Abstract:

Rystad Energy has developed a global oil supply model, UCube ("Upstream cube"). UCube is a ‘bottom-up’ model based on field by field production, summing up to one hundred percent of global production, and including estimated production from undiscovered fields.

We see the model as differing from other supply models primarily in being driven at a detailed asset-based micro level. In the model the decision as to whether any specific field or project is developed depends on the resource available, the price structure of this class of resource and its anticipated capital and operating spend profile, and hence on whether a positive NPV results at the model’s current assumed price level. Moreover, we believe that the model is calibrated using a broader set of sources than most comparable databases, where these sources include reported data from oil companies, oil service companies, governmental sources and scientific publications. In particular, the database aims to be consistent on resource estimates, for example by not mixing US 1P reserves with OPEC ~3P data.

In the paper we discuss how the model is constructed, the advantages of such an approach, and how it can be used to forecast future oil supply.
and oil field spending.

**Background**

Rystad Energy was started as a management consulting company specialising in data- and facts-driven strategic analyses. The primary purpose of the original database models developed was to answer industry-relevant questions, such as supply and spending trends and forecasts, analyses and benchmarking of E&P companies, valuation of assets and company portfolios, oil price effects and oil service market outlooks. Consulting projects resulted in new insights to be included into the models. As UCube developed to become a very powerful tool, it was decided to make it externally available to other analysts.

**Introduction**

Energy has always played a pivotal role in human development, and oil and gas are currently fuelling our modern world. New energy sources are developing, but still the world will rely on oil and gas for many years to come. A key question is thus: Can the oil and gas industry deliver on future demand?

The supply of oil and gas is not only a matter of resources, but is – as history shows – to a large degree industry and market driven. It is thus not meaningful to discuss supply without including above-ground effects of industrial importance, such as oil price, or politics. The oil industry is and will remain a very important industry. Many good papers (e.g. in this journal) have substantiated the need for models to understand the business and forecast future trends, both to support business decisions and to assess future energy supply and energy mix.

In this paper, we describe how the UCube database can be used to address a wide range of these questions. We will focus on oil, but the same methodology is applied to gas.

**An asset-based model**

UCube is a truly asset-based model, i.e. all data are at asset level. We define assets as produced or producing fields, fields under development, unsanctioned discoveries, exploration licenses or unawarded acreage. Thus, an asset is a real world asset that has resources and owners (the exception being unawarded acreage). All decisions are made at the asset
level: will the owners sanction development; when and how to develop; how much to invest; how to produce; when to shut down, etc. In order to forecast future activity it is necessary to mimic the industry rationality. It does not help that an asset holds large resources if it is unprofitable for the owners to develop them. Thus using the actual assets (fields, discoveries, licenses) as the building blocks for a global supply model has many advantages:

- It is possible to describe and capture the actual industry dynamics
- One can make better and more realistic assumptions at asset level than for larger aggregates of activity or fields (e.g. “US shale”, “OPEC”, “Venezuela heavy oil”)
- Any production profile - for a company, a country, or global supply – will be a sum of the production of assets
- Since all field attributes are at the asset level the resulting dataset can be analysed along a large number of dimensions
- The dataset will always be internally consistent

As an example of how the micro nature of the asset model works, consider a fall in oil price. The decisions made will be very different for unsanctioned fields (drop or postpone development), producing onshore fields (drill fewer wells) and producing offshore wells (smaller impact – some reduced infill drilling and EOR). Taking into account the diversity of the assets gives qualitatively different results than e.g. a top down global reduction in production by 4% applied to all producers.

Completeness is very important. The bottom-up sum of asset production must match the global production. When the model includes “all”, any analyses will be in absolute numbers and calibrated. One can say not only that something “.. will increase by 10%..”, but rather “.. will increase from 13.4% to 24.1%, and these are the assets that contribute..”.

The obvious challenge is to cover all the assets globally. A complete description of all assets is not possible, in particular for a model covering the time window from 1900 to 2100. We have used a number of different methods to populate the UCube asset universe. One key approach has been to use industry insight to fill in with models where data points are lacking, another the use of extensive calibration.
Asset production

In UCube all assets are attributed a resource volume, a production profile, investments and spending, ownership, and a large number of other attributes. It follows that the database is a result of historical facts, analyses of the industry, and extensive modelling.

The key to developing such a database is to establish models that can make good forecasts of production and costs from a minimum of input parameters, and that can take advantage of any information available to become more specific. This is particularly important for unsanctioned fields and discoveries where little information is available. For existing fields historical data override and calibrate the models, which still forecast future production. Different models are required for different development types (oil/gas fields, onshore/offshore, conventional/different unconventionals, etc.) and need to scale with or adapt to resources, infrastructure, rig availability, politics, etc. At the same time, models should be robust, and conceptually simple and easy to relate to for users to be comfortable with the results. The main idea is that if you make reasonable assumptions at each field, then you can also have confidence in the aggregated results.

Figure 1 shows a basic model for the production profile of a conventional oil field – a buildup, a plateau, and a decline phase. All parameters of this curve vary with field size and development concept. The most important input to the production forecast is the field resources. To be consistent UCube applies EUR resources, which are in general different from (larger than) reported reserves.

Figure 1: Generic asset production profile with build-up, plateau, and decline phases. Years of buildup, plateau level, years on plateau, and decline rates depend on asset parameters
The asset data

A wide variety of sources of public data have been used as input to UCube: data from governments, agencies and organizations, company annual reports, investor presentations and news releases, news streams and scientific publications, preferably primary data. This is not enough to populate all assets with historic data. Many countries are not transparent on field level data, and pre-electronic data are often not easily available. In many cases it is challenging just to get hold of field names and key parameters. However, combining all sources it is possible to build a puzzle from pieces with varying degree of certainty. To reach published country production numbers (or other benchmarks) we adjust the production of fields with very uncertain input data to ensure a calibrated history. As data coverage improves, fewer fields are adjusted. Further calibration is achieved by ensuring that the company reported production country by country matches the bottom-up production, for all companies. The data are consistent with all publicly available trustable benchmarks. The historical (and current) data are important for providing a history to analyse and learn from, and for providing the starting point for forecasting the future activities.

A challenge is that sources may conflict or are even internally inconsistent. On resources many otherwise good sources mix, e.g., company-reported proven reserves (e.g. US) with 3P estimates from governments (e.g. OPEC countries). In UCube these numbers have been calibrated to allow for the required ‘apples-to-apples’ comparison. Other sources may refer to national policies, on e.g. holding back production, or producing under capacity. Political decisions that are implemented, e.g. a CO$_2$ tax, or ban on certain developments for environmental reasons, will influence profitability and start-up decisions. However, information on political intentions are not used directly as input to the model. Rather we monitor the activity. If a country is holding back production it will show as lower (i.e. the actual) production from the fields. There is a common conception that Saudi-Arabia is producing under capacity. If this is correct then it is definitely not a matter of just opening the taps. Last year Saudi Arabia decided to “stop holding back” and increased production to protect their market shares. The country is now producing at all-time high, but this has been accompanied by an all-time high drilling campaign. In UCube, when we observe the drilling we increase the production forecast.
Unconventional assets

Conventional assets are mainly modelled as described above. For unconventionals we apply other models. Oil sands projects are based on developed or planned capacity. The development in North American shale is currently particularly important for precise supply analyses, and the shale assets (one asset is a part of a company’s acreage in one basin in one state) are based on all the operators’ published drilling plans, acreage size, and analyses of the well curves in the different acreage positions.

Since shale is modelled in such detail, it provides a good illustration of the robustness of a true bottom-up approach. Figure 2 shows how the UCube estimates for North America tight liquids production have developed with time. Given first the dramatic growth in shale production, and then the oil price collapse, the estimates have remained quite stable. First, one may note that from early on we approached the correct 2013 and 2014 levels, which were seen as controversially high at the time. This was the result of transforming the ongoing and planned drilling programs and known well characteristics into production.

As planned activity increases so do the estimates, as can be seen for the 2015 and later estimates in 2013H2. Secondly, mid-2014 we saw the efficiency gain won in pad drilling and fracking, and our longer-term estimates grew, while the 2015 estimate was little affected due to the long lead times. Based on this we issued a press release warning about oversupply and downward pressure on prices while the price was still going up. The oil price dropped much more than we expected and drilling was halved. This had little impact on the 2015 production estimate.

The reason is that the large backlog of uncompleted wells, efficiency gains and cost pressure reduced the breakeven prices of many developments so that many acreage positions would remain profitable, and the wells produced more. Analysing the breakeven prices (see below) we found early on a rule of thumb saying “at 50 USD/bbl, drilling will drop to 50%, and production level will stay flat”. This has happened, and consequently our 2016 estimate is close to the 2015 level. Our 2020 estimate is considerably higher. This is because we do not find the current oil price sustainable (discussed below), and as swing producer shale will step up with oil price. The small changes observed in shale output are in strong contrast to the general conception that shale production would drop dramatically when the oil price collapsed. It was in the numbers all the time - systematic observation and modelling trumps intuition.
Yet-to-find (YTF)

It is speculative to include undiscovered resources, but the picture would certainly not be complete without it. History tells us that exploration will continue, new acreage will be awarded, and more discoveries will be made. There are two types of YTF assets, exploration licenses and unawarded acreage.

For exploration licenses quite a lot of information is available. The ownership and often work commitments are known. Since companies would not commit to costs unless expected to be profitable, we scale prospective volumes by commitments, comparing with previous finding costs. On the other hand, only 1 out of 4 or 5 wildcat wells deliver commercial discoveries, and volumes are risked down correspondingly for the probability of success. Based on work commitments we simulate the drilling program, and “develop” the discovery to obtain the contribution to future production and spending. An alternative approach could have been to use creaming curves to estimate prospective resources. Again, we turned to industry practice: companies would make very different

Figure 2: Development over time of UCube forecasts for 2013, 2014, 2015, 2016 and 2020 for North America tight liquids production.
commitments to different blocks in the same basins in the same lease rounds. The bids reflect the assessments by company geologists, and we believe these are better and more specific indicators on prospectivity than a creaming curve treating all blocks the same.

Resource estimates for unawarded acreage are based on government or geological societies’ assessment of the subsurface potential, and calibrated and scaled to match industry consensus. To achieve a realistic development of the resources each sub-basin is simulated as a series of lease rounds. In this case ‘creaming curve’ logic is applied, and the current exploration agenda is reflected in the timing of rounds.

As a result of the above, UCube includes 25 000 fields of all different types (including discoveries), 22 000 exploration licenses and a large number of unawarded acreage assets, and the full portfolio of more

**Figure 3:** Forecast bottom-up production profiles of liquids plus gas for Norway and UK, by asset maturity. Data are for the years 2000 to 2040. The supply from producing and sanctioned fields is quite certain, but the contribution from discoveries and undiscovered assets requires development and exploration decisions.
than 3200 E&P companies. The production from all these assets can be aggregated to a global supply. More importantly, if the global result is unexpected one may drill down country by country, province by province, and trace production back to the individual assets. Figure 3 shows as an example the production forecasts for Norway and UK. As can be seen, both countries can maintain and even increase production levels the next 15 years, given that the players (oil companies through investments, governments through incentives) continue to sanction development of existing discoveries and continue to explore.

“Developing” assets

Based on case studies (e.g. submitted plans for development and operations (PDOs) or industry news items) we have developed models for estimating investments and operating costs for different development types – onshore, shelf, deepwater, subsea, oil sands, shale, etc.

![Graph showing example spending profile for a subsea field. Capex includes all investments in facilities and wells, and Opex all operational costs.](image)

**Figure 4:** Example spending profile for a subsea field. Capex includes all investments in facilities and wells, and Opex all operational costs.
An example for a subsea development is shown in Figure 4. Far less detailed data (e.g. contracts) are published on spending and development costs than for production. We calibrate the spending models by comparing the bottom-up sum of investments and operational costs to what the companies report in their annual reports for different regions. Breaking the spending down into 20 different cost types, some of the spending numbers can also be calibrated comparing to revenues for certain supplier segments. In UCube assets stop producing when the operating costs exceed the sales revenue (economic cut-off).

**Profitability of assets**

When the production profile is known for an asset, the revenue from the field can be calculated by multiplying by the oil price of a chosen price scenario. Further, when costs and fiscal regime are known one can calculate the government take (taxes, royalties, profit oil, etc.) and the free cash flow, i.e. the profit to the owners. From the free cash flow we calculate the net present value, NPV, and the discounted free cash flow. The NPV varies strongly with oil price, and it is thus useful to calculate the breakeven oil price for the asset. In UCube, the breakeven oil price is defined as the flat (in real terms) oil price that returns a zero NPV applying an industry standard 10% discount rate. Asset owners will not sanction for development discoveries with negative NPVs. Thus, the breakeven price is a good indicator for whether one can expect certain discoveries to contribute to future supply, and therefore an important tool in assessing both future supply and oil prices.

It should be noted that for a given oil price the price applied to a specific asset varies with oil quality and market access, and that fiscal regimes vary widely and are often not transparent.

**Oil price effects**

In different oil price regimes, operators behave differently. At higher oil prices they will do more (more infill drilling, EOR) to produce more resources. At lower prices they will do less, as additional wells do not necessarily pay back. In addition, economic cut-off is reached earlier at low oil prices. When the price is too low unsanctioned fields will not be developed until prices recover. Further, development and operational costs are higher in a high price regime, and lower at lower prices, due to constrained and spare capacity, respectively.
Global supply

With a complete set of assets with production profiles and profitability we have the tools we need to analyse global supply. In Figure 5, we show the resulting global liquids supply (crude, condensate, NGLs, refinery gains, biofuels and CTL) in a 100 USD/bbl case, split by field current maturity. The chart shows the production expected to exceed 100 million bbls/day (Mb/d) over a ten-year period from 2019. The chart illustrates clearly the underlying decline in production from currently producing fields, and the importance of current field developments to keep up production. Further, new developments must be sanctioned and exploration must continue to reach and sustain such a production level.

Figure 5: Forecast global liquids (crude, condensate, NGLs, refinery gains, biofuels and CTL) production profile by asset maturity, assuming a flat 100 USD/bbl oil price.
IEA *WEO* 2020 demand forecasts are 99.5 Mb/d in the Current Policies scenario and 98.0 Mb/d in the New Policies scenario. However, 100 USD/bbl during the next few years is unlikely. The UCube base case (not shown; oil price growing to 110 USD/bbl (nominal) in 2020) reaches 98.0 Mb/d in 2020, and does not exceed 100 Mb/d. By contrast, IEA demand estimates for 2040 (of 120.7 and 107.7 Mb/d in the two scenarios) are not within reach at 100 USD/bbl. This picture may change due to new play breakthroughs (like shale) or technology advancements.

**Figure 6**: Forecast global liquids production profile at flat (in real terms) oil prices 120 (upper), 100 (middle), and 50 (lower) USD/bbl. (The definition of ‘liquids’ is the same as Figure 5.)
In Figure 6 we compare the forecast liquids supply in a 120 USD/bbl (high), a 50 USD/bbl (low) and the 100 USD/bbl (mid) scenario above. The chart shows that the low price scenario will by far not meet the expected demand growth, from which we conclude that the current price level of 50 USD/bbl is not sustainable. The main reason the production drops so much in the low scenario is that many new unconventional and offshore developments become unprofitable and will not compensate for the decline in the underlying base production.

Another way of studying the sensitivity to oil price is through cost-of-supply curves. Such curves sort the produced volumes along the x-axis by increasing production cost or breakeven price (y-axis), so that the marginal producers end up in the upper right corner. Given an oil price one can read out how much will be produced at that price, or given a demand one can read out what price is required to make producers meet the demand.

**Figure 7:** 2020 liquids cost-of-supply curve. The curve shows the aggregated 2020 production (x-axis) as function of field break-even price. The boxes indicate the cost of supply from different important segments. The width of the boxes show daily production, the height indicates the spread in break-even prices, as of August 2015.
Figure 7 shows a cost of supply chart for global liquids in 2020. The dashed curve shows the aggregation of field by field 2020 liquids production by increasing break-even price. The boxes group the most important supply segments. The box width shows the contribution to global production, the height the span of break-even prices within the supply segment (60% confidence interval). The chart shows oil sands are the marginal producers, but also that producers in other segments have high break-even prices. For instance, fields that have development costs ahead will have higher break-even prices.

Validity of supply results

To our knowledge, UCube is the most comprehensive oil field database available. It is particularly useful for supply analyses due to its completeness, consistency and degree of calibration across multiple dimensions. UCube is transparent and lets the user drill down in all analyses to see which assets contribute to the results. However, we do not expect all other analysts to agree that Figure 7 shows the true future global liquids supply. First, Figure 7 shows the dependency of supply on price, and secondly, UCube is based on a large set of assumptions that are open to discussion, and that we have not touched upon so far. For example: How much can Saudi produce? How quickly will Iraq ramp up? What will be the future costs and break-even of shale production? Will we get developments in the Arctic? Will politicians ban new exploration and sanction fewer developments in order to reduce CO$_2$ emissions?

Each of these topics could be subject to separate papers. We analyse the activity in all countries as the basis for our assumptions, which in general are on the conservative side, and UCube is aligned with our view. However, more than providing the final answer UCube is a tool for analysts to test their hypotheses. As such, it imposes a useful disciplining restriction: Whatever changes in the assumptions, the assumptions should lead to changes in specific assets in the model, just like a real world supply response necessarily must come from real world assets. If Iraq is going to produce more, from which fields, and can you observe the required activity? Assets will either be produced or not, and produce more or less.
Global spending

Since development and operational costs are modelled and calibrated at field level, UCube also provides a new basis for bottom-up spending or market analyses. Again, according to the nature of the business, it is rational to assume that all commercial assets in UCube will be developed, even if there are no concrete plans or decisions as of now. This will require investments from oil companies, and aggregating these development costs gives robust estimates for future investments. Adding on top the operational costs required to produce the same fields gives an

![Figure 8: Historic and forecast capital expenditure in Egypt split by asset. Forecast spending for recent discovery Zohr is highlighted as the solid mid-grey areas at top of bars from 2016 onwards. (Note: The Figure only shows domestic development – potential LNG development is expected to be outside this time window.)](image)
estimate for the total oil service market. As an example, one week after the Zohr discovery in Egypt Zohr was already equipped with preliminary development costs in UCube. Clearly, these cost estimates are uncertain, but based on an assumption of a 2-phase development (domestic gas and LNG) calibrated models will produce reasonable estimates. Figure 8 shows the impact of this discovery on Egypt investment levels. One might consider it more correct to await Eni’s PDO decision before including spending on Zohr, but this would be highly misleading for anyone planning their business in Egypt.

Through the above we have seen that UCube by design provides robust forecasts. The traditional way of making spending forecasts is to

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**Figure 9:** Investment forecasts for the Norwegian SDFI portfolio made in 2006, 2008, 2010, and 2012 (dashed curves). Dotted curve shows 2014 forecast using 2012 methodology, and 2014-Rystad curve shows forecast based on UCube methodology. The solid line shows the actual investments (SSB).
sum up the oil companies’ investment budgets. First, due to the limited planning and budgeting horizon of oil companies this tends to result in a short term growth, falling off dramatically after a couple of years. In addition operators are notoriously optimistic on what things will cost, execution time, and how much will be produced. Secondly, operating costs are usually not included, despite on a global basis almost equalling investments.

This is illustrated in Figure 9, which shows the investment forecasts made for the SDFI portfolio (Norwegian State’s Direct Financial Interest) for the years 2006 to 2014. Systematically forecasts go up, and then fall

**Figure 10:** Investment forecasts for Norway. The 2006, 2008, 2010 dashed curves are scaled up SDFI estimates. The two long-dashed curves are Rystad Energy UCube estimates from 2007 and 2010. The solid line shows the actual investments seen from 2015 (SSB).
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off. We were privileged to do the 2014 forecast. The dotted line shows the result repeating the previous methodology, the upper right line shows UCube methodology applied to government data. The implication of the difference between these two curves is a completely different view on the future of the Norwegian oil and gas activity, and the “falling off the cliff” forecasts can lead to dramatically wrong strategic decisions.

This is further illustrated in Figure 10, where we have scaled up the estimates in Figure 9 to correspond to total investments in Norway, using the known share of SDFI investments and adjusting to actual cost development. For comparison, we have included corresponding UCube forecasts from 2007 and 2010, as well as actual investments. Clearly, the business based bottom-up model correctly predicts the trend going forward, unveiling the coming growth. And, obviously, the approach of

![Figure 10: Example of breakdown of the operator purchases into 11 main oil service segments for a subsea field.](image)
basing investment forecasts on operator budgets is useful only for very short-term forecasts, at best.

**Analyses of the oil service market**

Field based spending models also provide a good basis for oil service market forecasts. What is well capex to an oil company is revenue for rig owners, drillers, well service providers, steel producers, mud and drilling tool providers, etc. By systematically splitting the E&P spending into oil field services and products at each field it is possible to build bottom-up demand estimates for these services. Again, the estimates are robust, as the services are required to get the commercial fields into production. As an example, we show in Figure 11 the breakdown of capex and opex into

![Figure 12: Historical Baker Hughes revenue split onto their service segments, and revenue forecast assuming the company maintains its market shares. Curves follow legend from top to bottom.](image-url)
supplier revenues for 11 top level segments. The spending on each field can now be aggregated to global level for individual segments, and drilled down again to reveal geographic spread and customer identification.

As a final illustration of the power of asset-based bottom-up modelling, we show how the spending forecast can be applied to forecasts at oil service company level. We have analysed oil service companies and broken their reported revenues down to the same 150 oil service segments and products that are used in the E&P spend breakdown. The field-by-field demand provides the market trends for each segment. Assuming that the company maintains its market shares in all segments one can build a detailed company forecast. This is shown for Baker Hughes in Figure 12. The chart indicates that the company must prepare to step up (or in this case not build down) its capacity in the segments that are rebounding, but may prepare for a lower activity level in segments that show a negative to flat development.

**Conclusions**

In this paper we have described how a complete global asset based database successfully makes quantitative and robust future forecasts in the E&P space. The model is industry-driven rather than geology driven, and focuses on the activity and decisions made at each individual field. This is particularly important in order to capture the market dynamics when the oil price varies, and we have demonstrated how supply may vary with oil price. It follows that the near term supply is more determined by the market than by the industry and subsurface’s ability to deliver. This will change when the resource base is sufficiently depleted. Further, it follows that the current low oil price regime is not sustainable, as it does not encourage sufficient new supply to compensate for demand growth and decline in base production.

Assigning assets consistently with developing and operational costs provides a robust basis for forecasting of oil company investment levels and oil service markets. The bottom-up model provides insight far beyond what is available through observing current oil company investment levels and plans, which are by nature short term, and do not include operational costs.

The oil industry is large, long-term, and capital intensive. On the other hand, it has been subject to more ups and downs than most other industries, due to politics, or changing over- and under-supply. To
manoeuvre in this situation it is of vital importance for the players to understand the fundamental and underlying drivers of the business. A truly asset based database has proven to cover some of this need.

Finally we note that a limited-function version of UCube, UCubeFree, is available for download at no charge. UCubeFree provides historic and forecast production data by country, by onshore or offshore fields, by current field maturity, by conventional and unconventional, and by hydrocarbon type. It does not provide by-field data, field ownership, field economics, nor the scenarios (UCubeFree is based on our base scenario). We provide UCubeFree to support the company’s vision of ‘transparency in the oil and gas business’, and to increase public knowledge and stimulate discussions on global oil and gas supply. If you wish to obtain access to UCubeFree please register at: www.rystadenergy.com/Databases/UCubeFree.

References
