WORLD GOLD COUNCIL

Gold and climate change:
The energy transition

About the World Gold Council

The World Gold Council is the market development organisation for the gold industry. Our purpose is to stimulate and sustain demand for gold, provide industry leadership, and be the global authority on the gold market.

We develop gold-backed solutions, services and products, based on authoritative market insight, and we work with a range of partners to put our ideas into action. As a result, we create structural shifts in demand for gold across key market sectors. We provide insights into the international gold markets, helping people to understand the wealth preservation qualities of gold and its role in meeting the social and environmental needs of society.

Based in the UK, with operations in India, China, Singapore and the USA, the World Gold Council is an association whose members comprise the world's leading gold mining companies.

Wood Mackenzie
A Verisk Business

About Wood Mackenzie

Wood Mackenzie, a Verisk Analytics business, is a global leader in commercial intelligence for the natural resources sector, empowering clients to make better strategic decisions with objective analysis and advice on assets, companies and markets. Its metals and mining experts provide accurate industry analysis, as well as expert insights and advice to inform rapid, meaningful decision-making.

For more information

John Mulligan
john.mulligan@gold.org
+44 20 7826 4768

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Executive summary

To mitigate the potentially catastrophic impacts from climate change, the world needs to urgently reduce the amount of CO_2e emitted into the atmosphere. The global economy needs to reduce its emissions to net zero by 2050, in line with the Paris Agreement.[1] This requires all industries to rapidly reduce their dependency on energy derived from fossil fuels.

Climate-conscious investment groups have been particularly vocal in calling for more clarity from all sectors regarding their detailed plans to contribute to emissions reduction and climate stability. This research therefore seeks to provide those investors, their advisors, and wider stakeholder groups, with information on the range of opportunities open to gold mining companies in seeking to decarbonise their energy sources, while further clarifying the potential pathway for the industry to a net-zero carbon future.

The World Gold Council has previously identified that the source of most of the greenhouse gas (GHG) emissions[2] from the gold sector are related to gold mining operations. We estimate around 95% of those emissions are associated with purchased power or fuel combustion. Of this, electricity represents the largest source of emissions at the mine site. The ability for the gold industry to demonstrate its capacity to contribute to emissions reduction aligned to Paris targets is therefore largely dependent on its ability to change how it sources and uses power and fuels.

In our previous research,[3] we outlined a potentially accessible and cost-effective pathway for gold mining to meet climate targets; in this new analysis we have sought to examine in more detail a key part of that pathway – the decarbonisation of power, the largest source of gold sector emissions. This research evaluates the changing energy landscape in key gold mining jurisdictions and the impact and potential longer-term implications of gold mining's transition actions and plans, and what additional actions might be needed to allow the sector to reduce its emissions at a scale and speed sufficient to achieve the 'well below' 2°C or 1.5°C climate targets.

Given our previous analysis of gold mining's potential pathway to net-zero, and recognising the importance of changes over the next decade, we have evaluated power emissions[4] improvements against 27% and 46% reduction targets for the year 2030, which would put the sector roughly on track to meet the 2050 targets – 'well below' 2°C and 1.5°C, respectively.

Specifically, we have examined:

- Gold mining's current power consumption and associated emissions profile, including regional/national factors
- Gold mining companies' plans to implement lower carbon power solutions and their emissions impacts
- Scenarios of the impacts of different actions (shifts in power sources) on gold mining's ability to meet the Paris climate targets
- Changes in the wider energy landscape that will support gold mining's transition

Working in collaboration with energy and mining specialists at Wood Mackenzie, we based our observations on an examination of the power consumption of 158 mines located in 31 countries and owned by 31 major gold mining companies. These companies represent around 55%[5] of annual global large-scale, industrialised gold production.

All key data and primary analysis was provided by Wood Mackenzie.

1 "The Paris Agreement…for the first time brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort….The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius." https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

2 References to 'GHG', 'CO_2' and 'carbon' emissions all refer to CO_2e or 'carbon dioxide equivalent' - a unit of measurement of greenhouse gases that allows the different gases to be compared on a like-for-like basis relative to one unit of CO_2.

3 *Gold and climate change: An introduction,* World Gold Council, 2018; *Gold and climate change: Current and future impacts,* World Gold Council, 2019.

4 The term 'power emissions' refers to the GHG emissions associated with the generation and consumption of electricity.

5 55% of annual *attributable* LSM gold production.

Key findings

- Based on the current status and known plans of the gold mining industry, the emissions intensity of power used in gold production is estimated to fall by 35% by 2030.[6] This fall is based on the actions and plans of gold mining companies to replace direct site-generated electricity from diesel, heavy fuel oil (HFO) and coal with grid connectivity and the increased use of renewable energy sources (RES), alongside substantially reduced production from high emission sites. The combined impacts of these changes should enable a reduction in industry power emissions that is clearly aligned with the 'well below' 2°C climate target.

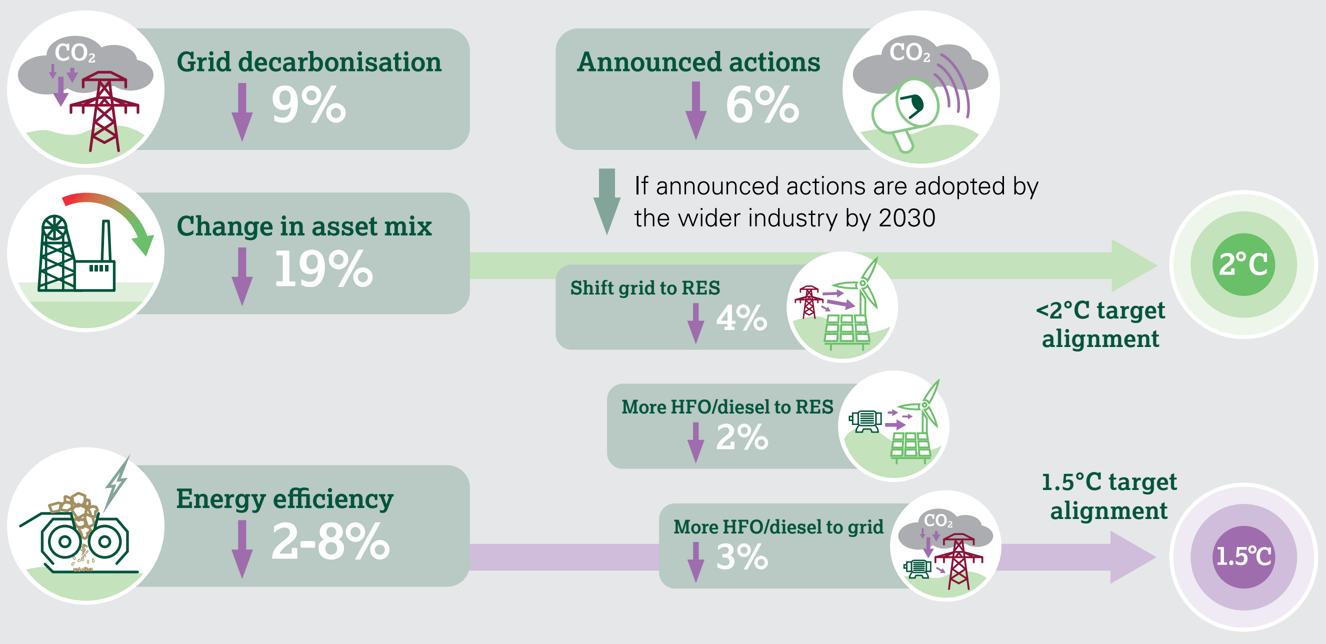
- The recently announced plans by a number of gold mining companies at the forefront of the energy transition to shift towards renewables[7] represent an industry in the early stages of change. The proposed shifts will only make a meaningful impact on sectoral emissions if the wider industry adopts similar plans. If current plans to transition to lower carbon power become commonplace over the next decade, we estimate that the shift in power mix could potentially reduce the emissions intensity of the power used in gold production by a further 9% by 2030. This, combined with the above changes, should place the 1.5°C target within reach.

- Accelerating and expanding these actions – to replace a substantial amount of power from fossil fuels – will make achievement of Paris-aligned climate targets, including 1.5°C, feasible. We have estimated the different combinations of actions that might contribute to target alignment; the replacement of mine-site generation of fossil fuel-based electricity and the increasing the role of renewables to supplement or replace grid-connectivity offer the most immediate opportunities for emissions reduction.

- The growing decarbonisation of grid-sourced electricity, continued improvement in the economics and practicality of renewables, alongside enhanced energy and operational efficiency, will support the sector's ongoing transition. They will likely be crucial if the 1.5°C climate target is to be met.

- Local and national factors will continue to play an important role, not least given the very different power options available to miners in particular locations and the constraints imposed by the policy environment that governs the use of power sources in some jurisdictions.

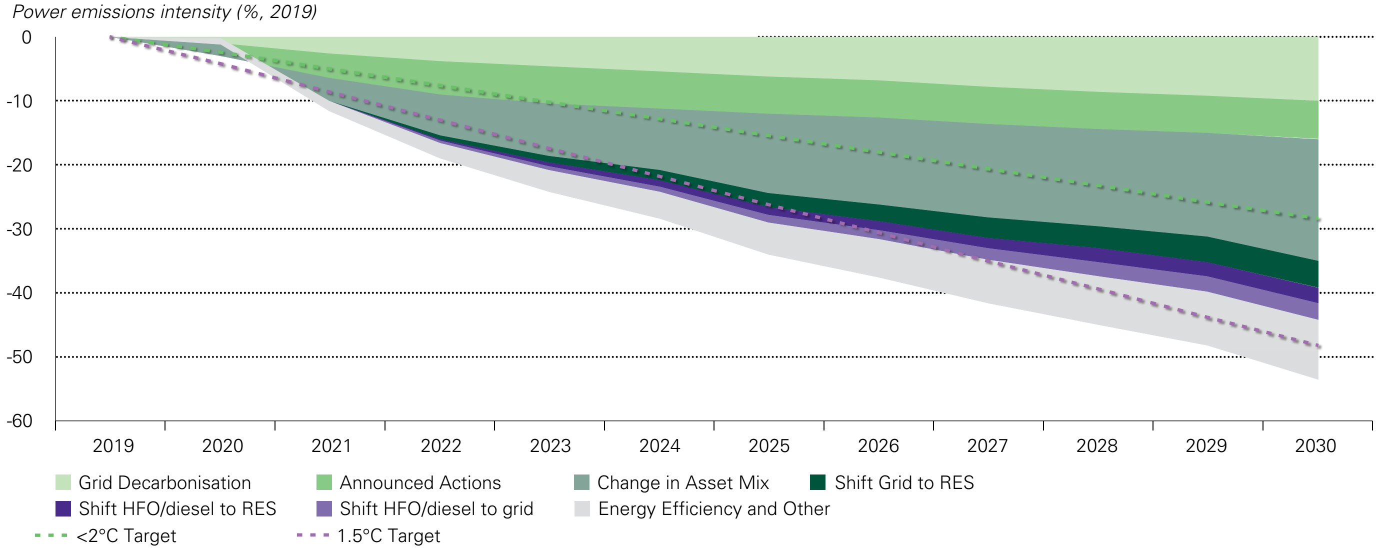
Estimates of potential reductions in gold mining's power emissions by 2030



6 Reductions in the overall emissions intensity of gold production will require commensurate falls in emissions from industry sources other than electricity consumption if climate targets are to be met. But the significance and scale of power emissions, and the near-term opportunities for their reduction, mean the assumption of corresponding, possibly later, reductions from other sources is not unreasonable.

7 'Renewables' here refers to renewable energy sources, primarily in the form of either solar, wind or hydro power.

Changes in gold mining power emissions and projected impacts on climate target alignment



Source: Wood Mackenzie

Next steps

This analysis was based on an examination of gold mining emissions from the generation and consumption of electricity *(power emissions)*. This focus was due, in part, to data access and consistency factors, and although the key trends highlighted in this report are likely representative of the immediate and substantial opportunities for emissions reduction that will shape the gold mining's ability to manage its climate impacts, they aren't comprehensive. There is more to be done – and more data to be collected and analysed – if we wish to understand the whole picture.

If current plans by gold mining companies to transition to lower carbon power become commonplace over the next decade, we estimate that this, combined with the other changes we have described, should place the 1.5ºC climate target within reach.

For example, although this report makes reference to the substantial steps taken by gold mining companies to improve energy efficiency and the technologies that might facilitate further efficiency drives, it does not seek to measure their impacts. Similarly, we also touch briefly upon some of the technologies that may support or complement current renewable energy sources, a number of which will probably be vital if the uptake and impact of renewables is to be accelerated, but acknowledge that any meaningful examination of these aspects of the energy transition are beyond the scope of this study.

Measuring these factors and estimating their impacts as they might apply to gold mining (or, potentially, any other sector), with any degree of empirical rigour or certainty, is still problematic. It will require better data, and greater transparency and consistency in the reporting of activities and technologies that have emission impacts. But such work – to better quantify potential sectoral emissions reduction from energy and process efficiency and the associated application of new technologies – might be the focus of future research, particularly if the required data becomes more readily available.

Introduction

> "Tackling climate change, securing energy supplies and ensuring clean air and water for all require a transformation of the way we produce and consume energy."
>
> Energy Technology Perspectives 2020, IEA, 2020

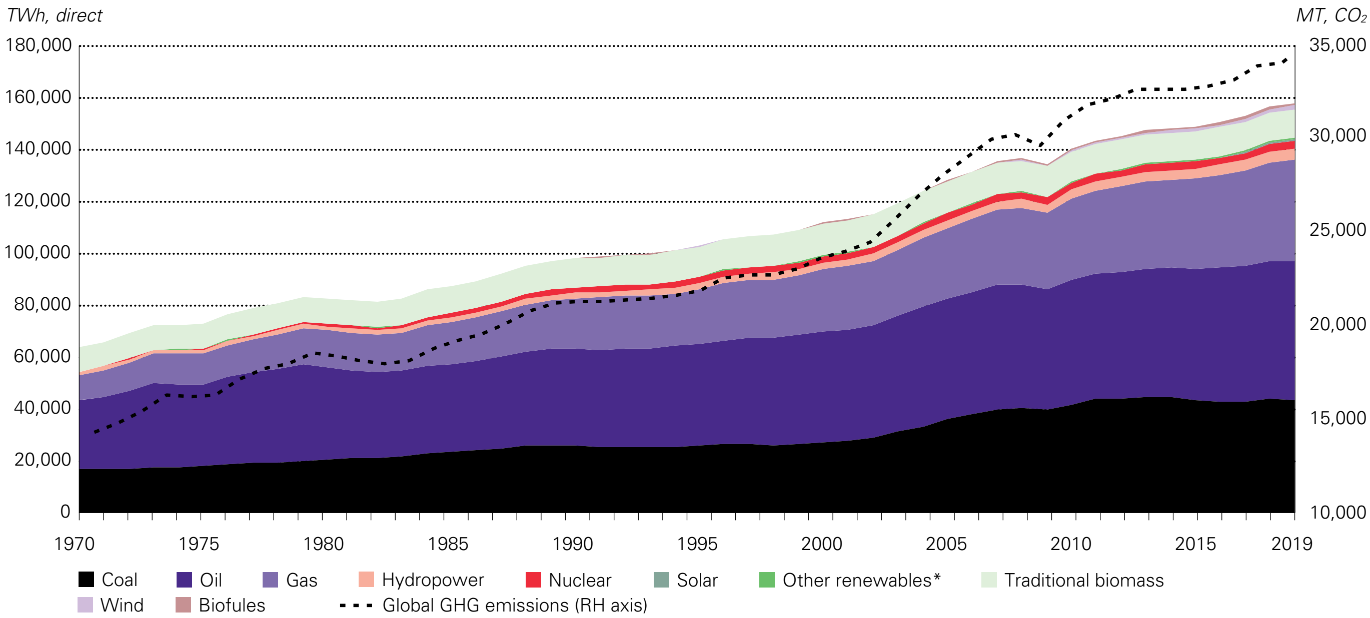
Climate change poses threats to nearly every aspect of our lives. The enormous quantities of carbon dioxide released into the atmosphere over the past century are warming global temperatures at an alarmingly rapid rate. This is causing extreme weather, flooding, wildfires, and other natural disasters that are occurring ever more frequently and with greater intensity. And the severity of these threats, which have far-reaching and potentially devastating environmental, social and economic consequences, will largely depend on how quickly we can cut greenhouse gas (GHG) emissions.

It is now widely recognised that one of the major steps needed to curb global warming is to wean the global economy off its dependency on fossil fuels. But this will not be a simple task as fossil fuels have powered economic growth since the industrial revolution and the world continues to use ever more energy each year. BloombergNEF estimate the global demand for energy with grow by 62% by 2050 (around 1.5% per year).[8]

Acknowledging the scale and urgency of this task, we have recently seen the financial sector take a lead role in seeking to drive the energy transition. This is an accelerating trend. The Institute for Energy Economics and Financial Analysis (IEEFA) recently stated that over 100 'globally significant'[9] financial institutions have now committed to divestment from coal mining and/or coal-fired power plants.

> Former Bank of England Governor Mark Carney has recently argued that how to plan for a net-zero carbon future is a "basic question" that every company's management now must be able to answer.

Chart 1: Global direct primary energy consumption and GHG emissions



*Includes geothermal, fuel cells, tidal, and others.

Source: BP Statistical Review of Global Energy 2020

8 https://about.bnef.com/new-energy-outlook/

9 IEEFA defines globally significant banks and insurers/reinsurers as those with assets under management (AUM) or loans outstanding in excess of US$10 billion; see https://ieefa.org/finance-exiting-coal/

Borden electric underground mining vehicle. Image courtesy Newmont.

The rapid change in demand for fossil fuels will likely result in a radical re-appraisal of asset valuations, with the risk that a range of fossil fuel assets and related investments become uneconomical, no longer able to yield the expected level of returns. The Bank of England has estimated that investments worth more than $20 trillion could be left stranded in this way,[10] particularly as governments set more ambitious climate targets and reposition their energy strategies.

As a consequence of these converging factors, and the rapidly improving technological performance and economics of renewable power sources, the global energy landscape is evolving rapidly. And nearly all sectors of the economy will be transformed with it.

Acknowledging this transformation, market ratings agencies and index providers are reframing their methodologies to incorporate energy transition and GHG emission factors into their performance metrics and benchmarks. This is changing how companies and assets are evaluated and selected. As former Bank of England Governor Mark Carney has recently argued, how to plan for a net-zero carbon future is a "basic question" that every company's management now must be able to answer.[11]

10 www.theguardian.com/environment/2019/apr/17/mark-carney-tells-global-banks-they-cannot-ignore-climate-change-dangers

11 www.power-technology.com/features/net-zero-strategy-is-basic-question-for-every-company-mark-carney/

Mining is a very energy-intensive industry, estimated to use up to 11% of total global energy consumption.[12] Much of this is currently through intensive use of fossil fuels to power mine sites, but the industry is now looking at ways of incorporating smarter and cleaner energy solutions into its operations. In addition to contributing to global GHG emissions reduction, miners are seeking to safeguard the reliability of energy supplies while ensuring an efficient use of capital to satisfy shareholders and investors. Fortunately, technology and economics are making the case for energy transition increasingly compelling as the cost and accessibility of cleaner energy have been improving very rapidly in recent years.

Among all metals and mined products, gold is unique in its diverse roles and functions. It is a luxury good, a financial asset and a component in industrial and technological applications; it has iconic, ceremonial, and cultural significance across nations and history; and it has helped shape the evolution of commerce, banking and monetary systems.

Looking upstream, gold mining has, historically, helped catalyse socio-economic development and is still vital to the prosperity and economic growth of many developing nations, as we have previously documented.[13]

How the gold value chain might be impacted by – and contribute to – the energy transition is therefore of very wide relevance. As with all sectors, there is now a pressing need to examine and explain how changes in gold mining's power consumption, might contribute to efforts to reduce GHG emissions in alignment with the Paris Agreement targets to keep global warming 'well below' 2°C (and preferably to no more than 1.5°C) above the pre-industrial average.

The World Gold Council has previously documented the scale of the gold industry's relatively small but not insignificant carbon footprint and mapped out a potential pathway to a net zero carbon future.[14] This is largely dependent on gold mining's ability to embrace change in how it sources and uses energy and fuels. It is estimated that around 75% of the emissions associated with gold production is related to purchased electricity or fuel combustion, with the transmission and distribution of fuels making up most of the remainder.[15] Looking at those emissions in more detail, this study focuses on the impacts from purchased and directly generated electricity – the largest source of emissions in gold mining operations and across the gold supply chain.

Specifically, this analysis aims to estimate the potential impacts of changes in gold mining's consumption and generation of electricity and how these might be reflected in the industry's potential ability to align to climate targets.

Climate-conscious investment groups have been particularly vocal in calling for more clarity from all sectors regarding their detailed plans to contribute to emissions reduction and climate stability. We therefore hope this research will provide those investors and their advisors, and wider stakeholder groups, with a firm indication of the range of opportunities open to gold mining companies in seeking to decarbonise their energy sources, while further clarifying the potential pathway for the industry as it seeks to navigate towards a net-zero carbon future.

12 https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action. It should be noted, however, that this estimate, by the World Bank, is the highest in a range of estimates that vary from 1.25% to 11% – see also https://rmi.org/wp-content/uploads/2017/07/RMI_Insight_Brief_Toward_Sustainable_Mining_2017.pdf and

13 *The social and economic impacts of gold mining,* World Gold Council, 2014

14 *Gold and climate change: An introduction,* World Gold Council, 2018; *Gold and climate change: Current and future impacts,* World Gold Council, 2019

15 See Haque, N & Norgate, T, *The greenhouse gas footprint of in-situ leaching of uranium, gold and copper in Australia,* Journal of Cleaner Production 84 (2014) 382-390; Norgate, T, Haque, N, *Using life cycle assessment to evaluate some environmental impacts of gold production,* Journal of Cleaner Production 29-30 (2012) 53-63; *Gold and climate change: Current and future impacts,* World Gold Council, 2019

Methodology, data, and definitions

Data coverage – geographic

Global gold mine production in 2019, including production from artisanal and informal sources, was estimated at roughly 3,300[16] tonnes, of which production from large-scale, industrialised mines (typically owned by listed companies) represented around 2,200 tonnes. This report primarily presents estimates for this latter source of supply (approximately 70% of the estimated annual global total), as data for the more informal, artisanal and opaque portions of the market are unreliable or unavailable.

Significant gold production volumes come from Africa, Latin America and the Caribbean, Oceania, North America and Russia and the Caspian, with smaller shares of production coming of the Middle East, Europe and Asia. While China is a major producer (the largest gold producing country in 2019), it is not covered in our data set due to lack of available and consistent data.

Data coverage – companies and mines

The base data set in this report is derived from the energy and electricity data reported by a sample consisting of 31 gold mining companies owning a total of 158 gold producing assets around the globe. In 2019, these 31 companies represented approximately 55% of 'costed' (LSM[17]) gold supply.

This report is primarily focused on the emissions impacts of the generation and consumption of electricity – power emissions – by the gold mining industry. Electricity generally represents the largest share of energy consumption and emissions for the gold sector. Thus, given the relative importance of electricity, this study focuses on its contributions to the carbon emissions intensity of gold production and analyses what is currently being done or might be done to reduce its emissions impacts.

Therefore, regarding emissions classifications, this study is wholly focused on those categories of Scope 1 and 2 emissions related to the generation and consumptions of electricity. For simplicity and consistency, often driven by data availability, we excluded some Scope 1 emissions from our analysis, such as those from fuels combusted in vehicle engines, but we acknowledge, in practice, they may represent a significant part of industry emissions.

This, and other exclusions, mean our emissions intensity estimates are lower than the total gold production emissions intensity figures reported in our previous work (see **Appendix 1: Data, definitions and methodology** for further details). But, given the difference in data sets, scope and coverage, the emissions figures are broadly consistent.

Emissions definitions and classifications

Power emissions (kt CO_2e / tonne gold) = Emissions intensity of power ($ktCO_2e$ / TJ) x Power intensity of production (TJ / tonne gold)

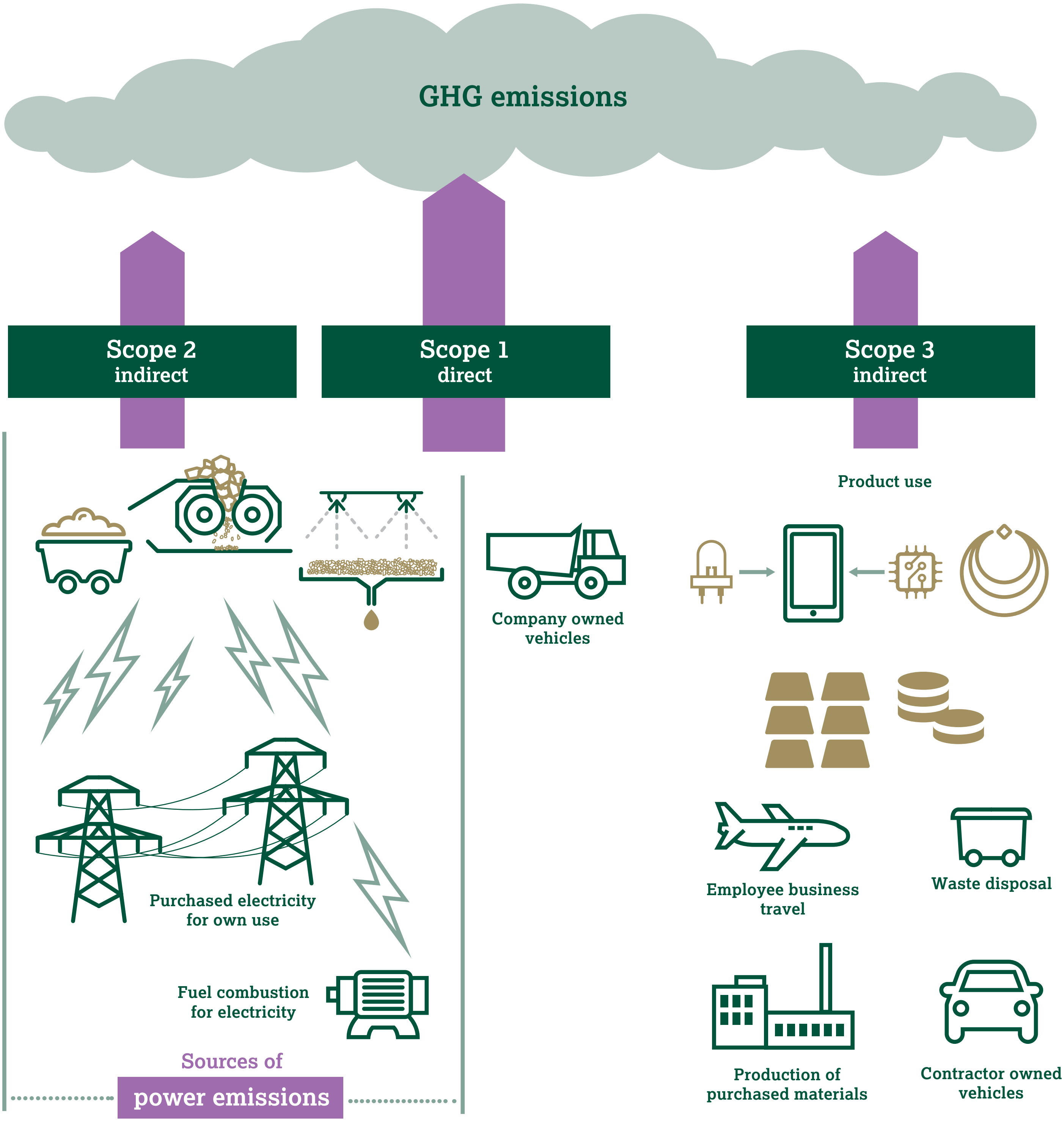
Emissions intensity of power ($ktCO_2e$ / TJ):
- Mix of power sources (%)
- Power sources emissions intensity ($ktCO_2e$ / TJ)

Power intensity of production (TJ / tonne gold):
- Power intensity of extraction and processing (TJ / tonne ore)
- Ore grade (tonne ore / tonne gold)

16 These are Wood Mackenzie's rounded estimates; WGC data suggests global gold production in 2019 was closer to 3,500 tonnes, but this largely due to an increase in artisanal production, which is beyond the scope of Wood Mackenzie's data set and this report.

17 LSM = Large-Scale Mining, referring to production from industrialised, typically exchange-listed, corporate mining companies

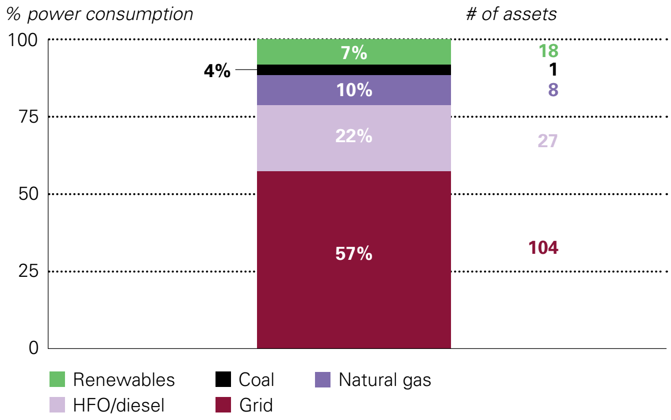
Figure 1: Gold mining 'power' emissions and other sectoral GHG emissions



1: Gold mining and power emissions

> "The world is in the midst of an energy shock that is speeding up the shift to a new order… As the public, governments and investors wake up to climate change, the clean-energy industry is gaining momentum."
>
> The Economist, *Power in the 21st century*, September 2020

Chart 2: Gold mining power sources and consumption, 2019



Source: Wood Mackenzie

The gold market has grown very substantially over recent decades. Since 2000, demand for gold has increased by around 50% in tonnage terms, while the volume of gold mine production has grown by 33% over the same period.[18]

Concurrently, however, as production volumes have increased, we have seen a gradual decline in the quality of ore bodies, and the increased geographic dispersal of projects as gold mining has moved into newer, often more remote, territories. These trends have had significant implications for the industry's energy consumption. And, while increased energy efficiency has become a more urgent priority for most gold mining companies, we estimate that the total energy consumption of the sector has risen approximately 23% over the last 5 years.

If the industry is to contribute to a decarbonised future, and be able to demonstrate alignment with the commitments made under the Paris Agreement to keep global warming well below 2°C, it will need to use energy more efficiently and that energy will need to be much cleaner. If it embraces these changes, however, there is a significant opportunity for gold mining to be at the forefront of the energy transition.

Currently, gold mining's investment in lower carbon power sources has been based around dual/hybrid solutions, with varying combinations of grid-connectivity, fossil fuel-based electricity generation and renewable energy sources. The 16 hybrid power sources we identified represent around 7% of the electricity consumed by the mines in our sample.

However, the low carbon component of these solutions, and therefore any associated emissions reduction, has been relatively small and, on a sectoral basis, unlikely to offset higher emissions from growth in mine production in regions with emissions-intensive power sources, and higher power requirements from lower grade or more complex ore bodies.

Our examination of the current status of gold mining's power consumption and emissions intensity suggest the following factors will drive the sector's ability to achieve emissions reduction beyond the margins:

- The regional and national context
- Grid factors, and the greening of grid power
- Gold mining company actions – current and projected – to replace fossil fuel-generated electricity

In addition, we have also considered the expected depletion or closure of mines with high GHG emissions that are coming to the end of their expected life. While plans for extending the life of a mine and, more broadly, for replacement of strategic reserves, are difficult to forecast, we suggest that energy strategies to support both options will likely veer towards lower carbon solutions.

18 Recycled supply has also grown to make up the shortfall.

Regional and national factors

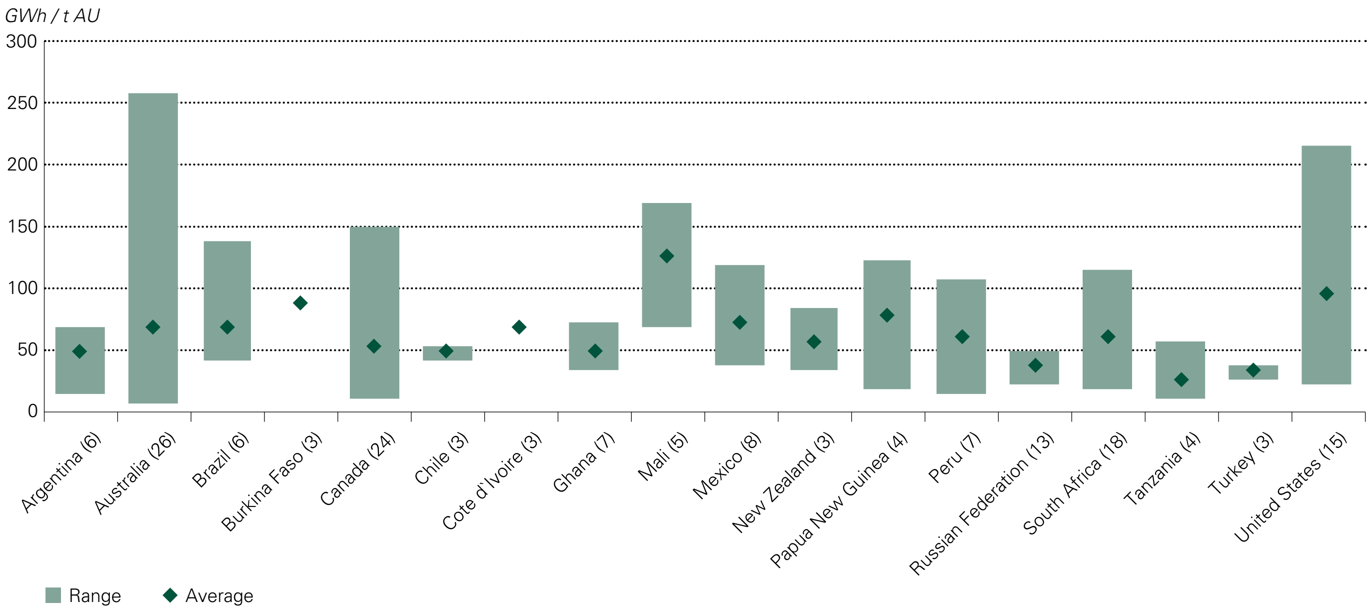
There are major regional, national and local factors that will shape the power choices used to power a particular mine and these will, in turn, impact its emissions profile.

Gold mining's power emissions are driven by the power intensity of gold production and the emissions intensity of the power supplied to gold mines – both of which vary widely between mines and countries. Our consideration of the regional and national context therefore focuses on these intensity factors in order to evaluate their potential impacts on gold mining's potential alignment with climate targets.

The energy intensity of mines will vary greatly, on a country and regional basis, as indicated by **Chart 3** below. The ranges in this chart suggest the very different energy requirements at different types of mine within each country.

Of the 158 gold mines we examined, grid-sourced electricity represented 57% of all the power they consumed on an annual basis.

Chart 3: Gold mine energy intensity by country, 2019



Countries selected have >2 gold mines in sample. Note: If 2019 numbers were not available, 2018 numbers may have been used as a proxy. Polymetallic mines with significant non-Au revenues were excluded from this chart. (N) Number of 'sample' mines in the country.

Source: Wood Mackenzie; company reporting

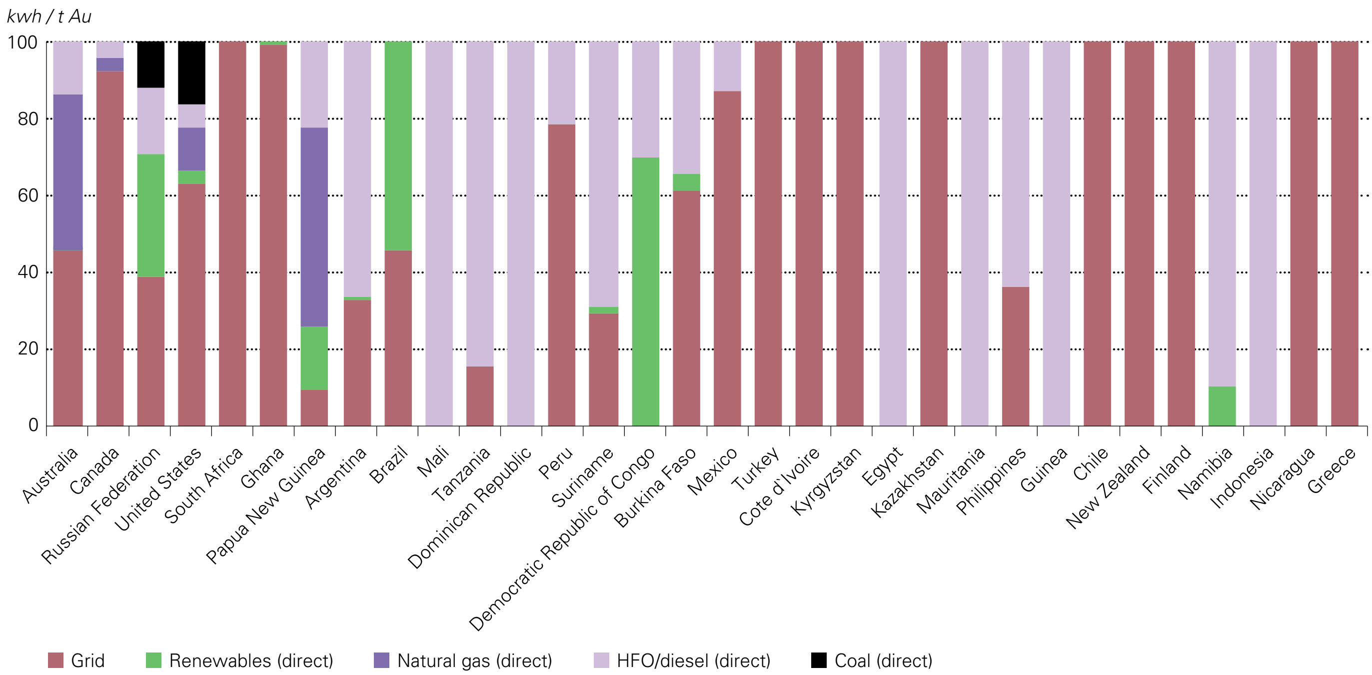
The average emissions intensity of power supply at gold mines will also vary considerably by country. For example, the prevalent use of local HFO and diesel generators at mine sites that have no grid-connectivity, such as in Mali and the Dominican Republic, will be reflected in the higher power emissions evident at mines in these countries. Elsewhere, the reliance on coal to power national grids, such as South Africa's ESKOM, or the use of coal-fired plants to directly power gold mines in regions of Russia, will also result in a higher level of emissions intensity of gold production in these countries.

A common notion about gold mining is that a large share of mines are remote and thus operating without access to the main electricity grid. But our analysis suggests that, globally, grid power currently plays a major role and has a very significant impact on gold mining's overall emissions profile.

Of the 158 mines we examined, 104 were connected to the grid, and grid-sourced electricity represented 57% of all the power they consumed on an annual basis. While our data indicates that mines in countries with a high volume of gold production are more likely to be grid connected, this varies greatly from country to country, as shown in the chart below (**Chart 4**). In some cases, for example in South Africa, Ghana, Turkey and others, all assets in the sample are connected to the grid; while in others – Mali, Mauritania, Democratic Republic of Congo and others – all mines are off-grid. In certain cases, local regulations may dictate what options are available to a gold mine company.[19]

In many instances, a grid connection may not be the only power source at a mine site; there may be back-up arrangements using diesel or, increasingly, cleaner alternative sources. The need for secure and stable power supply with be a major determinant of this mix, and the cost and emissions implications will vary widely. Electricity in gold-producing countries with limited grid connectivity is typically via direct (mine-site) generation from diesel or Heavy Fuel Oil (HFO),[20] resulting in higher emissions-intensity production.

Chart 4: Share of gold production by power source, 2019



Source: Wood Mackenzie

19 For example, in South Africa where ESKOM is the sole supplier of power (although there are indications these constraints may soon be relaxed).

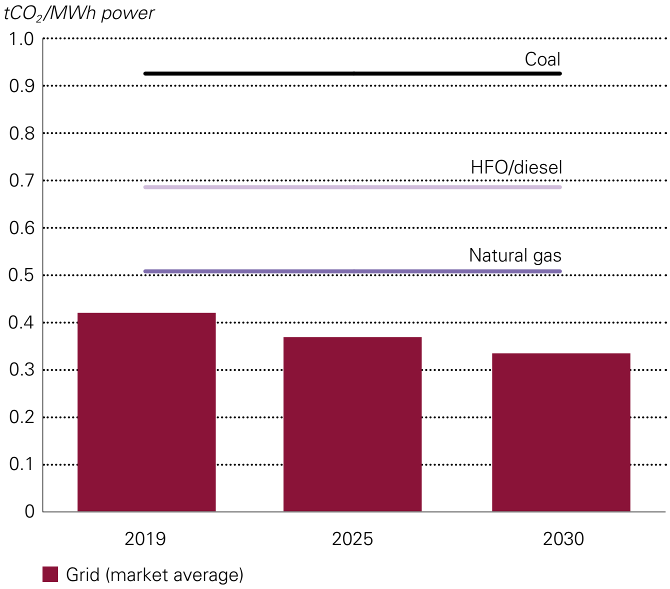
20 In this context, 'direct' indicates that the power source does not refer to what is delivered through the grid, but rather what is delivered *directly* to the mine through onsite generation or a bilateral agreement.

The greening of the grid

We have described above the significance of the nature of electricity supply from a national or state grid as the main power source for many gold mines – two thirds of our sample – in major producing countries.

Significantly, the emissions associated with these grids is expected to change quite substantially, with a sizeable shift in their power mix over the next decade likely to lead to considerable emissions reduction. Grids are transitioning to lower emission power sources and those mines connected to them will benefit as the average emissions intensity of grid-sourced electricity declines. We estimate that this will translate to a 20% reduction in the emissions intensity of grid power for the gold mines in our sample.

Chart 5: Grid emissions intensity by power supply type



Source: Wood Mackenzie

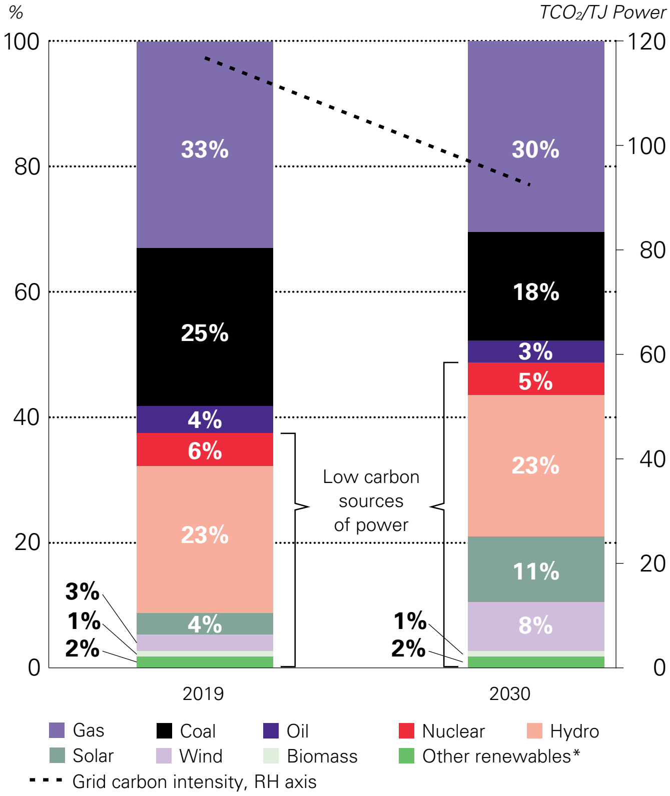
There are, however, major regional variations in the power mix of grids in different countries, as described previously, and this will likely be reflected in significant future differences in the nature and scale of their potential future emissions reduction. The power mix of grids has already evolved significantly over the last decade, and this evolution is anticipated to continue as indicated in **Chart 6**, showing the mix of power sources for the grid electricity consumed by the mines in our sample and the expected increased share for lower carbon power sources.

The emissions intensity of the grids[21] in several major gold-producing jurisdictions is shown in **Chart 7**. All these grids are expected to see significant reductions in emissions intensity. While some countries have proceeded further down the emissions reduction pathway, all are demonstrating evident commitment to drive major improvements in the coming decade. A notable example of the potential impact of grid transition is the US state of Nevada, where the CO_2e emissions associated with grid electricity are forecast to drop around 36% by 2030.

And the fall in grid emissions may outpace our estimates as the whole power industry accelerates its transition towards lower carbon sources. As coal is increasingly phased out and the share of power supply from renewables – particularly wind and solar – increases in key markets such as South Africa, Brazil, Canada, and Australia, important gains may be made in carbon intensity reductions at the mines in those countries.

Grids are transitioning to lower emission power sources and we estimate that, over the next decade, this will translate to a 20% reduction in the emissions intensity of grid power for the gold mines in our sample.

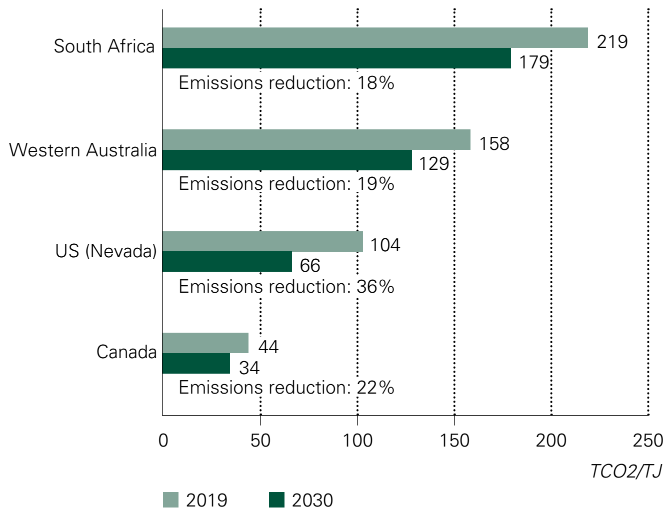
Chart 6: Grid power mix of gold producing countries, 2019 and 2030



*Includes geothermal, fuel cells, tidal, and others.

Source: Wood Mackenzie

Chart 7: Grid emissions intensity of key gold producing countries/regions, 2019 and 2030

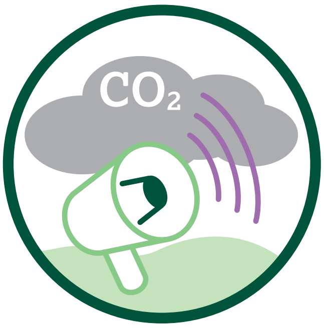


Source: Wood Mackenzie

21 Grid emissions intensity is based on the 'typical' carbon intensity for the various fuels used for power generation: 244.8 $ktCO_2/TJ$ for coal, 189.4 $ktCO_2/TJ$ for oil, 40.3 $ktCO_2/TJ$ for gas, 269.5 $ktCO_2/TJ$ of other solid fuels. 40% fuel efficiency assumed for power generators

Mine depletion and changing assets

One potentially significant change that was noted to have a marked impact on the projected overall emissions profile of our sample set relates to the actions that might be taken by companies when high emissions-intensity mines are nearly depleted or closed. Looking at the mines in our sample, several high-emission sites are expected to be closed or experience a substantial reduction in production levels over the next decade. For our sample set, the consequent emissions impacts are significant, resulting in a 19% reduction in emissions intensity. Of course, the active life of some of these mines may be extended if reserves allow and the gold price outlook renders them potentially economical. However, we expect the longer-term trend to be a preference for lower emissions intensity mines, which would be reflected in additional sectoral emissions reduction.



Recent announcements

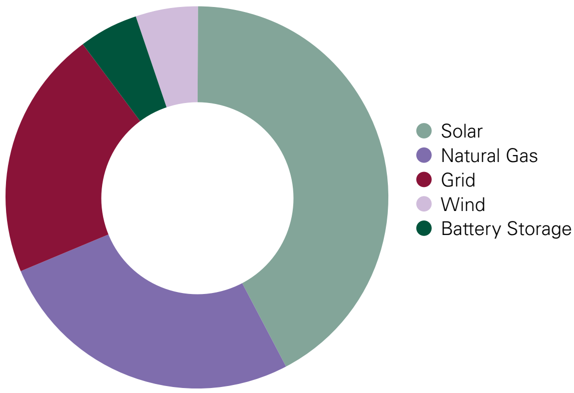
Our analyis of recent gold company and announcements to move to lower carbon power sources offer a strong indication that they are increasingly planning to utilise renewables in a substantive way (often as part of a hybrid power-sourcing arrangement, as described above). Looking at the recent announcements of the 31 gold mining companies in our sample, we identified 19 new initiatives focused on cleaner electricity consumption, with solar photovoltaics (PV) the preferred renewable energy source.

Looking at potential mine-level impacts from the announced actions by gold mining companies to move to lower carbon power sources, we estimate that they will reduce mine-site emissions by an average of 20% – and over 50% in some cases.

Gold mining investments in solar PV systems are currently mostly owned by third parties (65%), built onsite (82%), and connected to the grid (66%). Solar PV is the preferred technology due to its relatively low cost and low complexity, its scalability and frequent geographic fit. And non-direct ownership negates the need for large CAPEX investments, although it may also be reflected in marginal cost increases. Overall, however the range of ownership models (direct ownership, PPA with a third party, and leasing through a third party) suggests a flexible set of cost management options for companies in sunnier climes seeking to shift to renewables.

While natural gas is still a fossil fuel, and therefore cannot be properly classified as a 'low/zero carbon solution', its combustion to generate electricity typically produces less than half the CO_2e emissions associated with coal-fired power generation of a similar scale, and utilising it as part of lower carbon energy strategies is a current trend that is likely to endure for some time. It has already proven successful at many sites.[22]

Chart 8: Gold mining company announcements of investments in low- / lower-carbon power, 2020



Source: Wood Mackenzie

22 For example, at Newmont's Tanami mine in Australia, and at Barrick's Pueblo Viejo mine, in the Dominican Republic, where there are plans to switch to gas from heavy fuel oil (HFO), with an estimated fall in annual CO_2e emissions of up to 30%.

Although we did not identify any announcements of new commitments to hydropower in our sample, we recognise it is a key component of current gold mining low carbon power supply, typically delivered via local grids.[23]

Many gold miners make the point that their revised energy strategies are currently driven as much by cost efficiency and the need to build future resiliency as they are by the need to demonstrate action on emissions reduction. Nonetheless, even these early steps represent significant sectoral progress and, in these announced future plans, gold mining company commitments represent 16% of all known future renewable energy projects across the mining and metals sector (including coal, copper and iron ore production).

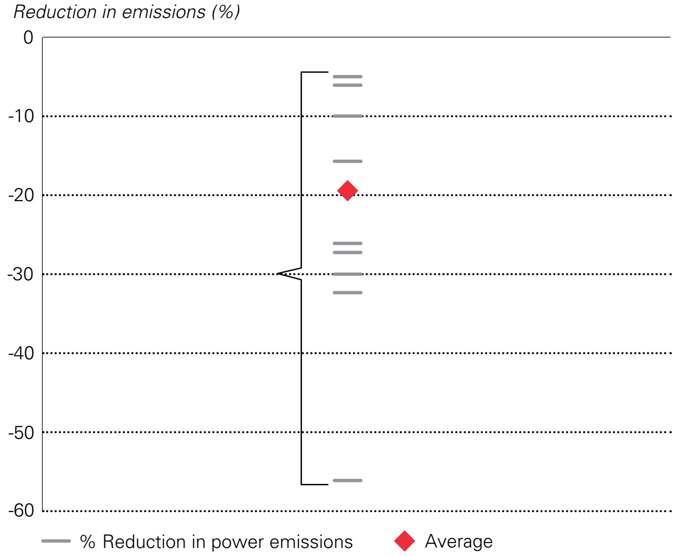
Early steps and initial impacts

Gold mining's current move to renewables can be perceived as a trend in its early stages, with the majority of 'active' renewables projects in our data set having an inception date[24] within the past 12 to 18 months.

However, even at this early stage, the impacts of current and planned shifts to lower carbon power sources are likely to result in a quite substantial reduction in gold mining's dependency on fossil fuels over the next few years. Our analysis of recent announcements from gold mining companies (to move to lower carbon power sources) suggests that electricity from direct HFO/diesel generation will be reduced by 34% and direct coal sources will fall by 59%. By the end of the decade, coal-fired power at the mines in our sample will be close to eliminated – except, perhaps, for one or two 'outliers'.

Even at this early stage, the impacts of current and planned shifts to lower carbon power sources are likely to result in a quite substantial reduction in gold mining's dependency on fossil fuels over the next few years.

Chart 9: Gold mining company announcements of investments in low- / lower-carbon power, 2020



Source: Wood Mackenzie

Looking more closely at mine-level impacts from the announced actions by gold mining companies, we estimate that, where implemented, they will reduce mine-site power emissions by an average of 20% – and over 50% in some cases. The impact of the planned changes on the overall emissions intensity of gold production, at least as represented by our sample, is to reduce emissions intensity by a little over 5%. This might seem relatively insubstantial, at least when measured against the emissions reduction needed to meet sectoral climate targets, but it can also be perceived as the first step on the path to a more substantial transition. As fossil fuels become a more marginal (and costly) source of energy, the fall in consumption is expected to accelerate. Furthermore, we might expect these initial steps towards decarbonisation of power to be more widely adopted across the gold mining industry and estimating the potential impacts of that wider adoption is examined in the following section of this report.

23 We acknowledge the current significance of hydropower at several gold mines, and accept that it is under-represented statistically in our data set, not due to its lack of relevance but more likely because of the way in which hydro-power data is reported. That is, it may be a key element in grid-sourced power that is not explicitly identifiable in the associated data and therefore specific sources may not feature as they are 'embedded' in the data relating to grid connectivity.

24 This refers to the reported Commercial Operational Date of these projects.

2: Transition impacts and climate targets

> "Achieving net-zero targets is both a massive challenge – as countries will need to transform their economies – and an opportunity to advance development and sustainable economic growth while avoiding the worst climate change impacts."
>
> World Resources Institute, 2020[25]

Decarbonisation targets and pathways

The World Gold Council has previously estimated that the emissions pathway needed for the gold mining industry to achieve a climate target limiting global warming to <2°C will require GHG emissions reduction of 80% by 2050. If a 1.5°C target is adopted, it will likely require emissions reduction from the industry of 92% by 2040 (or shortly thereafter).[26] In this study, we have evaluated power emissions reductions against conceptual 27% and 46%[27] reduction targets for the year 2030, which would put the sector roughly 'on schedule' to meet the 2050 targets defined in our earlier report, assuming linear emissions reductions.[28]

25 Levin, K., D. Rich, K. Ross, T. Fransen, and C. Elliott. 2020. *"Designing and Communicating Net-Zero Targets."* Working Paper. Washington, DC: World Resources Institute. www.wri.org/design-net-zero.

26 The Intergovernmental Panel on Climate Change (IPCC) have stated that to limit global warming to 1.5°C above pre-industrial levels and avoid the most catastrophic impacts of climate change, the world must halve CO_2 emissions by around 2030 and reach net-zero CO_2 emissions by mid-century.

27 Although our data is to 2019, projected reduction targets are calculated from 2020; these are indicative rather than definitive targets, as discussed further in the Climate Targets section of Appendix 1.

28 We acknowledge that, in practice, emissions reduction is very unlikely to be linear; however, the 2030 'hurdles' represent simplified but nonetheless realistic targets against which progress might be measured.

For gold mining's overall emissions to fall at a sufficient to rate to ensure these targets are met would likely require corresponding reductions (of around 27% or 46% by 2030) in emissions from non-power sources. These assumptions are to facilitate the analysis; in practice, the ability for power and non-power sources to decarbonise will likely vary considerably. However, it can be argued that the potential reductions in power emissions discussed in this study may represent the most immediate opportunities for gold mining to align itself with established climate targets.

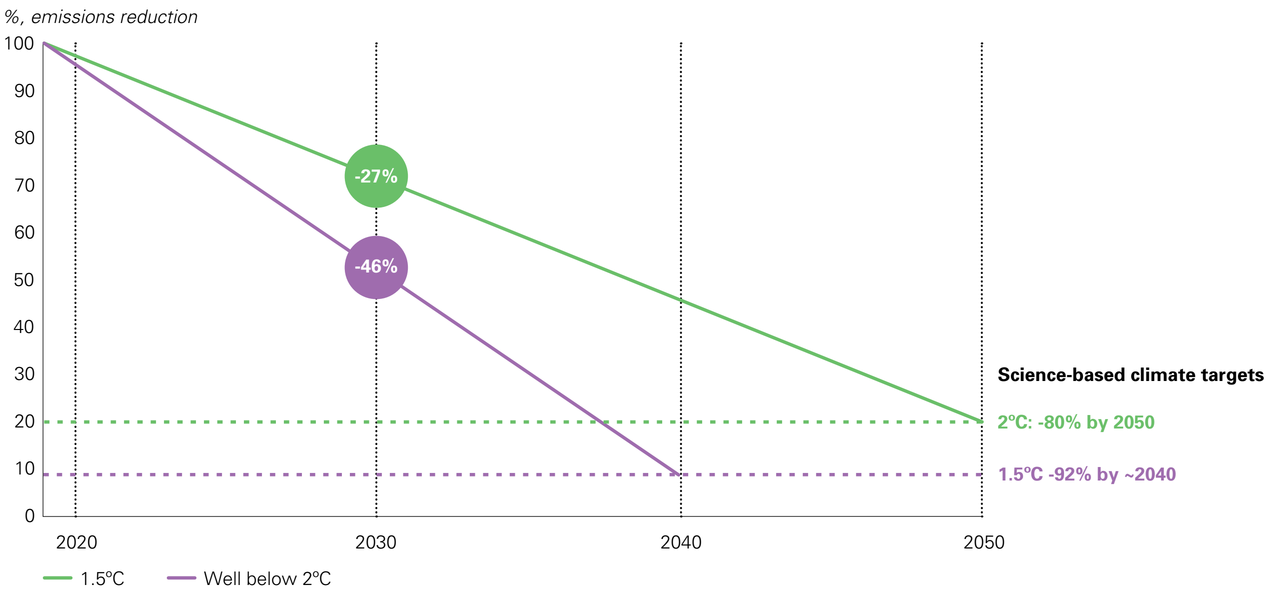
The combined impact of the shift in the power mix of grid-sourced electricity and the recent and announced changes in energy strategies among the companies in our sample is expected to result in a reduction in power emissions of around 16% over the next decade. While this is significant, particularly given that company initiatives to replace carbon-intensive power sources are still in their early stages, more clearly needs to be done to approach the level of emissions reduction needed if the gold mining industry is to meet net zero targets.

Our analysis projects a relatively flat level of overall gold mine production over the next decade, although we expect a significant shift in the nature of the 'asset mix' and the emissions profile of productive mines.[29] This assumes that any new mines or mine extensions and expansions (to compensate for declining production elsewhere in a company's portfolio of assets) will likely employ power solutions with emissions intensity that is close to or better than average. This shift is expected to result in a net reduction in the emissions intensity of global gold production, contributing to a further 19% fall in emissions, which would potentially surpass the 'well below' 2°C climate target.

Additional company actions and impacts

To evaluate what the impacts of recent gold mining company announcements to implement lower carbon power solutions might be on the industry's ability to meet climate targets, the same changes in power mix were applied to all the mines in our sample. The resultant additional average emissions reduction of 9% across the sample would allow gold mining emissions to approach the 1.5°C target.

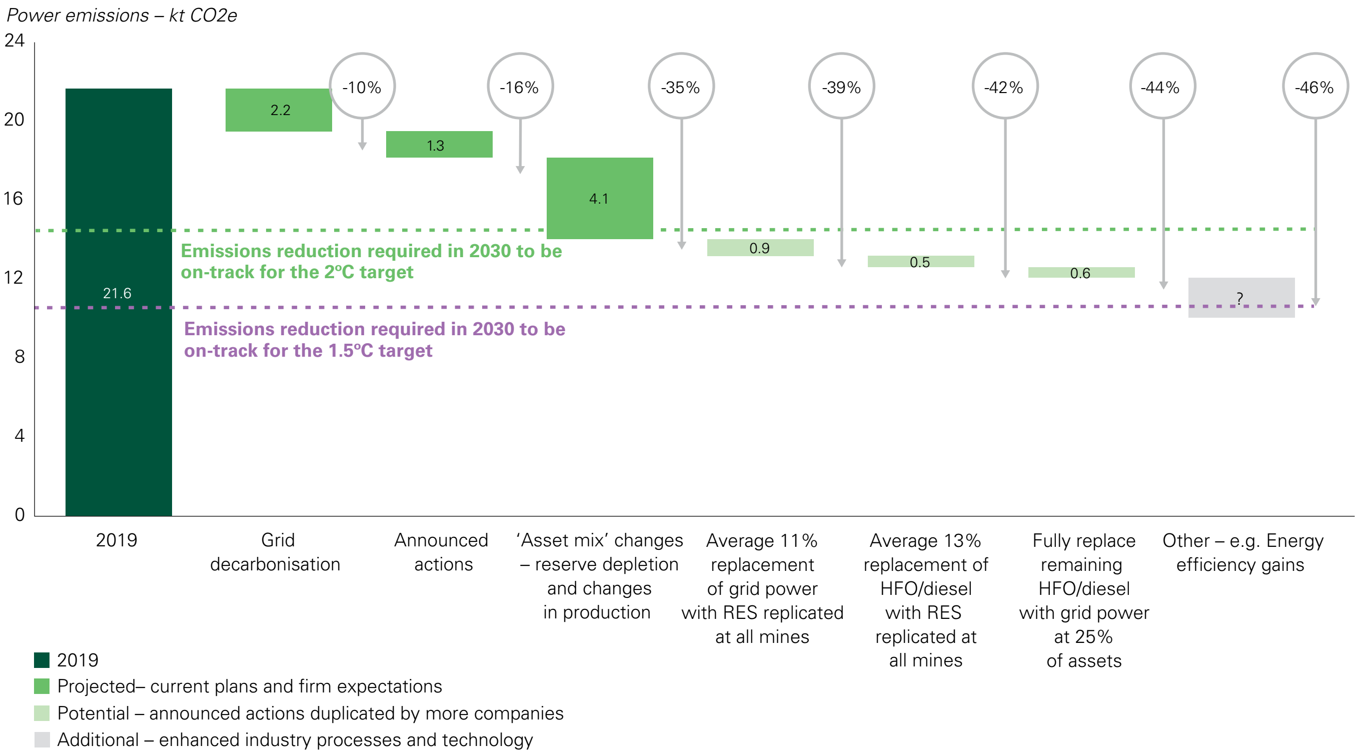
Chart 10: Carbon emissions pathways to limit warming to "<2ºC" or "1.5ºC "



Source: Wood Mackenzie

29 The assumption of flat mine production over the next decade is not unreasonable, as indicated by our closer examination of the sample (see Appendix 1), but also allows us to focus on power emissions intensity as a proxy for the total emissions from gold production.

Chart 11: Gold mining GHG emissions from power, 2019 and 2030 (projected) and climate targets



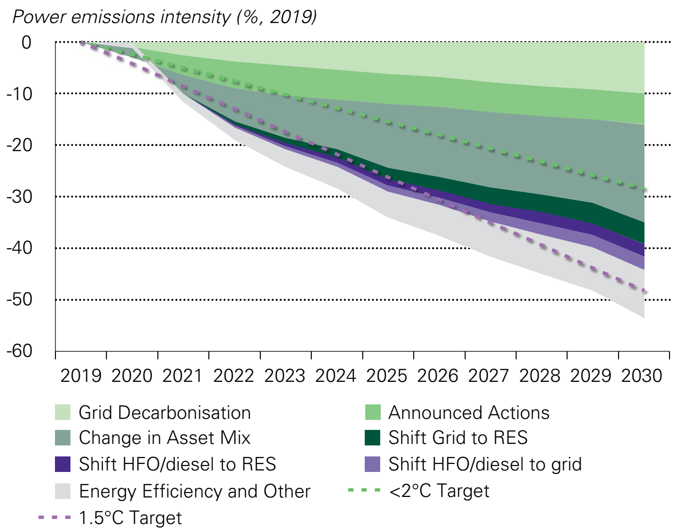
Source: Wood Mackenzie

The above chart (**Chart 11**) illustrates the accumulated potential impacts of the gold mining sector's changes in power emissions, including a number of power source replacement scenarios based on recently announced company actions, as measured against 2030 climate targets.

These estimates include an acknowledgement of the potentially significant role of energy and operational efficiency initiatives in driving further emission reductions. The impacts of such measures have not been fully analysed in this study, as consistent data on them is still limited. However, we estimate that a small annual increment in further emissions reductions from enhanced energy and operational efficiency, and supportive technologies, would be sufficient to allow the sector to remain aligned to a 1.5°C climate target.

Combining the key factors we have described above and projections regarding the shift in mine production across the sample, we arrive at a pathway to decarbonise power that allows potential alignment with both the 'well below' 2°C and 1.5°C climate targets (as illustrated in **Chart 12**).

Chart 12: Changes in gold mining power emissions and projected impacts on climate target alignment



Source: Wood Mackenzie

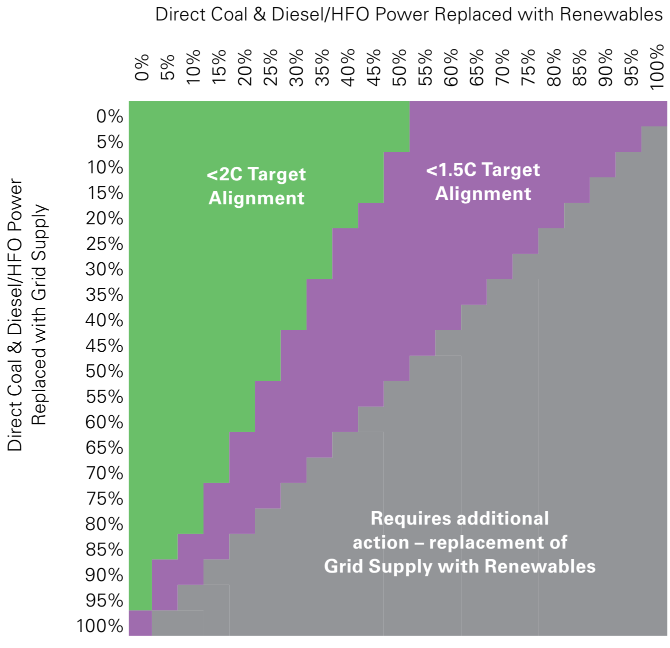
Renewables and further decarbonisation opportunities

While we cannot be confident that the current early steps by gold mining companies to decarbonise power represent a blueprint for wider sectoral action, there is considerable flexibility in how different gold mines might seek to reduce carbon-intensive power sources. Looking beyond the implications of current mining company plans, our analysis suggests that the categories of direct action available to gold mining companies to make a greater contribution to emissions reduction are, broadly, as follows:

- Replacing electricity from direct fossil fuel consumption with connections to a (lower emissions) grid
- Replacing electricity from direct fossil fuel consumption with directly generated renewable electricity
- Replacing connections to a grid with directly generated renewable electricity

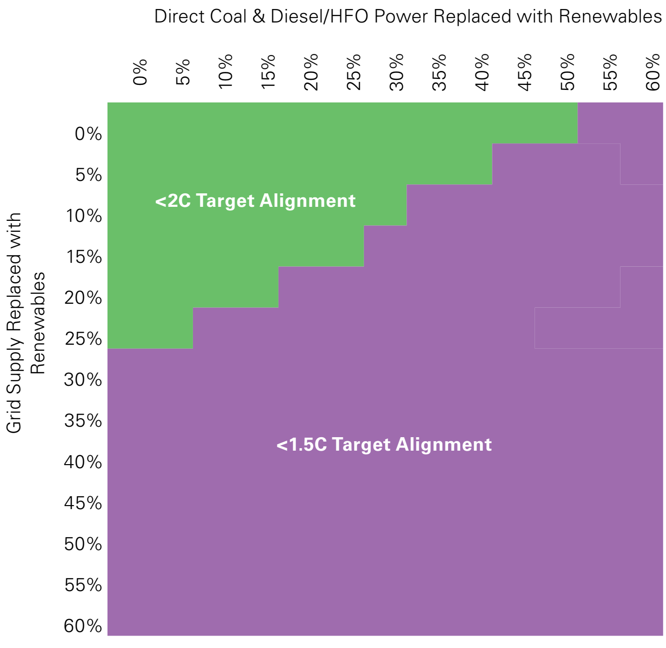
In practice, the mix of grid power and/or renewables used to replace electricity generated from coal, diesel or HFO will vary greatly from site to site. We have therefore estimated the combined impacts of replacing electricity from fossil fuels with, to varying degrees, power from both direct renewables and grid supply in order to achieve the 'well below' 2°C and 1.5°C climate targets. **Chart 13** illustrates the emissions impacts of these combinations and again underlines the importance of direct renewables in facilitating gold mining's ability to decarbonise. **Chart 14** illustrates the significant impact of additional shifts to replace grid supply with renewables.

Chart 13: Combined impacts on climate target alignment of replacement of fossil fuel-based electricity



Source: Wood Mackenzie

Chart 14: Combined impacts on climate target alignment of increased role of renewables to replace fossil fuels and grid connectivity



Source: Wood Mackenzie

There is considerable flexibility in how different gold mines might seek to reduce carbon-intensive power sources, but our analysis underlines the importance of the increased use of mine-site renewables.

These findings emphasise the range of opportunities open to gold mining companies in reducing power emissions at their mines. They suggest that, if *single* actions were taken to reduce a specific power supply with renewables, to enable 1.5°C target alignment[30] would require either:

- replacement of 55% or more of direct fossil fuel generated power with renewables

or

- replacement of 30% or more of grid supply with renewables.

But a *combined* replacement of, for example, 20% of the power supply from both grid and direct fossil fuel sources with renewables would also achieve 1.5C target alignment.

Even if we exclude the substantial impacts from a changing 'asset mix' – the expected closure of (or reduced production from) higher emission mines – from our scenarios, our analysis suggests that a substantial move to renewables would still enable industry alignment with the Paris targets. For example, replacing 45% of both grid power and direct fossil fuel-generated electricity would place the industry on track for the 1.5°C climate target.

(Further details of our analysis of the impacts of shifts in power supply on climate target alignment of can be found in **Appendix 2: Power sources, emissions impacts and targets.)**

30 Our estimates of industry alignment with climate targets assume that reductions in gold mining's power emissions will be matched by commensurate, although not necessarily concurrent, falls in emissions from industry sources other than electricity consumption. But the significance and scale of power emissions, and the near-term opportunities for their reduction, mean the assumption of corresponding, possibly later, reductions from other sources is not unreasonable.

Conclusions

> "There is no doubt that it is technically and economically possible to reach the zero-carbon economy which we need by 2050… But action in the next decade is crucial – otherwise it will be too late."
>
> Lord Adair Turner, Energy Transition Commission (ETC), 2020

Looking at how the changing energy landscape is impacting the gold mining sector's ability to decarbonise at a sufficient rate to be broadly aligned with 'well below' 2°C or 1.5°C climate targets, we find that target alignment is broadly achievable, although the 1.5°C target will require substantial additional moves away from fossil fuel-based power.

If the initial steps currently being taken by gold mining companies to change the power supply at mines to lower carbon sources are more widely duplicated, the sector should attain a level of emissions reduction by 2030 to make the <2°C target eminently achievable, and put 1.5°C potentially within reach.

The role of grid-sourced electricity in gold mining's power mix was more significant in many cases than was expected, and therefore how grids are evolving to embrace lower carbon energy sources will be a key determining factor in shaping the sector's emissions reduction pathway. The greening of grid power is broadly expected to support further emissions reduction, with very significant impacts in some locations.

However, persistent use of coal-fired electricity, either directly or via grid supply, in a few locations, is a potential obstacle to accelerating progress towards climate target alignment.

Our observations suggest that companies currently on grids are unlikely, in the near term, to disconnect and convert fully to self-generated renewable power. Therefore, dual/hybrid generation options, often featuring solar PV, will likely be pursued to increase the share of low carbon electricity powering a mine, especially as battery storage becomes increasingly effective and affordable.

> Our analysis suggests a range of options to replace carbon-intensive power sources with renewables will offer gold mines a degree of flexibility and be potentially sufficient to achieve emissions reduction by 2030 in line with Paris Agreement targets and net zero carbon by 2050.

Although not quantified from our sample data, we estimate incremental improvements in energy and operational efficiency, perhaps further facilitated by technological advancements, can also play a key role in reducing the industry's power emissions at target levels.

To reach the 1.5°C target will, however, likely require the use of renewable energy sources at gold mines to be rapidly expanded. The most significant change likely to achieve the necessary levels of emissions reduction is the replacement of both fossil-fuels in direct electricity generation and grid supply with renewable power sources. Local constraints and conditions will clearly impact the accessible power options open to a gold mining company. However, our analysis suggests several variants – different ratios of replacing carbon-intensive power sources with renewables – will offer mines a degree of flexibility and be potentially sufficient to achieve emissions reduction by 2030 in line with Paris Agreement targets and net zero carbon by 2050.

Appendix 1: Data, definitions and methodology

Context and scope

The World Gold Council (WGC) is seeking to evaluate the gold industry's progress in shifting away from fossil fuels and toward renewable energy sources to better assess the industry's climate impacts and potential alignment with established climate targets. To achieve this, the WGC has sought independent data and analysis from Wood Mackenzie to demonstrate the outlook for the emissions related to power consumption by the gold industry, specifically gold mining, with a view to understanding whether the gold sector is on the right trajectory to meet global climate targets, and in order to understand what actions may be required to reduce sector emissions sufficiently to contribute to climate stability.

Factors determining the scope and coverage of the data gathered by Wood Mackenzie to perform this analysis are discussed further below.

Targets

For the purpose of analysing the industry's potential climate impacts, Wood Mackenzie has measured the gold sector's projected performance against targets outlined by science-based targets[31] to help mobilise companies to align with the commitments of the Paris Agreement to limit the average global temperature rise to 'well below 2°C, while pursuing efforts to limit it to 1.5°C.

Previous studies by the WGC have indicated that gold sector emissions need to be reduced by 80% by 2050 to be aligned with the 'well-below' 2°C scenario, or 92% by – or shortly after – 2040 to align with a 1.5°C scenario. This analysis assesses how gold mining's changing power consumption might contribute to the sector being on-schedule to meet those targets based on announced changes, and wider contextual shifts, and approximates how much additional action might be needed to close the gap.

Acknowledging the significance of near-term actions and the next decade in achieving potential target alignment, we have evaluated power emissions reductions against conceptual 27% and 46% reduction targets for the year 2030, which would, assuming linear emissions reductions, put the sector roughly 'on track' to meet the 2050 targets. We have opted for indicative simple target dates, but given the lag in data (to 2019 at the latest) and projection dates (2020 to 2030), it would perhaps be more mathematically accurate to state, 'well below' 2°C targets will require GHG emissions reduction of 27%-28% by 2030 and, if the 1.5°C target is adopted, it will likely require emissions reduction from the industry of 46%-48% by 2030.

Data sources

Wood Mackenzie's analysis leverages data from a sample representing approximately half of industrial primary gold production for which data is available ("industrial" excludes the primary production that comes from artisanal mining). The base data comes from the power and electricity data reported by a sample consisting of 31 companies[32] owning a total of 158 assets around the globe, although 20 assets were excluded because they were no longer operational or had insufficient data on their power consumption. Where electricity data was not broken out from total energy in sufficient detail by those companies, breakdowns were estimated based on benchmarking of comparable peers and insights from Wood Mackenzie's expert analysts and proprietary databases. Additional proprietary Wood Mackenzie gold and power market data were used together with the reported data to perform analyses of energy consumption, carbon emissions, and power supply mix for the sample gold sector companies. While Wood Mackenzie observed that there may be some methodology differences in data reporting between companies, reported data was used where available and broadly consistent.

31 As defined by the Science Based targets Initiative ("SBTi"), a joint initiative by the CDP, the UN Global Compact, the World Resources Institute and World Wildlife Fund

32 See Appendix 3: Companies and mines

Data coverage

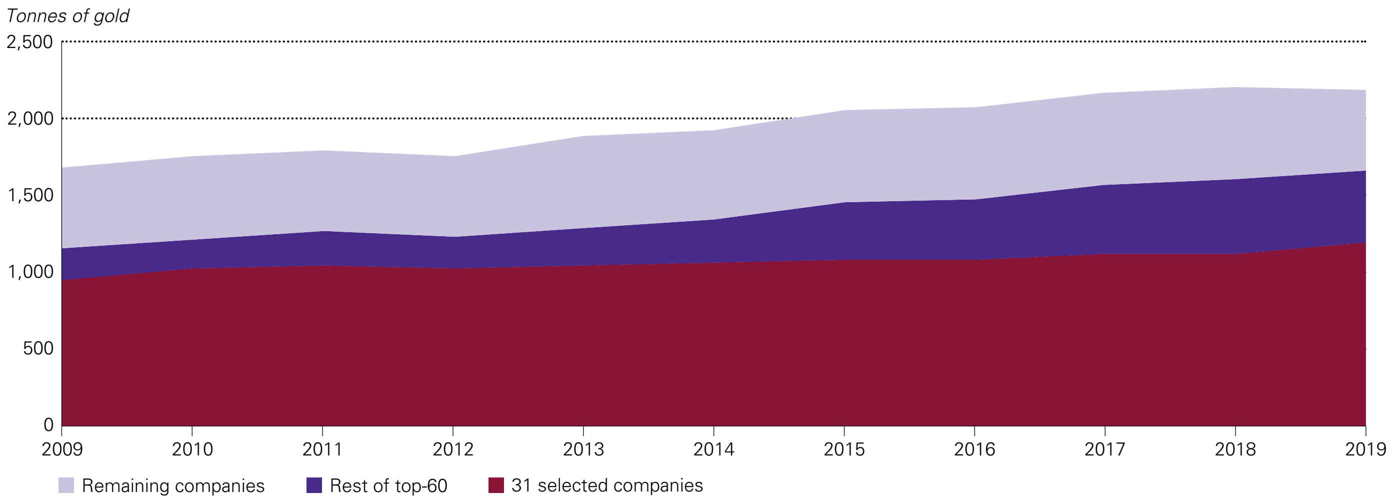
Estimated overall primary gold production in 2019, including production from artisanal and opaque sources, is 3,300 tonnes of which costed production represented 2,200 tonnes. This report will primarily present estimates for *costed* supply – 68% of the estimated sector total (see also *Sample methodology* below), unless otherwise indicated, as data for the more opaque/artisanal portions of the market are unreliable or unavailable.

Sample methodology

Wood Mackenzie has asset-level gold supply data for approximately 68% of primary production; the balance is approximately 20% artisanal/informal production and 12% from opaque or smaller sources in many countries (but especially in China and Russia). Wood Mackenzie calls this 68% of the market for which data is available "costed production" or "costed supply". Many of these "costed" companies do not yet publish detailed energy consumption or emissions data and attempting to collect data from the entire population would have been impractical at this time. For the purposes of this study, which is based on such reported data, it was therefore necessary to use a non-probability sampling method in which data was collected for a subset of companies for which data is available that together represent a majority of costed supply.

In 2019, the 31 sample companies represented approximately 55% of costed gold supply.[33] The rest of the top 60 producers collectively represent another 21% of annual production, and the remaining companies in the reference gold supply database make up the remaining 24%.[34] Data, if available and appropriate, from these latter companies was used to guide our consideration of wider sectoral impacts, but not included in the projections. Since

Chart 15: Global primary gold production



Source: Wood Mackenzie

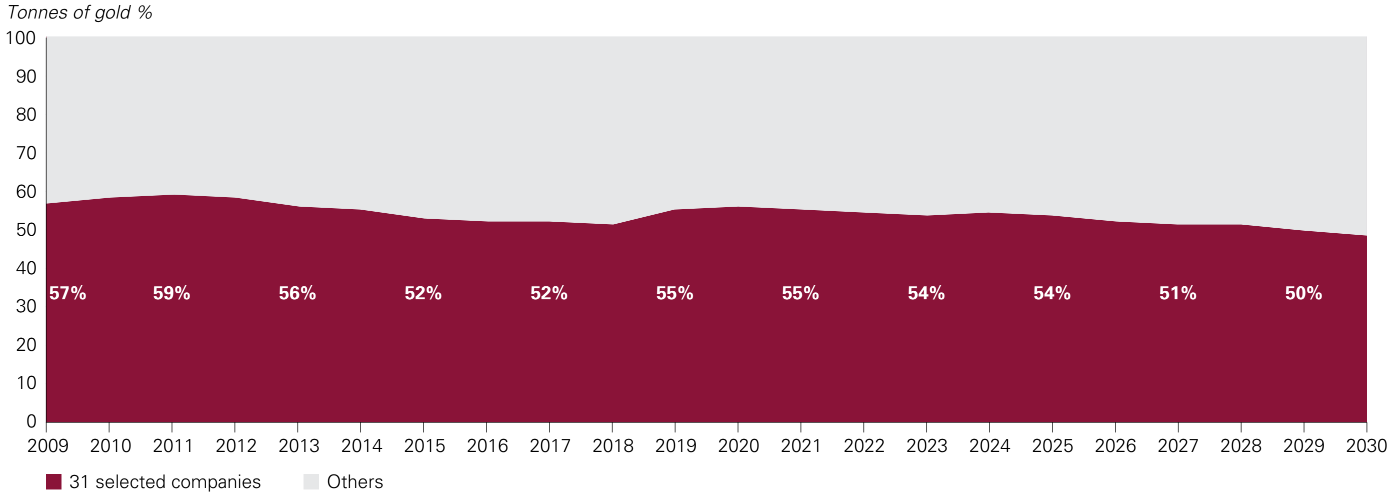
33 The mine production attributable to the 31 companies represents approximately 55% of costed gold production. This study is based on full (not attributable) production of the 158 assets operated by the sample companies, which represents approximately 62% of costed production. The difference between the 55% and 62% is joint/minority ownership of mines by multiple companies.

34 Wood Mackenzie are the primary source for all gold mining production and emissions data in this report. See Appendix 1 for further details.

2009, the sample companies' share of production has fluctuated, but has consistently remained well above 50%, as shown in the chart below. Looking forward, it may appear as if the sample companies' share will shrink as existing assets are depleted. For what Wood Mackenzie calls its "base case" supply (defined as operations currently producing plus projects in construction and with all conditions fulfilled to progress, e.g. board approval, financed, legal title, fully permitted, technically and economically robust), this is true. However, history has shown that a meaningful number of new projects tend to be acquired by the larger mining houses as they progress through development. We anticipate this will continue in the future. Thus, the 31 companies' current share of base case supply is likely a good proxy for their share of the overall market in the future, as shown in the graph below.

This persistently dominant share of the market enables use of the sample companies' data as a solid core for sector-level analysis. Findings from analyses of the sample company data can be extrapolated to the level of all costed supply, accounting for known differences between the sample companies' assets and those of the rest of the sector to minimise potential bias, such as the differences in geographic mix described previously. The share of gold production from Asia, Russia and the Caspian, and to a lesser extent Latin America is less in the sample companies than for the non-sample asset population.

Chart 16: Primary gold 'base case' production, historical and projected: 31 companies vs. rest of industry



Source: Wood Mackenzie

Adjusting for mine depletion and the construction of new mines

Gold deposits are non-renewable resources that contain finite amounts of economically recoverable minerals ("ore reserves"). As the ore reserves are extracted, gold production volumes from a deposit tend to decline somewhat and eventually cease when at the end of the life of the mine. Thus, a bottom-up "base case" view of gold supply nearly always shows a decline in production in the medium and long term, reflecting the natural depletion of existing mines over time. (This would be the case if our projections for future production simply reflected the known forecasts for supply from the sample mines.) While gold supply has steadily increased over the last decade, Wood Mackenzie forecasts primary gold demand will remain roughly flat over the next decade due in part, to the need of major gold companies to take action replace and sustain reserves against their ongoing depletion.

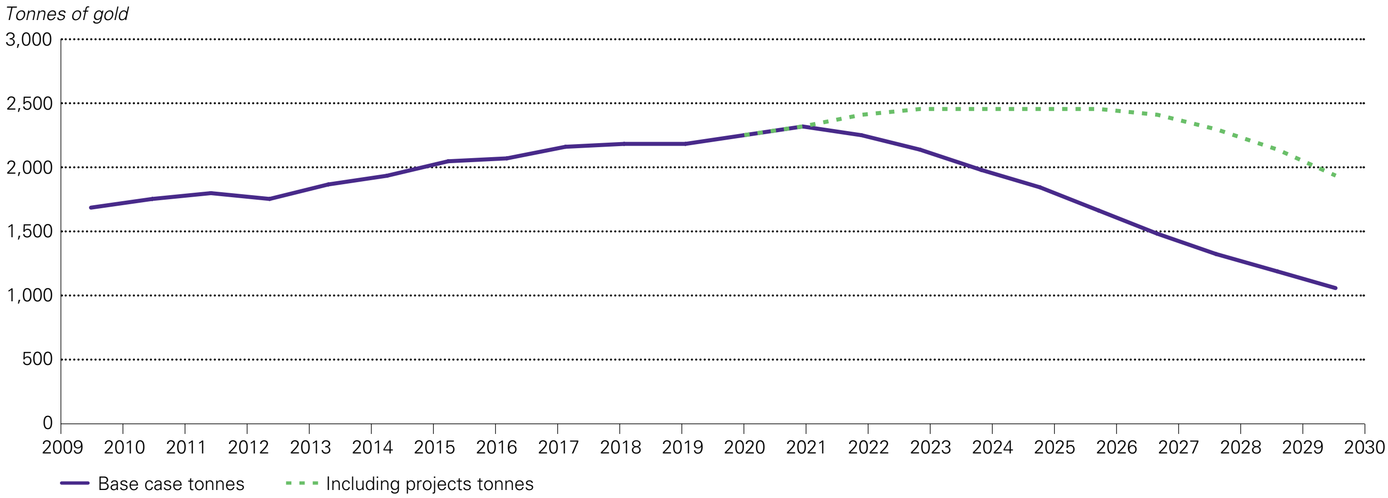
If companies are to maintain their production levels additional mines will have to be built. Wood Mackenzie refers to this new supply as "projects." When significant discoveries are announced and sufficiently advanced, they are added to Wood Mackenzie's database as projects until they meet the criteria to be included in base case supply. These projects typically await a formal construction decision or the financing needed to proceed. Other factors include permit status and likelihood, technical and economic robustness, prioritisation in owner's portfolios, stage of development, etc. In the medium and longer term, additional discoveries will be announced and advance to project stage, as indicated by the dashed green line in the chart (**Chart 17**) below, reflecting the growing pipeline of potential projects.

The following graph displays the projected impact of ore reserve depletion on base case primary gold supply. 'Base case primary supply' here refers to the sum of all listed production in the Wood Mackenzie gold mine database (i.e. the 31 companies in our sample, plus the remaining 195 gold mining companies – the additional categories of base case production shown in **Chart 15**). The addition of potential new gold production from projects is also shown.

Given the time it takes to construct new mines and the magnitude of the supply gap to be filled, there is a risk that production could decrease if a material number of companies are not able to proceed according to the projected schedule. Despite the drop off in base case supply, significant investment in existing projects combined with mine life extensions, expansions and the commissioning of unidentified projects should be sufficient for the overall level of primary mine supply to remain relatively flat. Wood Mackenzie suggest a minor dip in production in the near-to-medium term appears likely as miners confront some headwinds to bring on enough new supply, but by the end of the decade sufficient investment should bring sector supply broadly in line with 2019 levels.

As a result, Wood Mackenzie use expectations of fairly flat primary mine supply over the coming decade as the basis for their projections.

Chart 17: Primary gold supply including projects



Source: Wood Mackenzie

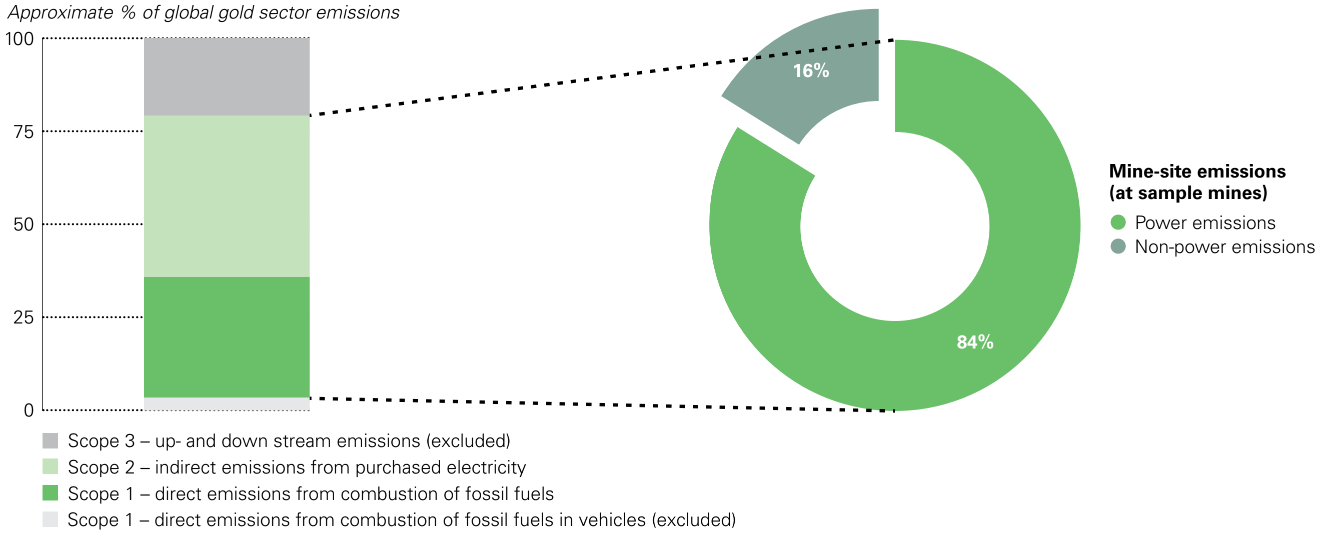
‘Power emissions’ and Scope 1, 2 and 3 emissions classifications

Compared to the previous estimates produced by the World Gold Council in quantifying the overall GHG emissions of the gold sector and gold mining, Wood Mackenzie adopted a narrower scope by focusing on ‘power emissions’, based primarily on reported data relating to asset-level energy/electricity consumption (see *Data sources* above). While fully compatible with GHG Protocol[35] definitions, the Wood Mackenzie data set does not seek to encompass all aspects of Scope 1, 2 and 3 emission categories. Specifically, in relation to gold mining and the WGC’s earlier works:

- it does not reference other fuel uses and associated emissions, such as those related to haulage and transportation
- it does not include an accommodation for the transmission and distribution of fossil fuels
- it does not reference Scope 3 (upstream/downstream) emissions.

Therefore, the emissions figures are best taken as indicative rather than comprehensive. However, while the production emissions intensity and total emissions estimates will be partial rather than fully representative of sectoral emissions, the ratios and trends produced from the analysis are fairly robust, drawn for a substantial sample with granular inputs. Given that our focus encompasses the largest categories of emissions from gold mining and that our sample covers over half of all (large-scale) annual mine production, we are confidence that our findings and projections should be broadly applicable across the sector.

Chart 18: Gold’s GHG emissions – Scope 1, 2 and 3 emissions and ‘power’ emissions



Source: *Gold and climate change: Current and future impacts,* World Gold Council; 2019 Wood Mackenzie

35 https://ghgprotocol.org/

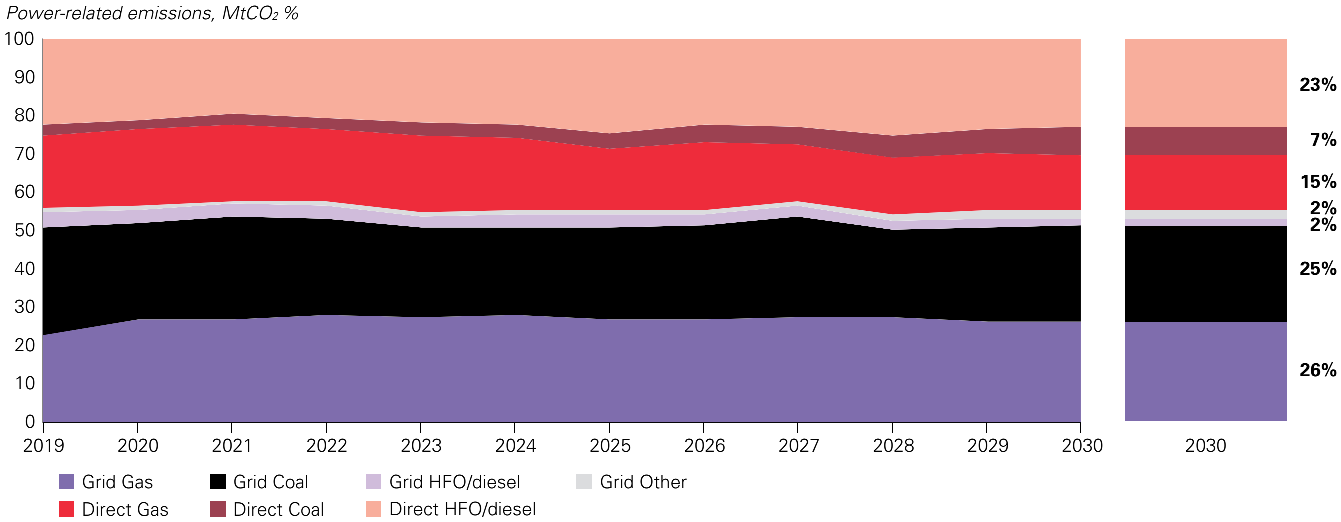
Power sources and emissions impacts

The projected breakdown of expected grid and direct power-related emissions in 2030 in **Chart 19** provides a basis for the sensitivity analysis allowing us to estimate the emissions reduction impacts of additional actions (beyond those already announced and factored into our analysis).

Estimates of the emissions impacts of additional replacement actions are based on observations that by 2030:

- Direct-generated fossil fuel power will make up nearly 45% of emissions for our sample if additional actions are not taken; HFO/diesel and coal alone would be 30%.
- Grid power will represent over 55% of emissions and, thus, actions to partially replace it with renewables have a substantial impact on target alignment.

Chart 19: Breakdown of power sources and emissions to 2030



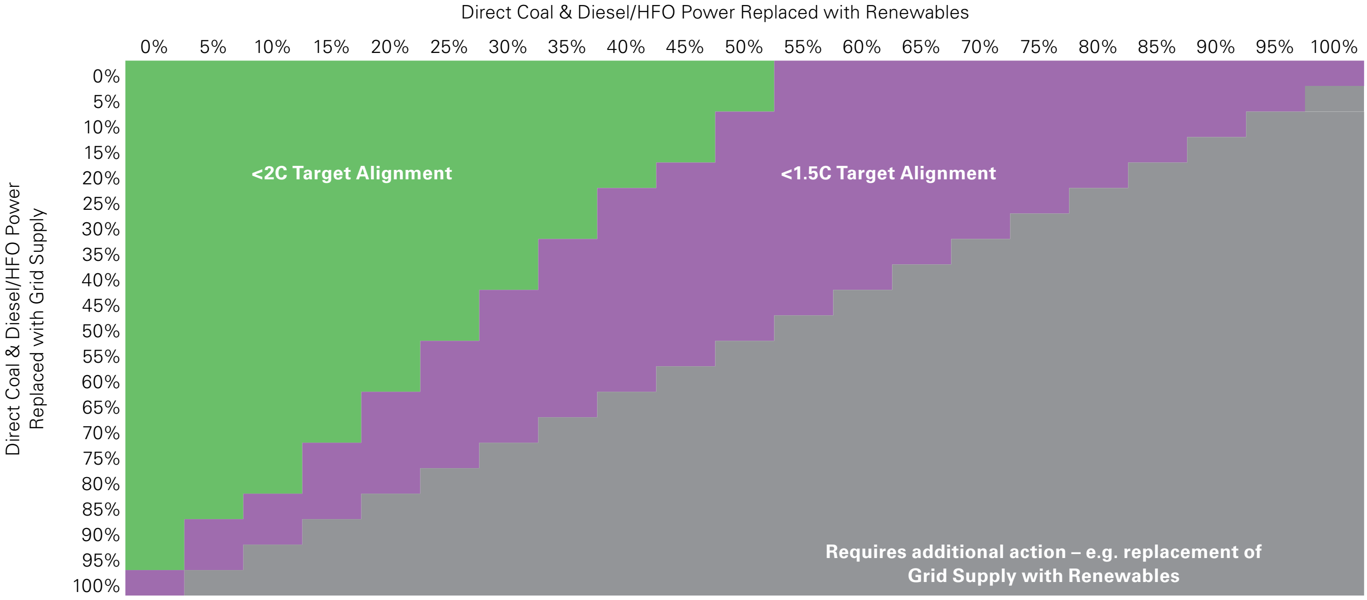
Source: Wood Mackenzie

Appendix 2: Power shifts, emissions impacts and climate targets

Our analysis of the combined impacts of replacing electricity from fossil fuels with, to varying degrees, power from both direct renewables and grid supply, in order to achieve the 'well below' 2°C and 1.5°C climate targets, suggested a wide range of options. These included the following observations:

- Coal/Diesel/HFO-generated electricity is emissions intensive, but only represents around 30% of gold mining emissions, so its replacement impacts are limited.

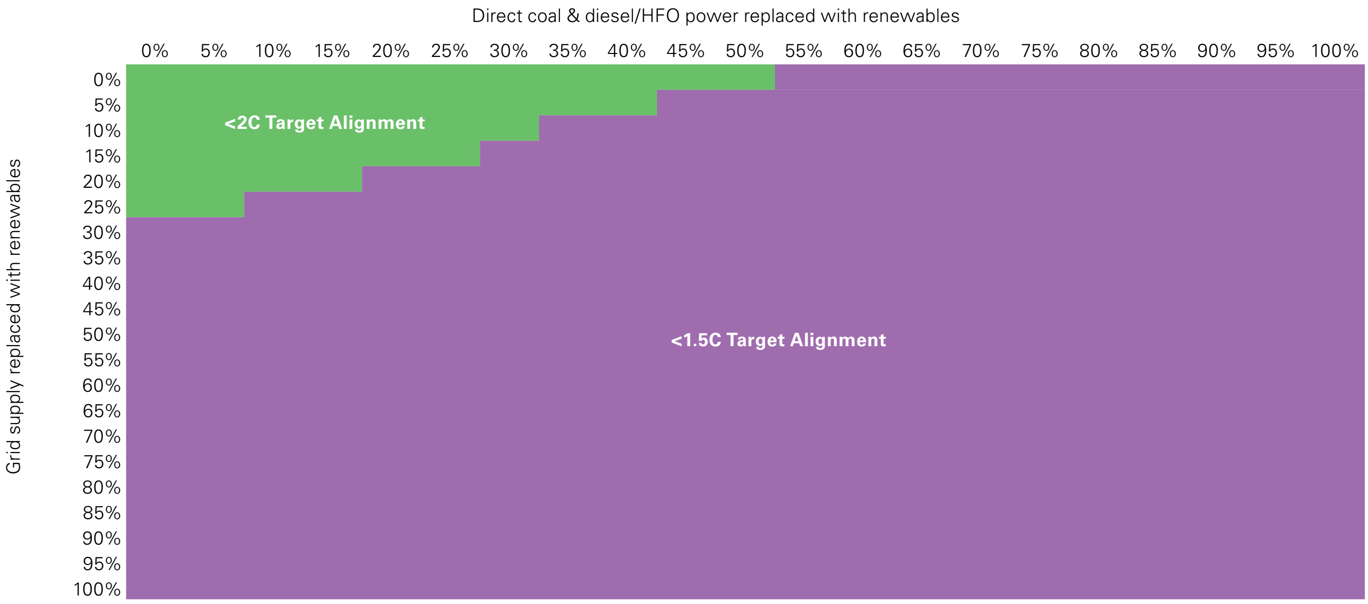
Chart 20: Replacement of direct fossil fuel-generated electricity



Source: Wood Mackenzie

- Increased use of direct renewables to partially substitute grid power or to reduce direct coal & HFO/diesel has potential for major impact

Chart 21: Replacement of grid and direct fossil fuel-generated electricity

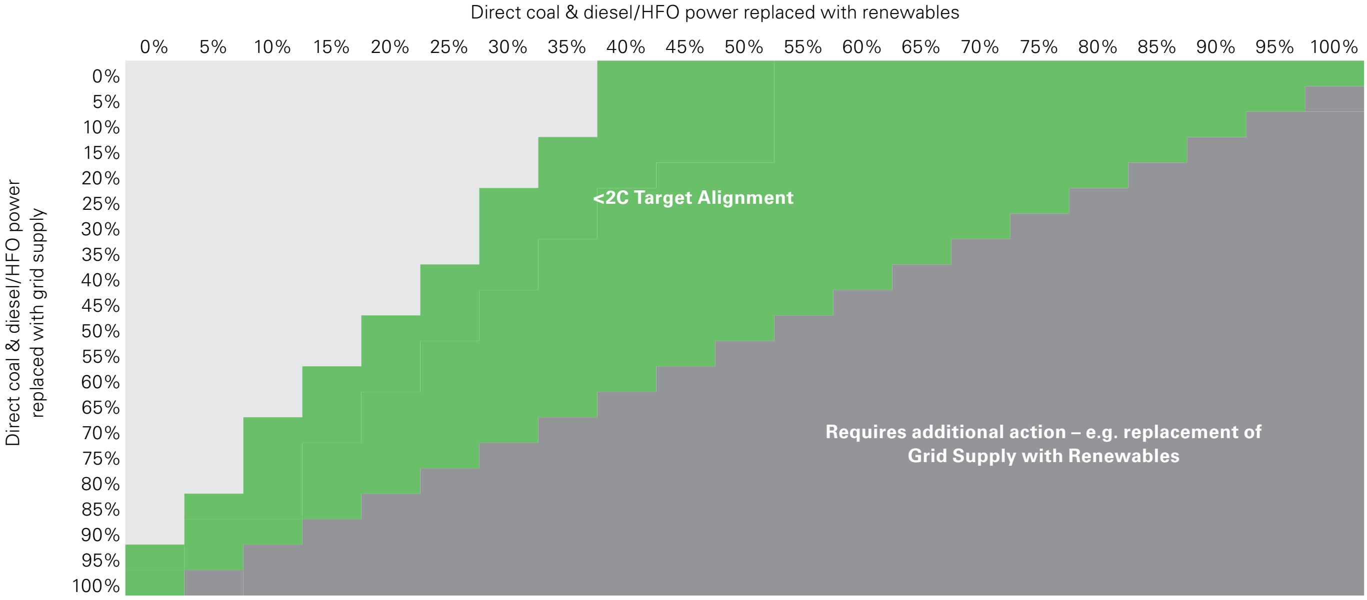


Source: Wood Mackenzie

To estimate the significance of these changes in contributing to climate target alignment, we calculated the impacts in **scenarios that exclude the expected change in the 'asset mix'.** That is, we removed any projected emissions reduction from the future closure of (or reduced production from) higher emission mines, allowing us to primarily focus on the potential impacts on climate target alignment of replacing higher-carbon power sources.

- Without emissions reduction from the expected shifts in the 'asset mix', diesel/HFO replacement alone would not be enough to meet the 1.5C targets.

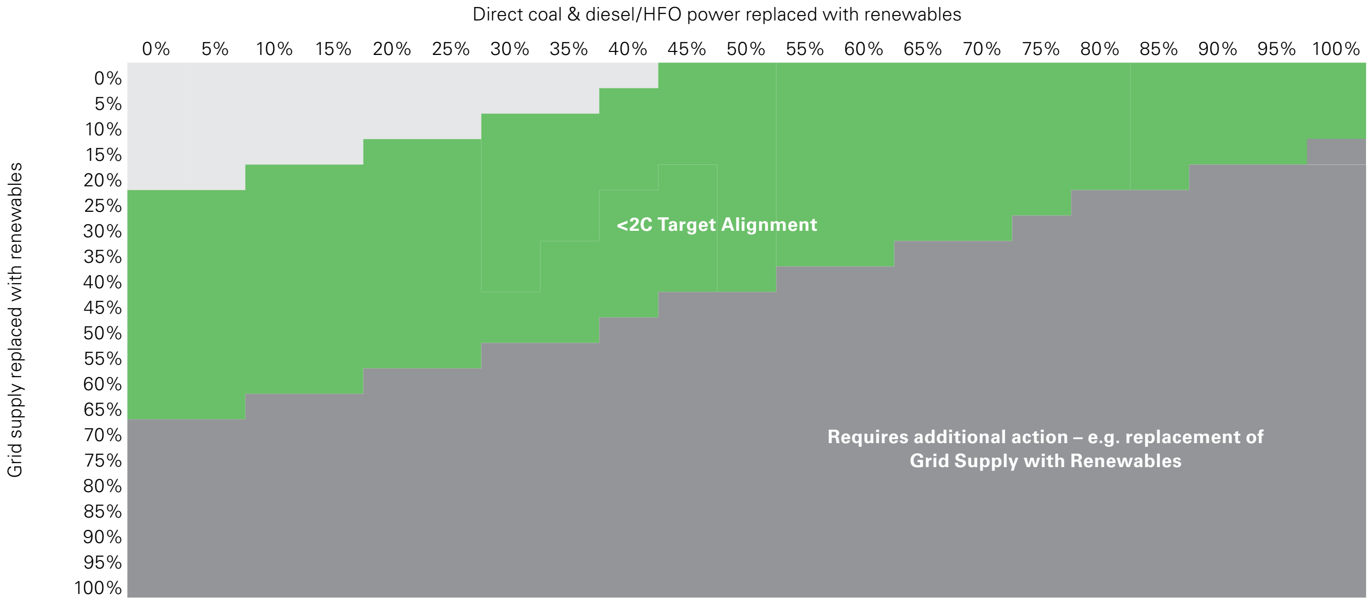
Chart 22: Replacement of direct fossil fuel-generated electricity (excluding 'asset mix' changes)



Source: Wood Mackenzie

- However, while a more substantial shift to renewables will be needed, both the <2C and 1.5 climate targets are still achievable.

Chart 23: Replacement of grid and direct fossil fuel-generated electricity (excluding 'asset mix' changes)



Source: Wood Mackenzie

In addition to the options assessed here, we acknowledge there are other opportunities to improve power-related emission, including conversion of direct natural gas generation to renewables, further net energy efficiency improvements (that outpace ore grade declines and the effects of more challenging geology) and technological advancements in production and processing. Each of these may also contribute to the gold mining's decarbonisation efforts going forward – possibly prior to 2030, but certainly in later years.

Appendix 3: Companies and mines

While not representative of the full data set used in this report, mine production and power consumption data from 158 gold mines owned by the companies listed below formed the core sample used by Wood Mackenzie in their analysis.

Companies

Agnico-Eagle Mines
Alacer Gold
Alamos Gold
AngloGold Ashanti
B2Gold
Barrick Gold Corporation
Centamin
Centerra Gold
Eldorado Gold Corp
Endeavour Mining
Evolution Mining
Gold Fields Ltd
Harmony Gold Mining
Iamgold
Kinross Gold
Kirkland Lake Gold Ltd Newcrest Mining
Newmont Mining
Northern Star Resources
Oceana Gold
Pan American Silver
Polymetal
Polyus
Pretium Resources
Regis Resources
Saracen
Sibanye Gold
SSR Mining
St Barbara Limited
Yamana Gold

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World Gold Council
7th Floor, 15 Fetter Lane
London EC4A 1BW
United Kingdom

T +44 20 7826 4700
F +44 20 7826 4799
W www.gold.org

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