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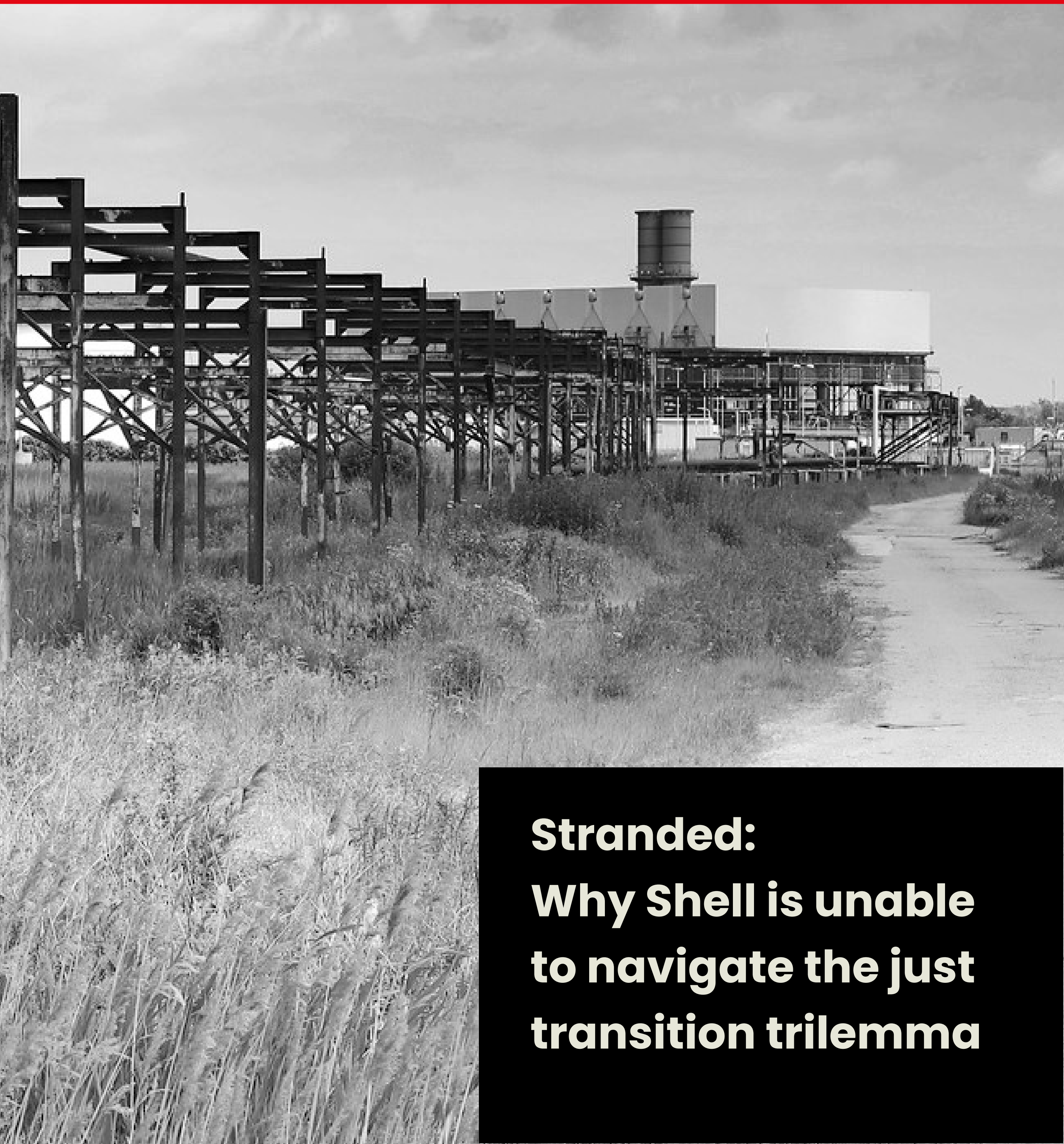

Stranded: Why Shell is unable to navigate the just transition trilemma

Content

Introduction

Shell's current strategy is not aligned with a 1.5°C pathway to reduce carbon emissions as set out in the Paris Agreement of 2015. Instead, Shell and its shareholders are betting on the continuation of the current non-system governing the emission of greenhouse gases (GHGs), which is based on self-regulation.

Under this system, the limits of producing and emitting GHGs, as stipulated in the Paris Agreement, have yet to be translated into legal caps or other forms of enforceable regulations for specific countries, sectors, and companies. In this report, we examine how Shell's corporate strategy since 2010 is leaving the company stranded in the fossil past.

There are no global nor national binding regulations to reduce carbon emissions. What currently exists is a patchwork of pledges by some countries and corporations – including a variety of 'net zero' strategies announced by oil companies like Shell. However, these are not sufficient to deliver the type of reduction that is required to save our planet's future.[1] In short: while Shell *seems* to project a sound and rational strategy towards a net zero business model, its actual strategy is not sound, rational, or moving towards net zero at all.

Over the past ten years, from 2010 to 2022, Shell's business model shows three elements that have the potential to shape the company's future options. First, Shell's investment in its capacity to produce energy followed a declining trend over this period. As a percentage of the total stock of productive capital, annual capital investments declined from 20 per cent in 2013 to 9 per cent in 2019.[2] Second, the company took on more debt during the same period. As a percentage of Shell's sales, total debt increased from 5.1 per cent in 2007 to 32.7 per cent in 2021. Third, Shell remained committed to rewarding its shareholders through dividends and share repurchases rather than redirecting resources to its own energy transformation. Shareholders received US$ 115 billion in dividends and US$ 34 billion in share repurchases from 2010 to 2021. Shell increased its total payouts from 35 per cent of operating cash flow in 2010 to 60 per cent in 2019. Between 2010 and 2022, Shell's total payouts amounted to 82 per cent of its net income.

1 Stockholm Environment Institute (SEI), International Institute for Sustainable Development, Overseas Development Institute, E3G, and UN Environment Programme, 2021 Report. The Production Gap: Governments' planned fossil fuel production remains dangerously out of sync with Paris Agreement limits, 2021, p. 12, https://productiongap.org/wp-content/uploads/2021/11/PGR2021_web_rev.pdf

2 All the financial data in this paragraph are calculated based on data derived from Refinitiv Eikon (https://www.refinitiv.com/en/).

These developments suggest that, since the landmark Paris Agreement, Shell has wasted valuable time and cash flow on prioritising shareholders rather than developing a future-proof strategy. This has effectively constrained the company's capacity to shift investments from fossil-based to renewable assets and, as a result, Shell now faces limitations on incurring further debt. This means it may need to either reduce future payouts to shareholders or decrease capital investments in fossil activities in order to expand its green production capacity.

Looking towards the future, we sketch out three possible scenarios:

- **In the first scenario**, today's non-system would continue and allow oil and gas companies to emit GHGs far beyond the limits of the 1.5°C carbon budget.
- **In the second scenario**, energy companies like Shell are forced to operate within planetary carbon limits, stranding a significant quantity of assets as a result.[3] This would require an effective decarbonisation regime.
- **The third scenario** builds on the second, but now Shell would opt for a just transition so that – unlike before – Shell takes responsibility for the damages its operations caused worldwide. Shell internalises the associated costs at the expense of shareholder payouts.

The difference between the first and the other two scenarios is stark. In the first scenario, companies would be free to extract and burn hydrocarbons without incurring any stranded assets. The second and third scenarios would have major consequences for the cash flows and the valuation of the assets of global energy companies like Shell. However, we need to distinguish two types of renewable-energy-focused models for Shell with very different outcomes. In the second scenario, Shell merely sells its potentially stranded assets and distributes the proceeds to its shareholders, not taking any responsibility for damages done to people and the environment. Only in the third scenario would such damages be acknowledged and internalised, leading Shell to redirect resources towards compensation and restoration rather than funnel them into shareholders' pockets. In this case, Shell could become an actor in the 'just' transition.

According to the 2021 net zero emissions (NZE) scenario proposed by the International Energy Agency (IEA), the world has a remaining carbon budget of 618.7 billion metric tons (gigatons) of CO_2 ($GtCO_2$).[4] Based on the available global reserves of different fossil fuels, we assess that this would leave a carbon budget for Shell of around 1.9 $GtCO_2$ from 2020 onwards. This means that 68 per cent of Shell's current proven reserves would need to remain in the ground to be aligned with the IEA NZE 1.5°C pathway. The financial value of these stranded assets depends on future prices for oil and gas, which are impossible to predict. For the sake of illustration, however, we estimate the value of Shell's stranded assets to be around US$ 148 billion, based on average prices for oil and gas over the past decade. From 2020 to 2050, this would

3 We consider stranded assets as assets that will fail to generate adequate future income to justify their current value on the balance sheet as a result of an effective decarbonisation regime (see Chapter 3).

4 All data in this paragraph are derived from sources discussed in detail in the report's methodological annex.

translate into an additional annual depreciation of about US$ 5 billion, which is 17 times the amount Shell invested in wind and solar energy in 2021 (US$ 288 million).[5]

Given the fundamental uncertainty about the future and the paths leading to it, oil and gas companies have adopted a strategy that involves hedging. This strategy, which includes investing in fossil fuels as well as in renewable energy, aims to keep options open and buy time. However, the window to orderly transition away from a fossil-fuel-based energy system to a renewable energy system is closing rapidly. The possibility of keeping all options open will soon come to an end and companies will run out of road to buy extra time.

We argue that Shell will face a trilemma. It can achieve only a maximum of two out of three goals. For a just transition, Shell can only achieve one of the three goals. The three goals Shell is aiming for can be described as:

- **continuing to operate as an oil and gas giant profiting from consuming ever greater portions of the global carbon budget;**
- **continuing to pursue high shareholder returns; and**
- **transforming itself into a major renewable energy player.**

Shell's current strategy – which boils down to having your cake and eating it – is unrealistic under current conditions. How Shell deals with its stranded assets (either by externalising or by internalising their costs) and how long the company will postpone the changes needed to align its business operations with a 1.5°C pathway will determine whether Shell will become part of the solution at last – or whether it will remain on the wrong side of history as the world moves beyond fossil fuels towards a more sustainable future.

5 Royal Dutch Shell plc (henceforth 'RDS'), Annual Report 2021, p. 304, https://reports.shell.com/annual-report/2021/_scripts/download.php?file=shell-annual-report-2021.pdf&id=1273

1. The three gaps in the world's current decarbonisation architecture

Market-based governance allows for unrestricted emissions

In 2021, a Dutch court ordered Shell to reduce 45 per cent of its total GHG emissions in 2030 compared to 2019.[6] As the landmark verdict of the court indicated, there is currently a *governance gap*: an absence of effective government regulation to impose limits on emissions that comply with the Paris Agreement. This governance gap essentially results in market self-regulation, leaving the crucial strategic investment decisions in the hands of actors that prioritise the short-term interests of shareholders over the interests of future generations.

In order to explore the potential trajectories of future GHG emissions in this unregulated system, the United Nations Environmental Programme (UNEP) and others track existing legal commitments, investments, and pledges by governments and companies worldwide. UNEP and its partners exposed a *production gap,* namely, the difference between the likely trajectory of current emissions and a trajectory needed for sound decarbonisation scenarios (that is, those that stay within the limits of the carbon budget). The size and shape of the production gap (see Figure 1) demonstrate that the window to act will soon close. On the current path, the world's corporations are on course "to produce around 110% more fossil fuels in 2030 than would be consistent with limiting global warming to 1.5°C".[7] According to UNEP projections, the surplus of emissions will grow to 190 per cent in 2040 if this governance gap is left unaddressed. The longer it takes to achieve a downward trajectory, the harder decarbonisation will be.

Since the global energy system consists of interrelated locked-in processes of supply (for example, petrol or natural gas) and demand (for example, combustion engine cars or gas heating) there is a large degree of inertia to change. This inertia impedes

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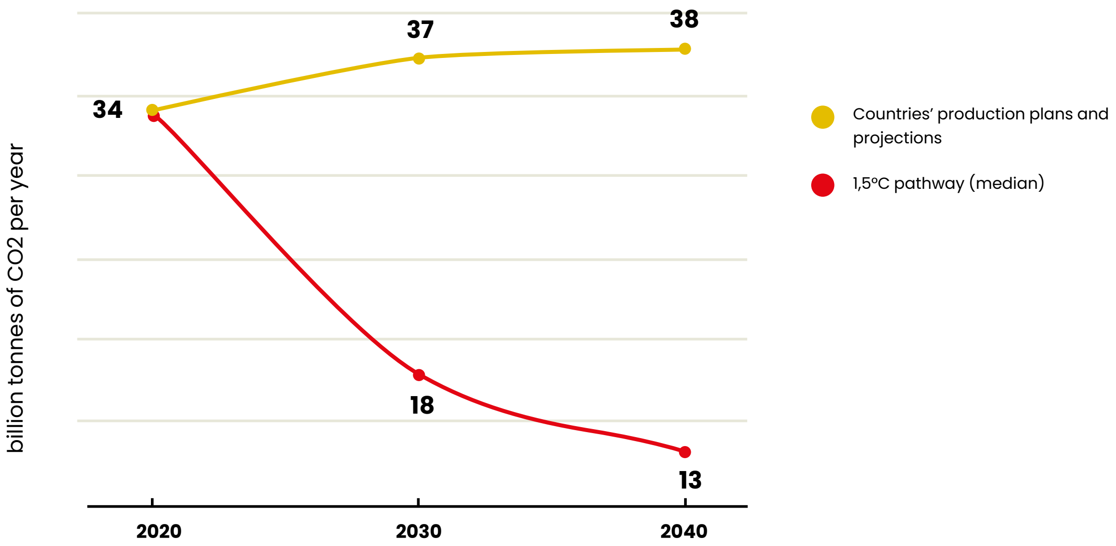
6 Rechtspraak.nl, Case number C/09/571932 / HA ZA 19-379, 2021, https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:RBDHA:2021:5337

7 SEI, UNEP, et al., 2021 Report. The Production Gap, https://productiongap.org/2021report/#R3

and slows overall progress in decarbonisation.[8] It is therefore complex and politically difficult to speed up (energy) transitions and achieve steeper decarbonisation pathways that will inevitably produce (new) losers and winners. Starting in time and aiming for gradual change is more realistic than a strategy based on delay and radical change in the future, often linked to untested technology. This is why the timeframe is important in designing an effective decarbonisation pathway. The absolute reduction of carbon emissions and the reduction in the production of fossil fuels in the next 10 years is critical in all 1.5°C-consistent decarbonisation models.[9]

Figure 1. The production gap: projected GHG emissions compared to emissions consistent with a 1.5°C pathway[10]



Despite the clear need for immediate and decisive action, the current governance gap allows energy giants to design their own decarbonisation scenarios without effective legal caps. These companies continue to invest in increasing the production capacity of oil and gas, which is inconsistent with a 1.5°C pathway and further widens the production gap.[11] There is a growing consensus among multilateral institutions that oil and gas companies cannot bring additional oil fields into production, let alone look for new fields, if they are to operate within decarbonisation limits that are consistent with the Paris Agreement.

In 2021, the IEA concluded that a 1.5°C pathway and its own NZE scenario for major oil companies are not compatible with additional productive capacity.[12] The IEA NZE scenario requires existing oil and gas production to shrink immediately by between

8 P. Kirby and T. O'Mahony, The Political Economy of the Low-Carbon Transition: Pathways Beyond Techno-Optimism, Springer, 2017.
9 International Institute for Sustainable Development (IISD), Navigating Energy Transitions: Mapping the road to 1.5°C, October 2022, p. 17, https://www.iisd.org/system/files/2022-10/navigating-energy-transitions-mapping-road-to-1.5.pdf
10 Source: SEI, UNEP, et al., 2021 Report. The Production Gap, p. 3.
11 D. Kenner and R. Heede, "White knights, or horsemen of the apocalypse? Prospects for Big Oil to align emissions with a 1.5° C pathway," Energy Research & Social Science, 79, 2021: 102049, https://www.sciencedirect.com/science/article/pii/S2214629621001420
12 IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, 2021, p. 21, https://www.iea.org/reports/net-zero-by-2050

2 and 4 per cent annually to be in line with its 1.5°C pathway. Similarly, the UNEP 1.5°C pathway requires an annual reduction of 4 per cent for oil companies and 3 per cent for natural gas producers between 2020 and 2030.[13] In response to such findings, Shell states that its production of oil and natural gas reached a peak in 2019 and will decline by 2 per cent each year as a result of the natural rate of depletion of its upstream assets and divestments. Shell's CEO publicly stated that Shell was no longer an oil and gas company but an "energy transition company".[14] In its energy transition strategy, Shell explains how it intends to achieve a 2 per cent annual reduction:

> "A natural decline in production happens in oil and gas reservoirs at a rate of around 5% a year across the oil and gas industry. It takes constant reinvestment to sustain production and extract resources. Our planned capital investment of US$8 billion in our Upstream business in the near term is well below the investment level required to offset the natural decline in production of our oil and gas reservoirs, and will not sustain current levels of production. As a result of this planned level of capital investment, we expect a gradual decline of about 1-2% a year in total oil production through to 2030, including divestments."[15]

Yet despite this pledge, Shell is planning to invest US$ 12 billion annually between 2022 and 2030 in developing *new* upstream oil and gas assets.[16] These investments are expected to result in oil and gas production remaining stable until at least 2030.[17] The emissions that result from these investments are also expected to remain flat throughout this period, in clear breach of the required decline of 45 per cent ordered by the Dutch court.

In addition to this production gap, Shell continues to explore new oil and gas fields with a view to developing them in future, thus generating an ever larger stock of potentially stranded assets. It is estimated that 756 (58 per cent) of the 1,300 oil and gas fields Shell wholly or partly owns are undeveloped.[18] Even though Shell owns these undeveloped oil and gas fields, which will be hard to develop given the carbon budget, it continues to explore additional undiscovered fossil fuel assets. Since the Paris Agreement (from the first quarter of 2015 until the third quarter of 2022), Shell invested US$ 14.4 billion in the exploration of new upstream assets[19] and it intends to continue at an annual cost of US$ 1.5 billion until at least 2025.[20] These investment decisions reinforce path dependency and are not consistent with a 1.5°C decarbonisation pathway. The governance gap thus exacerbates the production gap.

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13 SEI, UNEP, et al., 2021 Report. The Production Gap, p. 15.

14 A, Raval, "Oil producers face their 'life or death' question Fear of an imminent peak in demand means companies are less likely to invest. So does that make shortages and a price rise inevitable?" Financial Times, June 19, 2018, https://www.ft.com/content/a41df112-7080-11e8-92d3-6c13e5c92914

15 RDS, Shell Energy Transition Strategy 2021, p. 23, https://reports.shell.com/energy-transition-progress-report/2021/_scripts/download.php?file=shell-energy-transition-progress-report-2021.pdf&id=1310

16 Oil Change International, Shell's fossil fuel production: still pushing the world towards climate chaos, 2022, p. 16, https://priceofoil.org/2022/09/30/shell-fossil-fuel-production-climate-chaos/

17 Ibid., p. 13.

18 Ibid., p. 11.

19 Calculation based on (1) RDS, F-20 2017, 2018, p. 31; (2) RDS, F-20 2020, 2021, p. 36; (3) RDS, Third Quarter 2022 Results, Quarterly Databook, 2022, p. 9, https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q3-2022.html

20 RDS, Energy Transition Progress Report 2021, 2022, p. 18, https://reports.shell.com/energy-transition-progress-report/2021/

‘Net zero’ as a climate delay tactic

A crucial element of the governance gap is the absence of a rule-based decarbonisation regime. This omission allows oil and gas companies to cherry-pick their own future ‘net zero’ decarbonisation scenario and turn it into a discursive tool of climate delay.[21] Oil companies have a long history of disinformation campaigns ever since they became aware of their role in causing climate change.[22] Their public relations activities – from spreading doubts about the scientific mechanics of climate change to disinformation campaigns about the main drivers of emissions and lobby activities to block the effective regulation of emissions – aim to mislead and confuse the public discourse.[23] While in recent years oil companies have acknowledged the negative impact that their emissions are having on the climate, their publicity campaigns to achieve self-defined ‘net zero’ pathways in 2050 – *without* changing their business strategies – is yet another tactic of climate delay.[24]

The Oversight Committee of the US Congress set out to examine “Big Oil’s use of climate disinformation to keep our country reliant on fossil fuels and hold back the clean energy economy” in 2021.[25] The investigation had access to internal documents which clearly demonstrate the structured effort by oil and gas companies to mislead the public and influence decision-making bodies. It found that oil companies, including Shell, project the idea of transforming their business model to be consistent with a 1.5°C pathway while continuing business as usual:

> “Shell has touted its ‘Sky scenario’ as an ambitious path to achieve net-zero emissions, but internal emails emphasize this is ‘not a Shell business plan’ and has ‘nothing to do with our business plans’.”[26]

> “Internal Shell messaging guidance – which was developed to ‘insulate Shell’ from lawsuits about ‘greenwashing’ and ‘misleading investors’ on climate change – calls on employees to emphasize that net-zero emissions is ‘a collective ambition for the world’ rather than a ‘Shell goal or target’. The guidance urges Shell employees, ‘Please do not give the impression that Shell is willing to reduce carbon dioxide emissions to levels that do not make business sense’.”[27]

Despite its net zero pledges, Shell never obscured the fact that its business plan is not aligned to a 1.5°C pathway. Addressing its shareholders, Shell clearly states its business model should not be confused with its net zero pledges, and clarifies it does not intend to shift to a decarbonisation strategy over the next decade. Rather, Shell says

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21 M. Li, G. Trencher, and J. Asuka, “The clean energy claims of BP, Chevron, ExxonMobil and Shell: A mismatch between discourse, actions and investments,” PLoS ONE, 17, 2022, https://pdfs.semanticscholar.org/97e7/3882c40aac21531ca6d6a0ee336ccacc4e1a.pdf?_ga=2.241040384.2030945331.1669888530-1996540049.1669888530

22 Research has revealed that Exxon finished a comprehensive report on climate change in 1981, predicting with great accuracy the climate change we have witnessed. Shell finished a report on climate change in 1986. Links to both reports can be found at https://www.greenbiz.com/article/what-big-oil-knew-about-climate-change-1959#:~:text=In%201986%2C%20Dutch%20oil%20company,forced%20migration%20around%20the%20world

23 D. Michaels, The Triumph of Doubt: Dark Money and the Science of Deception, Oxford University Press, 2020.

24 W. Lamb et al., “Discourses of climate delay,” Global Sustainability, 3, E17, July 2020, https://www.cambridge.org/core/journals/global-sustainability/article/discourses-of-climate-delay/7B11B722E3E3454BB6212378E32985A7

25 Congress of the United States, “Investigation of Fossil Fuel Industry Disinformation,” 2022, p. 1, https://oversight-democrats.house.gov/sites/democrats.oversight.house.gov/files/2022.09.14%20FINAL%20COR%20Supplemental%20Memo.pdf

26 Ibid., p. 3.

27 Ibid., p. 3.

that it will only shift to another business model (if at all) when 'society' moves towards net zero emissions.

> "Shell's operating plan, outlook and budgets are forecasted for a ten-year period and are updated every year. They reflect the current economic environment and what we can reasonably expect to see over the next ten years. Accordingly, they reflect our Scope 1, Scope 2 and Net Carbon Footprint (NCF) targets over the next ten years. However, Shell's operating plans cannot reflect our 2050 net-zero emissions target and 2035 NCF target, as these targets are currently outside our planning period. In the future, as society moves towards net-zero emissions, we expect Shell's operating plans to reflect this movement. However, if society is not net zero in 2050, as of today, there would be significant risk that Shell may not meet this target."[28]

To its bondholders Shell also has communicated the risks associated with a rule-based decarbonisation regime. If regulations or laws are passed that force Shell to bring its total GHG emissions in line with a 1.5°C pathway, the company may not be able to fulfil its obligations. Specifically, it warns that "[t]here are certain factors that may affect an issuer's ability to fulfil its obligations", including "climate change concerns and additional regulatory measures".[29] Shell's auditor, Ernst & Young (EY), repeats Shell's strategy to only move after a large swath of society leads the way:

> "Meeting the goals of the Paris agreement is a global aspiration that must be cemented in reality. It requires the world economy to transform in a number of complex and connected ways. Shell's financial statements reflect the world as it currently exists and what management reasonably expects based on current facts and evidence. It does not reflect what management and the world wishes and desires – a Paris-compliant world."[30]

Shell has a long history of using decarbonisation scenarios as instruments of misinformation. In 2014, it responded to a study detailing its potential stranded assets in the future with a 20-page letter to its shareholders.[31] This letter shows the misleading framework Shell has since gone to work to deny having stranded assets on its balance sheet.[32] Shell simply circumvented the debate on stranded assets in 2014 by choosing a scenario that is not aligned with a 1.5°C pathway.[33] Instead it picked a scenario assuming that governments will fail to accomplish an effective 1.5°C decarbonisation

28 RDS, "Q3 2022 Results press release", October 27 2022, p. 9, https://www.shell.com/investors/results-and-reporting/quarterly-results/_jcr_content/root/main/section_1564161910/simple_copy_copy/list_copy_1861700816/list_item_copy_copy/links/item0.stream/1666949410668/1df7a49433e82491545b38572c8b803583cca3ce/q3-2022-quarterly-press-release.pdf

29 Shell International Finance B.V., "Multi-currency debt securities programme," 2022, p. 29, https://www.shell.com/investors/debt-information/euro-medium-term-note-programme/_jcr_content/root/main/section/simple/list/list_item.multi.stream/1667386501312/ed5149a485ea51a8f49974b6091bf79ccbe49d9d/v1-shell-2022-update-information-memorandum.pdf

30 RDS, Powering Progress, Annual Report and Accounts for the year ended December 31 2020, 2021, p. 203, https://reports.shell.com/annual-report/2020/servicepages/downloads/files/shell-annual-report-2020.pdf

31 RDS, Shell letter in response to shareholder enquiries on climate change, 2014, [Not online anymore] referred to in: OECD, Divestment and Stranded Assets in the Low-carbon Transition, 2014, p. 25

32 CTI, "Shell underestimates risk for up to $77 bln of high cost oil projects," July 2014, https://carbontracker.org/shell-response-press-release/

33 OECD, Divestment and Stranded Assets in the Low-carbon Transition, 2014, p. 8.

process and, as a result, it relies on a carbon budget that exceeds the limits of the Paris Agreement. This inflated carbon budget allowed Shell to present an imaginary scenario in which it can produce more oil and gas, for a longer period of time, enabling it to burn its unused upstream assets, and hence avoid stranded assets.

Why it is clear that Shell is not investing in a sustainable energy transition

Next to curtailing the burning of fossil fuels, providing an alternative to burning fossil fuels in the near term is the other pillar of transforming the world's energy system. The shift towards generating sustainable energy requires a radical relocation of investment flows, from fossil fuels to renewable assets. Yet currently there is an *investment gap*: a difference between investments in the infrastructure and the generation of sustainable energy that are required and the actual stock of investments. Here, too, there is a divide between the green energy narrative that oil companies like Shell promote in their publicity campaigns and their actual investment decisions. As in the reduction of fossil fuel use, much of the growth of renewable energy is governed by a market-based governance model, centred on self-regulation and without public actors defining a rule-based system. The combination of these two non-systems leads to a massive misallocation of capital, a loss of critical time, and hence a depletion of the scarce planetary carbon budget available for current and future generations.

In 2022, the International Institute for Sustainable Development (IISD) estimated that investments in, and production costs of, oil and gas in new fields that are incompatible with the IEA 1.5°C pathway will reach US$ 570 billion annually by 2030.[34] This annual capital expenditure on fossil fuels, which is inconsistent with the Paris Agreement, could cumulatively reach a total of US$ 4.2 trillion between 2020 and 2030. Put to better use, this sum would cover all the additional investments into renewable energy that are required to close the investment gap.[35] Unfortunately, oil companies like Shell remain committed to investing in additional fossil fuel assets instead of transitioning to renewable energy. Instead of proactively replacing fossil investments with green investments, Shell states that it only intends to start closing the investment gap after 'society' moves in the right direction.

> "Long term, it is expected that the current Shell portfolio will change and evolve with the energy transition. Decision-making on the future portfolio is guided by the pace of society's progress and the aim of being in step with society as it moves towards the goals of the Paris Agreement."[36]

Shell is therefore shifting responsibility to the demand side. However, an effective transition requires both the demand side and supply side moving away from burning fossil fuels.[37] Shell, being a massive corporation, a systemic climate company, with

34 IISD, Navigating Energy Transitions, p. 27.
35 Ibid.
36 RDS, Annual Report 2021, p. 244
37 G. Piggot, C. Verkuijl, H. van Asselt, and M. Lazarus, "Curbing fossil fuel supply to achieve climate goals," Climate Policy, 20:8, 2020, pp. 881-87, https://doi:10.1080/14693062.2020.1804315

considerable structural power and responsible for a large part of total accumulated global emissions since the start of the industrial age, has an exceptional responsibility which cannot be on the same footing as regular households or other corporations.

Another discursive tool for climate delay Shell uses to avoid having to shift investments from fossil fuels to renewable energy is the notion that fossil fuel assets generate the cash flows that finance green investments.[38] Shell states that it cannot fund its investments in renewable energy without the profits generated by selling fossil fuels.[39] There is a critical flaw in this argument, namely the payouts to shareholders (see Chapter 2). Instead of investing in renewables, Shell has channelled the vast majority of its profits, including the proceeds of fossil disinvestments, to shareholders. Rising fossil fuel sales thus do not simply translate into renewable energy investments and cannot be considered a precondition to invest in renewable energy.

The exceptional windfall profits that Shell and other oil and gas companies have generated in the wake of the Russian invasion of Ukraine in 2022 also shed light on the degree to which shareholders are prioritised over investments in green assets. While operational costs declined for upstream activities in 2022, sales jumped as a result of rising market prices after Russia invaded Ukraine. This caused an increase in the gross profit margin (the percentage of each dollar of revenue that the company retains as gross profit) of the upstream segment to an unprecedented 78 per cent in the third quarter of 2022, while the average margin was 58 per cent in the preceding 23 quarters (from 2017 to 2022).[40] In 2022, payouts to shareholders amounted to US$ 18.4 billion in share buybacks and US$ 7.4 billion in dividend payments.[41] Meanwhile, Shell's entire Renewables and Energy Solutions (RES) segment,[42] which includes renewable energy assets, only received investment in fixed capital of US$ 3.5 billion in the same period.[43] What this shows is that the exceptional profits that Shell made in 2022 were not used to invest in sustainable energy assets but were distributed to its shareholders and used to reduce its debt instead.

Shell only started to provide financial information about its RES segment in 2022 (for the years since 2017). The RES category, intended to clarify the amount of capital investments in renewable energy, is itself a tool of climate delay by obscuring the actual investments in renewable energy. In February 2023, the NGO Global Witness filed a complaint with the US Securities and Exchange Commission "for misleading US authorities and investors on its energy transition efforts".[44] The problem with the

38 RDS, Shell Energy Transition Strategy 2021, p. 17.
39 Volkskrant, "Shell-baas Ben van Beurden: 'Als wij een boom willen planten, is dat al verkeerd'", January 29, 2021, https://www.volkskrant.nl/cs-bb2ff62f
40 Calculations based on RDS, Third Quarter 2022 Results, Quarterly Databook, p. 9.
41 RDS, 4th quarter 2022 and full year unaudited results, p. 15, https://www.shell.com/content/dam/shell/assets/en/business-functions/investor/results-and-reporting/documents/2022/q4/q4-2022-quarterly-press-release.pdf
42 This RES segment was only formed in 2022 and includes "Shell's Integrated Power activities, comprising electricity generation, marketing, trading and optimisation of power and pipeline gas, and digitally enabled customer solutions. The segment also includes production and marketing of hydrogen, development of commercial carbon capture & storage hubs, trading of carbon credits and investment in nature-based projects that avoid or reduce carbon": RDS, https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q3-2022/_jcr_content/par/toptasks_1119141760_.stream/1666826523879/d8fd13b38ebe4a9aaa90c66b2c958a7860ee-ae09/q3-2022-qra-document.pdf, p. 9.
43 RDS, Fourth Quarter 2022 Results, Quarterly Databook, p. 17, https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q4-2022.html
44 Global Witness, "Shell faces groundbreaking complaint for misleading US authorities and investors on its energy transition efforts," February 1, 2023, https://www.globalwitness.org/en/campaigns/fossil-gas/shell-faces-groundbreaking-complaint-misleading-us-authorities-and-investors-its-energy-transition-efforts/?utm_source=hootsuite&utm_medium=twitter_

RES is that it bundles fossil and green investments together in a single category and thereby conceals the actual investments in renewable energy. Global Witness used the EU taxonomy to break down the RES category, with the numbers provided by Shell in its 2021 annual accounts, to estimate the actual size of renewable energy in the larger RES grouping.[45] Shell's own numbers disclose that total investments in solar and wind energy are only US$ 288 million (12 per cent of total capital investments in the RES) in 2021.[46] From the overall RES data, we can conclude that Shell is growing this segment, which suggests investments in renewable energy, but in fact it includes brown investments (not in accordance with the EU taxonomy) in the range of 71 per cent.[47]

Another measurement we can use to look at renewable energy in the portfolio of Shell is to consider the total capital employed (total amount of capital used to generate earnings) in the RES instead of looking at capital investments. In 2017, total capital employed in the RES (which is largely non-green) amounted to US$ 3.2 billion, rising to US$ 19.2 billion in 2022.[48] As a share of Shell's total capital employed, this represented an increase from 1.13 per cent to 7.09 per cent.[49] At first glance, the increase in capital allocated to the RES indicates a growing portfolio of green assets. Considering however that the underlying capital investments in the RES category consists of 71 per cent in activities that are not considered renewable energy in the EU taxonomy, the capital employed in green activities is probably only a third. We cannot estimate the exact amount as a result of a lack of transparency in this crucial figure.

The amount of capital employed, however, remains far from the necessary financial commitment to close the investment gap that would transform Shell into a climate-proof energy company, even if it were more than a third of the RES category. Also, the strategy to greenwash investments using the very category that is meant to filter the right financial data, by including in this category investments that are not considered green by the EU taxonomy, yet again reveals the intentions of Shell to obscure its strategy of delay.

45 RDS, Annual Report 2021, p. 304.

46 Ibid., p. 304.

47 Our depiction of 'renewable energy' in the RES category is larger compared to the estimates of Global Witness, who only include solar and wind energy (capex US$ 288 million in 2021). We also include the manufacture of bio gas, biofuel, and hydrogen (capex US$ 284 million in 2021) and "Infrastructure enabling low-carbon road transport and public transport" and "Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)" (capex US$ 118 million), totalling US$ 690 million: all data derived from ibid., p. 304.

48 RDS, Fourth Quarter 2022 Results, Quarterly Databook, p. 17.

49 Ibid., pp 7, 17.

2. Shell's path dependency: How the past shapes current options

To provide some context for the strategic options that Shell faces today, we will briefly revisit three key financial developments since 2010. First, Shell's investment in productive capacity followed a declining trend over this period. Second, the company took on more debt over the same period. Third, Shell reliably delivered benefits to its shareholders by means of dividends and share buybacks rather than redirecting resources to its own energy transformation.

These developments suggest that, since the Paris Agreement, Shell has spent valuable time and cash prioritising shareholders over developing a future-proof strategy. Constraining its capacity to shift investments from fossil to renewable assets, Shell now faces limitations when it comes to incurring further debt. As a consequence, it may need to either reduce payouts to shareholders or decrease capital investments in fossil activities to expand its green production capacity in future. How it will navigate this trilemma remains to be seen.[50]

Capping capital investments

Over the past decade, Shell has tended to reduce its relative investment share. After increasing the sum it devoted to capital expenditure from US$ 27 billion in 2010 to US$ 40 billion in 2013, these corporate resources declined to US$ 23 billion in 2022 (Figure 2).[51] Bolstered by mergers and acquisitions such as Shell's hitherto largest ever merger, with BG Group in 2016, productive capacity (here proxied by property, plant, and equipment) reached its highest values of US$ 236 billion and US$ 238 bil-

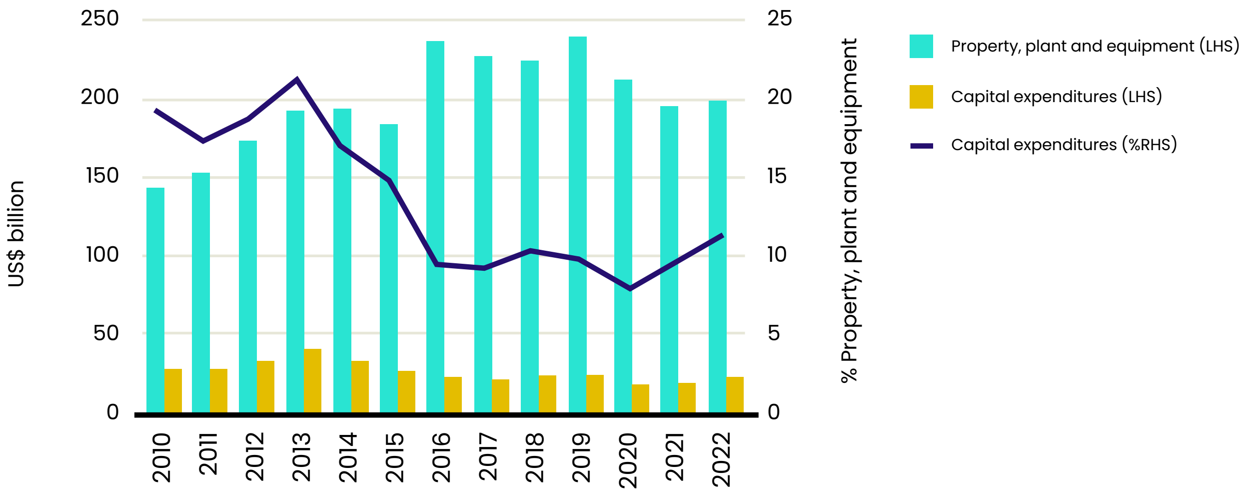
50 M. J. Pickl, "The renewable energy strategies of oil majors – From oil to energy?" Energy Strategy Reviews, 26, 2019, https://doi.org/10.1016/j.esr.2019.100370

51 RDS, Annual Reports 2010 and 2013, https://www.shell.com/content/shell/corporate/global/en_gb/about-us/annual-publications/annual-reports-download-centre/_jcr_content/root/main/section/list_1340539940/list_item_copy_copy__1365685867.multi.stream/1658488486028/5cab46fcc603585e21b47aa28069e27393feff2a/annual-report-2010.pdf, p. 101; and https://www.shell.com/about-us/annual-publications/annual-reports-download-centre/_jcr_content/par/tabbedcontent_f645/tab_ed06/textimage_79d6.stream/1519767055322/5553c0af2442fb1b0e586d1043b86669689083c0/annual-report20fsec-2013.pdf, p. 104; Annual Report 2021, p. 232.

lion in 2016 and 2019 respectively.[52] Measured against the stock of property, plant, and equipment, capital expenditure thus fell notably from 21 per cent in 2013 to 9 per cent in 2016, largely coinciding with dropping crude oil prices,[53] and have recovered only recently. These developments are not unique to Shell but follow a trend among other oil companies, in particular ExxonMobil and TotalEnergies, over the same period.[54]

Currently, Shell intends to keep its total annual capital expenditure in the range of US$ 19 billion to US$ 22 billion (of which an annual capital investment for renewables and energy solutions would be US$ 2 to 3 billion) in the future.[55] Once the total payout to shareholders reaches 20 to 30 per cent of operating cash flow, it plans to increase capital expenditure up to a maximum of US$ 27 billion.[56] Importantly, this makes additional capital investments conditional on the benefits shareholders receive as well as implying that shifting to green assets requires phasing out competing fossil investments. Even if additional capital expenditures were focused on the energy transition (which they are not likely to be, as discussed above), a lower investment rate bodes ill for lowering GHG emissions because it decreases the speed of energy efficiency gains.[57]

Figure 2. Shell's capital expenditures in US$ billion and as a share of its total net stock of property, plant, and equipment, 2010–2022[58]



52 RDS, Annual Report 2016, p. 119; Annual Report 2019, p. 192.
53 Macrotrends, "Crude Oil Prices – 70 Year Historical Chart," https://www.macrotrends.net/1369/crude-oil-price-history-chart.
54 SOMO, Enabling Putin's war: The ties between Amsterdam's financial centre and Gazprom, 2022, p. 3, https://www.somo.nl/nl/wp-content/uploads/sites/2/2022/03/Gazprom-in-the-Netherlands.pdf
55 RDS, Annual Report and Accounts 2021, p. 15
56 Ibid.
57 J. Copley, "Decarbonizing the downturn: Addressing climate change in an age of stagnation," Competition & Change, 2022, https://doi.org/10.1177/10245294221120986
58 Source: authors' calculations based on data from Refinitiv Eikon.

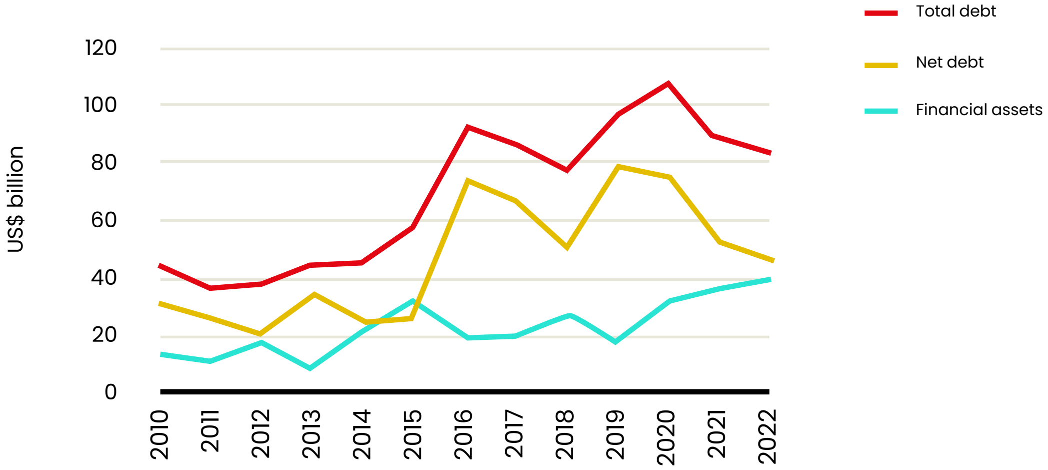
Rising debt levels limit future debt financing of a green transition

What about the financial resources, that is, debt, that Shell uses to finance capital investments? How has Shell's debt level evolved, and how much room does Shell have to take on more debt to support investments?

With capital investments declining relative to the total stock of fixed capital, it is noteworthy that Shell increased its debt significantly over the same period (Figure 3). In 2010, the company's total debt stood at US$ 44 billion, but by 2016 this had shot up to US$ 92 billion, and was set to climb to US$ 108 billion in 2020.[59] This increase in debt is largely in line with the larger non-financial corporate sector during this period.[60]

After the global financial crisis of 2008, central banks in the Global North embarked on a path of 'unconventional' monetary policy that included the purchase of government bonds and corporate bonds with newly created money, a policy labelled 'quantitative easing' (QE).[61] This monetary policy lowered interest rates and allowed corporations to increase their debt at lower costs. The consequence of QE has been to effectively subsidise fossil fuel investments and acquisitions by cheapening credit.[62] This environment only recently changed with rising inflation prompting central banks to slow down and suspend bond purchases and raise interest rates. Like other corporations, Shell seems to have seized upon the low interest rate environment. As a percentage of Shell's revenue, total debt increased from 5.1 per cent in 2007 to 22.0 per cent in 2022, down from 34.1 per cent just a year earlier.[63]

Figure 3. Shell's total debt, financial assets, and net debt, in US$ billion, 2010–2022[64]

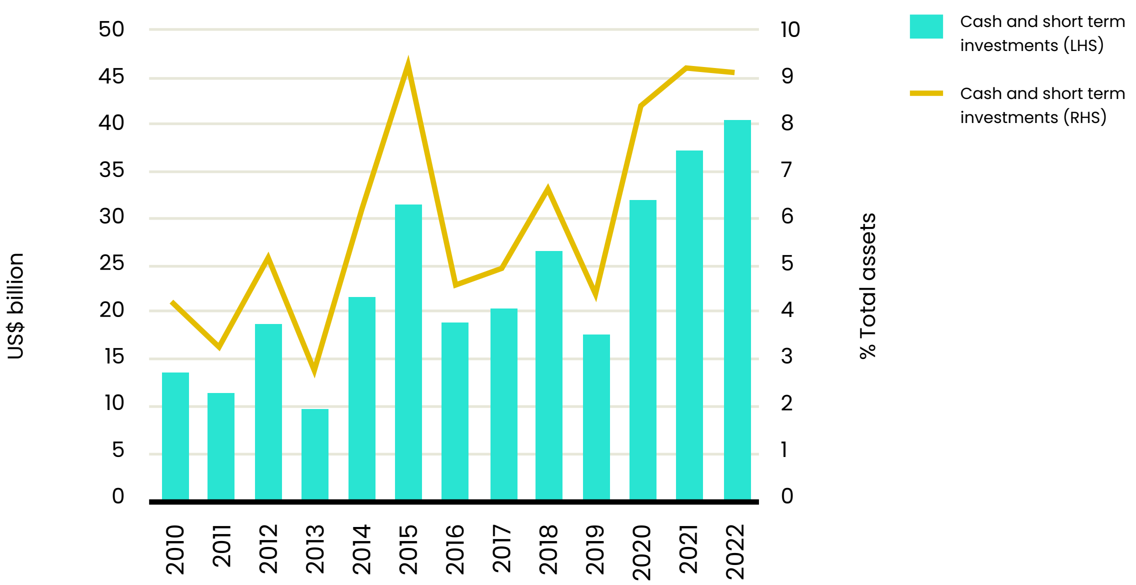


59 RDS, Annual Report 2010, p. 99; Annual Report 2016, p. 119; Annual Report 2020, p. 218.
60 SOMO, Aandeelhouders eerst: Hoe bedrijven dividend-machines werden, 2022, p. 19, https://www.somo.nl/wp-content/uploads/2022/06/SOMO-Aandeelhouders-eerst.pdf
61 SOMO, The politics of quantitative easing: A critical assessment of the harmful impact of European monetary policy on developing countries, 2018, https://www.somo.nl/wp-content/uploads/2018/06/Report-Quantitive-Easing-web.pdf
62 It is estimated that the purchase of corporate bonds of listed oil and gas companies in the Eurozone by the European Central Bank in just two months (from mid-March to mid-May 2020) amounted to € 3.2 billion: Greenpeace, ECB injects over €7 billion into fossil fuels since start of COVID-19 crisis, 2020, https://www.greenpeace.org/eu-unit/issues/climate-energy/3933/ecb-injects-e7-billion-into-fossil-fuels-coronavirus-crisis/
63 RDS, Annual Report and Form 20-F for the year ended December 31, 2008, pp. 113-14, https://www.shell.com/content/shell/corporate/global/en_gb/about-us/annual-publications/annual-reports-download-centre/_jcr_content/root/main/section/list_1340539940/list_item_copy_copy__1365685867.multi.stream/1658488486028/5cab46fcc603585e21b47aa28069e27393feff2a/annual-report-2010.pdf
64 Source: authors' calculations based on data from Refinitiv Eikon.

Shell's rising debt levels have recently caused concern among management. In its 2021 energy transition strategy, Shell announced that the long-term aim is to maintain *net* debt levels (that is, total debt minus financial assets) at US$ 65 billion.[65] Determined to reduce its debt levels, Shell had reduced its gross debt to US$ 84 billion by 2022 on the back of its exceptional windfall profits.[66] Shell's net debt level decreased sharply as a result of declining gross debt and rising financial assets, both of which could be said to result from cash flows being diverted to strengthen the balance sheet.

Recently, Shell's net debt stood at US$ 45 billion.[67] Total financial assets increased from US$ 18 billion in 2019 to US$ 40 billion in 2022 (Figure 4).[68] Meanwhile, total debt decreased from US$ 108 billion in 2020 to US$ 90 billion in 2021 and dropped further to US$ 84 billion in 2022.[69] As a result, Shell's net debt level decreased sharply in 2021 and 2022 to US$ 45 billion.[70] However, rather than being the outcome of a savvy corporate strategy, this decrease in debt was primarily enabled by the extraordinary environment of the past two years – that is, surging energy prices. Going forward, Shell identified that it would be able to shoulder additional debt in the range of US$ 17 billion. Compared to the previous build-up of debt over the decade, this seems rather modest and hence it takes some imagination that any sufficiently large green investment could be financed by incurring further debt.

Figure 4. Shell's financial assets in US$ billion and as a share of total assets, 2010–2022[71]



65 RDS, Shell Energy Transition Strategy 2021, p. 20.
66 RDS, 4th quarter 2022 and full year unaudited results, p. 12.
67 Ibid., p. 29.
68 RDS, Annual Report 2019, p. 192; 4th quarter 2022 and full year unaudited results, p 13.
69 RDS, Annual Report 2020, p. 218; Annual Report 2021, p. 230; 4th quarter 2022 and full year unaudited results, p. 29.
70 We use different metrics for net debt in this report compared to Shell, which includes the market valuation of financial derivatives. The values of the stock of financial assets Shell uses are US$ 5 billion (in the year 2020) and US$ 11 billion (in the year 2021) as a result of including the market valuation of financial derivatives. We exclude derivatives from our calculation of financial assets and as a result have a lower net debt. See RDS, Annual Report 2021, p. 256.
71 Source: authors' calculations based on data from Refinitiv Eikon.

Shell's financial assets hint at some undistributed profits and/or liquidity obtained through debt hitherto not reinvested in its operations. In 2022, Shell had US$ 40 billion in cash and cash equivalents (or 9.1 per cent of total assets) on its balance sheet, which is a sizeable increase from just US$ 13 billion in 2010 (4.2 per cent). On closer inspection, it seems implausible that Shell held these assets for the income they generated, as income from cash-like assets has been very low in relation to overall revenues. In 2022, just 0.33 per cent of total company revenues came from interest and dividend income explicitly.[72]

Shareholder payouts

Like other oil and gas giants, Shell is generally considered a reliable income source among investors, not least because it explicitly pursues an annual dividend growth rate of 4 per cent.[73] In most years, it devoted between US$ 8 billion and US$ 10 billion to paying dividends or buying back its own shares. Recently, however, Shell has gone far beyond this common practice, doubling the previous levels of shareholder payouts between 2018 and 2019 and, most recently, in 2022 (see Figure 5). The distribution to shareholders amounted to US$ 122.4 billion in dividends and US$ 49.5 billion in share buybacks from 2010 to 2022.[74]

Put into perspective, Shell increased its total payouts from 35 per cent of operating cash flow in 2010 to 60 per cent in 2019. The increasing trend was then interrupted by the impact of the pandemic. However, recent developments in 2022 – when payouts hit 38 per cent of operating cash flow – suggest a return to previous levels. Between 2010 and 2022, Shell's total payouts amounted to 82 per cent of its net income.[75] This begs the question whether distributing such vast amounts of cash to shareholders is occurring to the detriment of investments in the sustainable energy transition and, hence, may be difficult to reconcile with a 1.5°C pathway.

Reliable shareholder payouts do not seem to have helped Shell or its peers to garner extraordinary appreciation among investors in much of the recent decade. By and large, their share prices did not follow the general upswings in global markets, but instead showed more muted development.[76] In this respect, one might conjecture that the oil and gas sector's shares are traded at a discount relative to others due to the heightened uncertainty surrounding the decarbonisation governance gap. As seen by the recent rebound in fossil fuel stock prices, this discount may change with the vicissitudes of financial markets as the geo-economic fallout from Russia's invasion

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72 RDS, 4th quarter 2022 and full year unaudited results, p. 20. It is not uncommon for non-financial companies to increase their financial asset holdings at a time of falling interest rates. Observers regularly argue that growth in financial assets may partly be motivated by tax avoidance strategies rather than the pursuit of financial income proper: Z. Poszar, "Global Money Notes #11 Repatriation, the Echo-Taper and the €/$ Basis," Credit Suisse, 2018, p. 4, https://www.exunoplures.hu/wp-content/uploads/2023/06/19.pdf. This argument may well be applied to Shell too, for it is estimated that Shell recorded around 40% of all its profits in tax havens (excluding the Netherlands) in 2019: SOMO, Still playing the Shell Game: Four ways Shell impedes the just transition, 2021, p. 22, https://www.somo.nl/nl/wp-content/uploads/sites/2/2021/03/STILL-PLAYING-THE-SHELL-GAME.pdf

73 RDS, Shell Annual Report and Accounts 2021, p. 15.

74 Authors' calculations based on Refinitiv Eikon data.

75 Authors' calculations based on Refinitiv Eikon data.

76 The MSCI World Index. used to represent global markets, currently covers 1,511 listed equities from 23 developed economies, the largest of which are the USA (70.2%), Japan (5.8%), the UK (4.1%), Canada (3.5%), and France (3.1%): MSCI Index Factsheet, https://www.msci.com/documents/10199/178e6643-6ae6-47b9-82be-e1fc565ed-edb

of Ukraine, ensuing inflation concerns, and interest rate hikes force investors to reassess the attractiveness of oil and gas companies (Figure 6).

Figure 5. Shell's total payouts to shareholders in US$ billion and as a share of operating cash flow, 2010–2022[77]

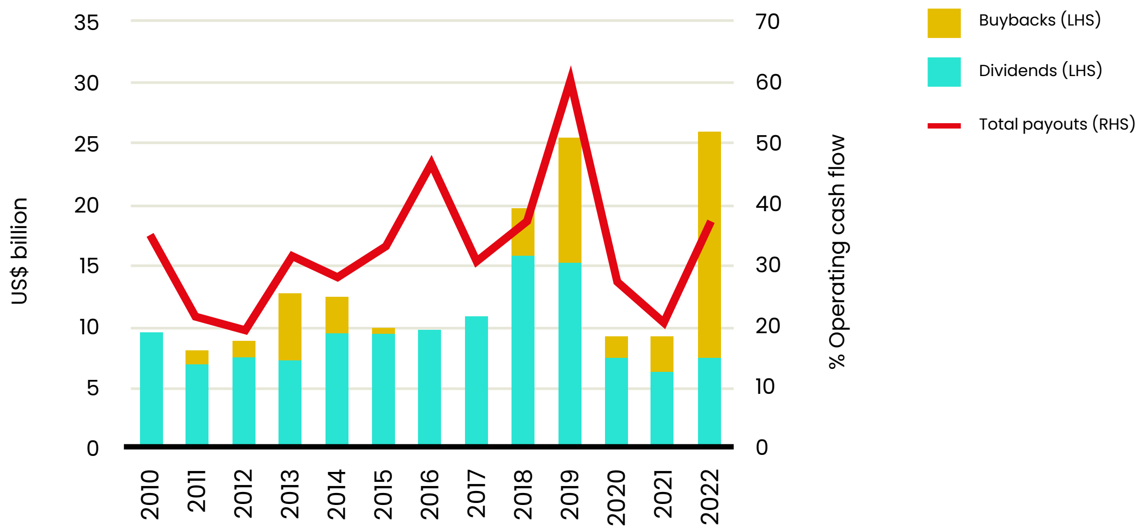
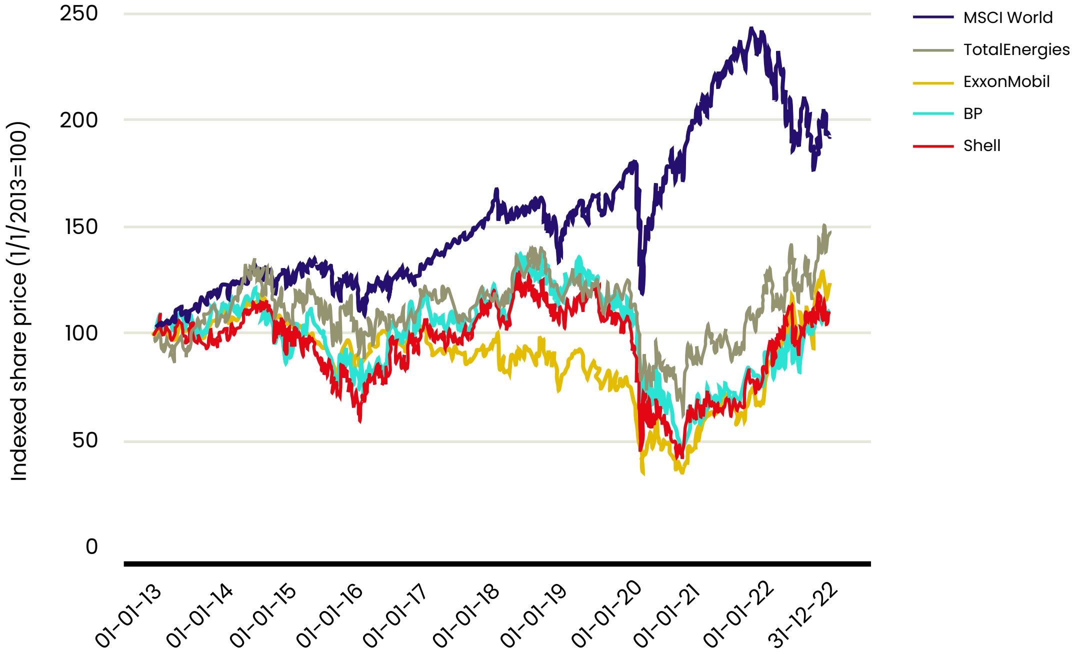


Figure 6. Market capitalisation of selected oil majors compared to the MSCI World Index, 2013–2022[78]



77 Source: authors' calculations based on data from Refinitiv Eikon.
78 Source: authors' calculations based on data from MarketWatch (https://www.marketwatch.com/) and Investing.com.

Conclusion: Shell's spending on fossil assets and shareholders is likely to prevent the company from being part of the energy transition

What are we to make of these broad observations? It seems that shareholder payouts were maintained in a period marked by increasing debt and stagnant to declining capital investments. In the future, Shell may well be unable, or at least unwilling, to carry on taking on more debt to expand its financial opportunities. With stabilising payout levels ranking high on the list of corporate priorities and existing fossil fuel assets requiring investments in maintenance if production is to continue, the question arises how the vast sums required to shift from fossil to renewable energy as Shell's primary business are to be financed. Seeing that Shell's renewable energy segment has not grown beyond 2.87 per cent (see section 1.3) of all of Shell's capital, we may conclude that valuable time and cash have been wasted since 2010 that the company needed to make the transition to a diversified energy provider.

3. How the future shapes current options

If we look towards the future, the key question is how current governance structures will be affected by the widening production gap. If the existing decarbonisation governance gap were closed and a rule-based decarbonisation regime were established, this would force oil and gas producers to operate within the limits of the planetary carbon budget.

Such a shift would have tremendous financial and operational ramifications for these companies, most importantly by rendering a large stock of oil and gas reserves unusable. Indeed, Shell expects there will be an increase in regulation at some point in the future and that this will cause an impairment (a reduction of the current value on the balance sheet) of its assets in the future:

> "Shell expects that a growing share of its greenhouse gas ('GHG') emissions will be subject to regulation, resulting in increased compliance costs and operational restrictions. Regulators may seek to limit certain oil and gas projects or make it more difficult to obtain required permits. Additionally, climate activists are challenging the grant of new and existing regulatory permits. Shell expects that these challenges are likely to continue and could delay or prohibit operations in certain cases. Achieving Shell's target of becoming net zero on all emissions from its operations could result in additional costs. Shell also expects that actions by customers to reduce their emissions will continue to lower demand and potentially affect prices for fossil fuels, as will GHG emissions regulation through taxes, fees and/or other incentives. This could be a factor contributing to additional provisions for Shell's assets and result in lower earnings, cancelled projects and potential impairment of certain assets."[79]

In addition, Shell expects that an increase in regulation and a decline in demand could have material adverse effects on its financial results:

79 Shell International Finance B.V., "Multi-currency debt securities programme," 2022, p. 12.

> "If Shell is unable to find economically viable, publicly acceptable solutions that reduce its GHG emissions and/or GHG intensity for new and existing projects and for the products it sells, Shell could experience financial penalties or extra costs, delayed or cancelled projects, potential impairments of its assets, additional provisions and/or reduced production and product sales. This could have a material adverse effect on Shell's earnings, cash flows and financial condition."[80]

If governments fail to close the decarbonisation governance gap through effective regulation, we are likely to be left with a continuation of today's self-regulatory environment, in which oil and gas companies are allowed to emit GHGs far beyond the limits of the 1.5°C carbon budget. The difference between the three scenarios mentioned in the Introduction is stark. In the first scenario, companies operate without the limits of a carbon budget and subsequently extract and burn hydrocarbons without incurring any stranded assets. In the second scenario, fossil fuel companies are forced to operate within planetary carbon limits, stranding a significant amount of assets as a result. The third scenario builds on the second. In this scenario fossil fuel companies are forced to take responsibility for their stranded assets and all social, economic, and environmental damages as a result of producing oil and gas, in line with the principles of a just transition at the cost of the shareholders.

Shell's auditor EY dodges this tricky question, and simply refrains from accounting for a 1.5°C-aligned future at all:

> "Importantly also, Shell has reported in Note 2 to the Consolidated Financial Statements that their operating plan and pricing assumptions do not yet reflect Shell's 2050 net-zero emissions target. For these reasons, it is neither possible nor appropriate for EY, as Shell's auditor, to attempt to provide in our audit opinion Paris-aligned assumptions that are not in our remit to determine, and the impact that any such assumptions might be expected to have on the financial statements."[81]

To understand what a hypothetical rule-based 1.5°C decarbonisation regime may look like for Shell, we will discuss different estimates of the size of stranded assets this scenario might produce. At its core, this is a hypothetical scenario in which Shell is obliged to operate within the limits of a certain carbon budget. It is important that Shell currently does not anticipate stranded assets in its energy transition strategy. Rather, it imagines that it will be able to fully consume its current upstream assets (in contrast to IEA estimates): "At December 31, 2020, we estimate that around 75% of our current proved oil and gas reserves will be produced by 2030 and only around 3% after 2040."[82] In this chapter, we explain the origins of stranded assets as a concept, as well as some of the methodological considerations to estimate their nominal value. Then, we apply one method to Shell's current balance sheet to calculate the size of its stranded assets.

80 Ibid.
81 RDS, Powering Progress, Annual Report and Accounts for the year ended December 31, 2020, p. 203.
82 RDS, Shell Energy Transition Strategy 2021, p. 29.

A brief introduction to stranded assets

Stranded assets have become a key element in current debates on decarbonisation, but there is not a universally accepted definition.[83] In the early 1990s, the concept was used by regulators to indicate 'stranded costs' or 'stranded investment' in a context of industry restructuring due to liberalisation.[84] Later studies revisited the concept to analyse the financial implications of the decarbonisation agenda resulting from the Paris Agreement. For this report, we consider stranded assets as assets that will fail to generate adequate future income to justify their current value on the balance sheet as a result of an effective decarbonisation regime. This approach is in line with definitions by the most authoritative institutions on the topic, namely the International Energy Agency (IEA),[85] the Carbon Tracker Initiative (CTI),[86] and the International Renewable Energy Agency (IRENA).[87] In accordance with methods developed in the literature, we focus on proven oil and gas reserves and ignore the stranded nature of fossil fuel infrastructure and downstream assets, ranging from refining capacity to transport, sales, and distribution of oil and gas.

The two main variables in calculating stranded assets

To understand the mechanics of stranded assets and estimate the range of their monetary value, we must first discuss two key variables. The first is the 'carbon equivalence' or 'carbon conversion factor' for fossil fuels. This variable translates different fossil fuel units such as crude oil, gas, and coal reserves into GHGs after being combusted. The convergence rates were originally estimated by the Intergovernmental Panel on Climate Change (IPCC) and became the standard in the literature.[88] The IPCC convergence framework is comprehensive and provides an equivalent for more than 42 varieties of fossil fuels.[89] In section A of the methodological annex of this report we discuss in more detail the conversion factors that were used.

The second variable is the 'carbon budget'. The carbon budget refers to the maximum amount of GHGs that can be emitted before global temperatures rise above a certain threshold compared to the pre-industrial era. That maximum amount of emitted GHGs can then be translated into the amount of fossil fuel reserves that may be burned, until the threshold is reached. As a variable, the carbon budget is high-

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83 K. Bos and J. Gupta, "Stranded assets and stranded resources: Implications for climate change mitigation and global sustainable development," Energy Research & Social Science, 56, 2019, 101215, pp. 3-4, https://doi.org/10.1016/j.erss.2019.05.025

84 IRENA, Stranded Assets and Renewables: How the energy transition affects the value of energy reserves, buildings and capital stock, Working Paper, 2017, p. 13.

85 IEA and OECD, Redrawing the Energy Climate Map: World Energy Outlook Special Report, 2013, p. 98, https://iea.blob.core.windows.net/assets/417cd627-fda9-470e-9380-1203a5315deb/WEO_Special_Report_2013_Redrawing_the_Energy_Climate_Map.pdf : "those investments which have already been made but which, at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return as a result of changes in the market and regulatory environment brought about by climate policy".

86 CTI, Stranded Assets, 2017, p. 1, https://carbontracker.org/terms/stranded-assets/

87 IRENA, Renewables: How the Energy Transition Affects the Value of Energy Reserves, Buildings and Capital Stock. Working Paper, 2017, p 14.

88 IPCC, Guidelines for National Greenhouse Gas Inventories, 2006, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf, p. 19.

89 Greenhouse Gas Protocol, Calculation Tools, Cross-sector tools, 2015, https://ghgprotocol.org/calculation-tools

ly contested and differs from one study to another. The variation between studies is largely the consequence of the different models that are used to predict global climate dynamics in the future. However, essentially the arithmetic is such that, the lower the degree of global warming and the higher the probability of restricting warming at a certain level, the lower the carbon budget gets.

A larger stock of accumulated GHGs results in a higher global temperature rise. The size of the global carbon budget one chooses dictates how much GHG can be emitted and therefore the budget that fossil fuel companies have available to burn oil and gas. Because there is currently no rule-based system in place to allocate any given carbon budget, these limits will be speculative. Moving forward, however, we will assume an effective decarbonisation regime, with the ability to allocate and enforce a carbon budget, to understand its hypothetical implications for Shell.

One of the first studies that applied the notion of stranded assets to explore the process of decarbonisation was *Unburnable Carbon* from CTI in 2011.[90] In this pioneering study, CTI proposed a carbon budget of 565 $GtCO_2$ for the period 2011 to 2050 to prevent global temperatures from rising above 2ºC. The current remainder of this carbon budget is 193.8 $GtCO_2$ for 2021 to 2050, indicating the speed at which we are consuming the carbon budget and the need to reduce it in the short term to stay within reach of a 1.5°C pathway. This carbon budget was not estimated by the CTI authors, but was taken from the body of climate studies literature at the time.[91] In addition, CTI considered a variety of fossil fuels reserves (coal, conventional and unconventional crude oil, and natural gas) and carbon conversion factors.[92]

CTI estimated the earth's proven fossil fuel reserves to amount to 2,795 $GtCO_2$ (65 per cent was coal, 22 per cent crude oil, and 13 per cent gas). If this estimate is right, it means that the earth's reserves of fossil fuel are nearly five times the carbon budget. This means that only 20 per cent of these reserves can be burned to stay within a 2ºC pathway. The remaining reserves should be considered to be stranded assets.

In the following years, CTI and other organisations, such as the IEA and IRENA, published more studies and revisited the initial assumptions. The carbon budget calculations and global warming targets were updated to reflect changes in climate change research. For example, in a CTI study from 2019, the carbon budget was two to four times larger than the initial study from 2011.[93] The new data and methods that emerged as climate science progressed include a detailed probability pathway to achieve the 1.5ºC or 2ºC temperature goal from the IPCC[94] and an update on the stock of fossil fuel reserves.[95]

90 CTI, Unburnable Carbon: Are the World's Financial Markets Carrying a Carbon Bubble? 2011, https://carbontracker.org/reports/carbon-bubble/

91 M. Meinshausen, N. Meinshausen, W. Hare, Et al., "Greenhouse-gas emission targets for limiting global warming to 2 ºC," Nature, 458, 2009, pp. 1158-162, https://doi.org/10.1038/nature08017; P. Friedlingstein, R. Houghton, G. Marland, Et al., "Update on CO2 emissions," Nature Geoscience, 3, 2010, pp. 811–12, https://doi.org/10.1038/ngeo1022

92 IPCC, Guidelines for National Greenhouse Gas Inventories, 2006, p. 19.

93 CTI, Balancing the Budget: Why deflating the carbon bubble requires oil and gas companies to shrink, 2019, https://carbontracker.org/reports/balancing-the-budget/

94 IPCC, Summary for Policymakers [Global Warming of 1.5ºC], 2018, https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SPM_version_report_LR.pdf

95 BP, Statistical Review of World Energy 2021.

In Table 1, we present a selected number of carbon budget scenarios, ranging from more restrictive to more flexible budgets.[96] The first six scenarios have been derived from existing literature; the last scenario is calculated by us to reflect the latest advancements made by the UN Framework Convention on Climate Change Conference of Parties meeting in

2021 (COP26). The main difference between all scenarios is the projected size of the remaining carbon budget. This difference is the result of the type of input (for example, the introduction or not of carbon capture technology) and the variables (such as variations in temperature thresholds, year of peak emissions, and the probability of success) that were used. The sixth scenario, labelled 'de *jure*', is based on the concept of Nationally Determined Contributions (NDCs) approved in the Paris Agreement and ratified during COP26 in 2021.

The technical details of each scenario, its assumptions, and how it is calculated are highlighted in the methodological annex at the end of the report. The 'references and assumptions' in the table refer to the publication(s) from which each carbon budget is derived.

Table 1. Selected carbon budget scenarios[97]

	Scenario name	Calculated by	Carbon budget ($GtCO_2$)	Goal (°C)	Probability of success	Year of peak emissions	References and assumptions
1	2°C (Carbon Tracker original)	CTI, 2011	193.8	2°	-	-	Meinshausen et al., 2009;[98] Friedlingstein et al., 2010;[99] CTI, 2011;[100] BP, 2022[101]
2	1.5° (83% success)	GCI, 2021	266.0	1.5°	83%	-	IPCC, 2018;[102] GCI, 2021[103]
3	1.5° (50% success)	IEA, 2021	467.7	1.5°	50%	2020	IPCC, 2018[104]
4	IEA 450	CTI, 2015	618.7	2°	50%	2020	IEA, 2014;[105] CTI, 2015[106]
5	2°C (80% success)	CTI, 2013	632.5	2°	80%	-	Meinshausen et al., 2009[107] and other alternative assumptions; CTI, 2013[108]
6	De jure scenario (Paris Agreement + COP26)	Authors' calculations	667.0	2°	-	2030	BP, 2022[109]. Note: only the largest 15 emissions countries (including the EU taken as a single country) are considered
7	2°C (80% success with CCS)	CTI, 2013	757.5	2°	80%	-	Meinshausen et al., 2009,[110] other alternative assumptions, and carbon capture technology and storage; CTI, 2013[111]

96 We discuss the underlying assumptions of each scenario in section B of the methodological annex.
97 Source: authors' calculations; see the methodological annex for details.
98 Meinshausen, Meinshausen, Hare, Et al., "Greenhouse-gas emission targets for limiting global warming to 2 °C".
99 Friedlingstein, Houghton, Marland, Et al., "Update on CO2 emissions".
100 CTI Unburnable Carbon: Are the World's Financial Markets Carrying a Carbon Bubble?.
101 BP, Statistical Review of World Energy 2022, data workbook, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/xlsx/energy-economics/statistical-review/bp-stats-review-2022-all-data.xlsx
102 IPCC, Summary for Policymakers [Global Warming of 1.5°C].
103 Global Climate Insights (GCI), Part 1: Royal Dutch Shell GHG emissions, https://www.accr.org.au/research/part-1-royal-dutch-shell-ghg-emissions/
104 IPCC, Summary for Policymakers [Global Warming of 1.5°C].
105 IEA, World Energy Outlook 2014, OECD/IEA, https://www.iea.org/reports/world-energy-outlook-2014
106 CTI, The $2 trillion stranded assets danger zone: How fossil fuel firms risk destroying investor returns, 2015, https://carbontracker.org/reports/stranded-assets-danger-zone/
107 Meinshausen, Meinshausen, Hare, Et al., "Greenhouse-gas emission targets for limiting global warming to 2 °C".
108 CTI, Unburnable Carbon 2013: Wasted capital and stranded assets, 2013, https://carbontracker.org/reports/unburnable-carbon-wasted-capital-and-stranded-assets/
109 BP, Statistical Review of World Energy 2022, data workbook.
110 Meinshausen,Meinshausen,Hare,Et al., "Greenhouse-gas emission targets for limiting global warming to 2 °C".
111 CTI, Unburnable Carbon 2013: Wasted capital and stranded assets.

Translating the global carbon budget to Shell's 1.5°C pathway

The next step is to convert the global carbon budget to company-level carbon allowances. In addition, we compare the company-level carbon budget to the oil and gas reserves that companies have on their balance sheets to assess the share that will have to remain in the ground in a hypothetical scenario of a decarbonisation regime.

In order to take these two steps, we will consider two elements:

- First, we take into account existing projections about the transformation of the world's energy composition towards 2050. We use the projections from the IEA net zero scenario of 2021 to determine the changing volumes and composition of global energy consumption towards 2050.[112]
- A second element is the share of the world's total oil and gas reserves held by each company that owns such reserves.[113]

The data regarding Shell show that, at the end of 2021, the company owned 0.4 per cent of global gas reserves (27,744 billion standard cubic feet) and 0.3 per cent of the crude oil reserves (4.581 billion barrels).[114] These figures tell us that Shell's carbon budget is roughly the equivalent of 0.3 per cent of the global carbon budget we choose.[115] For the seven carbon budget scenarios mentioned above, this means that total emissions for Shell (oil and gas combined) lie in a range between 0.6 GtCO2 in the most restrictive scenario to 2.4 GtCO2 in the most flexible scenario.

If we follow the original Carbon Tracker carbon budget, shown in Table 3, we find that 72 per cent of Shell's natural gas reserves and 90 per cent of crude oil would be considered stranded. In the IEA 1.5°C carbon budget, the stranded assets for gas are reduced to 11 per cent of total reserves, and for oil to 68 per cent of total reserves. The only scenario that does not result in stranded assets for Shell is the 2°C scenario with the successful implementation of untested CCS technology (scenario 7 in Table 2). In this scenario, Shell has space to increase its gas reserves by 9 per cent of its current gas reserves, but 6 per cent of Shell's proven reserves remain stranded (Figure 7).

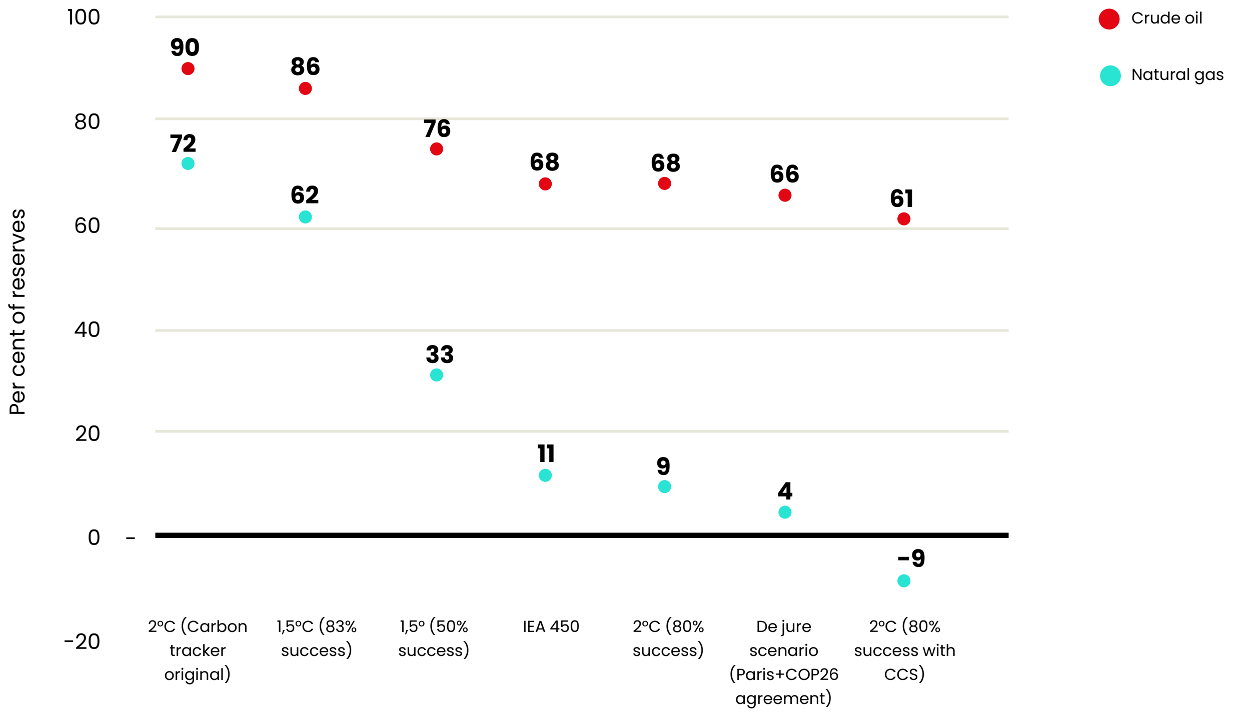
112 IEA, "Net Zero by 2050 Data Explorer," 2021, https://iea.org/data-and-statistics/data-tools/net-zero-by-2050-data-explorer

113 The data detailing the size of Shell's oil and gas reserves (proven developed and underdeveloped reserves) are derived from the company's 2021 F-20 reports to the US Securities and Exchange Commission (SEC) from 2022. See RDS, "Shell files Form 20-F with SEC," 2022, https://www.shell.com/media/news-and-media-releases/2022/shell-files-form-20-f-with-sec.html. The global reserves are taken from BP, Statistical Review of World Energy 2022, data workbook.

114 See section E of the methodological annex for details.

115 These assumptions, based on the relative weight in global oil and gas reserves, differ substantially from calculations rooted in Shell's global sales. Shell has much larger weight in global sales (14.9%; source: Refinitiv Eikon), which reflects its position as a major intermediary, purchasing a large proportion of the total fossil fuels it sells. However, we are interested in the assets not the sales.

Figure 7. Shell's unburnable oil and gas in different scenarios



The financial value of Shell's stranded assets

A final step is to estimate a monetary value in dollars for the stranded assets. While the previous calculation was already somewhat speculative and based on assumptions, this step adds even more speculative layers. The key unknown is the price of oil and gas. The future price of fossil fuel determines the potential future income of fossil fuel assets and hence is key for its valuation. Because future energy prices are impossible to predict, we explore different cases in line with potential future energy prices: high, medium, and low.[116] These prices are derived from the observed maximum, low, and average crude oil (West Texas Intermediate (WTI) crude oil per barrel) price in the last 25 years and average price for natural gas (US natural gas dollar price per thousand cubic feet) reported by the IEA.[117]

As shown in Table 2, our calculations produce the following values of stranded assets for Shell, in the range from scenario 7 (with 80 per cent successful CCS) to scenario 1 (the 2°C original scenario from CTI). In the case of high energy prices, stranded assets vary from US$ 256 billion to US$ 608 billion. In the case of medium energy prices, variations go from US$ 105 billion to US$ 280 billion, and in the case of low prices, from US$ 25 billion to US$ 87 billion.

116 In the high prices scenario, we assumed US$ 10 per thousand cubic feet for natural gas and US$ 100 per crude oil barrel. In medium prices, we assumed US$ 5.3 per thousand cubic feet and US$ 42 per crude oil barrel. In the low price scenario, we assumed US$ 2.1 per thousand cubic feet for natural gas and US$ 10.9 per crude oil barrel.

117 US Energy Information Administration (EIA), "Data: petroleum & other liquids," 2022, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000__3&f=m; "Data: natural gas," 2022, https://www.eia.gov/dnav/ng/hist/n3035us3m.htm

Table 2. Estimating Shell's stranded assets in US$ billion with different price projections and in different carbon budget scenarios

Shell					High energy prices (A)			Medium energy prices (B)			Low energy prices (C)		
Scenario	Carbon budget equivalent	Shell's equivalent carbonbudget	Stranded reserves		Stranded reserves proved			Stranded reserves proved			Stranded reserves proved		
			Units		Billions of US dollars			Billions of US dollars			Billions of US dollars		
	CO2 (G)	CO2 (G)	Natural gas (trillon of m3)	Crude oil (thousand millon barril)	Natural gas	Crude oil	All	Natural gas	Crude oil	All	Natural gas	Crude oil	All
2ºC (Carbon tracker original)	194	0,6	0,6	4,1	195,24	413	608	106,19	173	279	42,01	45	87
1,5º (83% success)	266	0,8	0,5	4,0	167,12	396	563	90,90	166	257	35,96	43	79
1,5º (50% success)	468	1,5	0,3	3,5	88,57	348	437	48,17	146	194	19,06	38	57
IEA 450	619	1,9	0,1	3,1	29,76	313	343	16,19	131	148	6,40	34	40
2ºC (80% success)	633	2,0	0,1	3,1	24,39	310	334	13,26	130	143	5,25	34	39
De jure scenario (Paris+COP26 agreement)	667	2,1	0,0	3,0	10,95	302	313	5,96	127	133	2,36	33	35
2ºC (80% success with CCS)	758	2,4	-0,1	2,8	-24,29	280	256	-13,21	118	105	-5,23	30	25
Shell proven reserves			**0,8**	**4,6**	**270,72**	**458**	**729**	**147,24**	**192**	**340**	**58,25**	**50**	**108**

What these projections tell us is that there is a high degree of uncertainty and that many moving parts influence the value of the impairment of Shell's stranded assets. When we take the most 'average' scenario (scenario 4 and the average price range for oil and gas), we find that the stranded assets from 2050 and beyond could amount to US$ 148 billion. This figure would result in additional annual depreciation to the tune of US$ 4.7 billion between 2020 and 2050 for Shell to avoid having to write down assets. More important than the exact value that will be stranded – which depends on various contingencies and is inherently speculative – is the wider process it could ignite. Depreciating upstream assets could set in motion a snowball effect by raising investors' questions about the value of property, plant, and equipment on the balance sheet of Shell and its downstream assets. This could result in a tipping point whereby the market capitalisation of the company declines sharply, as has happened to the electricity sector in the last decade.[118] This is why stranded assets are the Achilles heel of Shell's balance sheet.

118 Material Economics and SEI, Framing Stranded Assets Risks in an age of disruption, 2018, p. 13, https://www.sei.org/wp-content/uploads/2018/03/stranded-assets-age-disruption.pdf

4. The just transition trilemma Shell faces

The strategy that oil and gas companies have been pursuing over the past decade to deal with uncertainty in regulatory change has been characterised in the literature as 'hedging'.[119] Companies have used diversification into renewable energy as a means of insuring themselves against consequential policy changes. Rather than moving as quickly as possible, oil and gas companies are merely diversifying their energy mix to keep all their options open, as the direction of the future regulatory environment is unknown. Importantly, investments in oil and gas will not be abandoned as long as an effective cap on GHG emissions remains missing. As a result, oil and gas companies have been constructing their own trilemma, making it impossible to reach the goals they have set out.

The speed at which oil and gas companies move is determined by contingencies in the short and long term that affect the demand for hydrocarbons. Should demand for oil and gas drop structurally, fossil fuel prices will drop, narrowing profit margins and dimming prospects for future income streams. Taken together with regulatory measures, this will effectively strand assets, raise the sector's cost of capital, and shrink the market capitalisation of the companies. To hedge this cliff, some companies have at least made tentative, though highly insufficient, steps into producing and selling renewable energy.[120]

Recent years have seen unprecedented shocks to the global demand side of energy. The economic fallout during the Covid-19 crisis resulted in significant losses for Shell and its peers, with prices falling to US$ 22 per barrel in April 2020. Only two years

119 J. Green, J. Hadden, T. Hale, and P. Mahdavi, "Transition, hedge, or resist? Understanding political and economic behavior toward decarbonization in the oil and gas industry," Review of International Political Economy, 2020, pp. 2036-63, https://www.tandfonline.com/doi/abs/10.1080/09692290.2021.1946708

120 Pickl, "The renewable energy strategies of oil majors – From oil to energy?"

later, following the Russian invasion of Ukraine, oil prices rose sharply to US$ 117 per barrel.[121] Such large swings bring into sharp relief the degree of turbulence energy markets can experience, turbulence that may increase as policies to reduce demand start to take effect. Against the backdrop of radical uncertainty in the short term and the need to remain within the limits of a 1.5°C pathway in the long term, we now turn to exploring potential future scenarios based on Shell's financial position, the trajectory of its GHG emissions, and the possible impact of stranded assets.

Taking cues from energy researchers, we conceptualise Shell's future options as a trilemma.[122] A trilemma consists of three goals of which only a maximum of two can be realised at the same time. In this case in one scenario only one goal can be realised. The three goals with respect to Shell can be described as follows:

- **Goal A** continuing to operate as an oil and gas giant profiting from consuming ever greater portions of the global carbon budget;
- **Goal B** continuing to pursue high shareholder returns; and
- **Goal C** transforming itself into a major renewable energy player.

These three goals result in the following scenarios: 'business as usual', in which goals (a) and (b) are pursued; 'energy transition', in which goals (b) and (c) are pursued; and 'just transition', in which goal (c) is pursued.

With respect to these three goals, Shell's current strategy, which boils down to having its cake and eating it, is unrealistic. Strategic choices will have to be made, leading to different paths. So what do the most likely scenarios look like?

Business as usual (goals A and B): Maximising fossil-fuel profits and risking climate chaos

Under the first 'business as usual' scenario, Shell's total production of fossil fuels and the resulting emissions of GHG will not decline before 2030, and exploration for new upstream assets will continue until 2025 at least. Shell's energy mix will move towards gas in the long run (55 per cent in 2030), and the energy intensity of the company's production process will decline as set out in its energy transition strategy.[123] Meanwhile, its segment of renewable energy will continue to grow in accordance with Shell's current intention to invest an annual US$ 2 to 3 billion in its RES segment, totalling somewhere between US$ 19 billion and US$ 22 billion.[124] However, this would still amount to no more than 10 to 15 per cent of total capital investments. In the long run, the growth rate of green assets depends on the investment required to ramp up gas production.

In its 2021 energy transition strategy, Shell set a target to invest 55 per cent in the so-called 'growth' segment. Yet this segment combines gas, renewable energy, and a variety of other activities all under one header. The lack of granular data makes it im-

121 Macrotrends, "Crude Oil Prices – 70 Year Historical Chart," https://www.macrotrends.net/1369/crude-oil-price-history-chart
122 Pickl, "The renewable energy strategies of oil majors – From oil to energy?"
123 RDS, Shell Energy Transition Strategy 2021, p. 20.
124 RDS, Shell Annual Report and Accounts 2020, p. 25.

possible to assess how much will be directed to renewable energy. What is relatively easy to assess, however, is that large investments will be sunk into fossil assets, both oil and gas, undercutting capital investment in green assets. Indeed, such investment will remain a hedge against sudden shifts in the energy transition more broadly. Another hedge, possibly competing for corporate resources with renewable energy, will be a range of yet-to-be-scaled-up techno-fixes such as CCS and industrial-scale tree plantations to act as carbon sinks, all of which are part of Shell's RES segment.[125]

The big unknown in this scenario, however, is how much upstream assets and infrastructure will depreciate as a result of a possible decline in fossil fuel prices as the energy transition takes shape in the future. If prices were to drop, asset impairments would likely follow with adverse effects on Shell's ability to maintain its payout commitments. Shell's auditor, EY, explicitly heeds such concerns, warning that "[t]here is a risk that material impairments could have a direct impact on Shell's ability to pay dividends".[126] In this scenario, Shell and its investors will thus have to live with the looming risk of effective regulation, despite ongoing efforts by fossil fuel companies to frustrate such moves at every level of decision-making and public opinion.

Regulatory changes could result in a sudden downward shift in the valuation of a variety of assets, creating feedback loops through financial markets as the share price of fossil fuel companies declines. Upstream asset write-offs will drive down fossil fuel companies' market capitalisation, which in turn will impact both stockholders and bondholders with large exposure to this industry. This could potentially create the conditions for a major financial crisis. Economists from the French central bank, in a 2020 publication from the Bank for International Settlements (BIS), recognised the dangers of a climate-change-induced financial crisis.[127] They label this type of financial crisis a 'green swan' event, which is a potentially extremely disruptive event, caused by climate change transition dynamics resulting potentially in the next systemic financial crisis.

This notion of a 'green swan' has left central banks to wonder what role they have to play to mitigate the risks of climate change in the context of an enduring governance gap. On the one hand, they could intervene, and purchase stranded assets, similar to their rescue of the banking system in the global financial crisis.

This strategy would rescue oil companies to save the financial system: "Green swan events may force central banks to intervene as 'climate rescuers of last resort' and buy large sets of devalued assets, to save the financial system once more."[128] However, this behaviour by central banks could also strengthen moral hazard, the *Green swan* report argues, encouraging states and corporations to lean back and refrain from closing the governance gap – the very opposite of what central banks aim to achieve.

To be ahead of such a chain of events, Shell could divest upstream assets before reaching the cliff. This is a difficult process in many ways. First, Shell is already di-

125 In the short run, Shell intends to invest annually a sum of US$ 70 million in CCS and US$ 100 million in "nature based offsets": Shell Energy Transition Strategy 2021, p. 16.
126 RDS, Shell Annual Report and Accounts 2021, p. 216.
127 P. Bolton, M. Despres, L. Awazu Pereira da Silva, et al., The green swan. Central banking and financial stability in the age of climate change, Bank for International Settlements, 2020, https://www.bis.org/publ/othp31.pdf
128 Ibid., pp. 1-2.

vesting and concentrating its assets on particular areas to better match the location of production and sales.[129] This is mainly a hedging strategy, not meant to cease oil and gas production. Finding the right timing and speed to divest is difficult in this scenario given that Shell seeks to hold its position as long as it is profitable. An article in the Financial Times based on an interview with Shell's CEO stated that "[t]he 'single biggest' regret for the Shell boss would be abandoning its oil and gas business prematurely. That, he says starkly, is something Shell 'could not live with'."[130]

What is more, divestments are not a simple financial transaction. The assets in question are spatially fixed, embedded in local social and political realities. Selling production facilities, without the proper due diligence and guarantees, including responsibility for decommissioning, may result in a whole range of legal and political liabilities.[131] Shell explains these difficulties to its bondholders:

> "Shell is seeking to execute divestments in the pursuit of its strategy. Shell may not be able to successfully divest these assets in line with its strategy. Shell may not be able to successfully divest assets at acceptable prices or within the timeline envisaged due to market conditions or credit risk, resulting in increased pressure on its cash position and potential impairments. Additionally, in some cases, Shell has retained certain liabilities following divestments. Moreover, even in cases where Shell has not expressly retained certain liabilities, Shell may be held liable for past acts, failures to act or liabilities that are different from those foreseen. Shell may also face liabilities if a purchaser fails to honour all of its commitments. Accordingly, if Shell is unable to divest assets at acceptable prices or within its envisaged timeframe, this could have a material adverse effect on its earnings, cash flows and financial condition."[132]

Finally, in this scenario Shell and its peers will strengthen their efforts to influence decision-making, to mislead the public, and to affect electoral processes. Climate delay strategies, including the discursive strategies of promoting techno-fixes and projecting themselves as partners in the energy transition rather than culprits in its hindrance, are key levers left for fossil fuel companies to extend their carbon budgets.[133]

This scenario exhibits strong parallels to the financial crisis of 2008. Only this time it would be fossil fuel companies rather than systemically important financial institutions that would continue dancing on the volcano and postponing the inevitable, knowing that they are too big to fail and that societies need their energy security.

129 RDS, Shell Energy Transition Strategy 2021, p. 17.
130 Financial Times, 27 September 2019, "Royal Dutch Shell searches for a purpose beyond oil: Anglo-Dutch company faces dilemma as world shuns fossil fuels," https://www.ft.com/content/45a9b82e-df73-11e9-9743-db5a370481bc
131 A. Rempel, "An Unsettled 'Stranded Asset Debt'? Proposing a Supply-Side Counterpart to the 'Climate Debt' in a Bid to Guide a Just Transition from Fossil Fuels in South Africa and Beyond," Antipode, September 2022, https://doi.org/10.1111/anti.12868
132 Shell International Finance B.V., "Multi-currency debt securities programme," 2022, p. 11.
133 G. Ferns, K. Amaeshi, and A. Lambert, "Drilling their Own Graves: How the European Oil and Gas Supermajors Avoid Sustainability Tensions through Mythmaking," Journal of Business Ethics, 158, 2019, pp. 201-31, https://doi.org/10.1007/s10551-017-3733-x

Diversifying into green activities

Under the second scenario, the future looks radically different. Shell would accept the verdict of the court in The Hague and stop investing in oil and gas production. The rate of decline without maintenance reinvestment would equal 5 per cent annually, which would almost cut the production of fossil fuels and emissions in line with the 45 per cent the court ordered. To be sure, such a reversal of current trends would have major effects on cash flows. On the one hand, capital investments could be redirected on a much larger scale to green assets. On the other hand, sales and profits earned on green assets will need to increase rapidly to offset declining fossil fuel revenues. This transformation would require a radical overhaul of the current energy transition strategy and would impact the size and composition of Shell's workforce and operational geography.

In response to the company's current energy transition strategy (not aligned to 1.5°C), many of Shell's top executives quit and voiced concern that this plan would amount to "rearranging the deckchairs" and stated that "part of the frustration is that you see the potential, but the mindset isn't there among senior leaders for anything radical."[134] The executives who left the company included the head of the solar, storage, and onshore wind businesses and the leader of the energy transition strategy team. This rare show of dissent shows that there is sympathy among some of the staff to move in a different direction, make other choices, and accelerate the transition towards renewable energy.

The world of renewable energy, however, is very different from the carbon-based energy system in which oil companies matured. It is unclear how much Shell could leverage its past as one of the largest energy suppliers and engineering powerhouses, including designing and operating offshore structures, in this new environment. There are many risks and unknown unknowns, as different upstream renewable energy technologies, models for distribution and market-making, and corresponding network externalities are competing in an environment marked by constant flux. All the crucial parameters remain unclear, ranging from suitable corporate models, market structures, regulatory frameworks, distributions of value along segments of the value chain, and growth rates of supply and demand to renewable energy sources and technologies. Such dynamic environments challenge long-term strategic planning and the mitigation of risk.

What makes such an emerging environment even more daunting for oil and gas companies is that other corporate players are already making inroads into renewable energy on a larger scale. The list of potential challengers includes Amazon and Alphabet (Google), whose sales, financial reserves, and capital investment dwarf those of the largest oil and gas companies.[135] Indeed, Big Tech has been growing its portfolio of renewable energy production much faster than its Big Oil counterparts.[136]

134 A. Raval and L. Hook, "Shell executives quit amid discord over green push: Several clean energy leaders leave company with only weeks before strategy announcement," Financial Times, December 8, 2020, https://www.ft.com/content/053663f1-0320-4b83-be31-fefbc49b0efc

135 SOMO, The financialisation of Big Tech, 2020, https://www.somo.nl/wp-content/uploads/2020/12/Engineering_Financial-BigTech.pdf

136 IEA, "5 ways Big Tech could have big impacts on clean energy transitions," March 2021, https://www.iea.org/commentaries/5-ways-big-tech-could-have-big-impacts-on-clean-energy-transitions

What compounds this situation from the perspective of the latter is that Big Tech threatens Big Oil not only with regard to its physical infrastructure, but more importantly with respect to intangible assets such as data, intellectual property, and artificial intelligence (AI).[137] These intangible assets may well become central to future market structures and operating modes of renewable energy, promising to help match the supply of, and the demand for, highly fluctuating energy from wind or solar farms.[138] The rise of climate tech (such as DeepMind AI technology from Google)[139] complicates future predictions, but probably means that early adapters will strengthen their ability to influence the course of developments. The sooner oil and gas companies start to diversify into this brave new world of renewable energy, the larger their influence will likely be on future developments.

Addressing the impunity gap: a just transition

From a climate justice and human rights perspective, the energy transition is not simply a matter of rearranging the energy portfolio deckchairs on major fossil fuel companies' balance sheets.[140] Rather, the climate emergency the world is facing exposes different layers of injustice.[141] The global history of GHG emissions that has grown since the emergence of industrial capitalism is highly concentrated in the Global North, resulting in a climate debt from the Global North towards the Global South. Most recently, this fundamental issue was widely acknowledged with the agreement creating a 'loss and damage' fund at COP27.[142]

Not only are early industrialisers responsible for the largest share of accumulated global GHG emissions, the current per capita consumption of the global carbon budget also remains heavily skewed towards high-income OECD countries. The minerals (including copper, lithium, and cobalt) that will be indispensable to forge a green future, on the other hand, are largely situated in the Global South.[143] Meanwhile, the intangible assets – that is, technology and intellectual property – and the financial resources required to become a dominant player in this emerging economic sphere are concentrated in the Global North.[144] These historically grown spatial inequalities will likely reproduce existing imbalances in the future, characterised by a lack of economic and climate justice. Short of systemic change, they do not permit a green transition generating inclusive development of the Global South.

137 BCG, How AI Can Be a Powerful Tool in the Fight Against Climate Change, 2022, https://web-assets.bcg.com/ff/d7/90b70d9f405fa2b67c8498ed39f3/ai-for-the-planet-bcg-report-july-2022.pdf

138 K. Sennaar, "Artificial Intelligence for Energy Efficiency and Renewable Energy – 6 Current Applications," EMERJ, July 2019, https://emerj.com/ai-sector-overviews/artificial-intelligence-for-energy-efficiency-and-renewable-energy/

139 DeepMind and Google, "Machine learning can boost the value of wind energy," February 2019, https://blog.google/technology/ai/machine-learning-can-boost-value-wind-energy/

140 A. Rempel and J. Gupta, "Equitable, effective, and feasible approaches for a prospective fossil fuel transition," Wiley Interdisciplinary Reviews: Climate Change, 13(2), 2022, https://doi.org/10.1002/wcc.756

141 P. Bond, "Climate debt owed to Africa: What to demand and how to collect?" African Journal of Science, Technology, Innovation and Development, 2(1), 2010, pp. 1-29, https://hdl.handle.net/10520/EJC10528

142 F. Harvey, N. Lakhani, O. Milman, and A. Morton, "COP27 agrees historic 'loss and damage' fund for climate impact in developing countries," Guardian, November 20, 2022, https://www.theguardian.com/environment/2022/nov/20/cop27-agrees-to-historic-loss-and-damage-fund-to-compensate-developing-countries-for-climate-impacts

143 J. Nem Singh, "The Challenge of Securing Access to Minerals for the Green Transition", NewSecurityBeat, 2021, https://www.newsecuritybeat.org/2021/11/challenge-securing-access-minerals-green-transition/

144 S. Weko and A. Goldthau, "Bridging the low-carbon technology gap? Assessing energy initiatives for the Global South," Energy Policy, 169, 2022, https://doi.org/10.1016/j.enpol.2022.113192

Therefore, from a climate justice perspective it is not simply a question of whether Shell will reallocate its capital investments from fossil fuels to renewable energy, as explored in section 4.2. The question is whether Shell and other oil and gas giants are going to operate within certain ecological limits that respect human rights in the broad sense while also accounting for historic climate debt. This touches on both dis-investing and abandoning fossil fuel production and distribution sites, as well as the mining of the minerals that a green transition requires. Fundamentally, this requires internalising costs incurred in the past, in particular when it comes to taking responsibility for the stranded workforce, and in the future, the mining of minerals.

The shift from externalising costs (the primary cause of the climate crisis) to internalising costs will fundamentally transform the distribution of cash flows within corporations such as Shell, simply by increasing costs and leaving fewer funds to be distributed to shareholders. The adverse financial impact of stranded assets may also be larger in a just transition as a result of internalising the costs of decommissioning existing production sites, instead of divesting (selling off) assets and externalising the costs. Prioritising shareholders in its current fashion, which has consumed 82 per cent of Shell's net income over the past 12 years (see section 2.3), may not be compatible with a business strategy that aims to achieve and grow a *just* transition paying living wages to its workers across the value chain, honouring fair tax obligations, and operating within planetary limits that respect human rights.

However, the high payouts do show that there are sufficient financial resources available to pay a fair share. Going back to the green transition trilemma, this means that an *unjust* green transition would combine maximising shareholder returns with a green transition at the cost of reproducing the dynamics that created the climate crisis in the first place, namely by profiting from externalising real costs.

A just transition therefore requires addressing a governance gap on three fronts. First, the *production* gap in order to force the global economy to operate within planetary boundaries. Second, the *investment* gap to provide funding for an alternative energy system that can operate without the use of fossil fuels. And third, the *impunity* gap to ensure that both states and corporations take responsibility for avoiding human rights abuses and operating within a democratic and inclusive set of ethical principles rooted in social justice.

5. Conclusion and recommendations

The window to impose an effective rule-based decarbonisation regime and to limit global warming to 1.5°C is closing fast. Climate science is pointing at the production gap that remains wide open. Emissions are not declining in line with the necessary reductions required to stay within the limits imposed by the carbon budget. The longer it takes to close the production gap, the steeper reductions will have to be in future. This will make limiting emissions increasingly painful and difficult to achieve. The political costs are set to increase as governments postpone imposing rules and seek to muddle through.

Oil majors, such as Shell, are central actors in the overall planetary adjustment from a carbon-based economy to a renewable-energy-powered global economy. These large oil and gas companies are not passive rule takers but have a considerable degree of structural power that enables them to influence decision-making and public opinion. Shell and other fossil fuel companies have known for many decades that their profitable business model revolving around extracting, selling, and burning fossil fuels while externalising the costs was causing climate change. The strategy these companies chose was to deny the science, misinform society, and delay decision-making on effective steps worldwide. Their current net zero strategies should be understood in that context, as yet another climate delay tactic. Examining Shell's financial commitments we find no indications of a genuine net zero strategy. Shell's disclaimer to investors and bondholders makes it very clear that the net zero pledge should not be mistaken for its actual business model and investment plans. In addition we find there will be considerable stranded assets in the event of effective regulation. This model is to knowingly dance on the volcano and to profit for as long as possible.

The net zero strategies, however, do involve some investments in sustainable energy. These insufficient and very limited investments are part of a hedging strategy aimed to keep options open and muddle through. However, the window to an orderly transition away from a fossil-fuel-based energy system to a renewable energy system is closing rapidly. The possibility of keeping all options open will soon come to an end and companies will be forced to pick sides. Will companies remain on the wrong side of history and delay the actions that are necessary to bring global emissions in line with the planetary carbon budget? Or will they continue on the path of climate denial and delay and produce as much natural gas and oil as possible to maximise value for their shareholders?

In this report, we have argued that Shell will face a trilemma with respect to these questions. It can achieve only a maximum of two out of three goals. The three goals Shell is aiming for can be described as:

- **Goal A** continuing to operate as an oil and gas giant profiting from consuming ever greater portions of the global carbon budget;
- **Goal B** continuing to pursue high shareholder returns; and
- **Goal C** transforming itself into a major renewable energy player.

For a just transition, Shell can achieve only one of the three goals. In addition to transforming itself from an oil and gas company into a major renewable energy player, and thereby closing the production and investment gaps, Shell would be required to address the impunity gap. The non-just transition or 'green capitalist' option would mean that Shell would divest and walk away from the historic liabilities it has accumulated. Shell would choose to maximise shareholder value instead of taking responsibility for the social and environmental damage caused by its business model of externalisation.

Moving forward, society will need clarity over the current strategies of systemically important energy corporations, such as Shell. Companies that occupy key positions in the future direction of the global energy and climate future will have to become transparent and be held accountable. Shell, just like other oil majors, has a long documented history of pursuing strategies of deception and delay. Their intentions and actual activities remain clouded by well-funded public relations strategies that include the capture of state bodies, news outlets, and public opinion. To make these systemic energy companies accountable, society will require better accounting tools geared to aiming for a climate-proof future as a starting point.

Policy recommendations

- Governments have an obligation to future generations to set up an effective rule-based decarbonisation regime that translates the Paris Agreement into clear and enforceable laws.
- This decarbonisation regime should include carbon budgets for each country and corporation.
- This should result in a transparent framework that enables states and society to assess whether companies and countries are on track to meet their legal obligations to remain within their carbon budget.
- This framework should include the obligation to have five-year targets for absolute reductions in all (Scope 1, 2, and 3) GHG emissions, with annual reviews to inform stakeholders of the direction each company and country is heading.

- Shell should start to publish granular data on its RES investments, clearly distinguishing green from brown categories, enabling society and investors to assess the direction the company is taking.
- Auditors should examine and publish the likely impact of effective regulation safeguarding the carbon budget associated with a 1.5°C world. This should result in an impairment assessment detailing how the existing capital stock and future cash flows of Shell are likely to be affected under different scenarios
- Auditing for a 1.5°C world should include estimates for decommissioning oil and gas assets, including costs associated with social plans for the stranded labour and environmental damage. These costs will inform investors and society of the price a just transition will have.

Methodological annex

This annex provides background to the discussion of stranded assets in Chapter 3 and will consider the methods and sources used to estimate the stranded assets on Shell's balance sheet. The overall method entails a combination of different variables, each with their own methodology, assumptions, and data. These are all separate steps that in the end come together in a particular formula that estimates the monetary value of the stranded assets on the balance sheet of a particular company for particular prices and carbon budgets.

The annex starts by discussing the different emissions of different types of fossil fuel (section A). Section B provides details of how the different scenarios we use in the report were calculated. Section C shows the estimates of the IEA relating to the future global energy mix and how these impact the size of stranded assets. Section D discusses the assumptions used to estimate fossil fuel price ranges in the future. Section E provides details about the size of Shell's oil and gas reserves. Section F brings all elements together in a single equation.

A. Carbon factor equivalence

All the carbon factor equivalence coefficients for emissions of CO2 and other GHGs from different studies originally came from the Guidelines for National Inventories of Greenhouse Gases published by the Intergovernmental Panel on Climate Change (IPCC, 2006).[145]

The IPCC Guidelines indicate that there is a basic level of analysis (tier 1) and other more complex levels (tier 2 and others) where new variables enter, such as the specific emission factor per country for each category of origin of combustion and type of fuel for each GHG, the technology of combustion, operating conditions, control technology, quality of maintenance, and the age of the equipment used in fuel burning.

To obtain tier 1 emissions, fuel consumption must be multiplied by its emission factor:

$$Emission_{GHG,Fuel} = Fuel\ consumption_{Fuel} * Emission\ factor_{GHG,Fuel}$$

145 IPCC, Guidelines for National Greenhouse Gas Inventories, 2006, p. 19.

In the case of fossil fuel input, it is important to correctly differentiate between different types of fossil fuel reserves, each with a different CO2 footprint. In our calculations, we distinguish between crude oil and natural gas type of proven reserves for Shell to properly assess the stranded assets for each variety of fossil fuel. The different GHG emissions are then translated into a single CO2 equivalent (Table A).

Table A. Carbon factor equivalence for different fuel types in CO_2-equivalent units[146]

Fuel	Amount of fuel	CO2 emission factor
Natural gas	Trillion of cubic metres	1.88496
Crude oil	Thousand million barrels (bbl)	0.394370243
Anthracite	Millions of metric tons (t)	0.00262461
Sub-bituminous coal	Millions of metric tons (t)	0.00181629

B. Carbon budget scenarios

Scenario 1: 2°C (original from Carbon Tracker)

The first scenario is based on the carbon budget presented in the report *Unburnable Carbon: Are the world's financial markets carrying a carbon bubble?* (CTI, 2011),[147] which shows that with an 80% probability of not exceeding 2°C above pre-industrial levels, the cumulative emission of CO2 for the first half of the 21st century without taking into account other GHGs must be 886 GtCO2. This carbon budget was obtained from a paper prepared by academics at the Potsdam Climate Institute and published in the journal *Nature Geoscience* (Meinshausen et al., 2009),[148] where the authors use the MAGICC 6.0 software and a reduced-complexity-coupled-carbon-climate-cycle model.

This carbon budget also counts the cumulative emissions for the first 10 years of the 21st century since the publication in *Nature Geoscience*, which was estimated at 282 GtCO2 from fossil fuel emissions and 39 GtCO2 from land use (Friedlingstein et al., 2010).[149] For our own calculation, we start with CTI (2011) data, subtract emissions between 2011 and 2020 from BP (2022),[150] and obtain the remaining carbon budget for 2021–2050 of 193.8 GtCO2.

Scenario 2: 1.5°C (83% success rate)

The second scenario considers the carbon budget from the document Part 1: *Royal Dutch Shell GHG emissions* (GCI, 2021),[151] which reports Shell's strategy for the climate transition to 2050. In the case of probability of success and the remaining carbon budget, the document uses the 2021 IPCC study where a carbon budget of 300

146 Source: author's elaboration based on ibid., p. 19.
147 CTI, Unburnable Carbon: Are the World's Financial Markets Carrying a Carbon Bubble?, 2011.
148 Meinshausen, Meinshausen, Hare, et al., "Greenhouse-gas emission targets for limiting global warming to 2°C".
149 Friedlingstein, Houghton, Marland, et al., "Update on CO2 emissions".
150 BP, Statistical Review of World Energy 2022, data workbook.
151 GCI, Part 1: Royal Dutch Shell GHG emissions, 2021.

GtCO2 was measured with a probability of not exceeding 1.5°C equal to 83% from 2020 onwards. We update the remaining budget by discounting the 2020 emissions from BP (2022)[152] and obtain a 266 GtCO2 budget.

Scenario 3: 1.5°C (50% success rate)

This scenario is built based on the IEA (2021) special report Net Zero by 2050. *A Roadmap for the Global Energy Sector*.[153] It presents a carbon budget in line with the net zero emission goals for 2050 and a not exceeding 50% probability of not exceeding a temperature of 1.5°C above pre-industrial levels. It also announces that its emissions peak should have been in 2020 and that its success depends on even stronger decarbonisation commitments. The presented budget covers from 2020 to 2050 and is around 500 GtCO2, of which 460 GtCO2 would correspond to emissions related to energy and industrial processes, and the remaining 40 GtCO2 would be due to emissions from land use. In addition, this is consistent with the carbon budget presented in the special report *Global Warming* of 1.5°C (IPCC, 2018).[154] By deducting 2020 emissions from BP (2022),[155] we obtain an updated budget of 467.7 GtCO2.

Scenario 4: IEA 450 (2°C, 50% success rate)

The fourth scenario is based on the publication *The $2 trillion stranded assets danger zone* (CTI, 2015),[156] which uses the *World Energy Outlook* (IEA, 2014)[157] to estimate a GHG emissions trajectory consistent with GHG stabilisation in the atmosphere with the objective of reaching 450 ppm (parts per million) of CO2 equivalent and complying with containment of the temperature at no more than 2°C above pre-industrial levels with a probability of 50%.

According to the IEA, the reduction in emissions will be the product of stronger government policy including a set of measures that together will not jeopardise economic growth. These measures include energy efficiency, limits on the use and construction of coal-fired power plants, minimising upstream methane emissions in the oil and gas industry, and accelerating the removal of subsidies for fossil fuel consumption. Moreover, energy-related CO2 emissions should have peaked at 33 GtCO2 in 2020, then falling to 25.4 GtCO2 in 2030 and 19.3 GtCO2 in 2040. For the carbon budget, we consider CTI extended the emissions path from 2015 to 2050 of 820 GtCO2, and from this point we deduct emissions between 2015 and 2020 from BP (2022)[158] and obtain a carbon budget of 618.7 GtCO2 for the years 2021–2050.

Scenario 5: 2°C (80% success rate)

This scenario is based on the publication Unburnable Carbon 2013: Wasted capital and stranded assets (CTI, 2013),[159] which considers the carbon budget between 2013 and 2050 from the study by Meinshausen et al. (2009),[160] but adding some alternative assumptions such as "a higher level of aerosols in the atmosphere that offset part of

152 BP, Statistical Review of World Energy 2022, data workbook.
153 IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, 2021.
154 IPCC, Summary for Policymakers [Global Warming of 1.5°C].
155 BP, Statistical Review of World Energy 2022, data workbook.
156 CTI, The $2 trillion stranded assets danger zone: How fossil fuel firms risk destroying investor returns.
157 IEA, World Energy Outlook 2014.
158 BP, Statistical Review of World Energy 2022, data workbook.
159 CTI, Unburnable Carbon 2013: Wasted capital and stranded assets.
160 Meinshausen, Meinshausen, Hare, et al., "Greenhouse-gas emission targets for limiting global warming to 2°C".

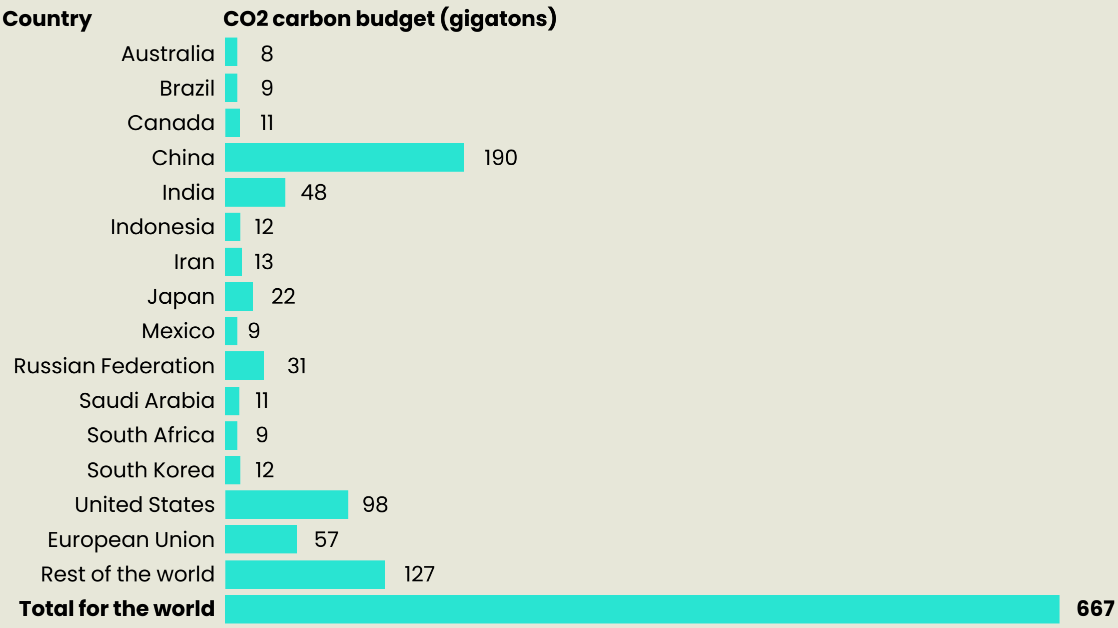
the warming effect of GHGs, and greater reductions in GHGs that are not CO2" (CTI, 2013, p. 10).[161] In this case, the methodological approach reveals that the carbon budget compatible with temperature stabilisation below 2°C by 2050 with a 50% chance of success is 1075 GtCO2. We update this budget by discounting the emissions between 2013 and 2020 from BP (2022),[162] and obtain a carbon budget between 2021 and 2050 of 632.5 GtCO2.

Scenario 6: De jure (Paris Agreements)

This scenario was estimated by the authors. We add the national commitments to future CO2 emissions declared in the Paris Agreements plus COP26 new commitments.[163] These commitments consist of the emission reductions declared in the Nationally Determined Contributions (NDCs), and ratified at COP26 of 2021, of the 15 countries that emit the most CO2 (taking the European Union as a country). The emissions commitments to 2030 of all countries were taken whenever the year of net zero emissions indicated would be, with the exception of Iran, Australia, and Mexico (they do not declare any specific commitments).

For this group of countries, the following assumptions were made: Iran will keep pace with CO2 reductions in a linear fashion; Mexico will also reduce its emissions, and its 2050 commitment was taken into account; and Australia was forced to reach net zero emissions.[164] For emerging countries, in 2050 CO2 emissions by the 15 largest-emitting countries would add 8.8 GtCO2 per year, reaching net zero in 2070. The accumulated amount between 2021 and 2050 reaches 667 GtCO2 (Table B).

Table B. Remaining carbon budget for scenario 6: De jure (Paris Agreement plus COP26)



161 CTI, "Unburnable Carbon 2013: Wasted capital and stranded assets, p. 10
162 BP, Statistical Review of World Energy 2022, data workbook.
163 Climate Action Tracker, Country overview dataset, 2022, https://climateactiontracker.org/countries/
164 Ibid.

Scenario 7: 2°C (80% success rate using carbon capture)

This scenario is identical to scenario 6, but includes the estimated CO2 absorption that would come from the development of carbon capture and storage technology (IEA, 2021).[165] This increases the carbon budget by 125 GtCO2 between 2015 and 2050, resulting in a 2021–2050 carbon budget of 757.5 GtCO2.

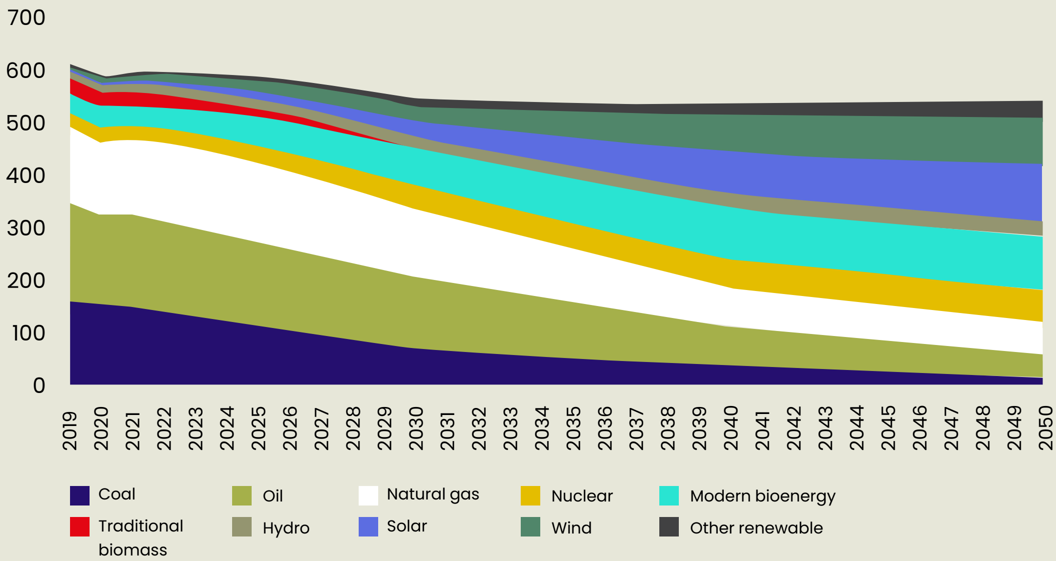
C. 2050 energy supply assumptions

In the stranded assets calculation it is important to assume a path for society's compliance with the velocity of the energy transition, especially for future renewable energy supply and demand. In the calculation, the different paths directly affect the carbon budget distribution between each type of fossil fuel reserves. The calculation indicates that the remaining carbon budget should be 'escalated' by the 2050 supply assumptions.

For example, according to the IEA, the current world energy supply of fossil fuels originated as 13% from natural gas, 21% from crude oil, and 66% from coal. If this current distribution remains, the world carbon budget would consist of 13% natural gas, 21% crude oil, and 66% coal.

In this sense, for example, the higher the commitment to energy transition goals, the larger the stranded asset of coal reserves would be in relation to natural gas reserves. But this would not remain the case in the future. In our calculations, we follow the IEA (2021) 2050 net zero scenario (see Figure A).[166] This IEA scenario projects that the energy supply from fossil sources will have originated as 51% from natural gas (11% of the total energy supply), 35% from crude and shale oil (8% of the total energy supply), and 14% from coal (3% of the total energy supply). Then, 51% of the world carbon budget would be 51% for gas, 35% for oil, and 14% for coal.

Figure A. The projected composition of the global energy supply in the IEA Net Zero scenario in exajoule, 2019–2050.[167]



165 IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector.
166 IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, 2021.
167 IEA, Net Zero by 2050 Data Explorer, 2021, https://www.iea.org/data-and-statistics/data-tools/net-zero-by-2050-data-explorer

D. Money value of stranded assets

In order to estimate the money value of stranded assets, we need to multiply the amount of unburnable fossil fuel reserves by a price. With regard to the simplicity of this, some methodological aspects are relevant.

Considering commodity market shocks and structural energy transition impacts, the price of gas and oil could be very heterogeneous in the future. Because of this, calculation of the money value of stranded assets is very sensitive to price: the higher (lower) the price, the higher (lower) the money value of stranded assets.

The assumptions made relating to the future price of oil and gas are very important. In our calculation, we consider three different scenarios – high, medium, and low energy prices – in order to have a range of money value for stranded assets.

In the high price scenario, we assumed US$ 10 per thousand cubic feet for natural gas and US$ 100 per crude oil barrel. As medium prices, we assumed US$ 5.3 per thousand cubic feet for gas and US$ 42 per crude oil barrel. In the low price scenario, we assumed US$ 2.1 per thousand cubic feet for gas and US$ 10.9 per crude oil barrel. All the ranges are based on maximum, mean, and minimum spot price for the last 25 years.[168]

E. Shell's proven oil and gas reserves

Table C. Summary of proved oil and gas reserves of Shell (including subsidiaries and share of joint ventures and associates) at 31 December 2021 and the world[169]

	Crude oil and natural gas liquids (million barrels)	Natural gas (thousand million standard cubic feet) [a]	Total (million barrels oil equivalent) [b]
Total proved developed and undeveloped			
Europe	214	3.303	783
Asia	1.738	13.133	4.002
Oceania	80	5.380	1.008
Africa	265	2.016	612
North America			
USA	610	615	716
Canada	538	1.539	805
South America	1.136	1.758	1.439
Total Shell[170]	**4.581**	**27.744**	**9.364**
Total World[171]	**1.732.366**	**6.415.212**	**2.838.437**
% shell of world reserves	0,3%	0,4%	0,3%

[a] Cubic metres (m3) converted to scf using a conversion factor of 34.11.
[b] Natural gas volumes are converted into oil equivalent using a factor of 5,800 standard cubic feet (scf) per barrel.

168 Oil and natural gas prices from: US EIA, "Data: petroleum & other liquids"; "Data natural gas".
169 Source: authors' elaboration based on Shell 20-F filings with US SEC and on BP, Statistical Review of World Energy 2022, data workbook.
170 RDS, "Shell files Form 20-F with SEC".
171 BP, Statistical Review of World Energy 2022, data workbook.

F. All-in-one equation

We can now present in a single equation how the different variables relate to estimate the money value of stranded assets:

$$\$\ SA_{i,j,s} = (CO2\ Budget_{i,j,s} - CO2\ Emission_{j}) * \frac{1}{CO2\ to\ Fuel\ Unit\ Conversion_{j}}$$

$$*\$\ Fuel\ Price_{j,p}$$

In this formula, i = type of company, ‘j’ = type of fossil fuel reserve, ‘s’ = CO2 scenario, and ‘p’ = price scenario.

Given ‘i’ type of company, ‘j’ the variety of fossil fuel reserve, and ‘s’ a selected CO2 budget scenario, we can insert Shell’s or another company’s fossil fuel reserve assets in order to obtain the CO2 emissions (section A of this annex). Then we subtract these values from the company’s CO2 budget (sections B and C of the annex). At this point, we would have resolved the first pair of parentheses in the formula, with the magnitude of stranded assets stated in units of CO2 equivalent.

The next step would be to reconvert this CO2 equivalent value to its fuel-of-origin unit by dividing the result by the inverse of the CO2 fuel unit conversion for each type of reserve (section A of the annex). Here we would have the stranded asset values quantitatively in barrels of oil, m3 of gas, and tons of coal. Finally, we need to multiply each quantity of fuel by a price to obtain the money value of each stranded asset (section D of the annex). Each price scenario would give a different stranded assets monetary value.

The main steps of this calculation do not deviate from the standard methodology used by CTI and the IEA. The differences are in the assumptions related to the CO2 budget, future fuel prices, and company-level information. In the case of the company, It is important to have separate figures for each company’s oil, natural gas, and coal reserves in order to calculate its emissions properly.

172 CTI, Unburnable Carbon: Are the World’s Financial Markets Carrying a Carbon Bubble?; CTI, Unburnable Carbon 2013: Wasted capital and stranded assets; CTI, The $2 trillion stranded assets danger zone: How fossil fuel firms risk destroying investor returns.

173 IEA, World Energy Outlook 2014.

Colophon

Stranded: Why Shell is unable to navigate the just transition trilemma

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Authors: Rodrigo Fernandez, SOMO, Netherlands
Tobias J. Klinge, KU Eichstätt-Ingolstadt, Germany
Nicolás Hernan Zeolla and Rodrigo Contreras Ramírez, Foundation for Research on Economic Development (FIDE), Argentina.
Laura Deruytter, KU Leuven, Belgium
Editor: Miles Litvinoff
Design: Karen Paalman
Cover image: Richard Harvey, Flickr

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KNSM-laan 17
1019 LA Amsterdam
The Netherlands
Tel: + 31 (20) 6391291
Email: info@somo.nl
Website: www.somo.nl