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Briefing Paper

The Case for a Coal Mine Moratorium:

Reserves within existing mines versus the carbon budget

Reuben Finighan
University of Melbourne

Executive Summary

In August 2015, the President of Kiribati proposed a global moratorium on new coal mines as a necessary step to limit global warming to 2°C. In the months that followed, the two largest economies and largest coal producers in the world—China and the U.S.— implemented three-year moratoriums. Does the data on coal reserves support the extension of this moratorium worldwide? Put another way, are existing mine reserves large enough to exceed the global carbon budget, or can the world safely build more coal mines?

This paper presents a novel analysis of reserves in existing mines to answer this question. The key findings are:

- **Data on coal reserves in existing mines is extremely poor quality, presenting a significant risk to global economic stability and the climate.** Surprisingly, the world's premier energy organisations provide almost no data on existing mine reserves, despite their critical implications for limiting global warming to 2°C and for limiting overinvestment in fossil fuel assets—which Citigroup estimates may cost US$100 trillion to 2050.
- **The world's "coal budget" requires that it consume only 85 to 145 billion tonnes of coal from 2016-2050, if it is to limit warming to 2°C.** McGlade & Ekins (2015) calculate the coal budget from the carbon budget, adjusting for modelled consumption of oil and gas. Whether the coal budget is closer to 85 or 145 billion tonnes depends upon the rate of improvement in the carbon capture and storage (CCS) technology and economics, which remains highly uncertain.
- **Under the moratorium scenario, where coal can only be extracted from existing mines, coal consumption to 2050 can be contained to around 126 billion tonnes—around the middle of the safe range.** Existing mines hold an estimated 150 billion tonnes of coal, of which 126 billion tonnes will be consumed by 2050. Depending on CCS technology, this may be compatible with limiting global warming to 2°C.
- **Under the IEA's business-as-usual scenario, four times the available coal budget is consumed over 2016-2050.** This figure falls to around 2.5 times the amount allowable assuming the most optimistic CCS case. Even minor business-as-usual expansions in coal mining are therefore incompatible with restraining global warming.

The world's governments, energy organisations and companies should commit to improving the quality and availability of data on existing mine reserves. If the estimates in this paper prove high, then there may be some room to construct additional mines; if they prove low, then existing mines will need early closure. Progress on CCS will be equally important for determining allowable coal consumption, and should be regularly and conservatively assessed. Global coal market segmentation is another crucial input to account for in future assessments of existing mine reserves.

Until such analyses are forthcoming, it is prudent to extend the U.S. and Chinese temporary coal mine moratorium worldwide. Detailed surveys of existing mine reserves and CCS progress can easily be completed by 2020, at which point the international community will be better able to assess whether a permanent moratorium is necessary to secure the twin goals of global financial stability and global warming limited to 2°C.

1. Coal Reserves in Existing Mines: The Moratorium Reserve

Kiribati's proposal for a global moratorium on new coal mines has received growing attention in recent months, as a potentially transformative policy in the effort to limit global warming to 2 degrees Celsius. The proposal has been welcomed by figures from the UK's Lord Nicholas Stern to the former Governor of the Reserve Bank of Australia, and has been followed by policy change in the U.S. and China—both governments have placed 3-year moratoriums on new coal mines.[1]

The notion of a coal mine moratorium is in part a response to mounting evidence that an immense carbon bubble threatens governments' climate goals and the stability of the global financial system. The fossil fuel holdings of private companies are vastly in excess of the global carbon budget, and yet this "unburnable carbon" continues to be included in company valuations. Failing to stem the growth of this bubble carries two risks: first, that the world will fail to limit global warming to safe levels, and second, that it will face a fossil fuel-induced financial crisis that could dwarf that triggered by the U.S. housing bubble—with Citigroup estimating potential costs as high as US$100 trillion to 2050.[2]

The proposed coal mine moratorium would prevent the construction of *new* mines, and major *expansions* of existing mines, across the globe. Those mining operations already active would be allowed to continue. Potential coal consumption under the moratorium scenario would therefore be capped around the size of economic reserves within mines already operating today. There may be some small changes in reserve size with changing economics, but given the moratorium would prevent significant expansions of existing mines these are assumed unimportant.[3] Under business-as-usual (BAU), in contrast, coal consumption is capped only by the total amount of coal that may ever be economically recoverable. The difference between these two scenarios is the volume of coal that a moratorium on new mines could prevent from being consumed.

This paper is an evaluation of the carbon impacts of the proposed moratorium. It is concerned with two questions:

- What proportion of the world's "proved economic" coal reserves, at the time of writing, are in existing mines?
- What are the effects of a coal mine moratorium versus BAU on the odds of keeping within the carbon budget and limiting climate change to 2°C?

1.1 The Missing Data

In seeking to answer these questions we immediately encounter a problem: data quality on coal reserves is poor. Even data on today's total global "proved economically recoverable" coal reserves, where there are at least figures available for all major coal mining countries, are plagued by a range of anomalies. There is extreme unexplained variation in some countries' reserve reports (some changes on the order of 99% year-to-year), some countries fail to regularly update their reserves (World Energy Council figures for the world's largest coal producer, China, have not been updated since 1992),[4] and more detailed geological surveys in the U.S. have cast doubt upon the economic viability of as much as 90% of reserves labelled as "proved economic" (with other country data likely of lower quality still).[5] Nonetheless, the World Energy Council produces a widely accepted figure: there are an estimated 869 gigatonnes (billion tonnes, "Gt") of proved recoverable coal.[6]

Data on coal reserves in *existing* mines, arguably more important given the direct implications for the world's chances of staying within the carbon budget, is poorer still. Only the U.S. publicly provides an aggregate figure on coal reserves in active mines, and only scraps of data on other countries are available. Given how crucial information about existing mine reserves is to preventing overinvestment in potentially stranded coal assets, and overshoot of the carbon budget into dangerous global warming, this is a serious oversight in international planning of the response to climate change.

1.2 Estimating coal reserves in existing mines

This section undertakes a novel analysis of coal reserves within the world's existing mines. Two methods are used to estimate existing mine reserves:

- Method 1 extrapolates from the ratio of total reserves to existing mine reserves within five countries that hold around 50% of the world's coal. This method produces an estimate of 140 Gt of coal reserves in existing mines.
- Method 2 draws on present mine production rates and estimates of remaining mine life, especially relying on higher-quality data from the U.S. It produces an estimate of 150 Gt of coal reserves in existing mines.

The latter figure is emphasised due to advantages in the approach and especially source data quality, as it uses well-studied production rates rather than questionable reserve figures that often leads to comparing apples to oranges. Regardless, with only a 7% difference between the methods there is little material effect upon the conclusions of the paper. Using Method 2 and the model of decline of coal production detailed below, around 126 Gt of coal is consumed by 2050.

Method 1: Estimating existing mine reserves using available country-level data

The U.S. has the largest proved recoverable reserves in the world, at 257 Gt, or close to 30% of the world total. The U.S. Energy Information Administration (EIA) reports that some 19.7 Gt, or just 7.7% of U.S. recoverable reserves, are in actively producing mines.[7] This is unsurprising: there is only sufficient demand for coal to justify mining a small part of the entire U.S. coal reserve at any given moment.

Scraps of data available from other countries provide higher estimates of the proportion in active mines: in Australia, 22 Gt of a total 124 Gt (17.8%) are in active mines;[8] in Poland, 5 Gt[9] of a total 20 Gt[10] (25%) are in active mines; in South Africa, 7.8 Gt[11] of a total 30.2 Gt[12] (25.8%) are in active mines; and in Ukraine, 6.1 Gt of a total 34 Gt[13] (17.9%) are in active mines. Figures from the latter four countries provide an average proportion in existing mines of 19.6%.

Together Australia, Poland, South Africa, Ukraine and the U.S. account for around half of the world's economic coal reserves, and according to the assembled data around 13% of these reserves sit within existing mines. If this figure were extended to the world, around 113 Gt of global coal reserves would sit within existing mines. However, the U.S. is almost certainly an outlier with a low proportion of total reserves in existing mines compared to other countries: it has around 30% of the world's total coal reserves, but only around 13% of the world's coal production. If other countries around the world look more like Australia, Poland, South Africa and Ukraine—if we apply the rate of 19.6% to the remaining 404 Gt of proved reserves outside of the five countries examined—then we would expect around 16.1% of global reserves to sit within existing mines, or 140 Gt.

Method 2: Using current mine production and estimated mine life

World coal production from existing mines was 7.5 Gt in 2014. If the world were to restrict production to these mines alone, as per the proposed moratorium, how long would we expect them to produce at this rate—and how much would they therefore produce over this lifespan?

The remaining life of existing mines is estimated from two sources of data, both of which point to around 20 years:

- first, the imputed average lifespan for US producing mines today, given current production rates and remaining economic reserves at producing mines. Active US mines produced approximately

1 Gt of coal in 2014 from the active mine reserve of 19.7 Gt,[14] hence in 2014 the US had 19.7 years left at then rates of extraction; and

- second, industry data on coal mine lifespan. Based on a range of data sources, the average remaining life of currently producing mines agrees with the U.S. estimate of around 20 years.[15]

How much coal sits within existing mines globally using this estimate? With an existing mine capacity of 7.5 Gt and an average mine life of 20 years, there are an estimated 150 Gt of reserves in currently active mines—or around 17.2% of the global total of economically recoverable reserves. These values are consistent with the previous extrapolation from the existing/total ratio, with countries outside the U.S. indeed looking more similar to Australia, Poland, South Africa, and Ukraine in terms of this ratio.

Modelling the moratorium into the future with a 5% p.a. decline in coal production,[16] I estimate that the production rate falls to half today's level by 2030, so that around 126 Gt of coal is consumed by 2050.

2. The Coal Budget: Moratorium vs. Business-As-Usual

How much coal would the moratorium would prevent from being burned, and is this sufficient to keep the world within the "coal budget"? The answer depends upon the timeframe used in the analysis, and this paper compares the moratorium to the BAU scenario under two timeframes:

1. first, the period to 2050. Here I use the widely accepted IEA Current Policies model of 1.7% p.a. growth in coal consumption to 2035, and extend this with zero growth for the next fifteen years, to provide a baseline estimate of coal consumption to 2050;[17] and
2. using proved recoverable resources—869 Gt according to The World Energy Council—as the upper limit on consumption, all of which could conceivably be consumed on the long-run in the absence of policy action.[18]

Coal consumption and related emissions

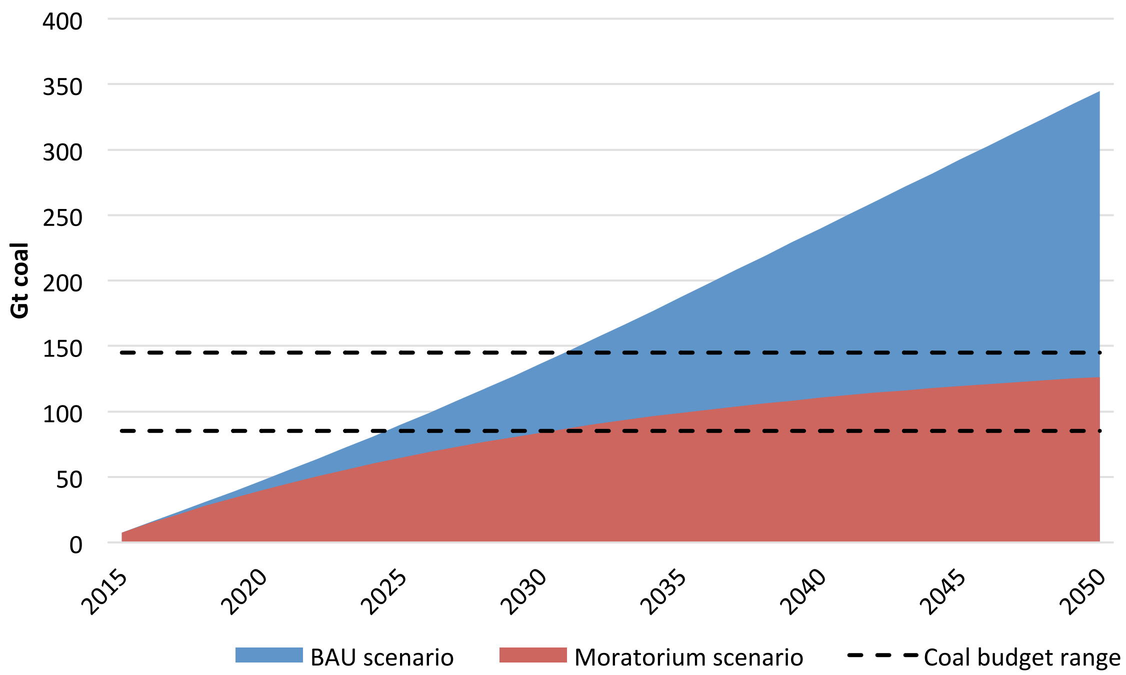
Under BAU some 345 Gt of coal are combusted to 2050, compared to 126 Gt under the moratorium condition. The moratorium therefore saves 219 Gt of coal consumption to 2050. In the proved recoverable reserves model, all 869 Gt of proved recoverable reserves are eventually consumed, and the moratorium on coal mining would prevent the combustion of as much as 719 Gt of coal.

Looking at carbon emissions to 2050, with 126 Gt of coal burned under the moratorium scenario, around 240 Gt of CO_2 is released into the atmosphere.[19] The moratorium would, however, prevent the combustion of 219 Gt of coal, saving around 415 Gt of CO_2. Looking at carbon emissions on the long-run, if we assume that up to 150 Gt of coal will be burned under the moratorium scenario, then up to 285 Gt of CO_2 will be released. In this case the moratorium would prevent the combustion of the remaining 719 Gt of proved reserves, saving a further 1,365 Gt of CO_2.

Coal consumption and the "coal budget"

The total carbon budget over the 2011-2050 period is around 1,100 Gt of CO_2-equivalent. In order to stay within this budget, McGlade & Ekins (2015) calculate a "coal budget"—the amount of coal reserves that are burnable, taking into account probable consumption of gas and oil resources (which also use up the carbon budget). The budget from 2011-2050 is 120 Gt of coal.[20] This amount must be reduced, however, to account for the five years of coal production from 2011-2015, with around 35 Gt of the coal budget consumed over this period.[21] The remaining coal budget for 2016-2050 is therefore 85 Gt. Finally, McGlade & Ekins (2015) make some room for the possibility that CCS technology may increase the amount of burnable coal, and this increases the coal budget by at most 60 Gt. Under the most optimistic CCS scenario a total of 145 Gt may be consumed over 2016-2050.

Figure 1. Cumulative coal consumption in BAU and moratorium scenarios compared to the "coal budget", 2016-2050



The moratorium scenario, in which an estimated 126 Gt is mined to 2050, sits close to halfway between these two scenarios and may therefore restrict coal-related emissions enough to limit global warming to 2°C or below—if CCS proves modestly successful (see Figure 1). In the case that CCS is highly successful, coal mining may be increased modestly, whereas if technical and economic roadblocks continue to render CCS unviable at scale, the moratorium will be insufficient to contain coal consumption to a 2°C-consistent scenario and some mines will need to be closed before they have completed extraction. The most probable outcome is that CCS is viable for a modest subset of existing mines. As such, on the medium term the moratorium pathway is a prudent middle road, reducing the costs of responding as the uncertainty on CCS is gradually resolved.

3. Conclusion

Leading international energy analysis organisations do not provide even basic data on the size of coal reserves within the world's mines today. The lack of such data is inconsistent with the international consensus on restricting climate change to 2°C, and makes rational planning of coal consumption difficult, if not impossible. At present, the risk is concentrated on the side of over-production and over-investment: coal mining appears extremely likely to exceed the levels of production allowable under the 2°C carbon budget (and associated coal budget), and the resulting over-investment may cause as much as US$100 trillion in financial turmoil to 2050.[22]

The analysis of existing mine reserves within this paper suggests that a moratorium would limit coal consumption to 2050 to within the range allowable within the coal budget. The analysis suggests two policy priorities:

The first is to implement coordinated policies across the world that equitably and efficiently restrict future coal extraction to between 85-145 Gt, depending on CCS performance, with a mid-range figure acceptable as a short-medium term target while information improves. By limiting coal production to 126 Gt to 2050, the proposed moratorium on new mines is one such policy consistent with this challenge.[23]

The second priority is for governments, energy organisations and companies to ground the analyses contained within this paper with hard data on actual mine reserves across all major mining countries. As this work proceeds, we may learn that the job is either bigger or smaller than this analysis suggests. In the meantime, prudence suggests that a temporary moratorium—with the U.S. and Chinese three-year coal mine moratoriums as two examples—should be in place until information improves. By 2020, the international community should aim to assess whether a permanent moratorium is necessary to meet its climate commitments.

Summary of Estimates: Effect of a moratorium compared to business-as-usual	
Q1: Have what effect on global coal prices?	Short-term prices will be unaffected due to current extreme oversupply, while medium to long-term prices will increase until they are capped by competition with gas and renewable energy sources.
Q2: Leave how much land undisturbed, and prevent how much deforestation?	Around 7.6 million acres of land saved to 2050 (around the size of Belgium), and an estimated 9.7 billion tonnes of forest and soil carbon emissions to 2050—equivalent to the carbon sequestered in around 15 billion trees.
Q3: Have what impact on existing coal mining jobs?	Increase mining job security on the short-medium term, given existing mines will become extremely valuable and cease closing down. The industry will then gradually shrink, halving by 2030, providing ample time to reskill workers.
Q4: Save how much in avoided capital investment?	At least US$110 billion in savings, and as much as US$378 billion, to meet demand to 2035.
Q5: Prevent how many lives lost from coal-associated pollution?	Approximately 10 million coal-related deaths, principally from air pollution, would be prevented to 2050.
Q6: Save how many tonnes of water from being wasted annually?	A total between 550 billion to 1.1 trillion cubic meters by 2050. At this point annual savings would be between 23 to 50 billion cubic meters, enough to meet the basic needs of 1 to 2.5 billion people.
Q7: Save how much money in environmental clean-up costs of coal mines?	Approximately US$80 billion to 2050.
Q8: Withdrawing oil subsidies, including untaxed externalities, would provide enough money to spend on what?	US$1.1 trillion in fiscal gains would be enough to eradicate extreme poverty with a US$2 per day basic income to the world's poorest billion, and provide the 3.5 billion people who live in low-income countries with basic medical care, basic maternal and newborn services (saving 300,000 mothers each year), and universal, quality pre-school, primary and secondary education—with US$165 billion spare.

This paper responds to a Greenpeace request for approximations of moratorium-related impacts on a range of issues: jobs, land disturbance, coal prices, water consumption, capital investment, and health. It also examines the global fiscal gain from removing oil subsidies (including externalities), and potential avenues for spending this gain. Note that the coal analysis draws upon a deeper study of coal reserves—both total economic reserves and the proportion of these reserves that sit within existing mines—in Finighan (2016).[1] The analysis in Finighan (2016) is not discussed here, but specific results are used:

- Under a moratorium scenario, 126 Gt of coal would be mined from 2016-2050, and as much as 150 Gt on the long-run. Compared to the business-as-usual scenario, a moratorium would prevent an estimated 219 billion tonnes of coal being consumed by 2050 and as much as 719 Gt on the long run.
- Emissions associated with the moratorium scenario are 240 Gt of CO_2 to 2050, and 285 Gt on the long-run. Compared to business-as-usual, the moratorium would save an estimated 415 billion tonnes of CO_2 by 2050, and as much as 1,365 billion tonnes on the long run.

- While business-as-usual would fill the carbon budget for coal 2.5 to 4 times over by 2050, the moratorium is exactly in the middle of the range predicted to restrict warming to 2°C—with the success of carbon capture and storage technology important for determining whether the lower or upper part of that range is more appropriate.

Q1: How will global coal prices be affected by a moratorium?

A1: International coal markets are in a state of extreme oversupply. The moratorium would have little short-term impact on the international price for coal, given the short-term effects of the moratorium on supply are modest. Share prices for companies operating existing mines would soar, in anticipation of future profits in a low-competition market, and current job losses in coal mining would reverse. On the medium to long term, prices will increase steadily until they are capped by competition with gas and renewable energy resources.

Global coal prices today are at extreme lows due to a glut of supply and lower than expected demand, especially from China. Two thirds of global coal output is made at a loss at current international prices, which sit at around US$55.[1] This compared to highs of around US$140 in 2011, which brought about a surge in coal mining investment.

Given these conditions, the short-term effects of a moratorium on the price for coal would be modest, given the short-term effect of the moratorium on supply would also be modest (so long as speculative hoarding could be prevented in the same way that it is restricted in oil markets). However, the share prices of companies with active mines would immediately increase sharply from their current lows, in anticipation of secure future profits in a low-competition market. This may be sufficient to win the support of incumbent coal mining companies, some of which stand to gain substantially under a moratorium.[1]

On the medium term, prices would increase to, or climb above, the long-term trend. Such increases will be capped, however, by competition with energy sources like gas, wind and solar. If the cost of coal power increases above these alternatives, then demand for power from coal will decline and pressure on prices will be reduced. The price of coal power will therefore tend to stabilise around the price of alternatives.

Q2: How much land would be undisturbed, and forest/soil-related emissions prevented, under a moratorium?

A2: A moratorium would save around 7.6 million acres of land from being disturbed by 2050 (around the area of Belgium), and up to around 20 million acres on the long run (more than the combined area of the Netherlands and Belgium). It would save an estimated 9.7 billion tonnes of forest and soil carbon emissions to 2050, or as much as 32 billion tonnes on the long-run, equivalent to the carbon sequestered in around 15 billion and 50 billion trees respectively.

Based on US data, it is estimated that 35 acres are disturbed per million tonnes mined.[1] At this rate of land disturbance, under the moratorium up to 5.25 million acres of land will be disturbed—an area around 360 times the size of Manhattan). Mining all proved recoverable reserves would disturb as much as 25.2 million acres. The moratorium would therefore save up to around 20 million acres of land from being disturbed—more than the combined area of the Netherlands and Belgium.

Epstein et al. (2010) estimate the deforestation impact of coal mining in forested areas and find that it adds between 7% and 17% to total lifecycle emissions.[1] Using the lower figure of 7%, this would add around 20 Gt of CO_2 to the moratorium scenario, and the moratorium would save 96 Gt of CO_2 relative to the proved economic reserves scenario.[1] If we assume that only 30% of coal mining land is forested as per the global land average,[1] then these figures fall to 7 Gt of CO_2 under the moratorium scenario, saving 32 Gt of CO_2.

How many trees does this equal? From Tufts University, take the average CO_2-release potential of a tree as 0.64 tonne.[1] This means that the moratorium scenario emissions are equal to 10.4 billion trees worth of forest-associated emissions, or 455 billion trees worth of emissions over the total coal lifecycle. The moratorium saves the equivalent of 50 billion trees of forest-associated emissions under the proved economic reserves scenario, and around 2 trillion trees of emissions if we include the complete coal lifecycle. There are only 3 trillion trees in the world today, hence we would need another planet if we wished to plant enough trees to sequester this carbon.

Q3: What impact would a moratorium have on existing coal mining jobs?

A3: The moratorium would have a positive impact on security of work in coal mining on the short-medium term. Existing mines will be high-value under the moratorium and will operate until their resources are exhausted. The reduction of industry size on the long-term will be gradual and predictable, halfway completed by 2030, providing ample time for reskilling workers that are not past retirement age.

Employment in the coal industry is currently in decline. Many mines are closing or shrinking under difficult market conditions that have seen the world's largest coal company, Peabody Energy, lose 95% of its share value over 12 months.[1] In the U.S. alone, some 27,000 coal miners have lost their jobs since 2009.[1] On the short-term, the moratorium would paradoxically halt this decline and increase the value of existing mines and their holding companies to an all-time high level. On the medium-term, however, without new mines or mine expansions there would be a steady decline in jobs available in the coal industry. Under the model estimated, around half of positions disappear by 2030.[1]

With a long lead time and a gradual, predictable reduction in size of the coal industry of around 5% per annum, the task of reskilling and transitioning workers to other industries is manageable. Companies holding existing mines that experience supernormal profits due to the moratorium could be required to invest some of that unearned windfall into reskilling workers.

Q4: How much capital investment would be avoided under a moratorium?

A4: A moratorium would save at least US$110 billion, and as much as US$378 billion, in capital expenditure to meet demand to 2035.

The Carbon Tracker Initiative (2014) predicts up to US$488 billion in total capital expenditure on both new and existing mines to 2025, in order to meet demand to 2035.[1] Of this, US$268 billion is expended on new mines and US$220 billion on existing mines. The latter figure can be further broken down into approximately two halves of US$110 billion,[1] one for sustaining existing mining operations and one for major expansions at existing mines. Notably, CTI predicts that under the persistent low demand scenario—the most likely given the decline in Chinese coal consumption—that extensions of existing mines will be sufficient to requirements.[1]

A moratorium that prevented major expansions of existing mines would therefore require expenditure of approximately US$110 billion to sustain operations. It would prevent at least another US$110 billion in the expansion of existing mines, and as much as US$378 billion if new mines under high-demand scenarios are avoided.

Q5: How many lost lives due to coal-associated pollution would be prevented under a moratorium?

A5: A global coal moratorium would prevent approximately 10 million coal-related deaths to 2050, mainly from reduced air pollution.

Markandya & Wilkinson (2007) calculate that there are 24.5 coal-associated deaths per TWh of power generated in the U.S.[1] Based on these figures and coal consumption, Lockwood et al. (2009) estimate that around 50,000 deaths in the U.S. each year are attributable to coal.[1] In China, meanwhile, air pollution in the form of particulate matter less than 2.5 microns in size (known as $PM_{2.5}$) causes an estimated 1.6 million deaths per year—not from coal alone, although coal is the principal contributor.[1]

Conservatively, let us assume that coal emissions cause one million deaths per year globally. These deaths are associated with the 7.5 Gt of coal that is mined and consumed each year, giving an estimate of around 133,000 deaths per gigatonne of coal. By keeping 719 Gt of recoverable coal in the ground, the moratorium would prevent as many as 96 million deaths. However, we can expect technology improvements that will reduce the death rate associated with coal over time. I assume a rapid 5% compound reduction in the death rate per annum. Under these assumptions, and using the IEA's 2013 "Current Policies" scenario as the business-as-usual case,[1] a moratorium would prevent approximately 10 million coal-associated deaths by 2050.

Q6: How many tonnes of water would be saved annually under a moratorium?

A6: The moratorium would save 550 billion to 1.1 trillion cubic meters by 2050. It would save between 23 billion and 50 billion cubic meters each year by 2050, relative to the business-as-usual scenario, enough to meet the basic needs of 1-2.5 billion people.

Greenpeace analysis finds that around 19 billion cubic meters of water are consumed annually by coal power stations—enough to meet the basic needs of more than one billion people.[1] Relative to the IEA's "Current Policies" condition, declining coal use under the moratorium condition means that around 23 billion cubic meters are saved each year by 2050. Over the years from 2016-2050, the moratorium would save more than 550 billion cubic meters of water.

Greenpeace figures are on the conservative end: the IEA reports coal power station water consumption of as much as 40 billion cubic meters annually,[1] in which case a moratorium would save around 50 billion cubic meters every year (enough to meet the basic needs of around 2.5 billion people) by 2050. Total water saved from 2016-2050 would be more than 1.1 trillion cubic meters.

Q7: How much money in environmental clean-up costs would be saved under a moratorium?

A7: The moratorium would save US$80 billion in the environmental clean-up costs of coal mines.

Using The Australia Institute's estimate of US$0.38 in remediation costs per tonne of coal extracted,[1] the moratorium would save over US$80 billion compared to the current policies scenario by 2050.

Q8: If subsidies were taken out of the oil industry globally as of 2017, what could we spend that money on?

A8: Removing global subsidies, including untaxed externalities, from the oil industry globally would provide US$1.1 trillion of annual fiscal gains—enough money to eliminate extreme poverty completely with a US$2 per day basic income to the poorest billion, to provide the 3.5 billion people who live in poor countries with basic medical care, basic maternal and newborn services (saving 300,000 mothers each year), and universal, quality pre-school, primary and secondary education, with US$165 billion spare.

The IMF calculates that post-tax oil industry subsidies, including externalities, are around US$1.5 trillion per year.[1] Eliminating these subsidies through taxation would generate an estimated fiscal gain of around US$1.1 trillion every year (smaller than the full post-tax subsidies given internalising these costs through taxation would modestly reduce demand). This could pay for:

- well over the amount needed to eliminate extreme poverty. For US$730 billion we could pay a basic income of US$2 a day (above the US$1.90 per day that is considered the international extreme poverty line) to the one billion people that live in extreme poverty, increasing their incomes by well over double;[1]
- more than seven times the US$154 billion needed to provide basic, life-saving medical care for the 3.5 billion people who live in low and low-middle income countries—half the world's population;[1]
- around 100 times the amount needed to provide basic maternal and newborn services in those same low and low-middle income countries. About US$12 billion could reduce maternal mortality by 70% (saving the lives of more than 300,000 mothers each year);[1] and
- more than 28 times the amount—US$39 billion—needed to provide universal and good quality pre-school, primary, and secondary education in low and lower-middle income countries.[1]

In fact, the US$1.1 trillion could pay for ***all of the above***, with US$165 billion left over every year.

This is a big amount of money in wealthy countries too—in just over a single year, it could wipe out all existing U.S. university student debts.[1] It would take less than another year to eliminate all student debt in the world.

[1] The U.S. moratorium is restricted to federal land leases, which contribute around 40% of coal production.
[2] See Citi GPS (2015) 'Energy Darwinism II', Citigroup. Available at: https://www.citivelocity.com/citigps/
[3] With some movement in "reserves" expected as the economics of coal evolves over time, given mineral reserves are more an economic than a geological concept.
[4] World Energy Council (2013) 'World Energy Resources: 2013 Survey', Chapter 1: Coal.
[5] In 2007, the National Resource Council argued that "Present estimates of coal reserves are based upon methods that have not been reviewed or revised since their inception in 1974… updated methods indicate that only a small fraction of previously estimated reserves are economically recoverable." See National Research Council (2007) 'Coal: Research and Development to Support National Energy Policy', National Academic Press. Available at: http://www.nap.edu/read/11977/chapter/2. The US Geological Survey (USGS) examined the most productive coalfield in the world, the Gillette coalfield in Wyoming, and found that economically recoverable reserves constituted only 6% of the total resource—a significant downward revision. See Luppens, JA, Scott, DC, Haacke, JE, Osmonson, LM, Rohrbacher, TJ & Ellis, MS (2008) 'Assessment of Coal Geology, Resources, and Reserves in the Gillette Coalfield, Powder River Basin, Wyoming', U.S. Geological Survey Open-File Report 2008-1202.
[6] World Energy Council (2013) 'World Energy Resources: 2013 Survey', Chapter 1: Coal.
[7] Energy Information Administration (2015) 'How large are U.S. coal reserves?', U.S. Department of Energy, U.S. Government. Available at: 'http://www.eia.gov/tools/faqs/faq.cfm?id=70&t=2
[8] Geoscience Australia (2015) 'Australia's Identified Mineral Resources: Table 1', Australian Government, Canberra. Available at: http://www.ga.gov.au/scientific-topics/minerals/table1 Note that JORC ore reserves are analogous to reserves in existing mines, although these figures may be overstated due to inclusion of "probable" reserves at existing mines. Brown coal JORC reserves are unrecorded, but the same ratio of production to existing mine reserves is assumed for brown coal as for black coal.
[9] World Energy Council (2013) 'World Energy Resources: 2013 Survey', Chapter 1: Coal.
[10] Euracoal (2015) 'Country Profiles: Poland'. Available at: http://euracoal.eu/info/country-profiles/poland/
[11] Osborne, D (2013) *The Coal Handbook: Towards Cleaner Production: Coal Utilisation,* Vol. 2, Elsevier, p.112.
[12] World Energy Council (2013) 'World Energy Resources: 2013 Survey', Chapter 1: Coal.
[13] Osborne, D (2013) *The Coal Handbook: Towards Cleaner Production: Coal Utilisation,* Vol. 2, Elsevier, p.115.
[14] EIA (2015) 'Quarterly Coal Report, July-September 2015', US Department of Energy, Washington, D.C.
[15] The lifespan for a typical coal mine ranges from 10 to 40 years, with estimates tending towards thirty years. Given the progressive increase in global coal production, the analysis assumes that the average producing mine is only one third through that 30-year lifespan (more mines have been newly constructed than are near retirement). Mine lifespan is confirmed across a range of resources: Galvin, J (2016) *Ground Engineering-Principles and Practices for Underground Coal Mining*, Springer; U.S. Department of the Interior (1979), *Proposed development of coal resources in the Eastern Powder River*, Volume 1, U.S. Government; U.S. Office of Technology Assessment (1984) *Environmental Protection in the Federal Coal Leasing Program*, OTA-E-237, U.S. Government, Washington D.C.; expected mine life of ~20 in the Hunter Valley, a major coal mining region in New South Wales, Australia (with Australia one of the world's major coal mining centers): Booz and Co. (2009) 'Mine Life Assessment – Hunter Valley Region', for the Australian Rail Track Corporation; and EIA (1996) 'U.S. Coal Reserves: A Review and Update', US Department of Energy, Washington, D.C.
[16] With a 20-year average lifespan, roughly one in twenty—or 5%—of existing mines shut down in a given year. The resulting curve reflects that the distribution of mine lifespan is known to be positively skewed by a small number of very long-lived mines.
[17] IEA(2013) 'World Energy Outlook 2013'. Available at: https://www.iea.org/publications/freepublications/publication/WEO2013.pdf
[18] Analyses like Rutledge, D (2011) 'Estimating long-term world coal production with logit and probit transforms' *International Journal of Coal Geology*, 85(1), pp.23-33, find that this is an unlikely scenario, although under BAU the amount of coal consumed still vastly exceeds the McGlade & Ekins (2015) carbon budget for coal.

[19] The World Energy Council reports that 45% of proved reserves are bituminous coal, 32% sub-bituminous, and 23% lignite (each with different emissions factors), and for the purpose of this analysis it is assumed that reserves within existing mines are found in the same ratio. See World Energy Council (2013) 'World Energy Resources: 2013 Survey', Chapter 1: Coal.

[20] Our estimates of the total coal resource differ (this paper uses more recent updates from the World Energy Council than do McGlade & Ekins, 2015), but the amount that can be burned within the carbon budget does not change.

[21] Using WEC figures for 2011 consumption—around 7.5 Gt per annum—and conservatively adjusting for the small decline noted in recent years. See World Energy Council (2013) 'World Energy Resources: 2013 Survey', Chapter 1: Coal.

[22] See Citi GPS (2015) 'Energy Darwinism II', Citigroup. Available at: https://www.citivelocity.com/citigps/

[23] An economically ideal moratorium would allow a new, efficient mine to open if it were accompanied by an equal closure of a less efficient mine. This may assist transfer of mining operations from countries where coal can be cheaply replaced with alternatives to countries where it cannot be cheaply replaced (with some potential equity gains for developing countries, for example). The result would be a form of allowance trading within the specified coal budget. However, such schemes have political economic challenges that do not make them obviously more optimal than a simpler system like the proposed moratorium.