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Article

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Emerging alternatives in megaproject management: the pioneering LNG energy project in Cyprus

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Aim: The aim of this paper is to contribute to the project management studies by systematization, generalization, and structurization of information about an energy megaproject in Cyprus, as well as to provide practical insights and guidance on how megaprojects can be started and managed in other locations.

Design / Research methods: By its research design, this paper is a case study analysis. The major focus of the case study is the decision-making process of the LNG energy megaproject in Cyprus.

Conclusions/findings: Even positive emerging alternatives, like the discovery of new natural resources, can delay a megaproject instead of speeding up due to impact on the decision-making process and reassessment of the value creation.

Originality/value of the article: The LNG energy megaproject in Cyprus provides a unique example of an emerging strategic alternative that requires a reassessment of the initial approach and its comparison in terms of value creation with the newly appeared opportunity.

Keywords: project management, emerging alternatives, megaprojects, LNG energy project, value creation, risk assessment, ESG

JEL: G31, H43, P28.

1. Introduction

The strategic long-term vision of the European Union is to have a prosperous, modern, competitive, and climate-neutral economy by 2050. The overhauled EU energy policy incentivizes its member states to transition from conventional fossil fuels with high CO₂ (Carbon Dioxide) emissions to more “green” alternatives to minimize emissions.

Cyprus is an island with no indigenous hydrocarbon energy sources. Its energy grid is isolated with only one vertically integrated electricity company and no interconnections to neighboring systems. The power generation system of the Republic of Cyprus completely depends on imported fuels, which are primarily heavy fuel oil and gasoline with high CO₂ emissions.

To address the challenge of limited resources, isolated location, and negative environmental impact Cyprus’ national energy project has been initiated to introduce natural gas for power generation purposes. The import of natural gas into Cyprus would advance the country’s economic model by cutting energy prices, creating new job positions for providing new services (e.g. bunkering), opening competition in the energy sector, as well as reducing the effects of energy system isolation and decreasing CO₂ emissions due to the lower carbon content of natural gas compared to liquid fuels.

The investment technology-driven project in Cyprus, as described in this article, should be understood as a megaproject due to its regional importance and long-lasting socioeconomic impact. The delivery of megaprojects is a complicated project management task. Due to the multidisciplinary nature, long planning horizons, lack of appropriate expertise, required unique technology solutions, and involvement of multiple stakeholders in the decision-making process, the megaprojects are known for their poor performance and time and cost overruns.

The aim of this article is to contribute to the project management studies by systematization, generalization, and structurization of information about an LNG energy megaproject in Cyprus, as well as to provide practical insights and guidance on how megaprojects can be started and managed in other locations.

It took more than 10 years of active effort to start the LNG energy project in Cyprus, although the original technology solution was found relatively quickly because there are technologies that are suitable specifically for islands to advance in their clean energy transition. Floating Storage and Regasification Units (FSRU) are becoming more and more popular because they are relatively cheaper, more flexible, and, in general, easier to implement, especially in the Mediterranean Sea. Cyprus's ideal location promises a lot of potential for this solution.

Meanwhile, the technology solution suitable for importing natural gas into Cyprus was challenged by an emerging strategic alternative – the discovery of its own natural gas in Cyprus. The article shows that the discovery of gas in Cyprus instead of speeding up the project, as everyone would expect, actually delayed it. The reason for this is the common misbelief that in a few months after the discovery, natural gas would have been available for all sorts of purposes on the island.

Thus, the LNG energy megaproject in Cyprus provides a unique example of an emerging strategic alternative which requires a reassessment of the original approach and its comparison in terms of value creation with the newly appeared opportunity.

Emerging alternatives are an interesting phenomenon in project management, which is more pronounced for megaprojects due to their long-term nature. In the case of the LNG energy project in Cyprus, natural gas was discovered before the gas import project started. In general, strategic alternatives may emerge during the megaproject planning phase, during the implementation phase and after the completion of the megaproject. Management of emerging alternatives is phase-specific, but value creation comparison of the original and emerging solutions is common throughout.

The paper continues with a literature review on megaproject management and practices, technological solutions for sea gas import projects, their economic analysis, and the related risks in section 2. Section 3 explains the case study research design and methods. We go on in section 4 with presenting the Cyprus LNG energy project, while section 5 provides an analysis of the research findings of the case study. The paper's last section gives the conclusions of the research.

2. Literature review

2.1. Megaproject management and practices

Within the project management academic literature increasing attention is given to megaproject studies. That corresponds to the growing number of megaprojects carried out in energy, transportation, urban planning, and high-tech sectors worldwide.

The definition of megaprojects in academic literature usually includes volume and impact criteria:

- “megaprojects are large-scale, complex ventures that typically cost US\$1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people.” (Flyvbjerg 2014);
- “megaprojects are temporary endeavours (i.e. projects) characterised by: large investment commitment, vast complexity (especially in organisational terms), and long-lasting impact on the economy, the environment and society” (Brookes 2015);
- “very often megaprojects have sooner or later a measurable socioeconomic impact at a macro level, rather than only a compartmentalized microeconomic impact. It is conjectured that a trigger to a classification as a megaproject is that its approval always reaches the top-level governing body in companies, or government, Parliament, public interest groups, and last but not least, the press.” (Pau 2016).

The numerical threshold of US\$ 1 billion mentioned by Flyvbjerg (2014) is debatable, being subject to regional adjustments and it should thus not serve as a constraint in defining megaprojects, in particular, in developing economies and small countries. For example, the European Cooperation in Science and Technology Association defines megaprojects as “extremely large-scale investment projects that typically cost more than EUR 0.5 billion” and emphasizes that “megaprojects are united by their extreme complexity (both in technical and human terms)” (COST 2023).

Taking into account the regional importance and the long-lasting socioeconomic impact of the LNG energy project in Cyprus it could be concluded that the project should be classified and analysed as a megaproject because both volume and impact criteria are satisfied.

The next outcome of the megaproject definition considerations is that the value creation by megaprojects can not be assessed only through the traditional paradigm of positive NPV for the cash flows generated by a megaproject. The value impact of the other aspects of the megaproject, as a delivery model for products and services, should be taken into account.

Megaprojects are historically associated with poor delivery, both in terms of schedule and cost performance (Brookes 2015). The following properties are considered typical characteristics of megaprojects (Flyvbjerg 2014):

- megaprojects are inherently risky due to long planning horizons and complex interfaces;
- projects are led by planners and managers without deep domain experience;
- decision making and management involve multiple stakeholders with conflicting interests;
- technology solutions are often non-standard, leading to “uniqueness bias”, which impedes learning from other projects;
- overcommitment to a certain project concept at an early stage, resulting in “lock-in” and weak analysis of alternatives;
- due to the large sums of money involved, principal-agent problems and rent-seeking behaviour are common;
- the project scope or ambition level will typically change significantly over time;
- complexity and unplanned events are often underestimated, resulting in cost overruns, delays, and benefit shortfalls.

As it is shown in the paper many of these characteristics are valid for the LNG energy megaproject in Cyprus as well. Meanwhile, what is special about the megaproject in Cyprus was breaking news about the discovery of natural gas, i.e. the appearance of a strategic alternative. As a result of that, the start of the import LNG project in Cyprus was delayed due to its assessment and subsequent comparison with

the opportunity cost and value of the alternative energy project based on the own resources of the natural gas.

2.2 Technology solutions for gas-receiving terminals

Energy projects such as setting up and running a gas-receiving terminal require thorough consideration from various points of view and addressing a set of complex multidisciplinary questions.

A part of the academic literature is devoted to technology solutions. In general terms, the technological process of the project related to Cyprus can be described as follows: the imported gas in liquid form is transported by an LNG carrier by sea, and upon arrival, it should be converted back from liquid to gas form and fed to an energy system for electricity production. This technological chain is not unique and has been studied in the literature.

There are three major concepts for an LNG regasification marine terminal in sheltered waters and those are:

- a) Floating storage and regasification unit – FSRU Terminal
- b) Onshore storage and regasification – Onshore Terminal
- c) Floating storage unit and offshore berth regasification – FSU/Offshore Terminal.

The LNG regasification marine terminals have three major components which are then adjusted to give the concept desired by the customer. The Components are:

- a) LNG storage,
- b) LNG regasification
- c) Marine berthing for permanent mooring of the FSRU, temporary mooring of an LNG Carrier during transfer operations, or permanent mooring of an FSU (Barnes et al. 2017).

Figure 1. Different methods of import and regasification of LNG

Figure 1a)

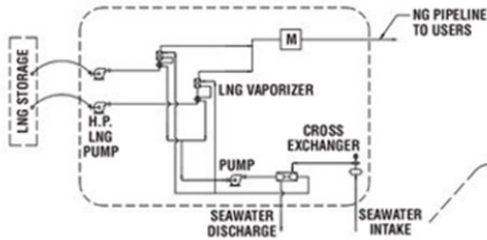


Figure 1b)

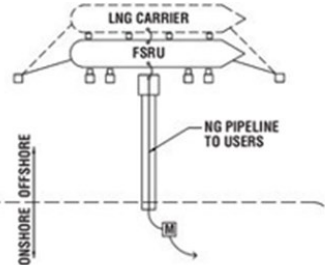


Figure 1c)

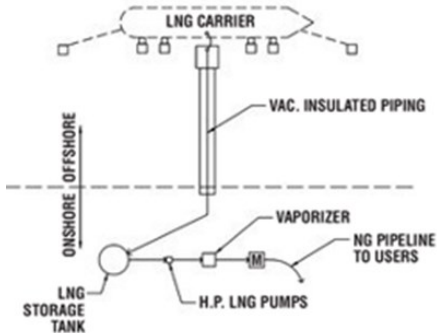
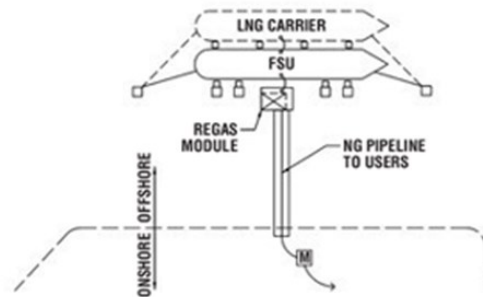


Figure 1d)



Source: Barnes et al. (2017).

Figure 1 illustrates:

- a) The regasification process (converting natural gas from liquid to gas).
- b) FSRU terminal processes. An LNGC docks next to the FSRU and unloads the LNG (ship-to-ship transfer). Then the FSRU transforms the LNG into gas and supplies it to the network. The regasification process is done offshore on the FSRU.
- c) Onshore Terminal processes. An LNGC docks at the jetty where via an insulated pipeline the LNG is transferred to the LNG storage tanks (ship to storage tanks onshore transfer). Then the regasification process of the LNG to a gas state is carried out onshore.

d) FSU / Offshore terminal. An LNGC docks next to an FSU and transfers the LNG (ship-to-ship transfer). The FSU then pumps the LNG to the regasification module (offshore or onshore), and from there to an NG pipeline to the end user.

The geographical locations of the three technological solutions (FSRU, FSU and Onshore terminal) are presented in Figure 2.

Figure 2. FSRUs, FSUs, and Onshore Terminal locations



Source: Norrgård (2018).

The most promising and fast developing is the FSRU technology. The primary impact of FSRU technology on the LNG market evolution is that it allows for more flexible and faster access to new demand sources.

2.3. Economic analysis of LNG import projects

The solutions to be implemented in course of the energy project realization shall be not only technologically sound but also commercially viable. The existing literature provides indications for the cost comparison between the three different technological solutions discussed above.

To have a proper comparison between the methods, some assumptions have to be made: the LNG regasification system and the marine berth are “similar” for each of these configurations and the loading platform for the FSU/Offshore Terminal configuration is larger than the loading platform for the other two configurations so that it can support the regasification module.

To compare the capital cost, taking into consideration the formulated assumptions, the cost is broken down into some sections. For each of the options, a

contingency of 25% of the cost is included, this is a usual rule of thumb for these types of projects. For each of the options, the capital costs are presented in Table 1.

Table 1. Capital cost comparison

FSRU Terminal	\$, m	Onshore Terminal	\$, m	FSU/Offshore Terminal	\$, m
FSRU	250	150,000 m ³ Storage Tankage	396	150,000 m ³ LNG Carrier	50
Marina Berth	25	Regasification Equipment	20	Regasification Equipment	20
Contingency 25%	69	Insulated Piping	3	Marina Berth	27
		Marina Berth	22	Contingency 25%	24
		Contingency 25%	110		
Total	344	Total	551	Total	121

Source: Barnes et al. (2017).

It could be concluded from Table 1 that the Onshore terminal is the most expensive solution out of the three options and the indicative price of the FSRU Terminal and the FSU/Offshore Terminal costs amount to about 60% and 20% of the Onshore terminal costs.

This conclusion is consistent with another literature source. According to Henderson (2017) the LNG facilities in form of FSRU have a price of around 50–60% of the onshore terminal price.

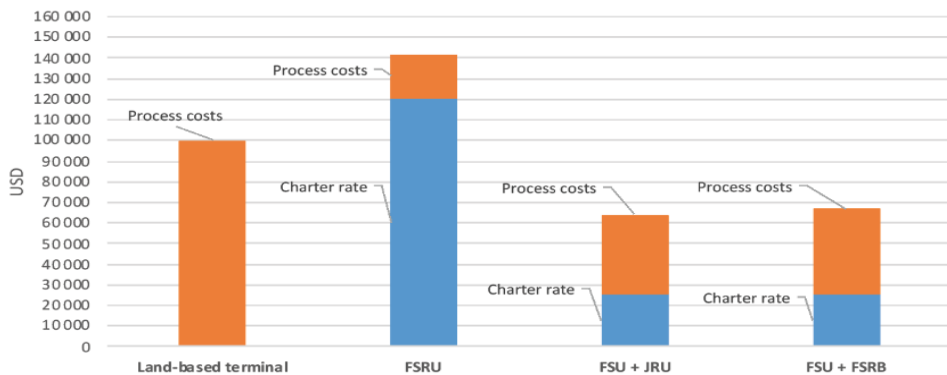
An important dimension of a gas terminal construction project is the completion time. Whilst projects vary considerably, below are some typical timeframes for the 3 different configurations:

- FSRU Terminal conversion. Converting an LNGC to an FSRU takes approximately 18 to 24 months. New builds typically can be constructed in 27–36 months (Songhurst 2017).
- Onshore storage and regasification. Onshore Terminal takes 3–5 years to be built (Hellenic Shipping News 2020).
- FSU/Offshore Terminal building takes approximately 22 months (Bulte, Foster 2017).

A similar assessment of the project completion time is provided by (Putra 2019). The construction times of FSRU are about half that of the onshore terminal LNG and another advantage of FSRU is that this facility can be moved to other locations when necessarily required.

The cost of the engineering, procurement, and construction project is determined by a variety of factors, including send-out capacity and storage size, as well as the project's location (bathymetry and met-ocean conditions). We can compare the CAPEX and OPEX costs of floating versus land-based LNG terminals by assuming a typical location that represents a majority of the FSRUs, such as onshore at a jetty head.

Figure 3. Illustrative cost comparison between options



Source: Norrgård (2018).

Table 2 summarizes the three most compelling reasons for investing in FSRUs.

Table 2. The most compelling reasons for investing in FSRUs

Advantage	Investment drivers
Lower capital cost	<ul style="list-style-type: none"> A new FSRU can cost 50–60% less than an onshore terminal. A 3 MTPA onshore terminal with a single 180,000 m³ storage tank is expected to cost \$700–800 million, compared to \$400–500 million for a similar capacity FSRU. On the other hand, the lower CAPEX must be balanced against the higher OPEX of the FSRU (depending on charter rates). Depending on commercial terms and load factor, OPEX can range from 0.4–0.7\$/MMBtu.

Table 2. Cont...

Shorter lead time	<ul style="list-style-type: none"> • FSRUs completion is half the time than that of an onshore terminal. • Onshore infrastructure construction typically drives lead time (not the development of the FSRU unit). • It takes 2.5–3 years to contract a new FSRU unit, and 1.5 years to convert a conventional LNG vessel. • Lead times can be shortened by repurposing/moving existing FSRU units, as evidenced by the fact that the second Egypt FSRU was completed in just 5 months.
Greater flexibility	<ul style="list-style-type: none"> • An FSRU can be utilized either as a floating storage unit, a floating regasification terminal (with storage) or as a traditional LNG vessel. • Given the right market conditions, additional flexibility can add significant value. • Before deciding to build a permanent onshore terminal, FSRU can provide an early gas option. • It is also possible to “retire” (and re-use) FSRU infrastructure at a low cost, reducing the risk of stranded regasification assets (4 have been retired by 2018) • In emerging markets, combined FSRU/power combinations (FSRU tethered to a barge with gas-fired generators) are gaining traction. • The physical flexibility of the FSRU translates into more commercial flexibility for operators (e.g., the ability to redeploy).

Source: Timera Energy (2018).

2.4. FSRU’s operational risks assessment

Although an FSRU project is expected to bring economic and social benefits, it can also be a source of environmental and social impacts during the construction and operational phases. Thus, one more important component of any LNG project for any of the technological concepts (FSRU, FSU, or Onshore terminal) is the risk related to the project. This aspect has also been addressed in the literature.

According to Baskoro (2019) a fire risk assessment on the FSRU loading arms and the gas export metering system can be carried out in several stages: identifying hazards, frequency analysis of hazards events, and consequences analysis. Finally, the result of the fire risk assessment can be carried out using the standard procedure of probability-impact risk mapping. The fire risk assessment indicates that the potential fire hazards which occur are jet fire, flash fire, and gas dispersion. Each hazard has leakage scenarios which are, small bore (10–50 mm), medium bore (50–150 mm), and

full bore (>150 mm). Thereupon, the result of consequence analysis indicates various forms of fire and expose areas that have an impact on marine crews.

Daryanto (2020) provides an approach to the risk assessment of the ship-to-ship operations, which is the process of berthing an LNGC to an FSRU, and then moving a number of LNG cargo from the LNGC to the tanks in the FSRU. The proposed risk assessment process includes similar to the fire risk assessment stages: hazard identification and risk assessment, job safety analysis, and ranking of risks using the risk matrix method.

Fadhil (2020) performs a risk assessment of another technological process – operations of the offloading system of LNG FSRU, which is supported by historical statistics of accidents that occurred during the process of loading and unloading liquid and accidents that ended in fire.

Having reviewed the proposed approaches for LNG FSRU activities, it could be concluded that the traditional operational risk assessment framework is based on the frequency-severity assessment.

Even though FSRU is actively studied in the literature and general approaches for FSRU are well developed, each of the FSRU projects is unique and requires project-specific solutions.

3. Case study research design and methods

The LNG import project is the biggest energy project ever undertaken in Cyprus. This energy megaproject offers valuable experience and practical insights on how such projects can be started and managed in other locations. An emerging strategic alternative is a remarkable phenomenon observed during the implementation of the energy megaproject in Cyprus.

By its research design, this paper is a case study analysis. In line with Yin (2014) the major focus of the case study is the decision-making process of the energy megaproject in Cyprus. The research questions of the study, why project management decisions were taken and how they were implemented, addressed across 5 dimensions: technology solutions, economic value, risks of the megaproject, environmental impact and assessment of emerging alternatives.

The project management perspective of the case study of the energy megaproject in Cyprus relates it to the following energy sector studies: Westerman (2014), Ochieng (2016), Brookes (2015), and others.

From the perspective of quantitative vs qualitative research, the paper is based on qualitative methodology, which deals with unstructured data derived from various sources like academic and media publications, interviews, focus groups, case studies and observations. The qualitative research method has been chosen due to its flexibility, multidisciplinary, and ability to set up a broad view of the subject.

The research has been performed in two stages. The first stage is thorough research, from published articles and with the use of the web, on the technical, economic, and environmental ESG aspects of the LNG energy project in Cyprus. This stage has been carried out in order to grasp as much as possible information on how an FSRU can be set to run in Cyprus.

In the second stage, any unanswered questions, or information that is not provided have been asked of key persons of the LNG energy project in Cyprus during face-to-face interviews.

Qualitative research in the form of face-to-face interviews was chosen for the primary research to acquire more in-depth details about the setting and running of the FSRU in Cyprus and to fill all missing gaps of the initial research. Although vast information is publicly available, the face-to-face interviews allow us to identify issues in the setting or operation of the FSRU, which can be later analyzed to suggest recommendations and solutions overcome any obstacles for a smoother operation.

The experts who gave interviews had a unique combination of hands-on experience and a broad strategic vision of the LNG import project in Cyprus. They have been involved in the project as active decision-makers. The experts are representatives of two organizations, which actively involved in the realization of the LNG project:

- DEFA, which is responsible for the import, storage, distribution, transmission, supply and trading of natural gas, and the management of the distribution and supply system of Natural Gas in Cyprus.
- Hill International, Inc., which was contracted by ETYFA as the Owner's Engineer for the supervision and monitoring of the progress of services with

respect to the implementation of the LNG import infrastructure development project in Cyprus.

The two face-to-face interviews took place in April – July 2021.

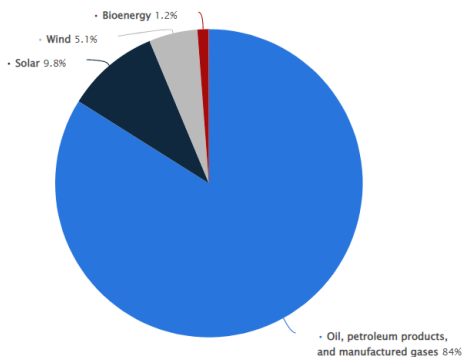
4. Cyprus LNG energy project

4.1. Technology solutions for the project in Cyprus

Cyprus is an island with no indigenous hydrocarbon energy sources. The power generation system of Cyprus totally relies on imported fuels for electricity generation. Currently, the primary imported fuel used in electricity generation is heavy fuel oil and gasoline.

As can be seen in Figure 4, oil and petroleum products are the main sources of electricity production. Cyprus is largely reliant on imports of such products, which accounted for 84% of its total electricity generation in 2021. By comparison, solar power contributed 9.8% to the power mix that year.

Figure 4. Distribution of electricity generation in Cyprus in 2021, by source



Source: Statista (2023).

Cyprus is a small island with an isolated energy grid with only one vertically integrated electricity company and no interconnections to neighboring systems. The use of Gas Oil and Heavy Fuel Oil for the production of electricity imposes great costs

on industries and households resulting in Cyprus has one of the most expensive electricity costs in Europe (CERA 2015).

This structure of electricity generation results in low energy efficiency and the major impacts on the Cyprus economy can be summarized as follows:

- High costs of electricity production slow down the economic growth driven by internal resources.
- Also, energy costs are among the Top-3 of the most frequently mentioned long-term barriers to investment in Cyprus (European Investment Bank 2023)
- The overhauled EU energy policy framework incentivizes its member states in transitioning from conventional fossil fuels and generate more CO₂ emissions in comparison with more “green” alternatives.

Starting to import gas to the island is an energy project that can address all the above challenges. Moreover, the LNG import project can change the country’s economic model, open the competition in energy resulting in better service and prices for the Cypriot consumer, and also open new job positions for Cypriot citizens. Furthermore, it has been debated that the transition to solar energy or other “green” alternatives, is much smoother from gas than it is from coal generators.

The introduction of gas as an electricity production source in Cyprus can reduce the cost of electricity due to the lower cost of gas and also it will open the market and stop the current monopoly of EAC, creating healthy competition, and resulting in lower costs to the end users. The gas import project would also contribute to Cyprus’s employability rate.

Furthermore, after the Paris Agreement, it has been the EU’s target to reduce carbon emissions and also to gain more independence in Gas supply throughout Europe as currently is heavily dependent on non-European countries, such as Russia. Therefore, the EU started a funding program aiding European countries in setting their own infrastructures for supplying gas. Hence, with an FSRU, gas can be provided by sea by different producers and adding to that, Cyprus’s discovery of its own reserves provides a great opportunity for Cyprus and Europe in general.

According to estimations of some experts (Andreou 2019), the new LNG terminal will enable Cyprus to replace the use of heavy fuel oil for power generation with natural gas, cut energy prices and reduce carbon emissions by at least 30%. Similar

projections are also provided in other publications. By replacing the conventional oil-burning method for producing electricity generation with the natural gas electricity production method, Cyprus will cut its carbon footprint by 25% to 30%. At the same time, taking the assumption on conservative estimates, the cost saving from the changeover, will range between 15% to 25% from 2022 to 2025 (FinancialMirror 2020).

The import of (liquid) natural gas, (L)NG, in Cyprus is a project not of only national, but also cross-border and European importance and for this reason, it has been included in the projects of Common Interest of the EU. This unique project helps reduce the effects of the energy isolation of Cyprus and helps it connect to the trans-European energy and transport networks. This project is a guarantee for the regulation of the domestic energy market and at the same time paves the way for the expected convergence with the rest of Europe.

Meanwhile, starting an LNG import project is a challenge for the Cypriot government which had no previous experience in the Oil & Gas sector. On one hand, the LNG import project is the biggest energy project ever undertaken in Cyprus, which puts Cyprus on the track of a new energy era and opens new prospects for the development of the economy and the welfare of the country and the people, while on the other hand, it is a management challenge of strategic importance for the future development of Cyprus.

In the due course of the managerial decision-making process, several important steps have been undertaken by the Government. The Natural Gas Public Company, known by its Greek acronym as DEFA, has been established in Cyprus as the concern was risen for the development of the internal gas market and network. Thus, DEFA is in charge of natural gas import, storage, distribution, transmission, supply, and trading, as well as the management of Cyprus' natural gas distribution and supply system. The Council of Ministers of the Republic of Cyprus issued a decree on June 18, 2008, appointing DEFA as the exclusive importer and distributor of natural gas in Cyprus and directing DEFA to secure the required natural gas amounts at the best economic conditions.

The main scope of DEFA's actions is (DEFA 2021):

- Purchasing, importing, storing, using, distributing, selling, and supplying natural gas in any form
- The Natural Gas Transmission and Distribution Network's operation.
- Any tangible or intangible goods, including Natural Gas, are negotiated, bought, sold, managed, stored, imported, exported, re-exported, and so on.

DEFA established the Natural Gas Infrastructure Company (ETYFA) Ltd. as a Special Purpose Vehicle (SPV) in 2018 to own and administer the LNG Import Terminal. DEFA owns 70% of ETYFA's shares, while the Cyprus Electricity Authority owns the remaining 30%. The LNG Import Terminal will be owned and managed by ETYFA, which has previously signed an EPCOM Agreement for its construction and operation and maintenance. The project consists of the FSRU, a jetty for mooring the FSRU, a jetty-borne gas pipeline, and all associated infrastructure (Natural Gas Infrastructure Company ETYFA 2021).

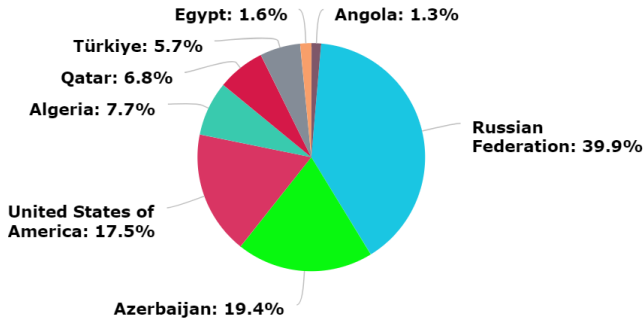
Another important initiative of the Government was to introduce Oil & Gas scholarships for master's and doctoral level postgraduate programmes to grow the local expertise in the area (Cyprus Mail 2022).

To run the project, the raw material is needed, which is LNG. The following two-stage process is introduced to acquire the LNG: 1) Expression of Interest (EoI); 2) Request for Proposal (RfP).

25 EoIs were received by Cyprus. Participants expressed their interest in supplying LNG to Cyprus through Sales and Purchase Agreements and/or Master Sales Agreements. The gas can be acquired from different prospective countries, according to the market at the time. There are prospective countries all over the world not just in the Mediterranean but even Australia is a prospect country. However, there will be some minimum specifications for gas providers.

Due absence of the history of imports of natural gas by Cyprus, some insights about the potential exporters can be received from the NG imports of Greece.

Figure 5. Imports of natural gas by Greece in 2021, terrajoule (gross caloric value)



Source: EUROSTAT (2021).

Thus, it could be concluded from Figure 5 that Azerbaijan, the United States of America, and Algeria are among the promising exporters of LNG to Cyprus. To secure more FSRU contracts, Cyprus will also deliver LNG to neighboring countries in the Mediterranean.

The project location is strategically selected to be adjacent to the east fence line of the Vassilikos Power Station and within the boundaries of the designated Vassilikos industrial area. The land parcels identified for development are owned by the Government of Cyprus. An FSRU, jetty, gas pipeline, ship-to-shore vessel loading arms, and a fire-protection system are the project's primary components.

Out of the three technological solutions for gas import terminals discussed in the literature review, namely FSRU Terminal, Onshore Terminal, and FSU/Offshore Terminal, for the Cyprus energy project, an FSRU-based LNG import was chosen. The FSRU solution was selected due to its flexibility.

FSRUs are flexible by nature and the project has been designed to allow flexibility in the use of the facilities: the FSRU will include an LNG bunker vessel connection and an LNG off-loading system to be able to use the infrastructure as a ship-to-ship bunkering facility. The marine infrastructure has also been designed to allow a future expansion with additional berthing positions, which can be used to serve ships to export natural gas. The natural gas pipeline will also be bidirectional. Finally, the

FSRU can also disconnect from its berth and travel under its own motive power as a regular LNG carrier if required.

The vessel, that was chosen to be the FSRU in Cyprus, is named “GALEA” LNGC, see Figure 6. It was owned by Shell Tankers Singapore Private Ltd.

Figure 6. GALEA LNGC



Source: MarineTraffic (2021).

The conversion from LNGC to FSRU is completed at HUDONG Shipyard in China. After the conversion is completed, the vessel will be classed as both LNGC and FSRU.

After converting from LNGC to FSRU, the vessel will be able to accept LNG from LNG carriers with capacities ranging from 120,000 to 217,000 cubic meters (Q-FLEX) (Andreou 2019).

The project includes the acquisition of an FSRU and the construction of associated infrastructure (including jetty, offshore and onshore pipeline) to import, store and regasify liquefied natural gas (LNG) back to its normal gaseous state. The FSRU will be permanently anchored to the seabed of about 1.3 km off the coast of Limassol in Vassilikos Bay and will connect directly to the adjacent and largest power station in the country, the Vassilikos power station.

Four alternatives were examined regarding the site selection for the project and construction technologies, aiming at the selection of the optimal solution.

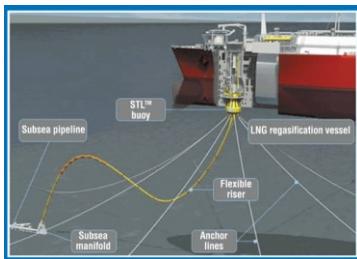
Alternative 1: Permanent Berthing of the FSRU at an existing access jetty, which belongs to VTT Vassilikos Ltd.

Alternative 2: Construction of a jetty/ trestle, which will serve the permanent berthing, as well as loading and unloading operations of the FSRU and LNG Carriers. The owner of the jetty will be the owner of the FSRU operation.

Alternative 3: Construction of an underwater gas pipeline leading to a central loading and unloading platform where the permanent berthing of the FSRU and LNGC is being serviced as well as their loading/ unloading operations. The alternative relates to the complexity of building an underwater pipeline and higher CAPEX.

Alternative 4: Construction of an underwater gas pipeline leading to a single point mooring (see Figure 7) for the vessel, which will serve the permanent mooring as well as the loading/ unloading operations of the FSRU and LNG Carrier. This alternative is ideal for locations with rough weather since the buoy can take the movement of the FSRU. It relates to high CAPEX as well.

Figure 7. Single Point Mooring



a) Underwater view

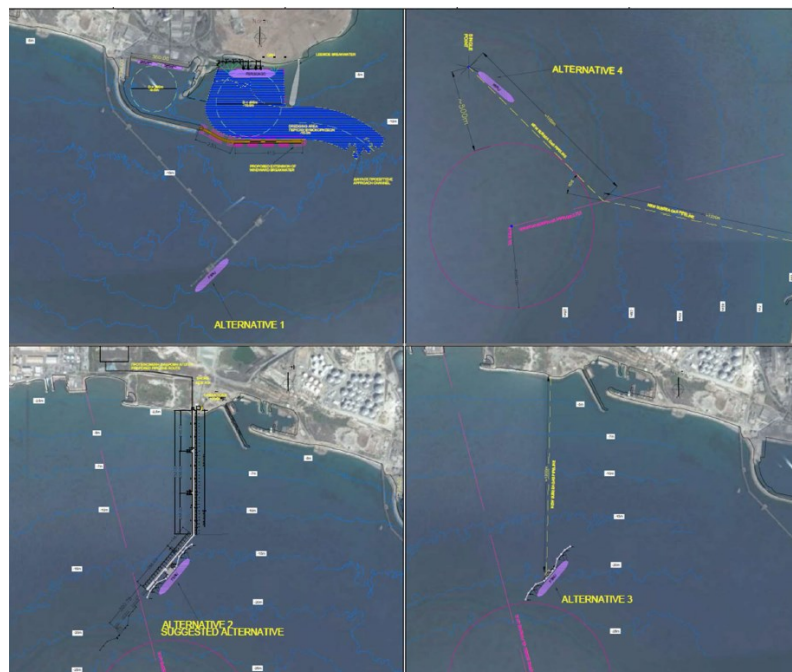
Source: Aisyah (2017).



b) Top view

Source: Exxon Mobil (2021).

Four alternatives under consideration for different FSRU berthing solutions are presented graphically in Figure 8.

Figure 8. Alternatives for different FSRU berthing solutions

Evaluation between 4 different alternatives of FSRU near Vassilikos Port has been carried out by various groups of experts. In consideration of the technical (flexibility and serviceability), economic, environmental, and future operation/synergies (expandability), Alternative 2 was chosen as the optimal solution for Cyprus by the Government.

The construction of the LNG terminal was awarded to a multinational consortium. The consortium, led by the state-owned China Petroleum Pipeline Engineering, a unit of CNPC, has secured the contract to build the terminal. The consortium includes Metron Energy Applications and Wilhelmsen Ship Management (Duran 2020).

The gas imported to the market through the FSRU will be supplied to the Vassilikos power plant. Currently, all power generating stations in Cyprus use heavy fuel oil for the steam turbine units and gasoline for the gas turbine units. Meanwhile, the three steam turbines at the Vassilikos power station are ready to shift from the use of heavy fuel oil to the use of natural gas. They are designed to run either on fuel oil

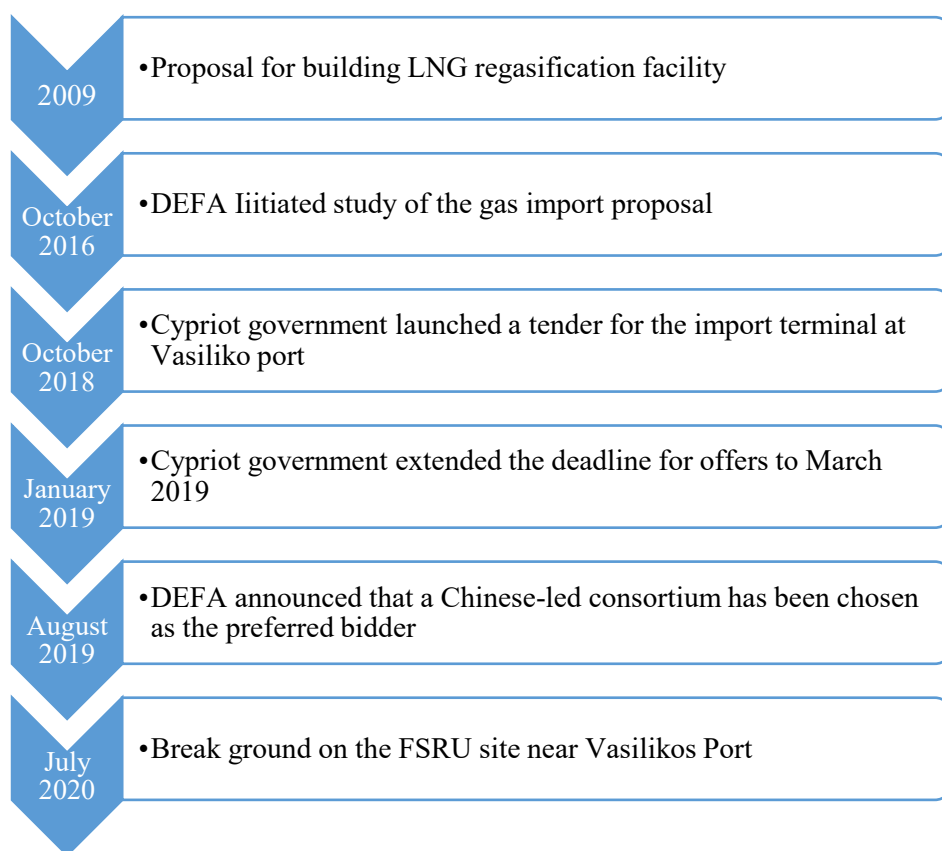
or natural gas. No CAPEX or lifetime extension of the plant will be required to enable this switch.

4.2. Financing of the LNG import project

In total, the energy project of setting up generating electricity from imported LNG includes a floating storage and regasification unit (FSRU), a jetty for mooring the FSRU, a jetty-borne gas pipeline and related infrastructure.

The government will own the LNG terminal through the Natural Gas Infrastructure Company of Cyprus (ETYFA), a subsidiary of the Natural Gas Public Company (DEFA), and supply gas to the Electricity Authority of Cyprus (EAC).

Figure 9. Illustration of the timeline from proposal to breaking ground



The planned LNG facility will have an LNG storage capacity of 120,000–250,000 m³ and will aim to provide a send-out capacity of regasified natural gas of up to 220T / hour initially and be able to cover additional capacity requirement in the future. Since at least 2009, the government of Cyprus has been promoting a proposal to build a liquefied natural gas (LNG) regasification facility near Vassilikos Port in Cyprus. More details for the chronological progress from the conception of the FSRU to be built in Cyprus to breaking ground on location can be seen below.

Although the project is of strategic importance for the Republic of Cyprus, it cannot be financed only internal resources. With a price tag of around €400 million, the project has been dubbed the biggest ever in the field of energy in Cyprus. The costs of the project are material in comparison with the country's GDP and amount to about 1.5% of Cyprus' GDP.

Table 3. Financing of the FSRU project

Description	Amount (EUR, mln)	Share (%)
ETYFA won a grant under the EU's Connecting Europe Facility	101	27%
European Investment Bank (EIB) loan	150	40%
European Bank for Reconstruction and Development (EBRD) loan	80	21%
Electricity Authority of Cyprus (EAC) contribution	43	12%
Total	374	100%

Source: Aristeidou (2020).

From Table 3, it could be concluded that only about 10% is internal funding and the remaining 90% share was provided by external sources. It is very helpful to the Republic, especially taking into account that about 25% is not refundable funding.

The commercial terms of the loans are not fully disclosed, but it is known that a guarantee from the Government of Cyprus was provided. Thus, the loans will benefit from sovereign guaranteed loan status.

The assessment of loans by creditors is undertaken from a social perspective as well, in particular, this includes the use of a lower interest rate applied to all economic values. The tenor of the EBRD's loan is 20 years from the date of signing of the loan agreements, which can be considered as corresponding to the nature of the project.

The repayment of the loans will depend on the revenues of ETYFA, and debt service capacity comes from electricity tariffs paid by consumers. The revenue structure can be assessed as robust.

4.3. Risk assessment of the energy project in Cyprus

The risks related to this energy project can be broadly grouped into two categories: risks related to operations of newly introduced industrial objects itself and potential environmental risks.

The location of the FSRU ensures adequate distance from the shore concerning the protection of community health and safety. The onshore facilities will be fenced, and access will be restricted. It is planned that the FSRU and the equipment used will have safety systems in place to identify and prevent safety risks (emergency shutdown, leakage limitation, fire protection, flood control and crew escape as well as any other security system and equipment required by the competent authorities and good industry practice). A safety zone will also be defined around the FSRU in collaboration with the port authorities and the Vassilikos Bay management authority to minimize collision risks and occupational and community health and safety risks (e.g. fishermen).

The project design has taken into consideration the seismicity of the region and the potential risks resulting from damage to the pipeline and FSRU because of earthquakes. Other natural hazards like extreme waves, winds and temperatures have also been taken into consideration. The client will review and monitor its contractors to ensure that proper actions are taken for the protection of the community in terms of environment and health and safety.

The assessment of the environmental and social impacts was carried out in the course of the decision-making process. The assessment of the environmental impact and corresponding risk mitigation actions can be summarized as presented in Table 4.

Table 4. The environmental and social impacts

Environment	Impact	Risk mitigation actions
Soil	moderate	Collection of used materials and waste Measures to prevent oil spills from leaks, negligence, etcetera
Atmosphere	low	During the operational phase of the project, an effort is being made to reduce the emission of gaseous pollutants and the MARPOL Convention on atmospheric emissions from ships' engines applies.
Water Resources	moderate	Establishment of an appropriate diffusion/dispersal system of the water used for the gasification of LNG to minimize the impact of seawater temperature pollution
Noise	low	during the operational phase, the project operator should operate and maintain all its equipment following the manufacturer's specifications and will take all necessary measures to reduce machine noise during normal operation.
Flora, fauna	low	No specific measures, monitoring.
Marine ecosystems	moderate	management of the produced solid and liquid waste as well as the used mineral oils and the rest petroleum products.
Natural resources	moderate	No significant impacts are expected on the natural resources of the study area during both the construction and operational phase.
Transportation – traffic	moderate	During the construction phase of the suggested works, a series of mitigation measures are suggested that apply to such large-scale projects.

Source: CYNERGY (2018).

The total impact on the environment is assessed to be positive as a result of the significant reduction of emissions of gaseous pollutants (SO_x, NO_x, PM₁₀, CO₂), due to the change in the fuel use from petroleum products to Natural Gas adopted by the Electricity Authority for the Cyprus plant.

Meanwhile, monitoring of risk factors shall be performed regularly during the constructional and operational phases of the project. Also, insurance, as a risk-transferring tool, in particular against rare but plausible events, which might have a catastrophic impact on the whole country, shall be in place.

4.4. Cyprus's future opportunities arise from the LNG energy project

A new market and industry opportunities from LNG imports can emerge. While the FSRU project is being set up, there will be a direct impact on the people living in Cyprus by utilizing the local workforce to set it up. That workforce can either be used

as labourers or even technical staff providing expertise. One additional positive factor in this is the experience and expertise locals will get from the LNG industry.

After the project is up and running, then locals, through DEFA or ETYFA will be hired and trained to fill the positions that are usually expats will fill at the beginning of the project. The number of local people that will be hired is not final yet, as adjustments will be made when the time comes.

The practice of transferring liquefied natural gas fuel to a ship for its own consumption is known as LNG bunkering. The primary benefit of LNG as a fuel is the significant reduction in pollution created by previous ship fueling methods such as heavy fuel oil, marine diesel fuel, and marine gas oil.

For Cyprus, this will be a perfect opportunity, either for independent companies, or the government itself, to play an important role in supplying LNG to the vessels that pass through Cyprus. Those vessels as described above can range from big cruise ships to small cargo vessels. The geographical position of the island, once again, can flourish Cyprus as an LNG hub.

In the year 2020 Cyprus government paid 40 million euros as a fine, which was imposed for not achieving the 2020 target for Renewable Energy Sources contribution to gross final energy consumption in transportation (Ellinas 2021). As a result, that money is added to the monthly electricity bill of the consumer (households, factories, etc.). Now, stating the above does not mean that Cyprus should be only dependent on renewables. The difference in usage of NG to produce electricity and oil/coal power plant is, that the NG can heat up and produce energy faster than its predecessors. Meanwhile, the decision of introducing NG should not be thought of as it would stop renewable energy sources. Fossil fuels have to coexist until renewables can be technologically advanced to cover all the demands and fluctuations of the market.

5. Analysis of research findings

Only during the interviews, it was realized how many different aspects had to be analyzed and organized to even begin setting up the LNG station. The most important role in this was the role of DEFA, which was founded with the goal of procuring and

introducing natural gas as a power production option for Cyprus. For more than 10 years, DEFA tried to begin setting up the LNG terminal in Cyprus. A key expert has explained how difficult was to even start negotiations due to the lack of experience and misconception of how Cyprus can extract and use its own gas immediately after the discoveries.

There were four attempts and only the fourth attempt for the LNG import project was successful.

- The first attempt was with Royal Dutch Shell, which made a competitive offer for a 20-year supply line of liquid natural gas to Cyprus. There was a discussion with Shell, but the agreement was cancelled in 2011. The main reason is that Shell's agreement coincided with the discovery of natural gas, Aphrodite of Block 12, in Cyprus. At that moment, people in Cyprus considered that in a few months after the discovery, NG would have been available for all sorts of purposes on the island. As Cyprus was new to this concept, the realization of the mistake came later, but in the meantime, the negotiations with Shell were cancelled.
- The second attempt was with a Russian company. The attempt failed in the commercial aspect. The agreement under discussion was considered to be very expensive.
- The third attempt, at building a terminal and having the LNG took place a few years ago. It did not proceed for two main reasons:
 - Again, the misbelief that Cyprus shall not import but shall use its own NG, because Cyprus will have and can monetize its NG reserves in the nearest future.
 - The commercial reason, the tender included both the development and the supply in one contract. Two distinctly different activities and distinctly different costs were combined together. The cost of the terminal is less than the one-year cost of fuel. The terms of fuel supply were significantly more heavily weighted than the terminal. So, the dynamics between the two did not work very well.
- The fourth attempt was based on a new approach to tendering. The first important amendment is that DEFA completely disengaged Cyprus' own

reserves. The focus was made on the supply of gas for power generation. It was decided that when Cyprus develops its own reserves and can sell NG to DEFA at a competitive price, DEFA will use gas from our own reserves.

However, the cost of delay in bringing NG to the Republic is very significant. About 10% of electricity bills constitute of penalties for emissions – under a simplifying assumption, at a half billion annual turnover, 10% of which makes 50 million euros per year. Thus, the costs of the project are comparable with the emission penalties for several years.

The second important amendment is the separation of the terminal construction from the NG supply. The reason for the separation is the completely different dynamics and durations of these two sub-projects. It was one of the reasons that the third attempt did not work. Thus, DEFA took out its own NG reserves of Cyprus from the considerations and separated terminal construction from LNG supply. The amendments gave flexibility in negotiations.

After achieving the separation of the reserves, the terminal and the supply, another key aspect was the securement of the grant from the EU Commission for 101 million euros. As the grant was not a loan, it shall not be repaid, and the grant brought the costs down significantly. According to experts, they have also secured a 20-year loan with very low-interest rates, emphasizing the good work accomplished by all stakeholders, including DEFA.

Thus, only through the process of several iterations for about 10 years, a correct approach had been elaborated and all stakeholders have aligned their interests to proceed and try to make the construction of the terminal a success for the benefit of the Cyprus economy.

Answering the question of either this project can be used as a model for other islands in a similar or smaller scale of FSRU, the key expert answered that the approach of Cyprus is being watched by many. The way how the project in Cyprus is approached and processed is made for the first time. In particular, a good step was to make an agreement with one consortium, so any issues they have to solve amongst themselves and come up with a solution. So, Cyprus is a kind of breaking new ground in this respect and this may be followed by different new projects.

Meanwhile, although DEFA got a vast significant experience, there is an understanding that Cyprus is coming to the industry quite late. There is no intention to reinvent the wheel, DEFA wants to hit the ground running. There is a two-way stream. DEFA is ready to both share experiences and to learn.

Concerning its own NG resources of Cyprus, as of now, there are no obligations of DEFA to buy it unless the price is competitive because a more expensive fuel will mean a higher price of electricity. Thus, the supply contract is flexible and reserves several time windows when the LNG supplier can be changed. Thus, Cyprus can switch to using its NG gas reserves.

The key expert expressed his opinion that the LNG import gas is an important intermediary step for the ultimate goal of transferring Cyprus to green renewable energy because the project allows not paying fines and penalties for the emissions for the next 15 years until the green technology based on only renewable sources of energy might be established.

When asked about Covid-19 and how it affected the project and if it imposed any delays, the key expert answered that it had some impact and made things difficult however the involved parties try to find solutions to avoid great delay on the timeline of the project. When the project started, the first electricity produced by NG was expected in January 2023. Meanwhile, in February 2022 mainly due to the pandemic and supply-chain issues for the delays, the project was rescheduled to mid-2023. According to the media in January 2023, it is impossible for the Vassilikos Port LNG terminal to be completed by mid-2023.

The expert also stated that NG will have a multiplier effect on Cyprus, and it is wrong to focus only on the possible 10–15% reduction in electricity prices. He explained that the project will boost jobs and introduce competition, and furthermore Cypriots will no longer be subject the fines for CO₂ emissions.

One of the commercial possibilities is bunkering. Bunkering is the supply of vessels with LNG. LNG bunkering is having a smaller ship coming to the FSRU, loading from the FSRU, going to the cruise liner, and giving fuel to the cruise liner. The FSRU terminal is already being designed to support bunkering operations. Cyprus is extremely well located for bunkering, because of the Suez Canal and the tourism in the area. Bunkering was rapidly being adopted by cruise liners, so all new cruise-

liners use LNG as fuel. At some point, the ship owners were resisting to use of LNG for other types of cargo (transportation ships, container ships, etcetera). However, it seems that new orders, of new ships, are also for LNG bunkering and that is an opportunity.

Choosing between leasing an FSRU and buying was a simple matter because the charter fees for 5 years are equal to the purchasing price of the vessel. But the most important aspect was that the grant does not support the chartering. The lifetime of the FSRU is 20 years. After 20 years the ship can be refurbished or sold. One of the requirements of the grant was that this facility is being developed and remains operational for the energy security of Cyprus. Even if Cyprus has its own reserves in 3–4 years, and even if they come with a pipeline to Cyprus, the concept for the FSRU and Cyprus' commitment under the grant is that the terminal remains operational for the next 20 years.

In the process of deciding on the capacity of storage, historical and projected data for electricity consumption from CERA, the Cyprus Energy Regulatory Authority, was taken into account by DEFA. Also supportive was a collaboration with Cynergy, which is a project funded by the European Commission. Cynergy aims to study the maximum utilization and penetration of NG in the economy of Cyprus, and it covers everything from transportation to power generation.

According to experts, the storage capacity of the FSRU will be 125 000 m³ and the operating capacity will be 5 million tonnes per annum. The FSRU and the piping will be run at 80 bars. But for safety purposes, the whole system will be tested at 150 bar. To test the lines, the company will fill them up with water and pressurize them (hydro test).

The pipeline itself will be of carbon steel with a 1-inch thickness. The pipeline owner will be Vassilikos Power Station. Only two licensed IPP (Independent Power Producers) will be allowed to use the gas. For the first stage, the sole buyer of LNG will be Vassilikos Power Plant. The Vassilikos Cement Works has also an IPP license but will not be set up in the first stage. Answering the question of what happens if another IPP will be licensed to get gas, the key expert said that DEFA will sell the gas to everybody at the same price. For the first 10 years, DEFA will have a monopoly in this role. So, nobody can buy gas in Cyprus from any other seller. The reason for this

is to encourage and facilitate the creation of a free market. Everyone who signs the contract at the same terms and gives the guarantees will be able to take the gas. The details will be defined if the situation emerges.

In case of extreme weather, the FSRU will have to be released from the jetty, for the structure (jetty) to be safe, and also for the FSRU. Thus, the next reasonable question is where the FSRU will have to be released, does that mean that the supply of LNG will stop and power generation as well? According to DEFA experts, the answer is no. This situation has been discussed and the following technical solution was found. The supply will be maintained for an additional 30 minutes from the point that the FSRU is released. As agreed with Vassilikos Power Plant, that time is needed to switch from gas-powered electric generators to conventional power generators. To provide that buffer period, a 24-inch pipeline will be looped (the total length of pipework that will be used as “storage” tanks will be 7 km) underground to provide that volume for 30 minutes.

The jetty will be also designed for LNG bunkering purposes for future usage. The jetty will be 14,5 m wide and 15.5 m deep (at most). The jetty will be able to have two-way traffic for safety purposes, and also if there is ever a need for an ambulance to drive there.

During the interviews, nothing specific was revealed concerning the risk of the project. According to the experts, rollover (ship-to-ship) operations are always an operating issue in FSRU projects. Meanwhile, in general, LNG, being in liquid form, is a non-flammable material, so there should be no fear of ignition or explosion.

6. Conclusions

The realization of the LNG energy megaproject in Cyprus is extremely valuable for the further development of the country. Cyprus is a small island with no electricity interconnections to neighboring systems. The use of oil to produce electricity imposes great costs on industries and households resulting in Cyprus having one of the most expensive electricity costs in Europe. Also using conventional fossil fuels for power

generation results in higher CO₂ emissions in comparison with more “green” alternatives.

The introduction of the LNG in Cyprus can:

- reduce the cost of electricity to the end users due to the lower cost of gas;
- open the market and stop the current monopoly of EAC by creating healthy competition;
- provide additional income from selling LNG to other countries or vessels through bunkering;
- contribute to Cyprus’s employability rate through the creation of new working places;
- stop fines and penalties for CO₂ emissions paid by Cyprus and, what is more importantly, improve the ecological situation on the island due to the lower carbon content of natural gas compared to liquid fuels.

The above will just be the direct impact of the LNG megaproject in Cyprus. In addition, there is also the tremendous amount of knowledge and expertise that locals get from being involved in the Oil & Gas world. As can be seen from the findings, both the government and the team behind it, learn from their mistakes and adjust. This as a mentality, is one of the biggest assets the team management can have.

Managing the energy megaproject in Cyprus facilitated the accumulation of unique knowledge, skills and experience, which can provide practical insights and guidance on how megaprojects can be started and managed in other locations.

In the case of the energy megaproject in Cyprus, after a relatively fast selection of FSRU as the technology solution, the megaproject was delayed by the discovery of gas in Cyprus and the common misbelief that in a few months after the discovery, natural gas would have been available for all sorts of purposes on the island. Opposite to the intuition, this discovery of gas in Cyprus, which in substance is an emerging strategic alternative, worked counterproductive despite its positive nature. The new value introduced by the strategic alternative and the time needed to extract this value were misestimated and as a result, delayed the realization of the megaproject.

The impact of the strategic alternatives and the time of their appearance are very important for the implementation of the original megaproject. From this perspective, ongoing monitoring of emerging strategic alternatives, assessment of the value

introduced by the alternatives and establishment of decision-making processes with a fast reaction to the emerging alternatives should be vital components of the megaproject management framework.

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Annex**List of abbreviations**

Abbreviation	Explanation
CAPEX	Capital Expenditure
CERA	Cyprus Energy Regulatory Authority
CO ₂	Carbon Dioxide
EAC	Electricity Authority of Cyprus
EN	European Committee for Standardization
ESG	Environmental, Social and Governance
FSRU	Floating Storage and Regasification Unit
FSU	Floating Storage Unit
IPP	Independent Power Producer
ISO	International Organization for Standardization
kWh	kilowatt-hour
LNG	Liquified Natural Gas
LNGC	Liquified Natural Gas Carrier
NG	Natural Gas