LNG Projects: Concept, Constraints and Decision Making – The Contribution of ASPROFOS

Dr. Philip-Mark Spanidis
Oil & Gas Project Manager
ASPROFOS Engineering S.A.

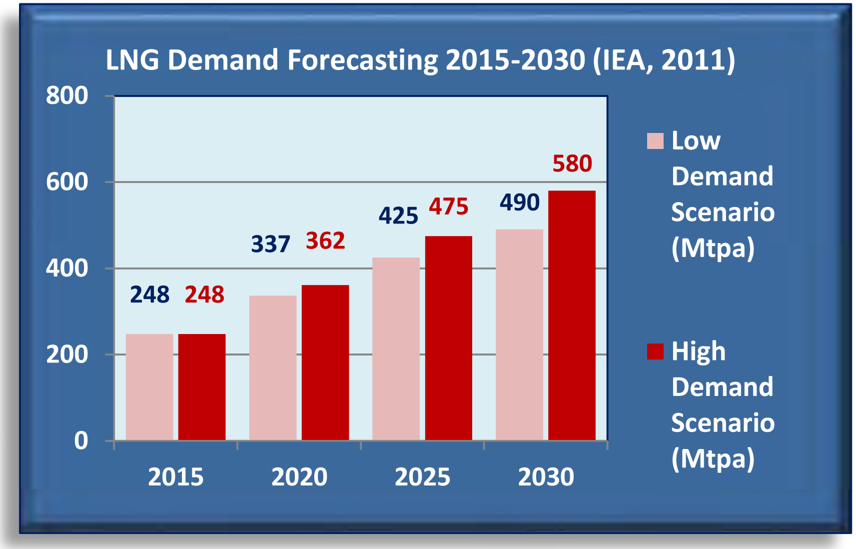
1. Overview

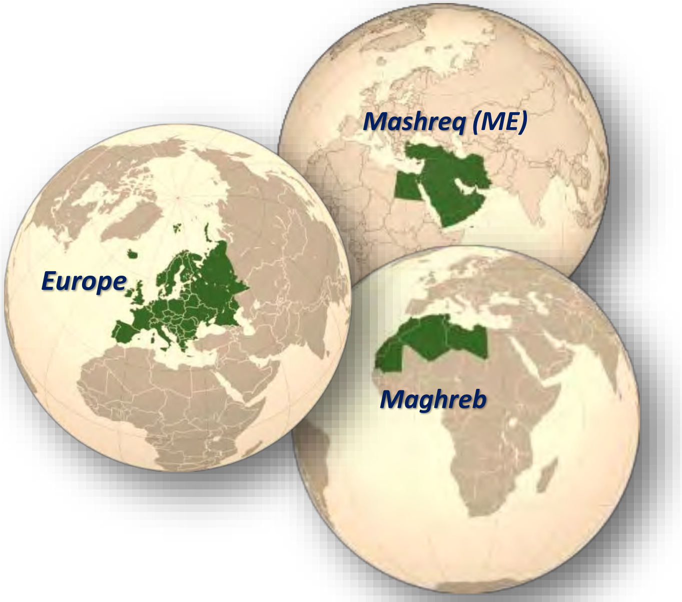
LNG Demand Side

- **LNG sector** presents an increasing growth in worldwide basis (IEA, 2011)
- **LNG** is competitive to pipeline technologies since the fuel can be transported **safely** and at **lower cost** to **remote locations**

Mediterranean is **a region of challenges** as:

- The gas exploitation from **existing fields** and the prospect of **new gas finds** (in Aphrodite, Tamar and Levant basins) are expected to increase the **LNG trade** and drive the **extension** of existing, or the **construction of new,** LNG projects
- The maritime corridors allow transportation of gas avoiding areas of **geopolitical conflicts** and, therefore**,** ensure the **security of gas supply** routes
- The **energy demand growth** of EU & ME countries constitutes possible the **interconnectivity** between LNG and offshore pipeline systems (EU COM(2016) 49, final)
- The diffusion of **medium** and **small LNG** technologies should be a driver the LNG industry to turn in **more agile** and **lower cost solutions**





2. LNG Projects

LNG Projects are classified as:

- **Large scale LNG** plants of high integration, supplied by huge LNG carriers (≥100.000 m^3) and maintaining facilities for regasification, storage, fractionation, power generation, jetties, truck loading, pipeline interconnections, etc.
- **Medium and Low Scale LNG** plants appropriate to accommodate and delivery moderate to low gas volumes, supplied by LNG carriers or bunkers (100.000-1.000 m^3) or operating in connection with FSRU/FSU/FPSO vessels
- **Micro-Scale LNG & Satellite stations** which are stationary storage and regasification units and local refueling stations delivering LNG/CNG volumes to inland consumers (industrial, domestic and commercial).

The **Context** of LNG projects requires:

- Strict **Safety design** considerations
- **Know-How** on international industry standards/practices
- Effective **Project Management** appropriate for **long term** and **high complexity** frameworks
- **Multidisciplinary** teams consisted of skilled engineering experts and specialists
- **Value Engineering** solutions

The LNG costs differ significantly **from each project** to **another**. For **large to medium scale** LNGs the cost breakdown is as follows (The Oxford Institute for Energy Studies):

Cost Breakdown	[%] of Total Cost	Remarks
Site Development	1%	Depends on geology, soil and nearshore terrain morphology
Gas Treatment	7%	
Fractionation	3%	
Liquefaction	28%	
Refrigeration	14%	
Utilities	20%	Depends on availability of industry utilities/infrastructures
Off-Sites	27%	Depends on the fuel logistics model associated to the plant

2. LNG Projects (cont'd)

Project Risk Severity Analysis: Medium/Small Scale LNGs are Projects of reduced risk(s)

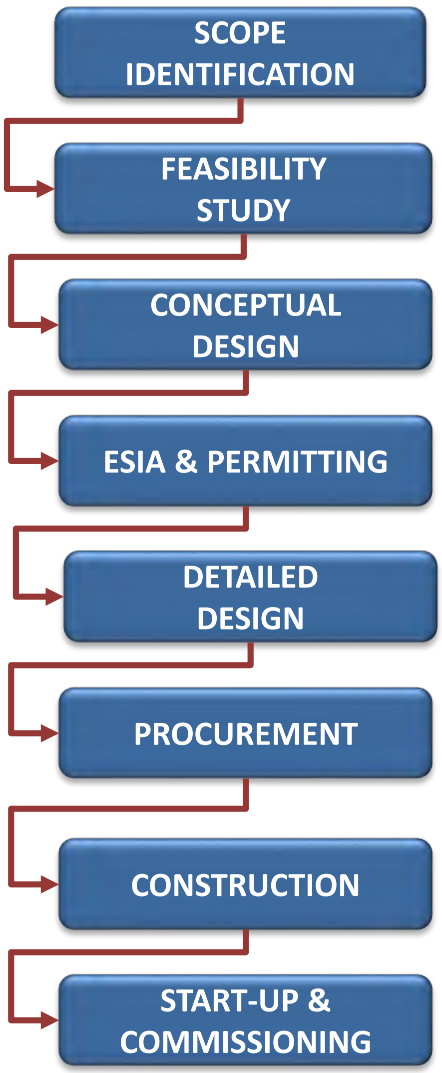
LNG Project Risks (*)	Risk Severity Large Scale LNG	Risk Severity Medium/Small Scale LNG
Geopolitical Conflicts	HI+	MD+
Changes of Energy Policies (local, regional, international)	MD+	LO
Estimation of Project Costs (CAPEX - OPEX)	MD+	LO+
Changes of Primary Energy Demand	HI	MD+
Energy Fuels Competition	MD+	LO+
Environmental Regulation & Permitting	MD+	LO
Geo-Hazards and Environmental Constraints	MD	LO
Social Acceptance	MD	VL
Safety Constraints	HI	HI+
International Crises	HI+	LO+
Engineering Design Failures	MD	LO
Misalignments of Project Stakeholders	LO+	LO
Project Management dysfunctions	LO+	LO

Risk Severity Scale
Very Low (VL)
Low (LO)
Medium (MD)
High (HI)
Very High (VH)

(*) combination of empirical evidence and IGU data (2017)

2. LNG Projects (cont'd)

Planning is sequence of phases/steps:



3. Project Constraints

In the **Feasibility/Conceptual design**, several **technical**, **social, geo-environmental** and **regulatory constraints** critical for the **Final Investment Decision (FID)** and selection of the LNG plant **location** are introduced:

- **Safety** (proximity to residential areas, hazardous sites, expressways, military facilities, airports, heavy duty industry, vulnerable populations , etc.)
- **Geo-Hazards: Seismicity** and **Slope stability**
- **Social acceptance**
- **Permits**
- **Seabed** topography (examination of nearshore corridors)
- **Geology** and **Soils**
- **Accessibility** to the plant
- **Approachability** to the Shoreline
- Availability of **Utilities** and **Services**
- **Ecosystems** and **Marine Environment**
- **Cultural Heritage** (archaeological sites and monuments)
- **Land Use** and **Infrastructures**
- **Land Acquisition**

On that basis, a **decision making process** is formulated for selection of the **most suitable location** for the project construction and operation

4. Decision Making Methodology

… is a **Process** for answering **critical managerial questions** with **impact to an LNG investment model** such as, for example:

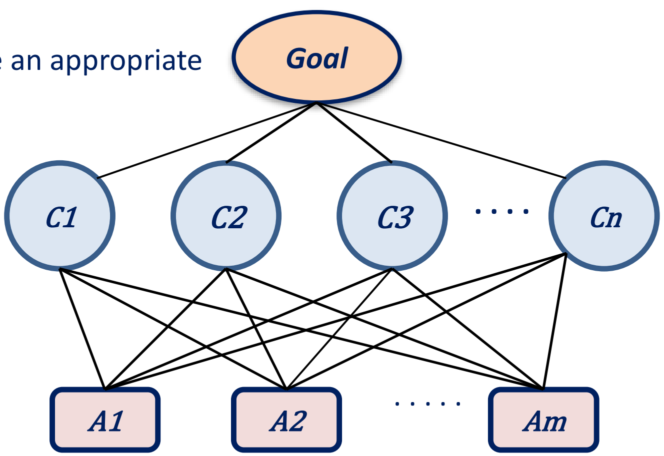
- Is the assessed model **cost-effective** and **profitable**?
- Is there any **alternative location** allowing **low-cost** installation, **approachability** and **expandability**?
- Does the feasibility/conceptual design studies consider all **constraints** necessary for the project area selection?

For selection of the **most appropriate LNG plant location** the decision making process is modeled in **three levels** as:

Goal: Choose an appropriate LNG Location

Criteria
i=1, 2, …, n

Alternatives:
J=1, 2, … , m



(*) **Analytical Hierarchy Process (AHP)**
See: Saaty (1987;1990) and Dey (2003; 2010)

Decision Making Steps (concise description):

- **Step-1**: The **selection criteria are** grouped so that to incorporate all project constraints
- **Step-2**: Definition of the **relative weight** of each criterion: $C_1 \rightarrow W_1, C_2 \rightarrow W_2, \ldots C_n \rightarrow W_n$
- **Step-3**: Estimation of the **relative performance** of all alternatives over each single criterion , i.e.

  - Alternative *A1*: $A_{11}, A_{12}, \ldots, A_{1n}$
  - Alternative *A2*: $A_{21}, A_{22}, \ldots, A_{2n}$

  . . . .

  - Alternative *Am*: $A_{m1}, A_{m2}, \ldots, A_{mn}$

- **Step-4: calculation of the score** Sj of each alternative A_j:

$$Sj = \sum_{i=1}^{n} Ajn.Wn = Aj_1.W_1 + Aj_2.W_2 + \cdots + Ajn.Wn$$

subject to: $1 > W_i > 0$ and $W_1 + W_2 + \ldots + W_n = 1$,
for $i=1,\ldots, n$ and $j=1,\ldots, m$

- **Step-5**: the **maximum value** S_{max} of the vector $S_j = [S_1, S_2, \ldots S_m]$ is the score of the **best alternative,** A_{Best}

5. Factors for the Successful Engineering of LNG Projects

- **Safety from the Design phase allows:**
  - Alignment to high safety standards for achieving **zero accident** solutions
  - Prevention of design likely to cause **failures** and **damages** to plant equipment
  - Introduction of **industrial control** technologies to increase **plant reliability** and **emergency** performance
  - **Minimization** of product loss, shutdowns, restoration and insurance costs. For this reason…

Safety Efficient Design Ensures Human & Environment Protection and Plant Integrity

- **Permitting**: permits are critical for the project to be **legally compliant for construction** and **operation**
- **Environmental Compliance***:* the produced design has to consider minimization and controlling of **GHG** emissions and any other **aerial**, **solid** or **aqueous pollutants** (waste water, oily wastes, operation residuals, etc.)
- **Time and Quality**: optimum time and quality management of engineering work prevent **time** and **cost overruns**
- **Long Lead Items (LLI):** the procurement of heavy duty equipment (tanks, vaporizers, pumps, etc.), in parallel to the design and prior to construction is critical for **on time project completion**
- **Low Cost Engineering**: Low cost/short time engineering is a **cause** of poor quality technical outcome and redesign effects
- **Value Engineering**: cost-effective solutions respecting budgetary constraints, optimization and flexibility of the plant operation and **reduced procurement** and **construction costs**
- **Risk Management**: the early understanding of project risks prevents **progress decelerations** and **remedial costs**.

6. The Contribution of ASPROFOS

ASPROFOS Engineering S.A. is a:

- **Leading** and **largest engineering company** in Greece
- **Member** of the Hellenic Petroleum (HELPE) Group of Companies
- **Over 34 years experience** in Oil and Gas projects

ASPROFOS provides:

- **Integrated** engineering/consultancy from the **very concept** to **start-up** (FEED, detail design, construction supervision)
- **Project Management** and **decision making support** (Pipelines, LNG terminals, Compressors and other gas facilities)
- Extensive **know-how** in **industrial projects** of high complexity
- Highly skilled and experienced **personnel**
- **Cost-Effective solutions** and **value engineering** considerations
- An **extensive reference list** of performed Oil and Gas projects

Main ASPROFOS Registrations:

- Kuwait National Petroleum Company (KNPC)
- Kuwait Oil Company (KOC)
- Abu Dhabi Company for Onshore Petroleum Operations (ADCO)
- Egyptian General Petroleum Corporation (EGPC)
- Petrochemicals of Saudi Arabia (SABIC)
- MOL, Hungary
- Qatar Petroleum
- TUPRAS

7. ASPROFOS References

Main Natural Gas References

- **LNG tanks - Cryogenics** of DESFA in Revithoussa (2 x 65.000m^3): Plant Selection, Feasibility Studies, Seismic Design, Detailed Engineering Review & Construction Supervision (1987-2001)
- **New LNG Tank** of DESFA in Revithoussa (95.000 m^3): Detailed Design Review & Construction Supervision (2013-today)
- **Second Upgrading** of Cryogenic Facilities in Revithousa: Detailed Design Review & Construction Supervision (2015-today)
- **Feasibility Study** for a new LNG Interconnecting Pipeline in Delimara, Malta (2014)
- **Feasibility Study** for a new Small Scale LNG terminal of DEPA in Kalokhori (2016)
- **ESIA**, **Safety & SEVEZO studies** for the LNG facilities of DESFA (2012)
- **TAP** (Greek and Albanian routes): FEED, ESIA, Permitting & Detailed Engineering (2012–today)
- **Gas pipelines** in Greece (high-medium pressure): management, engineering design and construction supervision

Other references

- **Modernization** and **revamping** of HEL.PE. refining and storage facilities in Greece and Balkan Countries
- **Refinery projects** in FYROM (OKTA), Serbia (NIS), Croatia (INA, VITOL) and Jordan (JPRC),
- **Oil & Gas pipeline** projects in Cyprus, Sri Lanka (CEYPETCO) and Gabon (TELEMENIA, Israel)
- …. and more….

…..Our Feat is:

12 mil man-hours of technical services in:

- ***LNG systems and Natural Gas pipelines***
- ***Refinery Process units & Main Revamp projects***

8. The Synergy SOFREGAZ and ASPROFOS

- **SOFREGAZ** (France) and **ASPROFOS** established a **synergy** for **business growth** and **performance improvement** in undertaking new LNG projects. The area of interest is **Mediterranean region** (…. but not limited to …)
- **Objective**: SOFREGAZ, being a widely known engineering organization with long term contribution in projects of gas sector, and ASPROFOS, constitute together a **sound engineering scheme** capable to provide substantial proposals and produce high quality engineering to customers, in a view for them to:
  - Establish a **customer centric** and **adding value** context ruled by **C.S.R.**, **trustfulness** and **consistency**
  - Formulate **LNG investment models** keeping high standards of safety, project management, cost-effectiveness and plant expandability, especially for the agile solutions of **small & low scale LNG** plants
  - Support **integrated frameworks of engineering** services for : basic/detailed design, construction supervision and operation of LNG plants

Why SOFREGAZ/ASPROFOS synergy?

because...

. . . . Our Common Vision is:

- ***Consultation for Successful LNG Investments***
- ***Engineering Solutions of high Quality & Reliability***
- ***High standards of Design and Operation Safety***
- ***Commitment of Consistency, Efficiency and . . . .***
. . . . full Customer support . . . .

9. Conclusions

- *LNG industry demonstrates a **rapidly growing trend** in worldwide basis*
- *In the near future, various **LNG** and **Pipeline** projects is expected to be launched in region(s) of Mediterranean and Southern Europe*
- *The **Large scale LNGs** are **integrated plants** of high cost, risk and complexity and constitute drivers for growth of **energy markets** creating **economies of scale,** but on the other hand….*
- *… the **Medium/Low LNGs** are **agile solutions** of lower cost, risk and complexity enabling enlargement of **LNG/CNG logistics** from nearshore points to remote areas of **energy consumption** and is expected to become an instrument for **integration** and **expansion** of the gas supply chain(s)*
- *The complexity of LNG projects requires **engineering production** of **high quality, performance capabilities**, **know-how** and early consideration of **essential constraints** being critical for the **decision making** and documentation of the **techno-economical** and **feasibility** studies*
- *The joined knowledge and capabilities of **SOFREGAZ & ASPROFOS** in the spectrum of natural gas industry, ensure for the customers **total services of high quality** ….*

. . . . . therefore:

…. SOFREGAZ & ASPROFOS is a reliable partner in providing Engineering & Consultancy for the LNG sector in S/SE Europe …..

Thank you very much for your attention !

284, El. Venizelou str.
Kallithea 176 65
Athens - GREECE
Tel.: +0030 210 9491600
www.asprofos.gr

10. Literature

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