OVERHEATED EXPECTATIONS

Valuing Saudi Aramco's IPO in light of climate change

Briefing note by Oil Change International, August 2017
Written and researched by Greg Muttitt and Hannah McKinnon

1. Summary

Since the oil price began to fall in summer 2014, a new urgency has been given to questions over the future of oil and gas investments. While the fall in price was caused primarily by excess supply, there is a real prospect that in the medium term, prices will remain low due to constrained demand, driven by both climate policy and disruptive low-carbon technology such as electric vehicles. Some commentators expect oil demand to peak in the 2020s. For these reasons, the Taskforce on Climate-Related Financial Disclosures, led by Michael Bloomberg, recently recommended that investors consider risk through a range of scenarios of climate mitigation.

Into this landscape steps Saudi Aramco, with what is set to be the world's largest ever initial public offering (IPO). Most analysts believe that Crown Prince Muhammad bin Salman's US $2 trillion estimate of Aramco's value was unrealistic, reckoning instead on somewhere in the range $1 - 1.5 trillion. But there has been a gap in commentary, on how moves to decarbonise the energy system will affect the IPO's valuation.

This briefing aims to fill that gap, examining the climate dimensions of the proposed IPO through three lenses: how oil price will affect Aramco's valuation (section 3), how Aramco's oil production will compete with that of international oil companies (IOCs) in light of constrained demand (section 4), and how Aramco's reserves relate to carbon budgets (section 5).

We estimate Aramco's value using a discounted cashflow method. We find that the most important factor affecting valuation is the expectation of future oil price. As a result, investors in the IPO face significant risk due to efforts to limit climate change:

- **Compared to a base-case estimate of around $1.5 trillion, the value of Aramco could be between 25% to 40% lower in the IEA's safer-climate scenarios** (which correspond to the absolute minimum ambition within the range of the Paris goals).

- **If oil prices stay at $50 in real terms, Aramco's value could be reduced to less than $700 billion, 55% below the base case**. Considering statements by Shell around their recent Q2 results, such a scenario may now seem much less unlikely than some years ago.

The question of whether Aramco is advantaged relative to IOCs because of its low production cost depends on the shape and timing of climate policy. Aramco has a monopoly right to extract Saudi Arabia's vast reserves, and it does so slowly: at current rates, it would take 59 years to extract the reserves, compared to an average of 34 years for the five majors (on a like-for-like basis). On the other hand, IOCs are more sensitive to oil price, due to their costlier operations.

If governments continue to drag their feet on reducing emissions, IOC production will remain viable for longer, and assuming governments ultimately act to keep warming below 2 degrees, a large proportion of Aramco's reserves may be left unburned. However, this scenario would also entail rapid emissions cuts later, forcing down prices within investment timescales of 15-25 years, and causing significant destruction of oil company assets. As such, it creates the greatest financial risk to all. We conclude:

- **If the IPO realises a value at the higher end of the likely range (say, above $1 trillion), its investors could face significant risk from climate policy**.
- **If it comes out lower, this may raise questions of whether IOCs are overvalued**. While Aramco's value is likely to be discounted due to investors' perceptions of political risk, we find this is less important to assessments of value than the oil price.

If fully extracted and burned, Saudi reserves would have a profound impact on the climate. Emissions from Saudi reserves would amount to 112 Gt of carbon dioxide, one seventh of total global emissions in a 2°C carbon budget, or one third of total global emissions in a 1.5°C carbon budget. The problem is not so much Aramco on its own, but Aramco in combination with IOCs, which constantly explore for and open up new reserves, to replace what they have extracted.

- **Emissions from the oil, gas and coal in the world's already-producing fields and mines are enough to take warming beyond 2°C**.
- **Aramco's reserves may only be fully extracted if IOCs immediately stop exploring for and developing new reserves**. The different production strategies of Saudi Aramco and of IOCs are together not compatible with achieving the Paris Agreement's goal of keeping global warming well below 2° Celsius and aiming for 1.5°.
- **If IOCs continue to add new oil and gas, Aramco's reserves stand to push the world beyond climate limits**: after carbon budgets are exhausted, there will still be strong economic incentives to extract them due to their low cost.

The world is rapidly approaching climate limits. There is an urgent need for rigorous scrutiny of any new investments in fossil fuels, not least of the partial listing of the world's largest oil company.

2. Introduction

The proposed IPO of Saudi Aramco will be a centrepiece of commentary in the finance world for the foreseeable future. An Aramco valuation of $1 trillion, for example, would generate $50 billion from the sale of 5% of the company double the size of the largest previous IPO, online retailer Alibaba Group. The Aramco IPO's symbolic impact is profound, as a partial reversal of the nationalization of Saudi oil in the 1970s, which was popular domestically, transformative for the global oil industry, and a defining moment for the Global South in the early postcolonial period.[*]

The offering comes at a time of political commitments to decarbonize energy systems, and will serve to test the degree to which potential investors and commentators are digesting the implications of the Paris deal and disruptive trends that could impact the value of fossil fuel shares. Given the scale of Saudi Aramco's oil reserves, the climate impacts of burning them would be significant. However, the IPO itself is unlikely to either increase or decrease extraction or combustion of carbon. Rather the IPO partially transfers ownership and control over extraction, which reshuffles decision-making,[†] responsibility and risk, and hence has important indirect political and economic consequences, including for the climate.

Increasingly, financial leaders are confirming that the need for a transition to low carbon must be a consideration for relevant investment decisions. An example of the growing concern is the work of the Task Force on Climate-related Financial Disclosures (TCFD), which has been supported by many of the world's largest financial institutions. Investments in fossil fuel companies have a high risk exposure,[‡] not only from their core product ultimately becoming obsolete, but also from declining prices of oil, gas, and coal during the transition, potentially within the next decade.

In this briefing, we look at three ways in which the Aramco IPO relates to climate change. Section 3 focuses on how the value of Aramco is affected by future oil prices. Section 4 examines the market interaction of Aramco (and other national oil companies) with the IOCs, in the context of reduced oil demand. Section 5 considers Aramco's reserves in relation to climate limits, via carbon budgets.

3. Aramco's Valuation in a Low-Emissions World

When first announcing the IPO in 2016, Prince Mohammad bin Salman estimated Aramco's value at US $2 trillion. He apparently did so using a simplistic rule-of-thumb approach based on a multiple of

---

[*] Until the 1970s, oil production in the Middle East was carried out almost exclusively by international oil companies (IOCs), primarily the so-called Seven Sisters (consisting of Exxon, Shell, Chevron, Texaco, Mobil, BP, and Gulf). Then, in the biggest structural change in the global oil industry's history, production was nationalized across the region between 1972 and 1980, facilitated by a young OPEC. The IOCs were forced to retreat to more expensive "frontier" production, starting with the North Sea and Alaska, and later to deepwater and unconventional oil. Ever since, the oil industry has essentially consisted of two parts: the cheap, huge reserves extracted by national oil companies (NOCs), and the expensive and small reserves extracted by IOCs.

[†] While the primary decision-making role on Aramco's operations will remain with the Saudi government, which will continue to hold 95% of the shares, the shape of agreements with minority shareholders are likely to place some limits on that decision-making power.

[‡] One dimension of transition risk beyond the scope of this briefing is litigation risk, as lawyers pursue a growing number of climate liability cases. Saudi Aramco is alone responsible for 4.5% of the global industrial greenhouse gas emissions since 1988, the second highest of any company or entity in the world, making it a potential target for action, especially if listed in the United States. Paul Griffin, "The Carbon Majors Database", CDP/CAI, July 2017, p.14, https://www.cdp.net/en/reports/downloads/2327

reserves. In reality, Aramco's true value cannot meaningfully be estimated in this way, not least because of the longevity of its reserves (at current rates of extraction, they would last for 60 years). Most observers estimate that $1-1.5 trillion is more realistic.

What factors affect Aramco's valuation?

In this section, we use a discounted cashflow (DCF) method to estimate the value of Saudi Aramco's core business, namely oil extraction. This methodology assumes the company value to be equal to the net present value of its future upstream cash flows.[1] Our purpose is not to make a precise estimate, [2] but to reveal the relative importance of different real-world factors to the outcome, especially in relation to climate change.*

We do not include Aramco's refining, petrochemicals, overseas, natural gas or non-hydrocarbon operations, which together may be worth something of the order of $100 billion (depending on the subsidised prices set by government).[3]

Our **base case** assumes current fiscal terms, oil prices as forecast in the International Energy Agency's (IEA's) **New Policies Scenario**, and a 10% real discount rate.

First, we look at sensitivity to oil price, by considering three other price scenarios, two of them forecast by the IEA,[4] assuming different levels of climate action:

- **450 Scenario (450S):** Giving a 50% probability of keeping warming below 2°C.
- **66% Scenario (66S):** A new scenario giving a 66% probability of keeping warming below 2°C.
- **Constant $50:** A constant oil price of $50 (in real terms). At the time of writing, WTI Futures for December 2025 were trading at $54 per barrel;[5] Goldman Sachs expects oil prices to stabilize around $50 over the long term.[6]

These price scenarios are shown in Figure 1, below.

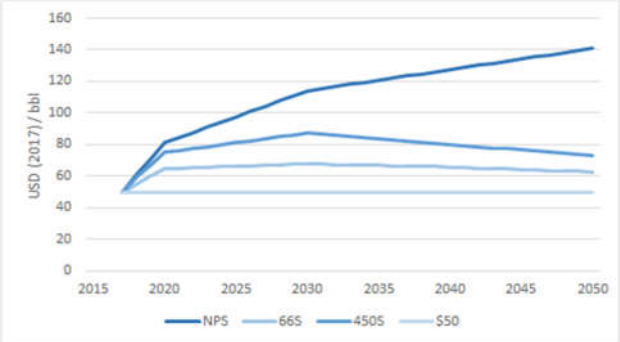


Figure 1: Price scenarios (in 2017 US dollars)

* For this reason, we do not consider other valuation methodologies, such as comparing various multiples (yield, price/earnings ratio etc) with other oil companies – such approaches reveal more about the financial market for oil company shares than about the oil market.

Second, we vary some of the other elements, considering three other scenarios, all with the NPS price and 10% discount rate:

- **85% Tax:** An 85% tax rate, to illustrate how the value would have looked before the Saudi government reduced the tax rate to 50% (which it did in March 2017 to increase the Aramco valuation).
- **Royalty Cut:** A reduction of royalty rate from 20% to 10%, which is reportedly being considered by the Saudi government.[7]
- **2040 Halt:** A stylized scenario where production suddenly stops from 2040 onward. This is obviously not a realistic (or desirable) scenario, but is included in order to explore how reserves size affects Aramco's value.

Finally, we vary the discount rate between 8% and 12%, in order to simulate how investors might factor in risk. This reflects a common range of discount rates used in international oil company projects and transactions (with higher perceptions of risk reflected in higher discount rates). While geological and operational risk are likely to be considered low, some investors will be concerned about political risk. For example, how will the Saudi government use its remaining 95% stake in decision-making? Will regulatory and fiscal terms change? In the long term, how stable is the House of Saud regime?

The Aramco valuations in these different scenarios are shown in Figure 2.

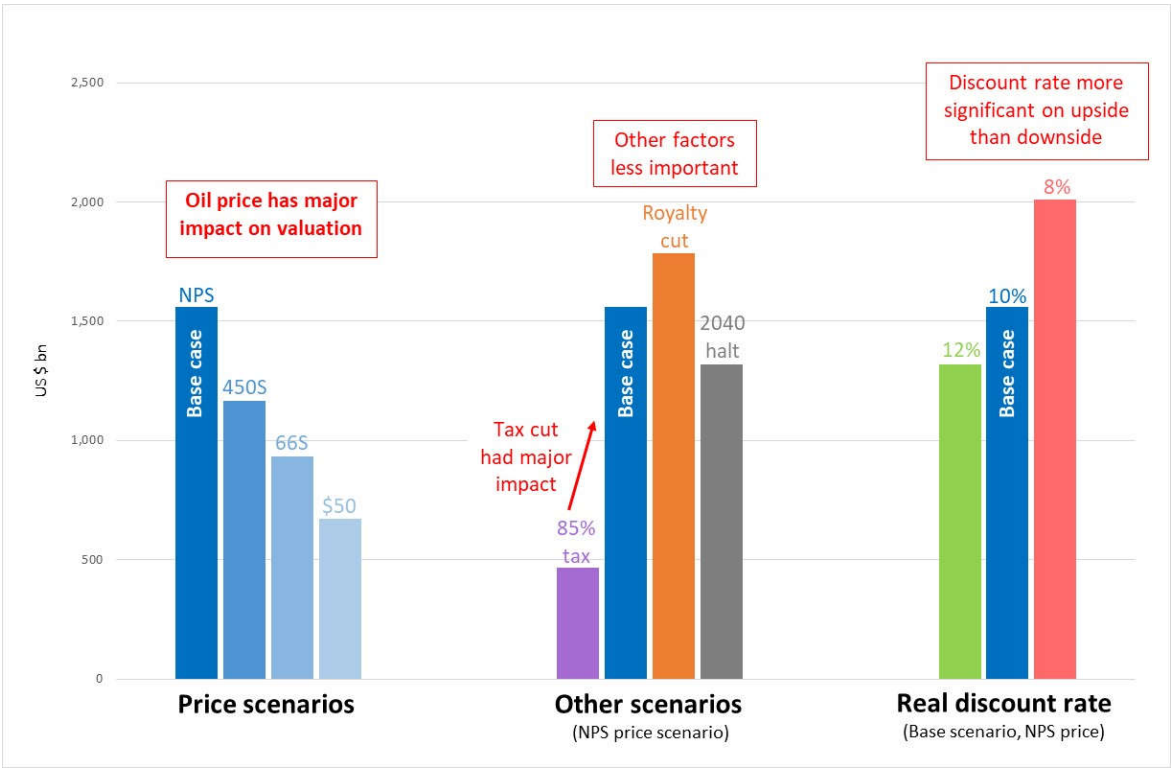


Figure 2: Factors affecting the valuation of Saudi Aramco. Sources: Rystad UCube, Oil Change International model

The graph shows why the tax cut from 85% to 50%, which Saudi Arabia enacted in March, was so important: it nearly quadrupled Aramco's value. Aside from that, we see that expectations of future price are the most important factor affecting Aramco's valuation. The prices in the IEA's 450 Scenario and 66% Scenario lead to valuations respectively 25% and 40% lower than the NPS base case. If prices remain at $50, the valuation is fully 55% below base case.

Discount rate also has a significant impact on valuation, though more on the upside than the downside. This suggests that while political risk is important, it may be less important than price risk.

The '2040 halt' scenario shows that simply leaving some portion of the reserves in the ground is less important to the current valuation than expectations of mid-term oil prices. The reason for this is the time value of money: What happens beyond 25 or 30 years is heavily discounted in the valuation. In other words, the reserves size itself is not a good measure of value (although it is a key indicator of risk to the climate – see section 5).

Climate change and oil price

Two of the price scenarios above are explicitly related to climate policy, where the IEA sees government action reducing emissions and hence oil demand and prices. The 66% Scenario, which would reduce Aramco's value by 40% compared to the base case, represents the minimum level of ambition within the range of the Paris Agreement goals. The Organization of the Petroleum Exporting Companies (OPEC) expects oil demand to peak in 2029, if governments' Paris emissions pledges are met.[8] (The pledges are estimated to put the world on course for 3°C or more, so achieving the Paris *goals* of 1.5 - 2°C would require an earlier peak).

While the oil price ceiling is currently set by the marginal cost of U.S. shale production, in the 2020s we can expect downward pressure on prices due to demand factors. These include improving vehicle fuel efficiency, lower car ownership in younger demographics, and the increased adoption of ridesharing and autonomous vehicle technology (both of which improve efficiency).

The most visible disruptive change is the penetration of electric vehicles, which is now being embraced by the world's largest auto manufacturers.[9] UBS predicts that by the early 2020s, the purchase price of an EV will be only very slightly higher than a petroleum-fueled car, with only small a fraction of the fuel and maintenance costs.[10] Regulation is also a major driver. Both France and the United Kingdom have announced plans to ban petrol- and diesel-fuelled cars from 2040, and several other European governments have also considered bans, some as early as 2025. [11] Cities are restricting the use of diesel vehicles, due to air pollution concerns. [12] The Indian government aims to achieve 100 percent electric cars sales by 2030, through incentives and innovative financing.[13]

Transportation accounts for 65% of world oil demand,[14] nearly two thirds of which is from light passenger vehicles, light trucks, bus and rail[15] – all of which will be increasingly electrified. Another nearly 20% of oil demand arises from industry and buildings, both also likely to reduce consumption due to climate policy and carbon pricing.

Some oil industry commentators foresee demand for oil peaking at some point in the 2020s. Shell's former Chief Financial Officer Simon Henry said he expects oil demand to peak within the next five to fifteen years.[16] Goldman Sachs suggests the peak could come as soon as 2024.[17] For an industry that has seen consistent demand growth throughout its 150 years of history – except in years of economic recession – the price dynamics will be fundamentally disrupted whenever the peak occurs.[18]

4. Will Assets be Stranded?

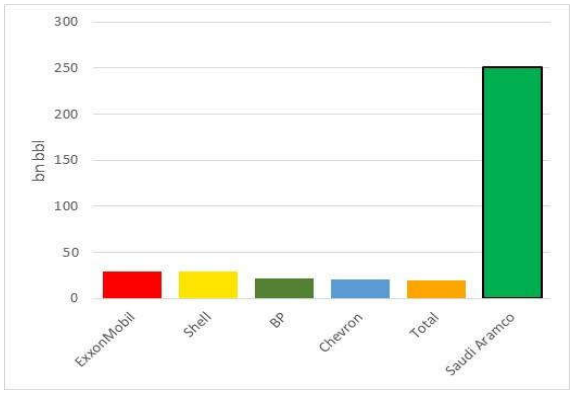
We saw in the previous section that Aramco's value is strongly dependent on oil price, such that a relatively high valuation (above $1 trillion) would leave investors highly exposed to risks arising from the transition to low-carbon energy.. In this section, we consider the interaction between Aramco and international oil companies (IOCs) such as Shell and ExxonMobil.

Aramco vs IOCs – reserves and market dynamics

Saudi Aramco's reserves are very different from those of the IOCs, in two key respects:

- **Aramco's oil reserves are huge**: roughly eight times those of ExxonMobil, the largest IOC.
- **They are very cheap to extract**: Aramco's operating expenditure per barrel is just half that of the five majors' average, and its capital expenditure per barrel is less than a third.

(a)



(b)

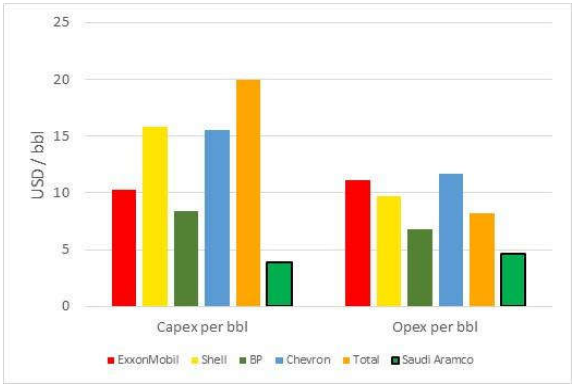


Figure 3: Saudi Aramco compared to five oil majors, by (a) oil reserves (at 1 January 2017) and (b) costs per barrel (2016). Source: Rystad UCube[19]

Furthermore, **Aramco extracts its reserves slowly**: at current rates, it would take 59 years to extract Saudi reserves, compared to an average of 34 years for the five majors (on a like-for-like basis*). The IOCs therefore constantly explore for and develop new reserves, to replace what they have extracted.

* Rystad UCube, 6 July 2017: Resources, excluding undiscovered.

Note that when IOCs speak of a 12-15 year reserves life, they are referring to proven (1P) reserves only. Comparable figures are not available for Saudi Aramco (at least until the IPO prospectus is published), and the BP Statistical Review of World Energy uses inconsistent reserves definitions for different countries. Rystad's definition is close to that of proven and probable (2P) reserves.

While IOCs tend to extract fields as quickly as they can, Saudi Arabia does not do so, for two reasons: to conserve reserves for future generations, and to sustain the oil price.[20] This is a fundamental dynamic of the oil market: slower extraction rates in the Middle East (primarily Saudi Arabia, Kuwait, Abu Dhabi, Iraq and Iran) make high-cost production elsewhere viable. This is more important in the big picture than OPEC's role in adjusting production, which influences the price in the short term.*

Aramco vs IOCs on the cost curve

One common way of exploring financial risk arising from the energy transition is through cost curves, where oil projects are arranged in order of increasing cost. Figure 4 illustrates the approach, showing the cumulative 20-year production of oil provinces, each with a range of costs.

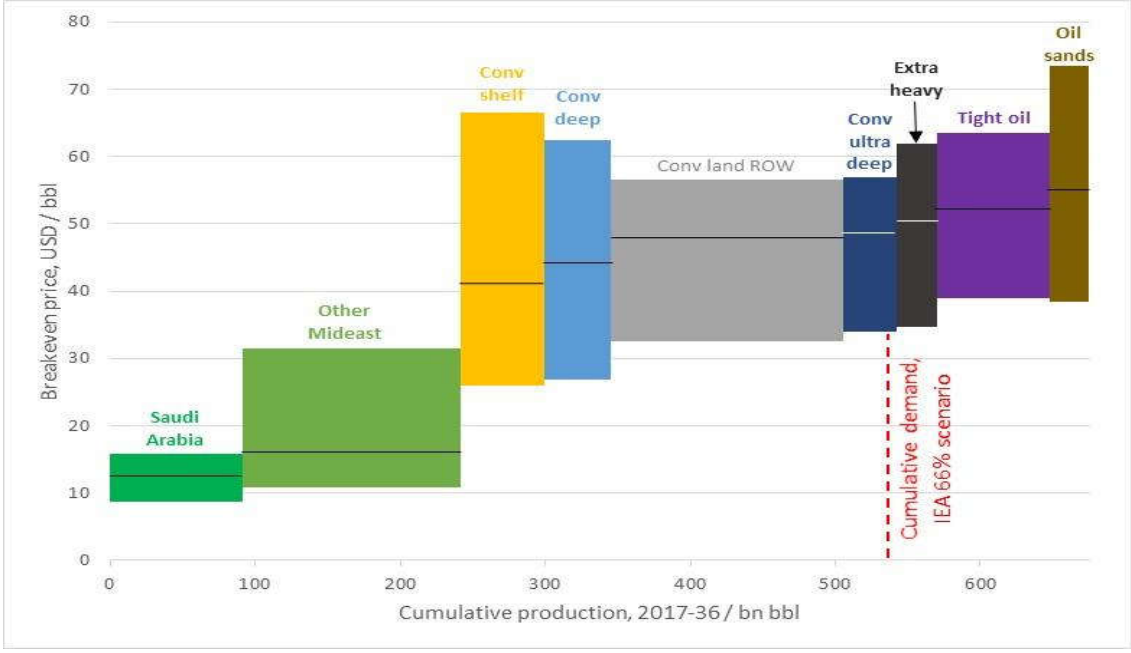


Figure 4: Cumulative projected oil production, 2017-36, vs breakeven price (median and interquartile range). Sources: Rystad UCube; IEA[21]

In Figure 5 below, we plot the same for individual projects, each of which has a unique breakeven cost, first for the world and second just for Saudi Arabia. It is assumed that price will equal the marginal supply cost at a given demand level:[22] production up to that price level will be viable, and more expensive production will not proceed. Marked against the cumulative production is cumulative demand in the IEA's scenario giving 66% probability of keeping warming below 2 degrees, which implies an oil price of $52; the second graph shows that almost all Saudi production is viable at that price.

* There are limits to Saudi Arabia's ability either to push up the oil price, or to drive the IOCs out of business through a price war. The effect of the former is to surrender market share to higher-cost oil elsewhere (the reason OPEC did not cur production in 2014), whereas the latter puts great strain on Saudi Arabia's oil-dependent economy (the reason OPEC eventually agreed a production cut in 2016)

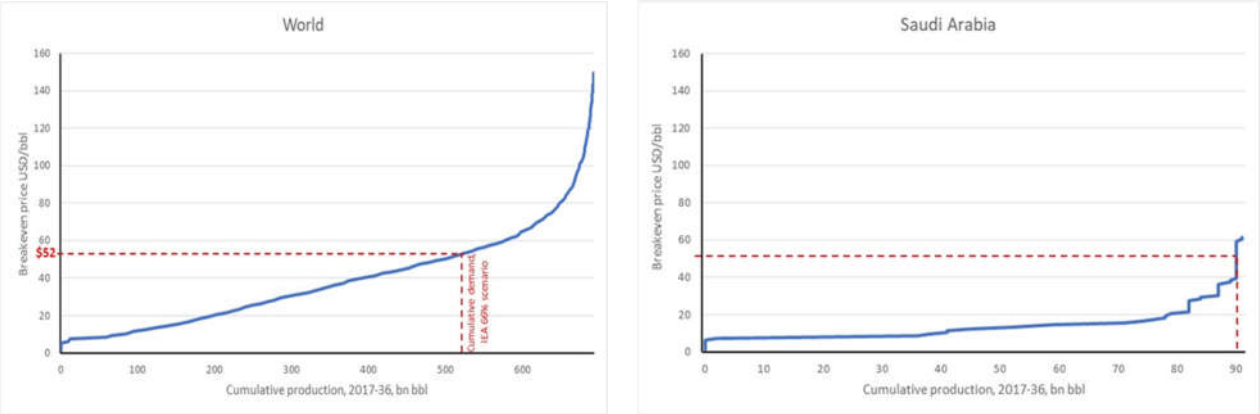


Figure 5: Cumulative projected oil production 2017-36, vs breakeven price. Sources: Rystad UCube; IEA [23]

A key decision to make in such analysis is the timescale over which the cost curve is estimated, which could be anything from a single year of production (to reflect the immediate market dynamic), to a few decades (to reflect investment timescales), to the full life of reserves (to reflect oil that might enter the market over the longer term). Table 1 shows the Saudi share of burnable cumulative production over three different timescales: 20 years, 30 years and the rest of the century (reserves).

Table 1: Saudi share of burnable oil, using cost curve methodology over different timescales. Sources: Rystad UCube; Oil Change International[24]

	Cumulative demand under IEA 66% scenario / bn bbl	Price (cost of marginal barrel)	Burnable Saudi oil / bn bbl	Saudi share of total burnable oil
2017-2036	517	$52	91	17.6%
2017-2046	698	$55	135	19.3%
2017-2099 (reserves)	833	$47	235	28.2%

In the three cases, Aramco's differing share of the total reflects how much it eats into potential costlier production; in the shorter-run cases, other production steals Aramco's share of the carbon budget. The question of whether Aramco is advantaged because of its low production cost thus depends on the shape and timing of climate policy. If governments continue to drag their feet on reducing emissions, IOC production will remain viable for longer, and assuming they ultimately act to keep warming below 2 degrees, a large proportion of Aramco's reserves may be left unburned. Conversely, earlier reduction in emissions will put downward pressure on oil demand, constraining IOCs' ability to profitably extract high-cost reserves.

Aramco's vs IOCs' financial risk

From a financial perspective, the concept of asset stranding is not really about whether reserves get extracted or not: Investments are stranded if they fail to make commercial returns on capital. Once a project has been developed, its marginal cost of production is reduced to operating expenditures – so its reserves may still get fully extracted even while delivering an effective loss on the capital invested. The risk to IOC capital (and hence to dividends and asset values) materialises if the oil price falls below the level the IOC was assuming when it decided to invest in a project.

Although a fall in oil price would reduce Aramco's value (as we saw in section 3), it would likely do so to an even greater extent for an IOC. While the calculation of IOC value's sensitivity to price is beyond the scope of this briefing note, we make the simple observation that at a certain price level, IOCs can be loss-making while Aramco remains profitable.

While Aramco's value is likely to be discounted due to investors' perceptions of political risk, we saw that this is less important than the oil price. Therefore, a relatively low valuation realised in the IPO could indicate expectations of lower oil prices, raising questions about whether IOCs are overvalued.

If governments continue to drag their feet on reducing emissions, IOC production will remain viable for longer. However, assuming governments ultimately act to keep warming below 2 degrees, the delay would entail rapid emissions cuts at a later date, forcing down prices well within the timescale of projects' capital exposure (they commonly take 15-25 years from investment to breakeven), and causing significant destruction of assets. Thus the short-term reprieve for IOCs would eventually create the greatest financial risk to all.

BOX: Will Aramco increase production?

In itself, the IPO does not alter the above Aramco-IOC dynamic, as long as Aramco's production rate is unchanged. Will production rates change, as a result either of the IPO or of climate action? Most obviously, Saudi Arabia has an interest in maximising price before the IPO, in order to gain maximum value for the shares. More interesting is what might happen subsequently.

One of the questions raised about the IPO is whether Saudi Arabia will still be able to set production according to OPEC quotas. Some investors will no doubt be uncomfortable with the notion of a government deciding production policy, based either on political negotiations in OPEC or on conservation policies. As yet there is no clear indication of how or whether this issue will be addressed.

If OPEC decision-making were removed, the impact would likely be much greater volatility in oil prices, as well as a profound symbolic change to the oil market. However, to us this seems unlikely, both because the Saudi government will probably be unwilling to relinquish that market role,[*] and because in the short to medium term, investors' interests are generally aligned with those of the Saudi government. Whereas investors do not care about future Saudi generations or about OPEC solidarity, they do care about maximising revenues, which in the case of a pricemaker like Aramco will not generally be achieved by maximising production.

Another possibility is that Saudi Arabia might increase production in response to an expectation of future climate policy. Dubbed the "green paradox" by German economist Hans-Werner Sinn,* this occurs where a fossil fuel producer increases production in the short term, in order to monetise its reserves before their value decreases due to carbon taxes, technological change or other demand constraint. The dynamics of such a strategy become more complicated for a pricemaker than for a price-taker.

Some commentators wondered whether the 2014 Saudi decision not to cut production to protect the oil price was motivated by such a concern. This seems fairly implausible to us, not least because the Saudi government shows little sign of accepting that climate change must constrain oil demand. With hindsight, we can also see that the price fell by more than 50%, so a 10% or even 20% cut in Saudi production would have delivered higher revenues overall.

In today's oversupplied market however, and with likely medium-term downward pressure on price, the calculus may be different.

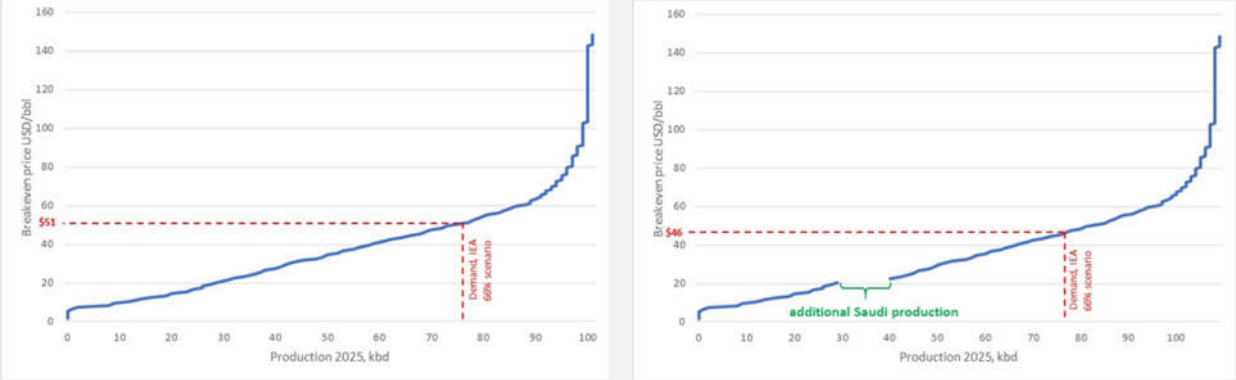


Figure 6: 2025 Global oil cost curve, plus illustrative effect of adding 8 mbd of Saudi production. Source: Rystad UCube*

The cost curve in Figure 6 suggests that as long as demand is below about 90 mbd, so the curve is in its linear section, even increasing Saudi production to 20 mbd (from the current 12 mbd) would reduce prices only by about $5/bbl – suggesting there may be strategic benefit in expanding production. (In contrast, at the right-hand end of the curve, which more resembles the situation in 2014, a small change in production could have a big impact on price). The Saudi government is unlikely to increase production before the IPO, as the price effects would happen more quickly than the volume effects.

On the other hand, projecting oil prices is a dangerous game, and Saudi Arabia would likely be concerned about how much other producers would be able to further reduce their costs (as happened with US fracking post-2014), or squeeze further subsidies from governments (as happened in the UK in 2015 and 2016). More prosaically, the Saudi government may not want to allocate tens of billions of dollars of investment in expanding oil capacity, given constrained budgets.

5. Is Aramco Holding Unburnable Carbon?

In this section, we look at the question of Saudi Aramco's impact on the climate. The logic of climate risk is not the same as the logic of financial risk. Whereas investment is concerned with returns, and hence commodity prices, from a climate perspective it is volumes of greenhouse gases that matter.*

Aramco reserves vs carbon budgets

We know from atmospheric physics that the key factor determining the extent of global warming is the cumulative amount of carbon dioxide (CO_2) emissions over time, because CO_2 stays in the atmosphere for centuries.[25] To keep warming within any particular limit – all else being equal – there is a maximum cumulative amount of CO_2 that may be emitted. This is the world's carbon budget, and as of start of 2017 it amounts to:

- 800 Gt of CO_2, for a likely (66%) chance of keeping warming below 2°C; or
- 350 Gt of CO_2, for a medium (50%) chance of keeping warming below 1.5°C.[26]

There is a natural comparison of cumulative emissions with the reserves of fossil fuels, which shape how much carbon will be extracted and hence burned. Saudi Arabia is home to the world's second-largest oil reserves, with 267 billion barrels (bn bbl) of oil, 16% of the global total.[27] Aramco has a monopoly right to extract these reserves. While there has been debate on the accuracy of these numbers, in anticipation of the IPO, Aramco has appointed two independent auditors whose initial findings have corroborated these estimates.[28] If fully extracted and burned, Aramco's reserves would lead to emissions of 112 Gt of CO_2.[29] This would amount to one-seventh of a 2°C global carbon budget, and one-third of a 1.5°C global carbon budget.

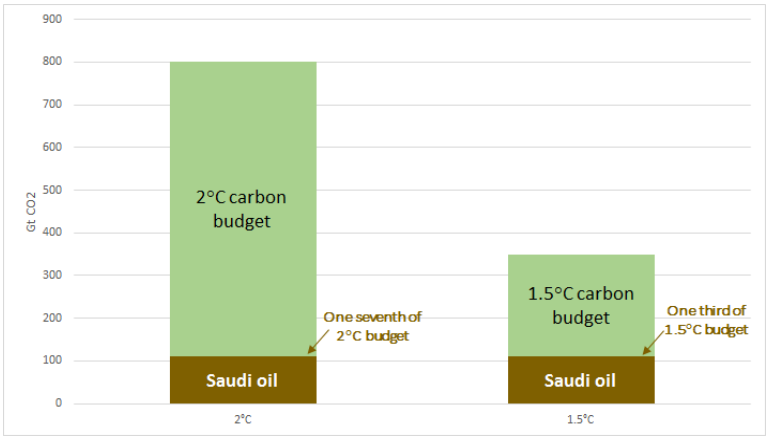


Figure 7: Portion of global carbon budgets used by Saudi oil if fully exploited. Sources: BP, Oil and Climate Index, IPCC, Global Carbon Project

* If markets allocated supply over the long term, these two would broadly align, assuming demand stays within climate limits. In reality however, markets operate primarily over short timescales, and nor are climate goals baked into markets as a hard limit.

Aramco reserves vs IOCs

Analysis by Oil Change International has found that the oil, gas, and coal *in already-producing fields and mines* – where the capital investments have been made and the physical infrastructure built – are more than the world can afford to burn while keeping likely warming below 2°C. And even if coal were phased out overnight, already-developed resources of oil and gas alone would take the world beyond 1.5°C. This is shown in Figure 8.

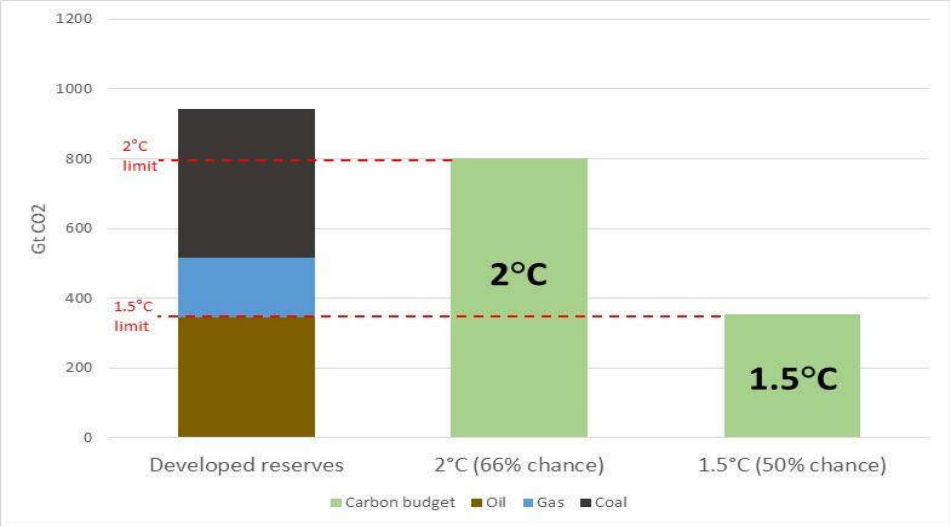


Figure 8: Developed fossil fuel reserves compared to carbon budgets. Sources: Rystad UCube, IEA, IPCC, Global Carbon Project, Oil Change International[30]

The importance of the focus on these *developed reserves* is that since oil and gas extraction are capital-intensive (and to a lesser extent coal), it is both politically difficult and economically costly to close down an already-operating field or mine. According to the Rystad UCube, 80% of Saudi oil reserves are in existing fields (ie are developed reserves).

The global carbon budget is finite, so carbon arithmetic is a zero-sum game: more production in one region will require less in another. Though there is a tendency of every producer to expect that *their* reserves will not be the ones affected, they cannot all be right. The logic is simple: if new fields or mines are developed, there are only two possible outcomes: (i) all of the fields and mines are extracted over their full economic lives, leading to emissions that push the world beyond the 2 degrees threshold; or (ii) warming is kept below 2 degrees (or lower), and some of the investments become stranded assets.

In other words, the combination of Aramco's long-lived reserves, and the constantly-replenishing reserves of IOCs, is not consistent with staying within climate limits. There is a conceivable scenario where most of Aramco's reserves are extracted, as long as IOCs stop exploring for and developing new reserves – indeed this would be the lowest-cost approach. Alternatively, if IOCs continue to add new reserves, it will be necessary for a significant portion of Aramco/NOC reserves to remain untapped. In that second scenario, it will be extremely difficult to stop ongoing emissions after carbon budgets are

exhausted: with the remaining Aramco/NOC oil low on the cost curve, continuing to burn it will be economically very attractive.

6. Conclusions

The world is rapidly approaching climate limits. There is an urgent need for rigorous scrutiny of any new investments in fossil fuels.

We have looked at how Aramco's value is affected by oil prices, and also at how Aramco will compete with IOCs in a scenario of lower oil demand, given the fundamental dynamic of the oil market: slower extraction rates in the Middle East (primarily Saudi Arabia, Kuwait, Abu Dhabi, Iraq and Iran) make high-cost production elsewhere viable.

We have seen that the oil prices in the IEA's 450 Scenario and 66% Scenario lead to valuations respectively 25% and 40% lower than the NPS base case. If prices remain at $50, the valuation is fully 55% below base case. If the IPO realises a company valuation above $1 trillion, investments may be at risk from climate policy.

On the other hand, IOCs' higher production costs leave them more at risk than Aramco. If the valuation is low, it raises a question of whether the IOCs are overvalued.

The different production strategies of Saudi Aramco and of IOCs are not compatible with achieving the Paris Agreement goals. The IOCs tend to extract fields as quickly as they can, and constantly explore for and open up new reserves, to replace what they have extracted. Saudi Arabia extracts its reserves more slowly, for two reasons: to conserve reserves for future generations, and to sustain the oil price. Aramco's reserves may only be fully extracted if IOCs stop exploring for and developing new reserves.

The question of whether Aramco is advantaged because of its low production cost thus depends on the shape and timing of climate policy. If governments continue to drag their feet on reducing emissions, IOC production will remain viable for longer, and assuming they ultimately act to keep warming below 2 degrees, a large proportion of Aramco's reserves may be left unburned. Yet that scenario also requires abrupt emissions cuts at some later date, which would cause the greatest destruction of assets.

Acknowledgments

We are grateful for valuable comments from Hilal Atici, Carbon Tracker Initiative, Gyorgy Dallos, Alex Doukas, Ivetta Gerasimchuk, Julien Jreissati, Charlie Kronick, Steve Kretzmann, Louise Rouse, Paul Spedding and Peter Wooders. The authors remain responsible for the content.

References

[1] We use Oil Change International models to forecast cashflows over the course of this century. Estimates of Aramco's future production, capex, and opex are taken from Rystad UCube, 16 May 2017: crude oil, condensate & NGL. We assume that all volumes are sold at market prices (ie if oil products continue to be subsidised for Saudi individuals and companies, Aramco will not be responsible for the subsidy). For simplicity, we assume that all capex is expensed (a reasonable assumption, given that capex is fairly constant over time), and ignore any tax allowances: Hence corporate income tax is essentially applied to net cash flows (after royalties). We assume Brent prices are realised FOB in Saudi Arabia (ie we ignore shipping costs). All in 2017 prices.

[2] However, our estimates are broadly in line with those quoted by various financial institutions and commentators, such as:

- Aramco insiders: $1.5 tn (Summer Said et al, "For Aramco Insiders, Prince's $2 Trillion IPO Valuation Doesn't Add Up", Wall Street Journal, 25 April 2017, https://www.wsj.com/articles/for-aramco-insiders-princes-2-trillion-ipo-valuation-doesnt-add-up-1493064170)
- Bernstein: $1.0 – 1.5 tn (Sam Wilkin, "Saudi Aramco's Valuation Could Top $1 Trillion After Tax Cut", Bloomberg, 28 March 2017, https://www.bloomberg.com/news/articles/2017-03-28/saudi-aramco-valuation-seen-topping-1-trillion-after-tax-cut)
- Rystad: $1.4 tn (ibid)
- FT: $0.9 – 1.1 tn (Alan Livsey, "The $2tn Saudi Aramco question", Financial Times, 3 April 2017, https://www.ft.com/content/7ed59bee-163b-11e7-b0c1-37e417ee6c76)

Like most other commentators, we find no evidence to support Muhammad bin Salman's initial $2 trillion estimate.

Wood Mackenzie valued Aramco at just $400 bn, but this was before the reduction of tax from 85% to 50% (Javier Blas and Wael Mahdi, "Saudi Arabia's Oil Wealth Is About to Get a Reality Check", Bloomberg, February 23, 2017, https://www.bloomberg.com/news/articles/2017-02-23/saudi-arabia-2-trillion-aramco-vision-runs-into-market-reality), and this is consistent with our valuation in the pre-tax-cut scenario.

[3] The *Financial Times* has estimated the value of the refining assets at $40 billion.(Livsey, "$2tn question", op cit). Robin Mills of Qamar Energy has estimated refining, petrochemicals and shipping to be worth $60 billion (Robin Mills, "Saudi Aramco's $2 Trillion Valuation Has Too Many Assumptions", Bloomberg View, 29 March 2017, https://www.bloomberg.com/view/articles/2017-03-29/saudi-aramco-s-2-trillion-valuation-has-too-many-assumptions).

While Aramco plans to roughly double its natural gas production over the next ten years, all of the production is expected to still be consumed within the Kingdom, as it replaces oil as a fuel for power generation. Prices are government-controlled, at subsidised levels. If we assume gas prices remain at current levels of $1.25/mBtu, we estimate the value of Aramco's gas production at about $25 billion, by the DCF method, assuming energy content of 1.047 Btu per cubic foot of Saudi gas.

[4] In World Energy Outlook 2016, p.45, and "Perspectives for The Energy Transition - Investment Needs for a Low-Carbon Energy System", March 2017, p.56

[5] http://www.cmegroup.com/trading/energy/crude-oil/west-texas-intermediate-wti-crude-oil-calendar-swap-futures.html

[6] Karen Gilchrist, "Goldman Sachs anticipates return to long-term oil price stability", CNBC, 12 Apr 2017, http://www.cnbc.com/2017/04/12/goldman-sachs-anticipates-return-to-long-term-oil-price-stability.html

[7] Livsey, "$2tn question", op cit

[8] David Sheppard and Anjli Raval, "Oil demand might peak in just over a decade, says Opec", Financial Times, November 8, 2016, https://www.ft.com/content/3f007354-a507-11e6-8898-79a99e2a4de6

[9] GM press release, "GM Employees on Mission to Transform Transportation", 7 May 2015, http://media.gm.com/media/us/en/gm/company_info/facilities/assembly/orion.detail.html/content/Pages/news/us/en/2015/may/0507-sustainability-report.html. Dave Guilford, "The next wave of electric vehicles", Automotive News, 3 October, 2016, http://www.autonews.com/article/20161003/OEM05/310039967/the-next-wave-ofelectric-vehicles; BBC News, "VW plans huge investment to become electric cars leader", 16 June 2016, http://www.bbc.co.uk/news/business-36548893

[10] Patrick Hummel et al, *Will solar, batteries and electric cars re-shape the electricity system?* UBS Global Research, 20 August 2014, p.4

[11] Alex Hern, "Netherlands moots electric car future with petrol and diesel ban by 2025", Guardian, 18 April 2016, https://www.theguardian.com/technology/2016/apr/18/netherlands-parliament-electric-car-petrol-diesel-ban-by-2025

[12] Fiona Harvey, "Four of world's biggest cities to ban diesel cars from their centres", Guardian, 2 December 2016, https://www.theguardian.com/environment/2016/dec/02/four-of-worlds-biggest-cities-to-ban-diesel-cars-from-their-centres

[13] Economic Times, "India aims to become 100% e-vehicle nation by 2030: Piyush Goyal", 26 March 2016, http://economictimes.indiatimes.com/industry/auto/news/industry/india-aimsto-become-100-e-vehicle-nation-by-2030-piyush-goyal/articleshow/51551706.cms

[14] IEA, Key World Energy Statistics 2016, p.33

[15] EIA, "Passenger travel accounts for most of world transportation energy use", 19 November 1015, https://www.eia.gov/todayinenergy/detail.php?id=23832

[16] Rakteem Katakey, "Energy Giant Shell Says Oil Demand Could Peak in Just Five Years", Bloomberg, 2 November 2016, https://www.bloomberg.com/news/articles/2016-11-02/europe-s-biggest-oil-company-thinks-demand-may-peak-in-5-years

[17] Jessica Jaganathan, "World oil demand could peak in 2024 on higher vehicle efficiency -Goldman Sachs", Reuters, 24 July 2017, https://uk.reuters.com/article/research-crude-goldman-idUKL3N1KF3ER

[18] Lynn Cook & Elena Cherney, "Get Ready for Peak Oil Demand", Wall Street Journal, May 26, 2017, https://www.wsj.com/articles/get-ready-for-peak-oil-demand-1495419061

[19] Rystad UCube, 6 July 2017, oil resources (crude, condensate & NGL) 2017 (excluding undiscovered); capex 2016 (excluding exploration capex). Note that the "reserves" are P(mean), a measure of the known amount most likely to be extracted – this is close to 2P reserves, and larger than 1P reserves. For a discussion of the different reserves types see Muttitt, *Sky's Limit*, *op cit*, p.46

[20] World Bank, "How is Saudi Arabia Reacting to Low Oil Prices?", July 2016, http://www.worldbank.org/en/country/gcc/publication/economic-brief-july-saudi-arabia-2016

[21] Rystad UCube, 6 July 2017. Oil production (crude, condensate & NGL), excluding undiscovered. Note Rystad breakeven prices use 10% discount rate in nominal terms (whereas section 3 is in real terms).

[22] Setting aside the price elasticity of demand.

[23] Rystad UCube, 6 July 2017. As above

[24] Rystad UCube, 6 July 2017. As above. Also IEA, "Perspectives For The Energy Transition", *op cit*, p.56

[25] Temperature change is roughly proportional to total cumulative CO_2 emissions (until emissions peak, and assuming smooth variations in emissions). IPCC Climate Change 2013, Working Group 1 report, sec.12.5.4, pp.1108ff, http://ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter12_FINAL.pdf

See also Reto Knutti presentation to UNFCCC Structured Expert Dialogue 2013-15 Review, 13 November 2013, 'Relationship between global emissions and global temperature rise', at https://unfccc.int/files/science/workstreams/the_2013-2015_review/application/pdf/7_knutti.reto.3sed2.pdf

[26] As of end-2011, the remaining carbon budgets were respectively 1,000 and 550 $GtCO_2$ (IPCC, *Climate Change 2014*, Synthesis Report, table 2.2, p.68, http://ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_All_Topics.pdf)

Emissions were 160 $GtCO_2$ in 2012-15 (Carbon Dioxide Information Analysis Center / Global Carbon Project, 2016 Budget v1.0, http://cdiac.ornl.gov/GCP/); and an estimated 36 Gt from fossil fuels and 3.7 Gt from land use change in 2016 (Le Quéré et al, "Global Carbon Budget 2016," Earth Syst. Sci. Data, 8, 2016, pp.630, 608, http://www.earth-syst-sci-data.net/8/605/2016/essd-8-605-2016.pdf)

[27] BP Statistical Review of World Energy 2017, http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

The BP Statistical Review lists only Venezuela's reserves as larger; however much of Venezuela's consist of heavy oil in the Orinoco Basin, which is unlikely to be extracted in the absence of a return to very high oil prices, and major technological advances in the Venezuelan oil industry.

[28] Rania El Gamal et al., "Saudi Aramco's oil reserves confirmed by external audit: sources," Reuters, January 27, 2017, http://www.reuters.com/article/us-saudi-aramco-reserves-idUSKBN15B1DN

[29] We use an emissions factor of 430 kg of CO_2e emissions per barrel. This is the amount of downstream (combustion) emissions from Saudi Ghawar oil, estimated using assays, by the Carnegie Endowment for International Peace's Oil and Climate Index, http://oci.carnegieendowment.org. It counts the portions of the oil used in gasoline, jet fuel, diesel, residual fuels and LPG.

This estimate does not include process emissions from extraction, transport and refining, estimated at a further 62 kg/bbl, some of which will come from use of Saudi oil but other portions from gas.

[30] Greg Muttitt, "The Sky's Limit: Why the Paris Climate Goals Require a Managed Decline of Fossil Fuel Production," Oil Change International, September, 2016, http://priceofoil.org/content/uploads/2016/09/OCI_the_skys_limit_2016_FINAL_2.pdf