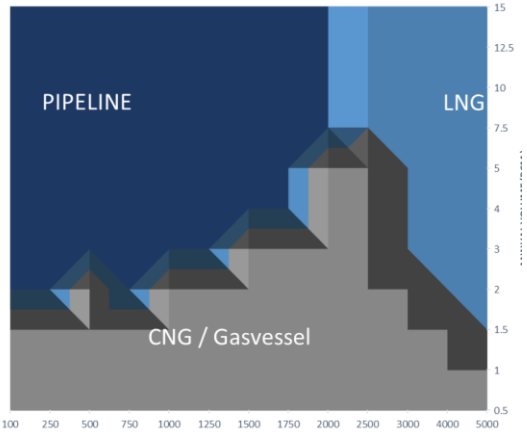
For each contour plot, the X axis represents the distance (100 to 5000 km), Y axis the yearly volume demand (0.5 to 15 bcm).

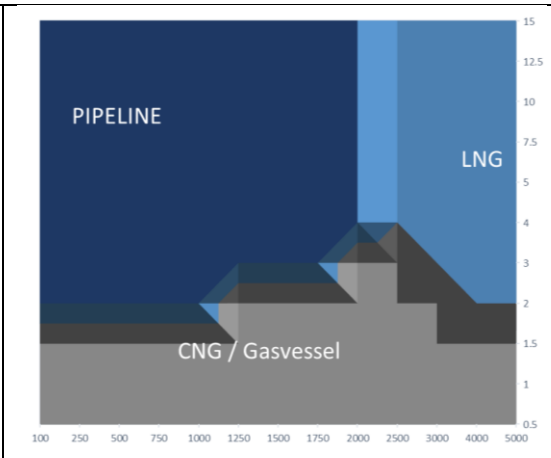
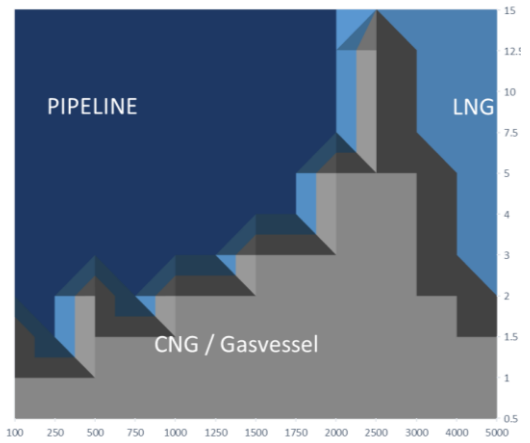
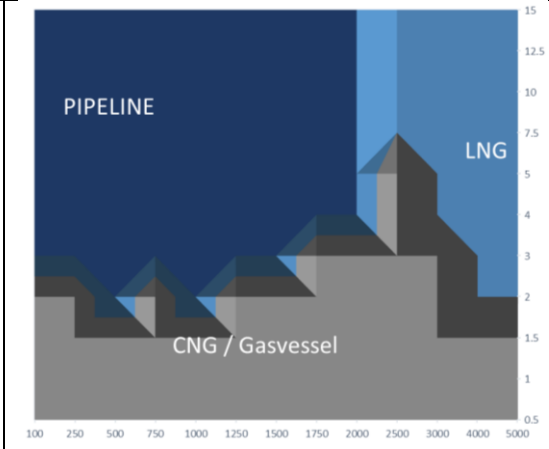
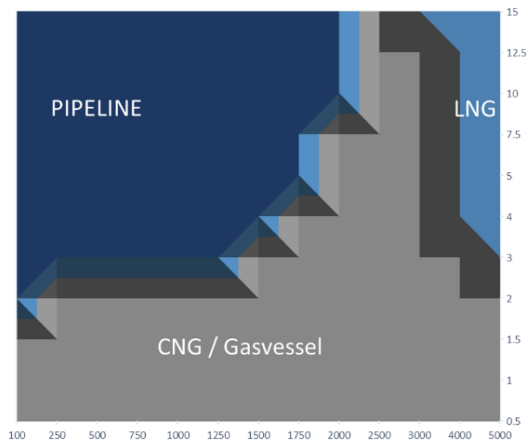
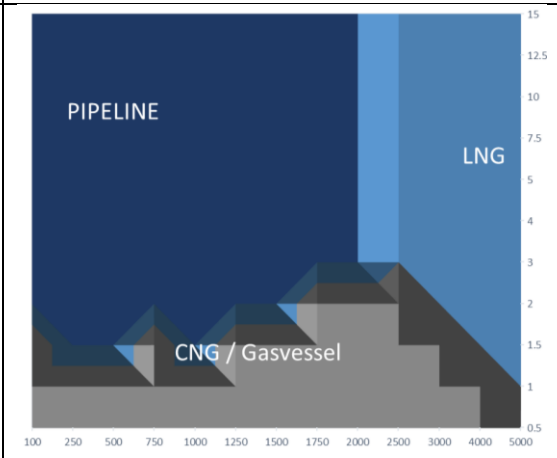
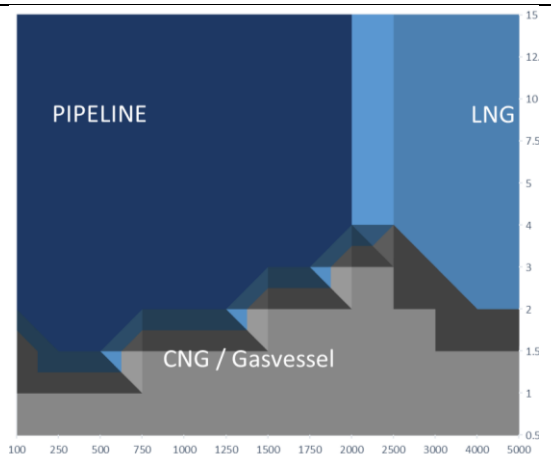
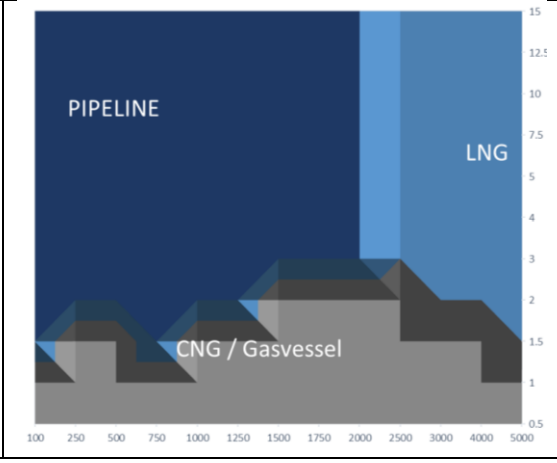
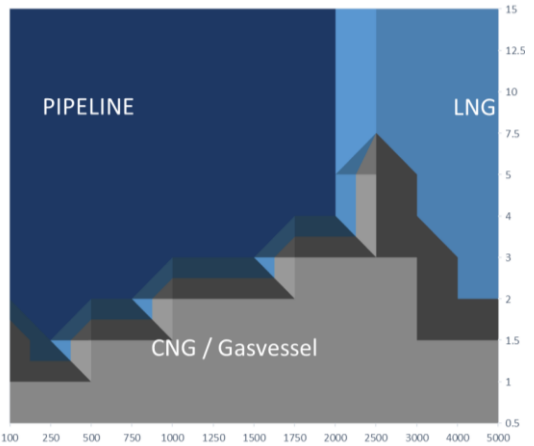
The classification of the input parameters' variations is the following:

- Delivery: C for *Continuous*, S for *Storage*
- Speed: 16, 14, 18
- Compressors: O for *onboard*, L/U for *at loading / unloading point*
- LNG carrier: L for large, M for medium size
- Fuel: gas fuel cost index as % of MGO cost 25%, 50%, 100%

- Operating days: 350, 325, 365

	GASVESSEL Ship B (12M Nm³)	GASVESSEL Ship A (15M Nm³)
Delivery: C, Compressors: O, Speed 16, Fuel: 50%, LNG: L, Op.days: 350		
Delivery: C, Compressors: O, Speed 16, Fuel: 25%, LNG: L, Op.days: 350		
Delivery: C, Compressors: O, Speed 16, Fuel: 75%, LNG: L, Op.days: 350		
Delivery: C, Compressors: O, Speed 14, Fuel: 50%, LNG: L, Op.days: 350		

Delivery: C, Compressors: O, Speed 18, Fuel: 50%, LNG: L , Op.days: 350		
Delivery: C, Compressors: O, Speed 16, Fuel: 50%, LNG: L , Op.days: 325		
Delivery: C, Compressors: O, Speed 16, Fuel: 50%, LNG: L , Op.days: 365		

Delivery: C, Compressors: L/U, Speed 16, Fuel: 50%, LNG: M , Op.days: 350		
Delivery: C, Compressors: L/U, Speed 16, Fuel: 25%, LNG: M , Op.days: 350		
Delivery: C, Compressors: L/U, Speed 16, Fuel: 100%, LNG: M , Op.days: 350		
Delivery: C, Compressors: L/U, Speed 14, Fuel: 50%, LNG: M , Op.days: 350		

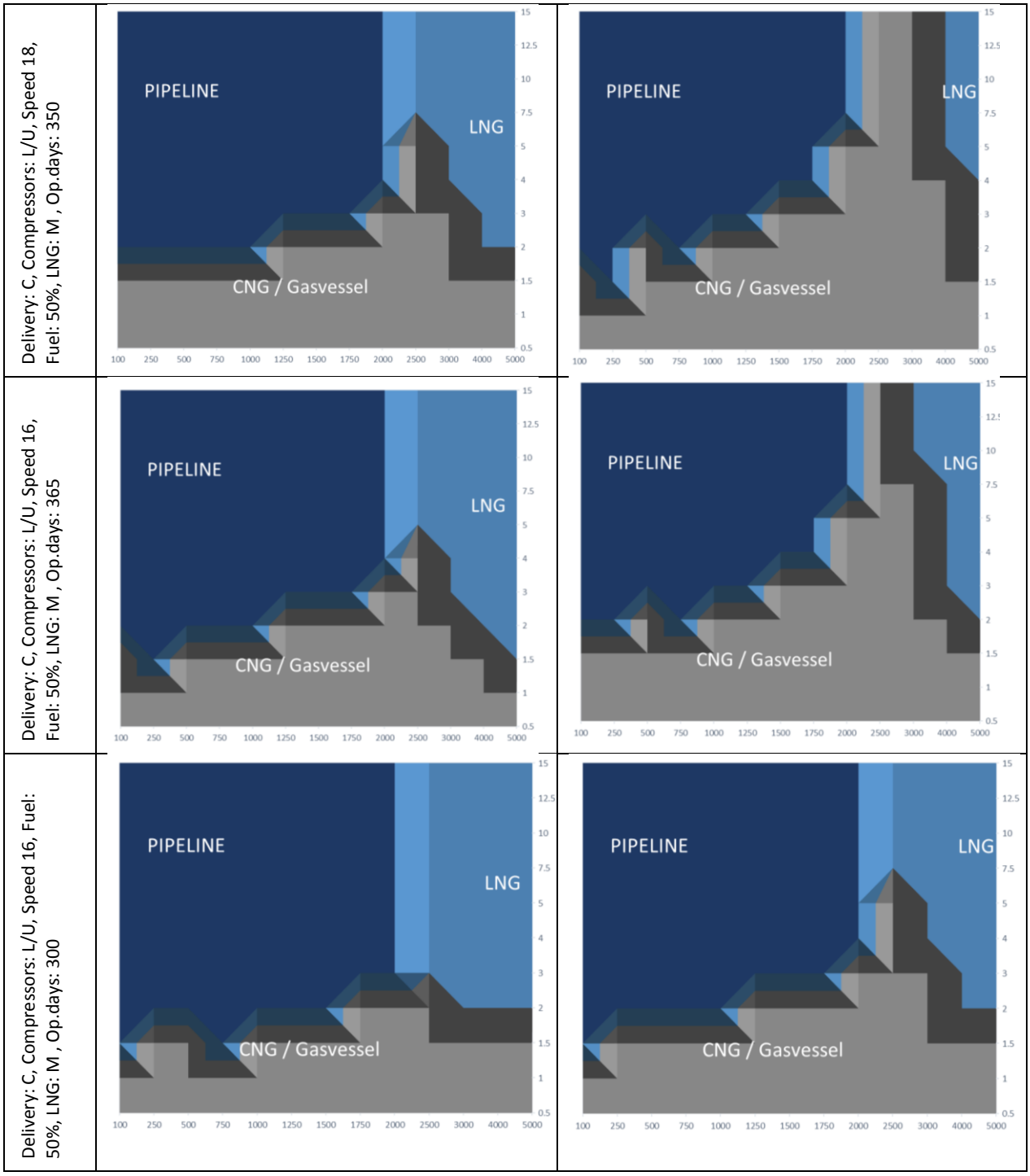


Figure 36: Comparison GASVESSEL – LNG – Pipeline onshore-onshore, continuous delivery, for Ship A and Ship B, distance range 100-5000km, volume range 0.5-15 bcm/year. Variation of input parameters operting days, operation years, speed, gas fuel cost, and tested for 2 distinct LNG vessel sizes (distinct shipping costs)

4.4 Specific scenario: Cyprus – Greece

To further explore the feasibility of GASVESSEL, a Cyprus-Greece scenario was selected. This scenario represents a realistic case for establishing a GASVESSEL fleet and transport system which can serve as a springboard for further technology and market development. The case represents a range of 2.5 BCM/year and sailing distance of approximately 1250 km for GASVESSEL, preceded with a pipeline upstream gas transport from offshore field to onshore storage. The scenario is described in Chapter 4.4.1.

4.4.1 GASVESSEL CASE

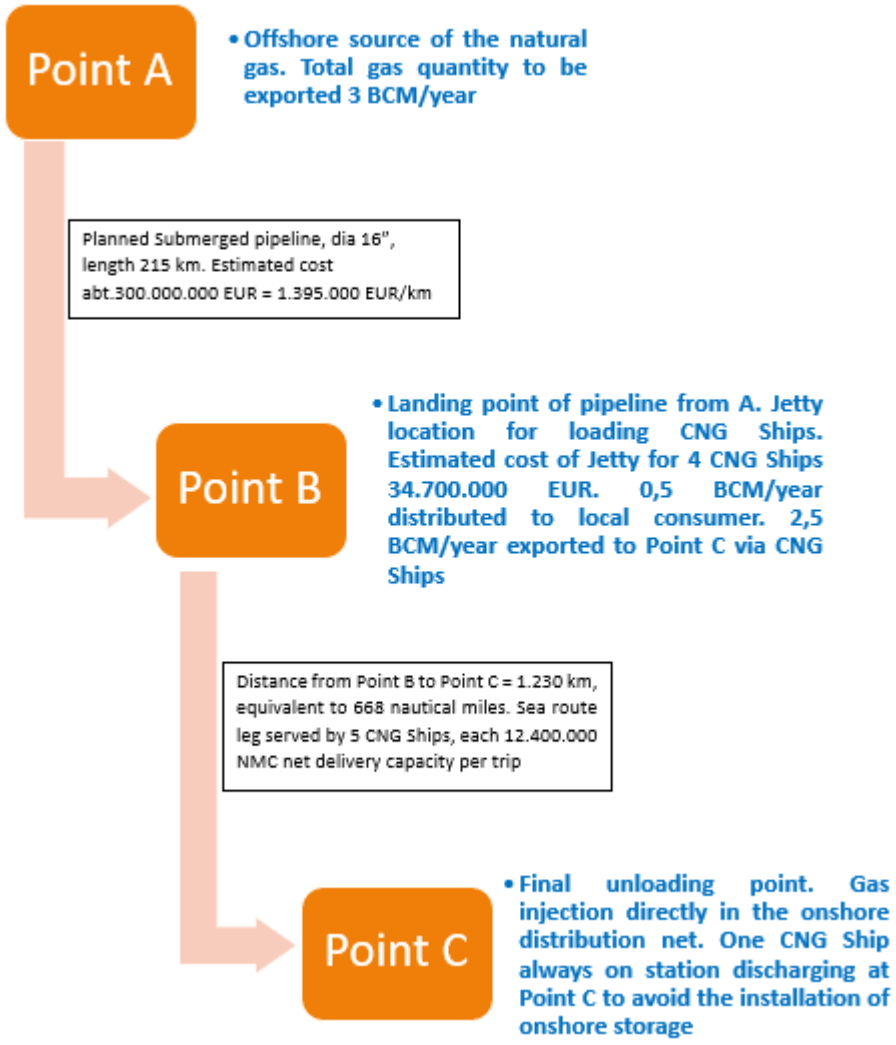


Figure 37: GASVESSEL scenario

The proposed GASVESSEL solution does not need to establish upstream and downstream buffer/storage facilities and is cost-estimated as a continuous-delivery scenario.

Point A: offshore gas field with FPSO; estimated production 3 BMC/year.

Point A to Point B: submerged pipeline - 16" inch, 215 km, with a max inlet pressure of 150 bar, a minimum arrival pressure of 40 bar, and possibility to increase the pipe diameter. It is expected that the pipeline volumetric capacity will avoid the need for buffer storage at the arrival in Point B. Max water depth 1 750 m. Estimated total cost 300 M EUR.

Point B: receiving point connected to the submerged pipeline and fitted with jetty facilities to accommodate the GASVESSEL CNG ships and loading equipment. Of the 3 BMC/year arriving, 2,5 BCM/year exported to

Point C via GASVESSEL CNG Ships. Estimated cost of jetty facilities for two GASVESSEL CNG Ships is 34.7 M €. Onshore compression station from min. 40 bar to 335 bar necessary to load the CNG onboard GASVESSEL located at point B. Estimated total cost 16 M €.

Point B to Point C: sea route. Waterborne GASVESSEL CNG transportation costs evaluation based on the following assumptions:

- Gas delivered: 2.5 BCM/year (6.85 mmscmd)
- Service duration 20 years (to enable comparison with FLNG and pipeline),
- Distance B-C (loading/unloading points): 668 nm (1 230 km)
- Distance A-C (field/final destination): 682 nm (1 262 km)
- GASVESSEL ship used: Navalprogetti type A (total capacity 15 M Nm^3)
- Net gas quantity delivered each voyage 12.4M Nm^3
- Loading time: 43 hrs; Unmooring: 2 hrs; Sailing: 42 hrs (668 nm/16 kn); Mooring: 3 hrs; Unloading: 61 hrs.
- Vessel operating days/year: 350, inconveniences due to the weather conditions or technical problems such as class renewal and ship maintenance/dry docks, etc.

GASVESSEL fleet and transport system:

- Roundtrip time: 198 hrs, 8.2 days.
- Maximum roundtrip per vessel per year: 42 (given operating days).
- Number of CNG ships required for annual delivery 2,5 BMC: 5 Ships
- This fleet size ensures constant debit (daily) and takes into account the unloading debit from the vessel is distinct from the daily demand over the unlading period (unloading flow 0.2 M Nm^3/hr vs. demand 0.28 M Nm^3/hr). The sailing fleet to ensure no time lap between two unloading periods, taking into account operation time of 350 days, is: 350/roundtrip time = 4 vessels (3,57). Number of vessels required at all times to ensure daily supply = 6,85 M Nm^3 / (12,4 M Nm^3) / (61hrs/24hrs)) = 1,4 vessel. Rounding up, the theoretical fleet size is 6 vessels. However, taking into account some variation in daily delivery, one additional vessel to the fleet is sufficient to ensure supply without a large storage buffer.

Point C: final destination; with delivered gas injected into the existing gas distribution net. As explained above, the gas quantity delivered by one GASVESSEL CNG Ship is enough for two days consumption, if one ship is permanently present at the unloading point there is no need of buffer/storage facilities. The GASVESSEL CNG Ship requires a similar jetty as in point B, with pressure reduction system to the 64 bar of the local gas distribution net and compressor.

4.4.2 Alternative options description

Pipeline and LNG options are considered both for the leg B-to-C (onshore to onshore) as well as starting at offshore field (leg A-to-C). These are illustrated in Figure 38 and summarized in Table 4.

Table 4: Gasvessel and alternative options for case Cyprus-Greece

Onshore-Onshore options				Offshore-onshore options		
	GASVESSEL	Option 1 LNG	Option 2 Pipeline		Option 3 FLNG	Option 4 Pipeline
A-B 215km	Pipeline	Pipeline	Pipeline	A-C 1262km	FLNG + LNG A-C	Pipeline starting offshore
B-C 1230 km	GASVESSEL	LNG	Pipeline			

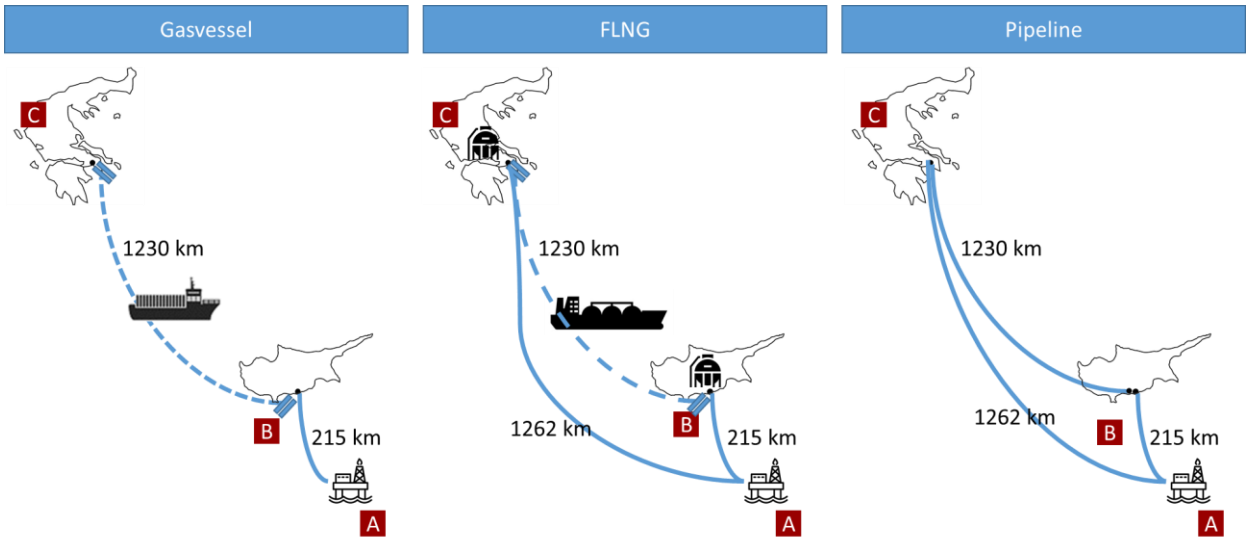


Figure 38: Gasvessel and alternative options for case Cyprus-Greece

The input cost data for each option are presented in the following tables:

Table 5: GASVESSEL fleet and transport system costs

	Total costs M€ Million Euros	Unit cost €/ Nm^3 2.5BCM*20years
A-B pipeline	300 M€	0.006
B Loading infrastructure + compression	34,7 M€ jetty Compressor 16 M€	0,001068
B-C GASVESSEL shipping cost	5 vessels: CAPEX: 204 M€ /ship annual OPEX: 8498 *365d = 3,03 M€/year/ship annual VOYEX: 18,1 M€ (202 roundtrips whole fleet)	0,0204 0,0062 0,00724 =0,034
B Unloading infrastructure + compression	34,7 M€ jetty Compressor 16 M€	0,001068

Table 6: Onshore Cyprus to mainland Greece via Nearshore LNG (option 1), CAPEX & OPEX

ONSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	8 - Onshore to MG via NFLNG_v2	BOE/ bbl Oil	1.00	Capital cost	1 483.88	Lifecycle cost	3 334.88
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	5.25	Cost/ BOE	11.81
		BOE/ Mscf Gas	0.17				
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 483.88	Operating cost	1 851.00	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	5.25	Cost/ BOE	6.55	Cost/ BOE	0.00
								Design production	
								0.13	84.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS						PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Production facilities	Wellpad groups	Terminals	Pipelines	FLNG	FSRU	Fixed OPEX	Variable OPEX	LNG	FSRU			Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.94**	**0.00**	**0.00**	**0.00**	**1 260.00**	**211.94**	**24.60**	**36.40**	**1 700.00**	**90.00**	**0.00**	**0.00**	**0.00**	**2.60**	**1 680.00**
1							11.94				378.00	63.58									
2											630.00	105.97	1.23	1.82	85.00	4.50				0.13	84.00
3											252.00	42.39	1.23	1.82	85.00	4.50				0.13	84.00
4													1.23	1.82	85.00	4.50				0.13	84.00
5													1.23	1.82	85.00	4.50				0.13	84.00
6													1.23	1.82	85.00	4.50				0.13	84.00
7													1.23	1.82	85.00	4.50				0.13	84.00
8													1.23	1.82	85.00	4.50				0.13	84.00
9													1.23	1.82	85.00	4.50				0.13	84.00
10													1.23	1.82	85.00	4.50				0.13	84.00
11													1.23	1.82	85.00	4.50				0.13	84.00
12													1.23	1.82	85.00	4.50				0.13	84.00
13													1.23	1.82	85.00	4.50				0.13	84.00
14													1.23	1.82	85.00	4.50				0.13	84.00
15													1.23	1.82	85.00	4.50				0.13	84.00
16													1.23	1.82	85.00	4.50				0.13	84.00
17													1.23	1.82	85.00	4.50				0.13	84.00
18													1.23	1.82	85.00	4.50				0.13	84.00
19													1.23	1.82	85.00	4.50				0.13	84.00
20													1.23	1.82	85.00	4.50				0.13	84.00
21													1.23	1.82	85.00	4.50				0.13	84.00
22																					
23																					
24																					

Table 7: Pipeline Onshore Cyprus to mainland Greece (option 2), CAPEX & OPEX

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	7 - Onshore to MG via Pipeline_v2	BOE/ bbl Oil	1.00	Capital cost	1 671.59	Lifecycle cost	2 250.65
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	5.92	Cost/ BOE	7.97
		BOE/ Mscf Gas	0.17				
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 671.59	Operating cost	579.06	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	5.92	Cost/ BOE	2.05	Cost/ BOE	0.00
								Design production	
								0.13	84.00
								1682.6	282.487

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
																	0	2.6	1680
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.79**	**1 659.80**	**0.00**	**542.66**	**36.40**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**2.60**	**1 680.00**
1							11.79	171.54											
2								689.89		26.77	1.82							0.13	84.00
3								233.67		26.77	1.82							0.13	84.00
4								233.67		26.77	1.82							0.13	84.00
5								233.67		26.77	1.82							0.13	84.00
6								97.36		29.19	1.82							0.13	84.00
7										26.77	1.82							0.13	84.00
8										26.77	1.82							0.13	84.00
9										26.77	1.82							0.13	84.00
10										26.77	1.82							0.13	84.00
11										29.19	1.82							0.13	84.00
12										26.77	1.82							0.13	84.00
13										26.77	1.82							0.13	84.00
14										26.77	1.82							0.13	84.00
15										26.77	1.82							0.13	84.00
16										29.19	1.82							0.13	84.00
17										26.77	1.82							0.13	84.00
18										26.77	1.82							0.13	84.00
19										26.77	1.82							0.13	84.00
20										26.77	1.82							0.13	84.00
21										26.77	1.82							0.13	84.00
22																			
23																			
24																			

Table 8: FLNG Offshore field to mainland Greece (option 3), CAPEX & OPEX

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	8 - Offshore CY to GRE via FLNG_v2	BOE/ bbl Oil	1.00	Capital cost	2 060.08	Lifecycle cost	4 833.00
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	7.38	Cost/ BOE	17.32
		BOE/ Mscf Gas	0.17				
E & A cost	0.00	Drilling cost	0.00	Facilities cost	2 060.08	Operating cost	2 772.92	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	7.38	Cost/ BOE	9.94	Cost/ BOE	0.00
								Design production	
								0.08	84.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**35.89**	**12.25**	**0.00**	**1 800.00**	**211.94**	**840.82**	**52.60**	**1 785.00**	**94.50**	**0.00**	**0.00**	**908.40**	**0.00**	**1.61**	**1 664.60**
1								1.84	3.06		540.00	63.58										
2								21.25	5.01		900.00	105.97										
3								12.80	4.18		360.00	42.39	27.88	1.75	85.00	4.50			30.28		0.06	55.49
4													41.83	2.63	85.00	4.50			45.42		0.08	83.23
5													41.83	2.63	85.00	4.50			45.42		0.08	83.23
6													41.83	2.63	85.00	4.50			45.42		0.08	83.23
7													41.96	2.63	85.00	4.50			45.42		0.08	83.23
8													42.71	2.63	85.00	4.50			45.42		0.08	83.23
9													42.23	2.63	85.00	4.50			45.42		0.08	83.23
10													41.83	2.63	85.00	4.50			45.42		0.08	83.23
11													41.83	2.63	85.00	4.50			45.42		0.08	83.23
12													41.96	2.63	85.00	4.50			45.42		0.08	83.23
13													42.71	2.63	85.00	4.50			45.42		0.08	83.23
14													42.23	2.63	85.00	4.50			45.42		0.08	83.23
15													41.83	2.63	85.00	4.50			45.42		0.08	83.23
16													41.83	2.63	85.00	4.50			45.42		0.08	83.23
17													41.96	2.63	85.00	4.50			45.42		0.08	83.23
18													42.71	2.63	85.00	4.50			45.42		0.08	83.23
19													42.23	2.63	85.00	4.50			45.42		0.08	83.23
20													41.83	2.63	85.00	4.50			45.42		0.08	83.23
21													41.83	2.63	85.00	4.50			45.42		0.08	83.23
22													41.83	2.63	85.00	4.50			45.42		0.08	83.23
23													13.94	0.88	85.00	4.50			15.14		0.03	27.74
24																						
25																						

Table 9: Pipeline Offshore field to mainland Greece (option 4), CAPEX & OPEX

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

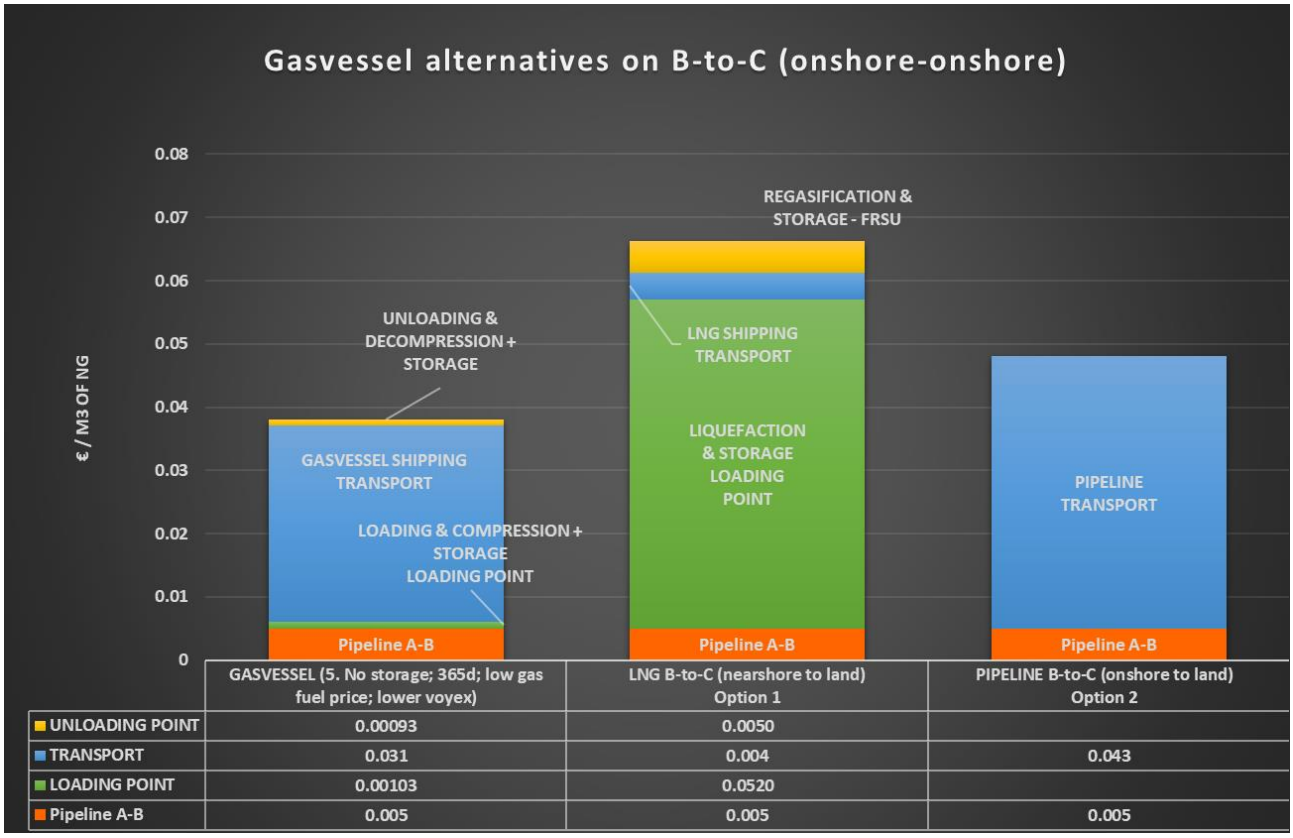
Project name	7 - Offshore CY to GRE via Pipeline_v2	BOE/ bbl Oil	1.00	Capital cost	1 626.51	Lifecycle cost	3 269.52
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	5.90	Cost/ BOE	11.85
		BOE/ Mscf Gas	0.17				
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 626.51	Operating cost	1 432.74	Decommission cost	210.27
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	5.90	Cost/ BOE	5.19	Cost/ BOE	0.76
								Design production	
								0.08	84.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS					DECOMM.	CO2 emitted	PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	Floaters	Other facilities	Fixed OPEX	Variable OPEX	Tariffs	Leases	CO2 tax		000s te/ yr	Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1 612.15**	**14.36**	**0.00**	**0.00**	**0.00**	**1 360.53**	**72.21**	**0.00**	**0.00**	**0.00**	**210.27**	**2 027.20**	**0.00**	**1.61**	**1 645.40**
1								172.55														
2								690.51														
3								230.49														
4								230.49	3.59													
5								230.49	3.43													
6								57.62	7.34				39.34	2.11					59.13		0.05	47.99
7													67.44	3.61					101.36		0.08	82.27
8													67.44	3.61					101.36		0.08	82.27
9													67.44	3.61					101.36		0.08	82.27
10													68.89	3.61					101.36		0.08	82.27
11													69.31	3.61					101.36		0.08	82.27
12													68.03	3.61					101.36		0.08	82.27
13													67.44	3.61					101.36		0.08	82.27
14													67.44	3.61					101.36		0.08	82.27
15													68.89	3.61					101.36		0.08	82.27
16													69.31	3.61					101.36		0.08	82.27
17													68.03	3.61					101.36		0.08	82.27
18													67.44	3.61					101.36		0.08	82.27
19													67.44	3.61					101.36		0.08	82.27
20													68.89	3.61					101.36		0.08	82.27
21													69.31	3.61					101.36		0.08	82.27
22													68.03	3.61					101.36		0.08	82.27
23													67.44	3.61					101.36		0.08	82.27
24													67.44	3.61					101.36		0.08	82.27
25													67.44	3.61					101.36		0.08	82.27
26													28.10	1.51					42.23		0.04	34.28
27																		81.77				
28																		128.50				

4.4.3 GASVESSEL vs Alternative options: results

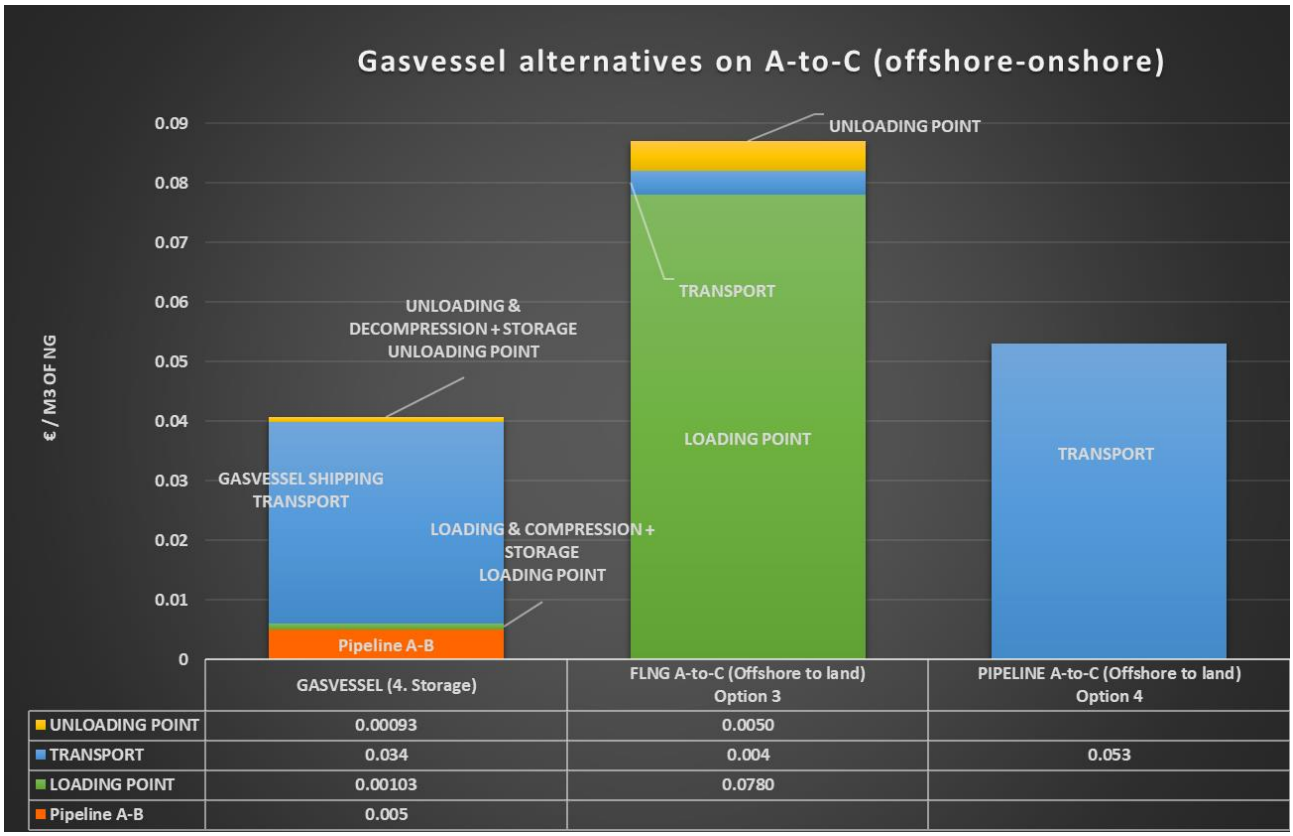
Figure 39 and Figure 40 show the comparison of GASVESSEL with pipeline and LNG, first with loading point for pipeline/LNG onshore (point B), then offshore (at point A). The GASVESSEL option remains the same in both comparisons, i.e., transport system combining pipeline A to B, then GASVESSEL shipping B to C.

The GASVESSEL system comes at 15-23% lower costs than Pipeline onshore and offshore options respectively (option 2 and 4), and 38-53% lower costs than LNG and FLNG respectively (option 1 and 3).



	GASVESSEL (5. No storage; 365d; low gas fuel price; lower voyex)	LNG B-to-C (nearshore to land) Option 1	PIPELINE B-to-C (onshore to land) Option 2
UNLOADING POINT	0.00093	0.0050	
TRANSPORT	0.031	0.004	0.043
LOADING POINT	0.00103	0.0520	
Pipeline A-B	0.005	0.005	0.005

Figure 39: Gasvessel vs. LNG and pipeline options, unit cost comparison on leg B-C onshore-onshore



	GASVESSEL (4. Storage)	FLNG A-to-C (Offshore to land) Option 3	PIPELINE A-to-C (Offshore to land) Option 4
UNLOADING POINT	0.00093	0.0050	
TRANSPORT	0.034	0.004	0.053
LOADING POINT	0.00103	0.0780	
Pipeline A-B	0.005		

Figure 40: Gasvessel vs. LNG and pipeline options, unit cost comparison on leg A-C offshore-onshore

5 Conclusions

The comparative analysis carried out in T7.2 reveals the potential of GASVESSEL compared to alternative gas transportation options pipeline and LNG. This cost competitiveness is studied for various conditions, and varies depending on the GASVESSEL ship in focus (Ship B 12 M Nm^3 total capacity, or Ship A 15 M Nm^3), the strategy followed (storage vs. continuous delivery), the localisation of the compressor (onboard the ship or at loading/unloading point), the localisation of the loading point (offshore or onshore), the ship speed and operating years, fuel cost etc. In this T7.2 comparison is based on cost, not NPV; this to avoid additional complexity and maintain transparency. The focus is therefore on comparison, and not excluding the non-viable options for GASVESSEL. In T7.3, a full economic profitability is carried out for the GASVESSEL scenario (Cyprus-Greece) presented in Chapter 4.4 (5 vessels, 1230 km, 2.5 bcm/year).

Based on the comparative analysis carried out GASVESSEL is cost competitive in the distance – volume range indicated in grey in the following figure.

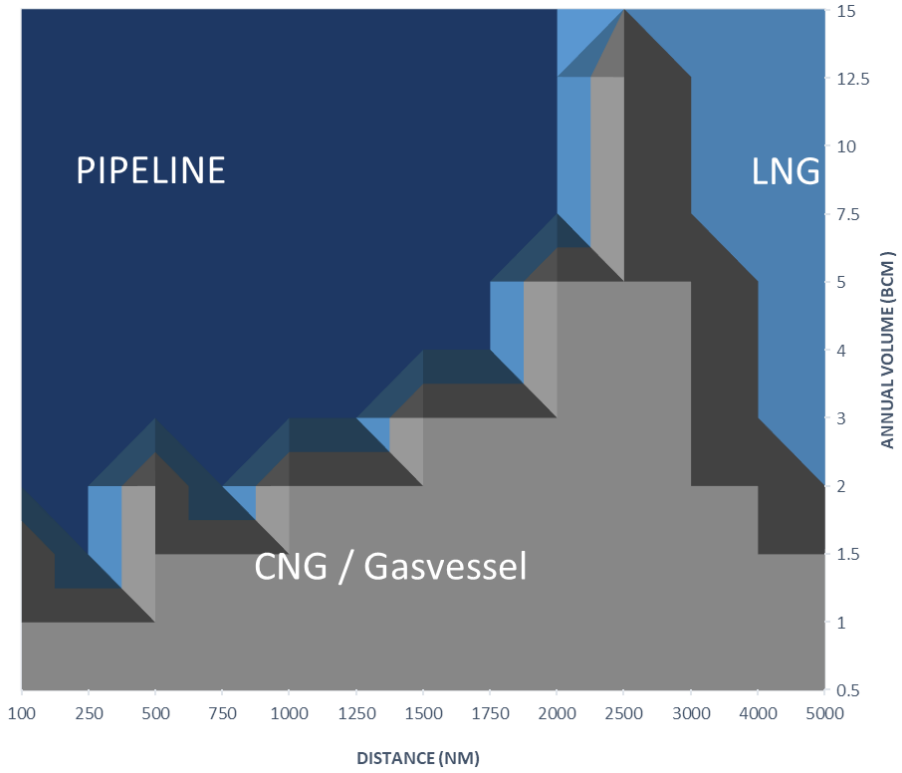


Figure 34 Contour plot unit cost for GASVESSEL (Ship A 15M Nm3), pipeline and LNG.

For a specific scenario, as analysed in Section 4.4 the GASVESSEL system comes at 15-23% lower costs than Pipeline and 38-53% lower costs than LNG .

6 Appendices

6.1 GASVESSEL scenarios: full dataset

Category	REFERENCE SCENARIOS INPUT PARAMETERS FOR COST CALCULATION
Source :	WP2: midstream tariff matrix calculation; WP2/7: NP midstream cost calculation; Esteco VOLTA scenario summary matrix
Last update	01.11.2021

Calculation parameters	UNIT	Gasvessel Scenarios >>	EAST MEDITERRANEAN ONSHORE LOADING				EAST MEDITERRANEAN - OFFSHORE LOADING				BARENTS SEA						BLACK SEA
			CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	CYPRUS-CRETE	CYPRUS-LEBANON	CYPRUS-EGYPT	CYPRUS-GREECE	ALKE 1 Nyhamna	ALKE 2 Polarled	ALKE 3 to UK	J.CASTBERG 1 Nyhamna	J.CASTBERG 2 Polarled	UKRAINE 1	
		GASVESSEL SHI	9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4	
		Daily demand r	0.5	1.4	6.2	2.5	0.5	1.4	6.2	2.5	0.4	0.4	0.4	0.5	0.5	2.3	
		Yearly volume	1.4	3.7	17	6.8	1.4	3.7	17	6.85	1.18	1.18	1.18	1.29	1.29	6.3	
		distance nm	400	120	285	665	287	264	146	682	646	377	1352	686	422	539	
		distance km	740	222	527	1230	531	488	270	1262	1195	697	2501	1269	781	997	
SCENARIO																	
Total yearly gas demand	M m3		511.00	1350.50	6205.00	2500.00	511.00	1350.50	6205.00	2500.25	430.70	430.70	430.70	470.85	470.85	2299.50	
Total yearly (possible) delivered gas	M m3		511.00	1350.50	6205.00	2500.00	511.00	1350.50	6205.00	2500.25	430.70	430.70	430.70	470.85	470.85	2299.50	
Sailing distance	nm		400	120	285	665	287	264	146	682	646	377	1352	686	422	539	
Load on/off			on	on	on	on	off	off	off	off	off	off	off	off	off	on	
Unload on/off			on	on	on	on	on	on	on	on	on	off	on	on	off	on	
SHIP PARAMETERS																	
Ship total capacity (volume)	Mm3		10	10	15	15	10	10	15	15	10	10	10	10	10	15	
Ship delivery capacity per ship (net)	Mm3		9.3	9.3	12.4	12.4	9.3	9.3	12.4	12.4	9.3	9.3	9.3	9.3	9.3	12.4	
Ship speed	knots		16	16	16	16	16	16	16	16	16	16	16	16	16	16	
Ship aquisition cost - 1 ship	MEur		186	186	204	204	186	186	204	204	186	186	186	186	186	204	
Ship working days per year	days		350	350	350	350	350	350	350	350	350	350	350	350	350	350	
Years of operation	years		20	20	20	20	20	20	20	20	20	20	20	20	20	20	
CAPEX																	
Ship CAPEX per m3, whole fleet (ALT 1 with storage)	MEur /m3		**0.018**	**0.014**	**0.015**	**0.020**	**0.018**	**0.021**	**0.013**	**0.030**	**0.022**	**0.022**	**0.043**	**0.040**	**0.020**	**0.022**	
Ship CAPEX per m3, whole fleet (ALT 2 Continuous)	MEur /m3		**0.036**	**0.021**	**0.016**	**0.024**	**0.036**	**0.021**	**0.015**	**0.024**	**0.043**	**0.043**	**0.065**	**0.040**	**0.040**	**0.022**	
OPEX																	
Ship OPEX per day - 1 ship	Eur /day		8498	8498	8498	8498	8498	8498	8498	8498	8498	8498	8498	8498	8498	8498	
Ship OPEX per year - 1 ship	MEur per /year		3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	
Ship OPEX per m3, whole fleet (ALT 1 with storage)	MEur /m3		**0.0061**	**0.0046**	**0.0045**	**0.0062**	**0.006**	**0.007**	**0.004**	**0.006**	**0.007**	0.007	0.014	**0.013**	**0.007**	**0.007**	
Ship OPEX per m3, whole fleet (ALT 2 Continuous)	MEur /m3		**0.0121**	**0.0069**	**0.0050**	**0.0074**	**0.012**	**0.007**	**0.004**	**0.007**	**0.014**	**0.014**	**0.022**	**0.013**	**0.013**	**0.007**	
VOYAGE																	
Arrival operation time / mooring (both ends)	hours		5	5	5	5	5	5	5	5	5	5	5	5	5	5	
Departure operation time / unmooring (both ends)	hours		5	5	5	5	5	5	5	5	5	5	5	5	5	5	
Gas loading time	hours		32	32	43	43	32	32	43	43	32	32	32	32	32	43	
Gas unloading time	hours		46	46	61	61	46	46	61	61	46	46	46	46	46	61	
Sailing time / roundtrip	hours		50	15	36	83	36	33	18	85	81	47	169	86	53	67	
Voyage/roundtrip duration (sailing, un-mooring, un-loading)	hours		138	103	150	198	124	121	133	200	169	135	257	174	141	182	
Voyage/roundtrip duration (sailing, un-mooring, un-loading)	days		5.77	4.31	6.26	8.23	5.18	5.06	5.53	8.32	7.05	5.63	10.72	7.26	5.88	7.58	
Round-trip fully load incl. storage																	
#deliveries per year to meet demand	#		54.95	145.22	500.40	201.61	54.95	145.22	500.40	201.63	46.31	46.31	46.31	50.63	50.63	185.44	
#roundtrips - sailed per year per ship (max capacity given ship working time)	#		60.71	81.26	55.95	42.51	67.61	69.21	63.28	42.05	49.67	61.99	32.64	48.24	59.52	46.19	
Number of ships needed to meet demand	#		0.91	1.79	8.94	4.74	0.81	2.10	7.91	4.79	0.93	0.75	1.42	1.05	0.85	4.02	
Nr (fully loaded) ship decided	#		1	2	9	5	1	3	8	5	1	1	2	2	1	5	
Max number of roundtrips all ships	#		60.71	162.52	503.58	212.54	67.61	207.62	506.22	210.26	49.67	61.99	65.27	96.48	59.52	230.93	
#roundtrip per year - all ships / delivery	#		54.95	145.22	500.40	201.61	54.95	145.22	500.40	201.63	46.31	46.31	46.31	50.63	50.63	185.44	
Continuous Alternative																	
Condition for round trip duration			waiting	waiting	tiple undloading	tiple undloading	waiting	waiting	tiple undloading	tiple undloading	waiting	waiting	waiting	waiting	waiting	tiple undloading	
Roundtrip time adjusted	(roundtrip time		10.58	4.93	6.26	8.23	9.97	5.71	5.53	8.32	13.15	11.69	16.99	12.70	11.27	7.58	
Max #roundtrip per ship - adjusted to roundtrip time			33.08	70.99	55.95	42.51	35.12	61.27	63.28	42.05	26.61	29.93	20.60	27.56	31.07	46.19	
#deliveries Continuous (if necessary unloading "to create a continuous delivery chain")	total yearly hou		54.95	145.22	146.41	151.57	54.95	145.22	144.61	151.81	46.31	46.31	46.31	50.63	50.63	149.82	
# ships per fleet Continuous			1.66	2.05	2.62	3.57	1.56	2.37	2.29	3.61	1.74	1.55	2.25	1.84	1.63	3.24	
#simultaneous unloading			0.29	0.76	3.50	1.41	0.29	0.76	3.50	1.41	0.24	0.24	0.24	0.27	0.27	1.30	
# ships total			**2.00**	**3.00**	**10.00**	**6.00**	**2.00**	**3.00**	**9.00**	**6.00**	**2.00**	**2.00**	**3.00**	**2.00**	**2.00**	**5.00**	
load factor overall			*0.80*	*0.53*	*0.88*	*0.73*	*0.72*	*0.73*	*0.86*	*0.75*	*0.85*	*0.71*	*0.67*	*0.91*	*0.77*	*0.75*	
VOYEX																	
Vessel power need - sailing mode (3 Engines @4070 kW, 85% load) = average load	kW		10379	10379	10379	10379	10379	10379	10379	10379	10379	10379	10379	10379	10379	10379	
Total kWh per voyage (adjusted to extended time at port - continuous delivery strategy)	kWh		548 231	184 984	406 509	899 306	401 635	371 797	226 176	921 536	867 370	518 393	1 783 273	919 263	576 772	736 020	
Fuel (Diesel) consumption propulsion per voyage (roundtrip) - Diesel consumption (85% load, gas mode)	tons		1.26	0.43	0.93	2.07	0.92	0.86	0.52	2.12	1.99	1.19	5.88	2.11	1.33	1.69	
Fuel (Gas)consumption propulsion per voyage (roundtrip) - Gas consumption (85% load, gas mode)	tons		79	27	58	129	58	53	32	132	125	74	256	132	83	106	
Gas consumption compressors/ (un)loading per voyage	ton of gas		75	75	99	99	75	75	99	99	75	75	75	75	75	99	
Total gas consumption per voyage	tons		153	101	158	229	132	128	132	232	199	149	331	207	157	205	
MGO price	Eur/ton		600	600	600	600	600	600	600	600	600	600	600	600	600	600	
Gas price for GASVESSEL fuel	Eur/ton		300	300	300	300	300	300	300	300	300	300	300	300	300	300	
Total fuel cost per voyage	Eur		46 754	30 594	47 904	69 828	40 232	38 905	39 882	70 816	60 952	45 427	102 768	63 260	48 024	62 563	
VOYEZ Alt 1 (option w/ storage)																	
Annual fuel cost (all voyages)	M Eur		2.57	4.44	23.97	14.08	2.21	5.65	19.96	14.28	2.82	2.10	4.76	3.20	2.43	11.60	
Port cost per annum	Meur		1.10	2.90	10.01	4.03	0.55	1.45	5.00	2.02	0.46		0.46	0.51		3.71	
VOYEX total / year (no Continuous)	M Euur		3.67	7.35	33.98	18.11	2.76	7.10	24.96	16.30	3.29	2.10	5.22	3.71	2.43	15.31	
VOYEX Euro per m3 (no Continuous)	Eur/m3		**0.0072**	**0.0054**	**0.0055**	**0.0072**	**0.0054**	**0.0053**	**0.0040**	**0.0065**	**0.0076**	**0.0049**	**0.0121**	**0.0079**	**0.0052**	**0.0067**	
VOYEX Alt 2 Continuous																	
fuel cost (backk.to.back) per year	MEur		3.09	6.52	26.80	17.81	2.83	7.15	22.71	17.87	3.24	2.72	6.35	3.49	2.98	14.45	
Port fees (per port call)	M€ per port cal		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
port cost (back.toback per year	MEur		1.32	4.26	11.19	5.10	0.70	1.94	5.69	2.52	0.53		0.62	0.55		4.62	
Voyage cost per m3 (Continuous)	Eur/m3		**0.0086**	**0.0080**	**0.0061**	**0.0092**	**0.0069**	**0.0067**	**0.0046**	**0.0082**	**0.0088**	**0.0063**	**0.0162**	**0.0086**	**0.0063**	**0.0083**	
STORAGE																	
Sorage autonomy needed (volume) - theoretical	Mm3		6.616	2.206	-31.061	-5.111	6.616	2.206	-31.061	-5.112	7.037	7.037	7.037	6.827	6.827	-3.706	
Cylinder Storage unit capacity	Mm3		0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	
Cylinder Storage unit cost (1 unit=12400 m3)	MEur per cylin		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
Cylinder Infrastructure for storage	MEur per cylin		0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	
STORAGE OPTIONS																	
STORAGE alt 1 Cylinder: CAPEX	M€ total		128.0	42.7	0.0	0.0	128.0	42.7	0.0	0.0	136.2	136.2	136.2	132.1	132.1	0.0	
STORAGE alt 2: Floating - CAPEX	M€ total		170	170	188	188	170	170	188	188	170	170	170	170	170	188	
Storage Cylinder OPEX	M€ total		12.8	4.3	0.0	0.0	12.8	4.3	0.0	0.0	13.6	13.6	13.6	13.2	13.2	0.0	
Storage Floating OPEX	M€ total		17.0	17.0	18.8	18.8	17.0	17.0	18.8	18.8	17.0	17.0	17.0	17.0	17.0	18.8	
Storage Cylinder CAPEX+OPEX (20yrs)	M€ total		140.8	47.0	0.0	0.0	140.8	47.0	0.0	0.0	149.8	149.8	149.8	145.3	145.3	0.0	
Storage Floating CAPEX+OPEX (20yrs)	M€ total		187.0	187.0	206.8	206.8	187.0	187.0	206.8	206.8	187.0	187.0	187.0	187.0	187.0	206.8	
Storage at Loading point CAPEX+OPEX per delivered m3	Eur/m3		0.0138	0.0017	0.0000	0.0000	0.0183	0.0069	0.0017	0.0041	0.0217	0.0217	0.0217	0.0199	0.0199	0.0000	
Storage at Unloading point CAPEX+OPEX per delivered m3	Eur/m3		**0.014**	**0.002**	**0.000**	**0.000**	**0.014**	**0.002**	**0.000**	**0.000**	**0.017**	**0.022**	**0.017**	**0.015**	**0.020**	**0.000**	
LOADING/UNLOADING FACILITIES (excl. STORAGE)																	
Loading concept			Onshore	Onshore	Onshore		Onshore/Storag	Onshore/Storag	Onshore/Direct		Offshore	Offshore	Offshore	Offshore	Offshore	Onshore	
Unloading concept			Onshore	Onshore	Onshore		e	e			Onshore	Offshore	Onshore	Onshore	Offshore	Onshore	
LOADING																	
WP6 Loading infrastructure CAPEX			25	21	62	34	19	25	61	34	16	16	16	16	16	34	
ALT2 equiped Jetty (based on 2-ship jetty cost) (same for back to back or with storage)	Meur		34.7	34.7	69.4	34.7	34.7	34.7	69.4	34.7	34.7	34.7	34.7	34.7	34.7	34.7	
CAPEX+OPEX halfcompressor cost at loadig point (Option 1 - storage)	Meur		11.0	19.0	75.0	43.0	11.0	27.0	67.0	43.0	11.0	11.0	19.0	19.0	11.0	43.0	
CAPEX+OPEX halfcompressor cost at loadig point (Option 2 - continuous delivery)			19.0	27.0	83.0	51.0	19.0	27.0	75.0	51.0	19.0	19.0	27.0	19.0	19.0	43.0	
(1) Loading CAPEX + OPEX (incl cost of compressor - ONBOARD ships, with Storage)	Meur		37.1	42.4	143.2	80.3	32.1	54.9	134.4	80.3	29.0	28.6	36.6	37.0	28.6	76.6	
(2) Loading CAPEX + OPEX (incl cost of compressor - ONBOARD ships, continuous delivery)	Meur		45.1	50.4	151.2	88.3	40.1	54.9	142.4	88.3	37.0	36.6	44.6	37.0	36.6	76.6	
(3) Loading CAPEX + OPEX (incl cost of compressor - onshore (only 1 compressor at loading point - either for "storage" or continuous delivery" options)	Meur		31.4	32.5	99.2	51.6	26.4	37.0	98.5	51.6	23.0	22.5	22.5	23.2	22.7	46.9	
UNLOADING																	
ALT1: Unloading system cost (ref VTG+NP)	Meur		88.00	88.00	163.00	131.00	99.00	115.00	155.00	131.00	70.00	70.00	68.00	78.00	60.00	106.00	
WP6 unLoading infrastructure CAPEX			22.00	23.03	47.03	29.21	18.86	23.23	48.50	29.22	12.90	13.00	13.00	12.90	13.00	31.07	
ALT2 equiped Jetty (based on 2-ship jetty cost) (same for back to back or with storage)	Meur		35	35	69	35	35	35	69	35	35	35	35	35	35	35	
CAPEX+OPEX halfcompressor cost at UNloadig point (Option 1 - storage)	Meur		11.0	19.0	75.0	43.0	11.0	27.0	67.0	43.0	11.0	11.0	19.0	19.0	11.0	43.0	
CAPEX+OPEX halfcompressor cost at UNloadig point (Option 2 - continuous delivery)			19.0	27.0	83.0	51.0	19.0	27.0	75.0	51.0	19.0	19.0	27.0	19.0	19.0	43.0	
(1) UNLoading CAPEX + OPEX (incl cost of compressor - ONBOARD ships, with Storage)	Meur		35.20	44.30	126.70	75.14	31.75	52.55	120.35	75.14	25.19	25.30	33.30	33.19	25.30	77.76	
(2) UNLoading CAPEX + OPEX (incl cost of compressor - ONBOARD ships, continuous delivery)	Meur		43	52	135	83	40	53	128	83	33	33	41	33	33	78	
(3) UNLoading CAPEX + OPEX (incl cost of compressor - onshore (only 1 compressor at loading point - either for "storage" or continuous delivery" options)	Meur		29.5	34.4	82.7	46.4	26.1	34.7	84.4	46.4	19.1	19.2	19.2	19.3	19.4	48.2	
LOADING uni cost /m3 (w/storage, option1; incl. infrastructure+GASVESSELcompressor)	Eur / m3		0.004	0.002	0.001	0.00161	0.003	0.002	0.001	0.002	0.003	0.003	0.004	0.004	0.003	0.002	
LOADING uni cost /m3 (w/continuous, option2; incl. infrastructure+GASVESSELcompressor)	Eur / m3		0.004	0.002	0.001	0.00177	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002	
LOADING uni cost /m3 (w/storageORcontinuous; incl. infrastructure+GASVESSELcompressor - Only 1 Compressor onshore)	Eur / m3		0.003	0.001	0.001	**0.00103**	0.003	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.002	0.001	
UNLOADING uni cost /m3 (w/storage, option1; incl. infrastructure+GASVESSELcompressor)	Eur / m3		0.003	0.002	0.001	0.00150	0.003	0.002	0.001	0.002	0.003	0.003	0.004	0.004	0.003	0.002	
UNLOADING uni cost /m3 (w/continuous, option2; incl. infrastructure+GASVESSELcompressor)	Eur / m3		0.004	0.002	0.001	0.00166	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002	
UNLOADING uni cost /m3 (w/storageORcontinuous; incl. infrastructure+GASVESSELcompressor - Only 1 Compressor onshore)	Eur / m3		0.003	0.001	0.001	**0.00093**	0.003	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.001	
RESULTS KPIS (all divided by demand, not actuall deliv vol)	Eur / m3																
OPTION 1: STORAGE																	
STORAGE AT LOADING POINT			0.014	0.002	0.000	0.0000	0.018	0.007	0.002	0.0041	0.022	0.022	0.022	0.020	0.020	0.000	
LOADING (option with storage, compressor onboard)	Eur /m3		0.004	0.002	0.001	0.0016	0.003	0.002	0.001	0.002	0.003	0.003	0.004	0.004	0.003	0.002	
LOADING (option with continuous delivery, compressor onboard)	Eur /m3		0.004	0.002	0.001	0.0018	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002	
LOADING (storage or continuous, 1 compressor at loading point)	Eur /m3		0.003	0.001	0.001	**0.00103**	0.003	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.002	0.001	
SAILING GASVESSEL CAPEX	Eur /m3		0.018	0.014	0.015	0.0204	0.018	0.021	0.013	**0.02040**	0.022	0.022	0.043	0.040	0.020	0.022	
SAILING GASVESSEL OPEX	Eur /m3		0.006	0.005	0.004	0.0062	0.006	0.007	0.004	**0.00620**	0.007	0.007	0.014	0.013	0.007	0.007	
SAILING GASVESSEL VOYEX	Eur /m3		0.007	0.005	0.005	0.0072	0.005	0.005	0.004	**0.00652**	0.008	0.005	0.012	0.008	0.005	0.007	
UNLOADING (option with storage, compressor onboard)	Eur /m3		0.003	0.002	0.001	0.0015	0.003	0.002	0.001	0.00150	0.003	0.003	0.004	0.004	0.003	0.002	
UNLOADING (option with continuous delivery, compressor onboard)	Eur /m3		0.004	0.002	0.001	0.0017	0.004	0.002	0.001	0.00166	0.004	0.004	0.005	0.004	0.004	0.002	
UNLOADING (storage or continuous, 1 compressor at loading point)	Eur /m3		0.003	0.001	0.001	**0.00093**	0.003	0.001	0.001	**0.00093**	0.002	0.002	0.002	0.002	0.002	0.001	
STORAGE AT UNLOADING POIT	Eur /m3		0.014	0.002	0.000	0.0000	0.014	0.002	0.000	0.0000000	0.017	0.022	0.017	0.015	0.020	0.000	
Total cost per m3 (with storage)	Eur /m3		**0.066**	**0.030**	**0.027**	**0.0370**	**0.068**	**0.045**	**0.025**	**0.040**	**0.082**	**0.083**	**0.117**	**0.103**	**0.077**	**0.039**	
Total cost per m3 (continuous delivery)	Eur /m3		**0.068**	**0.031**	**0.027**	**0.0373**	**0.070**	**0.046**	**0.025**	**0.041**	**0.084**	**0.085**	**0.119**	**0.103**	**0.079**	**0.039**	
OPTION 2: Continuous	Eur /m3																
STORAGE AT LOADING POINT	Eur /m3		0.000	1.000	2.000	3.0000	4.000	5.000	6.000	7.000	8.000	9.000	10.000	11.000	12.000	13.000	
LOADING (option with storage, compressor onboard)	Eur /m3		0.004	0.002	0.001	0.0016	0.003	0.002	0.001	0.002	0.003	0.003	0.004	0.004	0.003	0.002	
LOADING (option with continuous delivery, compressor onboard)	Eur /m3		0.004	0.002	0.001	0.0018	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002	
LOADING (storage or continuous, 1 compressor at loading point)	Eur /m3		0.003	0.001	0.001	**0.0010**	0.003	0.001	0.001	0.00103	0.003	0.003	0.003	0.002	0.002	0.001	
SAILING GASVESSEL CAPEX	Eur /m3		0.036	0.021	0.016	**0.0245**	0.036	0.021	0.015	**0.024**	0.043	0.043	0.065	0.040	0.040	0.022	
SAILING GASVESSEL OPEX	Eur /m3		0.012	0.007	0.005	**0.0074**	0.012	0.007	0.004	**0.007**	0.014	0.014	0.022	0.013	0.013	0.007	
SAILING GASVESSEL VOYEX	Eur /m3		0.009	0.008	0.006	**0.0092**	0.009	0.007	0.005	**0.008**	0.009	0.006	0.016	0.009	0.009	0.008	
UNLOADING (option with storage, compressor onboard)	Eur /m3		0.003	0.002	0.001	0.0015	0.003	0.002	0.001	0.002	0.003	0.003	0.004	0.004	0.003	0.002	
UNLOADING (option with continuous delivery, compressor onboard)	Eur /m3		0.004	0.002	0.001	0.0017	0.004	0.002	0.001	0.002	0.004	0.004	0.005	0.004	0.004	0.002	
UNLOADING (storage or continuous, 1 compressor at loading point)	Eur /m3		0.003	0.001	0.001	**0.0009**	0.003	0.001	0.001	0.00093	0.002	0.002	0.002	0.002	0.002	0.001	
STORAGE	Eur /m3		0.000	1.000	2.000	3.0000	4.000	5.000	6.000	7.000	8.000	900 %	10.000	11.000	12.000	13.000	
Total cost per m3 (with storage, compressors onboard)	Eur /m3		**0.066**	**0.030**	**0.027**	**0.037**	**0.068**	**0.045**	**0.025**	**0.040**	**0.082**	**0.083**	**0.117**	**0.103**	**0.077**	**0.039**	
Total cost per m3 (continuous delivery, compressors onboard)	Eur /m3		**0.066**	**0.039**	**0.030**	**0.045**	**0.063**	**0.038**	**0.026**	**0.044**	**0.075**	**0.072**	**0.113**	**0.069**	**0.066**	**0.041**	
Total cost per m3 (with storage, 1 compressor at (un)loading points)	Eur /m3		0.065	0.030	0.026	0.036	0.067	0.044	0.024	0.039	0.080	0.082	0.114	0.100	0.076	0.038	
Total cost per m3 (continuous delivery, 1 compressor at (un)loading points)	Eur /m3		0.063	0.038	0.029	0.043	0.061	0.037	0.025	0.042	0.071	0.069	0.107		0.066	0.063	0.039

6.2 Pipeline Costs (CHC)

6.2.1 Loading at offshore field

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	5 - Offshore CY to CRE via Pipeline
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	509.50
Cost/ BOE	0.73

Lifecycle cost	1 599.87
Cost/ BOE	2.28

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	509.50
Cost/ BOE	0.73

Operating cost	1 090.37
Cost/ BOE	1.55

Decommission cost	0.00
Cost/ BOE	0.00

Design production		
	0.21	210.00
4193.8	702.33332	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS						CO2 emitted	PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	Floaters	Other facilities	Fixed OPEX	Variable OPEX					000s te/ yr	Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	501.17	8.33	0.00	0.00	0.00	989.17	101.20	0.00	0.00	0.00	0.00	0.00	0.00	4.20	4 189.60
1								42.68														
2								223.97														
3								127.92	2.08													
4								106.60	6.25													
5													49.16	5.06						0.21	209.48	
6													49.16	5.06						0.21	209.48	
7													49.16	5.06						0.21	209.48	
8													49.16	5.06						0.21	209.48	
9													50.32	5.06						0.21	209.48	
10													49.99	5.06						0.21	209.48	
11													49.16	5.06						0.21	209.48	
12													49.16	5.06						0.21	209.48	
13													49.16	5.06						0.21	209.48	
14													50.32	5.06						0.21	209.48	
15													49.99	5.06						0.21	209.48	
16													49.16	5.06						0.21	209.48	
17													49.16	5.06						0.21	209.48	
18													49.16	5.06						0.21	209.48	
19													50.32	5.06						0.21	209.48	
20													49.99	5.06						0.21	209.48	
21													49.16	5.06						0.21	209.48	
22													49.16	5.06						0.21	209.48	
23													49.16	5.06						0.21	209.48	
24													49.16	5.06						0.21	209.48	
25																						
26																						
27																						

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	3 - Offshore CY to LEB via Pipeline
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	309.53
Cost/ BOE	0.44

Lifecycle cost	1 400.14
Cost/ BOE	2.00

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	309.53
Cost/ BOE	0.44

Operating cost	1 090.61
Cost/ BOE	1.56

Decommission cost	0.00
Cost/ BOE	0.00

Design production		
	0.21	210.00
4183.4	700.59964	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	Floaters	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	297.78	11.75	0.00	0.00	0.00	978.61	112.00	0.00	0.00	0.00	0.00	1 218.00	0.00	4.20	4 179.20
1								43.31														
2								183.30	2.94													
3								71.17	8.81													
4													40.49	4.67					50.75		0.18	174.13
5													48.59	5.60					60.90		0.21	208.96
6													48.59	5.60					60.90		0.21	208.96
7													48.59	5.60					60.90		0.21	208.96
8													49.50	5.60					60.90		0.21	208.96
9													49.75	5.60					60.90		0.21	208.96
10													48.79	5.60					60.90		0.21	208.96
11													48.59	5.60					60.90		0.21	208.96
12													48.59	5.60					60.90		0.21	208.96
13													49.50	5.60					60.90		0.21	208.96
14													49.75	5.60					60.90		0.21	208.96
15													48.79	5.60					60.90		0.21	208.96
16													48.59	5.60					60.90		0.21	208.96
17													48.59	5.60					60.90		0.21	208.96
18													49.50	5.60					60.90		0.21	208.96
19													49.75	5.60					60.90		0.21	208.96
20													48.79	5.60					60.90		0.21	208.96
21													48.59	5.60					60.90		0.21	208.96
22													48.59	5.60					60.90		0.21	208.96
23													48.59	5.60					60.90		0.21	208.96
24													8.10	0.93					10.15		0.03	34.83
25																						
26																						

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	1 - Offshore CY to EGY via Pipeline
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	441.03
Cost/ BOE	0.64

Lifecycle cost	1 743.34
Cost/ BOE	2.52

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	441.03
Cost/ BOE	0.64

Operating cost	1 302.31
Cost/ BOE	1.89

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.21	210.00
4123.41	690.60699

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	Floaters	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**411.46**	**29.57**	**0.00**	**0.00**	**0.00**	**1 129.11**	**173.20**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**4.21**	**4 119.20**
1								47.20	7.39													
2								295.75	2.89													
3								68.51	19.29				27.95	4.33							0.11	102.98
4													55.91	8.66							0.21	205.96
5													55.91	8.66							0.21	205.96
6													55.91	8.66							0.21	205.96
7													56.25	8.66							0.21	205.96
8													57.73	8.66							0.21	205.96
9													57.39	8.66							0.21	205.96
10													55.91	8.66							0.21	205.96
11													55.91	8.66							0.21	205.96
12													56.25	8.66							0.21	205.96
13													57.73	8.66							0.21	205.96
14													57.39	8.66							0.21	205.96
15													55.91	8.66							0.21	205.96
16													55.91	8.66							0.21	205.96
17													56.25	8.66							0.21	205.96
18													57.73	8.66							0.21	205.96
19													57.39	8.66							0.21	205.96
20													55.91	8.66							0.21	205.96
21													55.91	8.66							0.21	205.96
22													55.91	8.66							0.21	205.96
23													27.95	4.33							0.11	102.98
24																						
25																						

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	7 - Offshore CY to GRE via Pipeline_v2
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	1 626.51
Cost/ BOE	5.90

Lifecycle cost	3 269.52
Cost/ BOE	11.85

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	1 626.51
Cost/ BOE	5.90

Operating cost	1 432.74
Cost/ BOE	5.19

Decommission cost	210.27
Cost/ BOE	0.76

Design production	
0.08	84.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS					DECOMM.	CO2 emitted	PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	Floaters	Other facilities	Fixed OPEX	Variable OPEX	Tariffs	Leases	CO2 tax		000s te/ yr	Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1 612.15**	**14.36**	**0.00**	**0.00**	**0.00**	**1 360.53**	**72.21**	**0.00**	**0.00**	**0.00**	**210.27**	**2 027.20**	**0.00**	**1.61**	**1 645.40**
1								172.55														
2								690.51														
3								230.49														
4								230.49	3.59													
5								230.49	3.43													
6								57.62	7.34				39.34	2.11					59.13		0.05	47.99
7													67.44	3.61					101.36		0.08	82.27
8													67.44	3.61					101.36		0.08	82.27
9													67.44	3.61					101.36		0.08	82.27
10													68.89	3.61					101.36		0.08	82.27
11													69.31	3.61					101.36		0.08	82.27
12													68.03	3.61					101.36		0.08	82.27
13													67.44	3.61					101.36		0.08	82.27
14													67.44	3.61					101.36		0.08	82.27
15													68.89	3.61					101.36		0.08	82.27
16													69.31	3.61					101.36		0.08	82.27
17													68.03	3.61					101.36		0.08	82.27
18													67.44	3.61					101.36		0.08	82.27
19													67.44	3.61					101.36		0.08	82.27
20													68.89	3.61					101.36		0.08	82.27
21													69.31	3.61					101.36		0.08	82.27
22													68.03	3.61					101.36		0.08	82.27
23													67.44	3.61					101.36		0.08	82.27
24													67.44	3.61					101.36		0.08	82.27
25													67.44	3.61					101.36		0.08	82.27
26													28.10	1.51					42.23		0.04	34.28
27																		81.77				
28																		128.50				

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	7 - Offshore NOR to UK via Pipeline
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	1 236.07
Cost/ BOE	25.96

Lifecycle cost	3 678.12
Cost/ BOE	77.24

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	1 236.07
Cost/ BOE	25.96

Operating cost	1 979.30
Cost/ BOE	41.57

Decommission cost	462.75
Cost/ BOE	9.72

Design production	
0.02	14.60

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS					DECOMM.	CO2 emitted	PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	Floaters	Other facilities	Fixed OPEX	Variable OPEX	Tariffs	Leases	CO2 tax		000s te/ yr	Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1 226.40**	**9.87**	**0.00**	**0.00**	**0.00**	**1 963.70**	**15.60**	**0.00**	**0.00**	**0.00**	**462.75**	**496.80**	**0.00**	**0.40**	**283.40**
1								223.50														
2								703.39														
3								43.83														
4								43.83														
5								43.83														
6								43.83														
7								43.83														
8								43.83	0.18													
9								36.53	9.49													
10													85.66	0.78					24.84		0.02	14.17
11													85.66	0.78					24.84		0.02	14.17
12													85.66	0.78					24.84		0.02	14.17
13													90.42	0.78					24.84		0.02	14.17
14													85.66	0.78					24.84		0.02	14.17
15													85.73	0.78					24.84		0.02	14.17
16													85.66	0.78					24.84		0.02	14.17
17													90.42	0.78					24.84		0.02	14.17
18													85.66	0.78					24.84		0.02	14.17
19													316.91	0.78					24.84		0.02	14.17
20													85.73	0.78					24.84		0.02	14.17
21													90.42	0.78					24.84		0.02	14.17
22													85.66	0.78					24.84		0.02	14.17
23													85.66	0.78					24.84		0.02	14.17
24													85.66	0.78					24.84		0.02	14.17
25													90.49	0.78					24.84		0.02	14.17
26													85.66	0.78					24.84		0.02	14.17
27													85.66	0.78					24.84		0.02	14.17
28													85.66	0.78					24.84		0.02	14.17
29													85.66	0.78					24.84		0.02	14.17
30																						
31																		308.50				
32																		154.25				

6.2.2 Loading nearshore / onshore

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	5 - Onshore to CRE via Pipeline	BOE/ bbl Oil	1.00	Capital cost	685.57	Lifecycle cost	1 002.63
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	11.64	Cost/ BOE	17.02
		BOE/ Mscf Gas	0.17				
E & A cost	0.00	Drilling cost	0.00	Facilities cost	685.57	Operating cost	317.06	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	11.64	Cost/ BOE	5.38	Cost/ BOE	0.00

Design production		
	0.03	17.50
350.6	58.906	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**9.05**	**676.52**	**0.00**	**309.26**	**7.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.60**	**350.00**
1							9.05	47.58											
2								239.99		15.22	0.39							0.03	17.50
3								129.65		15.22	0.39							0.03	17.50
4								129.65		15.22	0.39							0.03	17.50
5								129.65		15.22	0.39							0.03	17.50
6										16.84	0.39							0.03	17.50
7										15.22	0.39							0.03	17.50
8										15.22	0.39							0.03	17.50
9										15.22	0.39							0.03	17.50
10										15.22	0.39							0.03	17.50
11										16.84	0.39							0.03	17.50
12										15.22	0.39							0.03	17.50
13										15.22	0.39							0.03	17.50
14										15.22	0.39							0.03	17.50
15										15.22	0.39							0.03	17.50
16										16.84	0.39							0.03	17.50
17										15.22	0.39							0.03	17.50
18										15.22	0.39							0.03	17.50
19										15.22	0.39							0.03	17.50
20										15.22	0.39							0.03	17.50
21										15.22	0.39							0.03	17.50
22																			
23																			
24																			

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	1 - Onshore to EGY via Pipeline	BOE/ bbl Oil	1.00	Capital cost	1 150.83	Lifecycle cost	1 669.79
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	1.63	Cost/ BOE	2.36
		BOE/ Mscf Gas	0.17				
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 150.83	Operating cost	518.96	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	1.63	Cost/ BOE	0.73	Cost/ BOE	0.00

Design production		
	0.32	210.00
4206.4	706.124	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**15.09**	**1 135.74**	**0.00**	**428.36**	**90.60**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**6.40**	**4 200.00**
1							15.09	110.70											
2								660.34		21.10	4.53							0.32	210.00
3								364.70		21.10	4.53							0.32	210.00
4										21.10	4.53							0.32	210.00
5										21.10	4.53							0.32	210.00
6										23.22	4.53							0.32	210.00
7										21.10	4.53							0.32	210.00
8										21.10	4.53							0.32	210.00
9										21.10	4.53							0.32	210.00
10										21.10	4.53							0.32	210.00
11										23.22	4.53							0.32	210.00
12										21.10	4.53							0.32	210.00
13										21.10	4.53							0.32	210.00
14										21.10	4.53							0.32	210.00
15										21.10	4.53							0.32	210.00
16										23.22	4.53							0.32	210.00
17										21.10	4.53							0.32	210.00
18										21.10	4.53							0.32	210.00
19										21.10	4.53							0.32	210.00
20										21.10	4.53							0.32	210.00
21										21.10	4.53							0.32	210.00
22																			
23																			
24																			

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	3 - Onshore to LEB via Pipeline	BOE/ bbl Oil	1.00	Capital cost	1 146.02	Lifecycle cost	1 579.38		
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	7.49	Cost/ BOE	10.32		
		BOE/ Mscf Gas	0.17						
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 146.02	Operating cost	433.36	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	7.49	Cost/ BOE	2.83	Cost/ BOE	0.00
								Design production	
								0.07	45.50

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**10.28**	**1 135.74**	**0.00**	**413.56**	**19.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.40**	**910.00**
1							10.28	110.70											
2								660.34		20.36	0.99							0.07	45.50
3								364.70		20.36	0.99							0.07	45.50
4										20.36	0.99							0.07	45.50
5										20.36	0.99							0.07	45.50
6										22.48	0.99							0.07	45.50
7										20.36	0.99							0.07	45.50
8										20.36	0.99							0.07	45.50
9										20.36	0.99							0.07	45.50
10										20.36	0.99							0.07	45.50
11										22.48	0.99							0.07	45.50
12										20.36	0.99							0.07	45.50
13										20.36	0.99							0.07	45.50
14										20.36	0.99							0.07	45.50
15										20.36	0.99							0.07	45.50
16										22.48	0.99							0.07	45.50
17										20.36	0.99							0.07	45.50
18										20.36	0.99							0.07	45.50
19										20.36	0.99							0.07	45.50
20										20.36	0.99							0.07	45.50
21										20.36	0.99							0.07	45.50
22																			
23																			
24																			

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	7 - Onshore to MG via Pipeline_v2	BOE/ bbl Oil	1.00	Capital cost	1 671.59	Lifecycle cost	2 250.65		
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	5.92	Cost/ BOE	7.97		
		BOE/ Mscf Gas	0.17						
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 671.59	Operating cost	579.06	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	5.92	Cost/ BOE	2.05	Cost/ BOE	0.00
								Design production	
								0.13	84.00
								1682.6	282.487

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX						Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
																	0	2.6	1680
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.79**	**1 659.80**	**0.00**	**542.66**	**36.40**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**2.60**	**1 680.00**
1							11.79	171.54											
2								689.89		26.77	1.82							0.13	84.00
3								233.67		26.77	1.82							0.13	84.00
4								233.67		26.77	1.82							0.13	84.00
5								233.67		26.77	1.82							0.13	84.00
6								97.36		29.19	1.82							0.13	84.00
7										26.77	1.82							0.13	84.00
8										26.77	1.82							0.13	84.00
9										26.77	1.82							0.13	84.00
10										26.77	1.82							0.13	84.00
11										29.19	1.82							0.13	84.00
12										26.77	1.82							0.13	84.00
13										26.77	1.82							0.13	84.00
14										26.77	1.82							0.13	84.00
15										26.77	1.82							0.13	84.00
16										29.19	1.82							0.13	84.00
17										26.77	1.82							0.13	84.00
18										26.77	1.82							0.13	84.00
19										26.77	1.82							0.13	84.00
20										26.77	1.82							0.13	84.00
21										26.77	1.82							0.13	84.00
22																			
23																			
24																			

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	1 - Onshore NOR to UK via Pipeline	BOE/ bbl Oil	1.00	Capital cost	1 056.23	Lifecycle cost	2 316.17		
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	21.39	Cost/ BOE	46.90		
		BOE/ Mscf Gas	0.17						
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 056.23	Operating cost	955.46	Decommission cost	304.48
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	21.39	Cost/ BOE	19.35	Cost/ BOE	6.17
								Design production	
								0.02	14.70

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS					DECOMM.	CO2 emitted	PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX	Tariffs	Leases	CO2 tax		000s te/ yr	Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**9.02**	**1 047.21**	**0.00**	**742.46**	**6.60**	**206.40**	**0.00**	**0.00**	**304.48**	**5.40**	**0.00**	**0.40**	**294.00**
1							9.02	148.20											
2								487.21		36.43	0.33	10.32				0.27		0.02	14.70
3								56.80		36.43	0.33	10.32				0.27		0.02	14.70
4								56.80		36.43	0.33	10.32				0.27		0.02	14.70
5								56.80		36.43	0.33	10.32				0.27		0.02	14.70
6								56.80		41.05	0.33	10.32				0.27		0.02	14.70
7								56.80		36.43	0.33	10.32				0.27		0.02	14.70
8								56.80		36.43	0.33	10.32				0.27		0.02	14.70
9								56.80		36.43	0.33	10.32				0.27		0.02	14.70
10								14.20		36.43	0.33	10.32				0.27		0.02	14.70
11										41.05	0.33	10.32				0.27		0.02	14.70
12										36.43	0.33	10.32				0.27		0.02	14.70
13										36.43	0.33	10.32				0.27		0.02	14.70
14										36.43	0.33	10.32				0.27		0.02	14.70
15										36.43	0.33	10.32				0.27		0.02	14.70
16										41.05	0.33	10.32				0.27		0.02	14.70
17										36.43	0.33	10.32				0.27		0.02	14.70
18										36.43	0.33	10.32				0.27		0.02	14.70
19										36.43	0.33	10.32				0.27		0.02	14.70
20										36.43	0.33	10.32				0.27		0.02	14.70
21										36.43	0.33	10.32				0.27		0.02	14.70
22																			
23															202.99				
24															101.49				

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	1 - Onshore GEO to UKR via Pipeline	BOE/ bbl Oil	1.00	Capital cost	1 322.27	Lifecycle cost	3 068.62		
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	5.06	Cost/ BOE	11.74		
		BOE/ Mscf Gas	0.17						
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 322.27	Operating cost	1 589.48	Decommission cost	156.87
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	5.06	Cost/ BOE	6.08	Cost/ BOE	0.60
								Design production	
								0.12	77.70

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS					DECOMM.	CO2 emitted	PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	Pipelines	Other facilities	Fixed OPEX	Variable OPEX	Tariffs	Leases	CO2 tax		000s te/ yr	Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.58**	**1 310.69**	**0.00**	**465.08**	**33.80**	**1 090.60**	**0.00**	**0.00**	**156.87**	**14.80**	**0.00**	**2.40**	**1 554.00**
1							11.58	135.77											
2								580.03		22.93	1.69	54.53				0.74		0.12	77.70
3								230.28		22.93	1.69	54.53				0.74		0.12	77.70
4								230.28		22.93	1.69	54.53				0.74		0.12	77.70
5								134.33		22.93	1.69	54.53				0.74		0.12	77.70
6										25.09	1.69	54.53				0.74		0.12	77.70
7										22.93	1.69	54.53				0.74		0.12	77.70
8										22.93	1.69	54.53				0.74		0.12	77.70
9										22.93	1.69	54.53				0.74		0.12	77.70
10										22.93	1.69	54.53				0.74		0.12	77.70
11										25.09	1.69	54.53				0.74		0.12	77.70
12										22.93	1.69	54.53				0.74		0.12	77.70
13										22.93	1.69	54.53				0.74		0.12	77.70
14										22.93	1.69	54.53				0.74		0.12	77.70
15										22.93	1.69	54.53				0.74		0.12	77.70
16										25.09	1.69	54.53				0.74		0.12	77.70
17										22.93	1.69	54.53				0.74		0.12	77.70
18										22.93	1.69	54.53				0.74		0.12	77.70
19										22.93	1.69	54.53				0.74		0.12	77.70
20										22.93	1.69	54.53				0.74		0.12	77.70
21										22.93	1.69	54.53				0.74		0.12	77.70
22																			
23															104.58				
24															52.29				

6.3 LNG

6.3.1 FLNG, loading offshore

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	6 - Offshore CY to CRE via FLNG	BOE/ bbl Oil	1.00	Capital cost	496.47	Lifecycle cost	1 596.67		
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	8.66	Cost/ BOE	27.86		
		BOE/ Mscf Gas	0.17						
E & A cost	0.00	Drilling cost	0.00	Facilities cost	496.47	Operating cost	1 100.20	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	8.66	Cost/ BOE	19.19	Cost/ BOE	0.00
								Design production	
								0.02	17.50

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**32.46**	**8.01**	**0.00**	**400.00**	**56.00**	**781.00**	**16.80**	**252.00**	**50.40**	**0.00**			**0.00**	**0.40**	**341.59**
1								1.84	2.00		120.00	17.00										
2								17.95	3.15		200.00	28.00										
3								12.67	2.86		80.00	11.00	25.93	0.56	12.00	2.40				0.01		11.38
4													38.90	0.84	12.00	2.40				0.02		17.08
5													38.90	0.84	12.00	2.40				0.02		17.08
6													38.90	0.84	12.00	2.40				0.02		17.08
7													39.03	0.84	12.00	2.40				0.02		17.08
8													39.50	0.84	12.00	2.40				0.02		17.08
9													39.17	0.84	12.00	2.40				0.02		17.08
10													38.90	0.84	12.00	2.40				0.02		17.08
11													38.90	0.84	12.00	2.40				0.02		17.08
12													39.03	0.84	12.00	2.40				0.02		17.08
13													39.50	0.84	12.00	2.40				0.02		17.08
14													39.17	0.84	12.00	2.40				0.02		17.08
15													38.90	0.84	12.00	2.40				0.02		17.08
16													38.90	0.84	12.00	2.40				0.02		17.08
17													39.03	0.84	12.00	2.40				0.02		17.08
18													39.50	0.84	12.00	2.40				0.02		17.08
19													39.17	0.84	12.00	2.40				0.02		17.08
20													38.90	0.84	12.00	2.40				0.02		17.08
21													38.90	0.84	12.00	2.40				0.02		17.08
22													38.90	0.84	12.00	2.40				0.02		17.08
23													12.97	0.28	12.00	2.40				0.01		5.69
24																						
25																						

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	4 - Offshore CY to Lebanon via FLNG	BOE/ bbl Oil	1.00	Capital cost	1 180.67	Lifecycle cost	2 835.51		
Currency (millions $)	US Dollars	BOE/ bbl Condensate	0.94	Cost/ BOE	7.88	Cost/ BOE	18.93		
		BOE/ Mscf Gas	0.17						
E & A cost	0.00	Drilling cost	0.00	Facilities cost	1 180.67	Operating cost	1 654.84	Decommission cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00	Cost/ BOE	7.88	Cost/ BOE	11.05	Cost/ BOE	0.00
								Design production	
								0.05	45.50

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**34.75**	**19.92**	**0.00**	**1 000.00**	**126.00**	**875.54**	**38.00**	**672.00**	**69.30**	**0.00**			**0.00**	**1.00**	**893.00**
1								1.84	4.98		300.00	38.00										
2								20.03	8.15		500.00	63.00										
3								12.88	6.79		200.00	25.00	28.97	1.27	32.00	3.30				0.03		29.77
4													43.45	1.90	32.00	3.30				0.05		44.65
5													43.45	1.90	32.00	3.30				0.05		44.65
6													43.45	1.90	32.00	3.30				0.05		44.65
7													43.58	1.90	32.00	3.30				0.05		44.65
8													44.84	1.90	32.00	3.30				0.05		44.65
9													44.11	1.90	32.00	3.30				0.05		44.65
10													43.45	1.90	32.00	3.30				0.05		44.65
11													43.45	1.90	32.00	3.30				0.05		44.65
12													43.58	1.90	32.00	3.30				0.05		44.65
13													44.84	1.90	32.00	3.30				0.05		44.65
14													44.11	1.90	32.00	3.30				0.05		44.65
15													43.45	1.90	32.00	3.30				0.05		44.65
16													43.45	1.90	32.00	3.30				0.05		44.65
17													43.58	1.90	32.00	3.30				0.05		44.65
18													44.84	1.90	32.00	3.30				0.05		44.65
19													44.11	1.90	32.00	3.30				0.05		44.65
20													43.45	1.90	32.00	3.30				0.05		44.65
21													43.45	1.90	32.00	3.30				0.05		44.65
22													43.45	1.90	32.00	3.30				0.05		44.65
23													14.48	0.63	32.00	3.30				0.02		14.88
24																						
25																						

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	2 - Offshore CY to EGY via FLNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	4 374.05
Cost/ BOE	6.30

Lifecycle cost	8 572.42
Cost/ BOE	12.34

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	4 374.05
Cost/ BOE	6.30

Operating cost	4 198.37
Cost/ BOE	6.04

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.21	210.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS						PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU			Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.14	27.91	0.00	4 300.00	0.00	984.37	148.00	3 066.00	0.00	0.00		0.00	4.20	4 144.01
1								1.84	6.98		1 290.00										
2								31.05	11.42		2 150.00										
3								13.25	9.51		860.00		32.51	4.93	146.00					0.14	138.14
4													48.77	7.40	146.00					0.21	207.20
5													48.77	7.40	146.00					0.21	207.20
6													48.77	7.40	146.00					0.21	207.20
7													48.90	7.40	146.00					0.21	207.20
8													50.70	7.40	146.00					0.21	207.20
9													49.70	7.40	146.00					0.21	207.20
10													48.77	7.40	146.00					0.21	207.20
11													48.77	7.40	146.00					0.21	207.20
12													48.90	7.40	146.00					0.21	207.20
13													50.70	7.40	146.00					0.21	207.20
14													49.70	7.40	146.00					0.21	207.20
15													48.77	7.40	146.00					0.21	207.20
16													48.77	7.40	146.00					0.21	207.20
17													48.90	7.40	146.00					0.21	207.20
18													50.70	7.40	146.00					0.21	207.20
19													49.70	7.40	146.00					0.21	207.20
20													48.77	7.40	146.00					0.21	207.20
21													48.77	7.40	146.00					0.21	207.20
22													48.77	7.40	146.00					0.21	207.20
23													16.26	2.47	146.00					0.07	69.07
24																					
25																					

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	8 - Offshore CY to GRE via FLNG_v2
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	2 060.08
Cost/ BOE	7.38

Lifecycle cost	4 833.00
Cost/ BOE	17.32

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	2 060.08
Cost/ BOE	7.38

Operating cost	2 772.92
Cost/ BOE	9.94

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.08	84.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS						PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU			Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.89	12.25	0.00	1 800.00	211.94	840.82	52.60	1 785.00	94.50	0.00	0.00	908.40	0.00	1.61	1 664.60
1								1.84	3.06		540.00	63.58									
2								21.25	5.01		900.00	105.97									
3								12.80	4.18		360.00	42.39	27.88	1.75	85.00	4.50			30.28	0.06	55.49
4													41.83	2.63	85.00	4.50			45.42	0.08	83.23
5													41.83	2.63	85.00	4.50			45.42	0.08	83.23
6													41.83	2.63	85.00	4.50			45.42	0.08	83.23
7													41.96	2.63	85.00	4.50			45.42	0.08	83.23
8													42.71	2.63	85.00	4.50			45.42	0.08	83.23
9													42.23	2.63	85.00	4.50			45.42	0.08	83.23
10													41.83	2.63	85.00	4.50			45.42	0.08	83.23
11													41.83	2.63	85.00	4.50			45.42	0.08	83.23
12													41.96	2.63	85.00	4.50			45.42	0.08	83.23
13													42.71	2.63	85.00	4.50			45.42	0.08	83.23
14													42.23	2.63	85.00	4.50			45.42	0.08	83.23
15													41.83	2.63	85.00	4.50			45.42	0.08	83.23
16													41.83	2.63	85.00	4.50			45.42	0.08	83.23
17													41.96	2.63	85.00	4.50			45.42	0.08	83.23
18													42.71	2.63	85.00	4.50			45.42	0.08	83.23
19													42.23	2.63	85.00	4.50			45.42	0.08	83.23
20													41.83	2.63	85.00	4.50			45.42	0.08	83.23
21													41.83	2.63	85.00	4.50			45.42	0.08	83.23
22													41.83	2.63	85.00	4.50			45.42	0.08	83.23
23													13.94	0.88	85.00	4.50			15.14	0.03	27.74
24																					
25																					

OFFSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	8 - Offshore NOR to UK via FLNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	768.29
Cost/ BOE	16.02

Lifecycle cost	2 649.54
Cost/ BOE	55.26

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	768.29
Cost/ BOE	16.02

Operating cost	1 881.25
Cost/ BOE	39.23

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.02	14.60

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS						PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Subsea	Pipelines	Topsides	Structures	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU			Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.12	9.17	0.00	730.00	0.00	985.65	13.60	882.00	0.00	0.00	0.00	0.00	0.40	285.40
1								1.63	0.18		219.00										
2								19.14	0.28		365.00										
3								8.35	8.71		146.00		32.82	0.45	42.00					0.01	9.51
4													49.23	0.68	42.00					0.02	14.27
5													49.23	0.68	42.00					0.02	14.27
6													49.37	0.68	42.00					0.02	14.27
7													49.30	0.68	42.00					0.02	14.27
8													49.28	0.68	42.00					0.02	14.27
9													49.26	0.68	42.00					0.02	14.27
10													49.37	0.68	42.00					0.02	14.27
11													49.30	0.68	42.00					0.02	14.27
12													49.23	0.68	42.00					0.02	14.27
13													49.28	0.68	42.00					0.02	14.27
14													49.39	0.68	42.00					0.02	14.27
15													49.30	0.68	42.00					0.02	14.27
16													49.23	0.68	42.00					0.02	14.27
17													49.23	0.68	42.00					0.02	14.27
18													49.41	0.68	42.00					0.02	14.27
19													49.32	0.68	42.00					0.02	14.27
20													49.23	0.68	42.00					0.02	14.27
21													49.23	0.68	42.00					0.02	14.27
22													49.23	0.68	42.00					0.02	14.27
23													16.41	0.23	42.00					0.01	4.76
24																					
25																					

6.3.2 LNG/FLNG, nearshore, onshore

ONSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	6 - Onshore to CRE via NFLNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	815.61
Cost/ BOE	13.85

Lifecycle cost	1 770.01
Cost/ BOE	30.05

E & A cost	0.00	Drilling cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00

Facilities cost	815.61
Cost/ BOE	13.85

Operating cost	954.40
Cost/ BOE	16.20

Decommission cost	0.00
Cost/ BOE	0.00

Design production		
	0.03	17.50
350.6	58.906	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Production facilities	Wellpad groups	Terminals	Pipelines	LNG	FSRU	Fixed OPEX	Variable OPEX	LNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	9.49	0.00	0.00	0.00	750.00	56.12	18.60	7.80	880.00	48.00	0.00	0.00	0.00	0.00	0.60	350.00
1							9.49				225.00	16.84										
2											375.00	28.06										
3											150.00	11.22	0.93	0.39	44.00	2.40					0.03	17.50
4													0.93	0.39	44.00	2.40					0.03	17.50
5													0.93	0.39	44.00	2.40					0.03	17.50
6													0.93	0.39	44.00	2.40					0.03	17.50
7													0.93	0.39	44.00	2.40					0.03	17.50
8													0.93	0.39	44.00	2.40					0.03	17.50
9													0.93	0.39	44.00	2.40					0.03	17.50
10													0.93	0.39	44.00	2.40					0.03	17.50
11													0.93	0.39	44.00	2.40					0.03	17.50
12													0.93	0.39	44.00	2.40					0.03	17.50
13													0.93	0.39	44.00	2.40					0.03	17.50
14													0.93	0.39	44.00	2.40					0.03	17.50
15													0.93	0.39	44.00	2.40					0.03	17.50
16													0.93	0.39	44.00	2.40					0.03	17.50
17													0.93	0.39	44.00	2.40					0.03	17.50
18													0.93	0.39	44.00	2.40					0.03	17.50
19													0.93	0.39	44.00	2.40					0.03	17.50
20													0.93	0.39	44.00	2.40					0.03	17.50
21													0.93	0.39	44.00	2.40					0.03	17.50
22													0.93	0.39	44.00	2.40					0.03	17.50
23																						
24																						

ONSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	4 - Onshore to LEB via NFLNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	1 106.36
Cost/ BOE	7.23

Lifecycle cost	2 433.16
Cost/ BOE	15.90

E & A cost	0.00	Drilling cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00

Facilities cost	1 106.36
Cost/ BOE	7.23

Operating cost	1 326.80
Cost/ BOE	8.67

Decommission cost	0.00
Cost/ BOE	0.00

Design production		
	0.07	45.50
911.4	153.006	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Production facilities	Wellpad groups	Terminals	Pipelines	LNG	FSRU	Fixed OPEX	Variable OPEX	LNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	10.28	0.00	0.00	0.00	970.00	126.08	21.00	19.80	1 220.00	66.00	0.00	0.00	0.00	0.00	1.40	910.00
1							10.28				291.00	37.82										
2											485.00	63.04										
3											194.00	25.22	1.05	0.99	61.00	3.30					0.07	45.50
4													1.05	0.99	61.00	3.30					0.07	45.50
5													1.05	0.99	61.00	3.30					0.07	45.50
6													1.05	0.99	61.00	3.30					0.07	45.50
7													1.05	0.99	61.00	3.30					0.07	45.50
8													1.05	0.99	61.00	3.30					0.07	45.50
9													1.05	0.99	61.00	3.30					0.07	45.50
10													1.05	0.99	61.00	3.30					0.07	45.50
11													1.05	0.99	61.00	3.30					0.07	45.50
12													1.05	0.99	61.00	3.30					0.07	45.50
13													1.05	0.99	61.00	3.30					0.07	45.50
14													1.05	0.99	61.00	3.30					0.07	45.50
15													1.05	0.99	61.00	3.30					0.07	45.50
16													1.05	0.99	61.00	3.30					0.07	45.50
17													1.05	0.99	61.00	3.30					0.07	45.50
18													1.05	0.99	61.00	3.30					0.07	45.50
19													1.05	0.99	61.00	3.30					0.07	45.50
20													1.05	0.99	61.00	3.30					0.07	45.50
21													1.05	0.99	61.00	3.30					0.07	45.50
22													1.05	0.99	61.00	3.30					0.07	45.50
23																						
24																						

ONSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	2 - Onshore to EGY via Land LNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	4 488.80
Cost/ BOE	6.36

Lifecycle cost	5 514.60
Cost/ BOE	7.81

E & A cost	0.00	Drilling cost	0.00
Cost/ BOE	0.00	Cost/ BOE	0.00

Facilities cost	4 488.80
Cost/ BOE	6.36

Operating cost	1 025.80
Cost/ BOE	1.45

Decommission cost	0.00
Cost/ BOE	0.00

Design production		
	0.32	210.00
4206.4	706.124	

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Production facilities	Wellpad groups	Terminals	Pipelines	LNG	FSRU	Fixed OPEX	Variable OPEX	LNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	16.45	0.00	0.00	0.00	4 472.35	0.00	39.20	90.60	896.00	0.00	0.00	0.00	0.00	0.00	6.40	4 200.00
1							16.45				1 341.70											
2											2 236.17											
3											894.47		1.96	4.53	44.80						0.32	210.00
4													1.96	4.53	44.80						0.32	210.00
5													1.96	4.53	44.80						0.32	210.00
6													1.96	4.53	44.80						0.32	210.00
7													1.96	4.53	44.80						0.32	210.00
8													1.96	4.53	44.80						0.32	210.00
9													1.96	4.53	44.80						0.32	210.00
10													1.96	4.53	44.80						0.32	210.00
11													1.96	4.53	44.80						0.32	210.00
12													1.96	4.53	44.80						0.32	210.00
13													1.96	4.53	44.80						0.32	210.00
14													1.96	4.53	44.80						0.32	210.00
15													1.96	4.53	44.80						0.32	210.00
16													1.96	4.53	44.80						0.32	210.00
17													1.96	4.53	44.80						0.32	210.00
18													1.96	4.53	44.80						0.32	210.00
19													1.96	4.53	44.80						0.32	210.00
20													1.96	4.53	44.80						0.32	210.00
21													1.96	4.53	44.80						0.32	210.00
22													1.96	4.53	44.80						0.32	210.00
23																						
24																						

ONSHORE INVESTMENT AND PRODUCTION PROFILES

Project name	8 - Onshore to MG via NFLNG_v2
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	1 483.88
Cost/ BOE	5.25

Lifecycle cost	3 334.88
Cost/ BOE	11.81

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	1 483.88
Cost/ BOE	5.25

Operating cost	1 851.00
Cost/ BOE	6.55

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.13	84.00

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS						OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Production facilities	Wellpad groups	Terminals	Pipelines	FLNG	FSRU	Fixed OPEX	Variable OPEX	LNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.94**	**0.00**	**0.00**	**0.00**	**1 260.00**	**211.94**	**24.60**	**38.40**	**1 700.00**	**90.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.80**	**1 680.00**
1							11.94				378.00	63.58										
2											630.00	105.97	1.23	1.82	85.00	4.50					0.13	84.00
3											252.00	42.39	1.23	1.82	85.00	4.50					0.13	84.00
4													1.23	1.82	85.00	4.50					0.13	84.00
5													1.23	1.82	85.00	4.50					0.13	84.00
6													1.23	1.82	85.00	4.50					0.13	84.00
7													1.23	1.82	85.00	4.50					0.13	84.00
8													1.23	1.82	85.00	4.50					0.13	84.00
9													1.23	1.82	85.00	4.50					0.13	84.00
10													1.23	1.82	85.00	4.50					0.13	84.00
11													1.23	1.82	85.00	4.50					0.13	84.00
12													1.23	1.82	85.00	4.50					0.13	84.00
13													1.23	1.82	85.00	4.50					0.13	84.00
14													1.23	1.82	85.00	4.50					0.13	84.00
15													1.23	1.82	85.00	4.50					0.13	84.00
16													1.23	1.82	85.00	4.50					0.13	84.00
17													1.23	1.82	85.00	4.50					0.13	84.00
18													1.23	1.82	85.00	4.50					0.13	84.00
19													1.23	1.82	85.00	4.50					0.13	84.00
20													1.23	1.82	85.00	4.50					0.13	84.00
21													1.23	1.82	85.00	4.50					0.13	84.00
22																						
23																						
24																						

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	2-Onshore NOR to UK via NFLNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	739.02
Cost/ BOE	14.96

Lifecycle cost	1 623.82
Cost/ BOE	32.88

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	739.02
Cost/ BOE	14.96

Operating cost	884.80
Cost/ BOE	17.92

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.02	14.70

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**9.02**	**730.00**	**0.00**	**38.20**	**6.60**	**840.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.40**	**294.00**
1							9.02	219.00											
2								365.00		1.91	0.33	42.00						0.02	14.70
3								146.00		1.91	0.33	42.00						0.02	14.70
4										1.91	0.33	42.00						0.02	14.70
5										1.91	0.33	42.00						0.02	14.70
6										1.91	0.33	42.00						0.02	14.70
7										1.91	0.33	42.00						0.02	14.70
8										1.91	0.33	42.00						0.02	14.70
9										1.91	0.33	42.00						0.02	14.70
10										1.91	0.33	42.00						0.02	14.70
11										1.91	0.33	42.00						0.02	14.70
12										1.91	0.33	42.00						0.02	14.70
13										1.91	0.33	42.00						0.02	14.70
14										1.91	0.33	42.00						0.02	14.70
15										1.91	0.33	42.00						0.02	14.70
16										1.91	0.33	42.00						0.02	14.70
17										1.91	0.33	42.00						0.02	14.70
18										1.91	0.33	42.00						0.02	14.70
19										1.91	0.33	42.00						0.02	14.70
20										1.91	0.33	42.00						0.02	14.70
21										1.91	0.33	42.00						0.02	14.70
22																			
23																			
24																			

COMBINED INVESTMENT AND PRODUCTION PROFILES

Project name	2-Onshore GEO to UKR via NFLNG
Currency (millions $)	US Dollars

BOE/ bbl Oil	1.00
BOE/ bbl Condensate	0.94
BOE/ Mscf Gas	0.17

Capital cost	1 420.58
Cost/ BOE	5.44

Lifecycle cost	3 204.38
Cost/ BOE	12.26

E & A cost	0.00
Cost/ BOE	0.00

Drilling cost	0.00
Cost/ BOE	0.00

Facilities cost	1 420.58
Cost/ BOE	5.44

Operating cost	1 783.80
Cost/ BOE	6.83

Decommission cost	0.00
Cost/ BOE	0.00

Design production	
0.12	77.70

Year	PROJECT COSTS	EXPLORATION & APPRAISAL			PROD. DRILLING		FACILITIES COSTS			OPERATING COSTS							PRODUCTION		
		Expl.	Seismic	Apprsl.	Tangible	Intangible	Facilities	FLNG	FSRU	Fixed OPEX	Variable OPEX	FLNG	FSRU				Oil MMbbl/ yr	Cond. MMbbl/ yr	Gas Bscf/ yr
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.58**	**1 210.00**	**199.00**	**44.00**	**33.80**	**1 620.00**	**86.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.40**	**1 554.00**
1							11.58	363.00	60.00										
2								605.00	99.00	2.20	1.69	81.00	4.30					0.12	77.70
3								242.00	40.00	2.20	1.69	81.00	4.30					0.12	77.70
4										2.20	1.69	81.00	4.30					0.12	77.70
5										2.20	1.69	81.00	4.30					0.12	77.70
6										2.20	1.69	81.00	4.30					0.12	77.70
7										2.20	1.69	81.00	4.30					0.12	77.70
8										2.20	1.69	81.00	4.30					0.12	77.70
9										2.20	1.69	81.00	4.30					0.12	77.70
10										2.20	1.69	81.00	4.30					0.12	77.70
11										2.20	1.69	81.00	4.30					0.12	77.70
12										2.20	1.69	81.00	4.30					0.12	77.70
13										2.20	1.69	81.00	4.30					0.12	77.70
14										2.20	1.69	81.00	4.30					0.12	77.70
15										2.20	1.69	81.00	4.30					0.12	77.70
16										2.20	1.69	81.00	4.30					0.12	77.70
17										2.20	1.69	81.00	4.30					0.12	77.70
18										2.20	1.69	81.00	4.30					0.12	77.70
19										2.20	1.69	81.00	4.30					0.12	77.70
20										2.20	1.69	81.00	4.30					0.12	77.70
21										2.20	1.69	81.00	4.30					0.12	77.70
22																			
23																			
24																			