The Lebanese Gas; Exploration and Exploitation

Adrien Sémon
Reviewed by **Alain Bifani**
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www.kas.de/libanon
info.beirut@kas.de

The Lebanese Gas;
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This study was prepared by
Mr. Adrien Sémon, a specialist in the field of Humanities and Geography of the Eastern Mediterranean Basin region at the Higher Institute of Sciences and Letters in Paris.
It was carried out under the supervision of:
Mr. Alain Bifani
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Foreword

As the whole world struggles with energy issues, the energy mix in major economies is shaken between immediate needs, with heavy reliance on fossil fuels, and critical medium term climate objectives that require decisive investments in clean energy.

On a regional level, the hydrocarbon reserves of the Mediterranean have obviously become more visible and useful to European countries, and even more valuable to Levantine players. Already before the new tragic developments in Eastern Europe, the fight for hydrocarbons in the Mediterranean or beyond had contributed to wars and tensions in the area.

In Lebanon, the country's hardship on one hand and the necessary delimitation of maritime borders on the other hand have brought the topic of exploring and exploiting the offshore assets to the top of the agenda again, also pushed by foreign insistence for the finalization of this long-awaited matter.

Today, the country needs to put the framework in place, explore the promising areas, make the most of the opportunities upstream and downstream - including job creation, sustainable businesses, and systemic reforms – and preserve the financial assets obtained against petroleum while making sure that present and future generations optimally benefit from the revenue generated by the related investments.

Based on various assessments, our study covers the estimated costs related to our offshore petroleum assets, the investments that are required, the price projected, and the share of the Lebanese government after covering local energy needs from extracted gas, after assessing the increase in electricity demand related to demographic and GDP evolutions. We analyze four scenarios and their possible implications on Lebanon's revenue, and we assess neighbors' consumption needs to draw our future policies, as well as secure our gas transportation infrastructure, and build our alliances.

01

Gas reserves in the Eastern Mediterranean and in Lebanon

A 2010 US Geological Survey report (Schenk, 2010) reported the presence of hydrocarbons in the Levantine basin in the Eastern Mediterranean. It estimated natural gas reserves at 3,465 billion m^3, P50, with a range from 1418 billion m^3, P95, to 6,441 billion m^3, P5[1].

The presence of gas in the Eastern Mediterranean was already known before the publication of this report – Egypt and Israel were already exploiting gas – but it led to an increase in exploration and discoveries in the Levantine basin during the 2010s. In this way, several important deposits were unearthed[2]:

- Israel: Tamar in 2009, 283 billion m^3, (McCulley, 2013) and Leviathan in 2010, 623 billion m^3, (Beckman, 2020),
- Cyprus: Aphrodite in 2011[3], Calypso in 2018[4] and Glaucus in 2019[5] (Henderson, 2019).

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[1] P95, P50 and P5 are probability indicators. For example, P95 means that there is, based on the observed data, a 95% probability that there will be more than 1,418 billion m^3 of gas.

[2] In 2005, Egypt's gas reserves were estimated at 1,894 billion m^3 and Egypt produced 42.5 billion m^3 per year (World Energy Council Survey of energy resources, 2007, p. 176, https://web.archive.org/web/20110409010229/http://www.worldenergy.org/documents/ser2007_final_online_version_1.pdf). Israel discovered in 2000 the Mari-B gas field, containing about 30 billion m^3 and put it into operation from 2004 ("Noble Energy starts natural gas production from Mari-B field", Offshore Magazine, 30/12/03, *https://www.offshore-mag.com/home/article/16771037/noble-energy-starts-natural-gas-production-from-marib-field)*.

[3] 127 billion m^3

[4] 170 to 227 billion m^3

[5] 142 to 227 billion m^3

- Egypt: Zohr in 2015[6] (L'EnerGeek, 2017).
- Gas reserves in Lebanon are estimated at between 340 and 708 billion m^3 (SiaPartners, 2019) & (Bou-Hamdan, 2020) According to estimates provided in September 2014 by the Lebanese Petroleum Administration at a conference of the Research and Strategic Studies Center of the Lebanese Armed Forces, blocks 1, 4 and 9 would be the most likely to harbor gas with respective expectations of 422, P50, 368, P50, and 430, P50, billion m^3 (Arbid, 2014). It should be noted that the sum of these latter figures exceeds the estimated total reserves without there being any explanation for this apparent contradiction.

In February 2018, the consortium of Total, 40%, ENI, 40%, and Novatek, 20%, was awarded exploration and production licenses for blocks 4 and 9 whose water depth is between 1,400m and 1,800m (TotalEnergies Marketing Lebanon, 2022). Drilling operations for the first well in Block 4 took place between 25 February 2020 and 26 April 2020 at a depth of 4,076m below sea level. If traces of gas were found, the well did not encounter a tank (TotalEnergies Marketing Lebanon, 2022).

As for Block 9, the possession of which less than 8% is disputed in Lebanon by Israel, the surveys are to take place in 2021. Total was planning to drill its first hole in the block 25 km north of the disputed area (Chesnot, 2021) and should have completed these operations before August 13, 2022 (N. C. , 2021).

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[6] 850 billion m^3

02

The cost of gas extraction in the Eastern Mediterranean

In order to establish the cost of extracting gas in Lebanon, we can use the following formula that provides the break-even point of the extracted gas:

$$P_0 = \frac{(CRF+MC)C}{Q} / 3{,}627 \times 10^7$$

- **P_0** is the gas break-even point for the operating company in \$/MMBTU,
- **C** is the initial cost of gas extraction infrastructure in \$ which includes the cost of drilling the wells, the cost of the gas processing platform, and the cost of the pipelines that connect the wells to the platform and the platform to the terminals on the coast.

- **MC** are the annual maintenance and operating costs in %,
- **CRF** is the capital recovery factor expressed in % and calculated as follows:

$$\frac{i(1+i)^n}{i(1+i)^n - 1}$$

- Where i is the annual interest rate established to make it possible to amortize the initial investments and to generate a substantial profit over a depreciation period of n years,
- **Q** is the amount of gas extracted each year in billions of m^3, bcm. This amount varies every year. Typically, the rate of extraction peaks about two years after the start of extracting, which lasts for several years before the rate begins to decline as the deposit approaches

depletion[7]. Also, for this study, when it is relevant, we will take two estimates of Q, one being the peak Q_{max} and the other being an average estimate Q_{ave} established by dividing the volume of the deposit by the duration of exploitation. To estimate this duration, we will establish a minimum operating time by dividing the volume of the deposit by the annual rate of exploitation at its peak, then we will multiply this result by 3/2[8].

- And finally, there are 3,627x10^7 MMBTU per bcm.

To assess the cost of extracting the Lebanese gas, we rely on the ongoing maritime operations in the Eastern Mediterranean, that is to say in Egypt and Israel, because these are recent operations on deposits with characteristics very similar to those expected to be found in Lebanese waters, particularly in terms of the depth of the underwater shelves and the depth of the wells to be drilled.

Exploitation of the Karish and Tanin deposits by Israel

The Tanin deposit is located 21 km northwest of the Tamar deposit at 5,550m below sea level and under a water depth of 1,550m. The Karish deposit, meanwhile, is located 32 km northeast of Tamar at 4,800m below sea level and under a water depth of about 1,700m (Vara, 2018). It should be noted that the Karish deposit was increased in 2019 by the discovery of the Karish North deposit. Together, these three fields contain gas reserves of 93 billion m^3 (Solomon, 2019) and are expected to be exploited as early as the fourth quarter of 2021 (Ellichipuram, 2021).

The maximum extraction capacity Q_{max} is 8 billion m^3 per year, which implies a minimum operating life of 11.6 years. In this way, the true duration of exploitation can be estimated at 17.4 years with an average Q_{ave} extraction quantity amounting to 5.3 billion m^3 per year.

The total cost of infrastructure is, according to 2021 estimates, $1.7 billion (Ellichipuram, 2021), of which $500 million was spent on the development of an FPSO unit (Vara, 2018), which is a vessel equipped with infrastructure for the treatment of extracted gas as well as the storage of this gas. FPSOs are useful for exploiting small gas deposits located in deep waters and far from the coast. They also have the advantage of being able to be moved once the deposit has been exhausted and therefore to be reused on another deposit.

Drilling an offshore well costs between $600,000 and $800,000 per day[9]. To drill its well at a depth of 4,076m in the Lebanese Block 4, Total needed two months (TotalEnergies Marketing Lebanon, 2022). The depth of the boreholes in the Mediterranean basin being of the same order of magnitude, it can be estimated between 60 and 70 the number of days required to drill a

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[7] See, for example, the proposed oil and gas development scenarios in the Gulf of Mexico par Luiz Amado, Reservoir Exploration and Appraisal, Gulf Profesional Publishing, Oxford, 2013, pp. 64, 94.

[8] It comes back to say that $Q_{ave} = 2/3\ Q_{max}$. Of course, this estimate is artificial, but it should be noted that it applies, for example, to the Israeli Mari-B deposit. Commissioned in 2004 with a maximum rate of 6.2 billion m^3 per year, it contained around 28 billion m^3 ("Noble Energy starts natural gas production from Mari-B field", Offshore Magazine, 30/12/03, *https://www.offshore-mag.com/home/article/16771037/noble-energy-starts-natural-gas-production-from-marib-field*). Operated in this way, it would have lasted only 5 years, but it was closed only in 2012, that is to say 8 years after the beginning of its operation (S. Surkes, "Gas company reports high prices, huge debt; public still waiting for wealth fund", The Times of Israel, 20/07/20, *https://www.timesofisrael.com/gas-company-reports-high-prices-massive-debt-no-benefit-for-the-state-in-sight/*.

[9] Reservoir Exploration and Appraisal

well. As a result, it costs a total of between \$36 million and \$56 million. Three wells were dug for Karish and six for Tanin, meaning that the cost of drilling was between \$324 million and \$504 million. A total to which must be added the \$150 million that the development of Karish North cost (Ellichipuram, 2021). The rest of the money – about \$500 million – was used to set up a 90 km gas pipeline connecting the FPSO to the terminals on the coast.

We now need to assess the maintenance and operating costs for all of the project's components listed above. For an FPSO unit, we offer two estimates of annual maintenance and operating costs: a low estimate at 15% of the initial cost, and a high estimate at 25%[10]. Regarding the pipeline, we refer to the article by Jonathan Demierre who sets the annual maintenance costs at 5% (J. Demierre, 2015).

Finally, the maintenance costs of offshore drilling represent around 10% of the total maintenance costs of gas exploitation[11]. In the case of this example, maintenance costs for the FPSO and pipeline are already between \$100 million and \$150 million. Therefore, the cost of maintaining the wells is expected to be between \$11 million and \$16 million, that is, 2.5% of the initial costs for drilling.

Finally, for the capital recovery factors, CRFs, respective to each of the infrastructures mentioned above[12], we will take by default the estimate of an interest rate i at 8% that Jonathan Demierre applies to gas pipelines (J. Demierre, 2015). This is certainly a high rate, but it seems preferable to us to apply it as it is because of the bad Lebanese political and economic situation, which makes any investment in the gas sector risky. As for the number of years n, this may not exceed the duration of operation of the gas field. In fact, for the Karish and Tanin operation, we take n = 15 years. Thus, CRF = 11.7%.

To avoid too much dispersion of the results, it must be borne in mind that the greater the use of the installations, the more it generates maintenance and operating costs. Thus, Q_{ave} will only be used for the low estimates of the above data and, conversely, Q_{max} will only be used for the high estimates[13].

Taking Q_{max}:

$$P_0 = \frac{[(0{,}117+0{,}25)\,500\,x10^6] + [(0{,}117+0{,}05)\,500\,x10^6] + [(0{,}117+0{,}025)\,654\,x10^6]}{8\,x3{,}627\,x10^7}$$

P_0 = 1,24 \$/MMBTU

Taking Q_{ave}:

$$P_0 = \frac{[(0{,}117+0{,}15)\,500x10^6] + [(0{,}117+0{,}05)\,500\,x10^6] + [(0{,}117+0{,}02)\,474\,x10^6]}{5{,}3\,x3{,}627x10^7}$$

P_0 = 1,48 \$/MMBTU

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[10] See Appendix A.

[11] See Appendix B.

[12] Wells, FPSO and gas pipeline

[13] The terms low and high estimates here refer only to the data presented and not to the prices calculated.

Summary table

	FPSO		Gas pipeline		Well	
	Low estimation	High estimation	Low estimation	High estimation	Low estimation	High estimation
C ($M)	500	500	500	500	474	654
MC (%)	15	25	5	5	2	2,5
CRF (%)	11,7	11,7	11,7	11,7	11,7	11,7
Q (bcm/an)	5,3	8	5,3	8	5,3	8

Exploitation of the Tamar deposit by Israel

Discovered in 2009 and put into operation in 2013, Tamar contains 283 billion m^3 of gas and produces 10.65 billion m^3 each year. The Tamar deposit has at least six functional wells to which must be added the Tamar-SW-1 well[14]. These are connected by a 150 km gas pipeline to a fixed gas processing platform (Offshore Technology, 2013).

In 2017, the capital invested for operations amounted to $4.6 billion, while the annual maintenance and operating costs were estimated at $150 million[15]. With regards to the capital recovery factor, in the absence of data on this subject, we have chosen to keep the interest rate i = 8% mentioned above for a number of years n = 30. Thus, CRF = 8.9%.

However, we will only offer one estimate of Q, namely 10.65 billion m^3, as (Tamar Petroleum, 2018) projections for maintenance and operating costs were for this quantity only.In this way:

$$P_0 = \frac{[(0{,}089+0{,}032)\,4600\,\mathrm{x}10^6]}{10{,}65\,\mathrm{x}\,3{,}627\,\mathrm{x}10^7}$$

$$P_0 = 1{,}44\ \$/\mathrm{MMBTU}$$

Exploitation of the Zohr deposit in Egypt

Discovered in 2015 by ENI, the Zohr deposit, containing 850 billion m^3, was commissioned in 2017. In 2021, the capital invested for the development of the field amounted to $12 billion, which was used to build a gas processing plant in Port Said, a gas field management platform, two gas pipelines of 216 km and 30 inches in diameter connecting the field to the plant (Offshore Technology, 2021) & (ENERGY EGYPT, 2018) & (Enppi, 2020). Of the 254 wells planned throughout its operation, 15 are now drilled and functional and allow a production of more than 3 billion ft^3 per day, or 31 billion m^3 per year (State Information Service, 2020).

This capacity is a plateau reached in 2019 and which should last until 2040 (French Treasury D. G., 2018), so for our price estimate, given the long duration of the peak, we will take only one estimate of Q, namely 31 billion m^3 per year.

Annual maintenance and operating costs were estimated in 2016 at between 8 and 12% of total investments (N., 2016). As for the CRF, capital recovery factor, we keep the default estimate

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[14] Tamar-5 did not encounter any gas. Tamar-8 is in service. As for Tamar-7 and Tamar-9, they were planned in 2016, but we did not find any data for their commissioning. In this way, wells 1, 2, 3, 4, 6, 8 are at least in service. (CSA Ocean Science, Noble Energy, « Tamar Field Development Project Environmental Impact AssessmentTamar-7, 8, 9 Drilling and completion; Tamar SW-1 completion »,mars2016,*https://www.gov.il/BlobFolder/generalpage/enviromental_info_file/he/Tamar_Field_7_8_9_SW_EIA_Mar_2016.pdf)*.

[15] i.e. 3.2% of investments

we proposed for Tamar, namely 8.9%. We will calculate two estimates for the break-even point.

Low estimate:

$$P_0 = \frac{[(0{,}089+0{,}08)\,12000 \times 10^6]}{31 \times 3{,}627 \times 10^7}$$

$$P_0 = 1{,}80 \ \$/\mathrm{MMBTU}$$

High estimate:

$$P_0 = \frac{[(0{,}089+0{,}12)\,12000 \times 10^6]}{31 \times 3{,}627 \times 10^7}$$

$$P_0 = 2{,}23 \ \$/\mathrm{MMBTU}$$

The price of gas in Lebanon

As far as Lebanese gas prices are concerned, it must be borne in mind that the Zohr field is exceptional in many aspects. It is the largest in the entire Eastern Mediterranean, its volume even exceeds the supposed gas reserves in Lebanon. Moreover, it is located about 190 km from the Egyptian coast – the Lebanese EEZ does not extend beyond 150 km from the coast. Finally, Zohr is connected directly to the shore by two 216 km gas pipelines located at depths of up to 1,500m and which can carry at least 31 billion m^3. The implementation of a construction site to exploit such a field generates very significant costs and certainly higher than any gas site in Lebanon.

Therefore, we will retain a low break-even point estimate for Lebanese gas of P0 = $1.50/MMBTU and a high estimate of $2/MMBTU. However, the final prices achieve significant margins on these break-even points. The example of ENI's exploitation of Zohr is eloquent in this respect. The Egyptian company EGAS buys the gas between $4 and $5.88/MMBTU. Of this amount, 40% is reserved for the repayment of ENI's investments in Zohr's operation and the margin is shared between ENI, 35% and the Egyptian State, 65% (Oxford Business Group, 2016).

Like the prices provided by ENI for Zohr, it can be considered that the break-even point defined for Lebanese gas constitutes 40% of the final price, the margin, therefore, constituting 60%. These estimates are consistent with those provided by (Ellinas, 2021) for the price of gas leaving the Leviathan field: approximately $4/MMBTU.

	Low estimate	High estimate
Break-even point P_0	1,50 $/MMBTU	2 $/MMBTU
Final price	3,75 $/MMBTU	5 $/MMBTU
Margin	2,25 $/MMBTU	3 $/MMBTU

The Lebanese government has negotiated the following taxes with the Total-ENI-Novatek consortium in the event of gas discovery and production (Charbonnier, 2020):

- For Block 4, the revenues paid to the State will be between 63 and 71% of the margin.
- For Block 9, which area is disputed with Israel, these revenues will be slightly lower: between 56 and 61% of the margin.

The following table shows a range for Lebanese government revenues according to the location of the gas and according to the low and high estimates of the break-even points for gas extraction.

Lebanese State revenues for gas exploitation

	Block 4		Block 9	
	Low estimate	High estimate	Low estimate	High estimate
$/MMBTU	1,42	2,13	1,26	1,83
$/billion M3	51 412 725	77 255 100	45 700 200	66 374 100

03

Current Lebanese energy production

Lebanon's electricity infrastructure

The vast majority of the Lebanese electricity fleet is composed of thermal power plants operating with fuel derived from oil (diesel, gas-oil) entirely imported. In 2018, these thermal power plants produced 95% of Lebanon's electricity. According to (Lebanese Republic, Ministry of Energy and Water, 2019), these facilities include two combined cycle thermal power plants in Deir Ammar and Zahrani, both with a capacity of 455 MW and built between 1998 and 2002. Initially planned to run on gas according to data from (International Energy Agency), they have, apart from a short interlude with gas in 2010, burned only diesel.

In 2018, the total electricity production by the power plants of the national electricity company of Lebanon, EDL, amounted to 1,1254 GWh, to which must be added the 3,578 GWh purchased from ship-fired power plants and Syria, as well as the 253 GWh produced by the Kadisha company (98% owned by EDL), which manages the hydroelectric dams on the eponymous river (Shabani & Chaaban, 2020). This total production corresponds to a theoretical effective capacity of 2,339 MW (Lebanese Republic, Ministry of Energy and Water, 2019) including 1,800 MW for EDL plants (Boutros, 2020), while demand reached 3,562 MW in 2018 (Lebanese Republic, Ministry of Energy and Water, 2019). To this lack of theoretical power, we must add the losses of the transmission and distribution networks up to 34% (Lebanese Republic, Ministry of Energy and Water, 2019). In fact, EDL, accompanied by the purchased electricity, can only produce two-thirds of the electricity requested and provides only half of the Lebanese demand because of the losses. As a result of these poor production conditions, the price of electricity reaches $136.2/MWh at the exit of the Zahrani power plant and $149.6/MWh at the outlet of the Deir Ammar power plant (Lebanese Republic, Ministry of Energy and Water, 2019).

The hypothetical price of electricity produced with gas

Suppose that all energy production in Lebanon in 2018 – 15,085 GWh – was carried out using gas burned in combined cycle thermal power plants with an energy efficiency of 60% (Association of Swiss Electricity Companies, 2020). Knowing that there are:

- $3{,}600 \times 10^9$ J/MWh
- $1{,}055 \times 10^9$ J/MMBTU

It can be determined that to generate 15,085 GWh of electricity it takes the following amount Qgas:

$$Q_{gaz} = (15085 \times 10^3)\,\frac{3{,}600 \times 10^9}{1{,}055 \times 10^9} \times \frac{100}{60}$$

$Q_{gas} = 8{,}58 \times 10^7$ MMBTU

That is:

$Q_{gas} = 2.37$ billion m^3

However, the electricity produced constitutes only two-thirds of the electricity demand. Excluding the losses of the network, it would have taken, in 2018, 3.55 billion m^3 of gas to meet all the energy needs of the population.

Let us now assume – which is more reasonable – that the use of gas to generate electricity in Lebanon will be restricted to the two combined cycle thermal power plants currently present in Lebanon, namely the Deir Ammar and Zahrani power plants.

These two plants produced in 2018 6,175 GWh of electricity {3,410 for Zahrani and 2,765 for Deir Ammar}, or 55% of the electricity produced by EDL plants (Shabani & Chaaban, 2020). With their 455 MW each, they are able to supply together between 25% and 30% of Lebanese demand {excluding losses from the electricity grid}.

As a result, it can be calculated that Zahrani operated about 7,500 h at full power in 2018, and Deir Ammar a little more than 6,000 h. Considering an average operating time of 7,000 hours for these plants, we obtain that they each provide 3,185 GWh of electricity in one year. Here is the quantity of Qgas required to operate only one of these plants:

$$Q_{gas} = (3185 \times 10^3)\,\frac{3{,}600 \times 10^9}{1{,}055 \times 10^9} \times \frac{100}{60}$$

$Q_{gas} = 1{,}81 \times 10^7$ MMBTU

Either:

$Q_{gas} = 0.50$ billion m^3

To ensure the operation of these two plants for a year, 1 billion m^3 of gas are needed.

As regards the break-even point for electricity produced with gas, it can be calculated as follows:

$$P_{electricity} = \frac{(CRF)\,C_{centrale} + MC + P_{gas}\,Q_{gas}}{Q_{electricity}}$$

With:

- $P_{electricity}$ is the price of electricity in \$/MWh.
- $Q_{electricity}$ is the annual amount of electricity produced in MWh. We keep the 3185 GWh which correspond to the operation at full power of a 455 MW power plant for 7000 h.
- $C_{central}$ is the initial cost of a combined cycle thermal power plant in \$. The average construction cost of a combined cycle power

plant is around $1000/kW[16]. A 455 MW plant like Zahrani or Deir Ammar would cost $455 million.

- CRF is the capital recovery factor (in %). The interest rate at 8% (High interest rate is usually used for gas infrastructure) is maintained and it is given an economic life span of 25 years (French Republic; Ministry of Ecology, Energy, Sustainable Development and Spatial Planning, 2014). Thus, CRF = 9.4%.
- MC are the annual maintenance and operating costs of the plant in $. These amount to $0.05/kWh (Jenkins, Kuo, & Harberger, 2019). Thus, we obtain a final cost of $159 million.
- P_{gas} is the price of gas in $/MMBTU. We assume, based on our gas price estimates, that EDL acquires it at $5/MMBTU.
- Q_{gas} is the quantity of gas purchased in MMBTU. It was set at 1.81. 107 MMBTU.

Since:

$$P_{electricity} = \frac{0{,}094 \text{ x } 455 \text{x} 10^6 + 159 \text{x} 10^6 + 5 \text{ x } 1{,}81 \text{x} 10^7}{3185 \text{x} 10^3}$$

$$P_{Electricity} = \$91.84/MWh$$

That brings us to an electricity cheaper by the third than the one currently produced with diesel in the Deir Ammar and Zahrani power plants.

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[16] In 2010, the International Energy Agency's Energy Technology System Analysis Program reported that this cost was $1100/kW. However, the study projected a decline to $1000/kW for 2020 (International Energy Agency - Energy Technology System Analysis Program, «Gas-Fired Power», April 2010, *https://iea-etsap.org/E-TechDS/PDF/E02-gas_fired_power-GS-AD-gct.pdf, p. 1)*.
This decrease seems to be confirmed by the following document: French Republic, Ministry of Ecology, Energy, Sustainable Development and Spatial Planning, "Public synthesis of the study of the reference costs of electricity production", April 2014, *https://www.ademe.fr/sites/default/files/assets/documents/20140407_Synthese-publique-couts-ref-prod-electrique.pdf, p. 7*.

04

Estimated future of the Lebanese electricity production

The evolution of Lebanese (GDP per capita)

In order to estimate the future Lebanese electricity production, our best bet is the model used for this purpose for the sub-Saharan zone by (J. Demierre, 2015) and reused by (Ruble, 2017) for the Eastern Mediterranean. The model first estimates the GDP per capita of the country concerned at a time t, then the energy needs per capita at the same time t, to finally provide an estimate of the country's gas needs.

This model assumes that a developing economy follows a process of catching up with the developed economy with which it maintains the most trade and results in the following equation:

$$\mathrm{GDP}_{i,\ t} = \mathrm{GDP}_{i,\,t-1} \text{ x } e^{[\mathrm{GDPc}_j + r(\ln \mathrm{GDP}_{j,\,t-1} - \ln \mathrm{GDP}_{i,\ t-1})]}$$

- $\mathrm{GDP}_{j,\,t}$ corresponds to the GDP per capita at a time t of the developed country j with which the country i has the most trade.
- GDP_{cj} is the average annual growth of GDP per capita of country j.
- r is a constant that measures the speed of the catching up of the economy i on the economy j. Jonathan Demierre estimates this value at 0.014, a value also adopted by Isabella Ruble and which we ourselves therefore keep.

To initialize this model for Lebanon, we postulate that the political situation is improving significantly so that the economy returns in 2025 to its level of 2018 prior to the political, economic and social crisis that the country is currently experiencing. If the discovery of a gas field were to be announced in 2022 by the Total-ENI-Novatek consortium, it would not be put into operation before 2025 anyway, the time to build the necessary infrastructure and plan the replacement of the combined cycle thermal power plants of Deir Ammar and Zahrani now at the end of their life[17]. It goes without saying that this is an optimistic hypothesis.

Concretely, we assume here that GDP per capita in Lebanon will return to its 2018 level in 2025, i.e. we will put it at $7 500[18].

Lebanon's main suppliers in recent years have been European countries (Groupe Crédit du Nord, 2019). In 2020, Switzerland accounted for 28% of Lebanese imports (French Treasury, 2021). Lebanon's main customers, on the other hand, are the Middle Eastern countries, led by the United Arab Emirates and Saudi Arabia. As the model assumes the catching-up of a developing economy – in this case Lebanon – with a developed economy, we choose the European Union as the reference economic entity in this modeling.

We assume that by 2025, GDP per capita in the European Union will have returned to its 2019 level and will therefore be around $45,000[19]. Between 2012 and 2019, GDP growth fluctuated from -0.9% to 2.63%. We therefore set an average value of 1.5% for the annual growth of GDP per capita in the European Union.

By entering all of this data into the equation outlined above, we get the following table:

Year	GDP per capita in the EU ($2020)	GDP per capita in Lebanon ($2020)
2025	45 000	7 500
2026	45 675	7 807
2027	46 360	8 123
2028	47 055	8 449
2029	47 761	8 785
2030	48477	9 132
2031	49 204	9 489
2032	49 942	9 857
2033	50 691	10 236
2034	51 451	10 626
2035	52 223	11 027
2036	53 006	11 440
2037	53 801	11 865
2038	54 608	12 302
2039	55 427	12 751
2040	56 258	13 213

This model also allows us, within the framework of the optimistic assumptions we have formulated, to estimate the evolution of the Lebanese GDP:[20]

Year	GDP in Lebanon ($2020)	Growth (%)
2025	47 979 337 500	
2026	49 392 203 392	2,94
2027	50 960 737 105	3,18
2028	52 693 591 034	3,40
2029	54 567 974 790	3,56
2030	56 571 297 144	3,67
2031	58 711 583 859	3,78
2032	61 018 319 378	3,93
2033	63 484 071 204	4,04
2034	66 091 732 938	4,11
2035	68 825 119 743	4,14
2036	71 687 249 920	4,16
2037	74 677 111 635	4,17
2038	77 779 493 416	4,15
2039	80 974 626 203	4,11
2040	84 251 333 561	4,05

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[17] In 2019, the Lebanese Ministry of Energy and Water anticipated these problems and issued a plan to replace end-of-life power plants and diversify the Lebanese energy mix while reducing the losses of electricity transmission and distribution networks (Lebanese Republic, Ministry of Energy and Electricity Water, «Update of the National Strategic Plan for the Electricity Sector», March 2019, *https://energyandwater.gov.lb/mediafiles/articles/doc-100511-2019_05_22_04_02_43.pdf)*.

[18] See Appendix D. For all of this modelling, the reference unit will be the 2020 US dollar.

[19] See Appendix E.

[20] See Appendix C for the evolution of the Lebanese population between 2010 and 2040.

The evolution of energy consumption

From GDP per capita, we can calculate the annual energy needs for electricity per capita (BEh).

$$BEh_t = PIB_{i,t} \ x \ I_t$$

With:

- $GDP_{i,t}$ the GDP per capita of country i[21] in year t
- I_t the electricity energy intensity of this country in year t. It measures the amount of electricity consumed to produce one dollar[22]. It is calculated by the ratio of annual electricity consumption to GDP in MJ/$. A model indicates that this intensity decreases by 1.14% per year on average, making one dollar consume less energy to be produced each year (J. Demierre, 2015).
- In 2018, the Lebanese electricity production reached 15,085 GWh. Leaving aside losses from the transmission and distribution networks, this generation could only meet two-thirds of the demand that would have required a capacity of 3562 MW[23]. It would have been necessary for the Lebanese power plants to produce about 22,500 GWh to meet all the demands of the inhabitants. In 2025, the Lebanese Ministry of Energy and Water forecasts that the power requirement will be 4,030 MW, a demand 13% higher than 2018 (Lebanese Republic, Ministry of Energy and Water, 2019). We will therefore estimate the Lebanese demand for electricity at 25,000 GWh in 2025 and assume that the production will manage to support it.

Year	Electrical energy intensity (MJ/$)	BEh (MJ/inhabitant)
2025	1,875807476	14 068,55607
2026	1,854423271	14 477,48248
2027	1,833282846	14 891,75656
2028	1,812383422	15 312,82753
2029	1,791722251	15 740,27997
2030	1,771296617	16 175,48071
2031	1,751103835	16 616,22429
2032	1,731141252	17 063,85932
2033	1,711406241	17 517,95429
2034	1,69189621	17 978,08913
2035	1,672608593	18 443,85496
2036	1,653540856	18 916,50739
2037	1,634690490	19 395,60266
2038	1,616055018	19 880,70883
2039	1,597631991	20 371,40552
2040	1,579418986	20 868,86307

It is now possible for us to obtain the annual energy consumption in Lebanon for the period 2025-2040[24]:

Year	Annual energy consumption (GWh)	Growth (%)
2025	25 000.0	
2026	25 442,8	1,77
2027	25 951,5	2.00
2028	26 528,1	2,22
2029	27 158,5	2,38
2030	27 834,6	2,49
2031	28 558,4	2,60
2032	29 342.0	2,74
2033	30 179,7	2,85
2034	31 061,2	2,92
2035	31 977,1	2,95
2036	32 927,2	2,97
2037	33 909,4	2,98
2038	34 915,5	2,97
2039	35 935,5	2,92
2040	36 963,4	2,86

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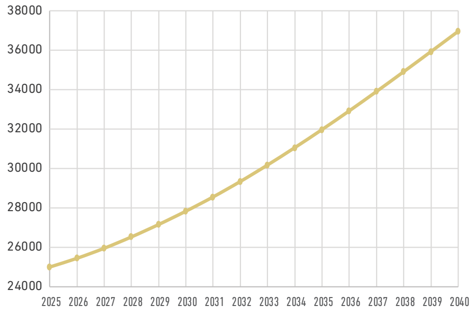
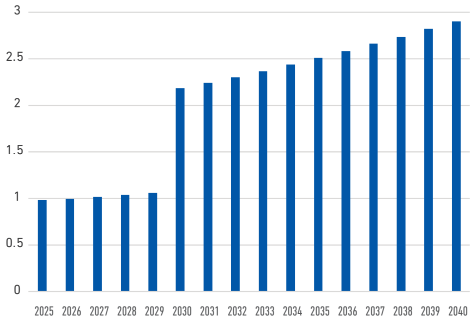
21. Here Lebanon

22. J. Demierre's model makes use of primary energy intensity. This intensity measures the amount of primary energy (gas, oil, coal, etc.) consumed to produce a dollar. We prefer to adapt this measure to the electricity consumption alone that is easier for us to measure.

23. See supra p. 13-14.

24. See Appendix C for the evolution of the Lebanese population between 2010 and 2040.


Annual energy consumption
(GWh) 2025-2040


Annual gaz consumption
(billion m3) 2025-2040

The evolution of the share of gas in the Lebanese energy production

The fleet of gas-fired combined cycle thermal power plants in Lebanon[25] has a total theoretical capacity of 910 MW. This fleet could in 2025 ensure 25% of the total electricity production of the country. As it ages, we must consider its total replacement for the 2025-2030[26] horizon. So we take the side, for this study, that gas will provide only 25% of Lebanese energy production until 2030, the time to renew the plants and add others for 2030, so that by that date 50% of the national electricity will be produced using gas. This is the scenario of electricity production that we retain.

Here are the annual quantities of gas needed to ensure these production levels:

	MMBTU	Billion M3
2025	35 545 023,7	0,980011682
2026	36 174 597,16	0,997369649
2027	36 897 867,3	1,017310926
2028	37 717 677,73	1,039913916
2029	38 613 981,04	1,06462589
2030	79 150 521,33	2,182258653
2031	81 208 720,38	2,239005249
2032	83 436 966,82	2,300440221
2033	85 819 052,13	2,366116684
2034	88 325 687,2	2,435227108
2035	90 930 142,18	2,507034524
2036	93 631 848,34	2,581523252
2037	96 424 834,12	2,65852865
2038	99 285 781,99	2,73740783
2039	102 186 255,9	2,817376783
2040	105 109 194,3	2,897965104

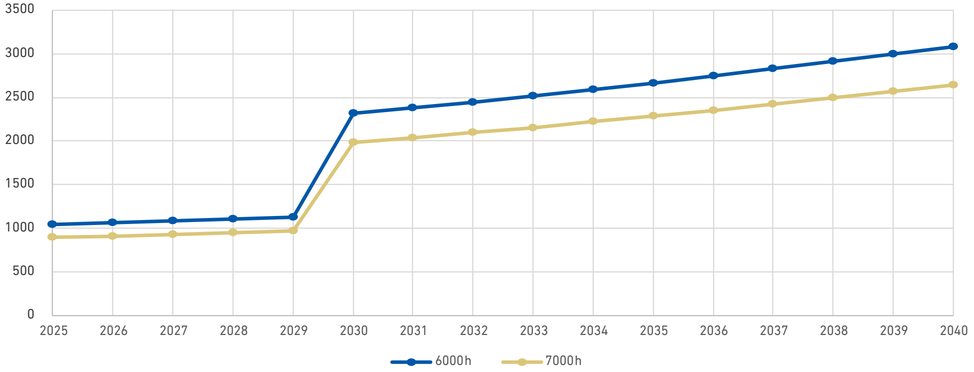
Depending on whether gas thermal power plants operate on average per year 6,000h or 7,000h, here is the annual power required of this fleet of power plants in MW:

---

[25] the current Deir Ammar and Zahrani power plants

[26] The Lebanese State is aware of this problem, but above all, provides for the replacement of thermal power plants in the Zuk, Jieh and Hrayché fuel oil which are much older (Lebanese Republic, Ministry of Energy and Water, «Update of the National Strategic Plan for the Electricity Sector», March 2019, *https://energyandwater.gov.lb/mediafiles/articles/doc-100511-2019_05_22_04_02_43.pdf)*.

Annual capacity of gas-fired power plants



Year	6000h	7000h
2025	1042	893
2026	1060	909
2027	1081	927
2028	1105	947
2029	1132	970
2030	2320	1988
2031	2380	2040
2032	2445	2096
2033	2515	2156
2034	2588	2219
2035	2665	2284
2036	2744	2352
2037	2826	2422
2038	2910	2494
2039	2995	2567
2040	3080	2640

Year	Profits ($)
2025	62 500 000
2026	63 607 000
2027	64 878 750
2028	66 320 250
2029	67 896 250
2030	139 173 000
2031	142 792 000
2032	146 710 000
2033	150 898 500
2034	155 306 000
2035	159 885 500
2036	164 636 000
2037	169 547 000
2038	174 577 500
2039	179 677 500
2040	184 817 000

It is therefore necessary to foresee, over the period 2025-2040, a tripling of the energy capacity – from 1,000 MW to 3,000 MW – of the gas thermal power plant park to ensure, in 2040, 50% of the production of electricity from gas.

Any price increase of $10/MWh[27] above the break-even point of $91.84/MWh[28] would result in EDL's net annual earnings as shown in the table below. The whole constituting a profit of $2.093 billion over the period 2025-2040.

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[27] i.e. $0.01/kWh

[28] See p. 11 above.

05

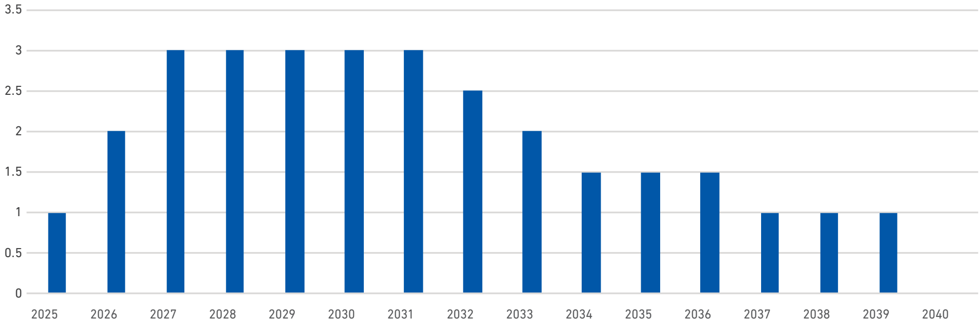
Exploitation and exportable share of Lebanese gas

We propose four gas exploitation scenarios, based on the largest field hypothetically discovered in 2022 and whose exploitation would start in 2025. The extraction peaks chosen for each of these scenarios are for illustrative purposes only. The aim is to formulate what the development of a gas field might look like according to its size, taking into account that the operating company will tend to increase the rate of extraction with the size of the deposit. There are several reasons for this. It should simply be noted that, on the one hand, initial investments grow with the size of the deposit and, on the other hand, that the operating company will seek to increase its profits without hindering the sustainability of the operation. To summarize, there is no exact formula for the establishment of these peaks of exploitation, so those that appear for each of these scenarios only allow to get an idea of the pace of the exploitation and to express the stakes of these, in particular for the potential export of gas.

Scenario n°1

Suppose that the largest deposit discovered has a volume of 30 billion m^3 – deposits of a lower volume are difficult to exploit because they are not very profitable[29]. For a peak extraction of 3 billion m^3 per year, the operating life can be estimated at 15 years[30], from 2025 to 2039. In this hypothesis, Lebanon would only be self-sufficient in gas, according to the consumption modalities specified above, between 2025 and 2032 and would only be able to export small quantities of gas during the same period.

Scenario n°1: Annual extraction (billion M3)



Year	Gas extracted (billion m^3)	Gas needed (billion m^3)	Exportable gas (billion m^3)	Gas to be imported (billion m^3)
2025	1	0,98	0,02	
2026	2	1,00	1,00	
2027	3	1,02	1,98	
2028	3	1,04	1,96	
2029	3	1,06	1,94	
2030	3	2,18	0,82	
2031	3	2,24	0,76	
2032	2,5	2,30	0,20	
2033	2	2,37		0,37
2034	1,5	2,44		0,94
2035	1,5	2,51		1,01
2036	1,5	2,58		1,08
2037	1	2,66		1,66
2038	1	2,74		1,74
2039	1	2,82		1,82
2040		2,90		2,90

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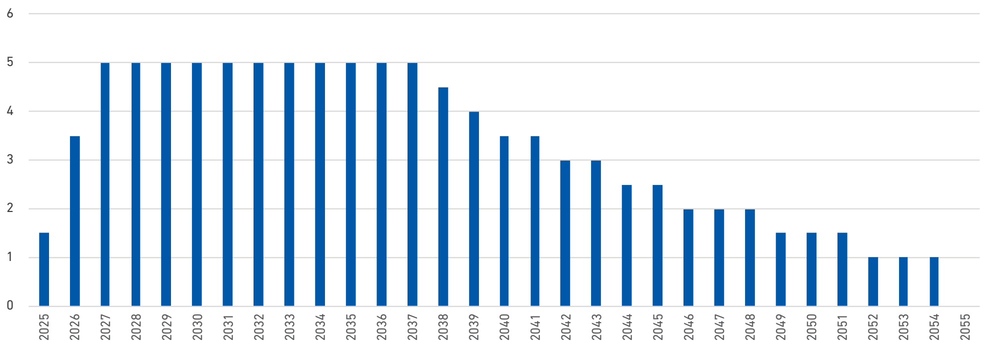
[29] There are of course exceptions, including the Noa deposit in Israel with 1.3 billion m^3 (« Noa well starts supplying Israel with natural gas », Reuters, 24/06/12, *https://www.reuters.com/article/us-noa-israel-idUSBRE85N0GR20120624)*. However, it was an annex to the Mari-B deposit and did not require the construction of new major infrastructure for its exploitation.

[30] See the calculation method on p. 6 of this study.

Scenario n°2

If the largest gas field discovered were to reach 100 billion m^3 at an estimate annual extraction peak of 5 billion m^3, Lebanon could extract gas for 30 years, from 2025 to 2054. However, it could only meet its full gas needs until around 2042. The exportable share of gas is between 2 and 3 billion m^3 for most of the period 2025-2040.



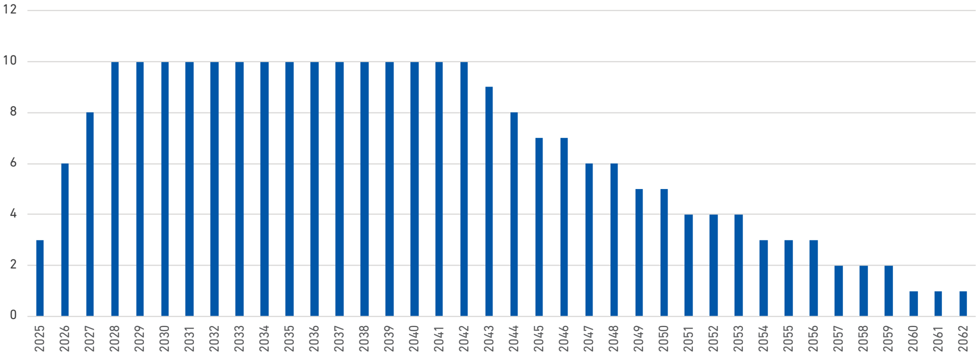
Scenario n°2: Annual extraction (billion M^3)

Year	Gas extracted (billion m^3)	Gas needed (billion m^3)	Exportable gas (billion m^3)
2025	1,5	0,98	0,52
2026	3,5	1.00	2,50
2027	5	1,02	3,98
2028	5	1,04	3,96
2029	5	1,06	3,94
2030	5	2,18	2,82
2031	5	2,24	2,76
2032	5	2,30	2,70
2033	5	2,37	2,63
2034	5	2,44	2,56
2035	5	2,51	2,49
2036	5	2,58	2,42
2037	5	2,66	2,34
2038	4,5	2,74	1,76
2039	4	2,82	1,18
2040	3,5	2,90	0,60

Scenario n°3

With 250 billion m^3 and an annual extraction peak of 10 billion m^3, the operation would last 37.5 years. Lebanon would remain self-sufficient and a gas exporter until around 2050. The share of exportable gas in this scenario reaches more significant levels, around 7 billion m^3 over most of the period 2025-2040, and remains above 5 billion m^3 between 2026 and 2044, which would establish the country as a regional exporter.

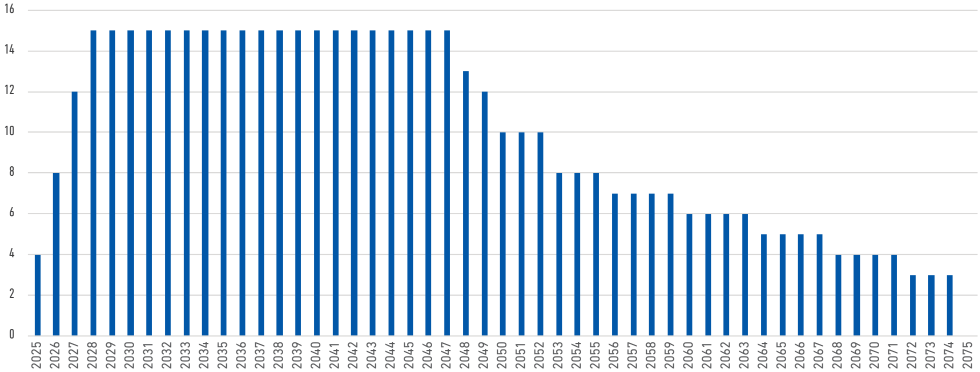
Scenario n°3: Annual extraction (billion M^3)



Year	Gas extracted (billion m^3)	Gas needed (billion m^3)	Exportable gas (billion m^3)
2025	3	0,98	2,02
2026	6	1,00	5,00
2027	8	1,02	6,98
2028	10	1,04	8,96
2029	10	1,06	8,94
2030	10	2,18	7,82
2031	10	2,24	7,76
2032	10	2,30	7,70
2033	10	2,37	7,63
2034	10	2,44	7,56
2035	10	2,51	7,49
2036	10	2,58	7,42
2037	10	2,66	7,34
2038	10	2,74	7,26
2039	10	2,82	7,18
2040	10	2,90	7,10

Scenario n°4

The last scenario visualizes the case where a deposit of 500 billion m^3 is discovered, which would therefore gather the vast majority of the presumed Lebanese reserves. In such a case, with an annual extraction peak of 15 billion m^3, the exploitation would extend over 50 years, from 2025 to 2074. Lebanon could then probably fully meet its gas needs until the early 2060s. The exportable share of gas, for most of the period 2025-2040, is above 12 billion m^3 and remains above 7 billion m^3 between 2026 and 2049, which would make Lebanon a major regional exporter.


Scenario n°4: Annual extraction (billion M^3)

Year	Gas extracted (billion m^3)	Gas needed (billion m^3)	Exportable gas (billion m^3)
2025	4	0,98	3,02
2026	8	1,00	7,00
2027	12	1,02	10,98
2028	15	1,04	13,96
2029	15	1,06	13,94
2030	15	2,18	12,82
2031	15	2,24	12,76
2032	15	2,30	12,70
2033	15	2,37	12,63
2034	15	2,44	12,56
2035	15	2,51	12,49
2036	15	2,58	12,42
2037	15	2,66	12,34
2038	15	2,74	12,26
2039	15	2,82	12,18
2040	15	2,90	12,10

06

Export of gas

It is now necessary to draw up a list of potential client States to purchase the possible exportable surplus of Lebanese gas as well as the list of existing or planned pipelines necessary for this export according to the exploitation scenarios established previously.

Potential client states

The most natural customers for Lebanon are obviously the neighboring states. Let's start with Syria. In the event that the Syrian political situation is stable enough to allow the economic reconstruction of the country around 2025 following a civil war that has now lasted for more than ten years, Syria would be a considered as a potentially privileged customer. Note that gas consumption decreased from 8.53 billion m^3 in 2010 to 3.26 billion m^3 in 2018, and its gas production, over the same period, fell from 8.80 billion m^3 to 3.63 billion m^3 (Syria, 2021). While an oil producer – Syria's proven reserves reached 300 billion m^3 of gas in 2020 (BP, 2021) – it is nevertheless expected to take several years before the country returns to its 2010 production level. In the meantime, Lebanon could prove to be a partner of choice for Syria to guarantee its gas supply during its economic reconstruction.

Assuming that the Syrian situation stabilizes around 2025, Lebanon could thus consider, depending on its production capacity, exporting up to 2 or 3 billion m^3 per year to Syria until around 2030-2035. After this date, Syria would most likely become self-sufficient in gas again, especially since it has the most important offshore gas reserves in the entire Eastern Mediterranean, estimated in 2013 at nearly 1,100 billion m^3 (Rigoulet-Roze, 2014).

Jordan appears to be a potential prime customer for Lebanon. Not a gas producer, Jordan depended in 2018 on 83% of this fuel to generate its electricity and had consumed that year 3.76 billion m^3 to do so. Depending on its production capacity, Lebanon could consider exporting up to 3 or 4 billion m^3 (Jordan, 2021) per year. Currently, Jordan imports 3 billion m^3 per year from Israel, via a 65 km gas pipeline crossing their common border (Ghazal, 2018).

Of course, it is for the moment quite excluded that Lebanon exports to Israel. However, to be exhaustive, we still analyze the situation of the latter for what it carries as teachings. Israel is currently a major gas producer – 9.13 billion m^3 produced in 2019 (Israel, 2021). However, the growth in gas demand in this country will be such that by 2040 it will no longer be possible to be self-sufficient in the absence of new field discoveries. By 2050, Israeli production would meet even a third of gas demand (Akyener, 2016). Egypt, currently the region's largest gas producer – 64.9 billion m^3 in 2019 (Akyener, 2016) – is expected to see its production fall after 2025 due to the gradual depletion of all its gas fields except Zohr (French Treasury D. G., 2018). Due to its high gas consumption, which fluctuated between 55 and 60 billion m^3 per year between 2017 and 2020 (BP, 2021), Egypt should find it difficult to extend its gas self-sufficiency beyond 2030 in the absence of new deposits. Initially, it could obtain supplies from Israel, which has already been the case since January 2020; Egypt has purchased a total of 85.3 billion m^3 from Israel, which has committed to supply them over a period of 15 years[31]. However, this can no longer be possible after 2040 for the reasons mentioned in the previous paragraph and Egypt will therefore have to obtain supplies from new partners. To be Egypt's partner, Lebanon must be able to sell it around 4 or 5 billion m^3 per year over a period of about 15 years, which is only possible under scenario 4. This is indeed inconceivable for scenario 3, because Lebanon could then maintain an exportable share of gas greater than 5 billion m^3 only until 2044.

Turkey is, after Egypt, the most gas-consuming economy in the Eastern Mediterranean with 46.4 billion m^3 in 2020 (BP, 2021). Highly dependent on Russian gas – a third of the gas consumed in Turkey came from Russia in 2020 – Turkey is seeking to diversify its sources of supply. The recent discovery of several deposits in Turkish waters in the Black Sea (a provisional total of 540 billion m^3) should allow it to do so, given that gas production is expected to start in 2023 (Kaya, 2021). The peak production could reach 20 billion m^3 per year (BP, 2021) and therefore meet about 45% of Turkey's gas demand. In the perspective of scenarios 3 and 4, Lebanon could sell to Turkey quantities of gas varying between 1 and 5 billion m^3 per year from 2025-2030, which would allow the latter to reduce the choice of imports of Russian gas, on which it is highly dependent, or those of Iranian gas, very expensive[32].

The last potential customer for Lebanon is the European Union. In the medium term, the latter is faced with the problem of gas supply. As a major consumer, it produces very little and imported mainly from the North Sea and Russia. The drying up of the former's gas reserves and

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[31] A. Lewis, A. Rabinovitch, « UPDATE 2-Israel starts exporting natural gas to Egypt under landmark deal », Reuters, 15/01/20, *https://www.reuters.com/article/israel-egypt-natgas-idUSL8N29K1R8*.
The genesis of this contract dates back to the years following the revolution that overthrew Hosni Mubarak. The Zohr deposit had not yet been discovered and production was beginning to decline sharply. It increased from 59.1 billion m^3 in 2011 to 40.3 billion m^3 in 2016 (BP, Statistical Review of World Energy, 70th edition, 2021, p. 36). As a result, Egypt very quickly considered the possibility of bringing gas from Israel via the Ashkelon-Arish gas pipeline. The agreements were finalized only in November 2019 ("Israel-Egypt gas pipeline deal, explained", TRT World, 04/11/19, *https://www.trtworld.com/mea/israel-egypt-gas-pipeline-deal-explained-31103)*.

[32] It seems that it is the latter choice that is for the moment privileged. In 2019, Turkey imported 14.6 billion m^3 of Russian gas and 7.4 billion m^3 of Iranian gas. In 2020, these quantities increased to 15.8 respectively. et 5,1 (BP, Statistical Review of World Energy, 69th edition, 2020, pp. 32-43; BP, Statistical Review of World Energy, 70th edition, 2021 pp. 34-45).
Turkey buys Iranian gas for a price of $205 per 1000 m^3 (O. Gunnar Austvik, G. Rzayeva, "Turkey in the geopolitics of energy", Energy Policy 107, 2017, p. 544), or about $7.25/MMBTU.

the EU's poor relations with the latter further complicate the equation.

To remedy this, a gas route that would pass through Turkey to reach the reserves of the Caucasus, the Caspian, Iran and the Eastern Mediterranean was envisaged in the course of the 2000s. Of this fourth gas route, only the TANAP pipeline that crosses Turkey to Azerbaijan and the EastMed gas pipeline project that is to connect Israeli gas fields to the EU by bypassing Turkey via Cyprus (Semon & Mavrommatis, 2021) and Crete remain today.

Signed in 2020, the construction of the pipeline is to be completed by 2025 (Abnett, 2021). In the event of a major gas discovery – scenarios 3 and 4 – and in the event of neutralization of the Israeli factor, Lebanon could join Cyprus in this project to export gas to the European Union, up to 3 billion m^3 per year. This would also allow it to sell to Cyprus a small part of the gas transiting through EastMed. Although the island has gas fields, the small size of its economy makes it unlikely that they will be put into operation, as almost all production is expected to be export-oriented even though Mediterranean gas is expensive to produce. This could create a possible commercial outlet for Lebanese gas to the tune of just under one billion m^3 per year[33].

The EastMed gas pipeline

The Arab gas pipeline is, without a doubt, the main network through which Lebanon will be able to export its gas. Its career path is as follows:

- The first section, commissioned in 2003, begins in Arish, Egypt, to reach Aqaba, Jordan, on a 265 km journey at a cost of $220 million (World Bank, 2013).
- The second section, whose contract was signed in 2004 and completed in 2005, connects Aqaba to Rehab in Jordan, measures 390 km, all at a cost of $300 million (World Bank, 2013);
- The third section, between Rehab and Jabber on the Jordanian-Syrian border, is 30 km long and was completed in 2007 at a cost of $35 million (World Bank, 2013);
- The fourth section was completed in 2008 from Jabber to Homs over a distance of 324 km at a cost of approximately $300 million (World Bank, 2013);
- A 96 km section connects Homs to Tripoli {the Deir Ammar thermal power plant is very close to Tripoli}, including 32 km in Lebanon between Addabousiya and Tripoli (World Bank, 2013).
- An additional section connects Homs to Baniyas. We are not interested in this one in the context of our study.
- Finally, in the late 2000s, a 240 km section was planned that would have connected Homs to Aleppo at a cost of $395.5 million (World Bank, 2013), then a 64 km section from Aleppo to Kilis in Turkey at a cost of $71 million (Kommersant, 2008). It was planned that each would have a capacity of 10 billion m^3 per year, but none saw the light. (World Bank, 2013).

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[33] The Cypriot economy produced 4627 GWh of electricity in 2019, production that could be ensured with 0.73 billion m^3 of natural gas (International Energy Agency, « Cyprus », 2021, *https://www.iea.org/countries/cyprus)*.

EastMed Gas Pipeline Section	Price in millions of $ (reference year)	Prices in millions of $ of 2021	Length (km)	Unit price ($million/km)	Cost of transporting gas ($/ MMBTU)[34]
Arish - Aqaba	220 (2003)	319	265	1,200	0,12
Aqaba - Rehab	300 (2004)	426	390	1,090	0,16
Rehab - Jabber	35 (2007)	45	30	1,500	0,02
Jabber - Homs	300 (2008)	372	324	1,150	0,14
Homs - Aleppo	395,5 (2008)	492	240	2,050	0,19
Aleppo - Kilis	71 (2008)	88	64	1,375	0,03

From Arish to Homs, the pipeline has a capacity of 10.3 billion m^3 per year[35], while the segment that connects Homs to Tripoli has a capacity of 2.2 billion m^3 per year (United Nations Development Programme, 2016). Regardless of the gas production scenario, the capacity of the Lebanese segment is insufficient in the long term to ensure both exports and imports when the country will no longer be able to support its gas consumption through its production. Scenarios 1 and 2 require a minimum capacity of 4 billion m^3 per year for this segment. Scenario 3 requires a minimum capacity of 6 billion m^3 per year to allow exports to Jordan, Syria and Turkey, while the last scenario requires a minimum capacity of 10 billion m^3 per year in order to be able to send gas to Egypt.

In order to estimate the construction costs of the Tripoli-Homs gas pipeline for each scenario, we can rely on Isabella Ruble's model which indicates the price per kilometer of pipeline in millions of dollars based on its transport capacity in billions of m^3 per year[36].

$$C = 0{,}4215 + 0{,}57Q^{1/2} + 0{,}039Q$$

However, it should be noted that this model, about the Arab gas pipeline, provides estimates 2 to 2.5 higher than the actual prices shown in the table above (for a capacity of 10.3 billion m^3 per year, the model estimates the cost of one kilometer of gas pipeline at $2.65 million). Therefore, for our estimates, we will halve the cost of a kilometer of gas pipeline predicted by this model.

Homs - Tripoli gas pipeline	Length (km)	Capacity (billion m^3 per year)	Unit price ($million/km)	Total price ($million)	Cost of transporting gas ($/MMBTU)
Scenario 1	96	4	0,86	82,5	0,08
Scenario 2	96	4	0,86	82,5	0,08
Scenario 3	96	6	1,03	98,5	0,06
Scenario 4	96	10	1,31	125,5	0,05

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34. To do this, we use the formula given on pages 5 and 6 of this study. The maintenance cost for a gas pipeline operating at maximum capacity is 5% of its initial price. The capital recovery factor is calculated using an interest rate of 8% established for a period of 30 years (i.e. CRF = 8.9%).

35. World Bank, Regional Gas Trade Projects in Arab Countries, 1, 2013, *file:///Users/adrien/Downloads/761140ESW0P12700CATALOG0AS010VOLUME.pdf*, pp. 40- 43.

36. The initial equation of Ruble (C = 0.4215 + 0.096Q1/2 + 0.0011Q), which it takes from Jonathan Demierre by slightly changing the coefficients, establishes the price in millions of dollars per kilometer of pipeline according to its capacity in billions of ft^3 per year. The equation presented here is a conversion that gives the price in millions of dollars per kilometer of gas pipeline according to its capacity in billions of m^3 per year.
I. Ruble, « European Union energy supply security: The benefits of natural gas imports from the Eastern Mediterranean », Energy Policy 105, 2017, pp. 348-349.
J. Demierre, M. Bazilian, J. Carbajal, S. Sherpa, V. Modi, « Potential for regional use of East Africa's natural gas », Applied Energy 143, 2015, p. 423.

The Tripoli - Tyre coastal gas pipeline

The construction of a gas pipeline between Tripoli and Tyre, with a length of 174km, had already been envisaged, from 2010, by the Lebanese government (L'Orient-Le Jour, 2010). However, this project, which was supposed to connect the Zahrani power plant, located between Tyre and Sidon, to the Tripoli gas terminal, never materialized.

In the event of a gas discovery, it goes without saying that this pipeline would be necessary. Nevertheless, the transport capacity to be allocated to it would depend on two factors: the amount of gas discovered and the location of this gas. Indeed, prospecting blocks 4 and 9 are the most suitable for looking for gas. However, if the first is rather in the north of the Lebanese exclusive economic zone, the second is located in the very south. In fact, a deposit discovered in Block 4 would be connected to the Tripoli terminal, but a deposit discovered in Block 9 would have to be connected to Tyre.

Assuming that a field is unearthed in Block 4, the coastal pipeline would then only be used to transport gas to power plants in the south of the country since it is excluded that it will go to Israel via a gas pipeline from Tyre to the Haifa gas terminal. Under scenarios 1 and 2, the pipeline would thus have a capacity of only 2 billion m^3 per year, more than enough to transit at least half of the gas consumed by the country over a year, even in 2040.

Tripoli-Tyre gas pipeline in the case of a gas discovery in Block 4[37]

Tripoli - Tyre gas pipeline	Length (km)	Capacity (billion m^3 per year)	Unit price ($million/km)	Total price ($million)	Cost of transporting gas ($/MMBTU)
Scenario 1	174	2	0,65	113	0,22
Scenario 2	174	2	0,65	113	0,22
Scenario 3	174	5	0,95	165	0,13
Scenario 4	174	5	0,95	165	0,13

Let us now assume that the deposit is in block 9. The coastal pipeline should then not only transit the gas necessary for the operation of the power plants in the north of the country {a capacity of 2 billion m^3 must be reserved there}, but also all the gas intended to be exported from Tripoli in the Arab pipeline. Thus, for scenarios 1 and 2, the pipeline should have a capacity of 6 billion m^3, 8 billion for scenario 3 and 12 for scenario 4.

Tripoli-Tyre gas pipeline in the case of a gas discovery in Block 9

Tripoli - Tyre gas pipeline	Length (km)	Capacity (billion m^3 per year)	Unit price ($million/km)	Total price ($million)	Cost of transporting gas ($/MMBTU)
Scenario 1	174	6	1,03	179	0,11
Scenario 2	174	6	1,03	179	0,11
Scenario 3	174	8	1,17	204	0,10
Scenario 4	174	12	1,43	249	0,08

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[37] The method of calculating prices remains the same as that chosen for the Homs - Tripoli gas pipeline. However, it seems that the prices shown are low estimates for the coastal gas pipeline. The Lebanese government's 2010 project was valued at $360 million. However, the transport capacity of the proposed pipeline has never been indicated (Ibid.)

Exporting gas to Europe

Due to the large quantities of gas available for export in scenarios 3 and 4, and the fact that Egypt is unlikely to acquire Lebanese gas before the end of the 2030s, the sale of gas to the European Union remains attractive, as it is possible as soon as the gas fields are put into production.

We can study several ways to do this, starting with the EastMed gas pipeline that is to be completed by 2025 and that will transport gas from Israeli fields to Greece via Vasilikos in Cyprus. If this project is executed, Lebanon could eventually join it – subject to neutralization of the Israeli factor – and build a submarine gas pipeline of about 250km and a capacity of 3 billion m^3 per year between Tripoli and Vasilikos of which a small amount, between 0.5 and 1 billion m^3 could be destined for Cyprus[38]. The cost of transporting the gas by EastMed to Greece can be estimated at around $4/MMBTU (Sémon & Mavrommatis, 2021). In the event of non-construction of the EastMed gas pipeline or non-neutralization of the Israeli factor, it will still be possible in Lebanon to build a gas pipeline with a capacity reduced to 1.5 billion m^3 to serve Cyprus[39].

The following table shows the construction costs for the two configurations of the Tripoli–Vasilikos gas pipeline[40]:

Tripoli - Vasilikos gas pipeline	Length (km)	Capacity (billion m^3 per year)	Unit price ($million/km)	Total price ($million)	Cost of transporting gas ($/MMBTU)
Absence of Eastmed	250	1,5	1,90	475	1,21
Presence of EastMed	250	3	2,77	692,5	0,88

Another possibility would be to transit the gas through the Arab pipeline to Damietta in Egypt where there is a liquefaction terminal and export liquefied natural gas, LNG. This option has the advantage for Lebanon of not requiring the construction of an expensive underwater gas pipeline. Total transportation costs include the cost of transportation to Egypt at approximately $0.50/MMBTU, the cost of gas liquefaction[41] and the cost of transportation by LNG carrier to a European LNG re-gasification terminal, $0.4 to $1.25/MMBTU[42]. That is a total transportation cost estimated between $3.50 and $4.35/MMBTU.

One last possibility is to export gas to Europe, but it can only be implemented under scenario 4, because it requires being able to export quantities of gas of around 5 billion m^3 per year over a period of 30 years to be profitable.

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38. See note 38.

39. Although Cyprus could cover its current electricity needs with only 0.73 billion m^3 of gas, the pipeline needs to have a higher capacity to adapt to the island's growing energy needs.

40. It is a deep underwater gas pipeline, so the calculations are not the same as for onshore gas pipelines. For more details on modelling the prices of deep-sea gas pipelines, see A. Sémon, E. Mavrommatis, «EastMed or the bypass of Turkey. Statistical study», Nemrod-ECDS, 17/06/21, *https://nemrod-ecds.com/?p=5453*.

41. approximately $2.6/MMBTU

42. R. Ripple, « U.S. Natural Gas (LNG) Exports: Opportunities and Challenges ». IAEE Energy Forum Int. Assoc. Energy Econ., Third Quarter, 2016, pp. 23–27.
Ripple estimates the price of US LNG delivered at the Zeebrugge terminal in Belgium between $5.12 and $5.98/MMBTU based on prices at Henry Hub in the United States ($2.15/MMBTU) and for a transport cost ranging from $0.4 to $1.25/MMBTU, so the liquefaction cost can be roughly estimated at around $2.6/MMBTU.

The aim is to build a gas liquefaction terminal in Tripoli. Such a project would require at least an initial investment of between $1 billion and $2 billion[43]. This solution is by far the most expensive of all in terms of infrastructure, and it does not allow the surplus to gain compared to the previous solution except for the transport cost of gas to Egypt.

Summary tables

The following tables summarize for each scenario the possible routes for the export of gas, the associated transport cost and two estimates, low and high, of the related gas selling price. It should be recalled that the selling price of Lebanese gas just after extraction is between $3.75 and $5/MMBTU[44].

Scenario 1

Customer country	Route	Volume for sale (billion m^3 per year)	Transportation cost ($/MMBTU)	Gas selling price Low estimate ($/MMBTU)	Gas Selling Price High Estimate ($/MMBTU))	Dates of possibility of sale
Jordan	Tripoli – Homs – Rehab	Between 1 and 2	0,24	3,99	5,24	From 2025
Syria	Tripoli – Homs	Between 1 and 2	0,08	3,83	5,08	From 2025 to 2035

Scenario 2

Customer country	Route	Volume for sale (billion m^3 per year)	Transportation cost ($/MMBTU)	Gas selling price Low estimate ($/MMBTU)	Gas Selling Price High Estimate ($/MMBTU))	Dates of possibility of sale
Jordan	Tripoli – Homs – Rehab	Between 1 and 3	0,24	3,99	5,24	From 2025
Syria	Tripoli – Homs	Between 1 and 3	0,08	3,83	5,08	From 2025 to 2035

Scenario 3

Customer country	Route	Volume for sale (billion m^3 per year)	Transportation cost ($/MMBTU)	Gas selling price Low estimate ($/MMBTU)	Gas Selling Price High Estimate ($/MMBTU))	Dates of possibility of sale
Jordan	Tripoli – Homs – Rehab	Between 1 and 4	0,24	3,99	5,24	From 2025
Syria	Tripoli – Homs	Between 1 and 4	0,08	3,83	5,08	From 2025 to 2035

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43. As a mere indication, the Egyptian liquefaction terminal at Damietta was built in 2004 with the capacity to liquefy 7.5 billion m^3 of gas per year and had then cost 1.3 billion $(« SEGAS Liquefied Natural Gas Complex, Damietta », Hydrocarbon Technology, *https://www.hydrocarbons-technology.com/projects/seagas/)*.

44. See page 12 of this study.

Customer country	Route	Volume for sale (billion m^3 per year)	Transportation cost ($/MMBTU)	Gas selling price Low estimate ($/MMBTU)	Gas Selling Price High Estimate ($/MMBTU))	Dates of possibility of sale
Turkey	Tripoli – Homs – Aleppo – Kilis	Between 1 and 5	0,28	4,03	5,28	From 2025
EU	EastMed	Between 1 and 3	4	7,75	9	From 2025
EU	LNG via Egypt	Between 1 and 3	Between 3.5 and 4.35	7,25	9,35	From 2025
Cyprus	Tripoli – Vasilikos (presence of EastMed)	Between 0.5 and 1	0,88	4,63	5,88	From 2025
Cyprus	Tripoli – Vasilikos (absence of EastMed)	Between 0.5 and 1	1,21	4,96	6,21	From 2025

Scenario 4

Customer country	Route	Volume for sale (billion m^3 per year)	Transportation cost ($/MMBTU)	Gas selling price Low estimate ($/MMBTU)	Gas Selling Price High Estimate ($/MMBTU))	Dates of possibility of sale
Jordan	Tripoli – Homs – Rehab	Between 1 and 4	0,24	3,99	5,24	From 2025
Syria	Tripoli – Homs	Between 1 and 4	0,08	3,83	5,08	From 2025 to 2035
Turkey	Tripoli – Homs – Aleppo – Kilis	Between 1 and 5	0,28	4,03	5,28	From 2025
Egypt	Tripoli – Homs – Rehab – Aqaba – Arich	4 or 5	0,50	4,25	5,50	From the end of the 2030s
EU	EastMed	Between 1 and 3	4	7,75	9	From 2025
EU	LNG via Egypt	Between 1 and 3	Between 3.50 and 4.35	7,25	9,35	From 2025
EU	LNG from Tripoli	5	Between 3 and 3.85	6,75	8,85	From 2025
Cyprus	Tripoli – Vasilikos (presence of EastMed)	Between 0.5 and 1	0,88	4,63	5,88	From 2025
Cyprus	Tripoli – Vasilikos (absence of EastMed)	Between 0.5 and 1	1,21	4,96	6,21	From 2025

07

Appendices

Appendix A: Annual Maintenance Costs of an FPSO Unit

The work of Rini Nishanth, Andrew Whyte and John Kurian on 11 FPSO units provides us with the following information (Nishanth, Whyte, & Kurian, 2018):

FPSO Unit	Initial cost	Maintenance and operating cost	Annual charter	Maintenance Cost Rate + Charter on Initial Cost
HP	272 100 000	6 750 000	45 000 000	0,190187431
Months	7 195 000 000	7 837 500	59 418 700	0,00934763
CD	660 000 000	14 726 250	98 175 000	0,1710625
BT	800 000 000	7 700 000	49 500 000	0,0715
NV	1 391 000 000	63 454 545	423 030 300	0,349737487
GD	175 100 000	3 000 000	20 000 000	0,131353512
MV	624 000 000	52 700 000	351 333 333	0,647489316
SB	1 125 000 000	61 071 429	407 142 857	0,416190476
PV	3 359 000 000	63 333 333	422 222 222	0,144553604
OH	4 214 000 000	55 600 000	N/A	0,013194115
NH	5 234 000 000	2 806 000 000	N/A	0,53611005

Thus, the last column shows us the rate between the annual charter, maintenance, and operating costs on the initial cost of the FPSO unit. The median is 0.1710625 and the mean is 0.2437. For our study, we choose to propose two estimates for maintenance, operation, and charter costs: a low estimate at 15% of the initial cost and a high estimate at 25%.

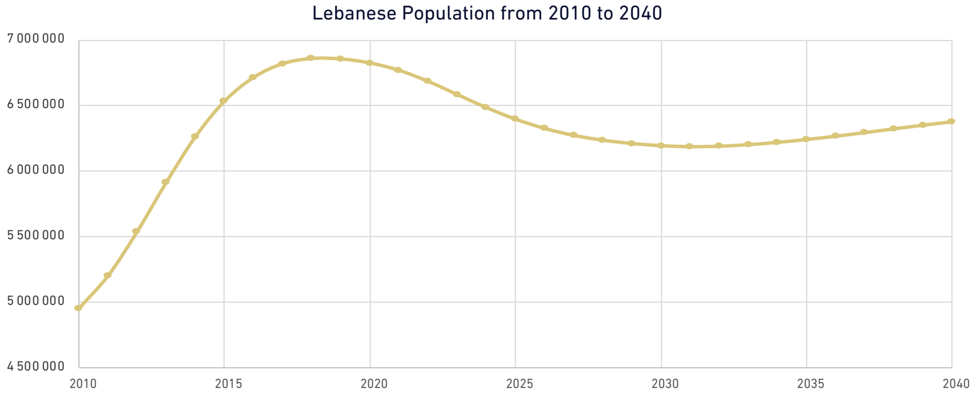
Appendix B: Annual Maintenance Costs of offshore Drilling

In Norway, between 2008 and 2020, data from (Investments and Operating costs, 2021) indicate that the maintenance costs of all wells represent between 6% and 13% of the total maintenance costs of hydrocarbon operations. The average of this data series is 10%. This is the figure that we will use for our estimates.

	2008	2009	2010	2011	2012	2013	2014
Total maintenance costs (billion NOK)	64,4	67,6	67,6	67,3	74,2	75,6	76,6
Well maintenance costs (billion NOK)	5,1	8	8,2	7,1	9,9	9,5	9,1
Ratio	0,07919	0,11834	0,12130	0,10549	0,13342	0,12566	0,11879

	2015	2016	2017	2018	2019	2020
Total maintenance costs (billion NOK)	69,1	60,6	58,8	61,2	62,4	57
Well maintenance costs (billion NOK)	8,2	4,4	4,8	5	3,8	4,7
Ratio	0,118668	0,072607	0,0816326	0,0816993	0,0608974	0,082456

Appendix C: Lebanese Population from 2010 to 2040[45]



Year	Lebanese Population	Year	Lebanese Population
2010	4 953 064	2025	6 397 245
2011	5 202 022	2026	6 326 656
2012	5 537 620	2027	6 273 635
2013	5 913 016	2028	6 236 666
2014	6 261 046	2029	6 211 494
2015	6 532 681	2030	6 194 842
2016	6 714 281	2031	6 187 331
2017	6 819 373	2032	6 190 354
2018	6 859 408	2033	6 202 039
2019	6 855 709	2034	6 219 813
2020	6 825 442	2035	6 241 509
2021	6 769 151	2036	6 266 368
2022	6 684 847	2037	6 293 899
2023	6 585 116	2038	6 322 508
2024	6 485 336	2039	6 350 453
		2040	6 376 397

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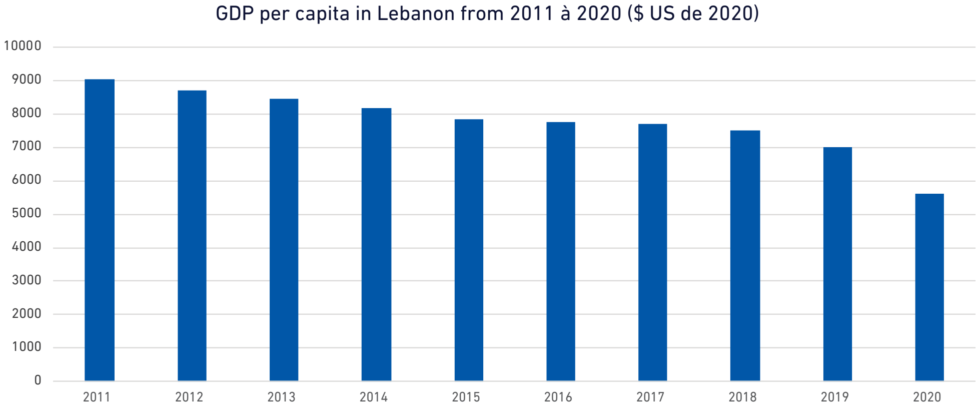
45. Here we take the estimates of the United Nations Department of Economic and Social Affairs for the period 2010-2020. As for the period 2020-2040, we take the projection made in 2019 by this same department with the projection variant «medium » (United Nations, Department of Economic and Social Affairs, Population Dynamics, World Population Prospects 2019, *https://population.un.org/wpp/Download/Standard/Population/)*.
There is a total of nine variants for the projection. The « medium » seems to us as the most pertinent for the Lebanese population (United Nations, Department of Economic and Social Affairs, Population Dynamics, World Population Prospects 2019, « Definition of projection variants », *https://population.un.org/wpp/DefinitionOfProjectionVariants/)*.
The population here includes indiscriminately all persons residing in Lebanon on a stable basis, whether or not they have citizenship or a residence permit. It includes all Syrian refugees in the territory currently estimated at 1.5 million people by the Lebanese government.

Appendix D: GDP per capita in Lebanon from 2011 to 2020[46]



Year	GDP per capita Lebanon ($2010)	GDP per capita Lebanon ($2020)	Growth (%)
2011	7 454	9 022	
2012	7 180	8 690	- 3,68
2013	6 981	8 449	- 2,77
2014	6 755	8 176	- 3,23
2015	6 488	7 852	- 3,96
2016	6 409	7 757	- 1,21
2017	6 364	7 702	- 0,71
2018	6 205	7 510	- 2,49
2019	5 792	7 010	- 6,66
2020	4 637	5 612	-19,94

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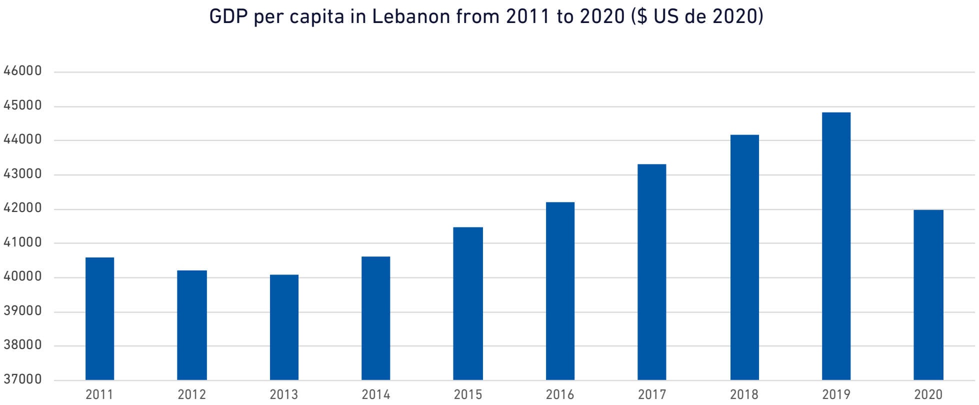
[46] World Bank, «GDP (2010 constant US$) – Lebanon», *https://donnees.banquemondiale.org/indicator/NY.GDP.MKTP.KD?locations=LB*.

Annex E: GDP per capita of the European Union from 2011 to 2020[47]



Year	GDP per capita in the EU ($2010)	GDP per capita in the EU ($2020)	Growth (%)
2011	33 536	40 589	
2012	33 233	40 222	-0,90
2013	33 135	40 103	-0,29
2014	33 570	40 630	1,31
2015	34 269	41 476	2,08
2016	34 881	42 216	1,79
2017	35 800	43 329	2,63
2018	36 496	44 171	1,94
2019	37 038	44 827	1,49
2020	34 689	41 984	-6,34

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[47] (World Bank, 2020)

08

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www.thecitizenfoundation.com
info@thecitizenfoundation.com