

Forecasting Oil & Gas Supply And Activity

Michael R. Smith
Globalshift Limited

ABSTRACT

This article discusses why comprehensive forecasts of oil and gas supply and activity are essential for the oil and gas industry - especially the service sector - to plan future investment. It describes the approach used by Globalshift Limited to achieve a quantitative analysis of past and future oil and gas production, drilled well numbers and associated activities. The discussion emphasises the importance of including and defining all types of hydrocarbon supply and demand in the analysis, along with drilled and active well numbers, to measure and project local and global industry activity. It also stresses the value of transparency in the methods of data collection and forecasting.

Globalshift publishes histories, and forecasts to 2050, of production volumes of hydrocarbon types by country and sedimentary basin, along with numbers of drilled and active wells by country. The forecasts are predicated on the behaviour of producing reservoirs in a finite hydrocarbon system, such as an oil field or a sedimentary basin. In such an environment extraction rates go up and then go down over an extended period. The shapes of the ensuing production and well number profiles always vary due to differences in the geology. In turn they are modified according to rates of investment in down-hole and surface facilities. This has been demonstrated many thousands of times in wells and fields and also in sedimentary basins and countries.

The production forecasts use a bottom-up method - by-field where the data are available - backed up by experiential analysis to discriminate reality from hearsay and cognitive bias. Regional historic and forecast drilling activities, in addition to past production and a range of subjective criteria, are used to provide estimates of potential future output and activity in the short and medium term.

Historic data are drawn from a very wide variety of open-file industry sources. These are inspected and scrutinised for reliability, missing values, ambiguity and reporting bias. Production rates and well numbers are forecast forwards in a variety of profiles dependent on location, data availability, hydrocarbon type, size of resource, history matching, and estimated local and global activity and demand levels.

1. INTRODUCTION

Although oil was used to seal boats in the Middle East at least 5,000 years ago, the first true oil well was drilled in 1859 in Pennsylvania. The subsequent oil boom supplied kerosene for artificial light at prices near US\$450 a barrel in today's terms. Diesel and gasoline were just waste products but were eventually adopted into the transport industry for use in internal combustion engines which developed through the 1880s.

After 50 years of slow growth the demand for oil products began to rise rapidly in the 1930s as the transport industry expanded. Most ended up burnt in trains, planes and automobiles and oil was recognized as an important but scarce commodity. The practice of predicting energy supply and demand became important for governments to make strategic decisions over sourcing the means to power and build the economy of a nation and its armies. But it was within the now influential oil and gas industry that forecasts of supply were especially needed.

Although the oil industry had always tried to predict output from individual wells and fields in order to plan future purchases of equipment and services, it was during the 1950s when the importance of basin, country and global forecasts began to be realised. Operations were spreading internationally and the use of expensive and specialized technologies was rapidly expanding. In 1956 a future peak in supplies from the USA was predicted within two decades. Soon after a new wave of resource nationalism ensured that industry forecasts of oil supply became valuable in more than just the local environment.

However, it was not until the 1990s that more robust global forecasting techniques were established when computing power became widely available and when the internet began to improve the ability of individuals with modest budgets to acquire data. Scientists began to recognise once again how vulnerable the world was to repeated oil shocks.

At the time many global forecasts appeared pessimistic to professionals who had seen only growth in their lifetime. The established industry and financial sector were quick to decry concerns about oil supply for the early part of the 21st Century; an establishment now silent about how prescient some of those forecasts actually were. Oil prices surged with energy prices becoming exceptionally volatile. Technologically challenging and more expensive supplies were failing to add sufficient oil to replace depletion in older areas to meet the full needs of the market. A permanent price jump was the result.

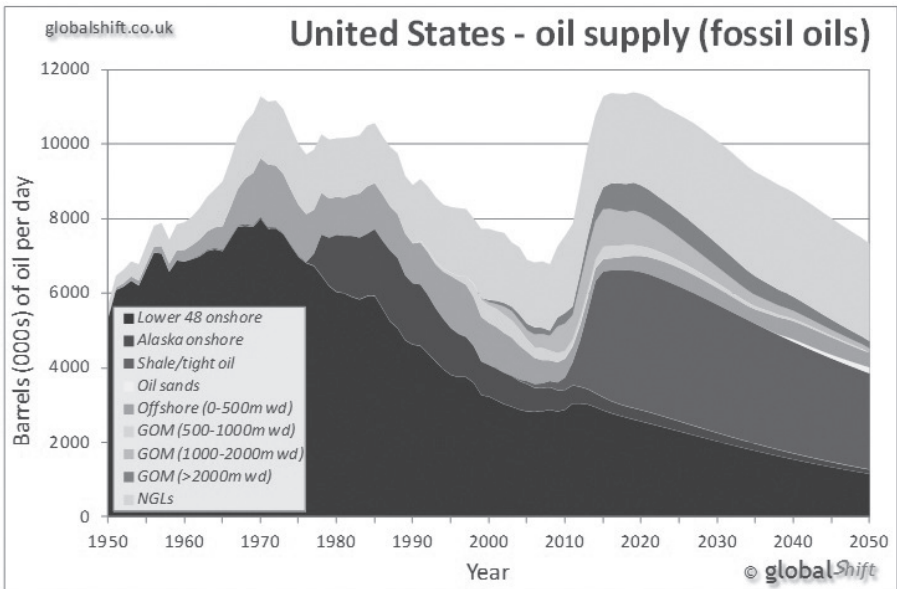


Figure 1: Historical data, and forecast, of all fossil oil production in the USA, 1950 – 2050 (includes shale/tight oil, oil sands and NGLs; excludes GTLs, CTLs & biofuels). For this oil, the USA will have 3 peaks: 1st driven by conventional onshore oil in 1970; 2nd driven by new Alaskan output in 1985; 3rd through a combination of shale oil, deep-water oil and NGLs around 2020

For example the forecasts of Energyfiles (the author's former company) repeatedly warned about a series of signals of tight supply foretelling rapidly rising oil prices, global recession and the need for technologies (and price levels) to access alternative hydrocarbon sources. The advent of higher oil prices did indeed facilitate large-scale exploitation of new sources using more costly methods and technologies, especially applied to deep waters and to fracturing oil and gas-rich shale beds.

The changing scene in the critically important USA market over the last 3 or 4 years was driven by the tight supply situation identified in those forecasts over a decade ago, and this may have been recognized by some of the first companies who became expert in the practice of fracturing tight oil reservoirs . Figure 1 gives Globalshift's current forecast of US all-fossil-oil production to 2050, including NGLs.

2. THE PURPOSE OF FORECASTS

The modern oil and gas industry is a long term one. Except on a small scale gone are the days when an oil well will be drilled, oil found and sufficient volumes of production sent to market in a timeframe that could have a rapid effect on supply and price. Oil from most fields of any size takes years to appraise, develop, produce, transport and sell to market. Even drilling for oil trapped in shale reservoirs requires a large number of wells before total volumes begin to have an impact on the global market. Output from the larger, more predictable fields is in relative decline and a huge industry has developed to service the more complex reservoirs and remote regions, especially offshore. The service industry employs technologies that often require large front-end investments.

Thus comprehensive, transparent forecasts have become increasingly valuable to direct such investment. Do you invest in new drilling rigs, platforms, ships, pipelines, service personnel, specialized subsea equipment and where do you put them if you do? Oil companies and their associated service industries have to make decisions on building and purchasing equipment that may not turn a profit for a decade.

For example a new deep water drilling rig can take three or four years to build and will cost over half a billion dollars. It must have some contractual certainty over the long term to justify the investment. Without believable forecasts of output of all the different hydrocarbons requiring all the different equipment it is hard for companies to raise the capital for such ventures.

3. GLOBALSHIFT FORECASTS

Oil field engineers know that when a successful well is completed and produced it usually delivers oil and/or gas at a rate that rises rapidly to a brief plateau. It then declines over a period of time - due to pressure decline in the reservoir along with water and/or gas encroachment - until it is abandoned. Growth, then decline has happened since the first well was drilled.

When a collection of wells is completed in a discrete accumulation - called a field - production rises and falls in the same fashion. When a collection of fields is developed in a sedimentary basin, with generally the biggest and best found and developed first, total production must rise and fall too. Of course the same is true for collections of basins in a country; countries in a region; and, ultimately, all regions in the world.

A comprehensive data-driven supply forecast has been developed by Globalshift to help define the timing and magnitude of this growth and decline, for fields, basins, countries, regions and the world. The forecasts are founded on empirical observations combined with technical analysis, insights into the historic hydrocarbon flow behaviour of oil and gas wells and of fields, and examination of the historic numbers of wells and items of associated equipment required to explore for, and to exploit, this oil and gas.

All forecasts made by Globalshift assume oil production activity will only be constrained by the macro effects of the global economy, including (occasionally) OPEC members' and other exporters' attempts to support oil prices when demand flags. Meanwhile petroleum technology is assumed to continue to improve in terms of better imaging of the subsurface, engineering advances in accessing new output and containment of costs in increasingly challenging areas.

Making technical forecasts for leaders, governments and economists - groups that prefer forecasts based on trends rather than science - is a thankless task. Even if the complex forecasts are understood there is a tendency to cherry-pick numbers that suit a current agenda. No one wants to run with a bold forecast that is out of line with the pack. And when forecasts do not meet shareholders or voters needs, 'chicken-and-egg' arguments are preferred, citing the importance of demand over supply or vice versa. Globalshift forecasts are thus aimed at the sharp end of the industry; the technical specialists that endeavour to find and exploit oil.

They focus on helping the oil and gas industry make the most effective decisions to maximize the potential returns on investment capital.

4. VARIABLES

Forecasts are made for every country and sedimentary basin for the following (*inter alia*):

- Oil production – onshore and offshore (0-500m, 500m-1000m, 1000m-2000m, >2000m water depth intervals) with separate analysis of field oils, natural gas liquids, shale/tight oils, heavy oils, extra-heavy oils and bitumens, retorted shale oil, gas-to-liquids, coal-to-liquids and biofuels; as well as speculative undeveloped and speculative undiscovered production profiles; and cumulative produced and cumulative remaining unproduced volumes by year.
- Sales Gas production – onshore and offshore (0-500m, 500m-1000m, 1000m-2000m, >2000m water depth intervals) with separate analysis of all field sales gases, shale/tight reservoirs and coal bed and coal mine methane; as well as speculative undeveloped and speculative undiscovered production profiles; and cumulative produced and cumulative remaining unproduced volumes by year.
- Drilled Wells - onshore and offshore (0-100m, 100-500m, 500-1000m, 1000m-2000m, >2000m water depth intervals) with separate analysis of exploration, appraisal, and development wells. For offshore the latter are divided into surface-completed and subsea-completed wells.
- Active Wells - onshore & offshore (0-500m, >500m water depth intervals). For offshore these are divided into surface-completed and subsea-completed wells.

The forecasts primarily address the upstream (from prospect to pipeline) and midstream (processing, gathering and transporting) parts of the industry. However, manufactured oils are also estimated, delivered from the downstream (refining and petrochemical) sector. Histories are from 1900 with published forecasts running to 2050 (although the models run further).

At www.globalshift.co.uk summaries and news can be accessed for every country in the world for those interested in the overall picture of future output in specific areas or globally. For people or companies needing to make costly decisions on investment, Excel files can be

purchased comprising historical and forecast numbers for production and wells; arranged into categories (a selected dataset for every country/region), or into individual countries and regions (giving all categories).

These files are presented in worksheets; historic from the year 1950, and forecast to the year 2050, and allow energy companies, oil companies, service companies, associated industries and governments to create presentations, evaluate assets and develop strategies and policies.

5. ASSUMPTIONS

The difference between a forecast and a projection is in the nature of the assumptions. In a forecast, the assumptions represent expectations of actual future events. A projection is a ‘what if’ scenario where the input assumptions are not necessarily the most likely.

Globalshift prepares forecasts based on geoscientific and engineering principles of field discovery, field exploitation and field depletion under commercial constraints combined with inspection of historic relationships between production and activity. Forecasts depend on three fundamental, empirical, observations:

- Supply from an oil and/or gas well grows to a maximum, has a short plateau, relative to the life of that well, and then declines. This is the basis on which engineers in the oil and gas industry forecast output from individual wells and, for a collection of wells, from fields.
- In general larger and cheaper (and easier to find and exploit) accumulations are found and developed first followed by progressively more difficult, more cost-intensive projects in concert with technological advancement.
- Real-world production and activity profiles can be heavily influenced by non-technical (economic, commercial and geographic) effects and these are accounted for by history matching and general expert evaluation of areas, regions, countries and country groups.

The forecasts try to account for ‘below-ground’ geological and engineering factors as well as ‘above-ground’ commercial, political and environmental (e.g. hurricanes in the Gulf of Mexico) factors, which are much more volatile. The most important of the ‘above-ground’ influences remains demand for oil. This is especially volatile when new supplies become more costly to access whilst political, financial and catastrophic

one-off events act to restrict maximum potential output in individual countries.

Each individual country supply forecast in Globalshift is thus modified with qualitative assumptions related to most-likely government policies, oil prices and oil demand. The most significant of these are:

- Oil demand will be driven by price. Despite encouraging words it is judged that there will be little political will to subsidise new fuel substitution, even within the European Union.
- Non-OPEC governments will allow investing companies to find and produce oil as fast as possible using the technologies available for profitable sale at the prevailing oil price.
- OPEC governments will eventually act, if they deem necessary, to support price by restricting output when the price level falls. However, the decision by OPEC to do this is dependent on which approach maximizes income, and different members have different needs.

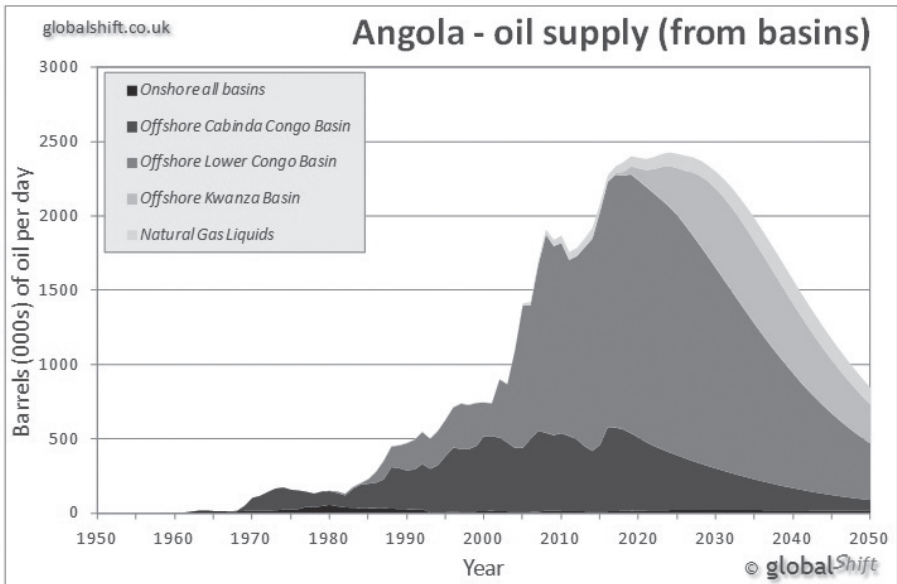


Figure 2: Historical data, and forecast, of oil supply in Angola, 1950 - 2050, by basin (including NGLs). The development of technologies to exploit deep water oil and more recently to image sub-salt has dramatically improved Angola's potential, such that all its offshore basins are now being explored and/or exploited.

In reference to the last of these the current forecasts assume that, up to the mid 2020s there will be a number of countries where output growth will proceed sufficiently fast to offset declines elsewhere; particularly Brazil; the OPEC countries of Iraq, Angola and Nigeria; NGLs from Qatar; heavy oils from Colombia and Venezuela; syncrude from Canada; oil from shales in the USA and elsewhere; and, later, potential pre-salt developments off West Africa such as in Angola (see Figure 2).

During this period it is assumed that higher cost oil developments will be curbed, and/or Saudi Arabia (and to a lesser extent other OPEC countries) will eventually restrict output into existing infrastructure to try to prop up oil prices and maintain global supply at a level that could meet 2% to 3% per year demand growth. Negotiations to do the latter, as always, will be protracted as individual members argue for quota. Even if some output reductions are met by unplanned cuts, for example those that occurred during rebellion in Libya and other North African countries, oil prices will always be volatile when supplies can meet demand.

By the mid 2020s the model indicates that no country will be left with spare capacity. Demand, driven by uncomfortably high oil prices in a supply-constrained environment, will have to decline, creating the conditions necessary for an energy transition. Whether such a transition is smooth or not depends on the response today to the production and activity forecasts presented by organisations such as Globalshift.

6. PROCESS

Stand-alone datafiles have been created for every country in the world within which individual production and activity spreadsheets have been formulated for onshore regions and offshore regions at a range of water depths. The sheets list, wherever possible, historic oil and/or gas output split into component types (light, heavy, extra-heavy, from shale/tight reservoirs etc.) for every year that oil and/or gas has been produced for every oil and/or gas field that has produced in that year, as well as by name for every field that has been discovered but, as yet, has not been developed.

Along with the production profile for each field the name, operator, license, sedimentary basin, year of discovery, year onstream (if applicable) and hydrocarbon type and reported volume are included (if available).

The files also list numbers of exploration, appraisal and development

wells drilled for onshore and offshore regions at a range of water depths for every year that drilling has been conducted from 1930, and for cumulative wells drilled prior to 1930 (see Figure 3).

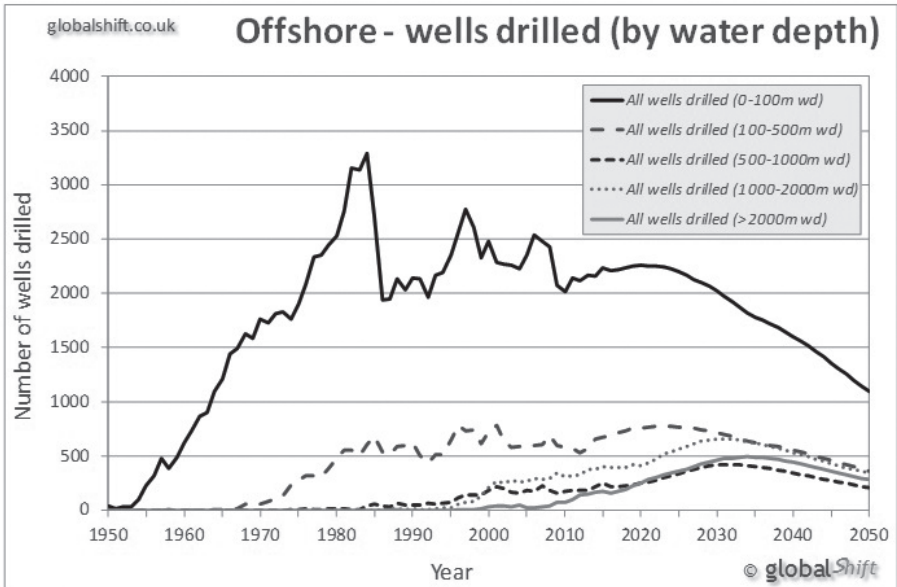


Figure 3: Historical data, and forecast, of global offshore drilling 1950 - 2050 by water depth. Drilling totals are dominated by shallow wells (drilled with jackups). Relative future growth is expected in ultra-deep waters (drilled with high-specification mobile rigs).

A forecast for each field is made based on history matching past performance - or typical performance in a reservoir or sedimentary basin where there is no history match. Future field total outputs are constrained by reported reserves and/or resources of each field (if numbers are available) after investigating the validity of such reports - a validity that depends on their provenance.

Inevitably there are many data gaps. Spreadsheet yearly totals are constrained by considering sums that match reported total country yearly production using estimates defined as 'balancing volumes.' These correspond to fields, field complexes or sedimentary basins that have no individual data reported but require balancing volumes to make up

the difference. Where only limited information is available or full data sets have not yet been analysed, estimates are made by interpolation or extrapolation in as much detail as possible using the data that can be obtained.

Also included in the spreadsheets, as far as possible, are all field discoveries which have not yet entered production but will be developed. These are called 'speculative undeveloped'. Many of these fields will have published estimates of volumes and future profiles. Otherwise volume and maximum output numbers are estimated based on analogy with neighbouring fields and by examining the exploration history and general geological potential of each area. The 'speculative undeveloped' component is added to the production forecast (using a model such as shown in Figure 4).

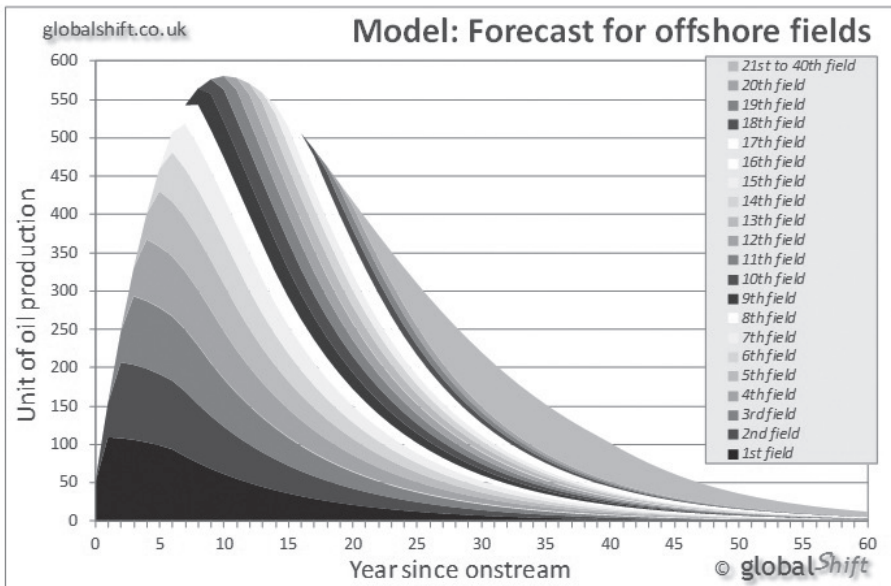


Figure 4: Model demonstrating summed field production profiles creating a right skewed distribution in a sedimentary basin. This model assumes no 'above ground' influences on activity. Most basins will only roughly follow this path, and countries rarely do.

Also included are all potential field discoveries (yet-to-find). These are called 'speculative undiscovered'. The volumes and maximum output of 'speculative undiscovered' are determined through subjective evaluation of how much exploration acreage remains to be explored in an area, how successful exploration has been in the past, how new technology is allowing access to new resources and how the history of exploration in a given area has panned out.

Of course there are many uncertainties in determining 'speculative undeveloped and undiscovered' profiles. Besides volume uncertainties, regional production curves only occasionally form a simple right-skewed bell shape as in Figure 4 (unlike individual field profiles). Regions are influenced by other factors beyond statistical, geological and engineering principles and these are considered accordingly. In particular a country usually comprises a collection of individual profiles delimited by the location of overlapping sedimentary plays or basins which sum together to create a full country profile. Unstable economics, investment, politics and other unpredictable events in a country or region are also disruptive. For example:

- Oil price fluctuations (determined by politics and economics as well as supply and demand) influence the amount of investment in a non-linear fashion
- Countries do not have borders coincident with sedimentary basins, so different areas may be developed at different speeds e.g. Alaska in the USA
- Offshore areas require different technologies and have usually (but not always) been developed later than onshore areas
- Deep waters, with their challenging technological requirements, have been developed independently from shallow waters
- Shale oils have been developed last of all, relying on high oil prices and rapid advances in horizontal drilling that occurred in the latter part of the 20th century
- Environmental influences and disasters, such as hurricanes in the Gulf of Mexico and accidents on platforms, e.g. the Piper Alpha disaster in the North Sea, can disrupt output in an unpredictable way
- Political events can have an effect on investment levels, e.g. changes of government (such as the demise of communism in the Soviet Union)

and sanctions (such as in Iraq whilst Saddam Hussein was leader), severely disrupt country output curves

- Artificial constraints on output conserve oil for the future; especially repeated attempts since the 1980s by OPEC to prop up prices through production quotas.

Different oils are considered in different ways, but always volumetrically (note they may have different energy densities). For example the future output of natural gas liquids is estimated based on past volumes as a constant ratio to total gas production forecasts. Oil sands output is project-based whilst shale oil output is determined through forecasting potential well numbers that could be drilled each year constrained by available volumes, acreage and logistics, as shown globally in Figure 5.

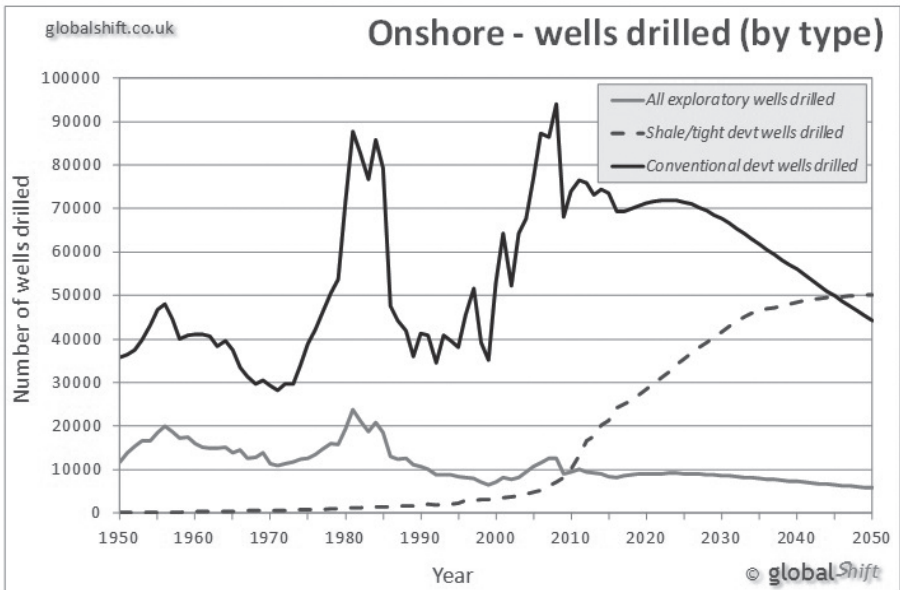


Figure 5: Historical data, and forecast, of onshore drilling, 1950 - 2050.

Development wells have shown an erratic path (dominated by the USA), matched by exploratory wells prior to 2000. Drilling for shale reservoirs is now surging, and other types will decline.

Updates are carried out whenever new information appears (which may be daily). Full reviews, to ensure that global interpretations are consistent and match the economic circumstances of the time, are carried out in January and July each year.

All spreadsheets are collated into a single folder, and compared graphically with actual consumption figures to ensure future global supply and demand match. The model is supply-driven with demand (and oil prices) moving to match available supply, which may be constrained by all or any of OPEC, geology, engineering, investment, varied political and economic events and, of course, energy prices that are themselves dependent on all or any of these.

7. DEFINITIONS

Clear-cut and consistent definitions are important to allow comparison between forecasts and to evaluate and criticise past forecasts, otherwise any comparison can be misleading. Complex models require transparent definitions. Selected ones applied to oil are as follows:

- “*Fossil Oils*” are volumes of fossil liquid hydrocarbons produced from a buried reservoir through wells (or rarely by mining) to the surface. Here they can exist as a liquid at surface temperatures and pressures without processing. They can be transported, before or after refining, in liquid form and are used, before or after refining, as fuels or in the chemical industry. The hydrocarbons include all oils and condensates from oil, oil and gas, and gas fields and dispersed reservoirs, all natural gas liquids, all drilled shale oils from shale reservoirs as well as extra-heavy oils (including bitumens) used for energy before or after conversion to syncrude.
- “*Field Oils*” are fossil hydrocarbon liquids extracted through wells from a field with a porous and permeable reservoir that can exist naturally as a liquid at the wellhead. They may also be called conventional oils.
- “*Drilled Shale/Tight Oils*” are fossil hydrocarbon liquids extracted through wells from tight (shale, sandstone or carbonate), non-field, dispersed reservoirs usually after fracturing the reservoirs underground.
- “*Oils from Oil Sands*” are extra-heavy oils extracted from shallow

sands (also known as tar sands) through wells (usually with steam), or by mining. They are often converted to syncrude by chemical processes, making them more convenient to transport and burn.

- “*Natural Gas Liquids (NGLs)*” are light oils recovered from associated/free gas in a processing plant, stable at normal temperatures. Liquefied Petroleum Gases (LPGs) are NGLs which comprise synthesised propanes and butanes that need pressurised containers for storage.
- “*Manufactured Oils*” are manufactured synthetic liquid hydrocarbons (not including syncrude made from oils from oil sands), with similar characteristics and used for the same purpose as fossil liquid hydrocarbons. They are oils created through chemical conversion processes from gas, from coal, from shale rock, and from biomass (bioethanol and biodiesel).
- “*Gas-To-Liquids (GTLs)*” are created in a refinery by converting natural gas or other gaseous hydrocarbons into longer-chain gasoline or diesel fuel either via direct conversion or via syngas as an intermediate. The Fischer-Tropsch and Mobil processes are the most commonly used methods.
- “*Coal-To-Liquids (CTLs)*” are created by coal liquefaction mainly using the Fischer-Tropsch process. Coal is gasified to make syngas and Fischer-Tropsch catalysts are used to convert the syngas into light hydrocarbons which are further processed into gasoline and diesel.
- “*Mined Shale Oils (retorted)*” also called kerogen oils, are created by heating and processing mined shale rock in a plant.
- “*Biomass-To-Liquids (BTLs)*” are liquid hydrocarbons made from plant material rather than petroleum products. They do not include biomass solids (crops and residue, wood, animal waste, aquatic plants and organic components of waste). Biodiesel is created when plant oils are combined with alcohol in the presence of a catalyst to form ethyl or methyl ester. Ethanol BTLs are formed during sugar fermentation of plants, including cellulosic ethanol created from woody biomass.
- “*Gains (Refinery)*” are liquid hydrocarbons, with the same characteristics and used for the same purpose as fossil liquid hydrocarbons. They represent the increase in volume of refined products compared to an input volume of crude. The processing of oil

and the associated chemical changes increase the volume by a few percent, depending on input and output characteristics.

- “*Production*” is defined as oils and gases produced and sold to refineries or other users and measured as a volume per time period. Production includes from ‘currently producing fields and those in development’ (all oil from existing fields and from fields that have operator-announced plans for their development), from ‘discovered fields which will be developed’ (all oil from potentially commercial drilled fields) and from ‘yet-to-find (undiscovered) fields which will be developed’ (all oil from potentially commercial undrilled areas).
- “*Production profiles*” are the shape of the production curve between two times. Profiles are created based on past production histories and output models for onshore and offshore areas.

Onshore and offshore hydrocarbons must be treated differently owing to their different development methods. Onshore fields are usually (but not always) developed early and sequentially, and offshore fields are usually (but not always) developed within a single development plan.

- “*Onshore production*” comes from onshore wells including wells drilled within lakes and swamps; regardless of their subsurface location, even when such wells are drilled from piers and/or deviated to locations beneath the sea.
- “*Offshore production*” comes from offshore wells; including those drilled from fixed platforms in shallow waters and from artificial islands unconnected to the mainland (not including wells located in freshwater inland areas). For fields overlapping on and offshore areas and water depth intervals the allocation is estimated. It is assumed that the location of the well completions define water depth.
- “*Very Shallow waters*” are defined as areas of oil and/or gas output from reservoirs beneath marine water depths ranging from greater than 0 meters down to 100 meters.
- “*Medium Shallow waters*” are defined correspondingly for water depths ranging from greater than 100 meters down to 500 meters, and likewise:
- “*Medium Deep waters*”: >500 meters to 1000 meters.
- “*Very Deep waters*”: >1000 meters to 2000 meters.
- “*Ultra Deep waters*”: >2000 meters.

The terms reserves and resources are often misunderstood and misused in the oil and gas industry and media. They may have multiple meanings. Here:

- “*Reserves*” are considered as ‘Cumulative Production’ plus ‘Remaining Production’. Proved, probable and possible reserves (P+P+P) are not used in Globalshift in this context. These represent the concept of 90% (proved reserves are subject to a 0.9 success risk), 50% (probable reserves are subject to a 0.5 success risk) and 10% (possible reserves are subject to a 0.1 success risk). Note that Globalshift ‘remaining production’, by definition, should be more than proved reserves for a field, basin or the world, and could roughly be equated to P+P (2P) reserves.
- “*Cumulative Production*” Is the total volume of oil and/or sales gas up to a given year that has been produced (in Globalshift this is to the current year minus one).
- “*Remaining Production*” equates to most likely remaining recoverable resources of oil or sales gas that have not yet been produced but will be recovered under economic conditions that could exist in the future. This assumes the world remains a stable, comfortable place to live with a price regime that satisfies demand whilst demand changes in manageable steps, and fossil fuels retain market share. They are summed output values over a future period (in Globalshift this is to the year 2100). Remaining production volumes are not statistically derived and are best thought of as one interpretation of ‘most likely’ numbers.
- “*Speculative Undeveloped (also known as potential additional resources)*” is that part of Remaining Production that represents all current field discoveries that have not yet entered production but will be developed. It is a speculative estimate based on subjective (but educated) examination of the relevant area. The term ‘Reserves Growth’ (not used by Globalshift) has often been used to define these volumes. ‘Reserves growth’ is a confused term with multiple definitions, including undeveloped fields (or fallow fields) and the use of improved technology to access hitherto un-producible volumes.
- “*Speculative Undiscovered (also known as yet-to-find)*” is that part of Remaining Production that represents all potential field discoveries

which have not yet been discovered but will be found and developed. It is a speculative estimate based on subjective (but educated) examination of the relevant area.

- “*Ultimate Production*” volumes are the sum of ‘Cumulative Production’ (volume of oil and/or gas up to a given year that has been produced) and ‘Remaining Production’ (the volume of oil and/or gas up to a given year that will be produced).
- “*Resources*” are all the oils or gases that exist in the earth from any source, including developed, undeveloped and undiscovered that, if produced (extracted from the subsurface), could be used for fuel or in the chemical industry.

Resources are not critical to forecast production profiles in Globalshift since a substantial portion of estimated resources will either be produced far in the future, when the world must no longer be dependent on fossil fuels, or will never be produced due to unfavourable economic and/or technological circumstances.

Full definitions of all other terms used in the database are available at www.globalshift.co.uk/definitions.html

8. SOURCES AND UNCERTAINTIES

All numbers in the database are either historical estimates or forecasts. There is no guarantee that such estimates are accurate, or that the forecasts will prove accurate.

Extrapolation, interpolation and judgement are used to complete spreadsheets where a full data stream is required or desirable. No one source is treated as perfect. Numbers are sense-checked and adapted.

Data are acquired from a wide variety of government websites, company websites, press releases, annual reports and personal written and verbal sources.

9. VOLUMES

The forecasts are about production and drilling profiles but volume estimates are also created. As defined above, cumulative and remaining, including speculative undeveloped and speculative undiscovered elements, individually make up the ultimate volumes in an area through summing each profile over a time period. When volumes are considered

in terms of these profiles three aspects become evident:

- Are the volumes there?
- Can we access them?
- Is it worth it?

Total production volumes of all-oils (excluding ‘manufactured’ oils) in current Globalshift production profiles are given in Table 1.

GLOBAL REGION	Cumulative Production <i>(bn bbls to 2013)</i>	Remaining Production <i>(bn bbls to 2100)</i>	Ultimate Production <i>(bn bbls to 2100)</i>
North America	286	356	642
Latin America	165	213	378
Europe	242	227	469
Africa	123	187	310
Middle East	372	629	1001
Asia-Pacific	140	217	357
GLOBAL	1328	1829	3157

Table 1: Production volumes of all-oils (not including “manufactured oils,” defined above).

10. MAXIMUM OUTPUT

In the decades after the oil shocks of the 1970s the industry changed. In the 1980s the focus had been technology, especially offshore. New frontiers of science and geography were optimistically targeted, unfettered by global resource or environmental fears. But in the mid 1990s, the focus moved to availability of oil supplies with recognition of the twin threats of fewer lower cost reservoirs and environmental change.

By the turn of the millennium an impending supply gap had been identified with the realisation that unconventional oils, including oils from shales and oil sands, could not, in the long term, fully offset declining conventional oils. The relative importance of geographic and technological frontiers (such as the Arctic) once again became central to analysis of future supply. Forecast drilling and spending levels were

crucial for identifying investment strategies to meet these challenges.

After a deep recession, the world now appears resigned to higher and, more especially, volatile oil prices. Demand has been hit, and a future of sharp and rapid price rises and falls, and scarcity of low cost oil resources, is expected - with resources shared amongst growing, affluent populations living under the dual threat of resource wars and environmental disaster.

Although there are many complications attendant on selecting a year for a global maximum in production, the data show a peak in output of all oil supplies (fossil oils plus other oils) will occur in the mid 2020s unless a huge new oil source is identified (Figure 6). Deep waters and shale oil are unlikely to ever meet more than around 20% of global supply.

However, the sharp end of the oil industry, engaged in exploring for, developing, and producing energy supplies, have little interest in discussions of global peak. The subject adds little to investment attitudes except to encourage companies to explore. It rarely influences

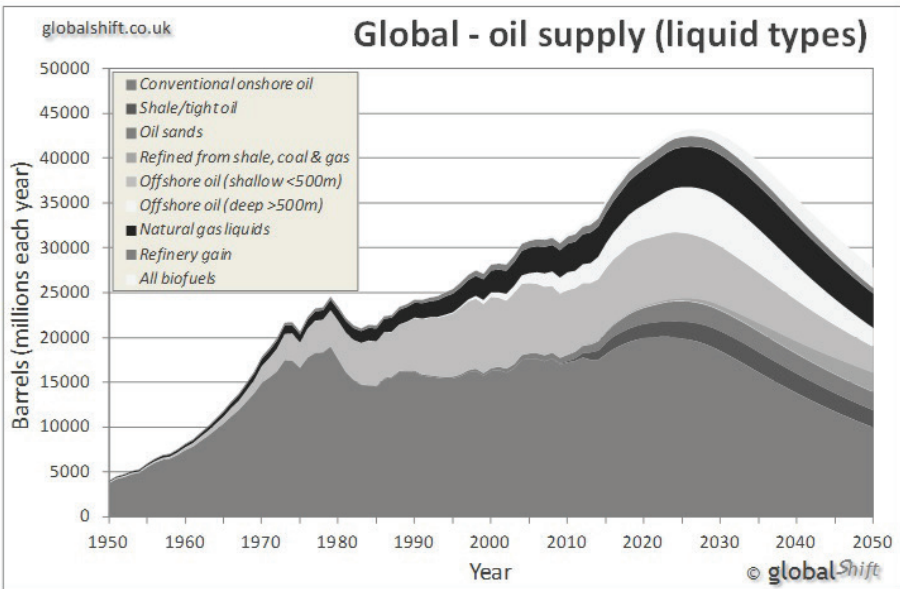


Figure 6: Historical data, and forecast, of all liquid types through to 2050. Shale/tight oil, oil sands and refined liquids act to maintain onshore output to the end of the 2020s, whilst new production from progressively deeper waters sustains offshore output.

government policy, especially since many economists and academics who engage in advising managers and governments have never worked in the oil exploration or production business.

Furthermore published material about growth and decline of energy supplies is affected by cognitive bias. The effects of social and emotional factors on economic decisions and the consequences for market prices and returns are bound to cause bias. Studies fall back on language such as; “production capacity” (to sit on the fence); “reserve growth” (to conjure up new volumes without examining the origin); and “years remaining” (to give comfort whilst ignoring the engineering issues). The term ‘*argumentum ad consequentiam*’ applies: ‘your theory is false because I do not like its consequences’.

The forecasts of Globalshift are not alone in showing that in the early 2020s, when the surge in output from the present-day growing countries ends, all countries will ramp up supply as fast as they can whilst the oil price escalates naturally and demand declines. There will then be room and economic pressure for more biofuels; CTLs; GTLs; even expensive oil extracted thermally from mined shales; as well as determined fuel substitution and ultimately conservation policies.

The true shape of the global all-liquids production curve during this period of plateau and peak will depend on demand volatility influenced by the fluctuating state of a global economy in periods of spiking oil prices, and on whether large-scale fuel substitution can be successful. The on-going balance of these issues will make the production curve more uneven than depicted by a simple supply model, since the period of plateau production must affect activity. Drilling activity in the relevant areas will follow a pattern consistent with production and price.

Many countries have already passed their oil production maximum. Libya (1970), Iran (1974) and Indonesia (1977), for example, had early peaks due to restriction of output in periods when production could have been greater. Although these countries may have growth potential they are unlikely to regain 1970s volumes. The USA (1970) has been rejuvenated by shale oil production, deep waters and NGLs just sufficient for it to regain the 1970 peak, but not in terms of energy return on investment.

Russia (1982) suffered a drop in output due to lack of investment as communism collapsed. Russia has grown almost back to former levels, but volumes and investment rates will probably be insufficient to return it to its 1980 maximum. The UK (1999) was the first of the major offshore

producers to reach maximum, closely followed by Australia (2000), Norway (2001), Mexico (2004) and Denmark (2004). Growing NGLs production in Australia will almost lead to recovery in Australia, whilst many other countries are being supported by new gas developments with associated oils.

Many peaks in oil production will occur in the 2020s. A higher oil price from the late 2000s drove comprehensive investment in most remaining remote and difficult areas. By 2025 there will be few opportunities in deep waters (even in Brazil), or in shale oil that are significant enough to delay a global maximum. OPEC countries that had growth potential will now be producing at capacity. Kuwait, Saudi Arabia, the United Arab Emirates, Angola and even Iraq are all expected to reach a peak in the 2020s. By the 2030s there will be few countries remaining with any unexplored or significant unexploited acreage.

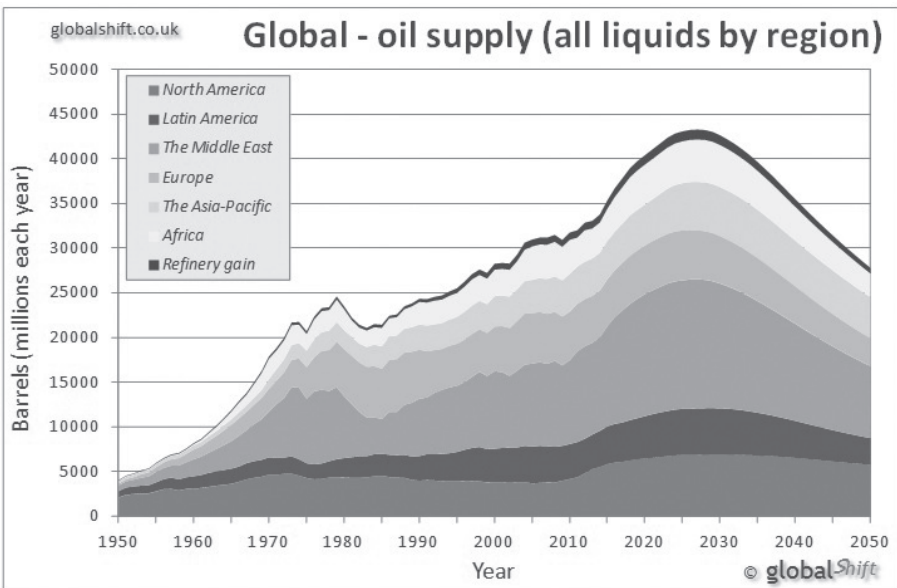


Figure 7: Historical data and forecast by region of all-liquids production, 1950 to 2050. North American oil supply has recently recovered due to shale oil from artificially fractured reservoirs and conventional oil from deep waters. The Middle East continues to grow as a percentage of the total, contributing a third of total oil to world supply by 2050.

These maxima are not signals of the end of exploration and discovery of oil. New oil is found every year. However, there will not be enough new discovery to fully offset decline in output from older finds. Most countries will never ‘run out of oil.’ Instead production will cease to rise. It will plateau for a period and then begin a slow and erratic decline (Figure 7) with occasional surges - such as the surge in output and consequent decline in oil prices (allied to weaker demand) in late 2014.

11. CONCLUSIONS

Oil companies, service companies and consumers have become increasingly reliant on oil that is hard to find and exploit because of:

- Geology; with new reserves trapped in complex, tight and restricted reservoirs
- Chemistry; with oils of inferior quality, requiring special technology to extract and process with lower energy content
- Geography; with new oil now buried under deep waters, in extreme climates and far from infrastructure
- Politics; with the low-cost, high return opportunities restricted to countries that are unstable and not keen to be exploited

Oil companies are spending more to maintain production rates and to increase them. Rising costs are mostly a result of aging fields and reduced opportunity. Many fields have produced for longer than expected as higher oil prices delay abandonment. These fields need maintenance. As the most profitable fields deplete companies are drilling smaller fields or more testing reservoirs in more difficult locations. Every so often new opportunities appear. These are driven by higher prices, such as shale oil, but each one is often more expensive than the last.

The service industry thrives as oil gets harder and more costly to find, but it is a volatile business. The service industry was in an upward cycle from 2009 which led to high inflation across most sectors. Consequently oil companies reported reduced earnings even though oil prices were stable. As costs went up, budgets fluctuated and oil companies became more selective in their choice of project. For example a glut in older deep-water rigs has materialised after a surge in new builds over the last three years. Oil companies are reining in expenditure growth, but increased volumes of higher specification equipment are coming into the market.

Low margin product lines must be sold or scrapped.

Service companies, more than ever, must rely on forecasts to plan effective investment strategies, appreciating both below-ground and above-ground issues. These forecasts should help companies, in an unbiased way, plan investment strategies for equipment such as drilling rigs and point them to regions where these will be required to cost-effectively take advantage of change.

Of course there is nowhere a complete or accurate database of oil production and reserves. Below-ground forecasts of supply will never be founded only on data and, in any case, above-ground events are erratic and can be catastrophic. No forecasts are always going to be right, but comprehensive forecasts based on real data with transparent methodology and definitions, avoiding simple extrapolation of trends, and aimed at investment decisions are, at least, founded in reality. Forecasts will always be relevant to the oil and gas industry for as long as it exists.