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Energy security prospects in cyprus and Israel: A focus on natural gas

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ABSTRACT

The global production of natural gas has increased from 1226 bcm in 1973 to 3282 bcm in 2010 and is projected to continue rising by an annual growth rate of 1.6% between 2010 to 2035. Cyprus and Israel have recently made major offshore discoveries of natural gas, which can supply to a great extent the two countries' current domestic energy needs for the next few decades and still export a substantial volume. MESSAGE, a global optimization model was used to explore the possible interactions between the two countries' energy systems. Scenarios are presented that assess the export potential for electricity (generated by gas-fired power plants), liquefied natural gas (LNG) or gas-to-liquid products (GTL). The results are compared to a scenario without any available reserves to illustrate the financial benefits that will arise from the exploitation of the gas resources in the two countries.

Keywords:

Natural gas markets;
Power generation;
Liquefied natural gas;
Gas-to-liquids

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1. Introduction

In the years 1973–2009, global production of natural gas has grown by 267% [1]. Increasing demand has led to subsequent regional increases in import prices over the years, with the average EU import price for LNG nearly doubling from \$3.42/GJ in 2003 to \$6.49/GJ in 2010, after experiencing a peak average of \$8.70/GJ in 2008. It is worth noting that import prices vary significantly across different regions. During the same period, the cost of LNG in the United States rose from \$4.45/GJ in 2003 to \$9.33/GJ in 2008 and then decreased to \$4.54/GJ in 2010 [2]. Prices in the United States have decreased due to increased production of unconventional gas, which reduced demand for imports [3]. Furthermore, demand growth rates are different in each region. In the New Policies Scenario of the International Energy Agency (IEA), between 2010 and 2035 natural gas demand is projected to grow annually by 0.5% and 0.6% in the US and EU respectively, while at the same time growth rates will reach 4.2% in India and 6.6% in China [4]. Despite increasing gas demand and the vast availability of gas reserves worldwide, construction of infrastructure for production and transportation is both complex and demanding in terms of funds and time, thus limiting the exploitation rate of recoverable gas resources [3].

With the global demand for energy increasing, as further discoveries of fossil fuel reserves are made, strategies will be required to ensure an efficient and economically optimum use of these resources. In this paper the authors address the case of two Eastern Mediterranean countries, Israel and Cyprus, which appear to have, relative to their size, significant offshore natural gas reserves available for exploitation. Despite ongoing natural gas extraction, Israel's energy sector imports significant volumes of gas and coal, while

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Cyprus relies almost entirely on imports; thus these two countries are interesting case studies. At the same time, the proximity of these reserves to continental Europe and the fact that they are quite extensive can have an effect on the energy security of the European Union, which seeks to exploit indigenous resources and promote diversification of supply. In existing literature the Israeli gas finds have been presented from a political perspective [5], but despite the estimated volume of gas discovered, there is a knowledge gap in regards to the quantitative assessment of the future development potential of these resources; the same applies for the case of Cyprus. This paper aims to conduct such a quantitative analysis in terms of power generation and gas export capabilities of the two countries under a range of scenarios. In light of the financial crisis that has recently hit hard the island of Cyprus, we present results of analysis of how these reserves may affect the power generation system of both countries over the coming decades and whether there is any grave prospect for exports.

The first section of this paper provides an introduction to the present energy sector of Israel and Cyprus and elaborates on the significance of this study. In Section 2 the methodology followed in this work and the software used are briefly described, while the scenarios formulated for analysis of the power generation systems and export potential of the two countries are defined. The main results from this analytical work are presented and discussed upon in Section 3. The paper concludes with a recollection of the main findings in Section 4.

1.1. Current energy status

In this section a brief overview of the current status of the energy sector in Israel and Cyprus is given, in an effort to indicate how significant these reserves will be to the two countries. Even though Israel had made small onshore discoveries of oil and natural gas in the 1950s, the most significant discoveries started in 1999, when natural gas reserves were discovered offshore. Natural gas production started in 2004, with most of it being used by a portion of the country's power plants, which were adjusted to use gas instead of oil as feedstock. Since then, a few major discoveries have been made offshore, with the most important ones being the Tamar field, which holds about 240 billion m^3, and the Leviathan field, with an estimated reserve of 450 billion m^3 of gas [6].

The natural gas extracted in Israel is primarily consumed by domestic power plants. Of the approximately 205 PJ of natural gas consumed in 2010, 5.5 PJ were used as fuel in oil refineries, 3 PJ in industry and the rest was used for power generation [7]. Due to the fact that the extraction of the domestic reserves is still at an early stage, until 2010 it was not yet sufficient to cover the nation's natural gas needs. In 2010 the share of fuels for electricity generation was 61% for coal, 36.6% for natural gas, 1.5% for diesel oil and 0.9% for fuel oil. With the exception of natural gas, Israel primarily relies on imports for its energy requirements. In 2010 56% of the natural gas used by the Israel Electric Corporation (IEC) was domestic, while the rest was imported from Egypt via a marine pipeline. Coal is imported from Africa, South America, Asia and Australia [8].

In contrast to Israel, Cyprus has made very few steps so far regarding natural gas exploitation. The first exploratory well started in autumn of 2011 in one of the 13 blocks (no. 12 named Aphrodite) available for exploration [9]. The reserve in this area is estimated to hold about 140 to 225 billion m^3 of gas [10]. During the second licensing round for exploration, Cyprus has decided to start negotiations for gas licenses of four other offshore blocks with Italian company Eni, Russian Novatek, French Total and South Korean KoGas [11].

It should be clarified that natural gas is not used as fuel in any of the sectors of the Cypriot economy [12]. In regards to power generation, Cyprus at present meets its demand almost entirely through imported oil. Currently, there are no grid connections going to and from the island, so it cannot trade electricity with surrounding countries. It was estimated that during the years 2011–2012, renewable energy sources would correspond to 4% of the electricity generation of Cyprus [13]. The rest of the electricity would be generated from fossil-fuelled power plants, the vast majority of which burn heavy fuel oil and to a lesser extent diesel [14]. All of the fossil fuels used on the island are being imported.

The cooperation of Israel and Cyprus along with Greece in the field of energy has been illustrated by the announcement of the future deployment of an undersea electricity cable. This will have a capacity of 2 GW and an estimated investment cost of approximately $2 billion. This linkage will connect Israel to Cyprus and then Greece [15], so as to allow sales of excess electricity from Israeli and Cypriot gas-fired plants to continental Europe. Moreover, there are thoughts of jointly developing an LNG terminal in the south coast of Cyprus, where natural gas from both countries could be processed before being shipped for export [16].

The energy systems of the two countries are presently independent of each other and were selected for analysis as they both have been, at least until recently, relying almost entirely on imports in order to meet their demand, while now they have a chance to transform into energy providers. It was hypothesized that these systems would largely transform when natural gas was introduced, taking into consideration that gas will be domestically produced in immense volumes. Nonetheless, exploitation of this gas would necessitate high-level political decisions, market accessibility, investments in infrastructure and technical expertise [3]; not only to supply the internal market, but also to export a substantial amount of the extracted resources.

In view of the fact that Israel and Cyprus have been heavily dependent on energy imports, analysis of scenarios in which these two countries have access to domestic resources becomes intriguing from a geopolitical viewpoint. As discussed above, experience in gas markets is low for Cyprus and to a certain extent for Israel, thus an assessment of possible development pathways is required to allow informed decision-making. Depending on the extent of available reserves, these two countries could emerge as important suppliers of natural gas and to a certain extent compete with major producers, such as Russia and the neighboring Middle Eastern nations. Therefore, it is vital to adequately assess the potential volume of exports that will become available, taking into consideration the domestic energy needs. The following section of this paper describes the approach followed to achieve this.

2. Material and methods

Quantitative analysis of the power generation systems of Cyprus and Israel was conducted through the construction of the existing power systems and formulation of scenarios to project and assess alternative pathways to energy system development. The modeling work was carried out using MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental impacts), which was initially designed by the International Institute for Applied Systems Analysis (IIASA) and subsequently further enhanced jointly with the International Atomic Energy Agency [17].

National and regional energy systems can be modeled and optimized in MESSAGE. It does this by selecting the most economical solution out of a variety of alternatives provided by the analyst. Technologies and energy sources can be linked along ‘energy chains’, thus enabling the user to construct a model from resource extraction to final energy demand. A set of constraints is added to investigate different scenarios or to simulate ‘real life’ attributes of the modeled system. These constraints may include limitations on new investment, environmental regulations, fuel availability and trade [17]. A reference energy system was developed for the two countries (Annex A) and was then modeled in MESSAGE. Detailed technology input data and assumptions used in the model are shown in Annex B.

2.1. Scenarios

In order to investigate how the two countries’ systems will respond under different conditions, a variety of scenarios was selected for assessment. In the baseline scenario, the conditions that currently apply for both countries, as well as the most likely courses of actions, were modeled. Based on the last year with a comprehensive data-set, 2010 was used as the initial year of model simulations. The natural gas reserves discovered so far were added to the model, corresponding to approximately 7 trillion cubic feet for Cyprus [10] and 28 trillion cubic feet for Israel [6]. Major development projects, such as the construction of the electricity cable for sales to Europe and a liquefaction plant for sales of LNG were added, and projections were made to 2050. The model was allowed to invest in an LNG terminal in both countries, even though in reality a joint plant may be built in one of the countries. It should be noted that the projections of final electricity demand of the two countries were made either based on trends in the past decade for Israel [18] or based on projections for the following decade for Cyprus [19]. Current average prices of gas and electricity were used to set export prices in the analysis; \$9/GJ for LNG, assuming sales to Europe, and 120\$/MWh for electricity, assuming sales to Greece [2].

The formulation of scenarios aimed at assisting potential decisions that would be required by policy-makers in the two countries. It was clear that the dilemma between using the available natural gas for the sale of electricity, LNG or GTL products should be focused on. Therefore, the chosen scenarios were the following:

1. The prospect of an additional cable to sell electricity to Europe.
2. Increasing exported LNG prices compared to stable electricity prices.
3. Increasing exported electricity prices compared to stable LNG prices.
4. The potential of converting natural gas to petrochemical products for export purposes.

Scenarios 1–3 investigate the conditions under which it is economically preferable to export LNG rather than electricity and vice versa, whereas scenario 4 examines the viability of GTL production when the price of oil is considerably higher than that of natural gas. In order to assess the selected scenarios, the appropriate variables, which would be changed in each case, were identified. These variables along with the fluctuating values are shown in Table 1.

3. Results and discussion

In this section, the most representative results were chosen to help reach constructive conclusions. It should be highlighted that all the results are based on the approximate volumes of gas that have already been found in the two countries and does not include reserves that are not yet proven.

3.1. Baseline scenario

3.1.1. Local production

Power generation in Cyprus changes drastically with the incorporation of natural gas as an energy source. Gas is allowed to enter the fuel mix in 2015 and over a short amount of time it completely replaces oil as the primary fuel for electricity generation. As shown in Figure 1, most of the electricity generation after 2015 relies on natural gas. The stepwise development of new gas-fired power plants, observed in the first few years, is due to limitations added on the rate of introduction of new technologies, so as to simulate real world conditions.

The big increase of electricity generation observed in the period 2022–2044 can be attributed to electricity sales to Europe. Immediately after extraction commences, which in our model is assumed to be in 2015, a portion of the gas is sold as LNG while the remainder is used to meet electricity demand in the island (Figure 2). The assumption is, however, that – if economic - a liquefaction plant could be built in the years prior to 2015, so it can be utilized as soon as natural gas becomes available; this is the case for Israel as well.

The situation in Israel seems to be different from Cyprus, in that coal is not completely substituted by natural gas. As can be seen in Figure 1, during the first two decades there is an increase in the share of natural gas, but as the reserves diminish, coal returns as the dominant energy source. In 2043, the last of proven reserves run out, so there is dependency on imports of natural gas once again.

Perhaps one of the most interesting results from Israel is the fact that even though there is plentiful supply of natural gas to cover domestic needs, it seems preferable to export LNG and use cheap coal to cover the internal power demand. However, unlike Cyprus, Israel completely runs out of natural gas in 2043 and switches back to the cheap alternative of coal for power generation. It should be mentioned that a gas import limitation of about 44 000 GWh was placed on Israel, which is approximately double the amount imported in 2010 [6]; this is an attempt to limit to a certain extent import dependency.

Table 1: Adjustments to model variables for scenario evaluation.

Related scenario	Description	Aspect or variable changed relative to baseline scenario				
1	*Second electricity cable to Europe*	Additional cable of 2000 MW to be built in 2020				
2	*Higher LNG prices - stable electricity prices*	**Price of LNG ($/kWyr)**				
		9 [a]	+25%	+50%	+100%	+150%
			(355)	(426)	(568)	(710)
3	*Higher electricity prices - stable LNG prices*	**Price of exported electricity ($/kWyr)**				
		120 [b]	+25%	+50%	+100%	+150%
			(1319)	(1583)	(2110)	(2638)
4	*Petrochemical production*	Gas-to-liquids production for export purposes				

[a] Used EU average for LNG import prices into Europe in USD/GJ for summer 2011 [2].

[b] Used Greece end-use Electricity prices for industry in USD/MWh for 2Q2011 [2].

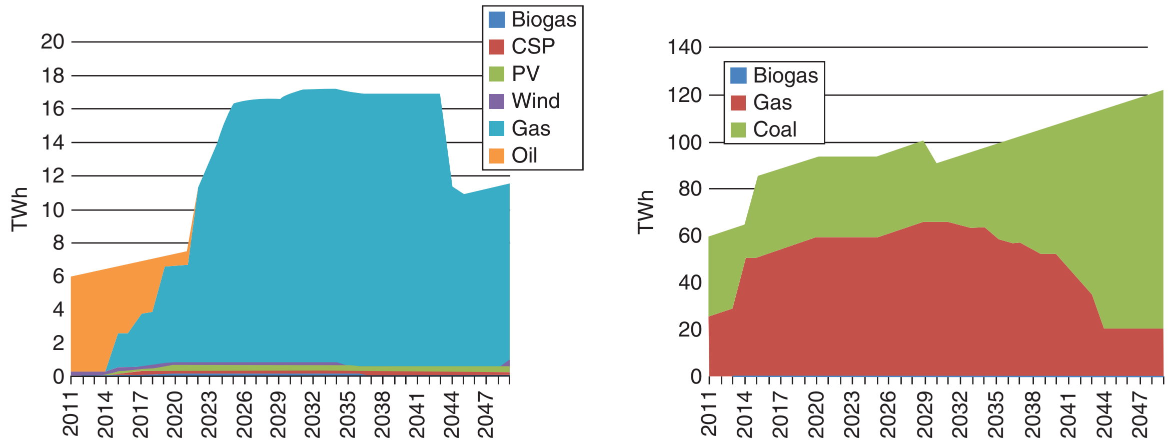

Figure 1: Projected electricity generation in Cyprus (left) and Israel (right) over the modeled period.

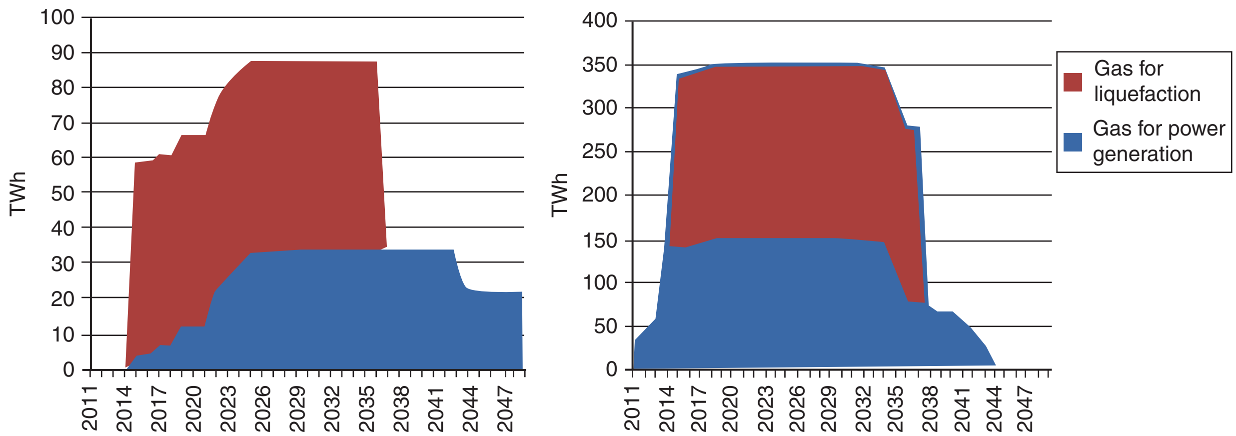

Figure 2: Fate of natural gas reserves from Cyprus (left) and Israel (right).

3.1.2. Exports

The discovery of natural gas in the Eastern Mediterranean in a time of economic crisis was well received by the implicated governments. This optimism stems from the prospect of acquiring revenue via exports of LNG and, to a lesser extent, electricity. Figure 3 shows the possible extent of these exports in the baseline scenario, which indicates that based on current prices, it is more profitable to sell LNG rather than electricity. The results suggest that, in relation to the total exported natural gas, both countries will sell a relatively small portion of electricity to Europe. At the beginning of the projection period, Israel makes nearly full use of the cable's capacity to export electricity, but then Cyprus also partially contributes, up to a point where Israel stops and Cyprus makes use of about 35–40% of the cable's capacity.

3.1.3. Cost comparison

An economic comparison was done between the baseline scenario and a scenario in which no gas reserves are available to either of the two countries. Figure 4 shows the annual cost of the energy systems in each country for these two scenarios, calculated based on the following equation:

Cost = Infrastructure investment costs (power plants, transmission system, LNG terminal, *GTL plant*) + operation & maintenance costs + fuel costs + Import costs – Export revenue.

In essence, this estimates the total system cost, taking into account potential revenue from exports, excluding however any revenue from sales of electricity domestically. In Figure 4a, the higher the line is on the graph, the costlier the system is, so it can be concluded at a first glance that the system is less costly to run when

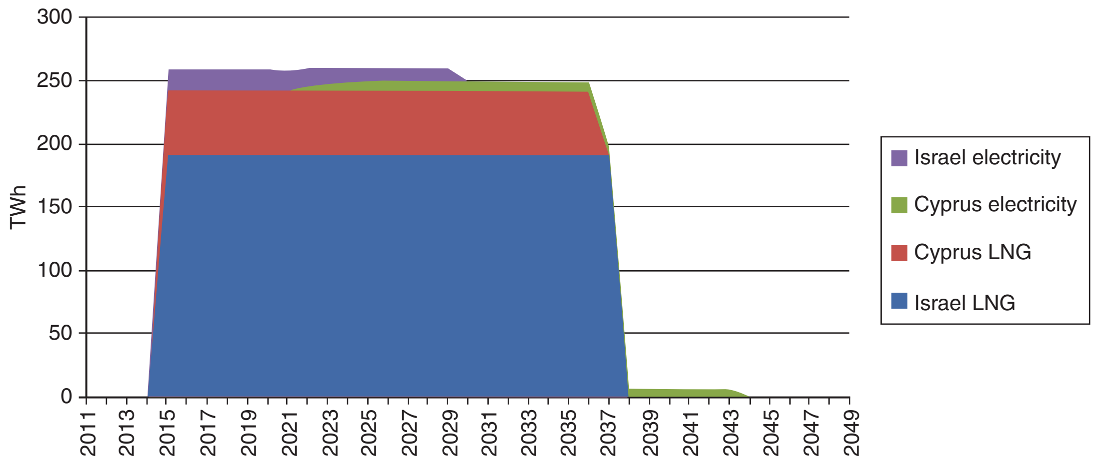

Figure 3: Exports of electricity and LNG from Cyprus and Israel.

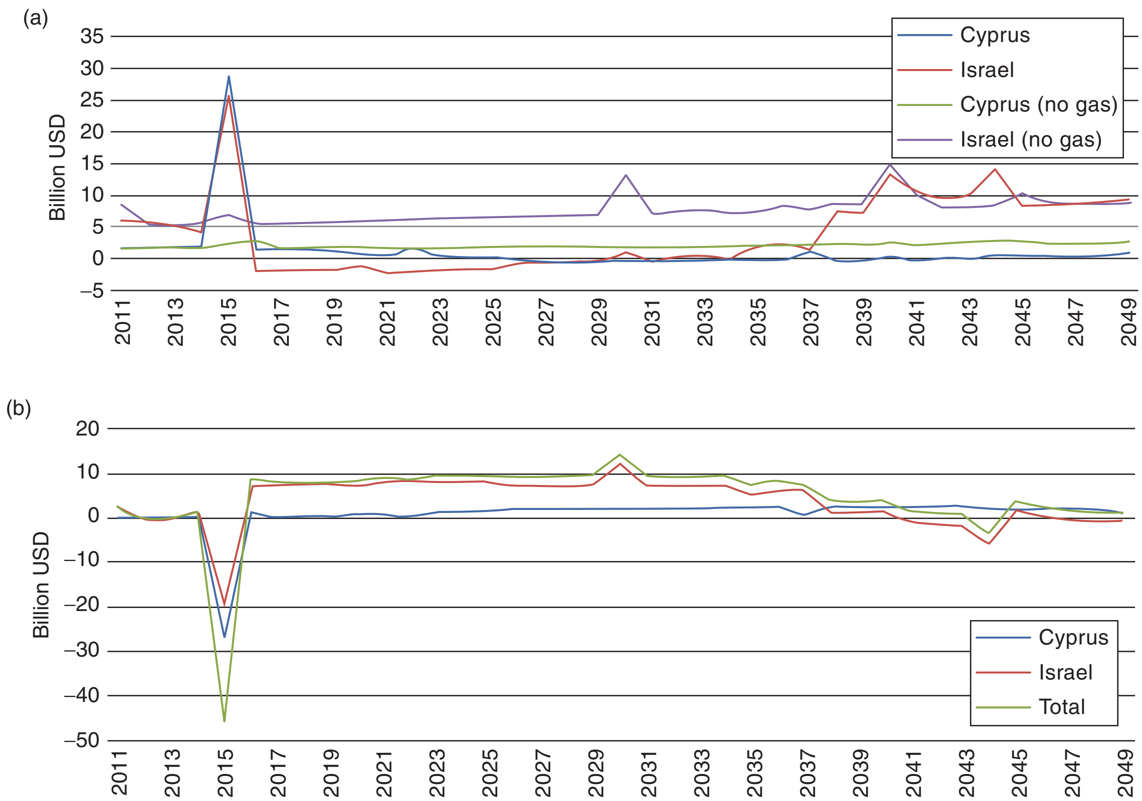

Figure 4: (a) Costs of the energy system of the two countries over the projected period in the baseline scenario and the “No Gas Reserves” scenario, and (b) cost savings achieved when exploiting gas reserves in the baseline scenario, in billion USD.

gas reserves are available. The peaks observed are large investments, such as the construction of the LNG terminal in 2015. During the entire projection period, the discounted cost savings of both systems amounts to 24 billion USD (Figure 4b).

It is worth noting that from these results, it appears that Israel is profiting significantly more than Cyprus. Of course, this can be attributed to the fact that in the model used, Israel’s natural gas reserves are four times larger than of Cyprus and consequently is able to export more gas; the proven reserves are expected to increase for both countries in the future. However, since the liquefaction facilities are likely to be built in Cyprus [15], in reality it remains to be seen what kind of agreement will be reached by the two countries. It is possible that Cyprus may be able to raise its profits based on revenue sharing agreements and through the use of transport tariffs.

3.2. Assessment of selected scenarios

3.2.1. The choice between exported electricity and LNG

In this sub-section, the results from scenarios 1–3 (Table 1) are evaluated to identify the circumstances under which electricity as an export product becomes more attractive than LNG and vice versa. Detailed results regarding exports and fate of extracted natural gas are provided in Annex C. As discussed, based on the current commodity prices, it seems more profitable for the two countries to sell LNG rather than electricity, as the cable's capacity is not used to its full extent for the majority of the period. When the capacity of the cable is allowed to double in the first assessment scenario, the amount of electricity sold to Europe from Cyprus doubles as well. However, the corresponding amount from Israel shows an increase of 38%. This means that the cable's capacity is not fully utilized, which is an indication that on balance LNG is more profitable at the assumed prices.

In scenario 2, it is interesting to see that as the price of LNG is increased, even by 25%, Cyprus completely shuts down its electricity exports and diverts that amount of natural gas, as well as some natural gas previously used for its own power generation, into LNG sales. Additionally, Cyprus chooses to import minor amounts of electricity from Israel as the price of LNG increases. This suggests that it seems preferable for the Cyprus system to sell its natural gas as LNG and cover those minute needs by imports. Evidently, as the price of LNG is increased further, Israel is more reluctant to sell electricity and also prefers to export LNG. Due to the fact that LNG prices vary significantly per region [2], it could be argued that it may be preferable for the two countries to sell LNG to Asian countries rather than Europe, as the prices there are higher.

On the other hand, once the price of electricity is increased in scenario 3, the outlook of exports changes to a considerable extent. Even with the smallest increase of 25%, Cyprus decreases LNG exports by 33% and more than doubles its electricity exports, when compared to the baseline scenario. The Israeli system in this case behaves very differently. It reduces both its LNG and electricity exports, but increases electricity generated from natural gas for internal purposes, thus reducing combustion of coal. This can be explained by the fact that since it is now more profitable to sell electricity, the Cyprus system likes to do exactly that, thus taking over the majority of the cable's capacity between the years 2022–2043 (Figure 5). Since the transmission losses from Cyprus to Europe are lower than those from Israel-to-Cyprus-to-Europe, MESSAGE recognizes that it is preferable for the system as a whole to sell electricity from Cyprus rather than Israel.

Nevertheless, as the price of electricity increases, the amount of electricity exported by Israel also increases and reaches higher amounts than the baseline scenario, once the price is doubled. It can be concluded from the

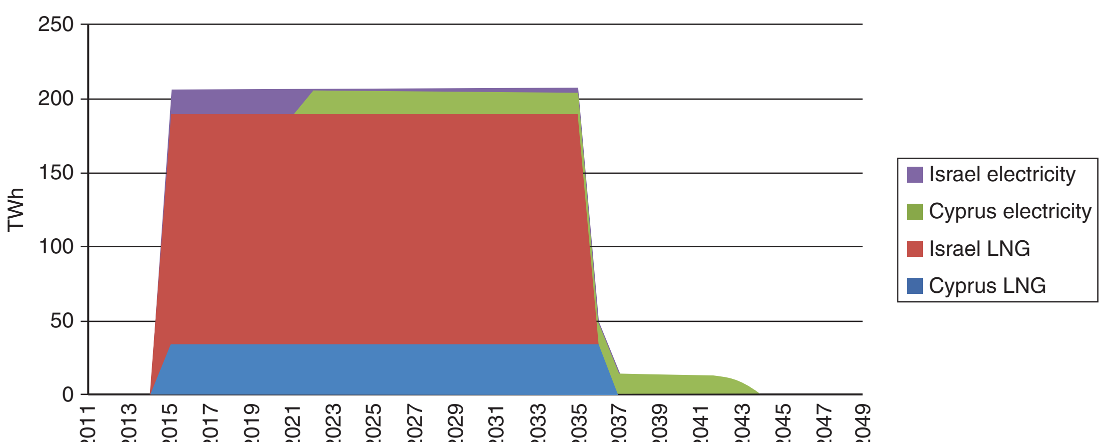

Figure 5: Exports in the scenario of higher electricity prices by 25%.

results of scenario 3 that if the price of LNG is reduced or if the price of electricity is increased, the two countries may have to compete for the right to sell their electricity to Europe via a common electricity link.

3.2.2. The prospect of petrochemical production

The following sub-section addresses the findings of scenario 4. As a result of the price difference between natural gas and oil products in the global market [20] and the discovery of gas reserves in areas away from demand, the possibility of converting natural gas into more transferable and competitive products has been gaining substantial attention [21]. Gas-to-liquids (GTL) plants have been in operation for several decades and under the right conditions have proven their commercial viability [22, 23]. The largest plant currently in operation was constructed in Qatar by Shell, and produces 140 thousand barrels of GTL products per day, among which are 120 thousand barrels of oil of natural gas liquids and ethane [24].

The interest in GTL production has been increasing in various areas of the world [25, 26]. In this scenario, the option of developing GTL plants in Cyprus and Israel was investigated. A plant with a small capacity of 17 thousand bbl/day was added to the system for each of the countries, an export price of $107.25/bbl was set and the model was run. Further assumptions regarding the specifications of the GTL plants can be found in Appendix B.

Model results of this scenario indicate that GTL production can be viable. In Figure 6, the fate of extracted natural gas in each of the countries can be seen. It has to be highlighted that in both cases the amount of natural gas converted to petrochemical products is equal to the maximum allowed quantity set in the model for the entire time of operation; 22 years in Cyprus and 20 years in Israel, which is shorter than the defined lifetime of the petrochemical plants set at 30 years. In this scenario, the total discounted system cost savings amount to 29 billion USD; 5 more than in the baseline scenario. This is an indication, based on the price assumptions adopted, that petrochemical production is more profitable.

As indicated by Figure 6, even though in this scenario GTL products are being exported, the majority of exports from the two countries is still LNG, due to the limitation placed on petrochemical production. However, there are a few important aspects that need careful consideration before deciding to invest in liquefaction or GTL plants. First of all, space could be an issue, especially in the case of Cyprus, a small island whose economy currently relies to a great extent on tourism. The construction of projects of such magnitude will most likely occur along the coast due to shipping. Since there are already questions about the location of the proposed LNG plant in Cyprus [27], finding a location for an additional GTL plant might offer some difficulty.

Secondly, security is another important issue and since the Eastern Mediterranean and the greater Middle East is a politically volatile region, costs for guarding facilities of huge significance could be quite high and

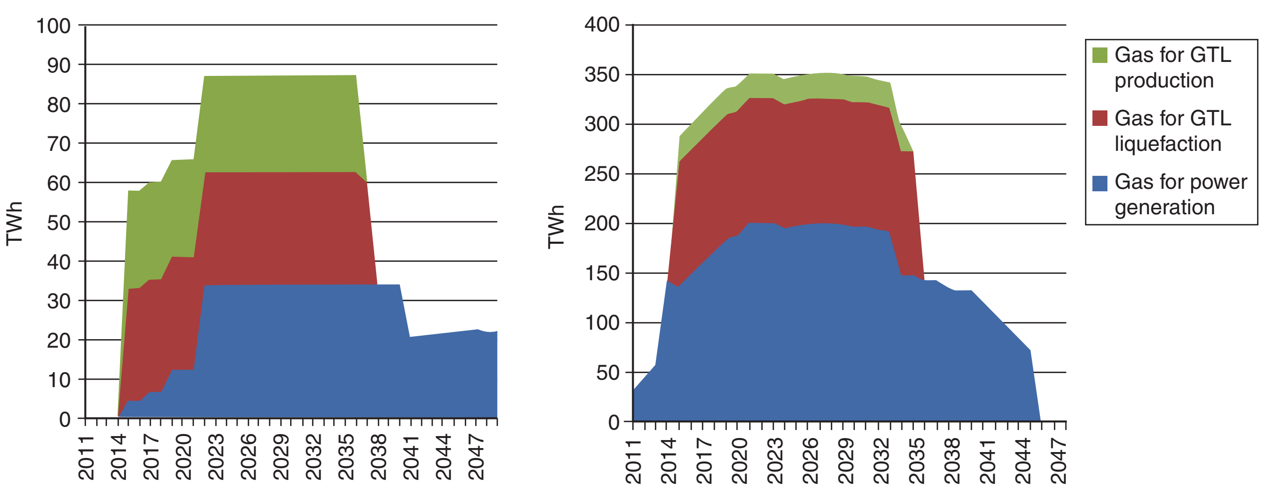

Figure 6: Fate of natural gas (GWh) for each year in Cyprus (left) and Israel (right).

having to protect two such locations undeniably raises overall expenses. Lastly, but perhaps most importantly, price fluctuations of oil and natural gas could affect GTL economic viability in the future. When the price gap between the two commodities is larger, the incentives for investment in GTL projects increase [20], which is the case with current prices. However, if prices for natural gas start to increase at a much faster pace than for oil, it will make more sense to invest in liquefaction plants and simply export LNG. Hence, the risk is rather high, thus the responsible authorities of the two countries should carefully assess the possible alternatives and make the appropriate decisions.

4. Conclusions

It is clear from the results above that the discovery of natural gas reserves in Cyprus and Israel can lead to major changes in the power generation of the two countries. Significant infrastructure investments will be required for the transformation and export of natural gas products. These gas discoveries will bring about major economic benefits for the two countries. It is estimated that the undiscounted total savings achieved by the two countries during the whole projection period add up to about 182 billion USD; the corresponding figure with a discount rate of 10%[1] reaches 24 billion USD. These figures do not include the revenue for utilities from sales of electricity within the local systems at a considerably lower cost nor any other socioeconomic aspects, such as the creation of jobs or the development of associated industry. Based on the assumed commodity prices, our results suggest that it is more profitable to export LNG rather than electricity, despite the high investment and operation costs of liquefaction plants. Similarly, the current price difference between oil and natural gas supports the prospect of petrochemical production.

The proven reserves of natural gas seem to be able to support the infrastructure required for exports of electricity, LNG or GTL products. Huge investments will be required in the two countries for extraction, installation of the electricity cable to mainland Europe, construction of pipelines, LNG terminal or GTL plant. One could expect that with the probable discovery of further natural gas reserves, the viability of such major projects, as well as the revenue from exports, will undeniably increase. In a time of economic crisis, this can act as an incentive for prompt decisions on a political level.

In this paper we only addressed the internal demand for power for the two countries. However, there is the prospect that a substantial volume of the gas could go into meeting demand for heat or transport. For instance, in 2010 the residential sector in Cyprus consumed 84 ktonnes of oil [7], mainly for heating purposes, so arguably there is potential for natural gas to replace this fuel. Furthermore, in the Middle East and North Africa consumption of gas has doubled from 1999 to 2010 and its use in energy-intensive industries is expected to continue to grow [28]. The possibility that a similar situation will happen in Cyprus and Israel should not be overlooked.

A proper assessment of external markets will be needed as well. For instance, gas can be sold at a higher price in South Korea and Japan than in Europe [2], but the distances are obviously greater. Furthermore, according to the European Union's Energy Security and Solidarity Action Plan, making full use of the union's indigenous energy sources and improving external relations with fuel suppliers are two key aspects in securing the EU's energy future [29]. Therefore, it could be argued that the EU itself could benefit from exploitation of these gas reserves and should encourage, if not actively participate in, the construction of the necessary infastructure. Israel and Cyprus may not have the reserves to develop into global competitors in the gas market, but they can have an influence on the European market, primarily in terms of diversification of supply [30].

It should be noted that the model used has some weaknesses. For instance, the option of importing natural gas was not given to Cyprus. Of course, Cyprus could import natural gas from Israel for the time being, until Cyprus extracts its own natural gas, since they will most likely cooperate in the exploitation of their reserves. Another weakness of the model is the exclusion of detailed transportation costing. Nonetheless, this relatively small cost would not make very big changes to the model results.

To sum up, a key objective of this paper was to evaluate infrastructure development trends under certain scenarios and how the natural gas reserves of the two

[1] A discount rate of 10% was selected to simulate a more competitive investment environment, in which there is relatively increased uncertainty regarding future cash flows; this conservative approach was employed to assess the viability of the suggested course of actions in such unfavourable conditions.

countries can be used most efficiently. Since the exploration and extraction processes are still in their initial stages, figures regarding the reserves are expected to change significantly in the near future, which means the work conducted will need to be updated. Furthermore, as more information becomes available, there are other aspects that could be added in the model, such as the use of natural gas in other sectors. This will supply greater detail and give a more complete picture of the potential effects of the gas reserves on the two countries' economies.

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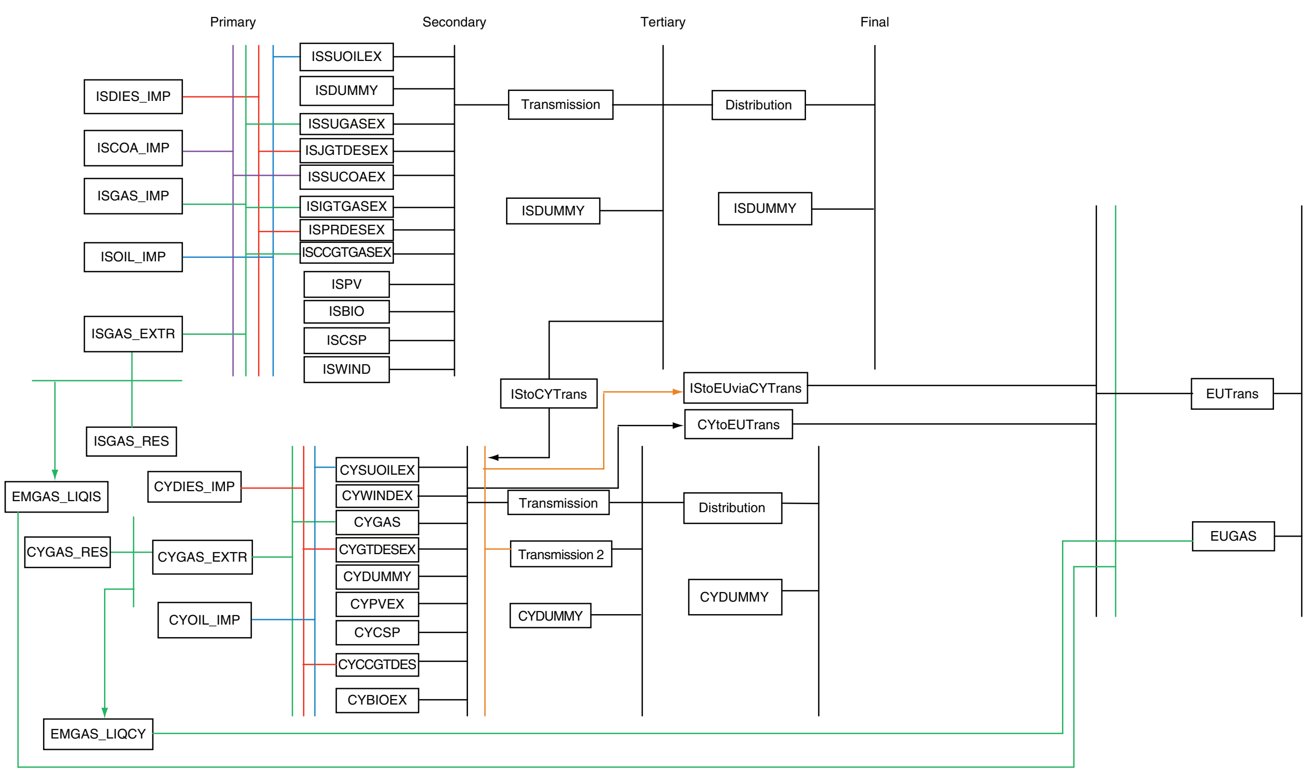
Annex A - Reference Energy System



Annex B - Technology Input Data

Table B1: Transmission, distribution, regional, fuel import and fuel extraction technologies.

Technology	MESSAGE model code	Efficiency	Variable cost ($/MWh) [2]	Investment cost ($/kW)	Ktonnes CO2/ MWyr [32]	First year
Cyprus						
Diesel Import	CYDIES_IMP	1	167.2 [a]		2.186	
Gas Extraction for Electricity	CYGAS_EXTR	1	3.42 [b]		1.581	2015
Heavy fuel Oil Import	CYOIL_IMP	1	62.3 [c]		2.186	
Transmission	ETrans	0.9825 [14]				
Transmission (bought electricity)	ETrans2	0.9825 [14]	120.4 [d]			
Distribution	EDist	0.95				
Liquefaction	EMGAS_LIQCY	0.95 [27]	6.84 [b] (includes extraction)	928.9 [27]		2015
Israel						
Diesel Import	ISDIES_IMP	1	140.3 [e]		2.186	
Coal Import	ISCOA_IMP	1	15.5 [f]		3.099	
Gas Import	ISGAS_IMP	1	23.2 [g]		1.581	
Heavy fuel oil Import	ISOIL_IMP	1	82.1 [h]		2.186	
Gas Extraction for Electricity	ISGAS_EXTR	1	3.42 [b]		1.581	
Transmission	ETransIS	0.98 [18]				
Distribution	EDistIS	0.977 [18]				
Liquefaction	EMGAS_LIQIS	0.95 [27]	6.84 [b] (includes extraction)	928.9 [27]		2015
Regional						
Israel to Cyprus transmission	IStoCYTrans	0.95		375 [15]		2015
Israel to Europe	IStoEUviaCYtrans	0.95		375 [15]		2015
Cyprus to Europe transmission	CYtoEUTrans	0.95		375 [15]		2015
Europe transmission	EUTrans	1	-120.4 [d]			
Europe gas uptake	EUGAS	1	-32.4 [i]			

[a] Used OECD Europe Automotive diesel oil prices for commercial use in USD/toe for 2Q2011.
[b] Assumption based on [31].
[c] Used Germany Heavy fuel oil prices for electricity generation in USD/toe for 2Q2011, assuming similarities.
[d] Used Greece end-use Electricity prices for industry in USD/toe for 2Q2011.
[e] Used total OECD Automotive diesel oil prices for commercial use in USD/toe for 2Q2011.
[f] Used OECD import cost of steam coal for 2Q2011.
[g] Used Israel Natural gas prices for electricity generation in USD/toe for 2Q2011.
[h] Used Israel Heavy fuel oil prices for electricity generation in USD/toe for 2Q2011.
[i] Used EU average for LNG import prices into Europe in USD/Mbtu for summer 2011.

Table B2: Power plant installations in Cyprus.

Technology	MESSAGE model code	Efficiency [14]	Variable cost ($/MWh) [33]	Plant life (yrs) [36]	First year	Investment cost ($/kW)	Historical capacity * (year-MW) [14]	Load/ capacity factor
Existing oil steam units	CYSUOILEX	0.3061	20	50			1966-60 1976-120 1982-60 1993-300 2000-390	0.85 [33]
Existing wind farms	CYWINDEX	1	25	25			2010-82 2011-51.5	0.2 [33,34]
Existing biogas	CYBIOEX	1	2.65	30			2007-8	0.85 [33]
Existing diesel gas turbines	CYGTDESEX	0.2121	24.25	50			1993-75 1995-75 1999-38	0.85 [34]
Existing photovoltaics	CYPVEX	1	50	25			2006-9.3	0.2 [33,34]
Existing diesel combined cycle gas turbines	CYCCGTDESEX	0.4689	24.25	40			2010-440	0.2 [33]
Potential concentrated solar power	CYCSP	1	27.5	25	2015	5500 [33,34]		0.3 [33,34]
Potential gas units	CYGAS	0.4689	5	30	2015	1300 [33]		0.55 [33]
Potential biogas	CYBIO	1	2.65	30		2550 [33,34]		0.85 [33]
Potential photovoltaics	CYPV	1	50	25		5500 [33,34]		0.2 [33,34]
Potential oil units	CYOIL	0.3604	20	40		1817 [33]		0.85 [33]
Potential diesel combined cycle gas turbines	CYCCGTDES	0.4689	24.25	40		461 [33]		0.85 [33]
Potential wind farms	CYWIND	1	25	25		2000 [33,34]		0.2 [33,34]
Dummy plants	CYDUMMY	1	11415	2		99999		

* The values are approximate and correspond to the addition of capacity on the given year.

Table B3: Power plant installations in Israel.

Technology	MESSAGE model code	Efficiency*	Variable cost ($/MWh)[33]	Plant life (yrs) [33]	First year	Investment cost ($/kW)	Historical capacity [8]**	Load/ capacity factor
Existing oil steam units	ISSUOILEX	0.3061	20	40			1980-428	0.144[8]
Existing gas steam units	ISSUGASEX	0.3061	5.38	35			1990-1344	0.461[8]
Existing diesel jet gas turbines	ISJGTDESEX	0.22	24.25	40			1970-27 1980-417 1990-60	0.144[8]
Existing coal steam units	ISSUCOAEX	0.3061	8.5	40			1990-1950 2000-2340 2001-550	0.808[8]
Existing gas industrial gas turbines	ISIGTGASEX	0.22	5.38	30			1990-420 2000-1374 2007-234 2010-777	0.461[8]
Existing diesel private producers	ISPRDESEX	0.22	24.25	40			2000-26 2009-134 2010-58	0.144[8]

Table B3: Power plant installations in Israel (Continued).

Technology	MESSAGE model code	Efficiency*	Variable cost ($/MWh)[33]	Plant life (yrs) [33]	First year	Investment cost ($/kW)	Historical capacity [8]**	Load/ capacity factor
Existing cycle gas turbine	ISCCGTGASEX	0.4689	gas 5	30			2000-337 2002-343 2003-315 2006-488 2007-142 2008-709 2009-465	combined 0.461[8]
Potential photovoltaics	ISPV	1	50	25		5500[33,34]		0.2[33,34]
Potential biogas	ISBIO	1	2.65	30		2550[33,34]		0.85[33]
Potential concentrated solar power	ISCSP	1	27.5	25	2015	5500[33,34]		0.3[33,34]
Potential wind farms	ISWIND	1	25	25		2000[33,34]		0.2[33,34]
Potential oil units	ISOIL	0.3604	20	40		1817[33]		0.144[8]
Potential diesel units	ISDES	0.3	24.25	40		461[33]		0.144[8]
Potential coal units	ISCOA	0.3604	8.5	40		3000[33]		0.808[8]
Potential gas units	ISGAS	0.4689	5	30		1300[33]		0.461[8]
Dummy plants	ISDUMMY	1	11415	2		99999		

* Assumed same thermal efficiencies as the corresponding plants in Cyprus [14].

** The values are approximate and correspond to the addition of capacity on the given year.

Table B4: GTL plant specifications.

Capacity (bbl/d)	Maximum production (GWh)	Efficiency[24]	Investment cost ($/kW)[20]	Operating cost ($/MWh)[35]	Plant life (yrs)	Export price ($/MWh)*
17 000	10 548	0.424	1694.4	4	30	63.1

* Used average price for crude oil during January-September of 2011 for IEA countries [2].

Annex C - Selected scenario results

Table C1: Total exports from Cyprus and Israel in each scenario, throughout the projection period (2011–2050).

	Cyprus		Israel	
Scenario	LNG (GWh)	Electricity (GWh)	LNG (GWh)	Electricity (GWh)
Baseline scenario	1 124 072	150 434	4 386 202	202 004
Additional cable	748 741	326 511	4 050 381	278 427
Higher LNG prices (+25%)	1 476 402	0	4 653 234	157 060
Higher LNG prices (+50%)	1 525 107	0	4 979 299	123 254
Higher LNG prices (+100%)	1 580 604	0	5 511 715	100 736
Higher LNG prices (+150%)	1 621 999	0	5 658 294	100 736
Higher electricity prices (+25%)	757 091	327 609	3 270 094	144 065
Higher electricity prices (+50%)	722 678	344 245	3 232 870	146 230
Higher electricity prices (+100%)	688 264	362 878	3 232 870	242 439
Higher electricity prices (+150%)	688 264	369 010	3 232 870	244 191

Table C2: Fate of extracted natural gas in each scenario, throughout the projection period (2011–2050).

Scenario	Cyprus		Israel	
	Liquefaction (GWh)	Power generation (GWh)	Liquefaction (GWh)	Power generation (GWh)
Baseline scenario	1 183 234	923 739	4 617 055	3 810 847
Additional cable	788 148	1 318 825	4 263 559	4 164 342
Higher LNG prices (+25%)	1 554 107	552 866	4 898 141	3 529 759
Higher LNG prices (+50%)	1 605 376	501 597	5 241 367	3 186 533
Higher LNG prices (+100%)	1 663 793	443 179	5 801 805	2 626 094
Higher LNG prices (+150%)	1 707 367	399 606	5 956 099	2 471 800
Higher electricity prices (+25%)	796 938	1 310 035	3 442 204	4 985 697
Higher electricity prices (+50%)	760 713	1 346 259	3 403 021	5 024 878
Higher electricity prices (+100%)	724 489	1 382 484	3 403 021	5 024 875
Higher electricity prices (+150%)	724 489	1 382 484	3 403 021	5 024 875

Table C3: Total system savings with discount rate of 10%.

Scenario	Savings (billion USD)
Baseline scenario	24.13
Additional cable	32.39
Higher LNG prices (+25%)	33.55
Higher LNG prices (+50%)	46.97
Higher LNG prices (+100%)	75.97
Higher LNG prices (+150%)	105.85
Higher electricity prices (+25%)	33.33
Higher electricity prices (+50%)	36.74
Higher electricity prices (+100%)	43.57
Higher electricity prices (+150%)	50.41
Petrochemical production	29.44