# Modelling Oil And Gas Depletion

C. J. CAMPBELL

## 1. INTRODUCTION

Oil and gas fuel the modern world, but are finite natural resources subject to depletion. Today more than fifty countries are producing less oil than at some date in their past, with some countries being long into decline. The study of hydrocarbon depletion is thus a critical issue for humankind. But the topic is a good deal less than an exact science, mainly because of the very poor data that are available.

This article summarises the data and methodology used by the author in his current oil and gas forecast model.

## 2. DATA

As already mentioned, the data for such modelling are generally poor, and there are historical reasons for this.

In the United States much of the onshore mineral rights were held by the landowner, which carried financial implications as an oil discovery became a valuable asset. It led the Stock Exchange to impose strict rules as to what could be reported as reserves. They were designed to prevent fraudulent exaggeration, but under-reporting was smiled on as laudable caution. The international oil companies quoted on the Stock Exchange were subject to the same rules. Reserves were classified as *Proved,* *Probable,* and *Possible* with the meanings the words imply. It was normal to estimate the size of a field on the basis of its *Proved* in full, two-thirds of its *Probable* and one-third of its *Possible*. More recently, probabilistic methods have also been employed, with the *Mean* or *Mode* values being taken as the best estimate.

There are also many commercial and political factors to be taken into account. The oil companies competed with each other, and naturally aimed to maximize their profits. Opening up a new prolific province such as Texas could give a glut of oil, depressing price with far-reaching financial consequences. This prompted moves to restrict production to support the price. In 1928, the major companies met at the Achnacarry Castle in Scotland to sign the *As-Is Agreement*, which set relative production limits; and in 1930 the US Government restricted production to a certain number of days a month in a policy administered by the Texas Railroad Commission.

Russia nationalised its oil industry in 1928, followed by Mexico ten years later, which set examples for Venezuela and several Middle East countries to do so later still. In 1960, the major producing countries formed OPEC to limit production between themselves to support price based on their respective reported reserves, oil revenue having become a critical component of their national budgets.

The commercial oil companies naturally needed to follow what their competitors were doing around the world. This led to the creation of a confidential industry database managed by Petroconsultants in Geneva. It maintained informal contacts with the companies and tracked their operations around the world, collecting information on concessions, the location of exploration wells, the size of discoveries and the level of production. The companies wanted valid information, and hence also gave this in return. But Petroconsultants changed ownership with the death of its owner in 1995, and some of the special relations with the oil companies were lost. Other commercial databases have since been built, but they are costly and subject to strict legal confidentiality, making it difficult for analysts outside the industry to gain access.

The main public-domain sources of oil and gas data are: the BP *Statistical Review*, the *Oil & Gas Journal*, *World Oil*, and the US Energy Information Administration. In addition, various countries publish national statistics, one of the best being that provided by the Norwegian Petroleum Directorate. In earlier times, the industry was dominated by seven major oil companies, but recent years have seen the proliferation of small promotional companies, and this also explains in part why gathering valid data has become more difficult.

It is important also to mention that OPEC official *Proved Reserves* have become extraordinarily unreliable. In 1985, at a time of low oil prices, Kuwait increased its reported reserves from 64 Gb to 90 Gb, although nothing significant had changed in its oilfields. The data suggest that the country may have changed to reporting its *original* rather than *remaining* reserves by not deducting past production; as indeed is normal industry practice when determining the respective ownership of an oilfield that crosses a lease boundary or frontier.

In 1987, Kuwait reported a possibly genuine further small increase in its reserves to 92 Gb, but that seems to have been too much for the other OPEC members. Abu Dhabi matched Kuwait's reserves exactly (up from 31 Gb); Iran went one better, to 93 Gb (up from 49 Gb); and Iraq out-did both at an even 100 Gb (up from 47 Gb). Venezuela for its part increased its declared proved reserves from 25 Gb to 56 Gb, but this included its *Heavy Oil* that had not previously counted for quota purposes. Saudi Arabia could not match Kuwait's move because it was already reporting larger reserves, but in 1990 increased its declared reserves from 170 to 258 Gb.

The oil minister of Kuwait has recently stated that the country's *Proved Reserves* stand at 28 Gb and the *Proved & Probable* at 51 Gb. This sounds reasonable: adding 51 Gb to current cumulative production of 41 Gb does indeed give *original* reserves (i.e., before production started) of 92 Gb. The distortions are important because of the large share of world production coming from the OPEC countries.

Finally, it is worth noting that the recent boom in 'fracking' *Tight Oil and Gas*, though yielding significant additional supplies in the US, partly reflects promotion and speculation by small companies, as actual profits are minimal. This speaks of a radical change in the nature of the oil industry, as no company would follow such an approach if adequate alternative supplies were available.

## 3. MODELLING DEPLETION

The foregoing has tried to summarise the nature of the oil business, by way of an introduction to the forecast model described below. The steps taken in the analysis for this model are listed, and the final results can be seen in Figure 1, and in detail by country in the recent update of an 'Atlas' of oil and gas depletion' published by the author in 2013 [9].

Ideally the regions modelled should be *Petroleum Systems*, namely areas having common geological conditions, but in general oil forecast modelling is more often done by general geological basin, or by country. The latter approach is easiest as this is how the data are often classified. It is the approach adopted for the model described here, where each of the world's 64 largest oil and gas producing countries is modelled, plus an 'other' category that combines the small producing countries.

Modelling countries separately is particularly helpful in identifying anomalies and uncertainties in the data, particularly once *Depletion Rates* are calculated. Results are summed to give regional and world totals. Calculations run from when production started in each country out to 2100. The spreadsheets perform the calculations annually from 1930 to 2050, and use single-number aggregates for data and calculations prior to 1930, and for the period 2051 to 2100.

Modelling discovery and production to the end of the present century, rather than to some hypothetical date when production stops, has been found expedient for several reasons. It avoids the need to worry about the fairly irrelevant 'tail-end' of production, recognising that the last barrel is unlikely to be found or produced. Also it allows a country's *Total Production to the end of the Century* ('*Total*') to be split into that from *Known Fields* ('reserves'), and that from fields Yet-to-Find. This avoids the many ambiguities surrounding the data and definitions of reserves. Also, by each category being expressed as a percentage of '*Total*', it allows the reasonableness of the past and future discovery to be compared on the basis of what is known about each country's petroleum geology.

Two examples of the spreadsheets used are given in the Appendix. The analysis involves the following steps for each country modelled:

### *Step 1.*

To model future total oil and gas production correctly, it is important to identify and model individually the different categories of oil and gas, as each has its own endowment, production characteristics, cost range, and depletion profile. Unfortunately there is no standard classification for categories of oil and gas, and this is the cause of much confusion in the public-domain oil and gas statistics. The following categories are used in the model:

1. *Regular Conventional Oil and Gas*: Oil from fossil sources, other than from the categories listed below. (A liquid, known as *condensate*, which naturally condenses from gas, is treated together with *Regular Conventional* oil). *Regular Conventional Oil and Gas* make up the majority of all oil and gas currently produced.

2. *Heavy Oils:* Oils with a density greater than 17.5$^{o}$ API, including bitumen. (Degree API is a measure of density). There is no agreed standard cut-off for the definition of *Heavy oil*: Canada, for example, uses 25$^{o}$ API, while Venezuela uses 22$^{o}$ API. The figure chosen for the model, of 17.5$^{o}$ API, is relatively low; but is seen as useful so that all oil that can be produced in more or less normal ways is included as *Regular Conventional.*

3. *Oil Shale*: Oil produced by heating immature source-rocks to retort the kerogen contained therein.

4. *Tight Oil and Gas (*also called *Shale Oil and Gas):* Otherwise conventional light oil, and gas, that is derived from rocks lacking adequate natural porosity and permeability, but which can yield adequate production when artificially fractured. This oil and gas is modelled distinct from *Regular Conventional* because of the large number of wells that need to be drilled, and the rapid declines typical from such wells (and hence also the relatively high energy requirement per average quantity produced).

5. *Deepwater Oil and Gas*: Oil produced from water depths greater than 500m.

6. *Polar Oil and Gas*. Oil and gas produced from fields located above the Arctic Circle. Both *Deepwater* and *Polar* are modelled distinct from *Regular Conventional* because of their generally higher cost, and typically rather different production profiles, than the latter.

7. *Natural Gas Liquids* from gas plants (where production, though included in the oil data, follows gas field discovery and production).

8. *Other Non-Conventional oils* (coal-to-liquids, gas-to-liquids) *and gases* (coalbed methane, gas from underground coal gasification, possible methane hydrates, etc.)

Not modelled are liquid or gas fuels produced from biomass. *Regular Conventional* oil has dominated past production, and will continue to do so for many years to come. The peak of its production in 2005 was therefore a critical turning point in global oil supply.

### Step 2.

The next step is to input past production by year. Published production data are reasonably reliable, although war-loss, which is to be regarded as production in this context insofar as it reduces reserves by like amount, is usually not taken into account but is included in the model. The spike in 1992 oil production in Figure 1 reflects Kuwait's war-loss.

It is not always easy to distinguish oil and gas production by the categories given earlier, but an attempt has to be made even if the result is no more than an approximation. This difficulty is however relevant only in those countries having a spread of different categories. In the literature production is normally reported in thousands of barrels a day (kb/d), which in the model is converted into billion barrels a year (Gb/a). These data are then summed by year to give cumulative past production, and this in turn determines the annual percent depleted and the *Depletion Rate* (annual production as a percent of total future production ) once Step 3 has been completed.

### Step 3.

The modeller must now take a deep breath and try to make reasonable estimates of the *Total quantities to be produced by 2100*, for each oil and gas category.

For *Regular Conventional* oil and gas, the following three statistical methods can be used: a) the *Creaming Curve* which plots cumulative discovery against cumulative exploration wells ('new-field wildcats') and extrapolates the trend to asymptote; b) the *Parabolic Fractal* which plots individual field size against rank on a log-log scale; and c) the *Derivative Logistic* which plots annual/cumulative production against cumulative production, and extrapolates any indicated trend. The first two methods need access to industry proved-plus-probable ('2P') data. The third approach works with public-domain data, but sometimes is not very useful, especially if a country's production is still some way before its peak. All three approaches are used where possible, and the results compared. Deriving the *Totals to be produced by 2100* is an iterative process, and is subject to examination of other relationships. For example, if the indicated current *Depletion Rate* for a country should exceed about 7% it suggests that the *Total produced to 2100* has been under-estimated.

Particular care is needed with former Soviet Union ('FSU') countries, as here the industry data on discoveries are probably closer to proved-plus-probable-plus-possible ('3P') than 2P, and need to be reduced. An estimate of the reduction ratio to use can be obtained by examination of plots of individual field production vs. cumulative production. Such plots, once a field is in decline, linearise exponential decline, and hence allow an estimate to be generated for the field's ultimately recoverable resource ('URR').

Significant efforts must also be made to arrive at sensible data for the OPEC countries. As explained in the section above on data, the public-domain reserves data for these countries are dubious, with in the past the declared proved (1P) reserves often, against logic, *exceeding* the data held in the industry databases for the countries' 2P reserves. Moreover, in recent years, in some industry databases and for some OPEC countries, the 2P data have grown to be closer to the public-domain 1P data. One approach employed in the model to address these uncertainties is to reduce an OPEC country's public-domain reserves by its cumulative production over the period that these reserves have remained static. Other approaches are also used. Overall, considerable judgement is needed to come up with consistent, justifiable data for the OPEC countries.

For oil and gas other than *Regular Conventional*, different approaches are needed, see Step 8.

### Step 4.

Subtract *Past Production* from the *Total to 2100* to deliver *Future Production* and then estimate the percentage of *Future* coming from *Known* fields, namely '*Reserves',* based on published and available confidential numbers which commonly show a range, sometimes a wide one. Subtracting the *Known* from the *Future* delivers the *Yet-to-Find*.

There is a difficulty with so-called *fallow fields*, which are discoveries that have not been developed for whatever reason and are not therefore counted as having *Reserves*. Their holdings, to the extent they enter the database, can best be treated as *Yet-to-Find*. It is another iterative process to try to come up with a reasonable working hypothesis, recognising that it is subject to revision as better information becomes available.

### Step 5.

Input reported discovery by year, again from industry '2P' data, distinguishing that in giant fields (>500 Mb), and then apply a small *growth* factor so that the total matches the sum of the assessed *Past Production* and the *Known Future*. The sum gives the total discovered to-date which is a useful statistic. Then, input past exploration drilling in so-called *New Field Wildcats* by year and estimate the future rate, assuming, say, a ten percent annual decline in a mature country. *New Field Wildcats* need to be distinguished from *New Pool Wildcats*, referring to additions to existing fields, and any reserve revisions have to be backdated to the date of the original discovery.

### Step 6.

Take another deep breath and estimate the future production *profile* by year based on several considerations. If the country has passed its midpoint of depletion and is in decline, it may be assumed that the decline continues at the current *Depletion Rate*. Naturally there will be departures from the indicated downward trend for all sorts of above-ground reasons, but the model self-adjusts, so that if less than the amount estimated is produced in a particular year, more is left for the future and vice versa. If the country has not yet reached its midpoint, as is the case with most OPEC countries, the production to midpoint has to be assessed in the light of local circumstances, it being normal to assume a plateau. Today, some fifty countries are past their midpoint of *Regular Conventional* oil, many being long into decline.

The analysis for gas production is similar to that described above for oil, but the model assumes that gas production normally reaches a plateau, set by infrastructure limits, including pipeline capacity, lasting from when a country is 30% to 70% depleted, after which production declines steeply at the then-current depletion rate. For gas it is also necessary to take into account the amounts flared, and that re-injected to maintain pressure in oilfields.

### Step 7.

Into the spreadsheets insert oil and gas consumption, and also other parameters of interest such as population, the country's area, population density, and trade; and summarise the various relationships involved, including the time-lag between the actual date of peak production and the indicated date of the indicated midpoint of depletion. It is a lengthy iterative process to use the various relationships to try to spot and correct any anomalous situations.

One statistic *not* to use is the *Reserve to Production Ratio* quoted in years, as reported for example in the BP *Statistical Review*. A recent Prime Minister of Britain was almost certainly being advised by this ratio when he declared that there could be 'no oil supply problem for 40 years', even though it is absurd to assume that current production can stay flat for a given number of years and then stop dead overnight, when in practice all oilfields decline slowly to final exhaustion.

### *Step 8.*

The *Non-Conventional* resources of oil and gas have also to be evaluated, each having its own production characteristics. It is a much more difficult task, but fortunately carries less weight, given that world production is dominated by *Regular Conventional* oil, and that this will continue to be the case for many years to come. A variety of sources need to be used, including industry Associations for the type of resource considered, and realistic estimates made of likely production into the future, taking into account resource production costs and projected industrial capacity.

### *Step 9.*

Finally, the data generated by the model can be presented in a variety of tables and graphs by country and by region, as well as for the World as a whole. The graphs include:

Graph 1: Production of Oil and Gas by Year 1930-2050 (area graph).

Graph 2: Status of Oil Depletion showing: a). initial endowment b). production c). remaining reserves (area graphs).

Graph 3: Cumulative discovery vs. Cumulative new-field wildcats (line graph).

Graph 4: Derivative logistic – 'Hubbert linearisation': Annual/Cumulative production vs. Cumulative production (line graph); with an arrow extrapolating the indicated trend. A clear trend is apparent in some countries, but not in all.

Graph 5: Production with a superimposed Hubbert Curve (Logistic).

Graph 6: Discovery (bars) versus production (line).

Figure 1 is an example a 'Type-1' graph, showing the model's forecast for all fossil oil (i.e., excluding biofuels), and all fossil gas (excluding biogas), out to 2050. There are many caveats on such a projection as examination of the methodology set out above will have made clear, but

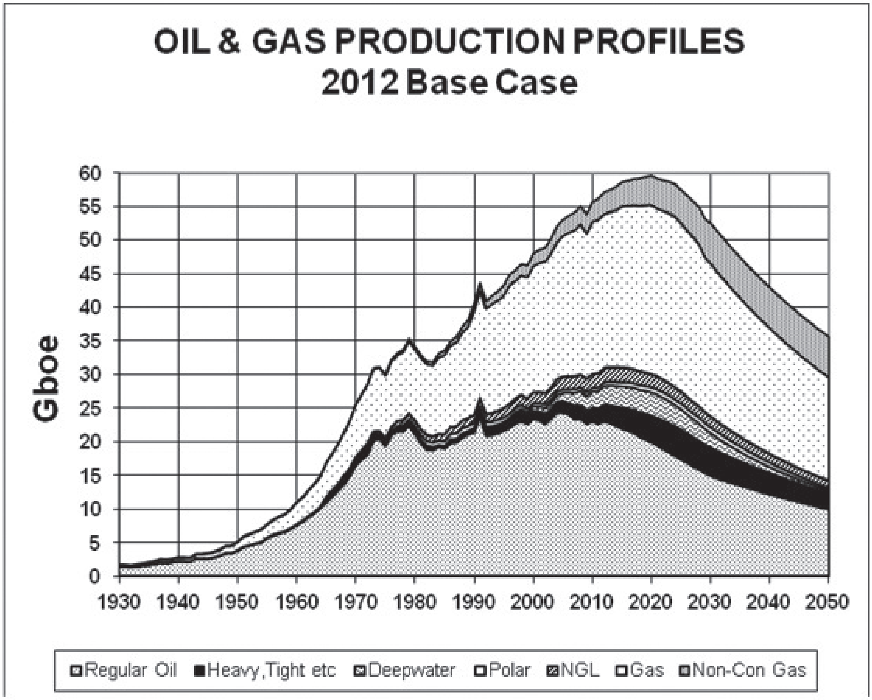


**Figure 1:** Current model forecast, as of 2014, reflecting an updated '2012 Base Case' model.

This gives total global production of all fossil oil and gas (and hence excludes production of oil and gas from biomass). Production of coal and gas to liquids, and of oil reported from kerogen, are not modelled explicitly but are assumed small throughout this forecast period. For definitions of the various categories of oil and gas shown see those in 'Step 1' above. (NB: The spike in production in 1992 reflects war loss in Kuwait, when some 2 billion barrels of oil went up in smoke.)

The Figure shows that the production of Regular Conventional oil peaked in 2005; while the production of all categories of oil is expected to peak in 2015; and all categories of gas in 2024. In this model, the global production of all fossil hydrocarbons reaches its peak about 2020.

Given the uncertainty of the underlying data, the importance of this Figure is not in the precise dates given, but in the decline indicated once the various peaks are past.

what is also clear is the nature of the hydrocarbon supply challenge that Mankind almost certainly faces in the relatively near future.

## 4. MIDPOINT PEAK

As mentioned, the study of oil and gas depletion is far from an exact science, principally because the data (and especially the public-domain data) on production, reserves and discovery are unreliable, and also because there is no standard classification of the different categories of oil and gas. Jean Laherrère has recently given a full review of these problems [31].

But, oil being a finite resource, it is evident that there is such a thing as an *Oil Age* in an historical context. In a general sense, it is reasonable to assume that the economic expansion of the *First Half* of the *Oil Age* will be followed by contraction during the *Second Half*, and that the turning point will come approximately at the midpoint of depletion. That said, there are departures in individual countries for all manner of reasons, including political incentives and constraints on both exploration and production.

## 5. NET-ENERGY

A new feature of the model, not yet included in the 'Atlas' [9], is accounting for *Net-Energy*. This topic has been studied for some years, especially by Professor Charles Hall and his group at the State University of New York at Syracuse. It is a critical issue, and also has an important impact on the range of uncertainty regarding future production forecasts of the different categories of oil and gas. It is the focus of a recent book by Tim Morgan, *Life After Growth* [53] which states that it is energy, not money, that drives economies.

The data in Figure 1 can be modified to reflect not the *total* barrels of oil (and barrels of oil equivalent, for gas) produced, but the '*net-energy*' contributed to society by these barrels after the energy required for their production is subtracted off.

There are many difficulties in determining net energy, and indeed in defining what should be covered in such calculations. The assessment could simply refer to exploration activity, or to the wellsite operations themselves, or ideally should also cover the energy consumed in pipelines, tankers, refineries and filling stations before it reaches the final consumer.

Calculating the actual energy consumed is thus a difficult task, but in a sense a comparison between the price of crude oil and marketed product gives an indication, although naturally distorted all by sorts of financial elements, including taxation, oil company profit and administrative charges.

In the initial model reported here the data for net energy are very approximate, and open to criticism and revision. So this calculation should be seen mainly as just a 'first pass' to understand the general nature of the issue. The assumptions used are:

An average oilfield of *Regular Conventional* oil will yield 20 times the total energy consumed in its exploration, production, refining and delivery over its lifetime; its 'energy return on energy invested' ('EROEI') of these activities. Put another way, for every 100 barrels of oil produced by the field, its yields 95 useful barrels of energy to society. So the 'net-energy' variant of the model multiplies the barrels of *Regular Conventional* oil in Figure 1 by 0.95 to yield an estimate of the useful 'net-energy' barrels.

Net energy yield varies over the life of a field. An aging North Sea field requires more maintenance than when at its prime, and improved recovery technology also makes heavy demands on energy. There are also close links to the field's profitability, which is ultimately based in part on the net energy the field delivers, so more detailed modelling would vary the EROEI ratio assumed across a field's life.

*Deepwater oil* and oil from *Polar regions* might be expected to have somewhat lower EROEI ratios. Here an EROEI of five is assumed for both types of oil, resulting in net-energy factors of 0.80.

Further down the energy scale, so-called *Tight Oil*, obtained by artificially fracturing productive rocks lacking sufficient porosity and permeability to form a normal reservoir, is assumed in the model to yield only four times the amount consumed in all the steps to produce; so barrels of *Tight Oil* in Figure 1 are multiplied by 0.75 to yield net barrels.

At possibly the bottom of the current energy scale is oil from *Tar Sands*, where EROEIs of 3 have been quoted in the literature (and even as low as 1.5), but where for simplicity the model assumes the same EROEI (and hence 'net-energy' factor) as for *Tight Oil*. (A similar low EROEI may well apply in future to oil produced by retorting kerogen from oil shales.)

NGLs (produced from gas) are modelled on their energy content, so total barrels produced are multiplied by 0.80 to give the net-energy barrels.

Regular conventional gas is assumed – on very limited data – to have perhaps the same EROEI of 20 as regular conventional oil; while Non-conventional gas (which can come from a wide variety of sources) is assumed to have an approximate EROEI of 6.7 (giving a net-energy factor of 0.85).

Putting these data together yields Figure 2, which should be compared to Figure 1.

Note: As the text mentions, there are significant uncertainties in the data used here, and in the calculation, that await resolution.

As can be seen the main overall effect to reduce the total barrels of oil equivalent produced (down from a peak of 60 Gboe/yr. to 55 Gboe/yr. when measured in net-energy terms); and in particular to reduce the contributions to world supply that come from the various *'Non Regular Conventional'* hydrocarbons.

Moreover, net energy carries another implication in relation to the resource assessment of the different categories of oil and gas, and their future production profiles. If, for example, estimates of future production

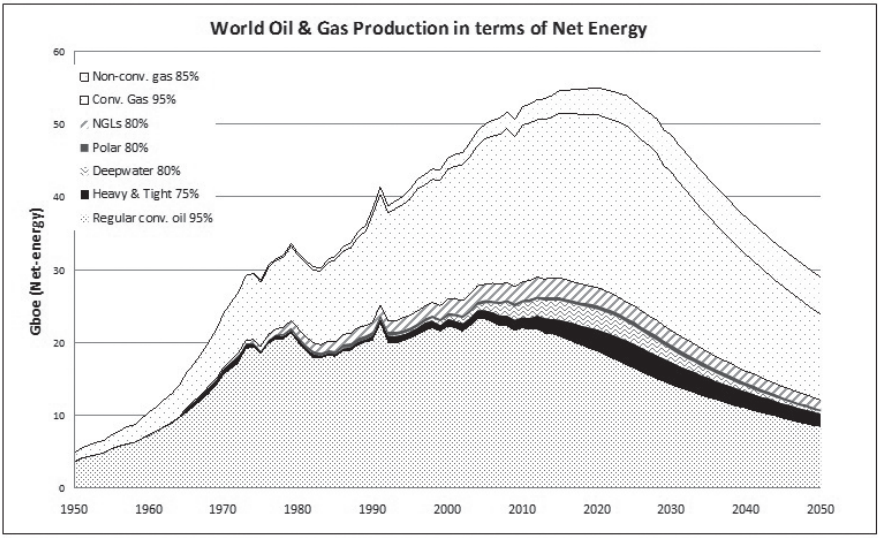


**Figure 2:** The same data as Figure 1, but now expressed in terms of 'net-energy barrels of oil equivalent' (i.e., barrels of useful energy delivered to society), once the energy used in the production of the oil and gas is subtracted off.

from a field of *Regular Conventional Oil* range from 100 Mb to 150 Mb, this gives a range of uncertainty of 50 Mb. If this oil has a net energy yield factor of 0.95, the corresponding uncertainty in terms of net energy is 47.5 Mb. If, on the other hand, a field of *Tar Sands* or *Tight Oil* with the same volume range has a net energy factor of 0.75, the uncertainty is less, at only 37.5 Mb.

This is an important result because it means that *Regular Conventional* oil and gas will continue to dominate world supply in *net-energy* terms, and the uncertainties relating to the amount coming from the *Non-conventional* oil and gas sources with lower net-energy yields are less significant.

## 6. CONCLUSIONS

It is recognised that this study does not perhaps comply with strict scientific standards, as the input data are far from reliable, and there are many places where estimates - and even guesses - of the numbers to use are needed. In particular, as mentioned, official reported oil and gas reserve estimates are subject to many commercial and political pressures.

Moreover, it is accepted that earlier versions of this model placed the global 'all-oils' peak around 2008, not then giving sufficient attention to the growth of costly *Non-conventional* oils (such as *Light-Tight*), made possible by the dramatic rise in oil prices.

Nevertheless the model is believed to deliver a valid overall picture of the situation, which is of critical world importance given the overwhelmingly dominant role of energy from oil and gas for society. The main values of the study are to highlight the coming post-peak decline, and to identify the need for better information with which to improve the model.

Despite these caveats, there is however increasing recognition that the peak of *Regular Conventional* oil was indeed passed in 2005 as indicated by the model (and where, incidentally, this peak came one year after the reported peak of oil production from the six major oil companies).

This peak of *Regular Conventional* oil prompted the oil price to surge to almost $150/bbl in mid-2008, compared with an average of $25/bbl over the previous century (2011 dollars; BP *Statistical Review*), and to stay in the $80/bbl to $100/bbl range for the majority of the period since. The high oil price has, in turn, contributed to the current global economic and financial problems, said to rival those of the Great Depression of 1930.

Turning to the various *Non-Conventional* sources, claims are made that these, especially *Light-Tight* oil, will yield significantly higher quantities than indicated here. But if the *net-energy* yield is taken into account, the impact of such increases is likely to be relatively small for the reasons explained above.

Overall, based on this model, it is fairly clear that the *First Half* of the *Oil Age* is about over. Society and governments are likely to have difficulty in coming to terms with what unfolds, as the *Second Half* of the *Oil Age*, with the supply of energy from oil and gas declining from natural depletion, is likely to see radical changes in the way we have to manage our affairs. Moreover, debt, which played a central role in the modern world as bankers lent more than they had on deposit confident of future economic growth, may no longer be so useful a construct as these critical energy supplies decline.

This is not necessarily a doomsday message. Once people come to understand that the depletion of these two critical fossil energy supplies is imposed by Nature, they may react in positive and constructive ways. Renewable energy can increasingly be tapped from wind, wave, tide, geothermal and solar sources; and energy-saving measures, for which there is plenty of scope, become more widely adopted. There may also be a reversion to localism, as people again come to rely on whatever their particular region can support.

It is a fascinating and important subject to observe, and to try to understand. It is hoped that the model presented here can help, in some measure, support the latter objective.

## 7. BIBLIOGRAPHY & REFERENCES

1. Aleklett K.,2012, *Peaking at Peek.* ISBN 978-1-4614-3423-8
2. Bardi U.,2011, *The Limits to Growth Revisited*. ISBN 978-1-4419-9415-8
3. Bentley, R.W., S.A. Mannan, and S.J. Wheeler, 2007, *Assessing the date of the global oil peak: The need to use 2P reserves.* Energy Policy, vol. 35, pp 6364-6382, Elsevier, 2007.
4. British Petroleum Co., *BP Statistical Review of World Energy*. Published annually by BP, London.
5. Brown L.R., 2012, *Full Planet, Empty Plates.* ISBN 978-0-393-34415-8

6. Campbell C.J., and J.H.Laherrère, 1998, *The end of cheap oil*. Scientific American March 80-86
7. Campbell C.J., 2005, *Oil Crisis*; Multi-Science Publishing. ISBN 0906522-39-0
8. Campbell C.J., 2011, *Peak Oil Personalities*. ISBN 978-1-908378-06-4
9. Campbell C.J., 2013, *Campbell's Atlas of Oil and Gas Depletion*. Springer. ISBN 978-1-4614-3575-4
10. Campbell C.J., 2013, *The Oil Age in Perspective* ; Energy Exploration & Exploitation. vol. 21-2 148-164
11. Clugston C.O., 2012, *Scarcity – Humanity's Final Chapter*. ISBN 978-1-62141-250-2
12. Deffeyes K.S., 2001, *Hubbert's peak - the impending world oil shortage*. Princeton University Press 208pp
13. Deffeyes K.S., 2005, *Beyond Oil – The View from Hubbert's Peak*. Hill & Wang, N. York 202p
14. Dittmar M., 2009, *The Future of Nuclear Energy : Facts and Fiction*. www.theoildrum.com Aug 5- Nov 10. Also a 2011 update
15. Duncan, R.C. & Youngquist, W., 1999, *Encircling the peak of world oil production*. Natural Resources Research, Vo. 8, No. 3
16. Energy Information Administration – annual reports.
17. Fleming D., 2011, *Lean Logic*. ISBN 978-0-955-0849-6-6
18. Gore A., 2000, *Earth in Balance*. ISBN 978-1844-074846
19. Gore A., 2009, *Our Choice – A Plan to Solve the Climate Crisis*. ISBN 978-0-7475-9098-9
20. Hall D.C., 2004. *External Costs of Energy*. Encyclopaedia of Energy 651-667 2.
21. Heinberg R., 2003, *The Party's Over*;.New Society Publishers 274p
22. Heinberg R., 2006, *The Oil Depletion Protocol*. ISBN 10-0-86571-563-7
23. Heinberg R., 2013, *Snake Oil : How Fracking's False Promise of Plenty Imperils our Future*. ISBN 978-0-9767510-9-0
24. Hirsch R.L., R.H.Bezdek & E.M.Wendling, 2010, *The Impending World Energy Mess*. ISBN 9-781926-837116
25. Hughes J.D., 2013 *Drill, Baby, Drill – can unconventional fuels usher in a new era of energy abundance?* Post Carbon Institute ISBN 978-1-482555233

26. International Energy Association, *World Energy Outlook* (published annually)
27. International Monetary Fund, 2012. *The Future of Oil: Geology versus Technology.* IMF Working Paper WP/12/109
28. Klare M.T., 2008, *Rising Powers – Shrinking Planet – The New Geopolitics of Energy*. ISBN 978-0-8050-8064-3
29. Laherrère J.H. 2003, *Will the natural gas supply meet the demand in North America?* International Journal of Global Energy Issues 19 n°1 2003
30. Laherrère J.H., 2013. *Very short world oil and gas production forecasts 1900-2100.* http://www.theoildrum.com/node/10009
31. Laherrère J.H., 2014. *Oil and gas perspectives in the 21st Century*. ESCP Europe London Campus
32. Leggett J., 2005, *Half Gone*. 312p, ISBN 1-84627-004-9
33. Leggett J., 2013, *The Energy of Nations: Risk Blindness and the Road to Renaissance.* ISBN 978-0-415-85782-6
34. Leonard, R., 2013, *The New Oil World : the Game has changed, but how ? Africa is becoming a Major New Player in the new World Hydrocarbon Order*. American Foreign Policy Interests 35:352-359
35. Longwell H.,2002, *The future of the oil and gas industry: past approaches, new challenges*. World Energy 5/3 2002
36. Norwegian Petroleum Directorate. *Facts* (published annually)
37. Perrodon A., J.H.Laherrere and C.J.Campbell, 1998, *The world's non-conventional oil and gas*. Pet. Economist
38. Peters, S., 2004, *Coercive western energy security strategies: Resource wars as a new threat to global security*. Geopolitics, Vo. 9 No 1, 2004
39. Powers L.W., 2012, *The World Energy Dilemma*. ISBN 978-1-59370-271-7
40. Reynolds D.B., 2011, *Energy Civilization – The Zenith of Man.* ISBN 978-0-615-52155-8
41. Rubin J. 2012, *The Big Flat Line: Oil and the No Growth Economy.* ISBN 978-0-230-34218-7
42. Simmons M.R., 2005, *Twilight in the Desert*. ISBN 0-471-73876-X
43. Skipper K., 2001, *Petroleum Resources of Canada in the Twenty-First Century* (AAPG Memoir 74, Chapter 8). ISBN 0-89181-355-1

44. Skrebowski, C., 2004, *Oil field mega-projects 2004.* Petroleum Review Jan. 2004
45. Stanton W., 2003, *The Rapid Growth of Human Populations 1750-2000.* ISBN 0-906522-21-8
46. Tolub L and M.A. Erb 2010, *Oil price band for the next decade : Utopia versus Reality.* Swiss Derivatives Review, Issue 43, Summer 2010.
47. Yergin D.,1991, *The Prize: the epic quest for oil, money and power.* ISBN 0-671-50248-4
48. Youngquist W., 1997, *Geodestinies: the inevitable control of earth resources over nations and individuals*. ISBN 0-89420-299-5
49. Ziegler, W.H., C.J.Campbell & J.J.Zagar, 2009, *Peak Oil and Gas*; Swiss Bulletin for Applied Geology 14/1-2
50. Zittel W., J. Zerhausen & M.Zerta., 2013, *Fossil and Nuclear Fuels – the Supply Outlook*. Energy Watch Group. www.energywatchgroup.org
51. Hall C. et al., 2003, *Hydrocarbons and the evolution of human culture*: Nature v. 4626.
52. Morgan T., 2014, *Life after Growth – How the Global Economy really Works and why 200 Years of Growth are Over*. ISBN 978-0857-193391

# APPENDIX: EXAMPLE SPREADSHEETS OF THE OIL & GAS FORECAST MODEL

## A1. Example Spreadsheet for Mexico

Below is part of the spreadsheet for *Regular Conventional* oil (as defined in Step 1 of the main text, above) for Mexico. The full range of individual year rows covers 1930 to 2050. Columns are listed alphabetically (A to O) from left to right, and the rows are numbered consecutively downwards. There is a corresponding spreadsheet for Mexico for *Conventional* gas.

Other categories of oil and gas (for countries that do, or will, produce these) are modelled in small additional spreadsheets (not shown here, but given in [9]); and results are accumulated to yield global production forecasts of 'all fossil oil', and 'all fossil gas'.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **COUNTRY** | **Mexico** | | | | | | **REGION** | | **L. America** | | **Revised** | 26/4/14 | 2013 |
| **PRODUCTION** | Gb | % | **MIDPOINT** | | | **TRADE** | **PEAK** | | **RESERVES** | | | **WILDCATS** | |
| **Current** | 0.94 | | Gb | | 28.00 | | Date | 2004 | O&GJ | 10.26 | Av | Past | 1574 |
| **PAST** | 41.84 | 75% | Date | | 2000 | | Depleted | 58% | BGR | 11.39 | 13.37 | Future | 119 |
| **FUTURE** | 14.16 | 25% | Lag | | 4 | | Disc | 1977 | BP | 11.40 | SD | Av Disc | 34.68 |
| **Known** 90% | 12.75 | 23% | **GIANTS** | | | | Lag Disc | 27 | ENI | 10.16 | 0.64 | **DEP RATE** | |
| **To be found** | 1.42 | 3% | Total | | 30.17 | **Post** | Wildcat | 2003 | EIA | 10.26 | 19.452 | MP | 3.6% |
| **Discovered** | 54.58 | 97% | % | | 55% | **2012** | Static Yr | 0 | Static | 0.00 | Growth | Current | 6.2% |
| **TOTAL** | 56.00 | | Last | | 1999 | DR | 5yr Trnd | -1% | Other | | 91% | Final | |
| **Consume kb/d** | 2082 | **Per Cap** | 6 | **Pop.** | 117.6 | 3% | **Area** | 1.966 | **Density** | | 60 | **Trade** | 480 |

| **DATE** | **PRODUCTION** kb/d | Gb/a | Cum | Y-t-P | Dep | **Cons -ume** | | **DEP. RATE** | **DISCOVERY** Giant | All | Grth | Cum | **WILDCATS** | Cum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre 1930 | | | 1.56 | 54.44 | | | | | 2.22 | 3.72 | 3.39 | 3.39 | | 64 |
| 1930 | 108 | 0.040 | 1.60 | 54.40 | 3% | 213 | -104 | | | 0.00 | 0.00 | 3.39 | 3 | 67 |
| 1931 | 91 | 0.033 | 1.63 | 54.37 | 3% | 215 | -124 | 0.06% | | 0.20 | 0.18 | 3.57 | 11 | 78 |
| 1932 | 90 | 0.033 | 1.67 | 54.33 | 3% | 217 | -127 | 0.06% | | 0.00 | 0.00 | 3.57 | 3 | 81 |
| 1933 | 93 | 0.034 | 1.70 | 54.30 | 3% | 219 | -126 | 0.06% | | 0.00 | 0.00 | 3.57 | 4 | 85 |
| 1934 | 105 | 0.038 | 1.74 | 54.26 | 3% | 221 | -117 | 0.07% | | 0.00 | 0.00 | 3.57 | 5 | 90 |
| 1935 | 110 | 0.040 | 1.78 | 54.22 | 3% | 223 | -113 | 0.07% | | 0.16 | 0.15 | 3.72 | 6 | 96 |

### *Cell Descriptions*

Cell A1 – Country (only significant producers are covered, with the minor producers being lumped together in the World assessment)

Cell C2 – The values are quoted in barrels (42 US gallons)

Cell C3 – Current production for the assessment year

Cell C4 – Past Production, being total produced to the assessment year

Cell C5 – Future Production, being Total (C9) less Past (C4)

Cell C6 – Known Future, being the assessed percentage of Future coming from Known Fields: in other words *Proved & Probable Reserves*. It is a critical step in the assessment, based on the numbers quoted in public databases (Cells K&L 3-7) and in available industry sources. It is an iterative process to try to come up with a plausible, albeit uncertain, value. Additions coming from enhanced recovery and/or fields not yet in production are treated as To-be-Found (C7).

Cell C7 – To be Found: this is the Future (C4) less the Known (C6).

Cell C8 – Discovered: this is the sum of Past Production and Known Future (C4+C6)

Cell C9 - TOTAL: this is an assessment of the total to be produced by the end of the century. It is the most difficult step in the assessment, and takes into account the status of depletion and the current Depletion Rate. If, for example, a country has a Depletion Rate in excess of about 6% in would be reason to increase the TOTAL.

Cell C10 – Consumption. Note that the EIA, which is the principal source, evidently includes the consumption in refineries and ships' bunkers, with some small islands and countries have anomalously high consumption per capita.

Cells D4-8 – List of the values as a percentage of the Total (C9)

Cell E10 – Consumption per capita (measured in kb/d).

Cell G3 - The amount produced at the Midpoint of Depletion when half the Total has been produced (C9/2).

Cell G4 - The date of Midpoint.

Cell G5 - The time lag between the date of the actual Peak of production and the Midpoint (J3-G4).

Cell G7 – The total amount of oil found in giant fields (>500 Mb). They are important, usually containing a large proportion of the country's total and are found early, being too big to miss.

Cell G8 – The percentage discovered in Giant Fields.

Cell G9 – The date of the last giant discovery.

Cell G10 – Population of the country.

Cell H10 - The assumed future decline rate of consumption.

Cell J3 – The date of peak production.

Cell J4 – The percentage produced at the date of peak production.

Cell J5 – The date of the peak of discovery.

Cell J6 - The time-lag between peak discovery and peak production in years.

Cell J7 - The date of the peak in the drilling of exploration wells ("wildcats").

Cell J8 - The EIA is taken as the prime source of production and reserve data by country, but in many cases it shows a country having the same reserves year or year, despite it being utterly implausible that new discovery would exactly match production except on very rare occasions. In practice, it probably means that the EIA have simply not received new information to update their reserves data. The reserves should naturally fall to match production unless new discoveries are made. This cell lists the number of years of unchanged reports.

Cell J9 – The production trend over the past five years.

Cell J10 – The area of the country including its offshore.

Cells L3-7 - List the reported reserves by the main public sources

Cell L8 - The amount of production during the period of unchanged reserves as reported by the EIA.

Cell L9 – The amount of reserves not classed as Regular Conventional.

Cell M4 – The average of the publicly reported reserve estimates.

Cell M6 – The Standard Deviation of the reported reserve estimates as an indication of the level of uncertainty.

Cell M9 - This is a so-called "Growth Factor" to adjust proportionately the indicted discovery by years in Col. K. so that it matches the assessment made here.

Cell M10 – Population density by area

Cell N1 – Date of revision

Cell O1 – Year of assessment.

Cell O3 – Total number of exploration wells ("*wildcats*") drilled to date.

In principle, they should be exploration wells that if successful find a new field, but in some countries, especially the USA, some wells drilled to find an extension of an existing field are treated as wildcats, and should be deducted.

Cell O4 – Estimated number of future wildcats to be drilled, normally assuming a 10% annual decline in mature countries as fewer and fewer valid prospects of ever decreasing size can be identified and considered capable of delivering a viable find if successful.

Cell O5 - The average past discovery per wildcat.

Cell O7 – The Depletion Rate (Annual as a percentage of estimated Future production at Midpoint (when half the Total has been produced).

Cell O8 – The current Depletion Rate.

Cell O9 – The final Depletion Rate in countries, not yet at midpoint, whose production is assumed to plateau or rise to midpoint and then decline.

Cell O10 – Trade, with export being positive values when production exceeds consumption and vice versa.

Line 13 – Sums any pre-1930 production, discovery and wildcat drilling.

### *Column Descriptions*

Column A – Lists the years from 1930 to 2030 (It is planned in future to change this period to 1950 to 2050, to give more meaningful results.) If a country has passed its midpoint, as have more than fifty, it is assumed that its future production declines at the current Depletion Rate. In the case of countries not yet at midpoint (mainly in the Middle East) it is assumed that production plateaus to midpoint and thereafter declines as the then depletion rate. Political events as for example in Syria or Libya are taken into account showing reduction in production over the near term, before recovering to the indicated available amount.

Column B – Lists annual production in kb/d (thousand barrels a day) by year.

Column C - Converts kb/d in Gb/a (billion barrels a year).

Column D – Lists cumulative production by year.

Column E – Lists the indicated amount of production to be produced in the future by year in Gb.

Column F – Lists the percentage depleted by year.

Column G - Lists consumption by year.

Column H – Lists Trade, namely production less consumption giving exports when positive and vice versa.

Column I – Lists Depletion Rate by year.

Column J – Lists discovery in Giant Fields (>500 Mb) by year.

Column K – Lists all discovery as reported (mainly in confidential databases) with future discovery being estimated on the basis of the average indicated discovery per wildcat.

Column L – Application of a Growth Factor (see Cell M9) so that the reported discoveries are adjusted to match the total discovered as calculated in the model (C8).

Column M – Cumulative discovery per year.

Column N – Number of wildcats drilled per year with the future rate normally being assumed to decline at 10 per cent a year (subject to reassessment).

Column O – Cumulative number of wildcats per year.

### *Sheet Descriptions*

The following regions, made up of the principal producing countries, are recognised:

AFRICA – Algeria, Angola, Cameroon, Chad, Congo(B), Egypt, Gabon, Libya, Nigeria Sudan, Tunisia, Uganda

ASIA-PACIFIC – Australia, Brunei, India, Indonesia, Malaysia, Pakistan, Papua-New Guinea, Thailand, Vietnam

EURASIA (former Communist world) – Albania, Azerbaijan, China, Croatia, Hungary, Kazakhstan, Romania, Russia, Turkmenistan, Ukraine, Uzbekistan.

EUROPE - Austria, Denmark, France, Germany, Italy, Netherlands, Norway, UK.

LATIN AMERICA – Argentina, Bolivia, Brasil, Chile, Colombia, Ecuador, Mexico, Peru, Trinidad, Venezuela.

MIDDLE EAST GULF – Iran, Iraq, Kuwait, Neutral Zone, UAE, Saudi Arabia.

MIDDLE EAST MINOR – Bahrain, Oman, Qatar, Syria, Turkey, Yemen.

NORTH AMERICA – Canada, USA,

MINOR – the other minor producing countries are lumped together.

ROUNDING – A rounding sheet provides a total of 23 Gb.

WORLD – The above sheets are summed to provide a WORLD assessment. The Rounded sheet provides enough to provide a rounded total of 2050 Gb

*(Note: There might be a case for reorganising the regions. The former Communist bloc is recognised as Eurasia because of its special past environment and reporting practices.)*

## A2. Example Spreadsheet for Britain

Britain started the depletion of its oil cautiously, even having a national oil company; but a change of government led to rapid development with capitalistic verve and every technological help. As a result, Britain exported oil for ten years from 1981 at a time of low oil prices, but now finds itself importing 55% of its needs at very high prices.

The calculation in the spreadsheet suggests that the actual peak of production in 1999 came two years after the midpoint of depletion. One of the reasons was the Piper Field accident that affected production over all UK North Sea fields for a period while systemic safety work was implemented.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **COUNTRY** | **United Kingdom** | | | | **REGION** | | **Europe** | | **Date** | 9/5/13 | 2012 |
| **PRODUCTION** | Gb | % | **MIDPOINT** | | **PEAK** | | **RESERVES** | | | **WILDCATS** | |
| **Current** | 0.32 | | Gb | 16.00 | Date | 1999 | O&GJ | 3.12 | Av | Past | 3385 |
| **PAST** | 25.40 | 79% | Date | 1997 | Depleted | 55% | BGR | 5.79 | 4.42 | Future | 172 |
| **FUTURE** | 6.60 | 21% | Lag | 2 | Disc | 1974 | BP | 3.1 | SD | Av Disc | 9.26 |
| **Known** 90% | 5.94 | 19% | **GIANTS** | | Lag Disc | 25 | ENI | 2.83 | 1.27 | **DEP RATE** | |
| **To be found** | 0.66 | 2% | Total | 12.87 | Wildcat | 1990 | EIA | 2.83 | 7.392 | MP | 5.3% |
| **Discovered** | 31.34 | 98% | % | 41% | Static Yr | 0 | Static | 0.00 | Growth | Current | 4.6% |
| **TOTAL** | 32.00 | | Last | 1993 | 5yr Trnd | -7% | Other | | 95% | Final | |
| **Consume kb/d** | 1519 | **Per Cap** | 9 | **Pop.** | 64.1 | **Area** | 0.246 | **Pop.Density** | 261 | **Trade** | -638 |

| **DATE** | **PRODUCTION** kb/d | Gb/a | Cum | Y-t-P | Dep | **Cons -ume** | **DEP. RATE** | **DISCOVERY** Giant | All | Grth | Cum | **WILDCATS** | Cum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre 1930 | | | 0.00 | 32.00 | | | | | 3E-04 | | 0.00 | | 16 |
| 1930 | 0 | 0.000 | 0.00 | 32.00 | 0% | | | | 0.00 | 0.00 | 0.00 | 0 | 16 |
| 1931 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 1 | 17 |
| 1932 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 1 | 18 |
| 1933 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 0 | 18 |
| 1934 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 0 | 18 |
| 1935 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 0 | 18 |
| 1936 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 3 | 21 |
| 1937 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 5 | 26 |
| 1938 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.00 | 15 | 41 |
| 1939 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.02 | 0.02 | 0.02 | 27 | 68 |
| 1940 | 0 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 6 | 74 |
| 1941 | 1 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 6 | 80 |
| 1942 | 2 | 0.001 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 3 | 83 |
| 1943 | 2 | 0.001 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 23 | 106 |
| 1944 | 2 | 0.001 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 12 | 118 |
| 1945 | 1 | 0.001 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 18 | 136 |
| 1946 | 1 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 6 | 142 |
| 1947 | 1 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 5 | 147 |
| 1948 | 1 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 12 | 159 |
| 1949 | 1 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 2 | 161 |
| 1950 | 1 | 0.000 | 0.00 | 32.00 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 3 | 164 |
| 1951 | 1 | 0.000 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 1 | 165 |
| 1952 | 1 | 0.000 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 1 | 166 |
| 1953 | 1 | 0.000 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 5 | 171 |
| 1954 | 1 | 0.000 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 8 | 179 |
| 1955 | 1 | 0.000 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 13 | 192 |
| 1956 | 1 | 0.000 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 6 | 198 |
| 1957 | 2 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.02 | 4 | 202 |
| 1958 | 2 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.03 | 17 | 219 |
| 1959 | 2 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.02 | 0.02 | 0.05 | 12 | 231 |
| 1960 | 2 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.05 | 13 | 244 |
| 1961 | 2 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.05 | 10 | 254 |
| 1962 | 2 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.05 | 6 | 260 |
| 1963 | 3 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.00 | 0.00 | 0.05 | 7 | 267 |
| 1964 | 3 | 0.001 | 0.01 | 31.99 | 0% | | 0.00% | | 0.01 | 0.01 | 0.05 | 8 | 275 |
| 1965 | 2 | 0.001 | 0.01 | 31.99 | 0% | 1486 | 0.00% | | 0.01 | 0.01 | 0.06 | 28 | 303 |
| 1966 | 2 | 0.001 | 0.01 | 31.99 | 0% | 1595 | 0.00% | | 0.04 | 0.04 | 0.10 | 31 | 334 |
| 1967 | 2 | 0.001 | 0.02 | 31.98 | 0% | 1718 | 0.00% | | 0.00 | 0.00 | 0.10 | 42 | 376 |
| 1968 | 2 | 0.001 | 0.02 | 31.98 | 0% | 1824 | 0.00% | | 0.00 | 0.00 | 0.11 | 41 | 417 |
| 1969 | 2 | 0.001 | 0.02 | 31.98 | 0% | 1967 | 0.00% | | 0.19 | 0.18 | 0.29 | 54 | 471 |
| 1970 | 4 | 0.001 | 0.02 | 31.98 | 0% | 2081 | 0.00% | 2.60 | 2.80 | 2.65 | 2.94 | 30 | 501 |
| 1971 | 5 | 0.002 | 0.02 | 31.98 | 0% | 2090 | 0.01% | 1.90 | 2.82 | 2.67 | 5.61 | 34 | 535 |
| 1972 | 8 | 0.003 | 0.02 | 31.98 | 0% | 2211 | 0.01% | 2.12 | 1.66 | 1.57 | 7.17 | 35 | 570 |
| 1973 | 9 | 0.003 | 0.03 | 31.97 | 0% | 2280 | 0.01% | 1.00 | 2.85 | 2.70 | 9.87 | 68 | 638 |
| 1974 | 10 | 0.004 | 0.03 | 31.97 | 0% | 2120 | 0.01% | 3.21 | 5.05 | 4.78 | 14.65 | 75 | 713 |
| 1975 | 34 | 0.012 | 0.04 | 31.96 | 0% | 1860 | 0.04% | 1.04 | 3.00 | 2.84 | 17.49 | 82 | 795 |
| 1976 | 253 | 0.092 | 0.13 | 31.87 | 0% | 1848 | 0.29% | | 1.00 | 0.94 | 18.43 | 73 | 868 |
| 1977 | 792 | 0.289 | 0.42 | 31.58 | 1% | 1870 | 0.91% | | 1.08 | 1.02 | 19.45 | 80 | 948 |
| 1978 | 1119 | 0.408 | 0.83 | 31.17 | 3% | 1930 | 1.29% | | 0.19 | 0.18 | 19.63 | 37 | 985 |
| 1979 | 1611 | 0.588 | 1.42 | 30.58 | 4% | 1947 | 1.89% | | 0.28 | 0.27 | 19.89 | 41 | 1026 |
| 1980 | 1663 | 0.607 | 2.03 | 29.97 | 6% | 1725 | 1.99% | | 0.21 | 0.20 | 20.10 | 41 | 1067 |
| 1981 | 1811 | 0.661 | 2.69 | 29.31 | 8% | 1590 | 2.21% | | 0.46 | 0.43 | 20.53 | 69 | 1136 |
| 1982 | 2065 | 0.754 | 3.44 | 28.56 | 11% | 1590 | 2.57% | | 0.52 | 0.49 | 21.02 | 92 | 1228 |
| 1983 | 2291 | 0.836 | 4.28 | 27.72 | 13% | 1531 | 2.93% | | 0.49 | 0.46 | 21.48 | 96 | 1324 |
| 1984 | 2480 | 0.905 | 5.18 | 26.82 | 16% | 1825 | 3.27% | 0.50 | 1.30 | 1.23 | 22.71 | 149 | 1473 |
| 1985 | 2530 | 0.923 | 6.11 | 25.89 | 19% | 1617 | 3.44% | | 0.56 | 0.53 | 23.24 | 135 | 1608 |
| 1986 | 2539 | 0.927 | 7.03 | 24.97 | 22% | 1637 | 3.58% | | 0.42 | 0.40 | 23.64 | 149 | 1757 |
| 1987 | 2406 | 0.878 | 7.91 | 24.09 | 25% | 1611 | 3.52% | | 0.38 | 0.36 | 23.99 | 94 | 1851 |
| 1988 | 2232 | 0.815 | 8.73 | 23.27 | 27% | 1692 | 3.38% | | 0.97 | 0.91 | 24.91 | 115 | 1966 |
| 1989 | 1802 | 0.658 | 9.38 | 22.62 | 29% | 1731 | 2.83% | | 0.59 | 0.56 | 25.47 | 117 | 2083 |
| 1990 | 1820 | 0.664 | 10.05 | 21.95 | 31% | 1776 | 2.94% | | 1.10 | 1.04 | 26.50 | 168 | 2251 |
| 1991 | 1797 | 0.656 | 10.70 | 21.30 | 33% | 1803 | 2.99% | | 0.47 | 0.44 | 26.95 | 148 | 2399 |
| 1992 | 1825 | 0.666 | 11.37 | 20.63 | 36% | 1815 | 3.13% | | 0.31 | 0.30 | 27.25 | 110 | 2509 |
| 1993 | 1915 | 0.699 | 12.07 | 19.93 | 38% | 1829 | 3.39% | 0.50 | 0.65 | 0.61 | 27.86 | 60 | 2569 |
| 1994 | 2375 | 0.867 | 12.94 | 19.06 | 40% | 1833 | 4.35% | | 0.10 | 0.10 | 27.95 | 70 | 2639 |
| 1995 | 2489 | 0.909 | 13.84 | 18.16 | 43% | 1816 | 4.77% | | 0.18 | 0.17 | 28.12 | 63 | 2702 |
| 1996 | 2568 | 0.937 | 14.78 | 17.22 | 46% | 1852 | 5.16% | | 0.40 | 0.38 | 28.50 | 81 | 2783 |
| 1997 | 2518 | 0.919 | 15.70 | 16.30 | 49% | 1804 | 5.34% | | 0.29 | 0.28 | 28.78 | 76 | 2859 |
| 1998 | 2616 | 0.955 | 16.65 | 15.35 | 52% | 1792 | 5.86% | | 0.10 | 0.10 | 28.88 | 56 | 2915 |
| 1999 | 2684 | 0.980 | 17.63 | 14.37 | 55% | 1797 | 6.38% | | 0.11 | 0.10 | 28.98 | 24 | 2939 |
| 2000 | 2275 | 0.830 | 18.46 | 13.54 | 58% | 1759 | 5.78% | | 0.09 | 0.09 | 29.06 | 31 | 2970 |