Optimization of Compressed Natural Gas transportation Vessel: GASVESSEL project

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Summary

- Gasvessel Project (CNG) – Description and Target
- Logistic optimization
- Structural optimization
- Risk analysis

ESTECO is an independent software provider,
highly specialized in numerical optimization
and simulation data management

Our products

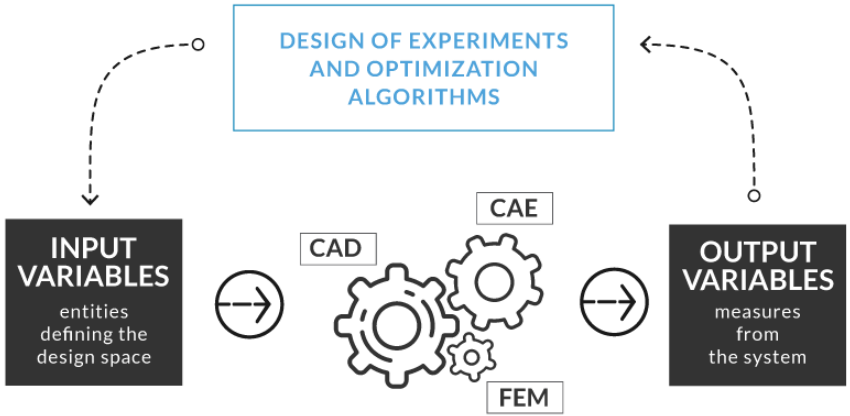
modeFRONTIER

The comprehensive solution for process automation and optimization in the engineering design process

VOLTA

The collaborative web platform for Simulation Process and Data Management (SPDM) and design optimization

Optimization-Driven Design



Enabling the optimization-driven approach allows for dramatic reduction of both development costs and time-to-market.

THINK OUTSIDE THE BOX

Take advantage of automated design space exploration and discover innovative solutions that might otherwise have been dismissed.

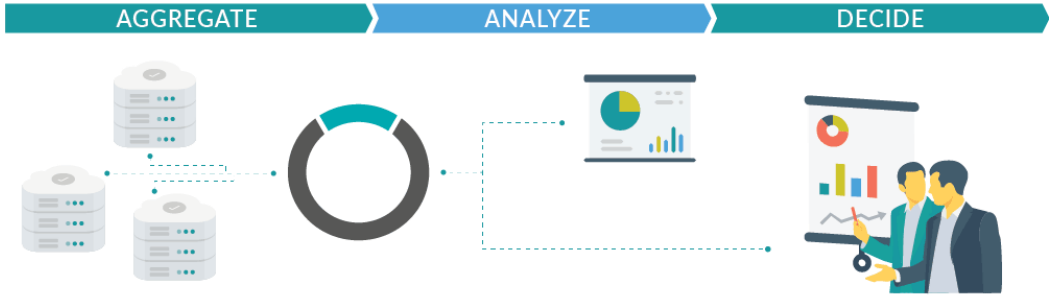
INNOVATE FASTER

Simulation is automated. Engineer focuses on the idea.

EXPLORE EFFICIENTLY

Balance conflicting objectives by taking into account multiple concerns and requirements.

Engineering Data Intelligence



Transform large amounts of data into valuable company assets and accelerate innovation

UNDERSTAND

Turn data into valuable insights and propel your innovation process using a comprehensive environment for data analysis and visualization.

FOCUS

Quickly identify relevant performance metrics so that you can focus on what is important and make better decisions, faster.

DEMOCRATIZE

Tools for synchronized data visualization are not just for data analysts: they empower experts from other departments to access and use data with confidence.

Our Customers & Industries

Embraer
Leonardo
Lockheed Martin
Bombardier
FCA
Ford
Honda
PSA Group
Toyota
Volvo Cars Corporation

Mahindra
TAFE
Volvo Trucks
ABB
Bajaj
BASF
Cummins
FAW
Whirlpool
Sony

Automotive

Aerospace

Industrial Equipment

Construction

Energy & Environment

Consumer Goods

Marine & Offshore

Electronics

Biotechnology

Navalprogetti

NAVALPROGETTI is a ship design company of Naval Architects, Marine and Industrial Engineers and Ship Surveyors that has been operating since 1975

Navalprogetti – Services and Skills

New building basic and detail design

Ship conversion, Ballast water treatment system and Scrabber retrofit design

Marine transportation of offshore structutes studies

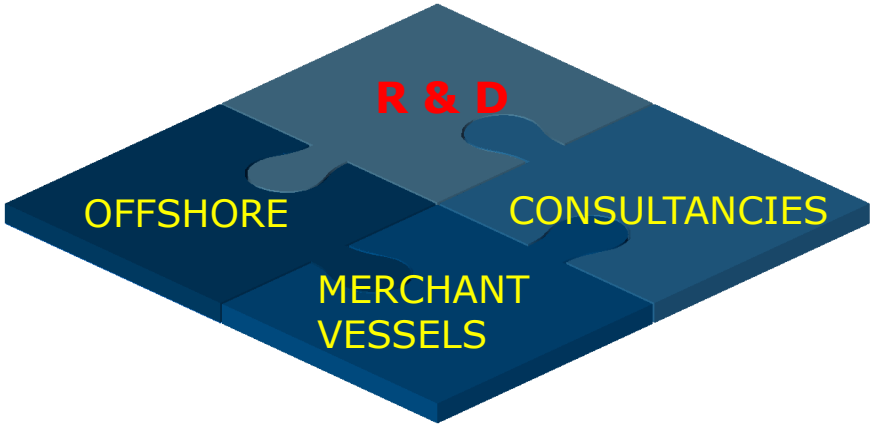
Alternative fuels (LNG, CNG, H2) studies

CNG Transportation – GASVESSEL (EU Project)

Model test assistance

Yard assistance

Inclining experiments and sea trials



Navalprogetti – Clients

Gasvessel Project

- CONSORTIUM formed by 13 Partner Companies
- 8 Countries represented:
  Belgium, Cyprus , Germany, Greece, Italy, Norway, Slovenia, Ukraine
- Project duration: 48 months (started June 1st 2017)
- EU contribution = Project's financial value = 12 M€

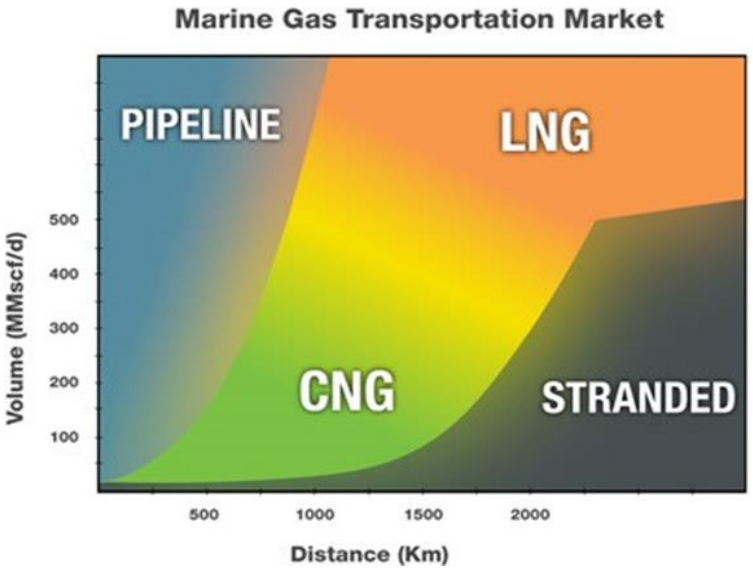
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723030.

EU Energy: Why Compressed Natural Gas (CNG)?

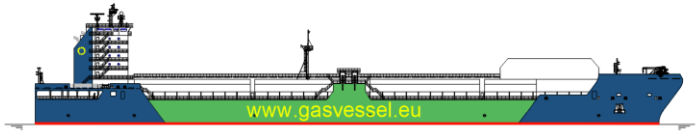
- **67% of gas in Europe is imported** (of which 37% from a single supplier)

- 5 times the amount of consumed gas is currently stranded in **unexploitable gas reserves**

- **Expensive alternatives**:
  - Pipelines
    - Construction costs
    - Environmental and political difficulties
    - Point-to-point
  - LNG
    - Expensive liquefying and re-gasifying plants

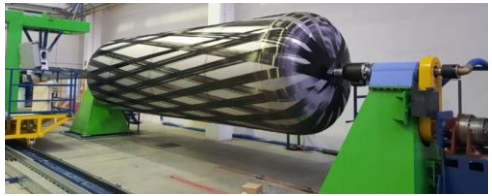


GASVESSEL solution



Innovative, cost-efficient **CNG transport system**

1. Novel lightweight **Pressure Cylinders**
   - **70% lighter** than state-of-the-art
   - **Large volume** cylinders
     up to 175 m^3 (liquid volume)



2. New **ship design**
   - Much **higher payloads**
   - Safe (un)loading at **300 bar**
   - Gas Capacity up to **15 MNm^3**

GASVESSEL Project

Built facilities and machineries for cylinder construction:

Hydroforming mould

Hydroformed cylinder

Winding machine

Curing station

GASVESSEL Project

Built facilities and machineries for cylinder tests:

Autofrattage and fatigue test pumping unit

for 10000 cycles

Burst test pumping unit

up to 1000 bar

GASVESSEL Project

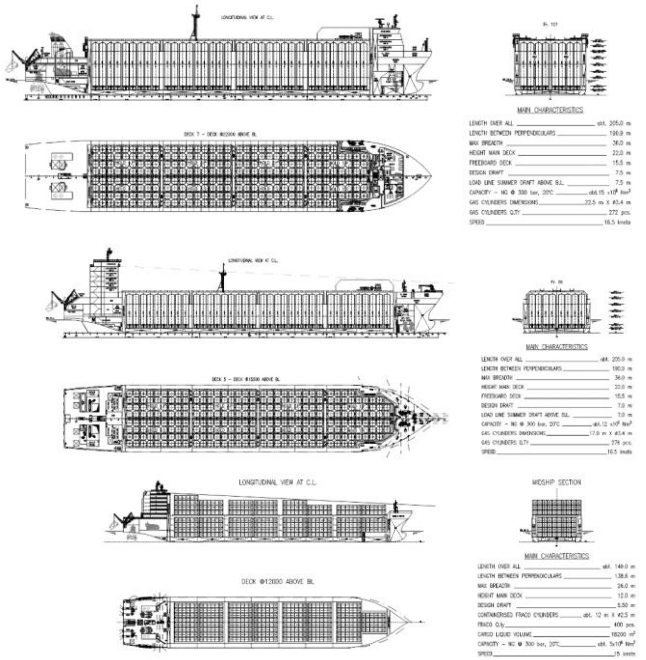
Ship Design

3 different capacity ships were designed:

- Up to **15 Milions Nm^3** with vertical large capacity cylinders
  - Cylinders length = 22.5 m
  - Cylinders diameter = 3.4 m

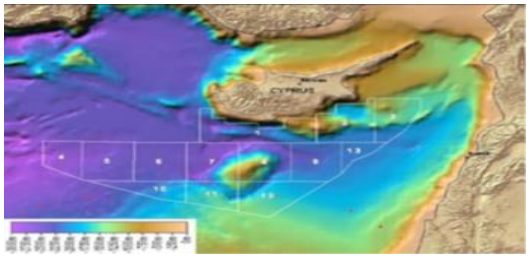
- Up to **12 Milions Nm^3** with vertical large capacity cylinders
  - Cylinders length = 17.5 m
  - Cylinders diameter = 3.4 m

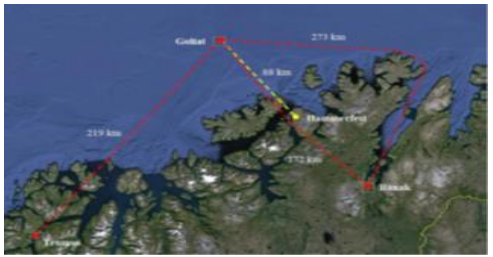
- Up to **5 Milions Nm3** with containerised cylinders
  - Cylinders length = 11.5 m
  - Cylinders diameter = 2.4 m



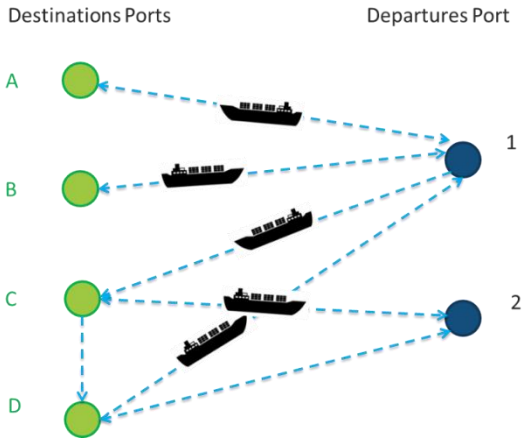
Transportation scenarios

- **Analysis of 3 real-life geo-economical gas exploitation scenarios**
  (East Mediterranean, Barents Sea, Black Sea)



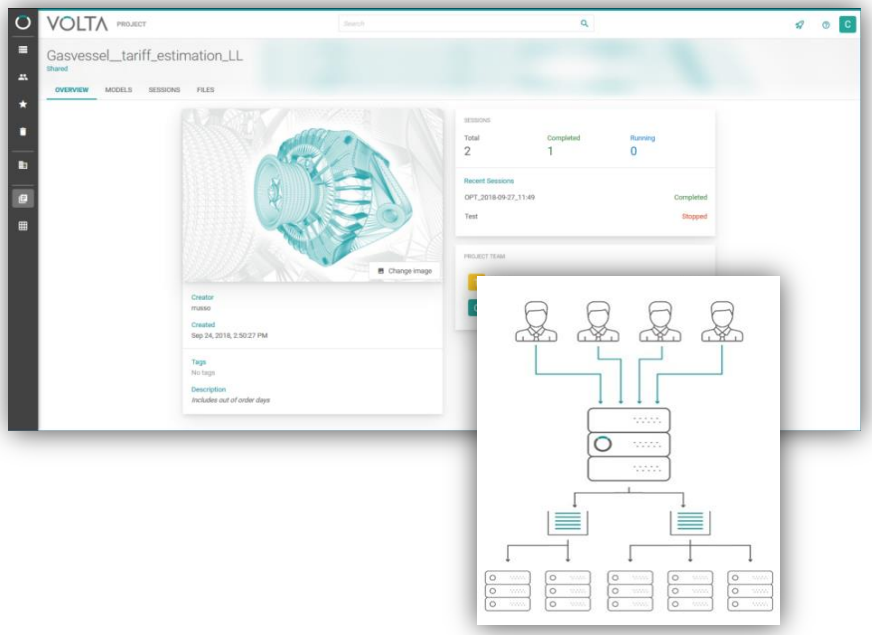


- **ESTECO software to optimize logistic**
  - Ship carrying capacity
  - No. of ship
  - Ship main design parameters
  - Transportation tariff

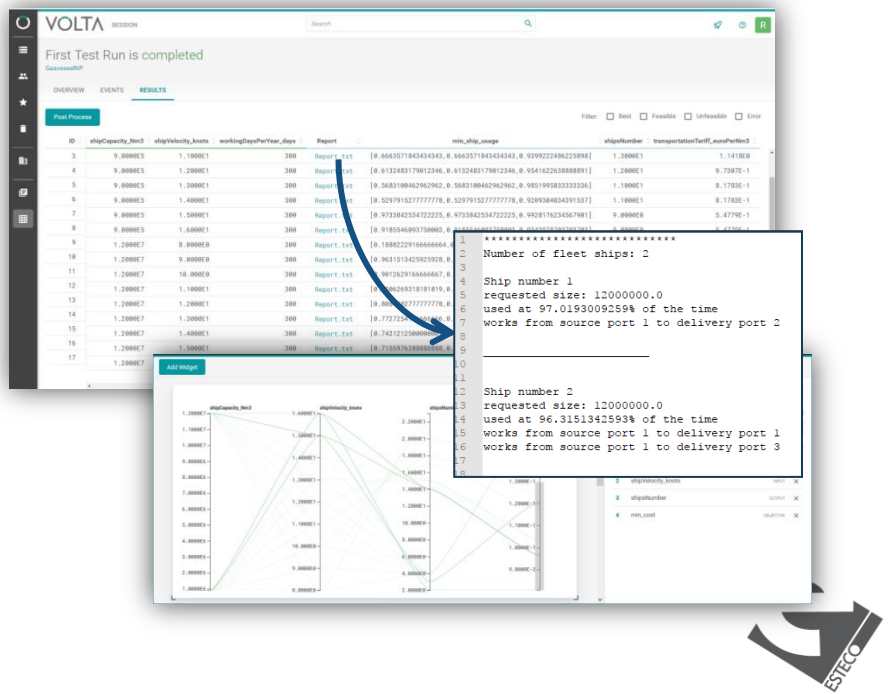


Web-based collaboration platform (VOLTA)

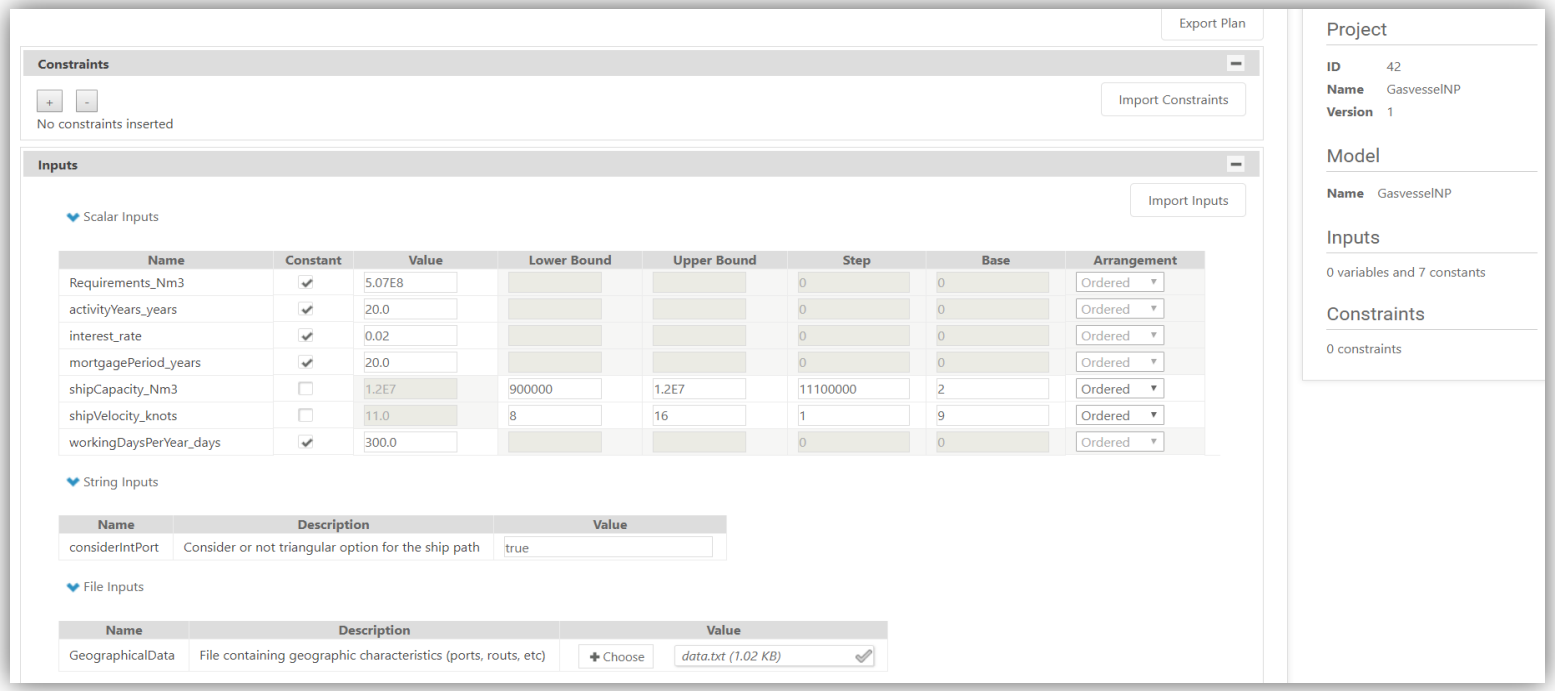
Shared project and distributed execution



Report analysis and Post Processing

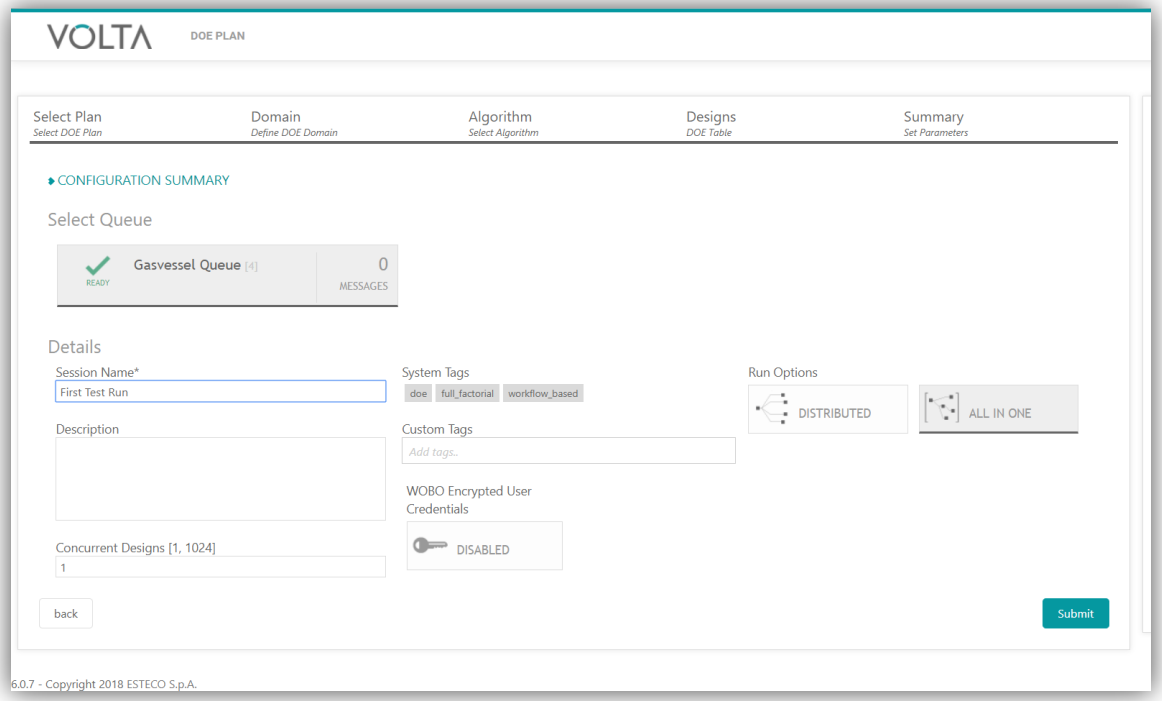


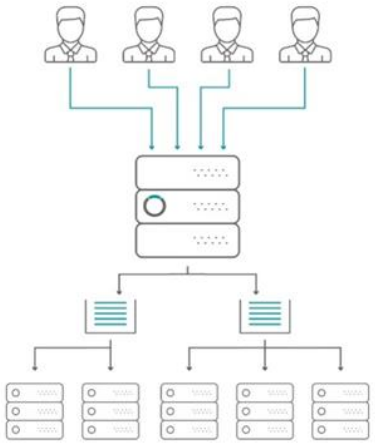
VOLTA Platform: define optimization problem



From the Project interface select range of variation of design variables and select objectives type

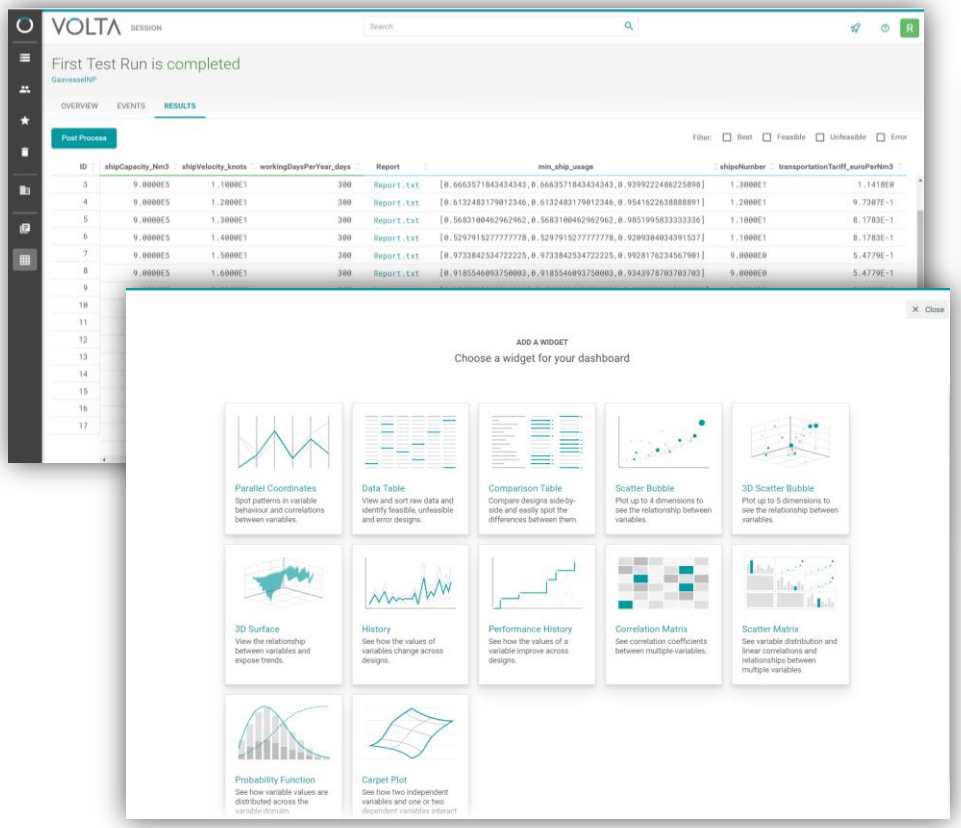
VOLTA Platform: define optimization problem

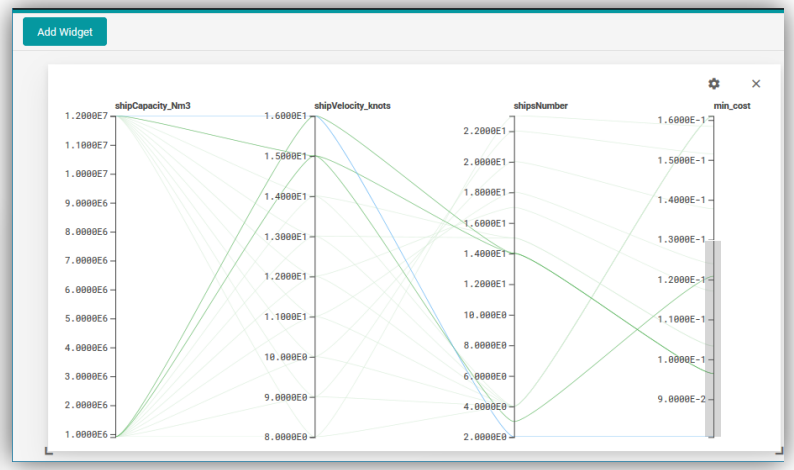




From the Plan interface select Computational queue where the simulations will be run

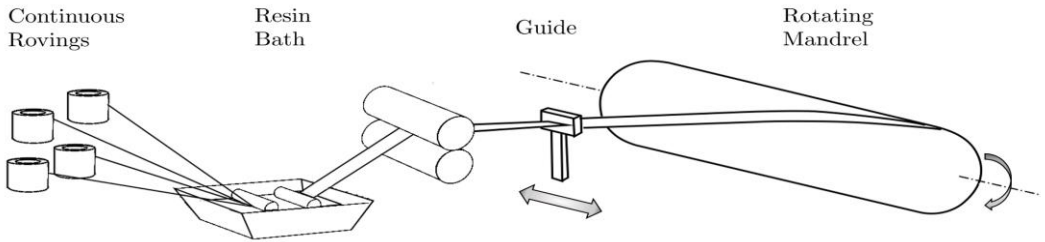
VOLTA Advisor: analyze results

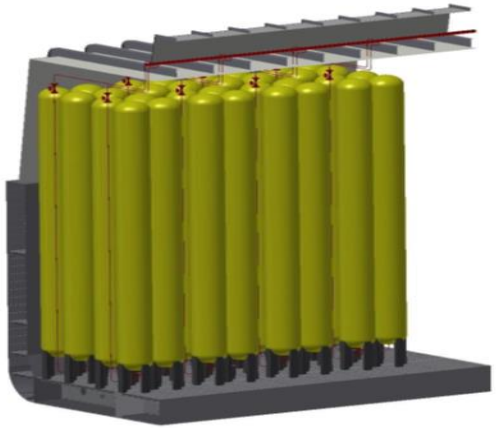




Use available charts to analyze solution and help decision making

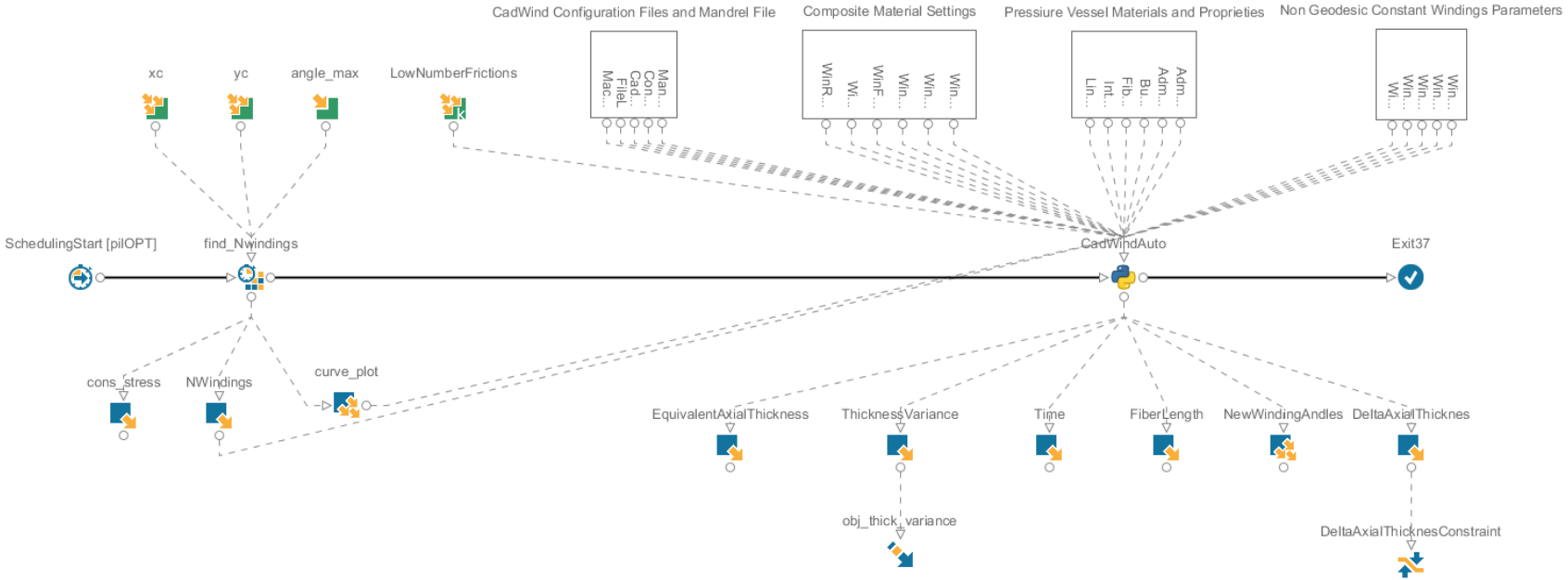
Structural Optimization of pressure vessels





- Pressure vessels are defined by a **steel liner and an overwrap of composite material**
- **Autofrettage** pressure (150% of exercise pressure = 300 bar) applied during production to obtain pre-stress that reduces operative stress
- **Geometry and material are optimized** (mass and safety factors)

Optimization workflow with modeFRONTIER

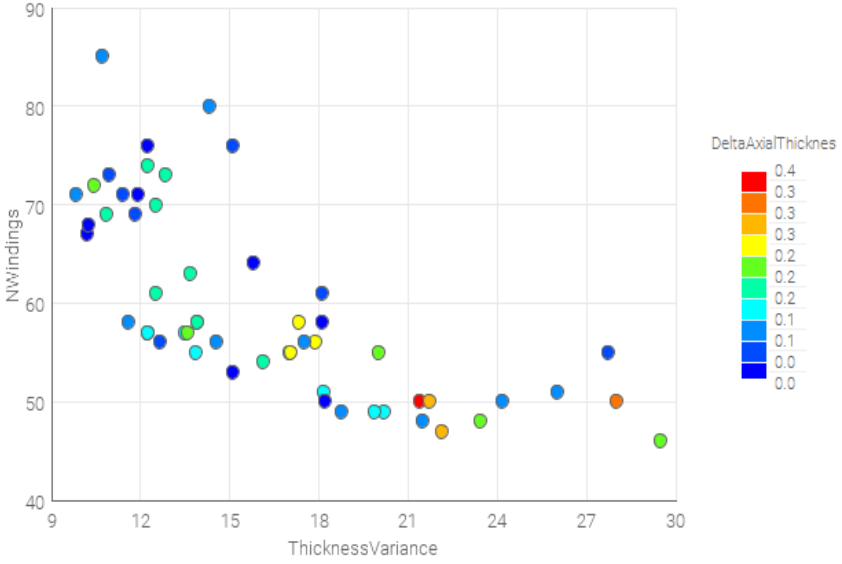


- **Inputs**: steel thickess and composite material, fibers %, angle of winding layers
- **Simulation:** structural analysis (Python code) and CADWIND to simulate winding manufacturing process
- **Optimization**:

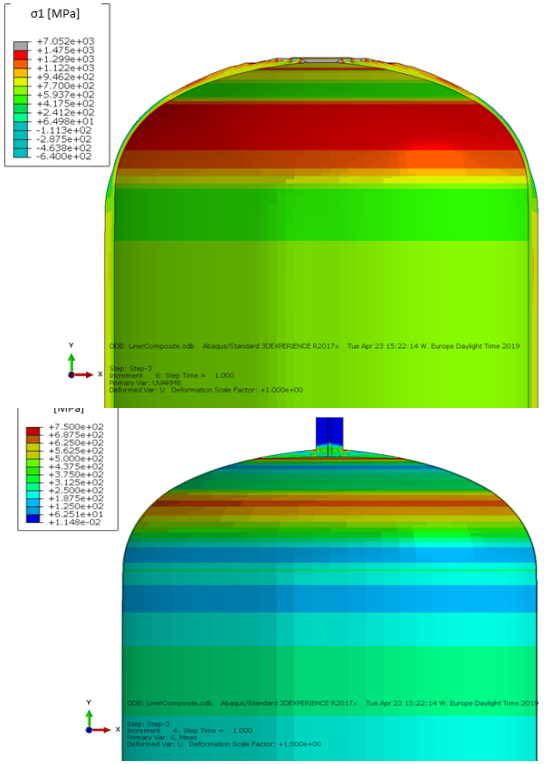
  minimum number of winding layers to respect admissible stress (burst pressure at 750 bar)

  minimize thickness variance (for an uniform coverage)

Optimization results: Pareto frontier



Pareto front (optimal solutions)



Overwrap Max stress:
2470 MPa

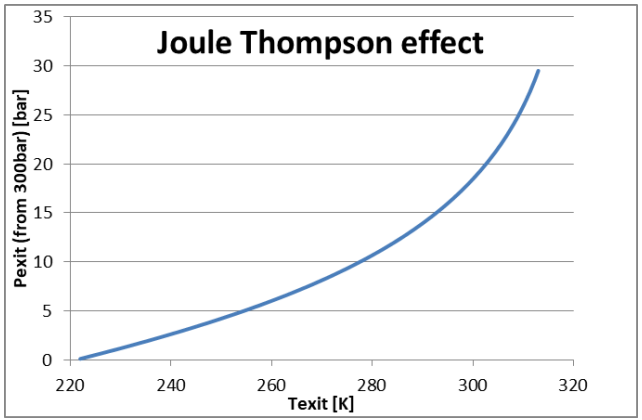
Liner Yield stress:
750 MPa

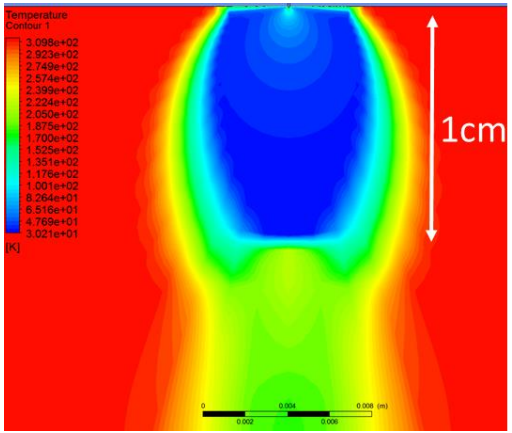
Chosen design validated by FEM analysis

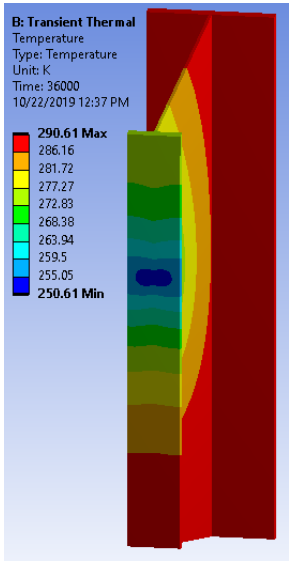
Experimental validation

First prototypes of the vessels have been built by BMPlus at Buttrio (Italy)
Burst and fatigue tests are in progress

Risk Analysis – Analytical model for leakage



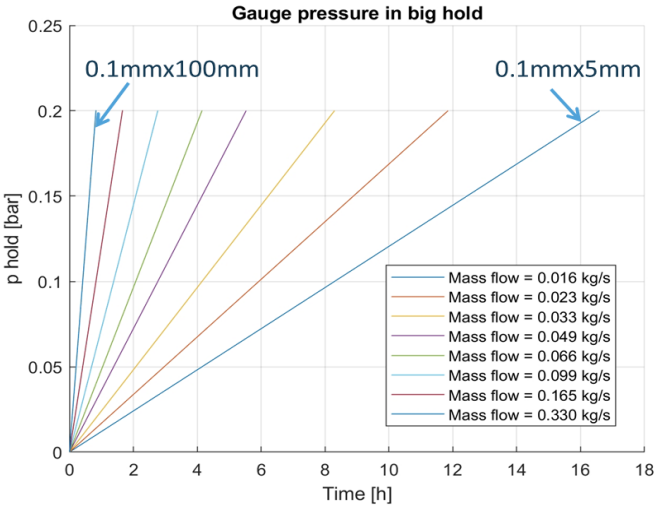


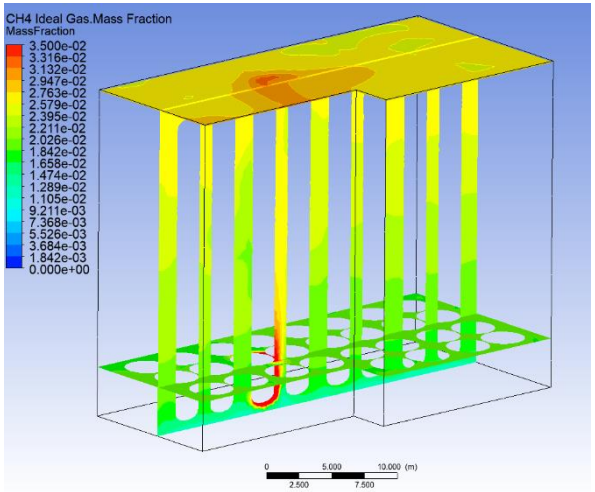


- Due to J-T effect, **gas dispersion** from cylinders (300 bar) occurs at low T (220K)
- By enthalpy balance we can predict how **gas mixture T and P** in the hold varies

- Local supersonic expansion (T<100K) from orifice recoverered within **1cm**
- At 1m of distance **support receives a gas jet** at 80m/s and 220K (thermal analysis confirms its resistance)

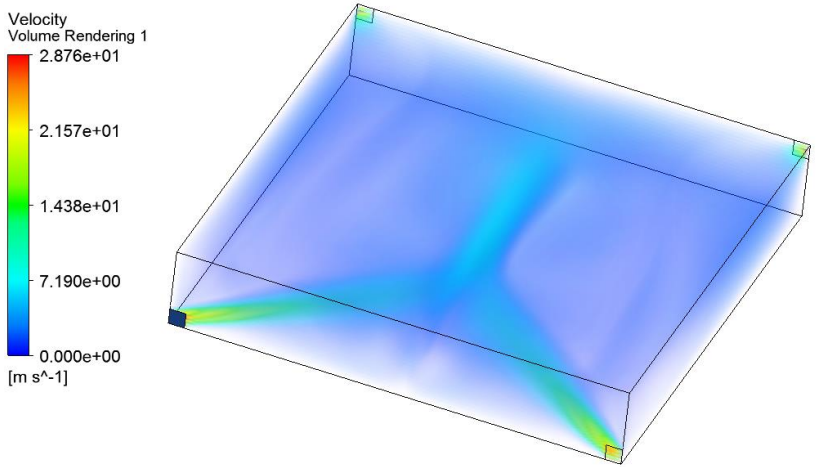
Risk Analysis – Analytical model for leakage

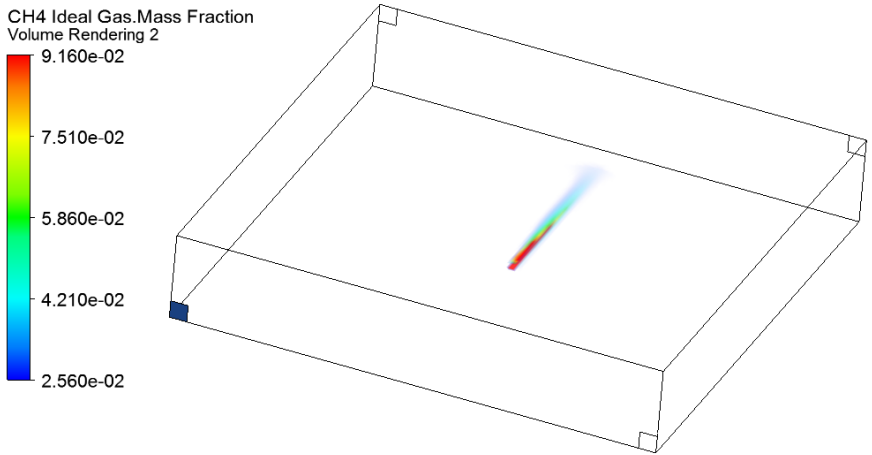




The model (Matlab, validated by CFD) can be automated by modeFRONTIER to analize **Pressure and Temperature variation** in the hold for different **mass flows**

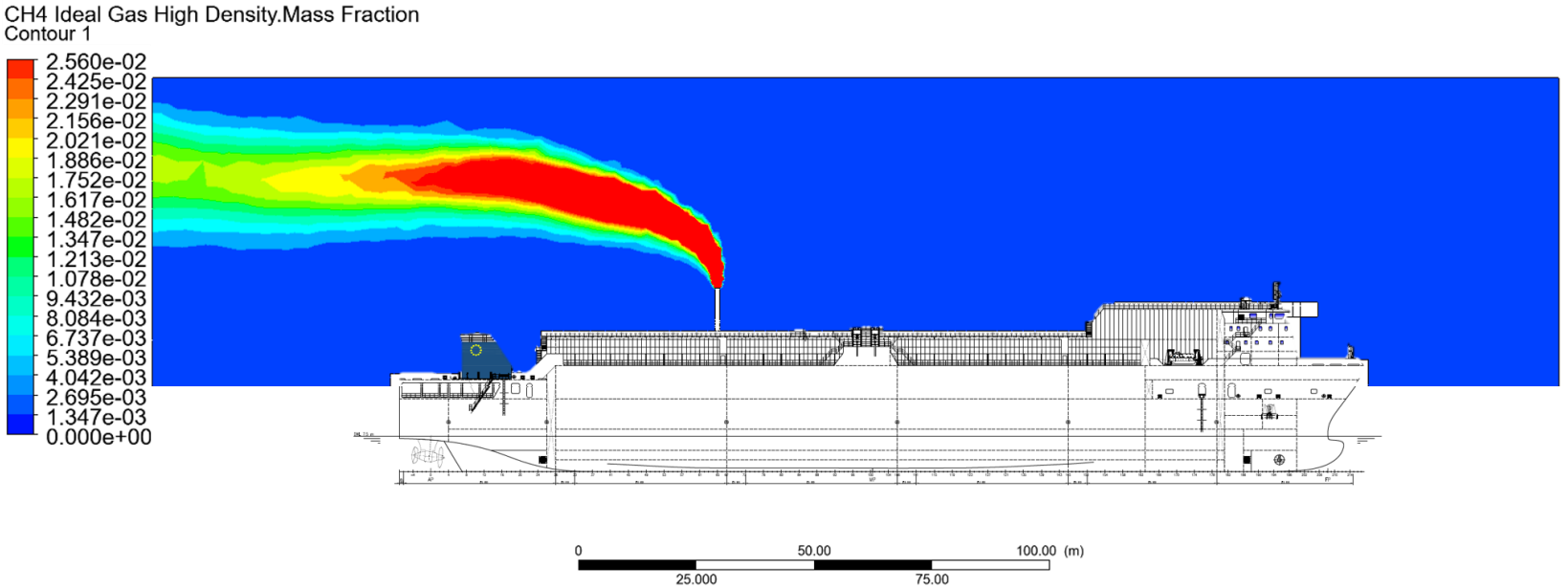
Risk Analysis – Compressor room





Optimized **ventilation system** reduces **critical concentration** of methane (2.56% of mass) and risks of explosion in compressor room

Risk Analysis – vent mast analysis



Vent mast system is designed (to evacuate gas when overpressure in hold is reached)
Critical mass concentration (red color > 2.56%) is dissipated immediately

Conclusion

- Gas **Transportation scenarios**: Minimize costs to fulfill requests
- Gas **cylinders**: Minimize costs and optimize layers uniformity, guaranteeing the respect of safety factors
- **Explosion risks**: analyze gas leakages to minimize risks

Thank you for your attention!

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