Cost-benefint analysis database

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DEM	Demonstrator, pilot, prototype	
DEC	Websites, patent fillings, videos, etc.	
OTHER		
ETHICS	Ethics requirements	
ORDP	Open Research Data Pilot	

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PU	Public	[X]
CO	Confidential, only for Members of the Consortium (including the EU Commission Services)	

Version Management

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Glossary, abbreviations and acronyms

CBA	Cost-benefit analysis
VOLTA	Name of optimization & cost calculation software developed by Esteco (WP2)
CAPEX	Capital expenditures
OPEX	Operating Expenses
VOYEX	Voyage expenses
NPV	Net Present Value
sm3	standard cubic metre
kWh	kilowatt hour
knots	nautical mile per hour
nm	nautical mile

1. Introduction

1.1 Executive Summary

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

This will be achieved through two main analysis:

- Option analysis (comparison of monetization options) in Task 7.2
- Profitability analysis of GASVESSEL (financial, socio-economic, environmental cost and benefit) in Task 7.3

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 have been gathered through Task T7.1.

Deliverable D7.1 outlines the structure and content of the CBA database per October 2019. Due to ongoing work to further populate the database - collecting updated data from other WPs as well as specific data to be identified through T7.2 and T7.3-, this deliverable is to be registered as the first of a serie of 4.

Version 1	October 2019	Cost and technical parameters from GASVESSEL (source: WP1-6); Datastructure; and calculation model description.
Version 2	May 2020	Updated input data and CBA calculation spreadsheets
Version 3	October 2020	Updated with output from T7.2 and T7.3
Version 4	January 2021	Updated with final results from T7.2 and T7.3

Summary of D7.1 CBA Database

In WP7 we will conduct multiple analyses, using different tools and detail levels, per scenarios or combining input from multiple scenarios. The role of T7.1 is to ensure that input data are used in a consistent manner in all WP7 calculations and other analyses depending on WP7 (most particularly in the Business plan to be set up in WP9).

D7.1 CBA Database consists of the following elements:

1. **GASVESSEL market scenarios** (volume, distance, location) identified in **WP2** as potential deployment scenarios for GASVESSEL. These will serve as:
    a. **Reference scenarios for the comparative analysis (T7.2)**, from which a set of distance/volume cases will be extrapolated in order to compare transport unit cost (€/sm3) 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).

   b. **Reference scenarios for the cost-benefit analysis of GASVESSEL (T7.3)**, to be analysed individually (feasibility per scenario) and in combination (per region, market etc.).

2. **Technical characteristics, CAPEX and OPEX** of

   a. **Pressure vessels (WP3 and WP4)**: to be used as input to logistics optimization and midstream costs calculation using VOLTA (T7.2) and financial NPV calculation (T7.3.1) and socio-economic analysis (T7.3.2).

   b. **Ship 15m and 10m (WP1, WP5)**: to be used as input to logistics optimization and midstream costs calculation using VOLTA (T7.2) and financial NPV calculation (T7.3.1) and socio-economic analysis (T7.3.2).

   c. **Loading/unloading system and infrastructure (WP6)** to be used as input to logistics optimization and costs calculation using VOLTA (T7.2) and financial NPV calculation (T7.3.1) and socio-economic analysis (T7.3.2).

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

3. **Alternative gas distribution options (Pipeline, LNG and competitive CNG concept)** to be identified in **(T7.2 WP7)** used in comparative analysis for distinct volume/distance scenarios as well as distinct loading/unloading concepts.
4. **Socio-economic impact factors** to be identified in **T7.3 (WP7)**:
   a. Occupational and socio-economic beneficial impact on; EU shipbuilding; gas composite Pressure Vessels production; Carbon fiber production lines; seafaring; energy companies;

5. **Environmental costs and benefits of GASVESSEL** to be identified in **T7.3 (WP7)**:

   a. **GHG emissions** from gas transport (based on emission factor from marine power systems)

   b. Beneficial impact on environmental issues by energy recovery from stranded gas and associated gas today disregarded, and gas flaring reduction

6. Other **parameters:**

   a. **Financial**: Interest rate, discount rate, tax,

   b. **Vessel operation**: working days, speed, etc.

   c. **Gas market** parameters: gas feed cost, gas sale price etc.

This data is compiled in D7.1 and **structured as follows**:

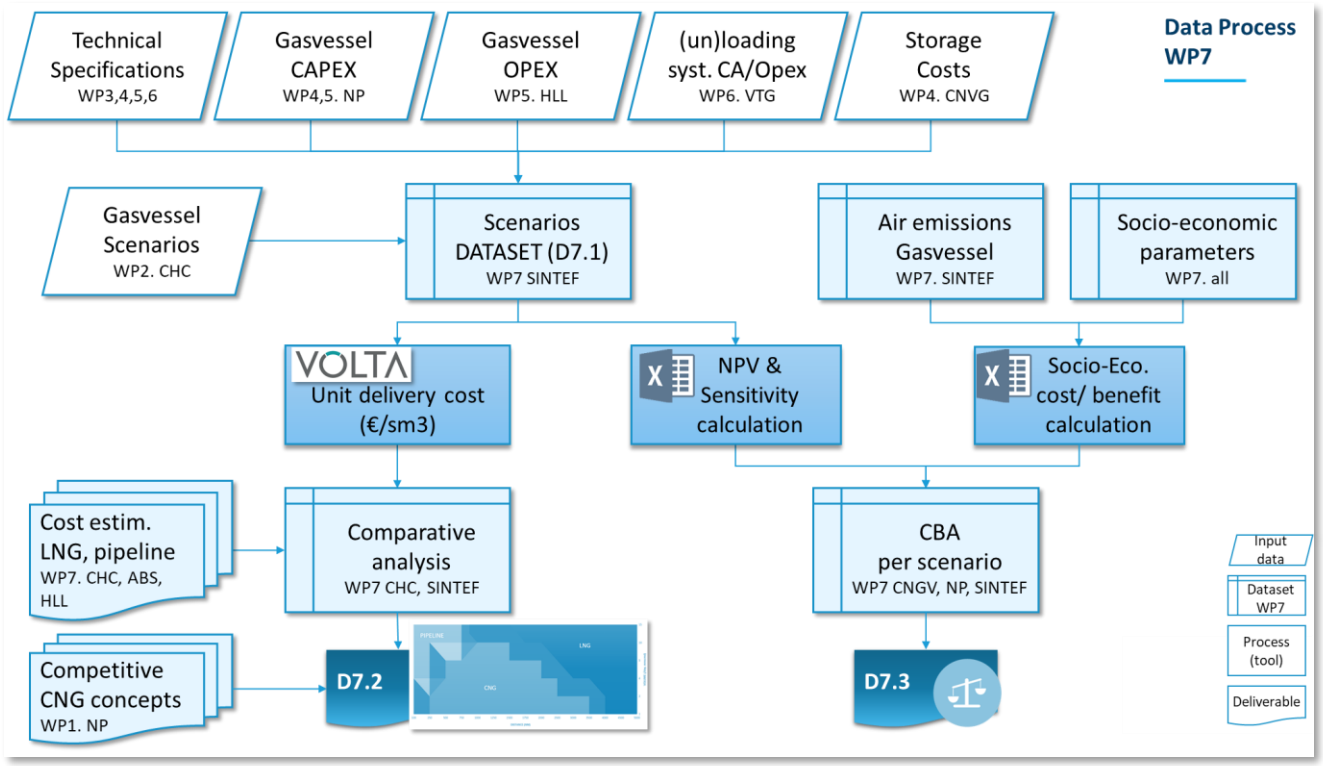


Figure 1: WP7 data process

[T7.1] The figure schematises the processing of data throughout WP7. All input data and information from WP1-6 is compiled into a Excel file "GASVESSEL WP7 T7.1 CBA Database". A summary dataset of Gasvessel scenarios is available in the sheet "7.1.2 REFERENCE SCENARIOS" which is the common dataset to be used for cost-benefit analysis.

[T7.2] This Dataset is further used as input to Esteco VOLTA software to identify GASVESSEL midstream / gas distribution costs (€/Sm3). These reference scenarios are then extrapolated into a wider set of volume/distance scenarios and distinct unloading/loading concepts and compiled into a dataset for comparative analysis, through which CNG/Gasvessel costs will be compared with LNG and pipeline options for each distance/volume case. Cost comparison with alternative CNG concepts will be made separately. Finally the result of this cost simulation and comparison will be presented into a report D7.2.

[T7.3] The scenario set and cost parameters set up in T7.1 will be fed in into T7.3.1 spreadsheet computing financial NPV and sensitivity analysis of each GASVESSEL scenario (individually and in combination). In parallel, air emission parameters and socio-economic parameters, translated into costs and benefits, will be compiled into a joint socio-economic analysis (Economic NPV calculation) of each GASVESSEL scenario (T7.3.2). The outcome of T7.3.1 an T7.3.2 will be presented into a report D7.3.

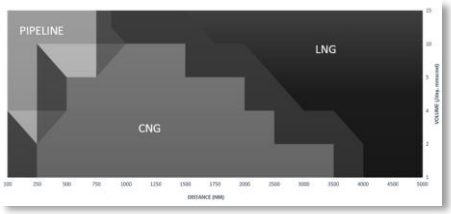
The main **analysis tools to be used in WP7** are described below:

Volta Esteco software to calculate midstream costs in €/sm3 (loading, transport, unloading, storage).

Utilisation: delivery costs per scenario.

7.2 Excel-based analysis tool for comparing delivery costs of gas between CNG, LNG and pipeline.

Utilization: gather delivery costs estimates from Gasvessel scenarios (VOLTA), secondary sources (LNG) and other calculation (pipeline); extrapolate and plot them in a volume/distance comparison chart. To be used in Task T7.2 for Delivery D7.2.



7.3 Excel-based cost-benefit calculation tool.

Utilization: estimate NPV per scenario, and socio-economic cost and benefits per market / region. To be used in Task T7.3 for Delivery D7.3.

7.3.1 spreadsheet: NPV calculation tool and Sensitivity calculation tool. To be used as tool to each scenario and combination of scenarios.

7.3.2 spreadsheet: Emission and socio-economic NPV calculation tool.

1.2 Purpose and Scope

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

This will be achieved through two main analysis works:

- Option analysis (comparison of monetization options) in Task 7.2 "Comparative Analysis"
- Profitability analysis of GASVESSEL (financial, socio-economic, environmental cost and benefit) in Task 7.3

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 have been gathered throughTask T7.1.

Deliverable D7.1 outlines the structure and content of the CBA database per October 2019. Due to ongoing work to further populate the database - collecting updated data from other WPs as well as specific data to be identified through T7.2 and 7.3 -, this deliverable is to be registered as version 1.

1.3 Relations with other deliverables

- WP7 collects information and data from WP2-6.
    - Deliverables: D2.1 Scenario description and characterization; D2.2 Decision Support Model; D3.2 Scenario analyses performed with the Decision Support model; D6.1 Technical proposals for the construction and equipment of Loading / unloading modules;
    - Other material: WP7 NP interim report "Midstream tariff - Matrix calculation" (March 2019); HLL OPEX calculatio 15M (sept.2019);
- WP7 deliver preliminary analysis and assessment tools to support business plan elaboration in WP9 (D9.5).

2. Research Methodology and Procedures

T7.1 has adopted a two-way method for identifying the data and data-structure necessary for cost-benefit analysis.

Bottom-up: gathered input from Gasvessel WPs and partners. Applied both the data delivered and the suggested methods and algorithms for midstream tariff calculation.

Top-down: sketched the methodology and set up calculation spreadsheet for comparative analysis and for profitability assessment. In collaboration with Esteco (developer of the Volta software) and CHC, this approach enabled the identification of missing data and further development of analysis tool. In the same way, the draft of NPV calculation model enabled to uncover the need for additional clarification of costs parameters.

3. Activities Description

The main activities in T7.1 towards D7.1 are listed up below:

- Defined scope of WP7, in collaboration with SINTEF, CHC, NP, CNGV (March 2019)
- Finetuned scenarios and input parameters for scenario analysis in Volta (including feedback to further development of Volta), in collaboration with CHC, Esteco and SINTEF, and based on input on midstream cost calculation (NP).
- Collected data from Gasvessel and from outside sources (input from WP1,2,3,4,5,6) (March – September 2019)
- Established methodology for T7.2 (comparative analysis), in collaboration between SINTEF, CHC, Esteco and ABS (May 2019)
- Established methodology for T7.3 (financial and socio-economic cost-benefit analysis), in collaboration with SINTEF and CHC
- Set up drafts of calculation tool for T7.2 and T7.3.1 (SINTEF)
- Initiated coordination with WP9 (PNO, CHC, SINTEF)

4. Results

The main results of T7.1 is the CBA database and structure described below. This database is to be populated as scenario analysis goes on in T7.2 and T7.3 during 2019 and 2020. Another significant result of the T7.1 work is the first version of methodology and tool for both T7.2 and T7.3.

4.1 D7.1 CBA structure

Structure

The WP7 database consists of all technical, economical and financial data necessary to carry out the cost-benefit analysis of the Gasvessel concept. It includes:

- documentation produced in the Gasvessel project: data and deliverables from other WPs, emails, presentations and other information documents, gathered from other work packages.
- secondary data and literature gathered from external sources.
- Primary data generated by WP7.
- CBA-Workbook: Excel-file containing all data processed in T7.1 gathered in the Scenario Dataset and calculation spreadsheets drafted in T7.1, that will serve as input data and tools for T7.2 and T7.3, respectively a model for comparison of gas transportation options and a tool for NPV calculation.

Localisation of WP7 Database

The WP7 Database is accessible by all WP7 partners on the following Sharepoint folder:

https://sintef.sharepoint.com/:f:/t/work-2350/EtTWsAZ3_-tCiJNcYPiJP7QBpX0XQKyyMnL4KDBpX-zC_w?email=a.kleanthous%40chc.com.cy&e=fdyfXg

Figure 2 summarises the main data to be collected/identified in WP7, per category, and indicates how these will be used in the Gasvessel cost-benefit analysis. These data, the results of WP7's calculation as well as the tools set-up in WP7 will also be made available for WP9 as support to the business plan.

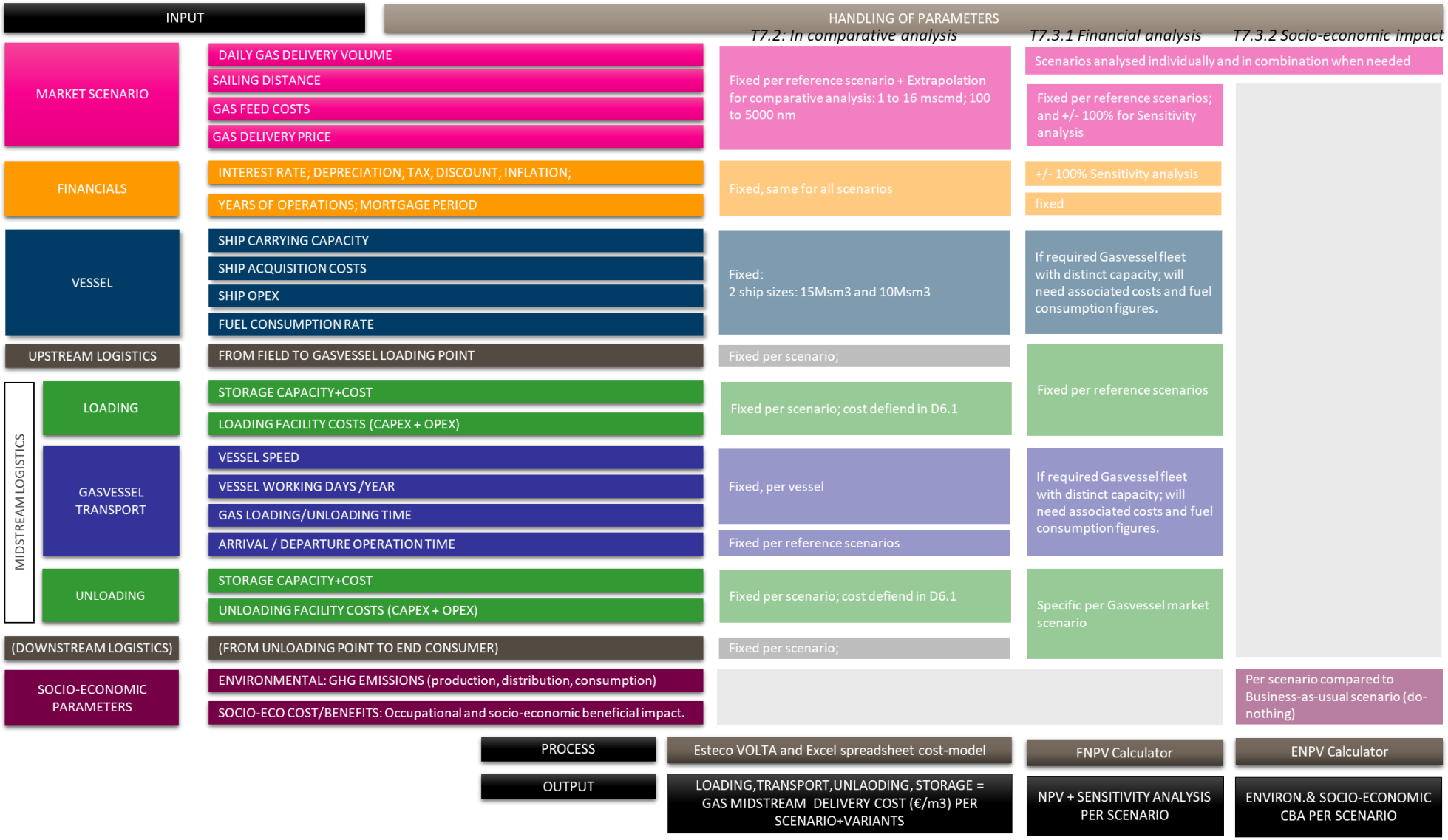


Figure 2: WP7 input data collected and utilisation in T7.2 and T7.3

4.2 Status of data collection

Table 1: status of WP7 data collection

DATA categories	SOURCE	Stored (T7.1)	Input to	STATUS
General parameters	Gasvessel + external sources	Sheet "General parameters"	T7.3.1	Need QA
GASVESSEL Gas Delivery SCENARIOS: location, quantity, main input parameters for cost calculation	WP2	Sheet "7.1.2 Reference Scenarios"	T7.2	Cost calculation done manually in Excel workbook ("7.1.2 REFERENCE SCENARIOS") to be finalized, and verified with Volta.
Scenarios cost parameters (CAPEX, OPEX, VOYEX)	WP2	Sheet "Reference Scenarios"		Need QA
Gas feed costs, gas sales prices	WP2,WP7	Sheet "7.1.2 Reference Scenarios"		to be defined (T7.3)
Scenario combination	WP7	Sheet "7.1.2 Reference Scenarios"	T7.3	to be defined (SINTEF / CHC)
Ship, pressure vessel technical parameters, building costs, OPEX (crew, stores/consum, technical mgt, insurance, general costs, maintenance)	WP3-4-5	Sheet "Ship parameters"	T7.2, T7.3	missing: • 10Msm3 OPEX and power system specifications (fuel consumption rate) • Need QA of fuel consumption rate (gas mode)
(un)loading concepts and infrastructure	WP6	Sheet "(un)loading system"	T7.2, T7.3	Missing OPEX. Need specification of storage system using Gasvessel cylinders (and applocation in Volta)
additional Storage	WP3-4-5-6	Sheet "7.1.2 Reference Scenarios"	T7.2, T2.3	Need QA storage volume and cost calculation + verify with Volta-software
Upstream and downstream costs	WP2,7	Sheet "7.1.2 Reference Scenarios"	T7.2	necessary for enable costarison of distribution tariffs among options (T7.2)
GASVESSEL CNG comparison scenarios – Extrapolated to a set of distance/volume cases (frequency, # vessels, distance, volume, midstream costs)	T7.2 (Volta)	Sheet " 7.2.1 CNG VOLTA cases"	T7.2 T7.3	To be calculated (CHC, SINTEF)
Cost of ALTERNATIVE MONITIZATION OPTIONS (per scenario) FLNG and pipeline	T7.2	Sheet " 7.2.2 Comparison transp options"	T7.2	To be estimated (CHC, ABS)
Possible combination of scenario – input to CBA	T7.2		T7.3	To be considered
Consideration of alternative floating CNG concepts	WP1	Sheet: "7.2.3 Alternative CNG concepts"	T7.2	NP
Financial NPV and Sensibility analysis	T7.3	Sheet "7.3.1.1 FNPV"; "7.3.1.2 Sensitivity"	T7.3	Draft available; need QA; sensibility analysis variables to be defined.
Environmental impact of Gasvessel (per scenario) (GHG air emissions)	T7.2	Sheet "7.3.2.1 Emissions"	T7.2 T7.3	To be calculated (SINTEF)
Socio-Economic Impact Qualitative and quantitative parameters to be defined	T7.3	Sheet " 7.3.2.2 ENPV"	T7.3	Other WP7 partners Methodology to be established in T7.3

4.3 Gasvessel scenario cost parameters and preliminary cost calculation

A dataset of Gasvessel scenarios is available in WP7 CBA Database. It contains main technical and cost parameters, input variable as well as results of preliminary calculations (based on currently available data, output to be cross-checked with results from Volta-scenario cost analysis).

Category	**REFERENCE SCENARIOS INPUT PARAMETERS FOR COST CALCULATION**
Source:	WP2: midtstream tariff matrix calculation; WP2/7: NP midstream cost calculation; Esteco VOLTA scenario summary matrix
Last update	21.10.2019
Notes	Cost structure established; can be used by adding acenarios or modifying input data

DRAFT Gasvessel scenarios cost analysis (input data to be updated; calculation to be re-run with Volta software)		**Gasvessel Scenarios >>**	**EAST MEDITERRANEAN**			**BARENTS SEA**				**BLACK SEA**
Calculation parameters	UNIT	Source	**CYPRUS-CRETE 1**	**CYPRUS-LEBANON 1**	**CYPRUS-EGYPT 5**	**ALKE 1 Nyhamna**	**ALKE 2 Polarled**	**J.CASTBERG 1 Nyhamna**	**J.CASTBERG 2 Polarled**	**UKRAINE 1**
Total gas demand (mmscmd)	mmscmd	scenario	**1,4**	**3,70**	**16,95**	**1,18**	**1,18**	**1,29**	**1,29**	**6,3**
SHIP PARAMETERS										
Ship aquisition cost -1 ship	M€	Gasvessel WP5	254	254	254	254	254	254	254	254
Ship working days per year	days	Gasvessel WP1	350	350	350	350	350	350	350	350
Years of operation	years	Gasvessel WP1	20	20	20	20	20	20	20	20
Morgage period	years	Gasvessel WP1	10	10	10	10	10	10	10	10
Interest rate (legal Italy 2019)	%	Gasvessel WP1	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8
CAPEX										
Ship capacity per ship	Mm3	Gasvessel WP5	12	9	12	9	9	9	9	12
Sailing distance	nm	Scenario WP2	400	120	285	646	377	686	422	578
Ship speed	knots	Gasvessel WP5	16	16	16	16	16	16	16	16
Ship Investment cost	M€	calculated	275	275	275	275	275	275	275	275
Ship CAPEX (/year)	M€/year	calculated	14	14	14	14	14	14	14	14
OPEX										
Ship OPEX (year)	M€ per ship/year	Gasvessel WP5 (15Mship)	3,40	3,40	3,40	3,40	3,40	3,40	3,40	3,40
Ship OPEX - Life time	M€	calculated	68,04	68,04	68,04	68,04	68,04	68,04	68,04	68,04
VOYAGE										
Arrival operation time / mooring (both ends)	hours	Scenario WP2	5	5	5	5	5	5	5	5
Departure operation time / unmooring (both ends)	hours	Scenario WP2	5	5	5	5	5	5	5	5
Operational time (hours) without sailing	hours	Sum operat. time	10	10	10	10	10	10	10	10
GAS LOADING TIME (hours)	hours	Gasvessel WP5,6	33	23	33	33	33	33	33	33
GAS UNLOADING TIME (hours)	hours	Gasvessel WP5,6	60	42	60	60	60	60	60	60
Vessel fuel comsumption - Diesel (gas mode)	g_per_kWh	Gasvessel WP5 (15Mship)	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
Vessel fuel comsumption - Gas (gas mode)	g_per_kWh	Gasvessel WP5 (15Mship)	135	135	135	135	135	135	135	135
Diesel fuel cost	€/kg	WP7 / to be defined	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
Gas fuel cost (for Gasvessel)	€/kg	WP7 / to be defined	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
Vessel power need (3 Engines @4240 kW, 85% load)	kW	Gasvessel WP5 (15Mship)	10812	10812	10812	10812	10812	10812	10812	10812
Voyage/roundtrip duration (sailing, mooring, loading)	days	to be verified	6,38	3,75	5,78	7,66	6,26	7,86	6,49	7,30
total KWh per round trip	kWh	to be verified	1 654 236	973 080	1 498 814	1 986 705	1 623 152	2 040 765	1 683 969	1 894 803
Gas consumption compressors/ (un)loading per voyage	ton og gas	calculated	80	80	80	80	80	80	80	80
Diesel consumption 85% load, gas mode per roundtrip	g	to be verified	3 804 743	2 238 084	3 447 271	4 569 422	3 733 248	4 693 760	3 873 129	4 358 047
Gas cosnumption 85% load, gas mode per roundtrip	g	to be verified	303 321 860	211 365 800	282 339 823	348 205 175	299 125 453	355 503 275	307 335 815	335 798 405
Diesel Fuel cost	€	calculated	2 092,61	1 230,95	1 896,00	2 513,18	2 053,29	2 581,57	2 130,22	2 396,93
Gas fuel cost	€	calculated	15 166	10 568	14 117	17 410	14 956	17 775	15 367	16 790
total fuel cost per round trip	€	calculated	17 259	11 799	16 013	19 923	17 010	20 357	17 497	19 187
#roundtrip	#	calculated	54,9	93,3	60,6	45,7	56,0	44,5	53,9	47,9
Annual fuel cost (all voyages)	€	calculated	947 537	1 101 262	970 309	910 786	951 742	905 942	943 659	919 655
Voyage cost - Life time (20 years)	M€		18,95	22,03	19,41	18,22	19,03	18,12	18,87	18,39
STORAGE										
Capacity per trip per ship (daily gas rate)	Mm3	calculated	1,88	2,40	2,08	1,18	1,44	1,14	1,39	1,64
Ships number - minimal	#	to be verified	0,74	1,54	8,16	1,00	0,82	1,13	0,93	3,83
Nr ship decided	#	calculated	1	2	8	1	1	1	1	4
Total Ships cost (M €) all ships included	M€	calculated	254	508	2032	254	254	254	254	1016
Coastal storage autonomy (volume)	Mm3	NP calculation	8,9	6,9	12,2	9,0	7,4	10,1	8,4	11,5
Storage capacity (M m3) - decided	Mm3	to be verified	9,0	7,0	12,3	9,1	7,4	10,2	8,4	11,6
Storage uni capacity	Mm3	Gasvessel WP4	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012
Number of units - minimum	#	to be verified	750	583	1025	758	617	850	700	967
Storage unit cost (1 unit=12000 m3)	M€ per cylinder	Gasvessel WP4	0,2	0,2	0,2	0,2	0	0,2	0,2	0,2
Storage Investement cost	M€	calculated	150	117	205	152	0	170	140	193
Storage cost (M€)			162,4	126,3	222,0	164,2	0,0	184,1	151,6	209,4
LOADING/UNLOADING FACILITIES										
Loading facility cost	M€	Gasvessel WP6	261,25	212,53	261,25	187,47	187,47	193,09	193,09	828,17
Loading facility - Investment costs	M€	calculated	282,91	230,16	282,92	203,02	203,02	209,10	209,10	896,87
Loading facility annual OPEX	M€ per year	to be defined	0	0	0	0	0	0	0	0
Unloading facility cost	M€	Gasvessel WP6	250,6	201,0	253,9	199,2	199,2	198,8	198,8	253,4
Unloading facility - Investment costs	M€	calculated	271,4	217,7	274,9	215,7	215,7	215,2	215,2	274,4
Unloading facility annual OPEX	M€ per year	to be defined	0	0	0	0	0	0	0	0
Total Unloading / Loading investment costs	M€		533,5	431,2	536,8	402,2	402,2	407,9	407,9	1150,3
UPSTREAM / DOWNSTREAM COSTS & TARIFFS										
Upstream costs										
Gas production costs (gas feed costs)	€/M3	to be defined	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13
Loading costs (outside scope of project, ref WP6))	€	Gasvessel WP6	217 231 134	163 084 018	217 231 134	2 768 969	2 768 969	2 768 969	2 768 969	-
Upstream costs (other)		to be estimated	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Total upstream cost per unit	€/M3	calculated	0,0213	0,0060	0,0018	0,0003	0,0003	0,0003	0,0003	0,0000
Downstream costs										
Unloading costs (outside scope of project)	€	Gasvessel WP6	2 486 538	2 486 538	2 486 538	2 486 538	2 486 538	7 777 761	7 777 761	1 928 016
Unloading costs (outside scope of project) per unit	€/M3	calculated	0,00024	0,00009	0,00002	0,00029	0,00029	0,00083	0,00083	0,00004
Gas downstream distribution costs	€/M3	to be defined	0	0	0	0	0	0	0	0
RESULTS										
Gasvessel costs										
Transportation cost	€/M3	WP7	0,035	0,014	0,003	0,042	0,042	0,038	0,038	0,008
Unloading/loading unit cost	€/M3	WP7	0,052	0,016	0,004	0,047	0,047	0,043	0,043	0,025
Storage unit cost	€/M3	WP7	0,016	0,005	0,002	0,019	0,000	0,020	0,016	0,005
Total Gasvessel gas delivery cost (midstream cost)	€/M3	WP7	0,104	0,034	0,009	0,108	0,089	0,101	0,098	0,037
Tariff calculation										
Upstream tariff	€/M3	to be verified	0,151	0,136	0,132	0,130	0,130	0,130	0,130	0,130
Midstream tariff	€/M3	to be verified	0,104	0,034	0,009	0,108	0,089	0,101	0,098	0,037
Downstream tariff	€/M3	to be verified	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,000
Gas sale price	€/M3	to be defined	0,211	0,211	0,211	0,211	0,211	0,211	0,211	0,211
Profit estimation	€/M3	to be verified	-0,044	0,041	0,070	-0,027	-0,008	-0,021	-0,018	0,044
Other KPIs for comparison with alternative concepts										
Total Gasvessel gas delivery cost (midstream cost)	€/m3	WP7	0,104	0,034	0,009	0,108	0,089	0,101	0,098	0,037
Total gas delivery (lifetime)	Mm3	to be verified	13 176	33 600	116 343	8 229	10 072	8 011	9 708	46 014
Ship cost - per unit	€/m3	calculated	0,021	0,016	0,019	0,033	0,027	0,034	0,028	0,024
Storage cost - per unit	€/m3	calculated	0,012	0,004	0,002	0,020	0,000	0,023	0,016	0,005
Loading/Unloading facility cost per unit	€/m3	calculated	0,040	0,013	0,005	0,049	0,040	0,051	0,042	0,025
other KPIs -		to be defined								

Figure 3: Screenshot of Gasvessel scenarios datase.

4.4 Application of CBA datastructure

4.4.1 T7.2: comparative analysis

The WP7 database contains spreadsheet dedicated to the Comparative analysis of Gasvessel CNG concept with alternative transportation options (LNG, pipeline).

A brief description of the methodology and approach to be followed in T7.2 is available in Appendix 2. The methodology is to be further described and applied in Task 7.2.

4.4.2 T7.3: Cost-benefit analysis

T7.3.1: Financial NPV

The WP7 database contains spreadsheet dedicated to Financial NPV calculation and sensitivity analysis applicable for individual scenarios.

A brief description of the methodology and approach to be followed in T7.2 is available in Appendix 3. The methodology is to be further described and applied in Task 7.3.

T7.3.2: Socio-economic analysis

The WP7 database contains spreadsheet dedicated to the socio-economic analysis, one for socio-economic impact and one for environmental impact.

The methodology is to be further described and applied in Task 7.3.

5. Conclusions

Deliverable D7.1 outlines the structure and content of the CBA database per October 2019. Due to ongoing work to further populate the database - collecting updated data from other WPs as well as specific data to be identified through T7.2 and 7.3 -, this deliverable is to be registered as the first of a serie of 4.

Version 1	October 2019	Cost and technical parameters from GASVESSEL (source: WP1-6); Datastructure; and calculation model description.
Version 2	May 2020	Updated input data and CBA calculation spreadsheets
Version 3	October 2020	Updated with output from T7.2 and T7.3
Version 4	January 2021	Updated with final results from T7.2 and T7.3

T7.1 will follow up the work being done in WP7 and the CBA tool will expand as T7.2 and T7.3 tools.

6. Proposals for Workshops and Dissemination

A preliminary comparison analysis and Gasvessel cost-benefit analysis will be presented though a short summary presentation Q2 -2020.

7. Appendices

7.1 WP7 CBA Spreadsheet

Available on Gasvessel WP7 sharpoint: https://sintef.sharepoint.com/:x:/r/teams/work-2350/Shared%20Documents/WP7%20CBA/Gasvessel%20WP7%20Sharepoint/Tools/GASVESSEL%20WP7%20T7.1%20Database%20version0.2.xlsm?d=w9d8d5436c64d4767b486b785879adbfc&csf=1&e=gSHhQg

7.2 T7.2: comparative Analysis – Draft methodology description

Outline / main assumptions:

The purpose of the comparative analysis is to identify the niche market (volume and distance) for CNG and Gasvessel in particular.

The main deliverable will be a diagram indicating the combination volume/distance for which either CNG, LNG or pipeline is most cost competitive. CNG solution to be compared with available technically feasible solutions.

The comparison shall be based on delivery costs from loading point to unloading point, i.e. consider the cost associated to loading / unloading concepts.

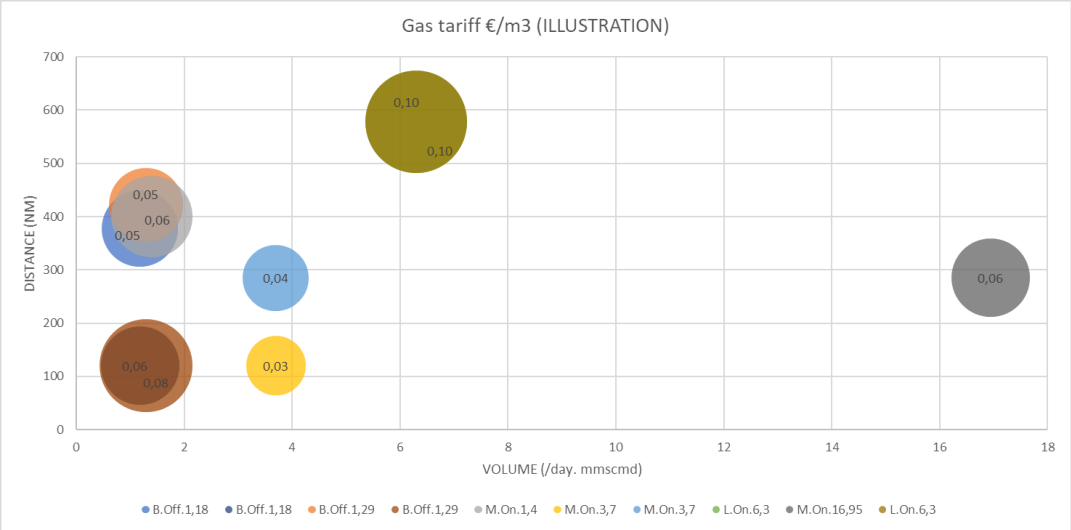
The basis for comparison is a scenario where none of the options is today available, i.e. have to be development (including investment costs).

To be able to plot a sufficient number of cases for comparison with LNG and pipeline, T7.2 will take the identified market scenarios as starting point, then extend the distance and volume for the corresponding scenarios.

One challenge is the overlapping volume and distance between the market scenarios currently identified, while the loading/unloading concepts vary. For instance, a similar combination volume/distance can be found in the Cyprus-Crete1 scenario (ref scenario list attached), and the Castberg-Polarled, while the (un)loading concepts varies from onshore-onshore to offshore-offshore. To be able to offer relevant comparisons cng-lng-pipeline, it is suggested to break-down the analysis in 4 distinct logistics concepts offshore-offshore, Offshore-onshore, onshore-onshore)

Approach:

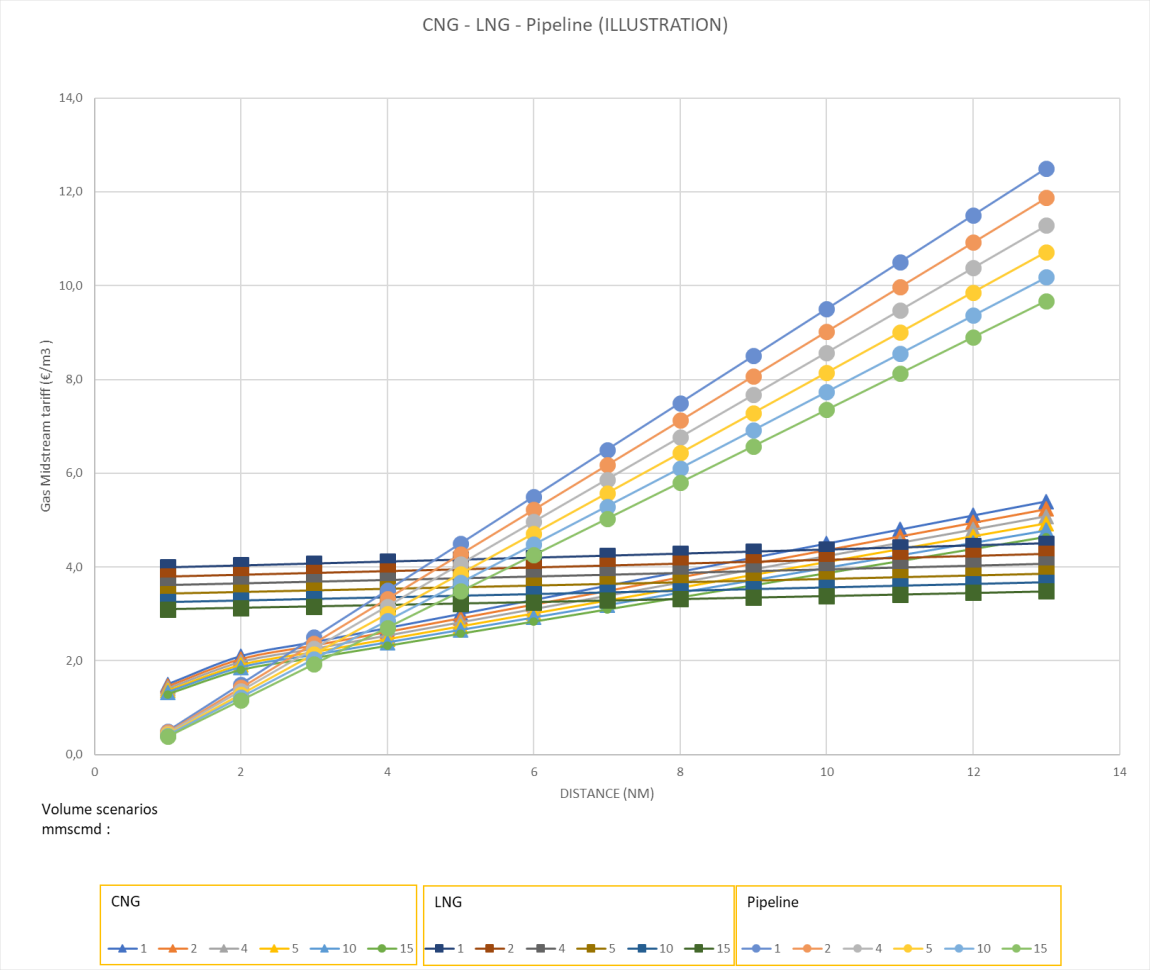
1. Identify the missing cost input to the current Gasvessel scenarios (facility costs, storage, fuel costs etc.)
    a. Offshore-offshore: loading point FPSO + hose, unloading point buoy + hose. Reference scenarios: Barents sea delivery Aasta Hansen.
    b. Offshore-onshore: loading point FPSO + hose, unloading point berth + storage.
    c. Onshore-onshore: berth + required storage. Reference scenarios: Black sea and East Med. Described in "Midstream tariff matrix calculation, NP march 2019"
    d. Near-shore – onshore: for the scenarios (East Med) requiring a pipeline to transfer gas from offshore field to loading point for Gasvessel, the pipeline will be considered as part of "upstream facility". The investment cost and opex of this upstream facility will be estimated using Questor (CHC). Considering this scenario concept is important to be able to compare cng, pipeline, lng from field to market; and doing so considering stranded gas. The scenarios are the same, just considering distinct options for loading/unloading concepts.
    e. All other parameters (fuel cost etc.): fixed
2. Run all Gasvessel specific scenarios in Volta and compare results accross logistics concepts.



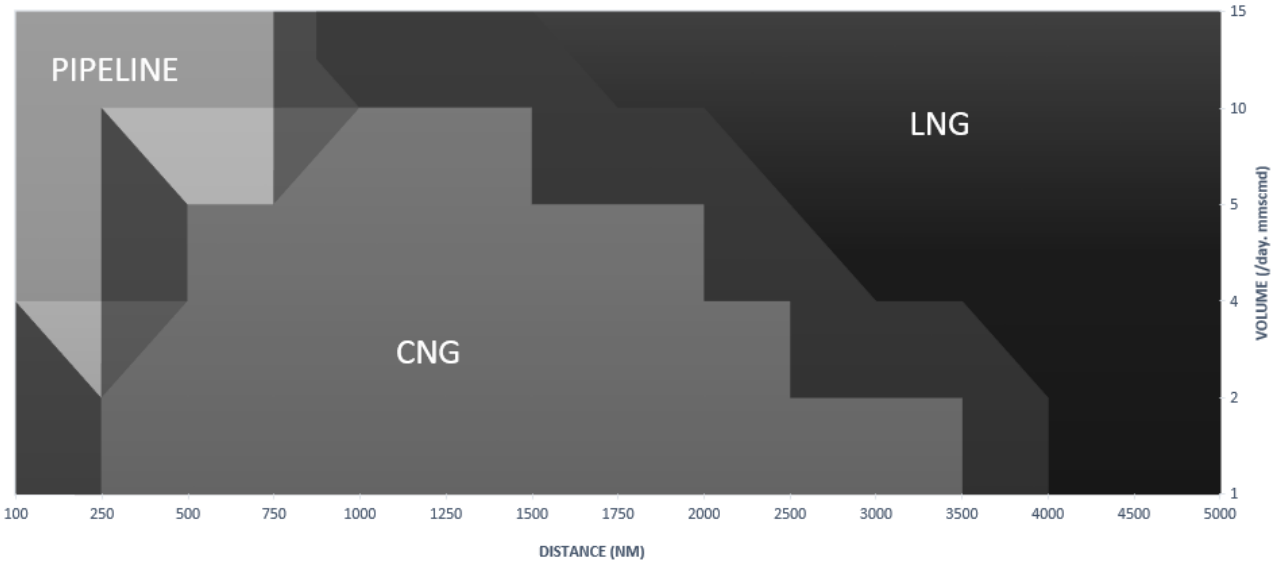
3. Extend Gasvessel scenarios into generic cases from 1 to 16 mscmd (size of market demands in Gasvessel scenarios) and from 100 to 5000nm. All other parameters kept fixed. Also vessel size. The purpose is to establish a set of theoretical scenarios for identifying a sufficient amount of observations for comparison with LNG and pipeline.

4. Run all cases in volta, and fill up the CNG cost matrix.

5. Identify LNG comparison cases.
    a. Same volume, vessel size and delivery, storage need etc. as in the CNG scenarios.
    b. Seek optimal set-up for same daily delivery (size size and storage)
    c. Input data / cost estimations: will be retrieved from secondary data from existing/previous studies (identified by Stavros: Enagas 2017, UWA 2017, ERIA 2018, IGU 2018, Oxford 2018, and Wartsila doc). We considered using Volta and adapting to LNG case for ensuring best possible comparison, but we conclude that there are sufficient secondary data for bulding estimates.
    d. Use conversion matrix from ABS and CHC
    e. Other estimations:
        i. Vessels identified: 20 000 sm3 LNG (=12Msm3 CNG) 120 MUSD; 14000 sm3 LNG (=8,2 Msm3 CNG) 60 MUSD; 7500 sm3 LNG (=4,4 Msm3 CNG) 52 MUSD
        ii. Storage need: 10-45 M sm3 CNG = 17000-77000 sm3 LNG
    f. Calculate unit cost of gas delivery (€/sm3) for all the scenarios (1-16 mscmd, 100-5000 nm). From loading point to unloading point, including facility and storage infrastructure and operation costs.
6. Pipeline cases.
    a. Identify input data needed to calculated pipeline cost (capex+opex)
    b. CHC to run Questor-tool to identify €/sm3 cost for the pipeline options for all the scenarios (1-16 mscmd, 100-5000 nm).
7. Build comparison curve volume / costs for the 3 options.
   For all the scenarios, we suggest to keep unit cost, not NPV.



8. Build competitiveness graph – showing vol / distance area with corresponding competitive option, base on all the scenarios tested. Illustration (excel contour chart):



7.3 T7.3: NPV and Sensitivity analysis

For each gasvessel scenario, as well as combination of market scenarios when necessary, T7.3.1 will calculate the NPV of the investmenet project over the entire life of the project.

Category	NPV, SENSITIVITY												
Source:	WP7 T7.3 Deliverable 7.3												
Last update	05.10.2019 (DRAFT FOR T7.3)												
Notes	Extimate NPV and IRR based on cost and technical paramaters from each scenarios and/or combination of scenarios in sheet "MAIN SCENARIOS/Volta optimized"												
Scenario Reference	ALKE 2 Polarled	*EXAMPLE SCENARIO FOR FNPV calculatio*											
Scenario Name	ALKE 2 Polarled												
Number of vessels	1	Number of vessel of same capacity per scneario investigated											
Vessel size	15M	Cost values to be retrieved from Ship Parameters											
Vessel building cost €	254 000 000	Ship+containement system											
Loading facilities													
Unloading facilities	395 965 910	Note: suggest to inlcude the (un)loading costs "outside project scope" in the FNPV calculation											
Total investment costs	649 965 910	***649 965 910***											
Loan	**324 982 955**	*ref: 50%=>*	324 982 955										
Nominal interest rate	2 %	*to be verified*											
Reduced balance depreciat	10 %	*to be verified*											
Annual operation time (da	350	*to be streamlined (per scenario)*											
Rate of taxation	15 %	*to be defined*											
Rate of inflation	2 %	*to be defined*											
Discount rate	7 %	*to be defined*											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
REVENUES													
Gas delivery - Annual (m3)	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503 580 350	503
Gas delivery price (€/sm3)	0,211	0,215	0,219	0,223	0,228	0,232	0,237	0,242	0,247	0,252	0,257	0,262	
Gas sales revenue (€/year)	**106 016 916**	**108 137 254**	**110 299 999**	**112 505 999**	**114 756 119**	**117 051 241**	**119 392 266**	**121 780 112**	**124 215 714**	**126 700 028**	**129 234 029**	**131 818 709**	**134**
COSTS													
Upstream costs													
Unit feed gas cost (€/mmbt	2												
Unit feed gas cost (€/Sm3)	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	
Feed gas cost €	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40 286 428**	**40**
Midstream costs													
OPEX (ship OPEX)	3 401 784	3 469 820	3 539 216	3 610 000	3 682 200	3 755 844	3 830 961	3 907 581	3 985 732	4 065 447	4 146 756	4 229 691	4
VOYEX (fuel cost)	951 742	970 777	990 193	1 009 996	1 030 196	1 050 800	1 071 816	1 093 253	1 115 118	1 137 420	1 160 168	1 183 372	1
OPEX loading infrast.													
OPEX unloading infrast.													
EARNINGS (EBITDA)	**61 376 962**	**63 410 229**	**65 484 162**	**67 599 574**	**69 757 294**	**71 958 169**	**74 203 061**	**76 492 850**	**78 828 436**	**81 210 733**	**83 640 677**	**86 119 219**	**88**
Depreciation	0	64 996 591	58 496 932	52 647 239	47 382 515	42 644 263	38 379 837	34 541 853	31 087 668	27 978 901	25 181 011	22 662 910	20
Interest on loan	0	6 499 659	6 369 666	6 242 273	6 117 427	5 995 079	5 875 177	5 757 673	5 642 520	5 529 670	5 419 076	5 310 695	5
EBT	61 376 962	- 8 086 021	617 565	8 710 063	16 257 352	23 318 827	29 948 047	36 193 324	42 098 248	47 702 163	53 040 589	58 145 614	63
Tax		-	92 635	1 306 509	2 438 603	3 497 824	4 492 207	5 428 999	6 314 737	7 155 324	7 956 088	8 721 842	9
Profit/loss after taxation	-	8 086 021	710 199	10 016 572	18 695 955	26 816 651	34 440 254	41 622 322	48 412 985	54 857 487	60 996 678	66 867 456	72
Repayment of loan		16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16 249 148	16
Cash flow	- 324 982 955	40 661 422	42 957 984	46 414 663	49 829 322	53 211 766	56 570 943	59 915 028	63 251 506	66 587 240	69 928 541	73 281 218	76
Cash (no loan)	- 649 965 910	63 410 229	65 391 528	66 293 065	67 318 691	68 460 345	69 710 854	71 063 852	72 513 699	74 055 409	75 684 588	77 397 377	79
	NPV (w/ loan)	358 102 825	*179383325*										
	IRR (w/ loan)	17 %	*12 %*										

7.1.0 General Parameters | 7.1.1 Ship Parameters | 7.1.2 REFERENCE SCENARIOS | 7.1.3 (un)loading system | **7.3.1.1 FNPV** | 7.3.1.2 Sensitivity | 7.2.1 CNG VOLTA CASES

Figure 4: screen-shot of NPV tool in WP7 CBA Spreadsheet

The sensitivity analysis will be carried out for the parameters which are believed to have a significant impact on the NPV. The variation suggested is -100% to +100%.

Category	**SENSITIVITY**										
Source:	WP7 T7.3 Deliverable 7.3										
Last update	05.10.2019 (DRAFT FOR T7.3)										
Notes	Extimate NPV and IRR sensitivity to selected parameters										
Scenario Reference	B1.1										
Scenario Name	Barent sea 1.1 Alke-Polarled (Off-Off)							Run sensitivity ALL			
Number of vessels	1	Number of vessel of same capacity per scneario investigated									
Sensitivity analyses - main parameters											
	Total investment costs			Loan			Gas feed cost			Gas sale price	
Calculate NPV	*649 965 910*			*324982955*			0,08				
Calculate Variation:	649 965 910			324 982 955			0,08				
Variation	**Investment cost**	**NPV-Inv.C**	IRR-Inv.C	**Loan**	**NPV-loan**	IRR-Loan	**Gas Feed Cost**			**Gas Sale pric**	
100 %	1 299 931 820	-318 865 187	3 %	649 965 910	617 074 008	#NUM!	0,16	-112 020 098	4 %		
90 %	1 234 935 229	-252 017 892	4 %	617 467 615	599 608 742	#NUM!	0,15	-66 195 402	5 %		
80 %	1 169 938 638	-185 170 596	4 %	584 969 319	582 183 761	#NUM!	0,14	-20 000 402	6 %		
70 %	1 104 942 047	-118 015 235	5 %	552 471 024	564 858 504	#NUM!	0,14	26 375 289	8 %		
60 %	1 039 945 456	-50 784 328	6 %	519 972 728	547 533 246	#NUM!	0,13	72 978 978	9 %		
50 %	974 948 865	16 660 122	7 %	487 474 433	530 207 989	#NUM!	0,12	119 922 293	10 %		
40 %	909 952 274	84 347 101	8 %	454 976 137	512 882 731	#NUM!	0,11	166 973 176	12 %		
30 %	844 955 683	152 267 822	10 %	422 477 842	495 557 474	#NUM!	0,10	214 468 736	13 %		
20 %	779 959 092	220 497 019	12 %	389 979 546	478 232 216	#NUM!	0,10	262 044 224	14 %		
10 %	714 962 501	289 148 080	14 %	357 481 251	461 056 260	#NUM!	0,09	310 033 069	15 %		
0 %	**649 965 910**	**358 102 825**	**17 %**	**324 982 955**	**443 883 869**	**#NUM!**	0,08	**358 102 825**	**17 %**		
-10 %	584 969 319	427 743 062	21 %	292 484 660	426 711 478	45 %	0,07	406 619 486	18 %		
-20 %	519 972 728	498 072 079	27 %	259 986 364	409 539 087	29 %	0,06	455 136 147	19 %		
-30 %	454 976 137	568 623 483	39 %	227 488 069	392 366 696	22 %	0,06	504 213 543	21 %		
-40 %	389 979 546	639 174 886	73 %	194 989 773	375 194 305	19 %	0,05	553 294 967	22 %		
-50 %	324 982 955	709 726 290	#NUM!	162 491 478	358 102 825	17 %	0,04	602 376 391	23 %		
-60 %	259 986 364	780 277 694	#NUM!	129 993 182	341 097 340	15 %	0,03	651 457 815	24 %		
-70 %	194 989 773	850 829 098	#NUM!	97 494 887	324 091 854	14 %	0,02	700 539 239	26 %		
-80 %	129 993 182	921 380 502	#NUM!	64 996 591	307 086 369	13 %	0,02	749 620 663	27 %		
-90 %	64 996 591	991 931 906	#NUM!	32 498 296	290 080 883	12 %	0,01	798 702 087	28 %		
-100 %	0	1 062 483 310	#NUM!	0	273 075 398	11 %	0,00	847 783 511	30 %		

Figure 5: screen-shot of Sensitivity analysis tool in WP7 CBA Spreadsheet