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Inflection point: The future of subcontracting in the petroleum industry

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ABSTRACT

Oil prices have been in the downturn since the recession of 2008. Since then, companies have struggled to survive as factors of production are being driven by external influences. International efforts to create a sustainable environment further intricates the supply and demand curve as countries develop policies and strategies to phase out fossil fuels. There has been a myriad of researches conducted by both public and private organisations that seem to agree and disagree on certain factors of a peak oil forecast. There is lack of research however, on finding common ground to determine the central tendencies if multiple predictions are accounted, which creates bias in decision making. The findings of this research provide a practical outlook for businesses and governments to better position their financial and policy decisions with regard to fossil fuels which could affect the lives of many. This research uses a novel prediction combination approach to determine an earliest-case peak oil occurrence through qualitative and quantitative methods for bias minimisation. The predictions are sourced from a balance of reputable private and public international agencies. The result interestingly finds commonality of reaching an earliest-case of peak oil in the year 2025 with feasible factors considered. The research discusses the inflection point forecast and financial risk mitigation recommendations for private entities and governments gathered from expert reports and articles in the field of oil supply and demand.

1. Introduction

Peak Oil is a hypothetical point in time when the maximum global oil production is reached, which has been the subject of many expert debates (Graefe, 2009). This event, although theoretical, will occur since there is a limit to the amount of oil that practically exists (Murphy, 2012). Therefore, the only question to ask is, “When?” The phrase “oil production” however, only refers to one of the two factors that dictate oil prices. Oil price inevitably obeys the Law of Supply and Demand. Hence, the more important concern in economic strategy would be on oil demand rather than on oil supply, according to Ederington et al. (n.d.). The Peak Oil emphasised in this research is not about supply, but about the salience of the demand.

The Paris Agreement in 2016 was ratified by 195 countries, including the world’s top greenhouse gas emitters: the United States and China. This accord details the commitment of both developing and developed nations in reducing emissions in order to limit the global average temperature rise to below 2 °C (Paris Agreement, 2016). This is one of the major endeavours in the area of geopolitics that directly and indirectly threatens the organisations and businesses that rely heavily on fossil fuels, both as a product and as a commodity. The drive is for economies to switch and invest in renewable and green energy for sustainability targets to be met (IRENA, 2019). There are other driving factors that contribute to the decline in demand for fossil fuels which will be discussed more in depth in this paper.

The influence brought on by governments, non-profit organisations and some private organisations is significant to any consumer. Burch and Gilchrist (2018) report that large private organisations such as Google and Apple are committed to running on renewable energy which includes both investments and corporate policies. Climate change is a serious issue considered not only a threat to businesses but also to national security by the United States (Henderson et al., 2018). Although some may disagree with the opinion that the United States trimmed its stakes on climate change through its withdrawal from the Paris Agreement on 1 June 2017 (Leggert, 2019), there are domestic and international influences that clamp the country’s commitment to climate change, rendering the announcement a mere delay but not a means of full discontinuation of greenhouse gas (GHG) reduction efforts (CAT, 2019).

Global policies and emerging technology trends further affect the demand for fossil fuel prices despite the private sector’s inclination towards profit generation. Prices of batteries used in electric and hybrid cars are on the sharp decline (Frankfurt School-UNEP Centre, 2018). The International Maritime Organisation’s (IMO) IMO 2020 guideline narrows the product selection of shipping industries to low-sulphur content crudes, creating downshifts in overall long-term demand (Gupte and Washington, 2019). Business expenditures and investments are governed primarily by demand. In short, it is the demand that initially dictates how future project investments are dispensed in terms of magnitude and time (Olson and Lenzman, 2016). Once projects are initiated by companies to support the
forecasted demand, the objectives of the project are only realised many years after the demand study is forecasted. This is the biggest threat to contracting and subcontracting in oil and gas projects (Berends, 2007). Even if projects are executed using fund reserves, companies will suffer losses due to interest and will only continue to do so due to storage expenditures. Hence, this strategy, if done without sound study is not only financially harmful but illogical.

Given the imminent conditions, it is therefore necessary and scientifically justifiable to have a basis for a peak oil demand estimate. This will provide a reference for organisations to react and prepare for this event, particularly to contracting and subcontracting life cycles in oil and gas projects. This article attempts to answer the question of when this estimated peak oil could be and how it impacts the project investment cycles of oil and gas entities (state-owned or otherwise) through a qualitative and quantitative study of economics and energy expert data and research. Many researches can be found that treat factors and dependencies differently, leading to a cumbersome identification of a single practical method. A novel method of combining multiple predictions to achieve a commonality and minimise prediction bias had been adopted in this research. The results present a pragmatic case for companies and governments to consider in timing strategies and decisions that can affect the lives of the general public.

This paper reviews literature relating to the subjects of oil supply, its trends, factors affecting peak oil, and project life cycles. This will then be followed by a methodology section explaining the activities done to collect, study, and analyse data from oil and gas subject experts through qualitative and quantitative analyses. The results will then be explained in the succeeding section with a last section concluding the findings.

2. Literature review

160 journal articles, reports and publications coming from expert sources and organisations have been reviewed, all of which are relevant to the subject of this research. The review involved coding the literature to specific themes in order to invoke the objective of the research methodology. This section shall organise the review by specific themes.

2.1. Decline of oil demand

The world's energy demand undoubtedly grows annually as a result of the natural economic growth of a country, applicable to both developed and developing nations. Many studies share this common result. A report done by Drebentsov and CIS Economics (2016) details historical data and forecasts of energy demand. There are also forecasts generated through studies by Pickl (2019) and IRENA (2019) which provide a statistical basis for this energy demand growth. These articles, however, also share the same conclusion that there is an energy mix in this rising energy demand. The energy mix consists of other sources of energy besides oil, such as gas, coal, and renewables. The ratio of the annual demand for these energy types is inconsistent year by year. The rise in cheaper raw materials and technology of renewable energy shifts the market power from the “seller” to the “buyer”. An article from Esser and Stansbury (2018) further exacerbates the issue in terms of investments as investors now feel uncertain about the oil and gas market. This uncertainty poses a great risk to future projects and contracts. Investments play a big role in business sustainability because investments finance projects. Some investments have now shifted from oil to renewable energy. According to Nagashima (2018), Japan has committed to becoming the world's first "Hydrogen Society", marking an ambitious effort to invest heavily in the development of clean energy. Japan has set aside US$1.5B for research, development, and subsidies. Investments are also shifting on the side of major oil players. Pickl (2019) conducted a study on the investments done by major oil companies in renewables, identifying Shell as the biggest stake taker in the renewable business. This only shows that there is an opportunity for oil companies to shift and become energy companies. The strategy of Saudi Arabia as a leader in Photovoltaic Cell technology in the world proves that there is great interest for companies to ensure financial sustainability through diversified project investments. Saudi Arabia launched a US$28B funding initiative as reported by Gordon (2019).

2.2. Increase of oil supply

The price of a commodity is determined by the equilibrium concept of supply and demand. Although it is evident that quantity curves may be forecasted to determine a price expectation, doing it in practice is quite difficult. One of the reasons why financial bubbles occur is the mismatch in investment cashflow (Girdzijauskas et al., 2010). Oil supply is a determining factor for current oil prices, which producers can exploit and use for capitalisation if trends are favourable. Supply forecasting is a very complex subject to analyse because decisions are made by cartels and organisations who influence government policy makers and vice-versa. The 1973 Oil Crisis was instigated by the decision of the OPEC to embargo oil to the Israel supporters, proving the extent of political power that oil-producing economies hold over the world, as the price of crude soared from US$12 to US$53 a barrel in less than 4 months (Smith, 2009). The recent COVID-19 virus outbreak affected the shipping and air travel industries, hitting many industries hard, including oil companies, as the demand sank sharply for the first time in 10 years, pressuring OPEC to cut supplies (Perkins, 2020). Oil price dropped to nearly 34% in a matter of days, creating an oil shock, as Saudi Arabia, OPEC and Russia failed to reach an agreement to cut supplies amidst the impact of the COVID-19 virus (Egan, 2020). These events only prove that oil supply is completely in the hands of select segments of society despite the status of the overall demand. This creates a decline in oil prices, shifting market share to those companies who win the competition due to low prices. However, in terms of opening up opportunities for new projects, it is unlikely that these companies will exploit their reserves unless they can accumulate substantial capital from their current earnings.

2.3. Investments in renewable energy

Renewable energy is defined as energy sources that are naturally occurring, sustainable and self-replenishing (Ellabban et al., 2014). Renewable energy investments have steadily grown in the last decade in terms of investments, government policies, research and development (Frankfurt School-UNEP Centre, 2018). There is apparent hesitation on the part of investors and banks in financing renewable energy projects. However, through government policies, projects are funded, and even private sector initiatives are awarded with grants to support climate change commitments. It is more challenging for developing countries to implement projects but governments of developing nations are gearing towards the adoption of policies. Developed nations, on the other hand, given the financial equipment and technical knowledge, have been aggressively pursuing the switch to renewables (Donastorg et al., 2017). In Frankfurt School-UNEP Centre's (2018) report, a total of US$79.8B has been spent on renewables, with a record high of US$323.4B in 2015 globally. Surprisingly, Saudi Arabia, one of the world's largest oil producers and exporters, has invested US$28B in renewable energy through the state's direct project funding and subsidies (Gordon, 2019). This development has now given rise to a new trend that is inspiring oil companies to transform into energy companies.

2.4. Government policies on climate change

Many governments around the world, both from developed and developing countries, have pledged commitments to efforts tackling climate change. One of the earlier conventions adopted was the Kyoto Protocol (United Nations, 1998). The driver for such an international initiative is that the business-as-usual mentality threatens the very existence of life on the planet, and that everyone is equally responsible in making sure that future generations can live in a sustainable environment. In order to meet this, at least ¼ of known global oil reserves must be left unexploited (Gencsu et al., 2017). Below are some, but not all of the major and specific
policies that governments are implementing or are planning to adopt, in order to meet the sustainability targets:

• supporting renewable energy electrification according to Gencsu et al. (2017),
• ratifying laws that will limit emissions from power plants (Piggot et al., 2019),
• improving waste and landfill management according to Oliveira (2009),
• diversifying energy generation (United Nations Climate Change Secretariat, 2019),
• promoting mass transit modes and discouraging private vehicle dependency (Rith et al., 2019), and
• increasing gas price and vehicle purchase cost (Rith et al., 2020).

2.5. U.S. withdrawal from the Paris agreement

The role of the United States in the battle against climate change is seen by the world as paramount to its success when the agreement was ratified. However, many analysts say that the United States’ move is merely a delay and will only provide more opportunities for China to leverage from their withdrawal (Bonanno, 2017). Moreover, despite the regret expressed by other developing nations of the accord such as France, Germany, and Italy, the same report states that these countries are aligned to dealing with private organisations and individual states directly in relation to climate change efforts. This is contrary to the public fear that this may serve as a precedent for other nations to also pull out or renegotiate the accord, since other countries are fully committed and no other nation has expressed plans in withdrawing at the time of this writing. Many analysts could not understand the full intention behind the Trump Administration’s decision to back out from the agreement. A report conducted by Hongyuan (2018) showed that 32 out of the 50 contingent states of the U.S. showed positive support on efforts to combat climate change, with 9 states remaining undecided.

2.6. Peak oil

The Peak Oil Theory was formulated by the American geologist M. King Hubbert in 1956. This theory works in the premise of the law of conservation of matter, with the point of discovery up to the point of production following a bell-shaped curve, from a minimum, to a maximum, and to a decline using a finite reserve model. When this theory was first introduced by Hubbert, it was mainly meant to predict the U.S. domestic market, during which his prediction of Peak Oil occurring in the United States in the 1970s was hailed as prophetic (Sen et al., 2015). Subsequent research spin-offs met criticism mainly for failing to accurately predict such an occurrence of peak production. Research conducted by Frans (2017) shows clearly that Peak Oil is a reality. Bardi (2019) studied the latest controversial prediction of Colin J. Campbell and Jean H. Laherrere, a geologist and a petroleum engineer respectively. This article, which was published in Scientific American in 1998, predicted that peak oil would occur in 2007. In his paper, Bardi (2019) studied Campbell and Laherrere's prediction based on 4 criteria derived from the original Peak Oil Theory, 3 of which were conclusively correct, with the most important criterion missing its mark. The prediction postulated that from 2010, “all liquid” fossil fuel production will not be more than 82 Mb/day. However, the International Energy Agency (IEA) recorded a global production of 97 Mb/day in 2017. Campbell and Laherrere (2018) were correct in meeting Peak Oil criteria which were:

1. oil production follows a normal curve,
2. oil discoveries will not match actual demand, and,
3. oil price will increase sharply prior to oil peaking.

2.7. Oil price trends

One of the factors to consider when predicting consumer behaviour is through oil price prediction. There is no single model to predict oil prices (Ederington et al., n.d.), which further adds to the volatility of oil stock prices. There are also agency-based forecasts that become bases for oil price watchers and investors, of which one of the most utilised is the Energy Information Administration or EIA, from the United States. The forecasts, however, are speculative and subjective, making the forecasts more fundamental rather than technical. Hence, the reason why some experts propose combining such methods to have a more accurate prediction model for oil price forecasting (Baumeister and Kilian, 2015).

Historically, oil price has increased at an annual average rate of 2.8$/barrel from the year 1970 up to before the recession in 2008 (Oxford Economics, 2010). Domestically in the U.S., the price of West Texas Intermediate (WTI) oil price followed a similar price trend, spiking just before the recession in 2008 (Graefe, 2009). The rise is only expected because global energy demand is proportionate to the GDP, or growth statistics of countries per capita. This means that as the world population increases so does the demand for energy (Nakanishi and Komiyama, 2006).

2.8. Oil and gas projects life cycles

Darko (2014) approximates a full development time cycle of 4–10 years. However, this does not only consider construction but also up to the first production. This estimate includes the involvement of establishing government contracts and permits which could take 5 years or longer to negotiate (Rui et al., 2017) leaving the actual project construction 5 years. In the context of this paper, the interest is narrowed to construction projects where the site is ready for development and subcontracts are being procured. Kim et al. (2018) conducted research on oil and gas projects arriving at an average duration of 42 months (3.5 years). A simulation was done by Yi et al. (2019) using data gathered from 3 overseas Korean EPC projects and applied Monte Carlo simulations in the baseline activities. Their study arrived at a project duration requirement of 42 months (3.5 years) for EPC oil and gas projects. These studies then give a gauge of 3.5 to 5 years for an average oil and gas construction project. The 3.5–5 years duration range only includes the construction stage after the FEED. The procurement stage, where contracts and subsequently, subcontracts are awarded is one of the critical factors that cause significant delays in oil and gas projects (Seddeeq et al., 2019).

3. Methodology

The latest insights or expert analyses of fourteen (14) of the world’s top business management consulting firms have been qualitatively examined (thus referred to as Private Experts). These insights are reports that are available in the public domain, particularly those that are extracted from the respective websites of the following firms (in random order):

1. McKinsey & Company
2. Boston Consulting Group (BCG)
3. Bain & Company
4. A.T. Kearney
5. PricewaterhouseCoopers (PWC/Strategy&)
6. Roland Berger
7. Accenture Strategy
8. KPMG International Cooperative
9. Ernst & Young
10. Oliver Wyman
11. L.E.K. Consulting
12. Arthur D. Little
13. FTI Consulting
14. Deloitte

These consulting firms house their own team of researchers and experts in a wide array of industries including energy. Their insight databases are very valuable sources of expert information which are relevant to the objective of this research. In order to eliminate bias and quantitatively analyse the results, the following steps were executed:

1. The Insights database of each firm was examined using the keywords or phrases: oil & gas, renewable energy, peak oil, oil & gas trends, and oil & gas forecasts.
The hits were analysed for relevance and included in the reviewed articles. The databases were again searched for any later articles that would have revised, retracted, or updated the initially retrieved reports or forecasts. The relevant insights were analysed to obtain specific and explicit conclusions pertaining to a peak oil point. The relevant insights were analysed to determine non-explicit references to a potential peak oil point or a dramatic shift in oil production or demand. The earliest probable peak oil demand period is obtained noting the scenario or condition, if specified, where the scenario is assessed as feasible or speculative.

The primary data that was sought is a quantitative global peak oil demand value projected per annum to induce a quantitative value of oil demand in MMb/d (million barrels per day). However, it was expected that not all insights and reports would explicitly indicate such values.

The relevant insights were analysed for a recommendation and proposed mitigation strategy for such peak oil events.

The results were analysed to form an expert basis of upcoming peak oil forecasts and compared with the latest major international organisations’ (or Public Experts’) forecasts from publicly available databases in the respective organisation websites:

1. Energy Information Administration (EIA)
2. International Energy Agency (IEA)
3. World Bank
4. International Monetary Fund (IMF)
5. International Association of Oil & Gas Producers (IOGP)
6. Organisation of Petroleum Exporting Countries (OPEC)
7. International Renewable Energy Agency (IRENA)
8. World Energy Council (WEC)
9. The Institute of Energy Economics, Japan (IEEJ)
10. Energy Community
11. Energy Watch Group
12. Asia Pacific Economic Conference (APEC)
13. United Nations Development Programme (UNDP)
14. World Petroleum Council (WPC)

Each of the international energy organisations were searched for reports with the key words: oil demand outlook, peak oil, and oil demand. The outcomes were compared, graded and classified with a peak oil outlook and neutrality similar to the procedure done with that of the Private Experts.

### 4. Theory/calculation

This research is focused on time predictions from expert sources in the unit of ‘years’. Certain predictions provide a range of years, while some are year-specific. In order to induce a commonality in the predictions, the author suggests that a summation algorithm be applied. Through this method, a peak, or peaks, on a time graph is expected. This algorithm applies only to the earliest-case scenario and not on multiple base cases that the expert sources may have. The inexhaustible earliest-case prediction variables from the expert sources are the rate of technological advancements, climate change efforts, government policies, energy transition, and geopolitics. These factors introduce a level of uncertainty, hence, in the qualitative analysis, the expert source must have had a feasible basis for such a prediction claim before it can be considered in the summation algorithm.

The summary of the peak oil forecasts shall be given probability ratings depending on the following classification criteria referred to as the APV (Assigned Probability Value):

1 – Where a source explicitly states a peak oil time period through qualitative data or quantitative data (e.g. charts, tables etc.)
0.5 – Where a source provides an implicit view of a peak oil period through qualitative data.
0 – Where no relevant qualitative or quantitative data is obtained.
-1 – Where a source rejects or explicitly states that no peak oil shall exist through qualitative or quantitative data (e.g. charts, tables etc.)

The APVs shall then be plotted on a chart with cumulative values to determine the common agreement of private and public forecast data sources by applying the following formula (Eq. (1)):

\[
f(t) = APV_T = \sum_{i=1}^{14} APV_{Pri,i} + APV_{Pu,i}
\]

where: \(APV_T = \text{Total Assigned Probability Value}, APV_{Pri} = \text{Sample Private Expert Probability Value}, APV_{Pu} = \text{Sample Public Expert Probability Value}\)

#### 4.1. Normalisation

Equation Eq. (1) yields peak annual values projected from accumulated assigned probability values. This method introduces a probability peak that has a value greater than 1.0. In order to contain a limit of 1.0 probability, the result shall be normalised by applying the algorithm below (Eq. (2)):

\[
f(t) = \frac{\sum_{i=1}^{14} (APV_{Pri,i} - \text{arg min}APV_T) + (APV_{Pu,i} - \text{arg min}APV_T)}{\text{arg max}APV_T - \text{arg min}APV_T}
\]

where:

\(APV_T = \text{Total Assigned Normalised Probability Value}\)

From reviewed literature, a time frame for contractors and subcontractors for business mitigation plans had been established based on oil & gas project life cycles. A value of 3.5-5 years was used to estimate a time period for a mitigation response time for contractors and subcontractors from the established common peak oil forecast.

### 5. Results

Fig. 1 shows the non-normalised probability forecast projected from 2019 to 2050. The time range was selected from the earliest peak oil forecasted and the latest peak oil forecasted gathered from Asia-Pacific Economic Cooperation (2019) and from Monzon et al. (2018) respectively.

The raw data are shown in Appendix A: Qualitative Data Analysis, and Appendix B: Quantitative Data Analysis.

Figs. 1 and 2 charts indicate a peak prediction concentrated in 2025. In order to validate the sources, the Private Expert and Public Expert projections are also shown and both projections generally agree.

The earliest peak oil prediction was expressed by APEC in its report implying that a peak oil forecast would occur in 2019. The latest forecast came from Arthur D. Little’s report which gave a range from 2040 to 2050. The forecast given by IOGP in its report was invalidated because its report data expresses clearly that the peak oil forecast of 2024 is based on a speculative case considering a sudden zero capital expenditure in oil and gas investments at the time the report was published. The report was found to reject the prediction of peak oil. The report from EIA (U.S. Energy Information Administration, 2019) does not indicate any future peak oil up to 2050 but instead only shows a steadily increasing oil demand. There is a significant difference in the peak oil graph of the private experts versus public experts. This difference is due to the inapplicable forecast data from 5 public expert sources, as compared with the private experts which had only 2 inapplicable predictions. This forecast is based on feasible factors that were considered by the private and public sources such as the rate of technological advancements, climate change efforts, government policies, energy transition, and geopolitics. Although the expert sources have sound statistical data or forecast modelling, human behaviour or a major natural occurrence may affect these factors (e.g. pandemic). The forecast presented in this result is based on earliest-case scenarios which are dependent on global drivers and other changes. Forecast considerations were included in the qualitative analysis to determine commonality among the forecast providers. These considerations were generally found to be feasible due to existing
peer-reviewed data. The 2 main themes found as bases for early peak oil predictions are:

1. Market share increase and technological advancements in transportation
2. Climate change geopolitics

A report released by the International Energy Agency (2019b) and Frieske et al. (2013) shows rapid growth in global electric vehicle market share and technology innovations. Developed nations are more capable of applying fossil fuel policies as these nations have the technological and financial advantages as compared to developing nations. Developed nations can easily apply certain demand controls (e.g. removal of fuel subsidies) since their people would be able to afford the increase in fuel prices. Developed nations also have the capacity to invest in renewable energy as compared to developing nations. Developing nations, on the other hand, will have difficulty creating such policies due to their governments’ and public’s financial limitations.

The top common themes as recommended mitigation and business action strategies by Private Experts were also gathered as the following:

1. Diversification of market portfolio
2. Digitalisation and analytics
3. Investments in renewable energy
4. Reduction of dependence on carbon-based products
5. Optimisation of business operations

6. Discussion and conclusions

The forecast prediction of this research provides governments and businesses with a feasible foresight of peak oil happening which can be used for timing investments, making policies, and structuring business operations. This, of course, considers the earliest-case factors occurring as predicted by the expert sources, which may vary. The emergence of technological advancements in transportation and renewable energy is further clearing the vagueness of a drastic downshift in oil demand. The role of the U.S. and China in the international drive for climate change policies is crucial even with the withdrawal of the U.S. from the Paris Agreement. The European Union, together with China, is taking a bold step in leading the global supply of renewable energy raw materials. With the subsidy policies and investments of major European Union countries including the U.K. and Germany, it is very unlikely that these countries will reverse their current climate change policies. Drastic global demand disruptors such as a pandemic or an economic depression can either accelerate or decelerate the occurrence of a peak oil scenario.

As the year 2025 approaches, governments, contractors and subcontractors need to be more aggressive in adopting new business mindsets and major changes in their portfolio to prepare for an earliest-case scenario. With a project development window of 3.5–5 years, contracting companies

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**Fig. 1.** Non-normalised cumulative peak oil probability forecast projections.

**Fig. 2.** Normalised cumulative peak oil probability forecast projections.
need to review their core competencies and re-align with upcoming market demands. The path to peak oil is not a straight line, therefore it can be expected that difficulties in exploiting project opportunities will only exponentiate closer to peak oil. Further and immediate research is needed to identify new markets and diversification options for project-based companies with emphasis on implementation strategies.

Appendix A. Raw qualitative forecast data

| SN | Organisation | Source/reference | Explicit earliest peak oil forecast | Implicit earliest peak oil rejection | Contradictory/peak oil rejection | Scenario/consideration | Feasible or speculative? | Strategy and mitigation recommendation | APV |
|----|--------------|-----------------|-----------------------------------|-------------------------------------|---------------------------------|------------------------|-------------------------|----------------------------------------|-----|
| 1  | McKinney and Company | (Mckinney, 2019) | On or before 2025 | Not applicable | Not applicable | Technological advancements in transport and chemicals could peak liquids demand before 2025 | Feasible | Digitalisation, analytics, improved product management and automation (Hamilton et al., 2019), Reduction of carbon-based assets and diversification (Garrett et al., 2019) | 1 |
| 2  | Boston Consulting Group (BCG) | (Brogaux et al., 2017) | 2025 and before 2030 | not applicable | Not applicable | Electric vehicle adoption | Feasible | Low-emission portfolio diversification, lobby for government support (Burchart et al., 2018) | 1 |
| 3  | Bain & Company | (Leis, 2019), (Bain and Company, 2017) | 2023 to 2026 | Not applicable | Not applicable | Due to declining demand from the transportation sector | Feasible | Scenario planning, assess business model to diversity competition, digitalisation, resource localisation, innovation, flexible financing metric (Leis, 2019) | 1 |
| 4  | A.T. Kearney | (Forrest et al., 2011) | On or before 2025 | Not applicable | Not applicable | Government’s low carbon energy mix and biofuels | Feasible | Diversify portfolio, Invest in renewables, Specialise in the value chain (Forrest et al., 2011) | 1 |
| 5  | PricewaterhouseCoopers (PWC, 2019) | Not applicable | On or before 2028 | Not applicable | | Energy transition and climate change action from governments | Feasible | Create new capabilities from existing capabilities, diversification, renewables investment, digitalisation (PWC, 2019) | 0.5 |
| 6  | Roland Berger | (Frans, 2017), (Roland Berger, 2018) | Between 2025 and 2035 | Not applicable | | Transition from internal combustion engine to electric vehicles | Feasible | Adapt with vision and realistic scenarios (Frans, 2017) | 1 |
| 7  | Accenture Strategy | (Ashraf et al., 2018), (Accenture, 2015), (Accenture, 2019) | Not applicable | Between 2025 and 2035 | Not applicable | Decarbonised energy systems, Energy Efficiency, Consumer Behaviour, Digitalisation | Feasible | Diversify energy portfolio, venture into supply chain changes, improve operational efficiency, digitalisation (Accenture, 2019) | 0.5 |
| 8  | LPMG International Cooperative Ernst & Young | Not Applicable | | | | | Not applicable | | 0 |
| 9  | Ernst & Young | (Brogan, 2018), (Brogan, 2019a), (Brogan, 2019b), (Laclau and Brogan, 2019), (Colle, 2019), (Brogan, 2019c) | Not applicable | Around 2025 | Not applicable | Rising interest rates will affect funding decisions in a mixed energy market due to rise of renewable energies | Feasible | Diversify core competencies to diversify expertise (Laclau and Brogan, 2019) | 0.5 |
| 10 | Oliver Wyman | (Wyman, 2019) | Not applicable | On or before 2025 | Not applicable | Due to emergence of affordable electric vehicles by 2025 | Feasible | Strategise for green energy markets (Wyman, 2008) | 0.5 |
| 11 | L.E.K. Consulting | Not Applicable | | | | | | | 0 |
| 12 | Arthur D. Little | (Monzon et al., 2018) | Between 2040 and 2050 | Not applicable | | Technological improvements and environmental concerns | Feasible | Diversify energy and non-traditional oil portfolio (Monzon et al., 2018) | 1 |
| 13 | FTI Consulting | (Rio, 2017) | Not applicable | Between 2025 and 2030 | Not applicable | Climate change targets | Feasible | Prepare for renewable energy markets (Backwell, 2017) | 0.5 |
| 14 | Deloitte | (Deloitte University Press, 2016) | Not applicable | | | Due to reduced transport fuel demand and increase in vehicle efficiency | Feasible | Diversify portfolio and optimise operation (England et al., 2015) | 0.5 |
| 15 | Energy Information | (U.S. Energy) | Not | Not | No forecasted peak | | | | -1 |

Acknowledgements and/or funding resources

The author would like to thank Ms. Julien Cyan Tupaz for proofreading the article.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
| SN | Organisation | Source/reference | Explicit earliest peak oil forecast | Implicit earliest peak oil forecast | Contradictory/peak oil rejection | Scenario/consideration | Feasible or speculative? | Strategy and mitigation recommendation | APV |
|----|--------------|-----------------|-----------------------------------|-----------------------------------|---------------------------------|------------------------|-------------------------|----------------------------------------|-----|
| 16 | International Energy Agency (IEA) | (International Energy Administration, 2019) | applicable | applicable | only increase | demand from non-OECD countries | Feasible | Not applicable | 1 |
| 17 | World Bank | (World Bank Group, 2019) | Not applicable | After 2020 | Not applicable | Due to economic downturns and current trends | Feasible | Not applicable | 0.5 |
| 18 | International Monetary Fund (IMF) | Not Applicable | Nil | Nil | Nil | Not applicable | Not applicable | Not applicable | 0 |
| 19 | International Association of Oil & Gas Producers (IOGP) | (International Association of Oil and Gas Producers, 2019) | Not applicable | Not applicable | | Sustainable development cases where no new capital investments in global oil production is ceased. | Speculative | Not applicable | 0 |
| 20 | Organisation of Petroleum Exporting Countries (OPEC) | (Organisation of the Petroleum Exporting Countries, 2019) | Between 2020 to 2025 | Not applicable | | Economic slowdown for developing countries and downtrend in electricity generation and transportation. | Feasible | Not applicable | 1 |
| 21 | International Renewable Energy Agency (IRENA) | (IRENA, 2019) | 2025 | Not applicable | | Energy transition to renewables. | Feasible | Not applicable | 1 |
| 22 | World Energy Council (WEC) | (World Energy Council, 2013) | Between 2025 and 2030 | Not applicable | | Climate change policies, technology innovations, renewable energy investments | Feasible | Not applicable | 1 |
| 23 | The Institute of Energy Economics, Japan (IEEJ) | (The Institute of Energy Economics, Japan, 2019) | Between 2025 and 2035 | Not applicable | | Technological advancements, climate change policies and renewable energy penetration | Feasible | Not applicable | 1 |
| 24 | Energy Community | Not Applicable | Nil | Nil | Nil | Not applicable | Not applicable | Not applicable | 0 |
| 25 | Energy Watch Group | (Energy Watch Group, 2017) | Between 2020 and 2030 | Not applicable | | Due to renewable energy investments and transitioning to gas | Feasible | Not Applicable | 1 |
| 26 | Asia Pacific Economic Conference (APEC) | (Asia-Pacific Economic Cooperation, 2019) | Not applicable | 2019 | Not applicable | Low carbon emission efforts for APEC countries. | Feasible | Not applicable | 0.5 |
| 27 | United Nations Development Programme (UNDP) | Not Applicable | Nil | Nil | Nil | Not applicable | Not applicable | Not applicable | 0 |
| 28 | World Petroleum Council (WPC) | Not Applicable | Nil | Nil | Nil | Not applicable | Not applicable | Not applicable | 0 |
## Appendix B. Raw quantitative forecast data

| SN | Organisation | APV 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 |
|----|--------------|----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
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