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Environmental impact assessment methodological framework for liquefied natural gas terminal and transport network planning

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HIGHLIGHTS

- Determined the optimal location for an LNG terminal in Cyprus.
- REGIME multi-criteria analysis used to prioritize alternative LNG terminal locations.
- Multiple modes of transportation connections were evaluated and geometric alignments were proposed.
- Environmental impact assessment and validation was undertaken based on a structured questionnaire and an expert panel.
- Parameters such as safety, existing infrastructure, and access were also considered.

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ABSTRACT

The recent discovery of significant offshore natural gas reserves in the Aphrodite field, south of the island of Cyprus in the Mediterranean Sea, changes the energy landscape in the greater Mediterranean-Middle East-Caucasian Region. In this paper, different alternative locations for the construction and operation of a liquefied natural gas (LNG) terminal station in Cyprus were evaluated, explicitly considering also their connection to the power generation station of Mari and the country's gateway.

The problem of determining the optimal location for an LNG terminal in Cyprus has been approached using multiple methodological components, which consider environmental and transportation issues, both technocratic in nature, as well as more subjective and based on expert opinion. The first step was a REGIME multi-criteria decision analysis used to prioritize alternative LNG terminal locations. Then, multiple modes (railroad and pipeline) of transportation connections were evaluated and geometric alignments were proposed, considering a multitude of restrictions. Finally an environmental impact assessment based on a structured questionnaire and an expert panel was conducted to validate and assess the impact of the alternative options (combination of location and transportation mode and route). During the evaluation process parameters such as safety, existing infrastructure, and access were also considered.

1. Introduction

Energy adequacy is universally recognized as a crucial parameter for the sustainable development of a nation. The main objective of an administration regarding the energy policy of a nation is to ensure balance between total energy demand and supply. This goal will be better achieved if the energy "mix" is obtained involving analysis of existing and potential energy sources in two ways by: (a) considering how future supplies can be guaranteed and (b) identifying future energy needs for various sectors (Verma, 2007). In order to maintain availability of energy supplies at affordable prices the energy policy of a nation should be based on the diversification rule of source supply. The constant increase in oil and gas demand requires the exploration, development and distribution of new energy sources (Tavana et al., 2012).

In late 2011, the Noble Energy Corporation announced the discovery of 5–7 trillion cubic feet of natural gas in the Aphrodite field (Block 12) of the Exclusive Economic Zone of Cyprus. The discovery is estimated to be worth billions and it could cover the electricity needs of the Republic of Cyprus for the next 210 years. The exploitation of the reserves and the transport to Europe and Israel could be made by an undersea pipeline, an alternative that has already been discarded due to economical (high cost),

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technical (deep seabed) and geopolitical (Middle-East region) issues. The construction of a liquefaction plant and gas transportation by ships to markets offer to Cypriots a particularly important advantage of non-dependence from countries where the pipeline may pass; however, this is also a quite expensive project considering various social-economic and environmental factors.

As of today, high dependency on imported energy sources and strong dominance of oil in Cyprus' energy balance is mainly considered. Also, the economic development of the country is strangled between the rapid increase in energy demand and difficulties in the connection with European energy networks due to its geographic location, as well as the relatively low penetration and utilization of renewable energy sources.

In recent years, Cyprus' energy system has profound capacity as it is undergoing a period of significant change, involving mainly the liberalization of energy markets as required by European Directives. The decision to import natural gas in the energy balance of the country requires the development of modern cogeneration systems and imposes structural interventions to address challenges in energy. The energy policy of Cyprus is fully harmonized with European Union (EU) guidelines ensuring healthy competition in the market, secure supply of energy and energy needs coverage of the country with the least possible economic and environmental burden.

The nature of this research is to propose a methodological framework for macroscopic infrastructure location decision-making based on environmental impact assessment. The output of this process would lead to the development of specific spatial plans, which would then be further considered at a lower level, in a more detailed impact assessment study. The aim of the analysis presented in this research is to evaluate various alternative locations for a liquefied natural gas (LNG) terminal station in Cyprus, based on REGIME multi-criteria decision analysis, and to examine the impact of its construction and operation on the natural and human environment. The selection of LNG terminal location will be done considering factors arising from current European and National legislation for natural gas and more particularly for LNG terminals (e.g. area, access, terrain, etc.). Also, the final location will be obtained after examination/evaluation of other specific parameters such as cost, safety, and existing infrastructure. Also an important issue for Cypriots is the transportation of LNG from the terminal to the major power plant in Mari and the country's gateway in order to be exported. Different appropriate transport modes (rail and pipelines) will be considered for the transport of LNG between the point it reaches the island and the energy conversion plant/export gateway. Alternative feasible geometric alignments are proposed and evaluated, considering a number of restrictions and guidelines, using a GIS-based approach. Then an environmental impact assessment (EIA) methodology is proposed to evaluate the alternative transport routes. The EIA analysis was based on a tableau format questionnaire answered by a group of environmental and transportation experts.

2. Background

2.1. Previous experience

The offshore oil and gas sector has been primarily developed in the North Sea since the mid 1970s. Land-based developments, such as pipelines, terminals, processing plants, production platforms installation, and the large number of construction workers were the two main issues that were characterized as crucial in early '80 (Lyddon, 1983). An analysis of the UK and Norwegian environmental impact assessment (EIA) adopted procedure related to North Sea oil development showed that issues related to land-use planning, public hearing, discharge standards, coastal legislation and bodies were considered important but for various reasons, such as bureaucracy, limited public participation and lack of information on biological and chemical effects of oil on marine environment, affected planning to a minor degree (Fischer, 1983).

Offshore oil and gas developments require regional planning and strategic coordination (Salter and Ford, 2001) due to high risk on a global scale to marine environment (Wagner and Armstrong, 2010). However, the oil and gas sector has limited experience of strategic environmental assessment (SEA) applications legislated under EU Directive (2001/42/EC). Fidler and Noble (2012) in their analysis about SEA in offshore oil and gas sector applied to Norway, Canada and the UK found that, without a coordination between the different levels of administration, SEA will fail to obtain decisions related to planning and development in a less restrictive environmental and socioeconomic context. An evaluation of EIA performance within the oil and gas sector in the UK showed that quality improvements related to the scientific quality of EIA, enhanced scoping, a greater level of integration and a better dissemination are necessary to significantly reduce the percentage of unsatisfactory quality environmental statements for decision making purposes (Barker and Jones, 2013).

2.2. Research perspective

The energy dependence of a country is a long-standing problem, which has to be managed by its administration. The geopolitical position of countries, such as Turkey and Greece, between the producer countries of Middle East, Caspian and Central Asia and the major consumer countries of Western Europe allows them to develop a leading role as “energy corridor” (Kilic, 2006). Failure to obtain adequate volume, continuous supply and reasonable price could lead into catastrophic impacts for the national security, economic and political stability of a country (Conant and Gold, 2000). In order to maintain energy adequacy and security, countries must comply with certain rules such as (Verma, 2007):

- diversification of supply from more than one sources;
- “security margin” in the energy supply system that will provide a buffer against shocks and facilities recovery after disruptions;
- importance of information; and
- recognizing the reality of integration.

The design and implementation of an oil and/or natural gas pipeline is not something trivial considering the impact of energy that will be transferred over great distances. In the planning phase of a pipeline routing, not only political but also environmental issues related to topography, land uses, ownership should be considered. The accelerated development of remote sensing (RS) in conjunction with the analysis that could be obtained using geographical information systems (GIS) contribute to the evaluation of alternative pipeline routes. Feldman et al. (1995) developed a prototype to obtain the least cost pathway for pipeline placement using remotely sensed data and GIS analysis. Their prototype was tested in a section of the Caspian pipeline. In their analysis, parameters such as pipeline length, topography, geology, land use, stream wetland road and railroad crossing were considered in order to determine a least cost pathway. Their results showed that a straight-line path was not always the cost-effective solution.

Jo and Ahn (2002) provided an analysis of various characteristics of pipelines including the potential size of the hazard area and developed an equation based on release rate, gas jet and heat flux from fire to estimate the hazard area. A quantitative risk