THE FUTURE OF OIL SUPPLY IN THE EUROPEAN UNION :

STATE OF RESERVES AND PRODUCTION PROSPECTS FOR MAJOR SUPPLIERS

SUMMARY

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Report from the *Shift Project*,
for the General Direction of International Relations and Strategy (DGRIS), French Ministry of the Army.

Editorial Committee

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The Shift Project

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The views expressed in this report are those of the authors and do not constitute an official position of the Ministry of the Army.

Summary

For lack of reserves large enough to make up for the current production decline, total oil supplies to the European Union are likely to drop by 10 to 20% over the 2030 decade, as compared to its current 2019 level. Assuming a high «light tight oil» (LTO) production in the United States would not eliminate such hazard.

Before an ultimate down surge predictable over the 2030s, total oil production from the main suppliers might remain relatively steady over the 2020s, at 4-10% below its 2019 level.

This report solely relies on the critical use of the database provided by Rystad Energy, a Norwegian company considered as a leading reference by the oil industry.

Our paper provides an assessment of oil production and reserves in sixteen countries that are the major providers for the European Union's (EU). None of these sixteen countries is an EU member. Most of the world's major producers belong to this group. EU member states import almost one-tenth of the global oil production, about as much as China.

The EU's crude oil imports, which had fairly diversified origins in the early 1990s, tend to rely increasingly on the 16 countries at stake. Their share of imports went up from 65% in 1990 to 95% in 2018. In descending order of importance, at that date: Russia, Iraq, Saudi Arabia, Norway, Kazakhstan, Nigeria, Libya, Azerbaijan, Iran, the United Kingdom, the United States, Mexico, Algeria, Angola, Kuwait and Egypt.

As far as current production is concerned (excluding US LTO), lby closely reviewing a sample of eighteen conventional oil fields, we came to the conclusion that Rystad Energy constantly underestimates several types of recurring operational risks, as well as of the amount of investment (CAPEX) and expenses (OPEX) necessary to maintain a steady production level. As a consequence, we are bound to **revise the volume of reserves initially suggested by Rystad Energy, by -10% for onshore and shallow offshore fields, and by -10 to -20% for deep offshore fields, depending on their degree of maturity**, regardless of the type and size of the fields and the producing country.

Concerning the reserves of undeveloped fields and prospective reserves of the sixteen countries under review (excluding LTO in the United States), the evaluation of the major explored fields and of the main basins identified leads us to a downward reappraisal of the reserves of two undeveloped fields located in the United Kingdom and in Iraq, and to confirm the estimate of the overall volume of prospective reserves proposed by Rystad Energy (with either upward or downward corrections, depending on each case).

A detailed analysis of the production and reservoir data concerning operating fields, as well as the conclusions regarding undeveloped and prospective reserves, **highlights two major trends affecting all of the EU's 16 main suppliers** (excluding LTO in the US).

- **The size of newly discovered and developed fields tends to decrease over time.** As a consequence, the number of fields in operation is increasing, steadily and sometimes sharply, in all countries reviewed.
- **The time lag between identification and development is increasing in all countries reviewed, without exception. This is due to the scarcity, over the last ten to thirty years, of significant new oil fields with a quality level or geographical location that would justify development within the timeframe previously in force in the industry.** In order to increase or even maintain national production, it becomes inevitable to develop some fields that were identified years ago, but whose development was postponed, due to their lower quality or higher operation costs (typically related to less advantageous reservoir conditions, or operational, societal or clerical issues).

Here is the current overall assessment of the oil situation for the sixteen main EU suppliers (excluding US LTO):

- **In all countries under review, the number of new fields identified has declined**, over a variable period of time;
- **14 countries display a decline or a production level inferior** to the maximum observed in the past;
- **the overall depletion rate of total cumulative oil field discoveries to date for the 16 countries is close to 70%.**

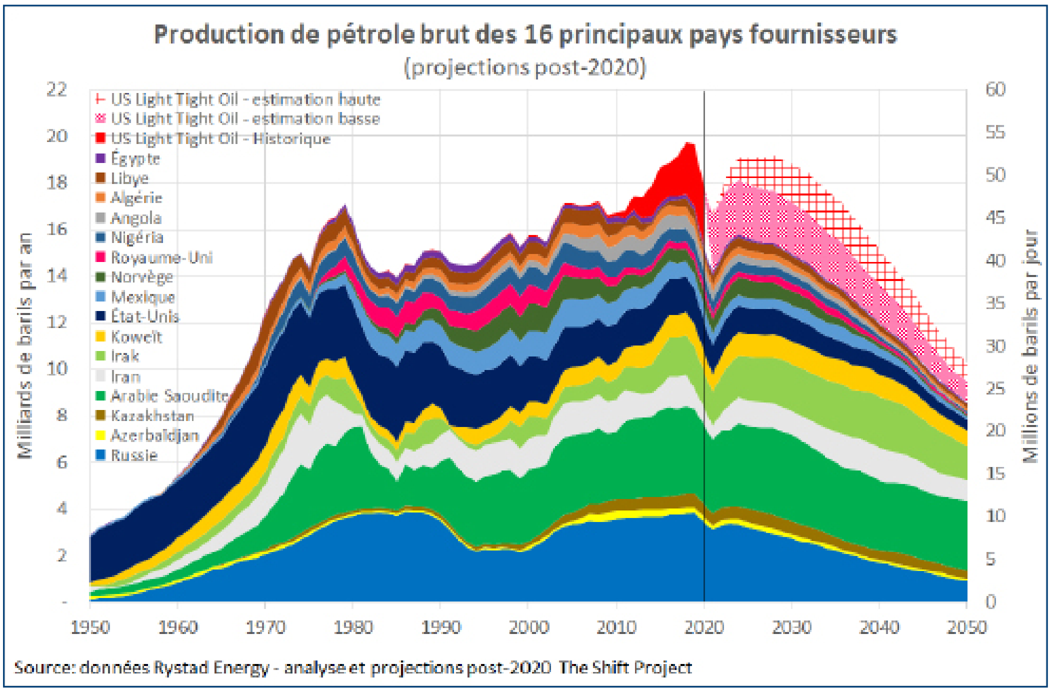
The aggregate crude oil production outlook for the sixteen major supplying countries, excluding US LTO, suggests:

- **a decline of approximately 12% in 2030, as compared to its 2019 level,**
- **a potentially sharper decline before 2030**, assuming that the operational and economic requirements for the development of ever-smaller fields, prove to be more stringent than estimated and selected for the purpose of this report's assessment.

From the 2030s onwards, no development potential (fields already identified or exploration potential) appears to be sufficient to reverse the predictable future decline in aggregate crude oil production, excluding US LTO, which will likely be irreversible.

Regarding LTO resources in the United States, institutional sources (International Energy Agency, Organization of Petroleum Exporting Countries, and Energy Information Administration of the USA) currently suggest a steady median production trend, and then a downward trend during the 2030s.

Considering the main uncertainty factors, two assumptions were selected: high and low estimates, both reflecting a lower potential growth rate than in the 2010 decade, followed by an expected decline in the 2030s.



The potential supply from new and emerging producer countries is not addressed in this report.

Over the 2005-2018 period, while the aggregate crude oil production of the 16 main EU suppliers (including US LTO production) increased by about 15%, total oil supplies to the EU and France declined by 17% and 20% respectively.

This contraction in European oil demand results from the replacement of oil by other energy sources (currently mainly electricity and gas in the industrial and residential sectors), as well as the downsizing and relocation of energy-intensive industrial activities. This trend occurs simultaneously with the emergence of new large consumer countries on the global oil market. **China, India and other countries with strong growth potential are competing for crude oil supplies with developed countries whose demand for crude oil remains massive.** Moreover, the increase in domestic consumption in many exporting countries is gradually eroding their export capacity, thus exacerbating the risk of a squeeze on net importing countries.

As a first approximation, the amount of oil supplies to the EU and France will be determined, as a trend and gradually, by the reserve levels and the availability of the resource in supplier countries. If, as is most likely, the oil consumption of non-EU countries keeps growing, the stability (at best) followed by the decline (by the 2030s at the latest) in the total production of the EU's current 16 main supplier countries is likely to limit the supply available on the world market to meet European demand. **This cut in the EU's share of the global market will amount to an unintentional constraint, should its pace be faster than the impact of EU-wide initiatives to reduce oil consumption.**

A closer look reveals that the supply volumes for the EU and specifically for France will depend on a range of factors that have potentially more impact in the short and medium term than the mere decline of available resources: adequacy between the quality of crude exported by supplier countries and the characteristics of the refining infrastructure of importing countries; availability of long-distance transport infrastructure (pipelines); geographical proximity and optimization of transport costs; creation and strengthening of bilateral international relations, in recognition of shared geostrategic interests, one of the objectives of which would be the securing of flows by mutual agreement between importing and exporting countries, disregarding the market mechanisms for resource allocation.

Methodology of the study

The expected production profile for each of the 16 main crude oil suppliers to the EU27 was designed by aggregating each of the following data, assessed separately:

- Fields in production and fields under development as of 2020
- Fields discovered but not developed as of 2020
- Prospective resources (undiscovered) as of 2020

The methodology is based on:

- Data retrieved from Rystad Energy's Ucube database
- Case studies of economic and production data provided by the Ucube database
- Analysis and critical re-assessment of the potential of undeveloped fields ("Discovered Resources Opportunities") and future discoveries ("Yet-to-find") as mentioned in the Ucube database

I. Underlying price scenarios of the Ucube database and consequences of the covid-19 crisis

The Ucube database integrates physical and economic quantities for both the retrospective and prospective parts:

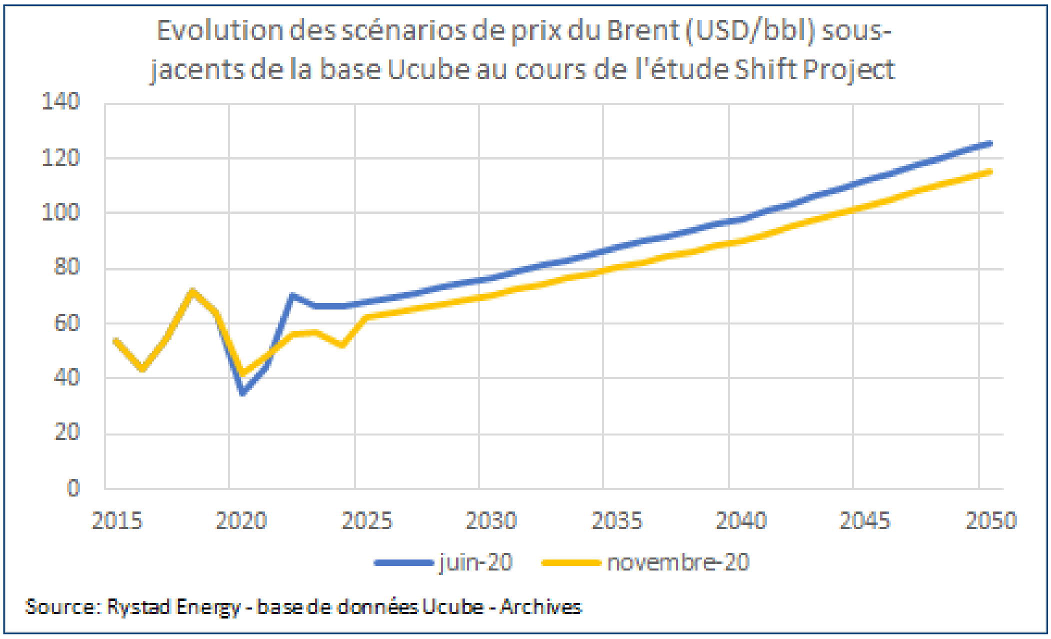
- the retrospective part is based on information collected or, when such data are missing, on the modelling of CAPEX, OPEX, revenues and the resulting cash flows based on actual oil and gas prices;
- the prospective part is based solely on modelling capital expenditure (CAPEX), operating expenditure (OPEX), revenues and cash flows, for which the key element is the expected evolution of oil and gas prices.

The Shift Project research was conducted from June to November 2020. During this period, the underlying oil price scenario, which is closely linked with the evolution of global demand, determines the estimates of reserves, production, CAPEX, OPEX and cash flows; it has been revised by Rystad Energy, in particular over the period 2020-2025 (see graph below).

Such revisions reflect the exceptionally high level of uncertainty in the global oil market situation, due to the unprecedented imbalance caused by the contraction in global consumption following the covid-19 pandemic.

The spread of oil price levels predicted by most analysts over the next 2 to 5 years is extremely wide: as a first approximation, the gap between expected and actual prices will result in an adjustment of the same order of magnitude for revenues and CAPEX. However, price uncertainty is an issue inherent to the oil market; the oil industry has gone through multiple phases, lasting from several quarters to several years, alternating periods of oversupply with low prices, and periods of undersupply with high prices. In this respect, while brutal in its swiftness of onset, the current crisis is in no way exceptional in its magnitude, as measured in terms of price.

Given the cyclical nature of the oil market, we consider the underlying Ucube oil price scenario to be consistent, with only a very limited downward revision over the period 2025-2050 being made between June and November 2020. By extension, we consider that the data and methodology of Rystad Energy's Ucube database remain valid for the analysis of the trend production outlook of the 16 main EU27 crude oil suppliers.



II. Use of Rystad Energy's Ucube database: assets and limitations

The Ucube database is the main source of information for this paper. It provides a comprehensive list of hydrocarbon fields for each country. Out of all the data available from that source, our report scrutinized the following:

- Field status: in production, under development, discovered but not developed, abandoned, speculative discovery (this item is based exclusively on Rystad Energy's proprietary modelling)
- Reserves (2P) classified by hydrocarbon type (crude oil, condensate, natural gas liquids, natural gas)
- Type of reservoir: conventional, tight reservoir/source rock (LTO)
- Location, onshore vs. offshore (with water depth)
- Capital expenditure (CAPEX) subdivided into surface infrastructure and well drilling
- Operating expenses (OPEX) subdivided into production costs, transport costs, overhead expenses and abandonment/dismantling costs
- Type of surface infrastructure/technology

The Ucube database provides a comprehensive historical record of operations for each field on a yearly basis, comparing economic data with production. Depending on the first oil date of the field and the date of publication of the database, the record includes both retrospective and prospective data.

Retrospective data are based on various sources, either public or private, depending on what information is available. Should no source of information be available, then Rystad Energy computes an estimate value. Prospective data are built on Rystad Energy's proprietary model, which involves a simulation of the main features of oil industry: price-driven cash flows (international crude oil price, regional gas price), worldwide allocation of capital based on technical production costs, each host country's specific tax policy, and the potential for discoveries up against new exploration expenditures.

As a result, Rystad Energy's Ucube database is a resource that does not provide a static snapshot but a dynamic and comprehensive description of the global hydrocarbon industry, updated monthly and based, for the prospective part, on a key variable: observations and scenarios pertaining to hydrocarbon prices on wholesale markets.

The following data are missing from The Rystad Energy Ucube database

- Type of reservoir rock (sandstone, carbonate, etc.)
- Depth of the reservoir
- Oil quality as measured by density and viscosity
- Number and unit cost for each drilled well (production, injection or exploration wells)
- CAPEX breakdown of drilled wells between production and injection wells
- Volume and historical record of hydrocarbon-related water production
- Volume and historical record of water injection into the reservoir
- Volume and historical record of gas injection into the reservoir (with some rare exceptions)
- Volume and historical record of flared gas (with some rare exceptions)

III. Case studies of economic and production data from the Ucube database

The Shift Project report complements the use of Rystad Energy's Ucube database by analysing the coherence of economic (investments and expenditures) and geo-physical (reserve and production volumes) data. Eighteen case studies were conducted, using a proprietary techno-economic model developed by our associate expert, Alain Lehner. The fields were selected based on the following criteria: volume of the reserves as initially estimated by Rystad Energy (by extension, their weight in the EU27 supplies), quality of data (especially volumes of gas injected and flared), and capacity for the research team to gain access to confidential information from the industry, in order to complete, confirm or dismiss, as the case may be, the data provided by the Ucube database.

Summary of case studies					
Fields	**Country**	**Location**	**2P Crude Oil Reserves Estimate by Rystad Energy (Mb) ***	**First oil**	**Comments**
Nahr bin Umar	Iraq	Onshore	3,742	1998	Uncertainty concerning flared gas
Minagish	Kuwait	Onshore	7,863	1961	Uncertainty about gas production and injection Significant overestimation of reserves post 2035
Majnoon	Iraq	Onshore	13,049	2002	Uncertainty about gas production and injection
Kaombo South	Angola	Ultradeep offshore	430	2019	Risks to end-of-life reserves, as submarine wells are difficult to monitor
Kashagan	Kazakhstan	Shallow offshore	13,058	2016	Underestimation of CAPEX for water production and treatment and for the treatment of associated H2S gas Overestimation of reserves
Ekofisk	Norway	Shallow offshore	4,039	1971	Underestimation of CAPEX for production and injection wells Risk of production stoppage on some platforms for safety reasons due to subsidence (platforms descending below the acceptable level for 100-year waves)

Egina	Nigeria	Ultra deep offshore	737	2018	Underestimation of CAPEX and overestimation of reserves: - subsea wells that are difficult to monitor (difficult reservoir management and loss of reserves with the first water inflows into the wells) - very high costs for underwater interventions
Ratawi	Iraq	Onshore	2,902	2010	Overestimation of reserves mainly due to excessive liquid production
Burgan	Kuwait	Onshore	60,476	1946	Underestimation of CAPEX for injection wells Overestimation of reserves
Azadegan	Iran	Onshore	6,096	2008	Underestimation of CAPEX for production wells and water treatment Uncertainty about gas processing Overestimation of reserves
Dalia	Angola	Deep offshore	1,381	2006	Underestimation of CAPEX and overestimation of reserves: - subsea wells that are difficult to monitor (difficult reservoir management and loss of reserves with the first water inflows into the wells); - very high costs for underwater interventions
ACG	Azerbaijan	Deep offshore	6,977	1997	Underestimation of CAPEX Overestimation of reserves
Ab-E-Teimur	Iran	Onshore	1,502	1991	Overestimation of reserves
Doroud	Iran	Shallow offshore	3,525	1964	Uncertainty related to flared gas Underestimation of CAPEX Overestimation of reserves
Yadavaran	Iran	Onshore	5,512	2012	Underestimation of CAPEX for injection wells and water treatment
Usan	Nigeria	Deep offshore	716	2012	Underestimation of actual technical problems Underestimation of CAPEX and overestimation of reserves: - subsea wells that are difficult to monitor (difficult reservoir management and loss of reserves with the first water inflows into the wells) - very high costs for underwater interventions
Umm Gudair	Kuwait	Onshore	5,281	1964	Underestimation of CAPEX for injection wells and water treatment Overestimation of reserves
Zuluf	Saudi Arabia	Shallow offshore	34,234	1971	Underestimation of CAPEX for injection wells, water treatment, and surface infrastructure Overestimation of reserves

* Data extracted in June 2020.

The assessments conducted for the 18 case studies support the general conclusion that CAPEX and OPEX data for water treatment, surface infrastructure, hydrogen sulphide (H2S) treatment or other technical issues happen to be underestimated in the Ucube database. By extension, the modelling of profiles that foresee the sustainability of operations over an extended period of time, with low levels of residual output at the end of the cycle, is questionable. These production volumes would seem to be inadequate and below the break-even point ("cut-off ") imposed by fixed operating costs, unless high price per barrel would make such undertaking sustainable. Within the scope of the cases reviewed the underestimation of costs also results from imperfect information concerning actual operational issues, which a database, no matter how well documented, is unable to grasp.

Moreover, the reserves for deep and ultra-deep offshore fields seem to be systematically overestimated in the view of these operating conditions. The development of these fields relies on Floating Production Storage and Offloading (FPSO) infrastructure with limited liquid and gas processing capacity. Besides, in the event of water or gas inflows in subsea wells, the origin of the problem is very hard to identify, since all wells are connected to the same production line and monitoring is difficult and costly. Whenever the water or gas inflow is significant, there is no other option but to cut the production, as the FPSO infrastructure has limited liquid and gas processing capacities. Optimising field recovery under these conditions becomes virtually impossible, leading to production losses at the end of the fields' life.

The quasi-systematic underestimation of CAPEX and OPEX and of operational risks, within the range of the selected cases, lead the author to apply two corrective factors to the post-2020 production projections:

- **10-20% reduction (increasing over time), applicable to all offshore fields with a water depth greater than 300 metres**, regardless of any other criteria;
- **10% reduction, applicable to all other fields** (*(onshore and offshore with a water depth less than 300 metres), regardless of any other criteria*

These adjustment factors are estimated based on historical data and estimates associated with the underlying oil price scenario as defined by Rystad Energy between June and November 2020. These corrective factors stem from structural factors and methodological choices, and are independent from the underlying oil price scenario.

IV. Analysis and re-assessment of the potential of undeveloped and yet to be discovered fields (future discoveries or "Yet To Find") in the Ucube database for the 16 EU27 supplier countries

Considering the natural decline of producing fields, the potential of any producing country over a 30-year horizon relies largely on undeveloped fields and the development of future discoveries.

For all 16 countries selected, we review:

- **the major undeveloped fields,** with reserves (2P) estimated by Rystad Energy in excess of 1 billion barrels of crude.
- **the prospective reserves** in the main basins, accounting for about 75 billion barrels out of the total of about 160 billion barrels of undiscovered (or yet to discover) reserves as estimated by Rystad Energy in the Ucube database and which could possibly be developed before 2050.

This expertise is based on a large body of public and confidential information as well as on the high-level professional experience of the research team.

In the undeveloped fields, two corrections were made to the Ucube database, concerning first the "Greater Lancaster" offshore fields in the United Kingdom, as a result of the downward re-estimation of the production potential, and second, the "Baghdad East" field in Iraq, whose development is considered very unlikely due to material constraints (operation incompatible with the demographic density of a neighbouring urban area).

Country	Fields	Estimated 2P reserves - source: Rystad Energy * (Mb)	Independent estimate by TSP project team
United Kingdom	Lancaster and Halifax (Greater Lancaster Area)	1,124	103
Iraq	Baghdad East	7,505	0

Country	Plays	Estimated reserves 2P Rystad Energy * (Gb)	Independent estimate bu TSP project team (Gb)
Iraq	Widyan Onshore	1.1	5.0
	Zagros Foldbelt Onshore	0.8	4.8
	Western Arabian Onshore	1.2	0.2
	Central Arabian Onshore	5.1	1.6
Kuwait	Central Arabian Onshore	7.1	1.7
Saudi Arabia	Central Arabian Offshore	13.8	1.7
	Central Arabian Onshore	8.5	6.0
	Rub al Khali Onshore	0.7	1.0
Russia	North Kara Sea Offshore	1.3	1.8
	Southern Barents Offshore	0	1.1
	Timan Pechora Basin Offshore	3.9	1.7
	Timan Pechora Basin Onshore	0.5	1.5
	Volga - Urals Onshore	0.2	1.3
	West Siberia Offshore	2.5	1.3
	West Siberia Onshore	0,5	1,5
	Bazhenov Shale	10,6	10,6
Norway	Bjarmeland Offshore	1.2	0.5
	Viking Graben Offshore	1.2	0.7
Nigeria	Benue Trough Onshore	0.1	0.3
	Niger delta Offshore	1.0	2.9
	Niger delta Onshore	0.3	1.5
	Niger Fan Ultradeep Offshore	0.2	2.0
Mexico	Gulf Deepwater Offshore	4.5	9.5
	Sureste Basin Offshore	0.8	0.6
	Sureste Onshore	1.3	2.4
	Tihonian La Casita	1.2	0.6
	Yucatan Platform Offshore	2.1	0.6
Libya	Sirte Basin Onshore	0.0	0.5
	Sirte Basin Offshore	0.0	1.0
	Sirte Shale	3.2	1.6
Kazakhstan	Precaspian Basin Offshore	0.3	0.7
	East Aral Slope Onshore	0.4	0.5
	Precaspian Basin Onshore	0.2	0.6
	Carboniferous Shale	3.2	2.3
Iran	Central Arabian Offshore	4.3	1.7
	Rub al Khali Offshore	0.3	0.6
	South Caspian Basin Offshore	0.5	1.1
	Zagros Foldbelt Onshore	1.2	9.7
Angola	Congo Fan Ultradeep Offshore	0.4	1.8

* Data extracted in June 2020.

Our research team's independent assessment of the selected main oil basins concludes that the overall volume of prospective undiscovered crude oil reserves in the top 16 EU27 supplier countries, as estimated by Rystad Energy, is in the order of 75 billion barrels.

However, the re-assessments basin by basin lead to corrections for each country that can be either positive (Iran +6.8 Gb, Nigeria +5.1 Gb, Iraq +4.5 Gb, Mexico +3.8 Gb, Angola +1.4 Gb, Russia +1.3 Gb) or negative (Saudi Arabia -14.3 Gb, Kuwait -5.4 Gb, Norway -1.2 Gb). The table above provides details of the re-assessments by country and by basin.

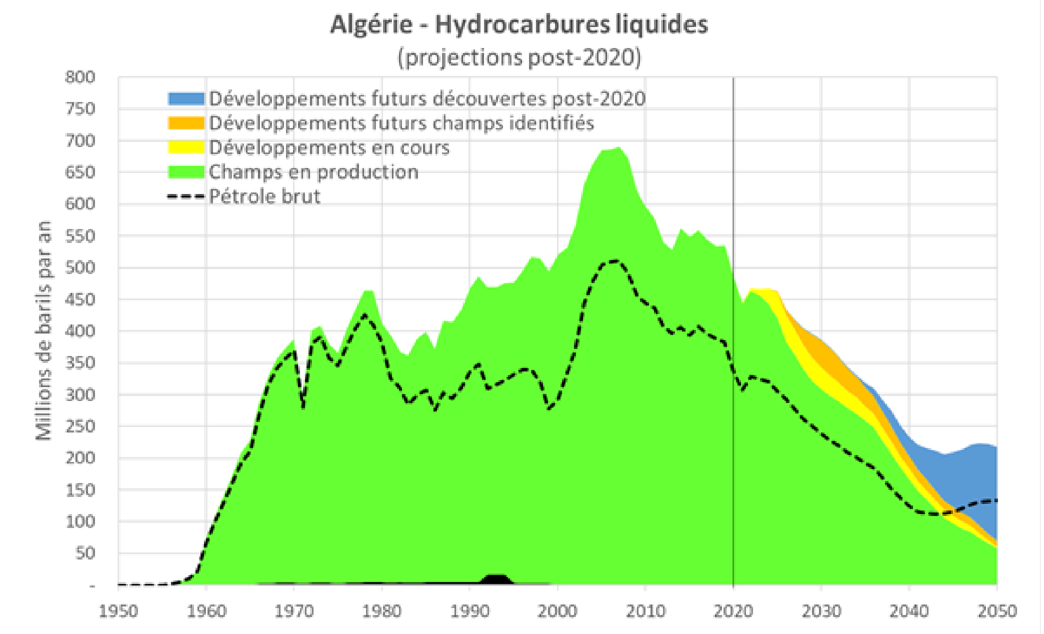
Algeria

Oil was discovered in Algeria in the 1950s, when the country was still under French rule. After the country's independence in 1962 and until the nationalisation of Algerian oil in 1971, the extraction was entrusted to a joint body, the Organisme Saharien, to ensure that the rights of French companies in the country were respected. Since 1971, the Algerian national company, Sonatrach, held the monopoly on oil extraction and exploration in the country.

To date, the crude oil produced in Algeria is from onshore fields. **Production has declined by 25% since 2007**, when it reached 510 million barrels (1.4 Mb/d). **Cumulative discoveries have increased marginally since 2000** dby 1.2 billion barrels (+4.5%) despite a period of high oil prices. The size of the fields coming online is decreasing steadily; besides, **it is estimated that two-thirds of the remaining reserves have a very high break-even point**, above $100 per barrel.

A major share of the 2020 production is provided by fields that were discovered before 2000 and is expected to decline by almost 50% in 2030 and by 92% in 2050.

As a result of the high depletion rate of reserves (79%) and poor prospects for renewal, **Algeria's crude oil production is expected to keep declining** at a rate comparable to the pace observed since the 2007 peak, to 38% below its 2019 level (0.7 Mb/d) in 2030, and 65% below in 2050 (0.4 Mb/d).



Source: données Rystad Energy - analyse et projections post-2020 The Shift Project

Angola

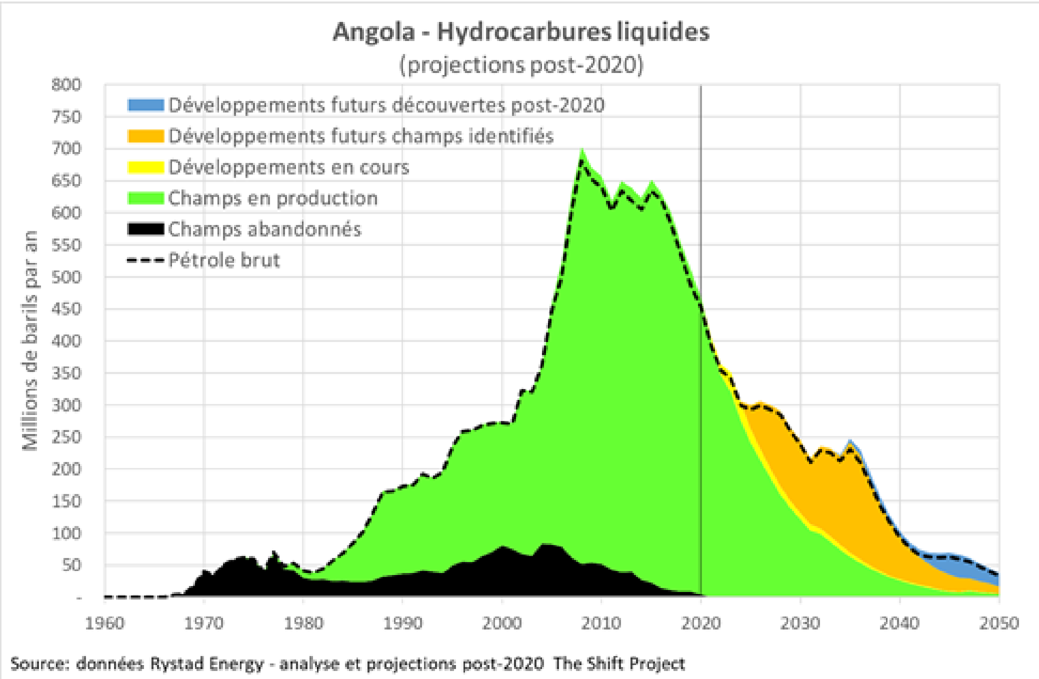
Most of Angola's oil resources are offshore. Production was hardly affected by the civil war between 1975 and 2002. Once the war was over, exploration and production grew rapidly, under in more technically complex areas (deep and ultra-deep offshore).

Since 2006, all new oil discoveries in Angola were offshore, yielding only a modest volume (4 billion barrels discovered over this period) despite annual exploration expenditure constantly exceeding $1 billion from 2006 to 2015. The average size of newly discovered fields has been declining: since 2010, no new field has exceeded 100 million barrels.

Angola's crude oil production has declined sharply since 2008 (-26%). In 2019, it amounts to almost 510 million barrels (1.4 mb/d). Volumes from fields that are in production by 2020 are expected to decline by 75% by 2030 becoming marginal by 2050.

Reserves have been declining since 2005, and currently stand at 5 billion barrels, an equivalent of 12 years of production at 2019 rates. For more than **half of these reserves the estimated break-even point exceeds $40**, whereas for two-thirds of current production the estimated break-even point is less than $40.

Angola's crude oil production is expected to decline to 0.7 Mb/d by 2030, almost 50% below its 2019 level. Despite an anticipated production plateau over the 2030-2035 period, production is expected to further its decline, due to modest potential for new discoveries. **By 2050, Angola's production is expected to lag, at 0.1 Mb/d.**



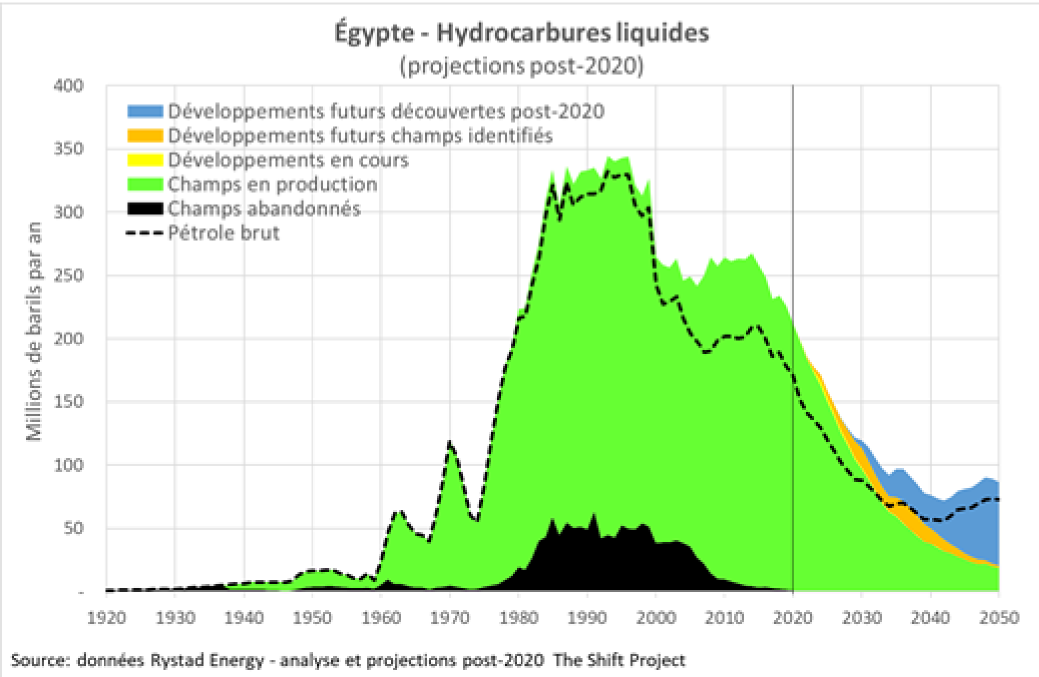
Egypt

An oil producer since the 1920s, Egypt became a net importer of petroleum products in 2010 as a result of increasing domestic consumption and declining domestic production. Nevertheless, Egypt remains a net exporter of crude oil, particularly to Europe, because its oil has desirable characteristics (high API and low sulphur content). Via the Suez Canal, Egypt is also a key player in the world of oil transport. Thus, in 2016, the total transit volume through the canal and the SUMED pipeline reached 5.5 million barrels of crude oil and oil products per day, corresponding to 9% of global traffic at the time.

Egypt reached its peak in offshore crude oil discoveries in 1965. However, since 2000, over 80% of newly discovered oil was located onshore. **Crude oil production has been declining since 1996**, despite a steady increase in the number of fields in operation, up to 250 fields by 2019. **Volumes from fields in production as of 2020 are expected to decline by nearly 60% in 2030 and by more than 90% in 2050.**

The decline in reserves is expected to continue. Since 1982, oil extraction in Egypt ceased to be offset by new discoveries. These amount to 2 billion barrels, or 15% of cumulative discoveries in 2020. The potential for new discoveries, estimated at 2 billion barrels of crude oil, is not expected to reverse this trend. The decreasing size of the fields coming online should contribute to the growing production cost in the coming years.

By 2030, Egyptian crude oil production is expected to fall by half as compared to its 2019 production level, from 0.5 Mb/d to 0.25 Mb/d. Over the 2019-2050 period, the production is expected to decline by around 60%, corresponding to a volume of ca. 0.2 Mb/d.



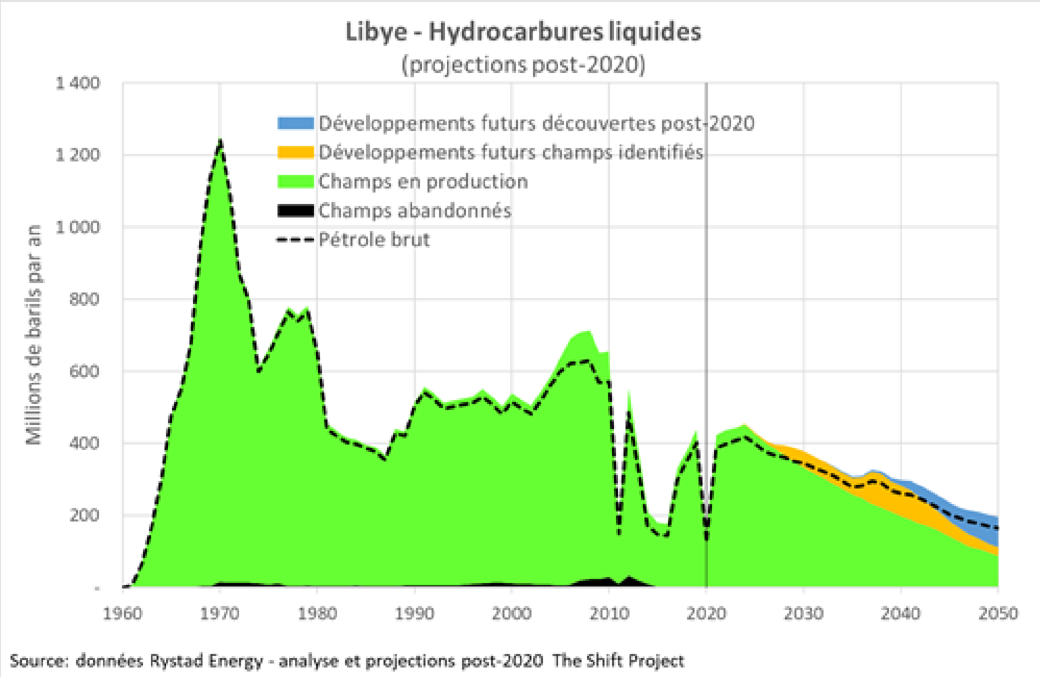
Libya

Libya became independent in 1951 as a federal kingdom. In 1969, a military coup overthrew the government and Colonel Muammar Gaddafi came to power. In 2011, a civil war broke out, leading to Gaddafi's death. Since then, two authorities claim to govern Libya: the UN-recognised recognised Government of National Unity, based in Tripoli, and the Tobruk House of Representatives, led by Marshal Haftar. The Tobruk authority controls most of Libya's oil production. Since the 1960s, Libya has been a major energy supplier to Europe.

In 2019, production was down 30% from 2010, mainly due to the outbreak of a second civil war. A major share of Libyan oil is extracted from onshore fields. **Crude oil new discoveries in Libya are rare, despite significant exploration investment over the past decade.** New discoveries have increased by only 5 billion barrels since 1985, while total production over this period was 15 billion barrels.

The size of newly discovered and developed fields is decreasing. In the future, Libya will be compelled to develop fields with a higher projected break-even point: while a third of the remaining reserves have a breakeven point exceeding $60 per barrel, only 7% of the current production displays a comparable break-even point.

With no new field developments, current or expected, and despite a relatively slow decline in current producing fields, Libyan crude oil production over the 2019-2030 period could shrink from 1.1 mb/d to 1 Mb/d, below the pre-civil war production level of 1.6 Mb/d in 2010. **1.1 mb/d to 1 Mb/d, below the pre-civil war production level of 1.6 Mb/d in 2010. Over the entire 2019-2050 period, Libyan production is expected to decline by almost 60% to** 0.4 Mb/d.



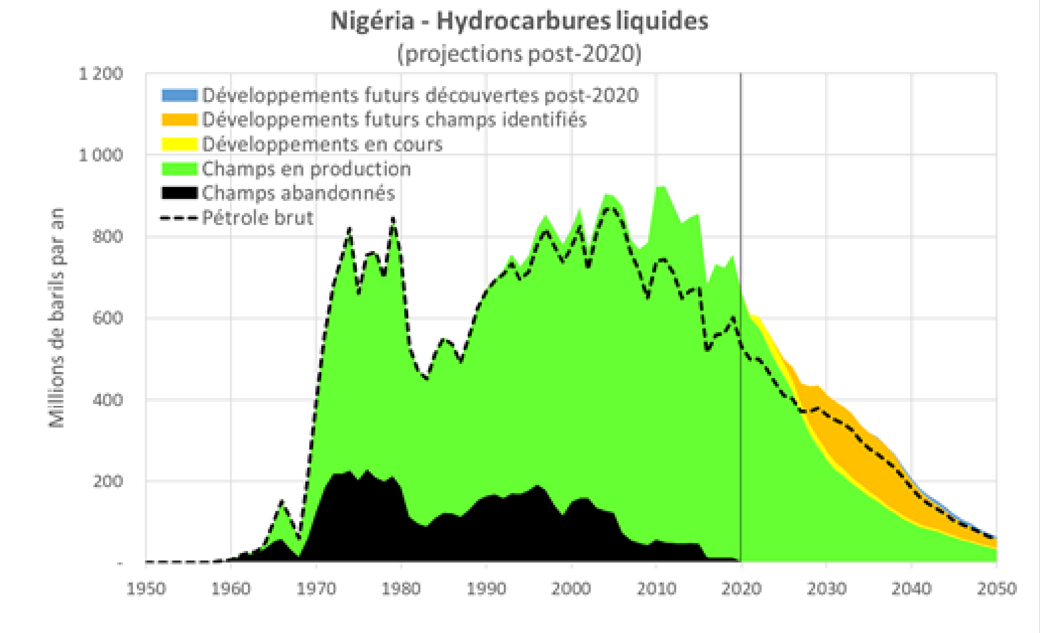
Nigeria

The Federal Republic of Nigeria gained its independence from the United Kingdom in 1960. In 2019, Nigeria was the leading African producer of liquid hydrocarbons, ahead of Angola and Algeria. Nigeria is also the continent's largest economic power, with a higher GDP than South Africa's and Egypt's. All country's oil resources are located in the Niger Delta and along the coast of the Gulf of Guinea. Nigeria exports most of its crude oil. However, due to inadequate investments in its refining industry, the country is compelled to import large amounts of refined oil products. A refinery with a processing capacity of 650,000 barrels/day is in construction by Dangote Group, backed by the Nigerian government, in an effort to make the country self-sufficient in refined products.

Crude oil production in Nigeria has shrunk by 30% since 2005, when it reached 870 million barrels (2.4 Mb/d). The volume of new discoveries has been modest since 2005: 1 billion barrels were added, for a total of 44 billion barrels despite fairly high investments in exploration. **The size of fields brought on stream is declining while the time lag between discovery and production is increasing.**

Volumes from fields currently in production are expected to drop by 65% in 2030 and 95% in 2050, as deep offshore fields account for a significant share of the production. **Nigerian crude oil production is expected to further its downward trend of that started in 2005. This decline is expected to amount to ca. 40% from 2019 to 2030**, dropping from 1.6 Mb/d to 1 Mb/d. By 2050, the estimated production should reach approximately 0.2 Mb/d, i.e. a 90% decline as compared to 2019.

Considering that for 65% of the remaining reserves the estimated break-even point exceeds $40 per barrel, as compared to only 20% of current production, **production costs are expected to increase over the coming years.**



Source: données Rystad Energy - analyse et projections post-2020 The Shift Project

United States of America

The United States of America is the leading oil superpower of all times. The start of modern oil exploration is thought by many authors to date back to 1859, when Edwin Drake drilled the first oil well in Pennsylvania. The Second World War triggered a major boom in the industry, and by 1950 the United States was producing more than half of the world's oil.

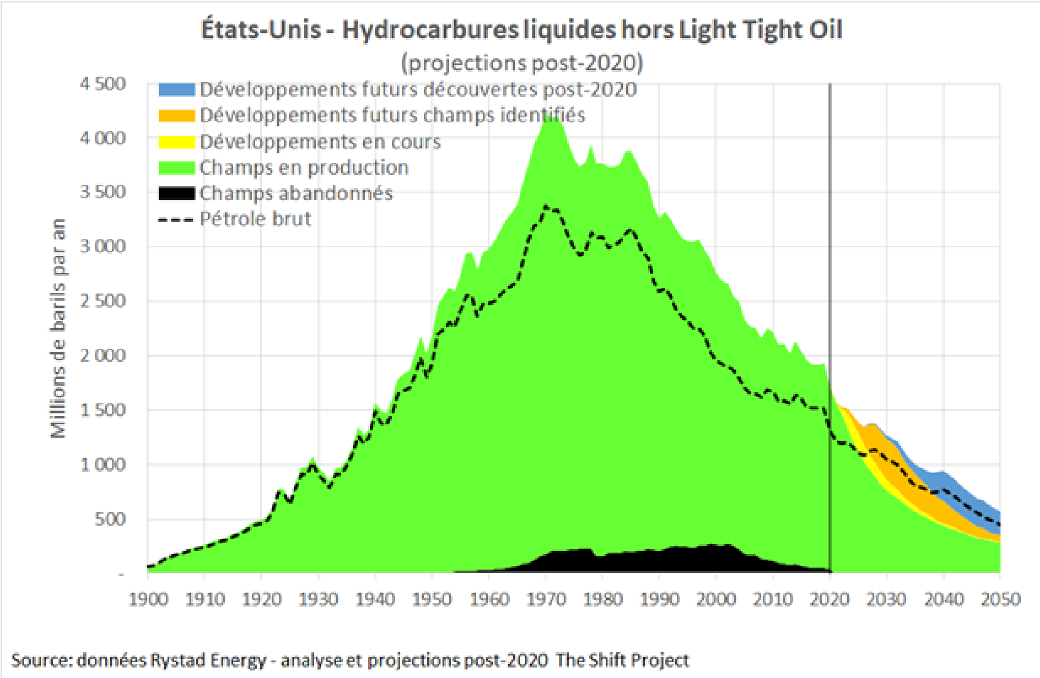
However, since 1970, the country has suffered a significant drop of its conventional crude oil production, along with a fall in reserves, by 72%. The pool of conventional fields in production, excluding Light Tight Oil (LTO), as of 2020, is expected to decline by 63% by 2030 and almost 90% by 2050. Since 2000, new discoveries of conventional crude oil have reached 17 billion barrels, while extractions have totalled 28 billion barrels over the same period.

The reserves of discovered yet undeveloped conventional fields and the potential reserves of conventional fields yet to be discovered by 2050, estimated at a total of about 63 billion barrels, are too limited to make up for the decline of current conventional production. Between 2019 and 2030, conventional crude oil production in the US is expected to decline by 34% from 4.2 Mb/d to 2.9 Mb/d and 1.2 Mb/d by 2050.

Since the 2000s, the United States also went through a boom in non-conventional liquid hydrocarbons production, "Light Tight Oil" (LTO). **Since 2014, this source has accounted for more than half of total US liquid hydrocarbon production.**

Three types of issues threaten the future of US LTO production. Firstly, there is no consensus among experts (including government agencies and international organisations) over the potential of technically recoverable resources. Secondly, so far, the LTO boom was supported by unconventional monetary policies that have allowed capital to flow in and fund the permanently negative cash flows. Future decisions by the FED and the evolution of oil prices are intrinsically hard to predict and remain outside the scope of this report. Third and finally, the LTO industry in the US operates in a regulatory framework that will likely change at both federal and local levels. Considering these remarks, here is our estimate concerning the trend for light oil production in the US (crude oil and all liquid hydrocarbons, crude oil, condensate, natural gas liquids):

- A lower scenario in line with the production decline observed in 2020 as a result of the covid-19 health crisis. In this case, production should decline gradually and steadily to a point estimated at one third of its 2019 production level by 2050.
- A higher scenario in line with the production increase observed until 2019. In this case, production should peak in the early 2030s at about 50% above the 2019 level, followed by a decline to about two-thirds of its 2019 level by 2050.


États-Unis - Hydrocarbures liquides hors Light Tight Oil
(projections post-2020)
Développements futurs découvertes post-2020
Développements futurs champs identifiés
Développements en cours
Champs en production
Champs abandonnés
Pétrole brut
Millions de barils par an
4 500
4 000
3 500
3 000
2 500
2 000
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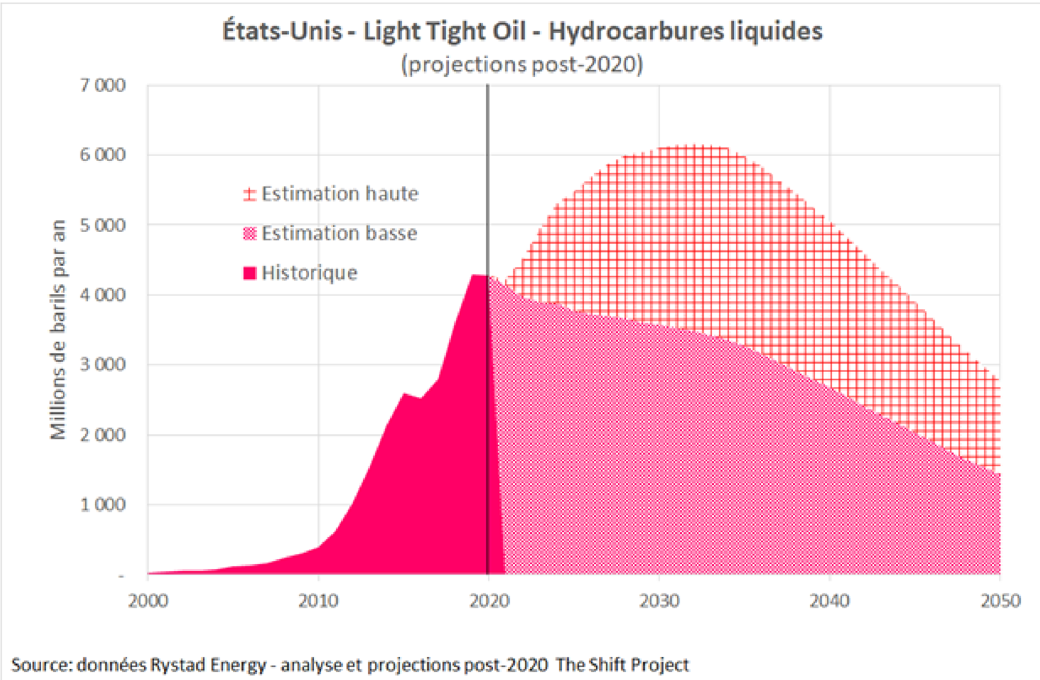
-
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050
Source: données Rystad Energy - analyse et projections post-2020 The Shift Project


États-Unis - Light Tight Oil - Hydrocarbures liquides
(projections post-2020)
Estimation haute
Estimation basse
Historique
Millions de barils par an
7 000
6 000
5 000
4 000
3 000
2 000
1 000
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2000 2010 2020 2030 2040 2050
Source: données Rystad Energy - analyse et projections post-2020 The Shift Project

Mexico

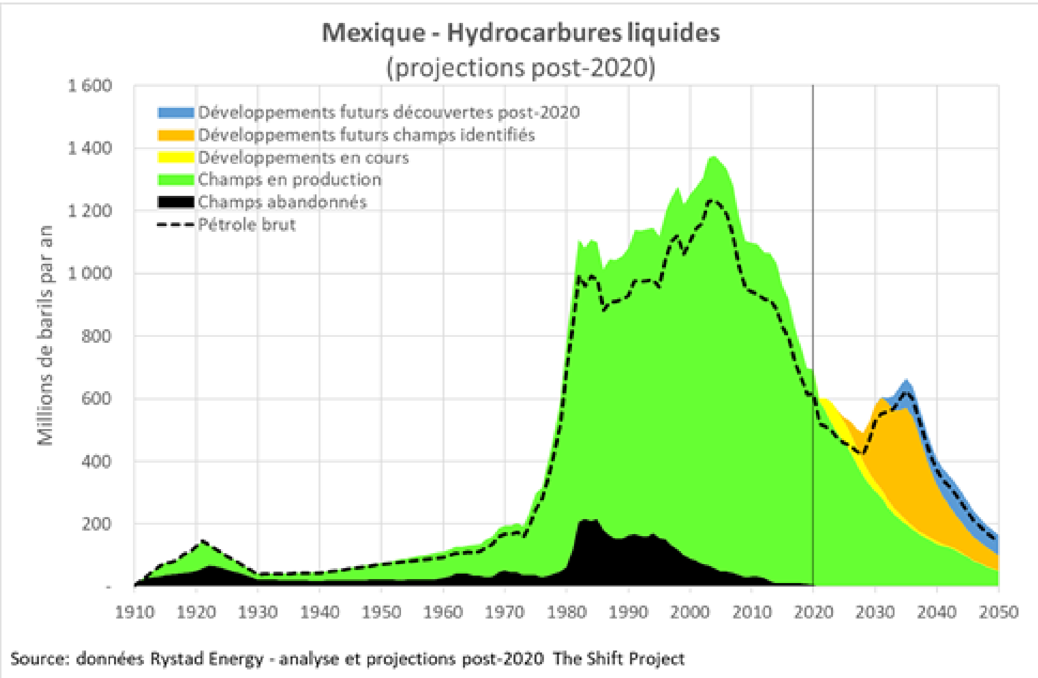
Mexico has long been an oil-producing country. Oil drilling started at the beginning of the 20th century. In 1938, in the wake of a social conflict, President Lazaro Cardenas nationalized the hydrocarbon wells previously owned by foreign companies. Mexican oil production has been declining since 2003, with a strong impact on public finances. In 2016, the national oil company PEMEX provided almost 20% of public revenues. President Andrés Manuel Lopez Obrador, in December 2018 was partly elected based on his promise to boost domestic oil production, and to stop oil theft that affects 10% of PEMEX production.

Reserves have been declining since 1990 and a peak in liquid hydrocarbon production (crude oil and liquid gas) was reached in 2003 at nearly 1.4 billion barrels. Volumes extracted from fields in production as of 2020 are expected to decline by almost 60% by 2030 and by nearly 95% by 2050.

Mexico has a substantial offshore potential, with 45 discovered fields. The potential for new discoveries is also significant, at around 16 billion barrels by 2050 compared to the 58 billion barrels already discovered by 2020 (+28%). The potential of offshore reserves allows us to envisage a limited rebound in production during the 2030s.

Production is expected to decline by 14% in 2030, as compared to 2019, to nearly 527 million barrels (1.4 Mb/d) and by 77% in 2050 to 140 million barrels (0.4 Mb/d).

The cost of production is expected to increase, with 65% of remaining reserves having an estimated break-even point above $40 per barrel, while 60% of current production comes from fields with an estimated breakeven point below $20 per barrel.



Saudi Arabia

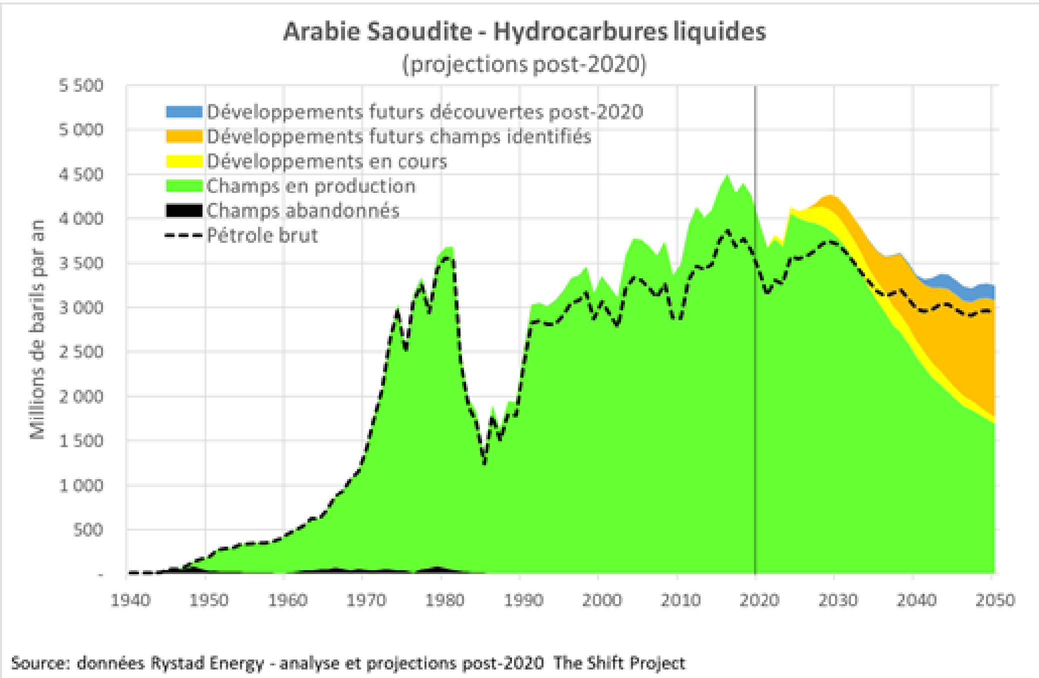
Saudi Arabia is the leading operator in the global oil market. This monarchy, under American umbrella since the 1945 Quincy Pact, has historically held the position of OPEC leader and swing producer, allowing it to regulate the quantity of oil available on the markets and thus to drive oil prices. With the diversification of supply sources and the development of irreducible expenditures in the Kingdom's budget, Saudi Arabia has to some extent lost the central role it once held on the global oil scene. Since the 2000s, Saudi Arabia has faced increased competition from the United States and Russia.

The fields currently in operation (including Ghawar, the world's largest field) are expected to suffer a limited decline of some 10% by 2030 followed by a more significant decline close to 60% by 2050. The country's historical production base, with its unparalleled oil resources both in terms of the volume of reserves and the size of fields, is not immune to the depletion process typical of all operationsn.

Crude oil reserves have been declining since 1971. The lack of newly discovered fields is forcing Saudi Arabia to start operating smaller fields that were discovered before 1970.

Saudi Arabia's crude oil production is expected to fall back to a level similar to its 2019 production levels by 2030 at around 10.2 Mb/d. The structure of Saudi production and the low potential for new discoveries, however, are expected to trigger its decline between 2030 and 2050 to 8 Mb/d, down by 20% as compared to 2019.

Without major new discoveries, the current distribution of remaining reserves suggests that **the cost of producing oil in Saudi Arabia is likely to increase significantly over the coming years.**



Azerbaijan

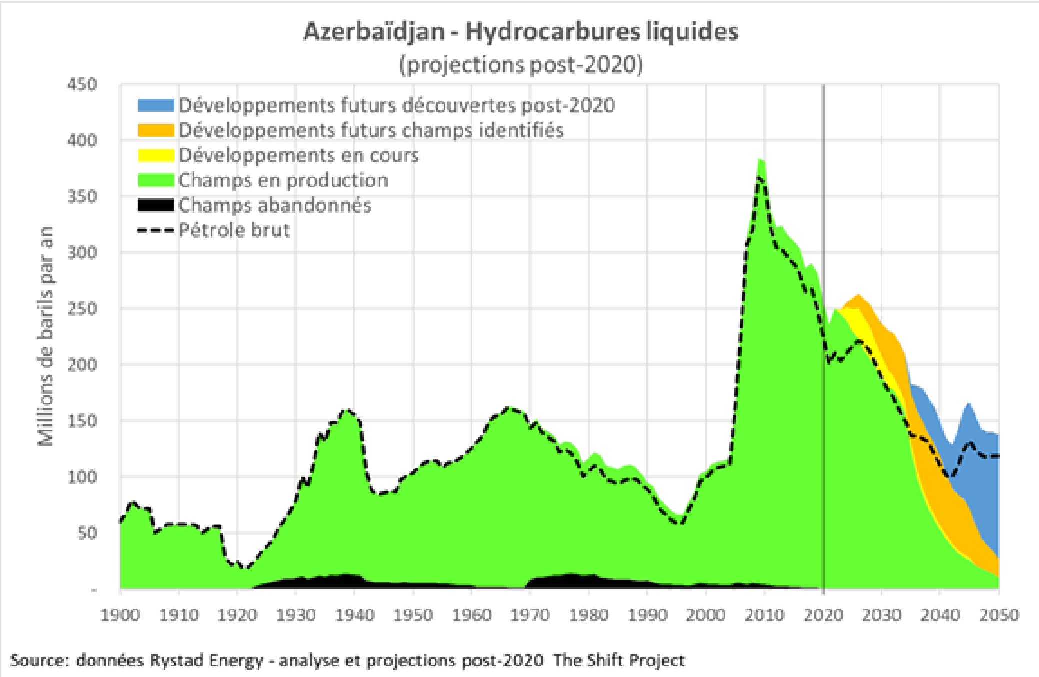
Formerly a province of the Russian Empire and later part of the USSR, Azerbaijan only gained its independence after 1990 and the collapse of the Soviet Union. Oil exploitation has played a major economic role since the 19th century. Some of the world's first oil wells were located in its capital, Baku.

Azerbaijan's liquid hydrocarbon production has reported a sharp decline since 2009 (-31% to date). This production is highly concentrated on a limited number of assets: 10 fields provide almost 90% of the production. Volumes from fields in production as of 2020 are expected to decline by around 35% by 2030, and become marginal by 2050 (-96% compared to 2019).

Fields discovered to date represent only a very limited reserve potential and the level of crude oil additions has been extremely low since the 1990s: only 1 field discovered for a total of 130 million barrels.

The estimated potential for additional discoveries between now and 2050 is relatively modest, considering the level of production over the last decade. It represents a volume of nearly 4 billion barrels which could, however, contribute to slowing the decline in production beyond 2040.

In the medium term, Azerbaijan's crude oil production is expected to continue the sharp decline that began in 2009, after a short plateau period between 2022 and 2027. By 2030, crude oil production is expected to stand at 0.5 Mb/d, down 25% from the 2019 production level (0.7 Mb/d). Over the 2019-2050 period, this decline should reach 53%, i.e. a production volume of 0.3 Mb/d.



Iraq

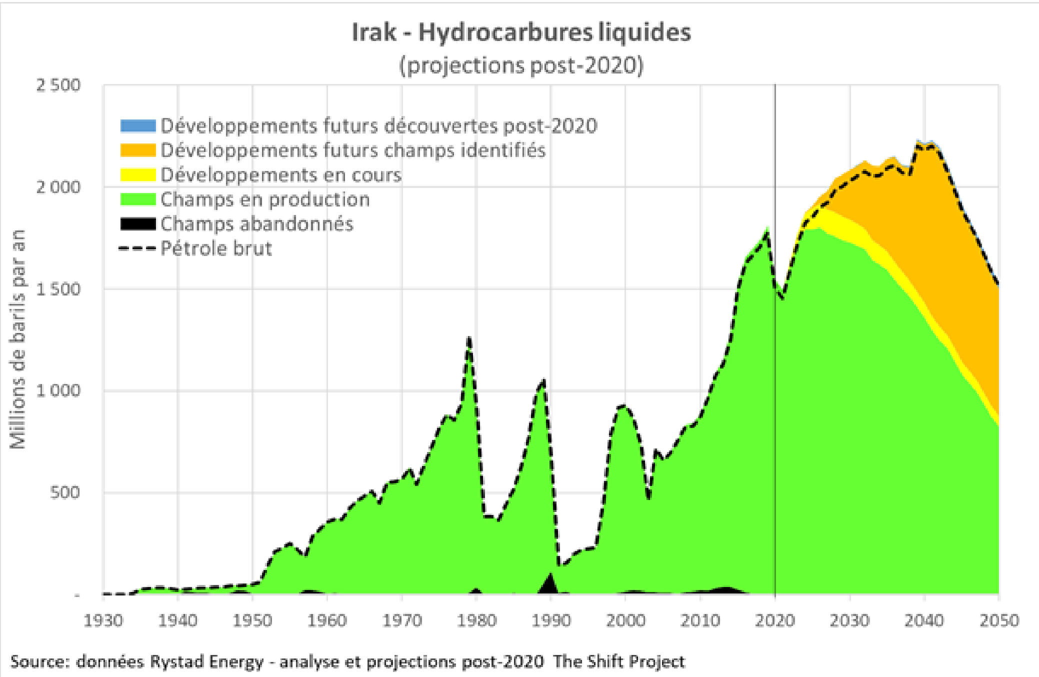
Since 1980, Iraq has been plagued by wars, invasions, civil wars and embargoes. These events have severely curtailed oil extraction, thus preserving the country's plentiful reserves.

Iraq has the fifth largest oil reserves in the world, with cumulative discoveries of 127 billion barrels by 2020. **Most of the production comes from relatively mature fields**, identified prior to 1980.

Iraq's crude oil production has a significant growth potential through the 2030s. Indeed, the decline of currently producing fields is expected to remain very limited before that date. However, the decline is expected to accelerate by 2050, with volumes falling by more than 50% by that date as compared to 2019.

In addition to the fields currently in production, **Ithe reserves of discovered undeveloped fields allow to anticipate production growth by 2040. On the other hand, future exploration is not expected to yield any major discoveries, at least as compared to previous discoveries.**

By 2030, Iraqi production is expected to be 2 billion barrels, up 14% from the 2019 level of 1.8 billion barrels (4.8 Mb/d). **Peak production is expected to occur around 2040 at approximately 2.2 billion barrels (6 Mb/d), a 24% increase over 2019.**



Source: données Rystad Energy - analyse et projections post-2020 The Shift Project

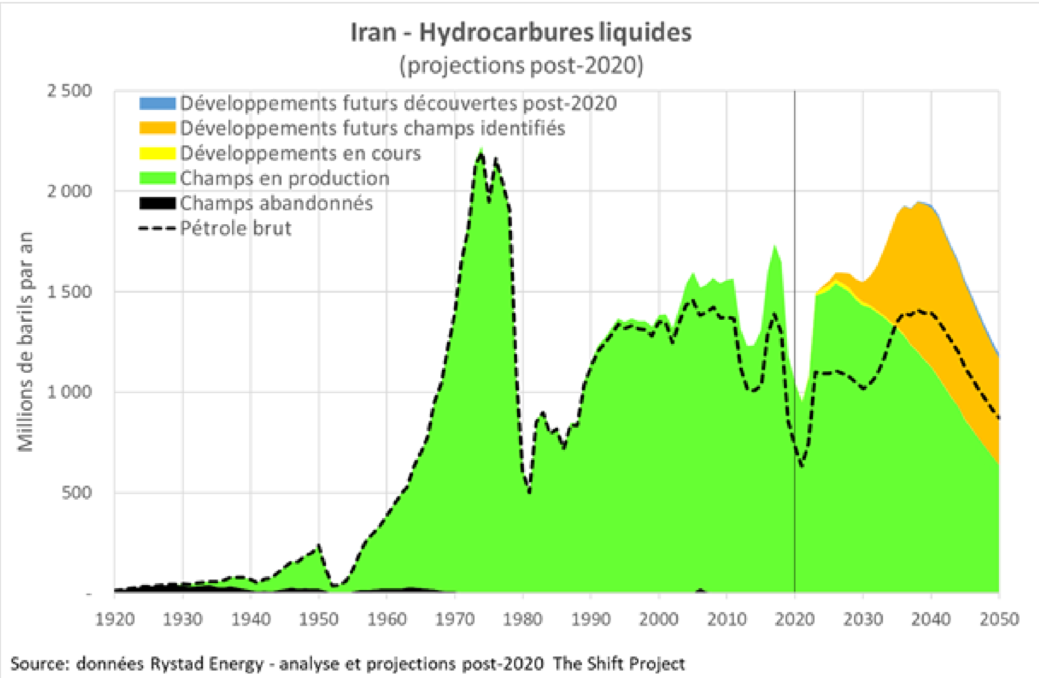
Iran

Iran is a long-time oil producer. Initially under British influence, it came under American umbrella with the deposition of the Iranian Prime Minister Mossadegh and the subsequent expansion of the power of the Shah, finally ousted by the 1979 Islamic Revolution. This Islamic regime is still in place today, although it has been crippled both by American economic sanctions (in response to the development of its nuclear program) and by structural difficulties.

80% of Iran's current production is provided by fields that were discovered before 1970. However, these fields in operation as of 2020 are expected to decline only slightly by 2030, and then by about 50% by 2050 compared to 2019.

The development of discovered fields offers the potential for production growth by 2040. Currently Iran has 52 remaining undeveloped fields, most of which are onshore. **The potential for future discoveries is significant.** These could add nearly 14 billion barrels by 2050 to the 124 billion already discovered by 2020. However, these fields are not expected to come on stream until the 2040s.

Between 2019 and 2030, Iranian crude oil production could increase by 18%, from 2.4 to 2.8 Mb/d. A secondary production peak is possible around 2038 at ca. 3.9 Mb/d. In 2050, the production level could be equivalent to the 2019 level with a volume of about 2.4 Mb/d. The potential for increased production is closely linked to the issue of international sanctions.



Kazakhstan

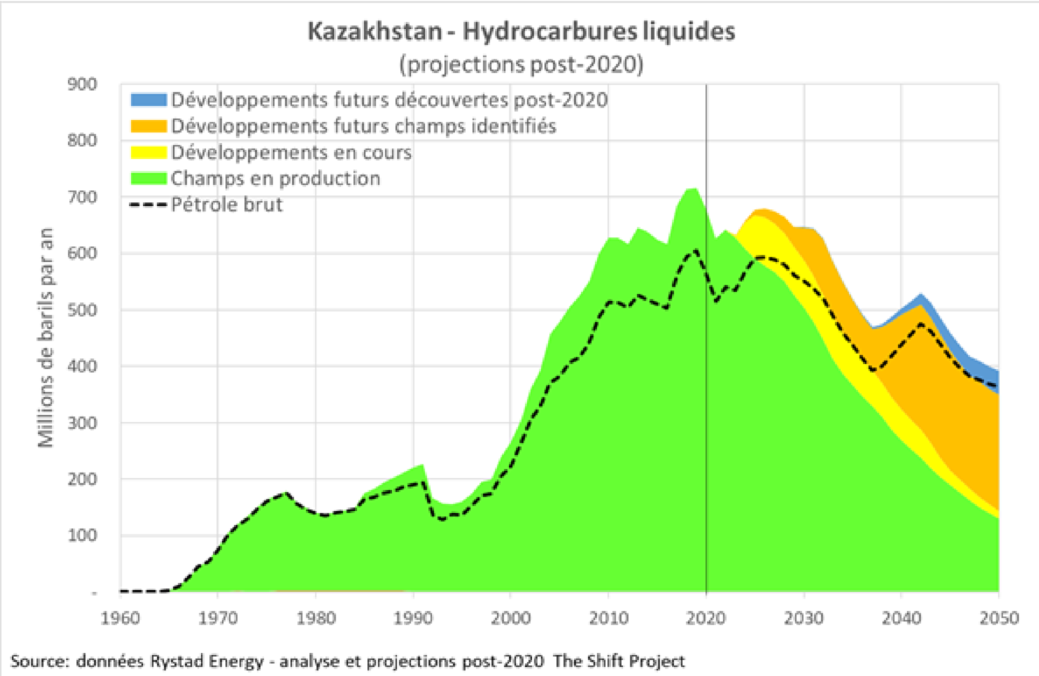
A former province of the Russian Empire and later a member republic of the Soviet Union, Kazakhstan gained independence in 1991 following the breakup of the USSR. Kazakhstan's oil industry was hardly impacted by the collapse of the USSR, unlike Russia's.

The discovery of the huge offshore Kashagan field in 2000 increased the volume of reserves by more than a third to nearly 33 billion barrels. **Liquid hydrocarbon production reached a record level in 2019**, at nearly 720 million barrels (2 Mb/d).

Volumes extracted from fields in operation in 2020 are expected to decline by approximately 30% by 2030 and 80% by 2050. **However, the start-up of new fields should make it possible to temporarily compensate for this decline over the 2020s.** Despite particularly disappointing exploration results over the last decade (2010-2019), future prospects of 6 billion barrels might trigger a limited rebound in production around 2040.

In 2030, Kazakhstan's production is expected to stand at 1.5 Mb/d, as compared to nearly 1.7 Mb/d in 2019, corresponding to a decline of nearly 8%. Over the entire 2019-2050 period, this decline is expected reach -40%, with production shrinking to 1 Mb/d.

Maintaining production will require operating smaller fields with a higher expected break-even point, mostly between $20 and $60 per barrel, whereas 70% of current production is obtained at less than $20 per barrel.



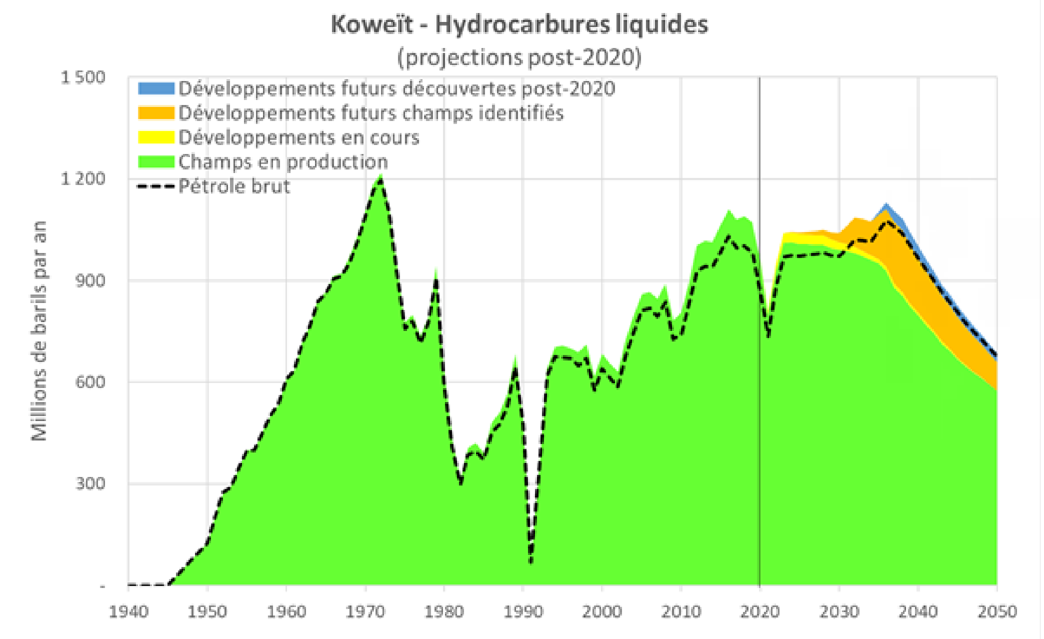
Kuwait

Since the first drilling operations in 1938, Kuwait's recent history has been closely linked to oil. In fact, while it has contributed to Kuwait's wealth, oil has also been a main cause for its brief occupation by neighbouring Iraq, in 1990, under Saddam Hussein. After a 7-month occupation, the country was liberated by an international military coalition led by the United States. The blowing-up of 732 Kuwaiti oil wells during the withdrawal of Iraqi troops caused a major ecological disaster.

Ninety-five percent of current crude oil production comes from fields discovered before 1980. The decline of currently producing fields is expected to remain modest to 2030, at less than 10%, before starting to increase in 2050, when their production is expected to fall by 40% as compared to 2019.

The depletion rate of reserves to date is moderate, at 56%. However, the volume of crude oil discovered since 1975 is limited, only 3.5 billion barrels as compared to a total production of nearly 31 billion barrels since that same date. **Exploration potential is also very limited**, estimated by 2050 at only 2.6 billion barrels, compared to 87 billion barrels already discovered.

From 2019 to 2030, crude oil production in Kuwait should remain almost constant, close to 980 million barrels (2.7 Mb/d). **A secondary production peak may occur around 2035** at 1 billion barrels (3 Mb/d), a 10% increase over 2019. **Production would then slip into an irreversible decline.** From 2019 to 2050, production could fall by approximately 30% to nearly 680 million barrels (1.8 Mb/d).



Source: données Rystad Energy - analyse et projections post-2020 The Shift Project

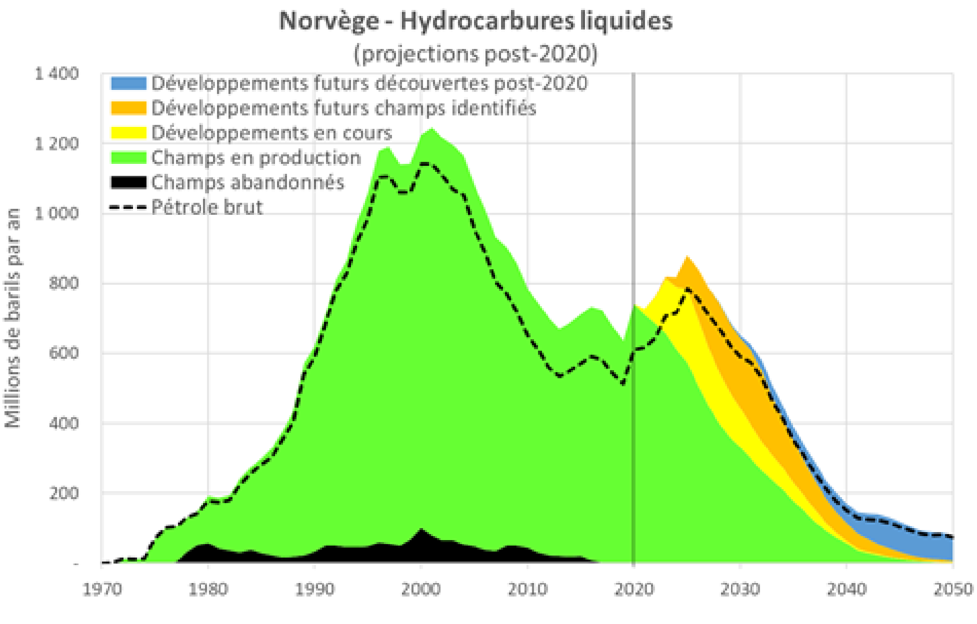
Norway

Since 1905, Norway has been a constitutional monarchy independent from Sweden. Due to its small population and considerable natural wealth, Norway is one of the richest states in the world with a GDP per capita of $81,000 current in 2018. The oil revenues collected by the Norwegian government are placed in a sovereign wealth fund that totalled $1014 billion in assets in 2019, making it the largest sovereign wealth fund in the world.

The country's oil production has declined by nearly 50% since its peak in 2001. Volumes from fields currently in operation are expected to decline by 40% by 2030 and become minimal by 2050. The steep decline rate results from operating exclusively offshore.

Current and potential developments are likely to temporarily make up for the decline in fields currently in operation. Norway has 10 billion barrels of reserves and a large number of untapped fields. With the exception of the huge Johan Sverdrup field (3 billion barrels) discovered in 2010, the limited size of these fields makes a possible upsurge of production uncertain. The potential **for discoveries by 2050 is estimated at approximately 4.5 billion barrels.** Despite the maturity of exploration, this amount appears credible in view of the discoveries made over the 2010 decade as a result of high exploration expenditure.

From 2020 to 2030 Norwegian crude oil production might increase by 15% from 510 to 590 million barrels (1.4 to 1.6 Mb/d), with a secondary peak in 2025 at 790 million barrels (2.2 Mb/d) thanks to the start-up of the Johan Sverdrup field at 0.5 Mb/d in 2020. Production is expected to enter a final decline thereafter, falling by 91% to 70 million barrels in 2050 (0.2 Mb/d).



Source: données Rystad Energy - analyse et projections post-2020 The Shift Project

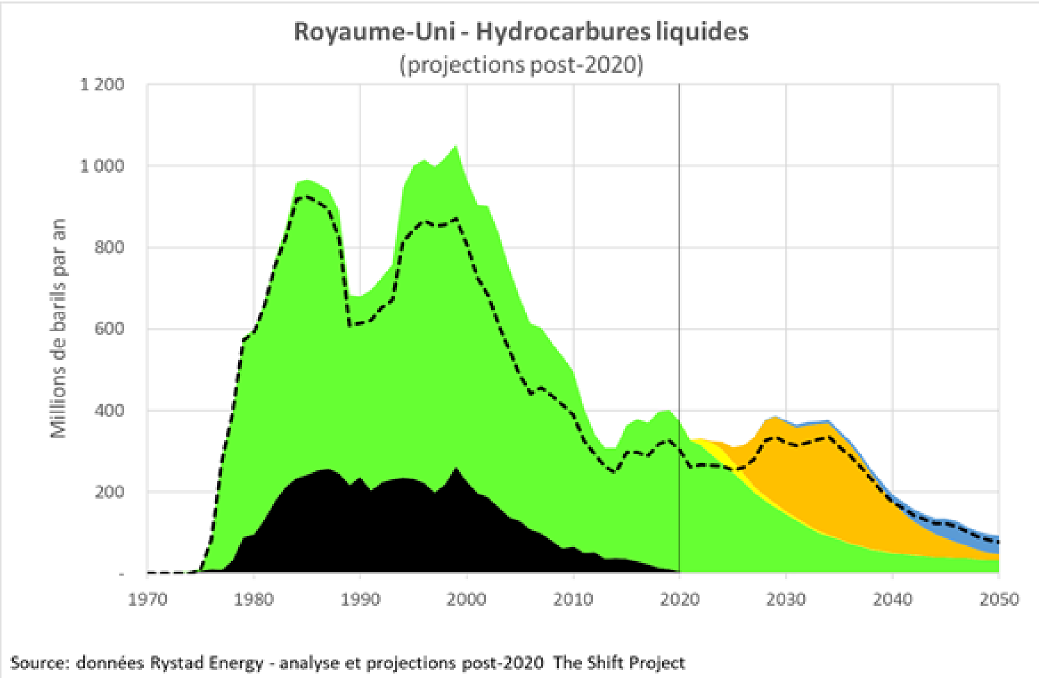
United Kingdom

The United Kingdom became a major hydrocarbon producer in the 1970s thanks to oil located mainly in the North Sea and to the surge in crude oil prices after the first oil crisis in 1973.

The UK is a highly mature oil country. UK oil production has declined by 61% since 1999 and reserves have been shrinking since 1978. Volumes of fields in operation in 2020 are expected to decline, by more than 60% by 2030 and by approximately 90% by 2050. This sharp decline is due to the fact that roughly 30% of the fields are located in the deep offshore.

However, production might remain stable over the 2020s, as compared to its 2019 level. In fact, in 2020, the United Kingdom has nearly 170 undeveloped fields, most of which are located in the shallow and deep offshore. However, the average size of these fields is a major uncertainty. **Presumably, new discoveries would be responsible for only an additional 1.5 billion barrels of crude oil on top of the 33 billion barrels already discovered by 20200.**

Provided that the many smaller fields are developed, crude oil production could remain almost stable between 2019 and 2030, falling from 330 million barrels (0.9 Mb/d) to 320 million barrels (-3%). **Production is expected to resume its decline thereafter** due to the lack of prospects for post-2020 discoveries. Over the entire 2019-2050 period, production is expected to decline by around 76% to nearly 80 million barrels (0.2 Mb/d).



Summary - The Future of Oil Supply in the European Union: State of reserves and production prospects for major suppliers

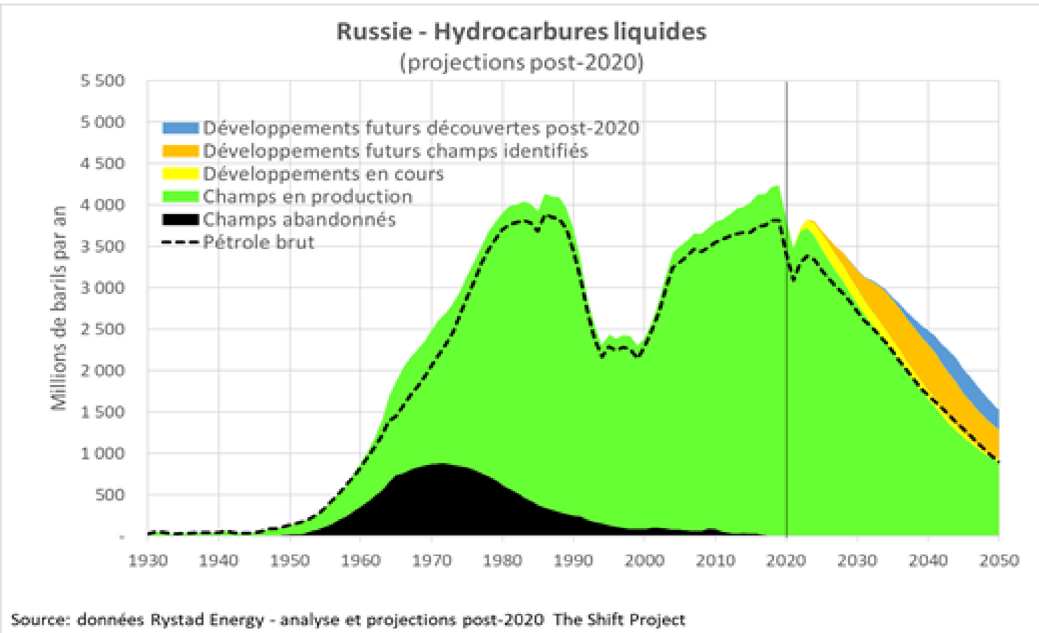
Russia

The Russian Federation, which emerged from the breakup of the Soviet Union, is a major oil producer. Russia experienced its first peak in crude oil production in 1986, 5 years before the collapse of the USSR, but is now producing more than 10 million barrels of oil per day, or one tenth of the world's global demand in 2019, on par with the US and Saudi Arabia. Historically a major supplier of hydrocarbons to Europe, Russia is now more oriented towards Asian demand. Thus, 30% of Russia's oil exports are now destined for Asia, as against 6% in 2006.

Russia is an established and mature oil country. Reserves have been declining since 1990. The volumes of fields in operation as of 2020 should undergo a moderate decline of around 35% by 2030, then a more marked decline of around 80% by 2050, consistent with the predominance of onshore fields.

Russia has 41 fields, either under development or undeveloped, accounting for a volume of 6 billion barrels, **and there is still significant potential for additional discoveries from now until 2050**,estimated at nearly 30 billion barrels of crude oil. However, except for a swift development of its unconventional resources (Bazhenov shale oil and Achimov LTO in Western Siberia), **the development of new fields should not be sufficient to compensate for the decline of the fields currently in operation.** In this event, crude oil production is expected to fall to 2.7 billion barrels (7.5 Mb/d) in 2030, compared with 3.8 billion barrels in 2019 (10.5 Mb/d) and close to 1 billion barrels (2.5 Mb/d) in 2050.

Among the 16 main EU27 supplier countries, **Russia has the second largest total identified and potential reserves of conventional crude oil, with about 100 billion barrels**, second to Saudi Arabia and ahead of Iraq.



The Shift Project is a think tank advocating the shift to a post-carbon economy. As a non-profit organisation committed to serving the general interest through scientific objectivity, we are dedicated to informing and influencing the debate on energy transition in Europe. Our members are major companies that want to focus on sustainable energy.

www.theshiftproject.org

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