HORIZONS

Every last drop
Using AI-powered analysis to find oil-field upside potential

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Forget new fields. If the upstream industry is to meet expected oil demand through mid-century, it is going to have to do much more with the ones it has. That might sound easier said than done, but Wood Mackenzie's new proprietary Synoptic AI-powered analysis of oil-field performance shows how it might be possible.

Using our data on reservoir geology, hydrocarbon quality, in-place resources, operator access to finance and technology, costs and fiscal terms, we estimate upside oil recovery factors for every significant field in the world.

By understanding the potential of existing fields, we can gauge how much the world will need new fields in future. This may range from zero (if enough existing fields are far from their full potential) to a huge call for more exploration and new-field development (if existing fields are running out of road).

The oil industry's challenge is enormous. Total liquids demand under our base-case Energy Transition Outlook scenario is just less than 1,000 billion barrels through 2050. Without upgrades to current development plans, today's onstream fields are set to fall short by almost 300 billion barrels. This deficit would grow by another 50 billion barrels under our delayed transition scenario.

Exploration will continue to add value by finding advantaged resources to displace higher-cost or otherwise disadvantaged barrels. However, new discoveries alone cannot come close to bridging a gap of this size.

In short, future energy security depends on fields already onstream. Whether or not they know it, oil consumers are counting on oil fields' relentless trajectory towards better and better recovery. But this can only happen for so long. Every field will eventually approach fundamental physical, technological or commercial limits to its recovery potential. Exactly when that will be will depend on each field's unique combination of rock, fluid and commercial characteristics – a calculation that can be bewildering amid few useful rules of thumb.

The results of our new AI-powered analysis, therefore, are encouraging. Better recovery from existing fields could yield an additional 470 billion to over 1,000 billion barrels of oil, easily wiping out the 300 billion barrels supply gap to 2050 under our base case demand outlook. Onstream fields are far from spent. Such upside does not depend on unproven technologies; operators merely need to deploy established best practices and invest accordingly.

Quite how this potential will be realised is another matter. The existence of recoverable reserves in the ground does not mean that these will be economically attractive or that the industry will make the investment required.

The national oil companies (NOCs) hold the lion's share of this opportunity, and many will need to raise their game. Much higher recoveries from NOC-operated fields are possible with better funding and wider deployment of the latest technology.

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The Majors and other leading international oil companies (IOCs) are showing the way, but that makes them victims of their own success, with only a small share of global upside remaining in their operated portfolios. They need to access fields with more running room. The IOCs should be enviously eyeing the NOCs' portfolios and will doubtless redouble their efforts to forge deeper partnerships with state-owned enterprises in the coming years.

New oil fields are not enough

Improved recovery factors will be essential to meeting future demand for oil. There are unlikely to be anywhere near enough new fields to offset the natural decline of existing supply.

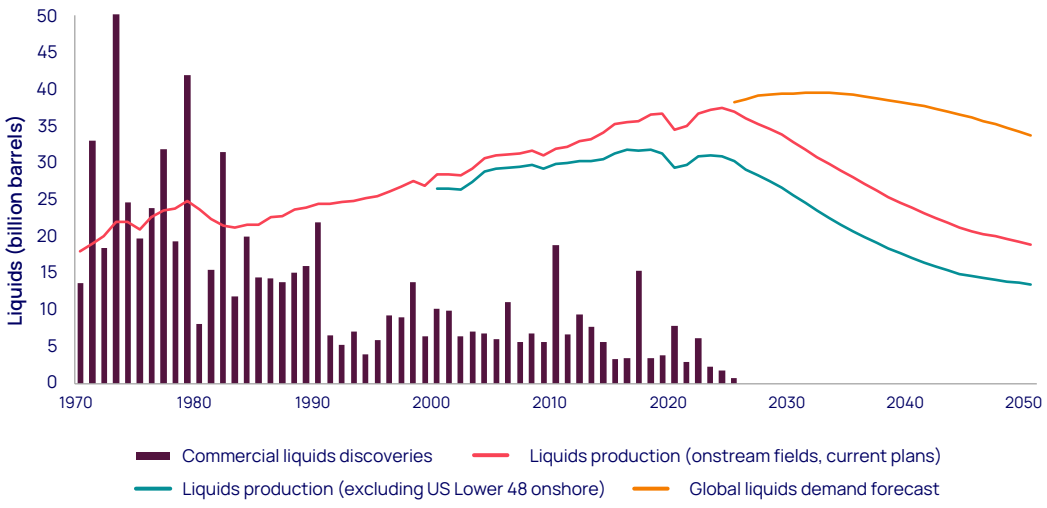
This reliance on existing fields is not new. Since the 1980s, the industry has been meeting growing oil demand with ever-upward revisions to existing fields and only a subordinate contribution from new finds. The gap between discoveries and production has widened with each passing decade.

The industry has a vast inventory of almost 2 trillion barrels of undeveloped greenfield resources, but most of it is going nowhere

The industry has a vast inventory of almost 2 trillion barrels of undeveloped greenfield resources, but most of it is going nowhere. Barely 10% looks commercially viable, with just a few tens of billions of barrels that might meet the investment hurdles of leading operators. Nearly all the rest is destined to stay in the ground.

Tight oil has come to the rescue somewhat, racing to more than 20 million barrels per day of liquids in less than two decades (20% of global supply). But tight oil might now be close to its plateau. If that happens, the need for conventional field revisions will loom even larger.

Figure 1: Commercial liquids discoveries versus production and demand



Source: Wood Mackenzie. Includes biofuels, NGLs and refinery processing gains.

Big fields get bigger… until they don't

Upward revisions at producing fields, particularly giants, have been the mainstay of reserves replacement and growth for decades. 'Big fields get bigger' is an oft-repeated industry truism. First, appraisal work can boost estimates of in-place oil resource. Second, the proportion of in-place oil expected to be produced (recovery factor) tends to increase over time.

Of the two, better oil recovery factors tend to be by far the more important source of reserve revisions. This is where the industry should focus if it is to meet long-term oil demand.

Long late-life production over many decades can nudge recovery factors very high and be handy in delaying abandonment costs

As recovery factors creep higher, operators face diminishing returns on investments such as infill drilling and secondary or tertiary recovery technologies. Such gains cannot continue forever. Each increment of growth becomes harder and harder to achieve.

Timing is an issue, too. Long late-life production over many decades can nudge recovery factors very high and be handy in delaying abandonment costs. However, most such supply adds minimal value and hardly addresses the industry's major challenges.

AI-powered analysis of oil-field recovery performance

Wood Mackenzie's AI-powered analogue finding offers a new way to learn from the industry's long and diverse experience of oil-field development. We leverage our global integrated subsurface and commercial datasets to identify best practice and predict how much upside may exist in similar fields elsewhere.

We identify analogues – fields that share similar characteristics – using Lens Subsurface Modelling. This considers more than 60 different parameters over more than 30,000 fields worldwide, spanning three broad categories:

- **Rock properties:** including reservoir lithology, depositional environment, porosity, permeability, depth and thickness.
- **Fluid properties:** including oil gravity, viscosity and gas-oil ratio.
- **Commercial factors:** including fiscal terms, operator peer group, development costs, post-tax economics, field size by reserves, water depth and year of development.

Each field's closest analogues are ranked using a machine learning-derived similarity score, calculated using a clustering technique known as Gower's distance.

AI-powered analogue finding is a big leap forward from outdated filtering-based methods

The power of this technique stems from:

- **Improved relevance:** we accurately identify the most similar analogues specific to each field based on WoodMac's uniquely integrated subsurface and commercial data. We avoid drawing lessons from fields with merely superficial similarity.
- **High quantity:** we find as many relevant analogues as possible to minimise possible data availability bias.

AI-powered analogue finding is a big leap forward from outdated filtering-based methods. Filtering tends to either drown users in noise or trap them in narrow, biased results. It gives the illusion of control but ignores the complexity of the data. Such analysis is anchored in user bias and blind to broader, more meaningful patterns.

Calculating the upside potential

What would the upside be if every oil field achieved best-practice recovery?

The world's conventional oil fields, outside the US Lower 48 and oil sands, hold over 8 trillion barrels of oil in place, with an average recovery factor of 29%. Of this, 15% has already been produced and 14% remains.

We use AI to identify the 100 most similar analogues for every oil field larger than 50 million barrels to understand each field's recovery factor in context. For each field, we analyse whether its recovery factor is better or worse than its cohort of similar assets across the industry. We are most interested in the potential upside that exists if performance can be improved.

The result of this analysis is a new proprietary dataset of four different reserve scenarios for more than 2,500 conventional oil fields, including:

- Most likely reserves based on current investment plans.
- Reserves based on an average recovery factor compared with analogues (P50 or median value within the dataset).
- Upside reserves based on a top-quartile recovery factor compared with analogues (P75 or 75th percentile within the dataset).
- Upside reserves based on a best-in-class recovery factor compared with analogues (P90 or 90th percentile within the dataset).

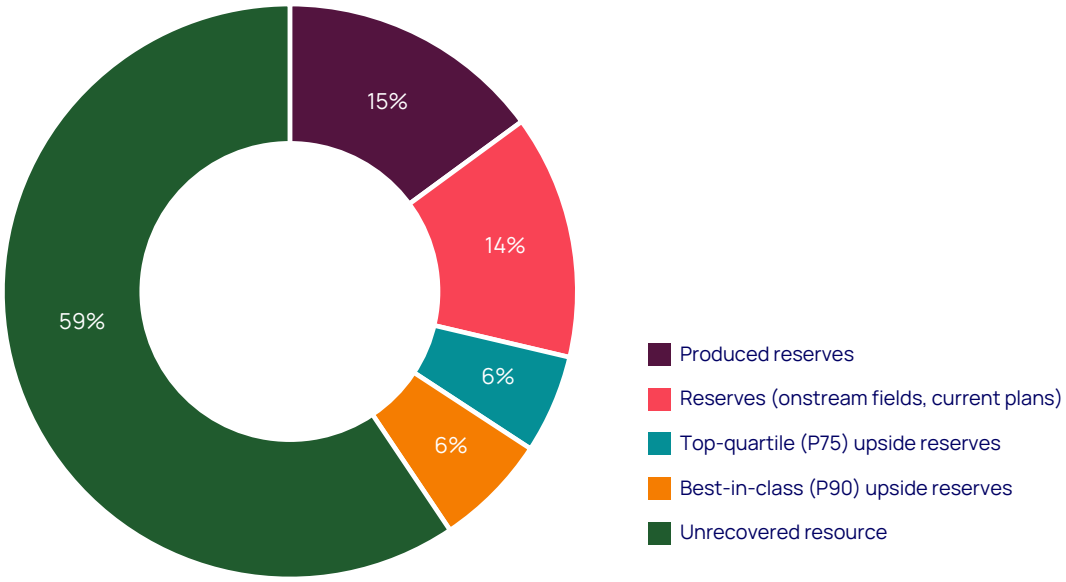
The global sum of these recovery upsides reveals how much extra oil can realistically be recovered without recourse to development approaches not already happening somewhere.

If every field were to achieve top-quartile performance, this would boost average recovery factor to 34%, adding 470 billion barrels of reserves.

Best-in-class performance would increase the average recovery factor to 41% and add more than 1,000 billion barrels.

These enormous volumes are not pie-in-the-sky figures based on unproven technologies. Such upside is already being achieved using technologies available today. Much is likely to be economically viable at current oil prices.

Figure 2:
Global conventional oil-field in-place resource and reserves



Source: Wood Mackenzie

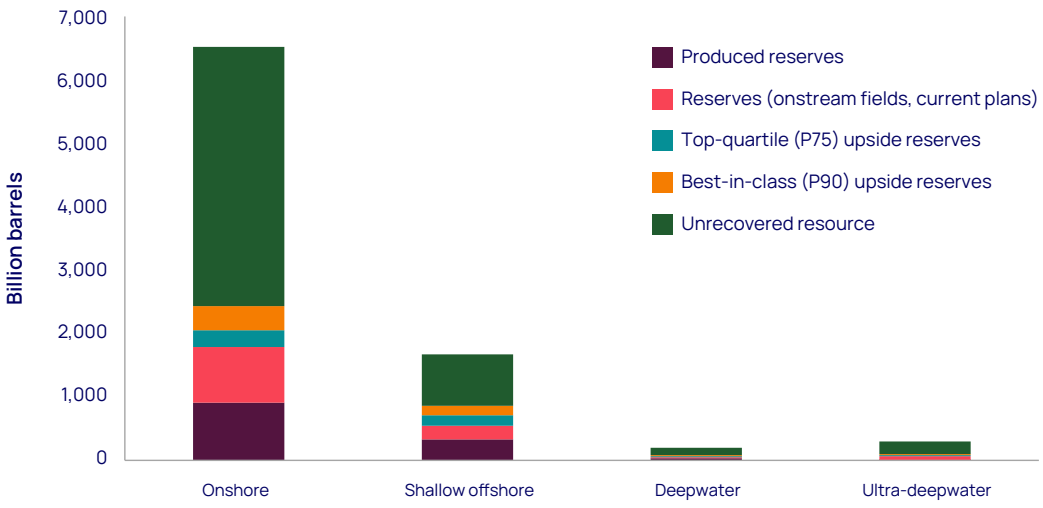
Where is this upside?

Recovery upside varies by basin and resource theme. This opportunity lies almost exclusively within onshore and shallow offshore fields, which account for 63% and 31% of the best-in-class upside, respectively. The industry must sharpen its focus here if it is to meet long-term demand.

By contrast, deepwater and ultra-deepwater fields barely register, together holding less than 6% of best-in-class upside. Such assets are typically operated by well-funded companies with excellent access to technology. The high fixed operating costs in deepwater create an urgency to recover reserves before production dips below a field's economic threshold. Deepwater reservoirs are often of excellent quality, quickly achieving most of their potential, leaving little headroom left to exploit.

This variation by resource theme means that field-recovery upside is unevenly distributed between countries. Iran, Venezuela, Iraq, and Russia stand out with the largest top-quartile reserves upside of any countries. By contrast, Saudi Arabia, Kuwait and the United Arab Emirates are already on track to achieve high recovery factors close to 50%, leaving these countries with far less upside.

Figure 3: Conventional oil-field in-place resource and reserves by water depth



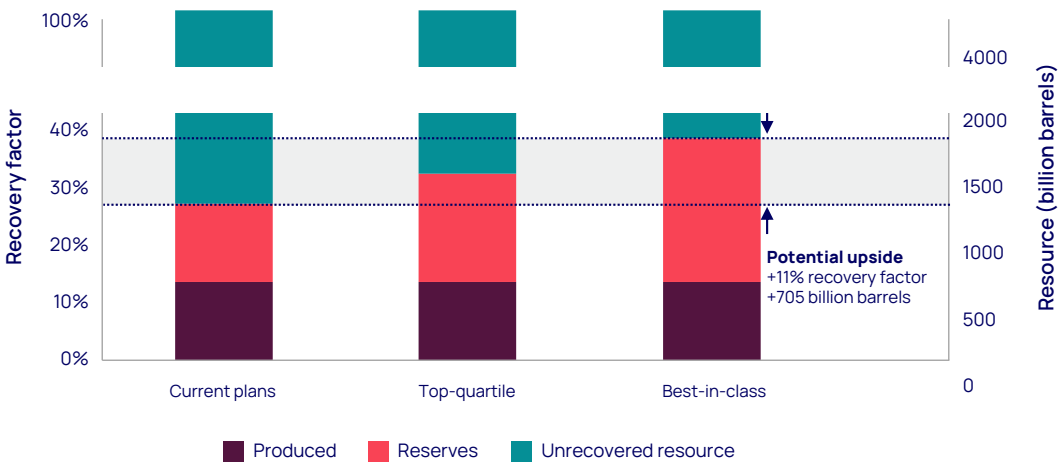
Source: Wood Mackenzie

Who operates this upside?

Over two-thirds of the potential additional recovery sits with the NOCs and other state-controlled enterprises. These operate fields with more than 320 billion barrels of upside on a top-quartile basis and 700 billion barrels of upside on a best-in-class basis.

The fields themselves are not unusual. NOC-operated fields generally have similar potential to other fields, with scope to achieve average recovery factors of 39% on a best-in-class basis, almost matching the industry overall best-in-class potential of 42%. At present, the NOCs are on track to achieve a slightly lower recovery factor of 28% compared with the industry average of 29%.

Figure 4: Conventional oil-field reserve upside operated by NOCs



Source: Wood Mackenzie

The Majors operate conventional oil fields of above-average quality, on track to achieve an average recovery factor of 33%. On a best-in-class basis, the Majors' fields have scope to reach 47% recovery, 5% better than the global best-in-class average.

The downside of this stronger performance is that the remaining upside is less. The Majors operate 32 billion to 58 billion barrels of upside on a top-quartile to best-in-class basis, corresponding to just 6% of global potential.

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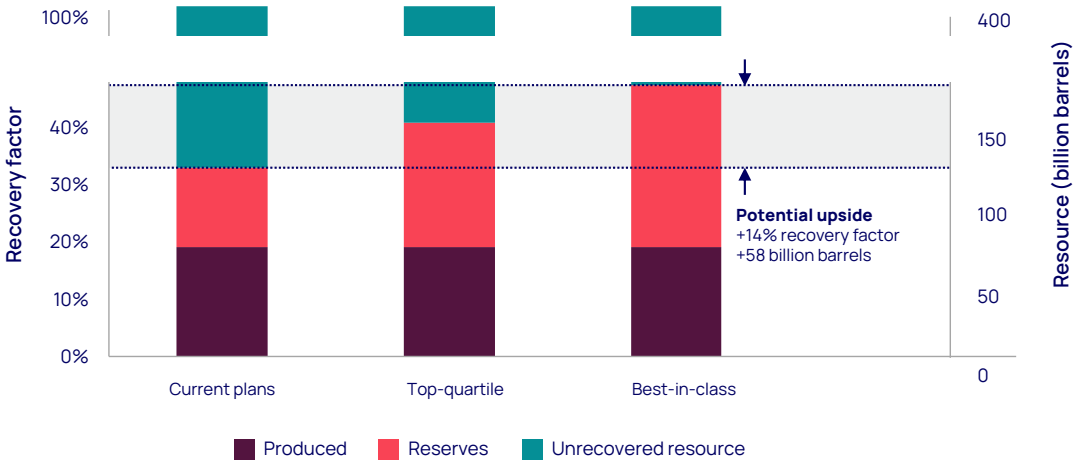
Figure 5: Conventional oil-field reserve upside operated by Majors



Source: Wood Mackenzie

Time for the NOCs to step up (and open up)

Our analysis confirms that existing fields easily hold the resources to meet oil demand for decades to come. We see no threat of peak oil supply here. Global security of supply need not be beholden to unpredictable exploration results or access to areas previously off limits. Nor must we hope for unproven technologies to drive ever-higher recovery. All of these factors will have some part to play, but will be far from the whole story. Proven technologies and existing fields can do the job.

While it may be unrealistic to expect today's best-in-class performance to spread across the whole industry, a step up to today's top-quartile performance should be achievable. The Majors are already operating well above industry average and hope to move higher still.

We see no threat of peak oil supply here

Norway, the UK and much of the global deepwater have good technology access and are already close to their recovery limit. They will lose market share.

The future of the oil industry will be increasingly onshore and operated by NOCs. Russia and much of OPEC, with less access to technology, challenging fiscal terms, and difficult rocks and fluids, have scope to grow market share. Supply will be strongest from the long-established onshore super-basins of the Middle East, Asia and the Americas.

Most IOCs will approach their upside limit sooner than most NOCs. Certain countries may choose to increase their upside through fiscal changes or improved access to technology.

Many NOCs will delight in this opportunity. But some will need more help. Their performance to date, outside of Saudi Arabia, Kuwait and the United Arab Emirates, lags the Majors and leading IOCs. NOCs must find ways to improve access to technology and investment if they are to capture market share. Therein also lies the greatest opportunity for both the IOCs and the upstream supply chain.

Those operators looking to invest internationally should find that the world is their oyster. There are more opportunities in producing fields than there is capital available. Host governments that want optimal development of their resources will need to offer attractive terms to lure the best operators.

There are more opportunities in producing fields than there is capital available

The upstream industry already has the assets to meet oil demand – even under our delayed transition scenario – to 2050 and beyond. What it needs are new partnerships forged between the NOCs, especially those which hold the lion's share of the untapped potential, and the IOCs and contractors that can bring the technology, know-how and investment to help unlock the opportunities.

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