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Decision Support Model

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Reviewed by		R. Russo, A. Clarich. Z. When
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Project Coordinator Name	Mr. Loris COK
Project Coordinator Organization Name	NAVALPROGETTI Srl
Address	Via dei Papaveri, 21 34151 TRIESTE (Italy)
Phone Numbers	0039 040 212918
Email	loris.cok@navalprogetti.net; gasvessel@navalprogetti.net
Project web-sites & other Access Points	www.gasvessel.eu

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Glossary, abbreviations and acronyms

EU	The European Commission or in general Europe
INEA	Innovation and Networks Executive Agency of European Commission
PO	Project Officer assigned by INEA to GASVESSEL Project
Partner	Company member of the GASVESSEL Project Consortium

Project	The GASVESSEL no. 723030 Project
CNG	Compressed Natural Gas
GA	Grant Agreement
CA	Consortium Agreement
PMS	Project Management System
PM	Project Management
TM	Team Management
PA	Project Administration
P&C	Planning and Controls
PR	Project Reporting
DC	Document Control
HSEQ	Health, Safety, Environment and Quality controls and assurance
PRM	Procurement Management
MM	Materials Management
WP	Work Package
NP	Navalprogetti Srl – Trieste – Italy – The Coordinator – Partner -Lead Beneficiary of WP1 and WP5
DOW	Dow Deutschland Anlaghengesellschaft mbH - Partner
DOWA	DowAksa Deutschland GMBH - Partner
PNO	PNO INNOVATION – Belgium – Partner – Lead Beneficiary WP9
VTG	VNIPITTRANSGAZ – Kyiv – Ukraine – Partner – Lead Beneficiary WP6
SINTEF	SINTEF OCEAN AS – Trondheim – Norway – Partner – Lead Beneficiary WP7
BMP	BM Plus Srl – Buttrio – Italy – Partner – Lead Beneficiary WP4
CNGV	CNGV d.o.o. – Izola – Slovenia – Partner – Lead Beneficiary WP3
CEN	CENERGY Srl – Trieste – Italy - Partner
HLL	Hanseatic Lloyd Schiffahrt GMBH & Co – Bremen – Germany - Partner

CHC	Cyprus Hydrocarbon Company – Nicosia – Cyprus – Partner – Lead Beneficiary of WP2
EST	ESTECO S.p.A. – Trieste – Italy - Partner
ABS	American Bureau of Shipping (Hellenic) – Athens – Greece – Partner – Lead Beneficiary WP8
O&G	Oil and Gas
WP1	Project Management
WP2	Scenario analyses
WP3	Prototyping activities, design of pressure cylinders and prototyping pilot line
WP4	Prototyping of pressure cylinders. Procurement/construction/arrangement of prototyping pilot line
WP5	Ship Design
WP6	Offshore & Onshore gas loading/unloading systems
WP7	Costs and Benefits Analysis
WP8	Class Design Review – Safety Assessments
WP9	Dissemination and Exploitation
QA	Quality Assurance
QC	Quality Control
CBA	Costs Benefits Analysis
Work Plan	Planning of Activities in Attachment 1 of Project Management Plan D1.2
WBS	Work Breakdown Structure

Decision Support Model

1.0 Model Overview

This document outlines the methodology employed to develop the Scenario Decision Support Model (Model) for the gas delivery to the identified markets as part of the Gasvessel project. The Scenario Decision Support Model is prepared by using the optimization software modeFRONTIER.

2.0 Objectives

The main goal is to develop a tool (Scenario Decision Support Model) to optimize the delivery of gas from the identified source locations to the identified markets using the Gasvessel concept in different scenarios.

The outcome of the model is an estimation of the CNG transportation tariff for the identified scenarios, providing essential information like the optimal ship size, the ship speed and the fleet size in order to reach the lowest gas transport costs per unit volume.

Three geographic areas have been chosen as they establish early take-up potential for the Gasvessel concept.

- **Barents Sea Offshore Gas and Assorted Gas Fields to regional markets**
- **East Mediterranean Gas Fields to regional markets**
- **Black Sea Region from Georgia to Ukraine**

The model has been developed with short term and long term objectives. In the short term, the model is meant for internal optimization use, while in the long term it is expected to be finalized and opened for public use.

Specifically, in the short term, it is expected to:

- Create a decision making model in order to simulate the three geo-logistic scenarios, based on basic inputs like vessel dimensions, distances between ports, demand volume, intermediate storage, etc. This will identify any gaps in the value chain to be improved through the ship design, cylinder technology, loading/unloading facilities.

- Run the model for indicative optimization output that would allow preliminary comparisons between natural gas end tariffs and competitive alternatives. This will demonstrate the price competitiveness of CNG technology versus pipeline natural gas and alternatives, like LNG.

In the long term, the model is expected to be made available for general use. This suggests that upon successful completion of the Decision Making Model, and after the technology is optimized and its related costs are clarified, the platform will be made availabe to the public to run similar simulations for other scenarios. In this case, apart from the basic inputs mentioned above, the user will be able to insert costs of gas as well market prices.

3.0 Methodology Description

3.1 The concept behind the Model

The Scenario Decision Support Model (Model) is developed using the optimization software modeFRONTIER. modeFRONTIER is an integration platform for multi-objective and multi-disciplinary optimization, it offers a seamless coupling with third party engineering tools or any in house/generic code and enables the design process automation and facilitates analytic decision making.

For Work Package 2 (WP2), an in house script code is developed to calculate, within the modeFRONTIER platform, the proper output variables starting from selected input variables. For each scenario the input and output variables are identified by the partners (CHC, SINTEF, VTG and NavalProgetti) and provided to Esteco.

The Model collects information from different parts of the Gasvessel transportation system, the complete gas supply and demand value chain and the optimization algorithms available in modeFRONTIER to drive the process into an iterative loop (Figure 101) to reach the lowest costs per unit volume of the proposed CNG technology.

The Model is also able to analyze the relationship between inputs and outputs and in particular to assess the effect of each input variable on the relevant outputs (sensitivity analysis).

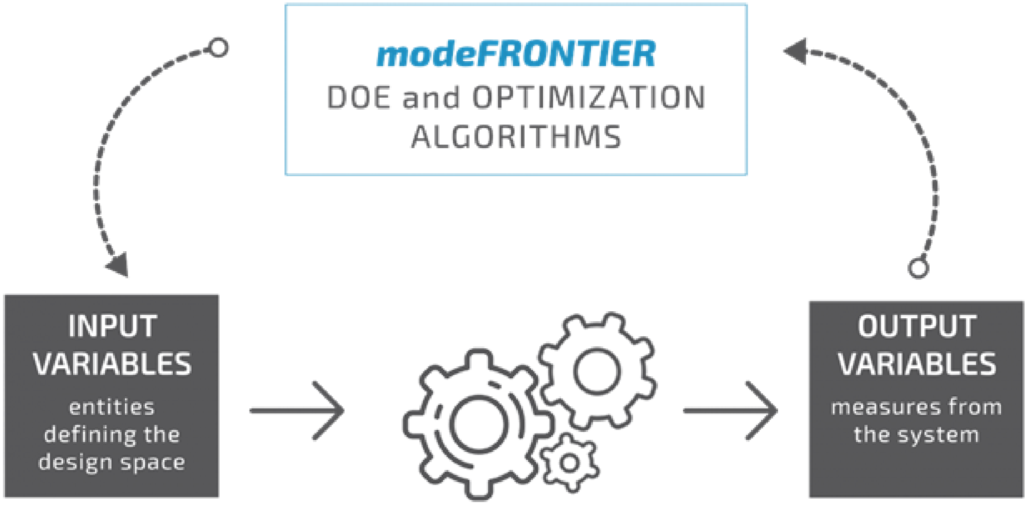


Figure 1: Optimization loop scheme

3.2 Model Description

As mentioned before, in the long run, the Model is designed to be flexible, generic and easily suitable for any further scenario in new areas. The flow chart below shows the logic:

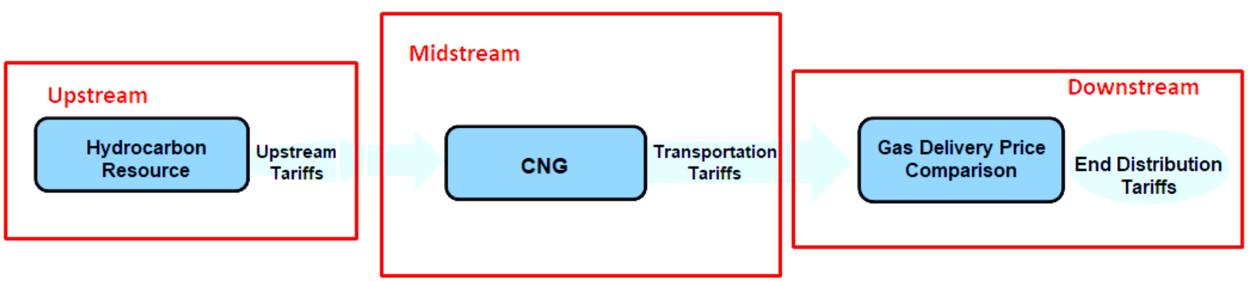


Figure 2: Gas transportation flow chart

The Model will only optimize the midstream CNG transportation cost; gas upstream tariff calculation and gas downstream cost estimation are to be provided by the partners for each scenario. The model evaluates the transportation tariff but it can report separately the following contributes.

- Gas upstram tarrifs (gas source and delivery cost up to the midstream element)
- CNG midstream tariffs (includes pre discussed elements)
- Gas downstream tariffs (distribution cost, receiving from the midstream element)

- Market gas prices (and alternative to Gasvessel monetisation options) for comparison reasons

Other alternative tariffs options can be provided by the partners for comparison but are not calculated by the Model. The alternative tariff to Gasvessel monetization options concern only the midstream element.

For each identified scenario, the Model will find the optimal ship size, ship speed and fleet size, taking into account storage at loading/unloading locations, in order to fulfill the estimated gas demand in the area at the lowest costs per unit volume (Gasvessel transportation tariff), given the geographical characteristics and the facilities at departure and destination.

This kind of information is an important input for the entire Gasvessel project, in particular the results of the scenarios analysis will be used in the design processes of WP3 (pressure vessel), WP4 (pre-industrial prototyping of pressure vessels) and WP5 (ship design). Once the optimization has been done, the commercial team, during the work at WP7 will perform an analysis of the markets to identify where the CNG concept is competitive compared to other monetization options.

3.2.1 Inputs

The input variables included in the Model are listed in the following table:

Parameter name	Description	Notes / Assumptions
Total gas demand [Nm3/year]	Gas demand in the identified market. Note that the total demand can be provided to different destination ports in the same geographical area; in such a case the gas rate demand to each destination port must be given.	This quantity is considered in general as a constant datum, not as an optimization parameter (but the impact of the different total demand on the final cost can be estimated). The gas volume loaded in each ship considers also the gas engine consumption for the transport.
Ship capability [Nm3]	Gas capability using cylinder (Pressure Vessel). It is the gas amount the ships can transport in each trip, it is a parameter to be optimized (the allowed ship sizes number can however be discrete within a certain range).	Optimization parameter. The transport by containers option can be made also available if requested
Ports distances matrix [Nautical Miles]	It represents the distance between the departure and the destination port(s). The distance is computed along the typical route from departure to destination.	It is a fixed parameter (no optimization). For each scenario the data are reported in a matrix with all the distances between source ports and delivery ports.
Ship velocity [knots]	The ship speed is an important parameter for the gas delivery tariff. It is the average ship velocity during the trips over one year in that geographical area.	Meteocean conditions can influence the ship velocity and fuel condition.
Working days per year [day]	It is the number of days that a ship is available over one year (considering all the stops for ordinary and extraordinary maintenance).	Meteocean conditions of a certain route may affect this input. It is a fixed parameter (no optimization).

Table 1: Main input variables for the Model

Other input parameters to estimate the CNG transportation tariff (not all of them will be accessible and changeable by the optimization platform):

Parameter name	Description	Notes / Assumptions
Gas loading time [hours]	Gas loading time from the gas source to the Gasvessel.	An accurate enough formula to estimate gas loading time as function of gas volume and pressure is given.
Gas unloading time [hours]	Gas unloading time from Gasvessel to the delivery port.	An accurate enough formula to estimate gas unloading time as function of gas volume and pressure is given.
Operational time [hours]	The operational times necessary for the ship at each arrival port.	It may be different for each port.

Ship CAPEX [€]	Ship CAPEX cost express in Euro.	Estimated the CAPEX cost as function of ship size.
Ship OPEX [€/Year]	Ship OPEX cost per year express in Euro.	Estimated the OPEX cost as function of ship size.
Activity years [year]	Life cycle of a ship for the scenario.	it is a fixed parameter (no optimization).
Mortgage period [year]	It is the period that it shall be returned on payment of the debt (investment).	it is a fixed parameter (no optimization).
Interest rate [%/year]	it is the amount of interest due per period (one year) as a proportion of the amount lent.	it is a fixed parameter (no optimization).

Table 2: Other variable parameters to estimate CNG transportation tariff

If available also the following data can be included to determine the total gas tariff.

Storage system CAPEX [€]	It is the CAPEX cost of the storage system at the loading and/or unloading location, it may be a function of the size	it is a fixed parameter (no optimization).
Storage system OPEX [€/year]	It is the OPEX cost of the storage system at the loading and/or unloading location	it is a fixed parameter (no optimization).
Loading/unloading facilities CAPEX [€]	It is the CAPEX cost of the loading and unloading system	it is a fixed parameter (no optimization).
Loading/unloading facilities OPEX [€/year]	It is the OPEX cost of the loading/unloading systems, it may be a function of the mass flow rate to load/unload	it is a fixed parameter (no optimization).

Table 3: Other constant parameters to estimate CNG transportation tariff

Moreover, in order to estimate also the gas value chain tariff, the model accepts the following information.

Parameter name	**Description**	**Notes / Assumptions**
Gas Upstream cost [€/Nm^3]	Gas cost at the source field; up to 3 options (A, B,C) can be analyzed at the same time).	If some options are not available the corresponding value can be set to 0

Upstream facilities CAPEX [€]	New gas terminal or pipeline building CAPEX; up to 3 options (A,B, C) can be analyzed at the same time	If some options are not available or not necessary the corresponding value can be set to 0
Gas Downstream facilities CAPEX [€]	New gas infrastructure/facilities CAPEX at the unloading points; up to 2 options (D and E) can be analyzed at the same time	If some options are not available or not necessary the corresponding value can be set to 0

Table 4: Additional information to calculate downstream tariff

3.2.2 Assumptions

The Model considers the following assumptions.

- Gas composition (Pure gas)
- Gas pressure (Upstream gas pressure 240 bar)
- Gas pressure (Downstream gas pressure to market 70 bar)
- One ship can transport gas to more than one destination port (the model automatically checks if this is possible and convenient) however each ship always goes back to the same departure port for the loading (this in case there were more than one departure port, the model is able to work with more loading points but for now the usage is limited to only one loading point per scenario).
- Each unloading point receives gas from ships that arrive always from the same loading point
- All the ships used to transport the gas in a certain geographical area are identical (i.e. it is not possible to have ships of different size or characteristics in the same area).

All the assumptions can anyway be adjusted anytime in the Model for best convenience.

3.2.3 Scenario Data and Description

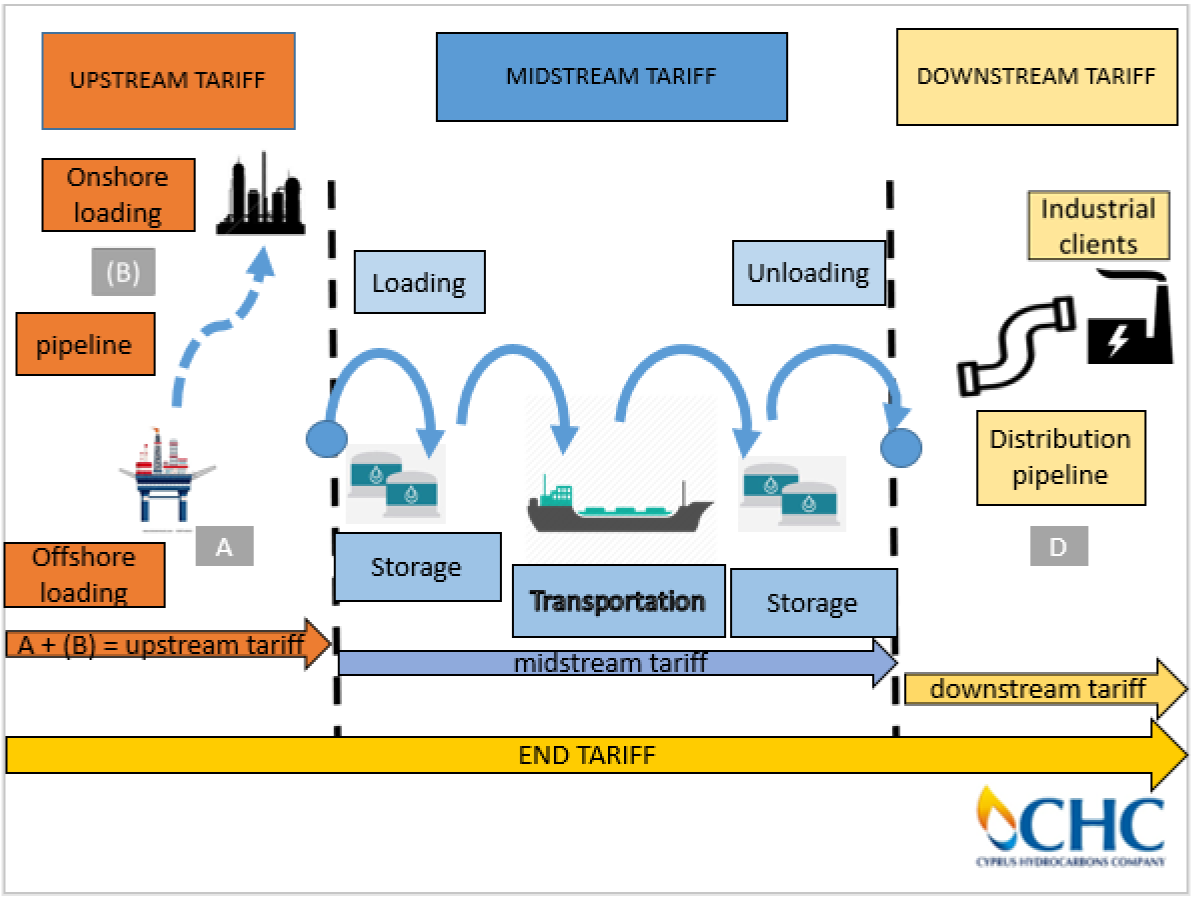
Three different scenarios cases were identified and characterized, representing both existing and new upcoming gas exploitations.

- **Barents Sea Offshore Gas and Associated Gas Field**
- **East Mediterranean Gas Fields**

- **Black Sea Region** (from Georgia to Ukraine)

In these cases the Gasvessel technology may be a valid alternative opportunity.

3.2.4 East Mediterranean Gas Field



Scenario 1: Offshore Eastern Mediterranean to Cyprus Vasilikos and Crete Linoperamata

Gas demand: 1445 mmscm/year

Vasilikos = 962 mmscm/year,

Linoperamata = 483 mmscm/year

Distance matrix [NM]:

Ports	Offshore Cyprus	Vasilikos
Vasilikos	159	-
Linoperamata	267	407

Scenario 2: Offshore Eastern Mediterannean to Cyprus Vasilikos

Gas demand: 962 mmscm/year

Distance matrix [NM]:

Ports	Offshore Cyprus
Vasilikos	159

Scenario 3: Offshore Eastern Mediterranean to Lebanon Zouk

Gas demand: 1252 mmscm/year

Distance matrix [NM]:

Ports	Offshore Cyprus
Zouk	269

Scenario 4: Offshore Eastern Mediterranean to Cyprus Vasilikos and Lebanon Zouk

Gas demand: 2214 mmscm/year

Vasilikos = 962 mmscm/year,

Zouk = 1252 mmscm/year

Distance matrix [NM]:

Ports	Offshore Cyprus	Vasilikos
Vasilikos	159	-
Zouk	269	123

Scenario 5: Offshore Eastern Mediterranean to Egypt

Gas demand: The gas demand for Egypt is very big, CNG can transport part of this demand, here we consider 3 different volume.

Gas demand (1): 962 mmscm/year

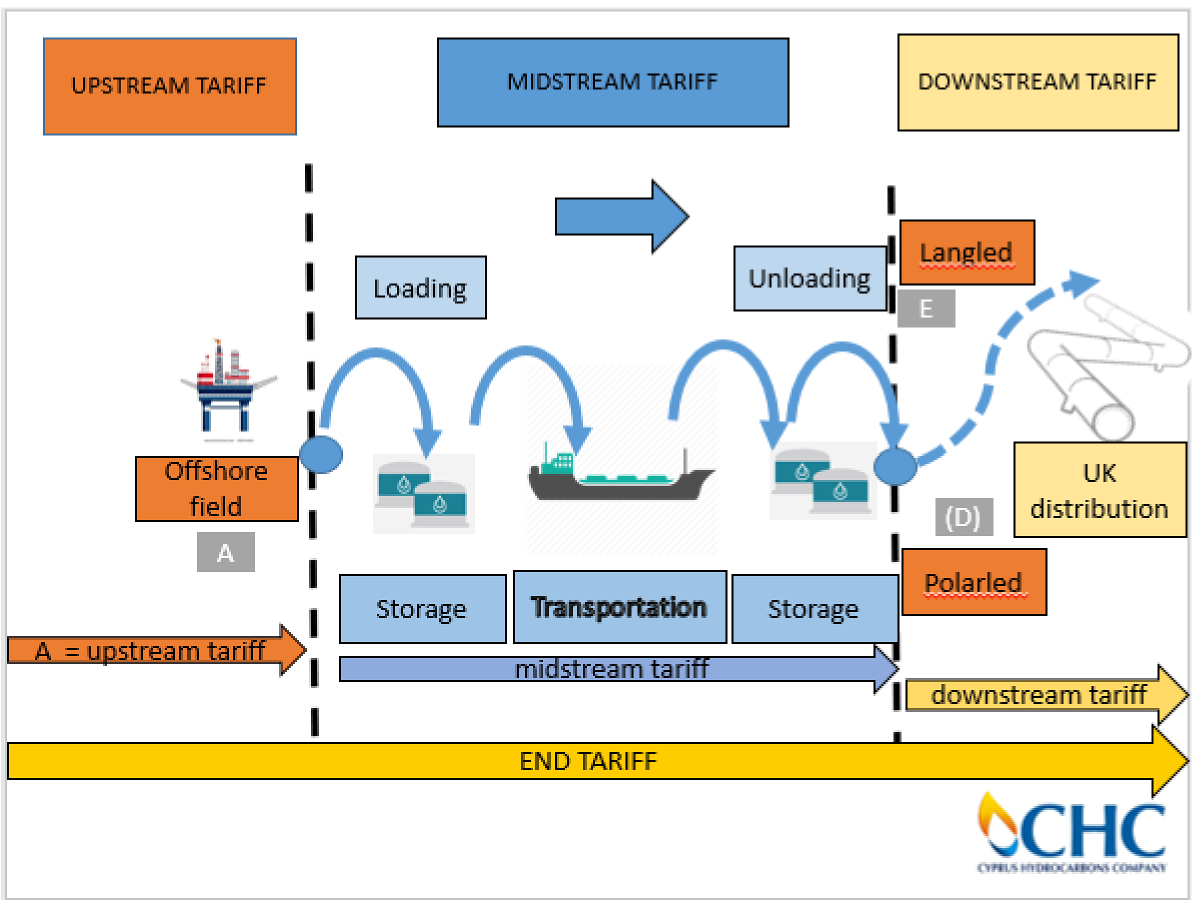
Gas demand (2): 2890 mmscm/year

Gas demand (3): 5781 mmscm/year

Distance matrix [NM]:

Ports	Offshore Cyprus
Egypt	188

3.2.5 Barents Sea Offshore Oil Field



Scenario 1: J.Castberg Oil & Gas field to Nyhamna or Polarled

Gas production: 507 mmscm/year (associate gas)

Distance matrix [NM]:

Ports	J.Castberg
Nyhamna	686
Polarled	800

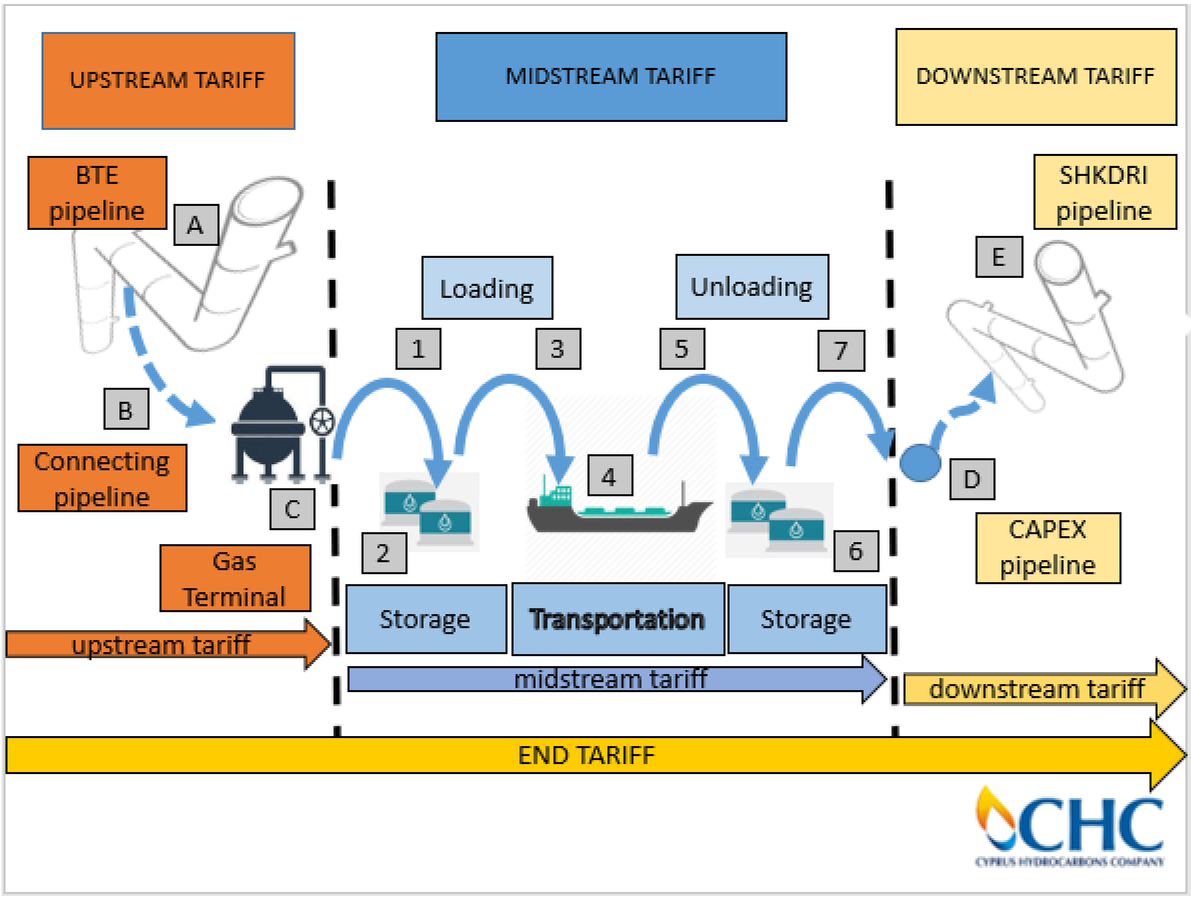
Scenario 2: Alke gas field to Nyhamna or Polarled

Gas production: 568,5 mmscm/year

Distance matrix [NM]:

Ports	Alke
Nyhamna	645
Polarled	743

3.2.6 Black Sea Region



Scenario 1: Shah-Deniz gas field to POTI-Georgia, delivery to YUZNE-Ukraine

Gas demand: 10.000 mmscm/year is the gas demand for Ukraine, Gasvessel may provide part of this demand. The platform investigates a possible demand range (for instance between 100 mmscm/year and 1.000 mmscm/year) to determine the gas quantity that could be conveniently delivered by the CNG technology.

Distance matrix [NM]:

Ports	POTI-Georgia
YUZNE-Ukraine	578

3.3 Ship Number and Size Assessment Platform

The model developed in modeFRONTIER contains the input variables described above; any of the previously mentioned inputs can be exposed, and all the necessary computations are implemented by a proper generic script. The output variables are then extracted and made available; see the workflow scheme below.

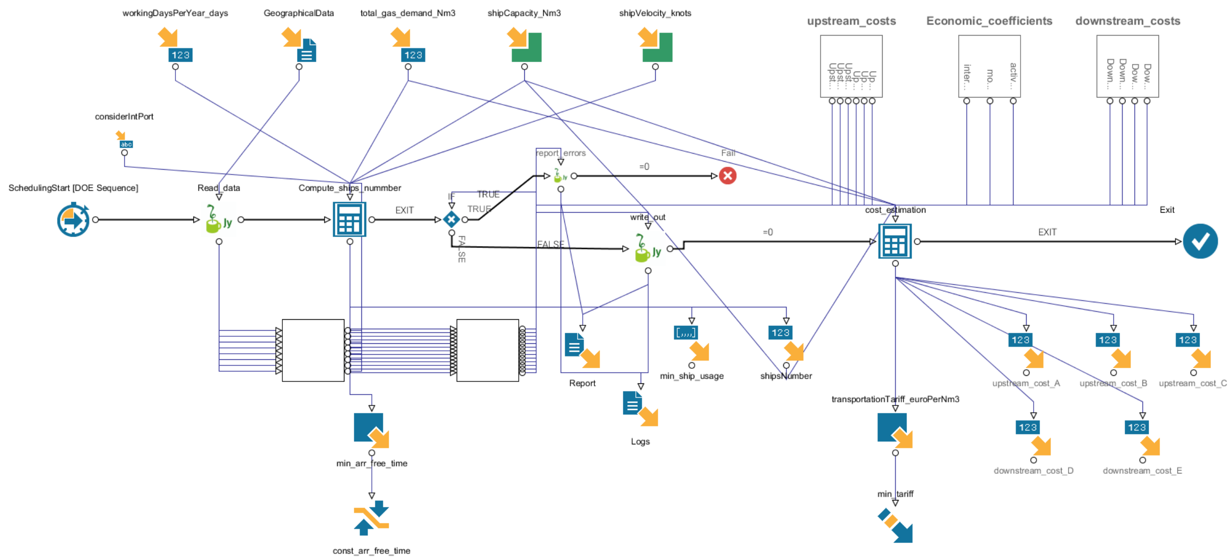


Figure 3: Model Workflow Scheme

In this way the final Model is flexible and easily adaptable for any new case.

A specific procedure has been implemented to find the optimal number of ships and size to satisfy the gas demand of the considered geographical areas.

The optimal solution considers the size and the number of ships necessary to fulfil the given gas demand trying at the same time to maximize the usage of the ships (the percentage of time the ship is on mission) reducing finally the cost/tariff. Possible scenario solution schemes:

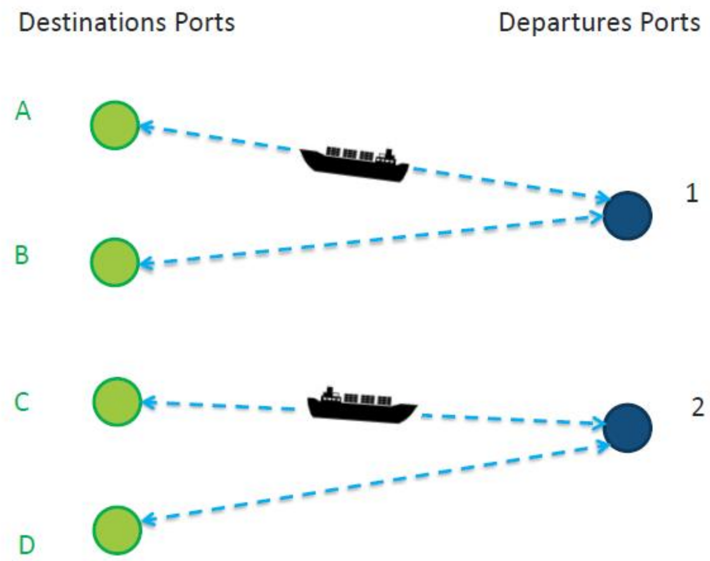


Figure 4: Source 1 is convenient for ports A and B, Source 2 for ports C and D

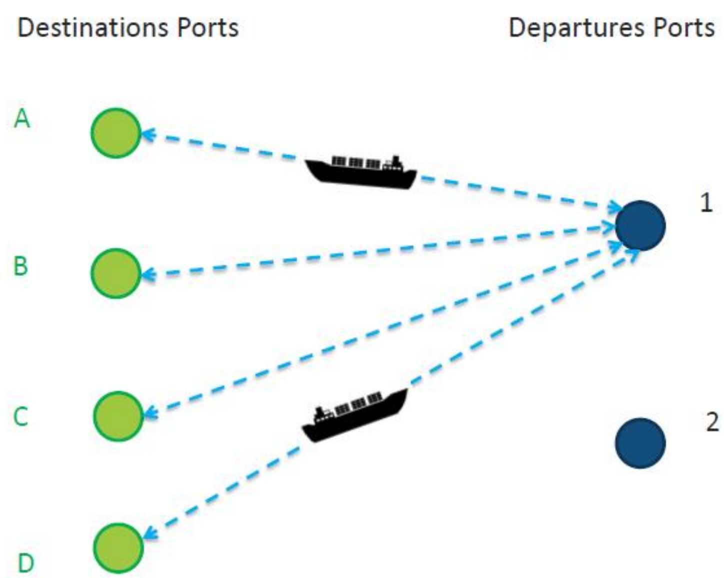


Figure 5: Source 2 is not convenient for ports A, B, C and D

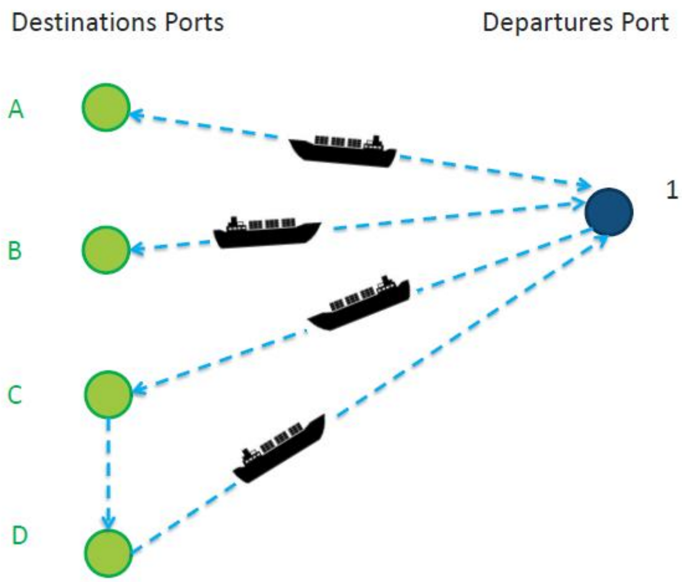


Figure 6: Optimal solution: combining ports C and D

3.4 Model Outcomes

For each set of the previously mentioned input parameters the following quantities are provided as output parameters:

- **Fleet size**: The number of ships necessary to fulfil the gas requirement in the geographical area, the ship number is computed considering the number of trips necessary during one year, the distances and the ships velocity;
- **Ships usage**: A percentage which denotes the time the ship is operational (either travelling or loading/unloading).
- **Time between two consecutive arrivals at the destination**: The minimum amount of time between two ships arrival at the destination, this variable cannot be less than 0 (otherwise two ships can be unloading at the same time). This control cannot be applied at the loading point (it is considered possible having more than one ship loading at the same time, this may occur only if more destinations are to be supplied by ships that load at the same point).
- **Minimum storage capacity**: The storage capacity needed at the loading and unloading points to guarantee the continuous gas production and demand requirements.

The optimization procedure will automatically set the input parameters for a set of variables in order to optimize the output parameters (the percentage of ship usage and/or the total cost and the transportation gas tariff estimation). Of course, this methodology also includes the possibility for one vessel to deliver CNG to more than one destination, wherever applicable.

For the first Model version the cost of the ships is considered a fixed parameter, in any case, the total cost optimization, in terms of CAPEX and OPEX, is something that will be determined once the costs estimation is provided as a function of the ship characteristics. Hence, the final outcome of the platform will actually be the gas tariff estimation (€/m3) in the considered geographical areas, by the Gasvessel technology and the comparison to target gas market prices and potentially with alternative monetization options

3.5 Improvements

At this stage the Decision Support Model is ready, the Model can calculate all the desired outputs for each identified scenario, however there are still some points that may be improved to obtain a more flexible and accurate Model, suitable for any scenario.

Here are the pending points and the partners that can contribute to each:

1. How to consider metocean data? (Could impact the average ship velocity and ship consumption or, more simply, the actual ship working days per year) – *SINTEF, CHC, NP, HLL*
2. Ship Consumption (to quantify the ship total loading gas volume) - *NP*
3. Loading and Unloading times are currently estimated using a simplified formula provided by Cenergy, a more accurate formula could be employed – *VTG, Cenergy*
4. Nice to have the ship building and OPEX cost for different ship estimate as function of ship size
5. Facilities costs at the departure and arrival ports should be provided to be included in the final gas tariff. At moment the platform can estimate the CNG transportation tariff but not the gas downstream tariff since the provided gas upstream tariff does not include gas loading and storage cost at the departure port. The unloading facilities cost at the arrival port is indeed necessary to estimate the gas downstream tariff – *NP, CHC, VTG, SINTEF, CEnergy, HLL*

4.0 Conclusion

The Decision Support Model developed in modeFRONTIER is a flexible workflow to calculate the CNG gas tariffs for any geologist scenario.

The Model allows the end user to have an easy tool to estimate the CNG cost and then the gas tariff. The flexible modular concept and parametrization can explore different combinations, options and locations by adding or removing modules, inputs and outputs suitable for the specific case study.

Moreover, the post process tools available in modeFRONTIER design space can be helpful to analyzed data and results, in order to understand which would be the most effective set of input parameters.

The modeFRONTIER optimization algorithms are used to locate the best option in an automatic way. The “Decision Support Model” is made available to all the Gasvessel partners and published as a web service by the VOLTA architecture developed at Esteco (a prototype is currently being tested by the interested partners).

A demo was provided during the General Assembly at Cyprus, 3-4 May 2018. Once WP3 and WP5 are completed, it will be possible refine the gas tariffs.

The “Decision Support Model” is now complete and works as expected. In the long term, the Model is expected to be made available for a general use and might be open to the public trough VOLTA platform to run similar simulations for other scenarios.