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Climate Risk and the Fossil Fuel Industry: Two Feet High and Rising

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Keywords

Climate change risk, fossil fuel, stranded assets, unburnable carbon, carbon bubble, carbon budget, divestment, carbon price, carbon tax, cap-and-trade, INDCs, COP 21, shareholder risk, leave it in the ground, greenhouse gas, GHG, decarbonization

Introduction

Burning coal, oil and natural gas is responsible for two-thirds of the world's emissions of greenhouse gases. These same fuels also represent the economic mainstay of resource-rich countries and the world's largest firms. Any steps humanity takes to reduce climate-warming emissions will damage commercial opportunities. Relief for the climate means danger for the fossil fuel business. Given the stakes, it bears asking: What, exactly, are the risks? How are they manifested and distributed?

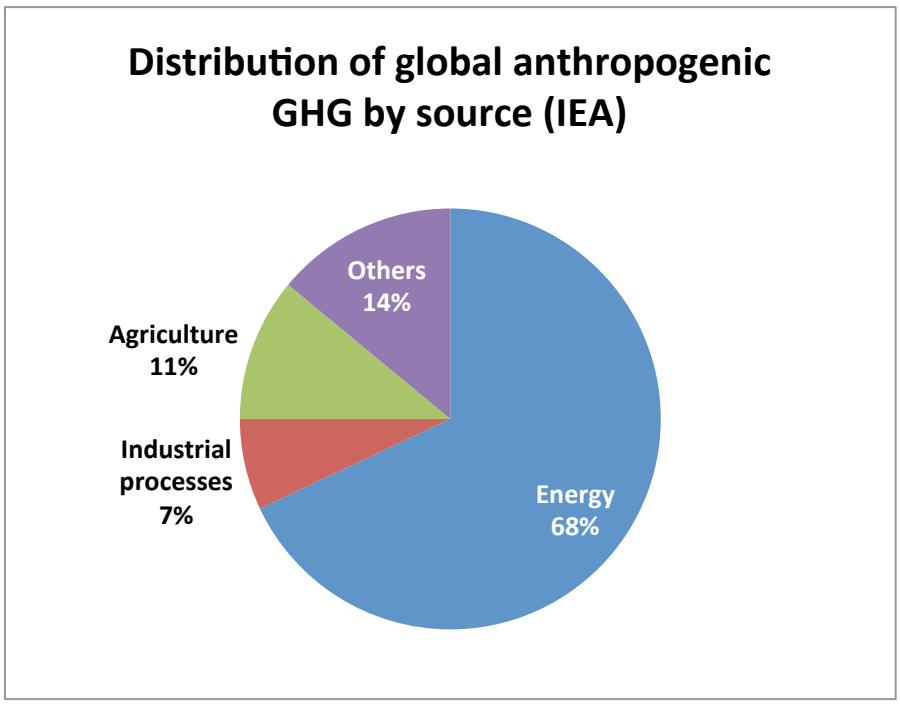
Luminaries such as the US president and the governor of the Bank of England have called for leaving large portions of oil, gas, and coal reserves in the ground. International Energy Agency director Fatih Birol has said that *two-thirds* of known fossil fuel reserves can never be burned if humanity is to prevent average global temperatures from rising by more than 2°C.[1] Pope Francis, the leader of the world's 1.2 billion Catholics, has called for "swift and unified global action" on climate change.[2] For fossil fuel businesses, such statements represent existential threats. By Citicorp's estimate, large-scale resource abandonment translates into an eye-watering $100 *trillion* in foregone fossil fuel revenues by 2050.[3]

[1] Frank McDonald, "Two-thirds of energy sector will have to be left undeveloped, Bonn conference told," *Irish Times*, June 12, 2013, http://www.irishtimes.com/news/world/europe/two-thirds-of-energy-sector-will-have-to-be-left-undeveloped-bonn-conference-told-1.1425009. Birol's statements are echoed in the International Energy Agency's World Energy Outlook 2013.

[2] Jim Yardley and Laurie Goodstein, "Pope Francis, in Sweeping Encyclical, Calls for Swift Action on Climate Change," *New York Times*, June 18, 2015, http://www.nytimes.com/2015/06/19/world/europe/pope-francis-in-sweeping-encyclical-calls-for-swift-action-on-climate-change.html.

[3] Citi GPS, "Energy Darwinism II: Why a Low Carbon Future Doesn't Have to Cost the Earth," Citicorp Global Perspectives & Solutions, August 2015.

Figure 1: Fossil fuels were responsible for two-thirds of global greenhouse gas emissions in 2010



While the consequence of these statements—and the likelihood of earth's warming lingering below the 2°C threshold—remain in doubt, it is clear that climate action will make life increasingly difficult for businesses that profit from fossil fuels. For the industry, a new set of risks has come to the fore. These range from legal and shareholder actions pertaining to big international oil companies (IOCs), government moves to block export pipelines,[4] and assessments that divide fossil fuel reserves into usable and "stranded" portions.[5]

The risk burden across the sector—for firms dealing in coal, oil, and natural gas—will not be shared uniformly. While much of the focus has been on oil companies and countries harboring large crude oil reserves, the most damaging effects have fallen upon businesses based on coal, the most polluting and carbon-intense of the fossil fuels. At the other end of the spectrum, the natural gas industry has benefited from climate action. Lower-carbon gas

[4] In his November 6, 2015 speech denying permission for the Keystone XL oil pipeline, US President Barack Obama mentioned the carbon-intensity of Canadian oil sands production and the need to keep some resources underground. https://www.whitehouse.gov/the-press-office/2015/11/06/statement-president-keystone-xl-pipeline.

[5] For instance, see: Christophe McGlade and Paul Ekins, "The geographical distribution of fossil fuels unused when limiting global warming to 2 °C," *Nature*, January 2015. Also: Carbon Tracker Initiative, "Unburnable carbon 2013: Wasted capital and stranded assets," April 2013, http://www.carbontracker.org/report/unburnable-carbon-wasted-capital-and-stranded-assets.

is widely accepted as a preferential replacement for coal and a "bridge" toward decarbonized electricity markets.

Decarbonization risks are also higher in the mature OECD economies, where abatement actions and government regulation is more common and robust. In much of the developing world, fossil fuel demand growth remains high. Governments can be expected to insulate state-owned energy businesses from some risks outlined here.

There are four main categories of climate risk for the fossil fuel industry:

- **Policy risk**: Government policies, regulations, and pledges that reduce carbon emissions; or policies that support competing technology
- **Demand risk**: Decline in global fossil fuel demand due to climate and other factors
- **Divestment risk**: Shareholder or grassroots activism that seeks to influence producer companies (and possibly countries) through financial or reputational means; or investor avoidance of fossil fuel shares
- **Competition risk**: Rivalry for market share among producers seeking to monetize reserves before they are rendered unburnable; competition between fossil and non-carbon sources of energy

Additionally, there are fuel-specific risks that are not shared equally among the three[6] fossil fuel types.

Below, this paper compiles and describes the *risk types* affecting fossil fuels. I do not attempt to measure or quantify these risks or estimate their effects on future carbon emissions or companies' balance sheets.

Policy Risk

Policy risk is a broader category for what is typically known as regulatory risk. Governments around the world, including at the subnational level, have imposed myriad restrictions on fossil fuel consumption. These involve pledges to reduce carbon emissions to a certain target, such as President Barack Obama's pledge to reduce CO_2 emissions by 26 to 28 percent below 2005 levels by 2025,[7] emissions trading schemes such as the European Union's Emissions Trading System, carbon prices and taxes. For example, British Columbia's relatively longstanding carbon tax is credited with a 13 percent reduction in per capita emissions between 2008 and 2013.[8]

[6] For purposes of simplicity, hard coal and lignite are lumped together, as are crude oil and natural gas liquids.

[7] "What is the U.S. Commitment in Paris?" Columbia University Earth Institute, December 11, 2015, http://blogs.ei.columbia.edu/2015/12/11/what-is-the-u-s-commitment-in-paris.

[8] "British Columbia/Canada," Carbon Tax Center, n.d. http://www.carbontax.org/where-carbon-is-taxed/british-columbia. Carbon taxes have also been imposed in Chile, Ireland, Sweden, and elsewhere.

In the future, policy risks for the fossil fuel sector could be globalized via the "carbon club" scheme advocated by economist William Nordhaus. Countries would align carbon policies and impose border taxes on "free riding" imports from countries where carbon is insufficiently regulated.[9]

Anti-carbon policies also include government encouragement of renewables, biofuels, and other non-fossil energy sources. For example, the governments of the United States, Canada, and Mexico each agreed in 2016 to generate half of their electricity from carbon-free sources by 2025.[10]

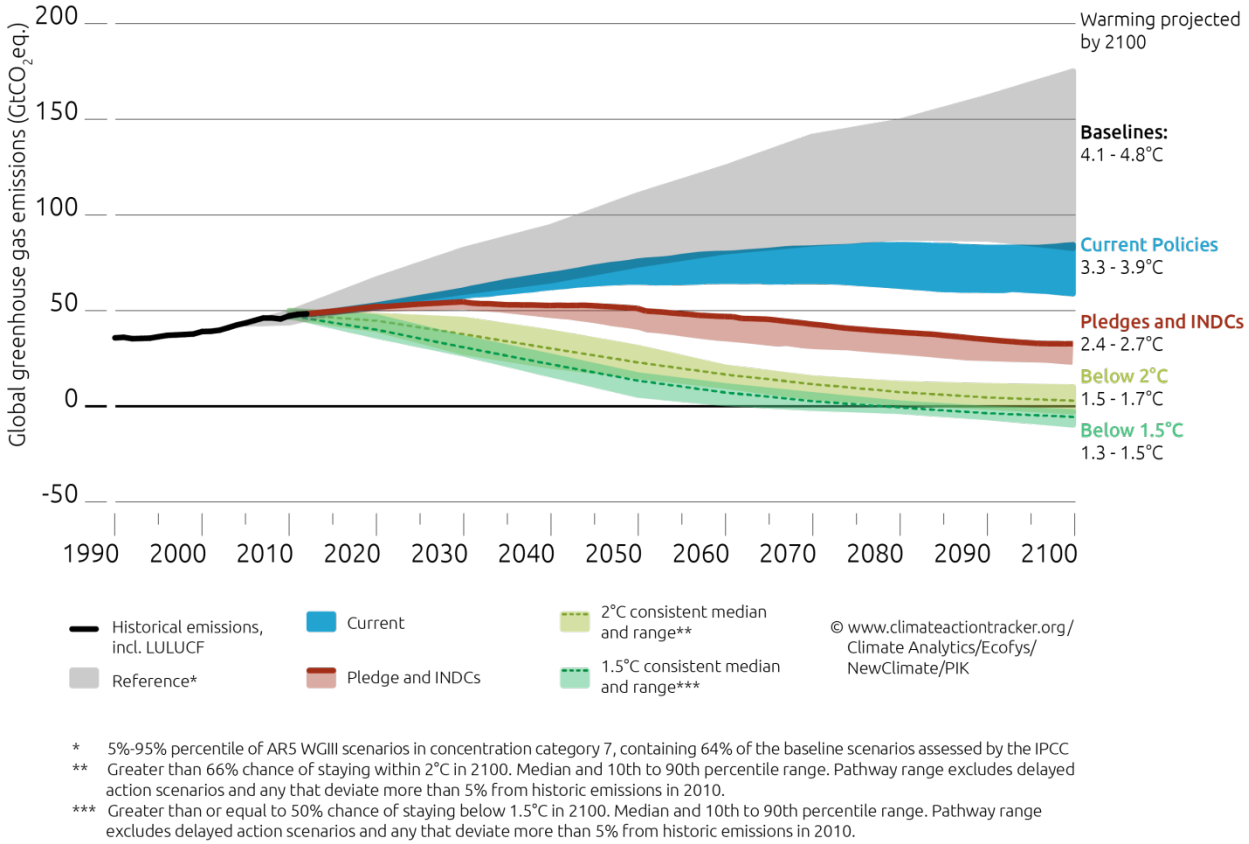
Finally, policy risk includes government pledges. The 2015 Conference of Parties (COP 21) climate agreement signed in Paris represents a global consensus on the need to turn away from fossil fuels. For the fossil fuel industry, the COP 21 presents an ominous milestone: promises to reduce carbon from nearly every country on earth, covering 99 percent of emissions. If realized, these national pledges would reduce carbon emissions from a business-as-usual (BAU) scenario by about 50 gigatons per year by 2050, the yearly equivalent of leaving 23 billion tons of coal or 158 billion barrels of oil unburned. That level of reduction would restrict the increase in average temperature in 2100 to around 3°C rather than 4°C under BAU[11] (see Figure 2). Deeper decarbonization is required to reach the 2°C threshold.

[9] William D. Nordhaus, "A New Solution: The Climate Club," *New York Review of Books*, June 4, 2015.

[10] Jennifer A. Dlouhy and Angela Greiling Keane, "U.S., Mexico, Canada Pledge 50 Percent Clean Power by 2025," *Bloomberg*, June 27, 2016, http://www.bloomberg.com/news/articles/2016-06-27/u-s-mexico-said-to-pledge-50-percent-clean-power-by-2025.

[11] Climate Action Tracker, http://climateactiontracker.org/global.html. Individual pledges have been cataloged on the Carbon Tracker website.

Figure 2: Forecast of effects of Paris pledges on future CO_2 emissions



* 5%-95% percentile of AR5 WGIII scenarios in concentration category 7, containing 64% of the baseline scenarios assessed by the IPCC
** Greater than 66% chance of staying within 2°C in 2100. Median and 10th to 90th percentile range. Pathway range excludes delayed action scenarios and any that deviate more than 5% from historic emissions in 2010.
*** Greater than or equal to 50% chance of staying below 1.5°C in 2100. Median and 10th to 90th percentile range. Pathway range excludes delayed action scenarios and any that deviate more than 5% from historic emissions in 2010.

Source: Climate Action Tracker.

There are plenty of other examples of government anti-carbon policies, which may or may not actually affect emissions. A full list would be far too lengthy to catalog here, but examples include:

- Government restrictions on hydraulic fracturing activity, such as those imposed by New York and other US states, France, Germany, and elsewhere.[12]
- The Obama administration's cancellation of the Keystone XL pipeline. The lack of an additional pipeline to US markets has undercut options for monetizing the carbon-intense bitumen deposits of the Alberta oil sands and probably renders a greater share unburnable.[13]

[12] Most "fracking bans" are not driven primarily by a wish to reduce greenhouse gas emissions. Neither have the bans shut-in ongoing production. They have thus far only restricted future opportunities. See: Kenneth B. Medlock III, "The Land of Opportunity? Policy, Constraints, and Energy Security in North America," Baker Institute research paper, June 2, 2014, http://bakerinstitute.org/media/files/files/94020ec4/CES-Pub-EnergySecurity-060214.pdf.

[13] Nathan Lemphers, "The climate implications of the proposed Keystone XL oilsands pipeline," Pembina Institute, January 2013.

- Lawsuits against ExxonMobil filed by more than a dozen U.S. state attorneys general alleging that the company misled the public about the dangers of climate change.
- Government reforms of fossil fuel subsidies—motivated only partially by climate concerns— that have raised end-user prices and, all else constant, should reduce demand.[14]
- Government-mandated efficiency standards for capital equipment such as vehicle fleets (US CAFE standards), building envelopes (LEED standards, when adopted by governments), and household appliances. Not all are climate related, but all act to reduce the energy intensity of services rendered.
- Incentive programs for electric vehicles from various governments, including small incentives in China[15] and larger rebates and inducements in Norway, Japan, California,[16] and parts of Canada.[17] More than 30 US states and 15 of the 28 European Union member states have launched EV incentives.

Policy risk to fossil fuel reserves

The IEA estimates that government climate policies aimed at the 2°C threshold could cause myriad fossil-fuel assets to become "stranded," or unable to earn a financial return prior to the end of their economic lives. The IEA's tally of assets stranded by 2035, unlike the Citicorp estimate above, is based on unrecovered investment costs and does not include revenues foregone from "unburnable" reserves:

- 165 gigawatts (GW) of fossil fuel power generation capacity with unrecovered sunk costs of $120 billion
- Oil and gas exploration costs worth $180 billion
- Some $4 billion in unrecovered coal mine investment[18]

These unrecovered investment expenses look small relative to the nearly $3 trillion in yearly energy investment of all types the IEA has forecast over a similar period.[19]

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[14] Middle Eastern states have recently embarked on fossil fuel subsidy reforms, following other oil producers such as Mexico, Malaysia, and Indonesia. These reforms actually provide a benefit rather than a cost to domestic oil companies. For the Middle East, see Jim Krane and Elsie Hung, "Energy Subsidy Reform in the Persian Gulf: The End of the Big Oil Giveaway," Baker Institute Issue Brief, April 28, 2016, http://bakerinstitute.org/files/10489/.

[15] Since Chinese electricity is produced mainly by coal, its electric vehicles offer minimal benefits in CO_2. China and Europe surpassed the United States as the No. 1 and 2 EV markets in 2015. See: "Global Plug-in Light Vehicle Sales Increased by About 80% in 2015," U.S. Office of Energy Efficiency and Renewable Energy, March 28, 2016.

[16] California Clean Vehicle Rebate Project, 2016. https://cleanvehiclerebate.org/.

[17] Ontario's EV rebates are funded by revenues from its carbon cap-and-trade program. Jeremy Van Loon and Josh Wingrove, "Ontario to Offer E-Car Rebates in $6.5 Billion Carbon Plan," *Bloomberg*, June 8, 2016. http://www.bloomberg.com/news/articles/2016-06-08/ontario-to-offer-e-car-rebates-in-6-5-billion-carbon-plan.

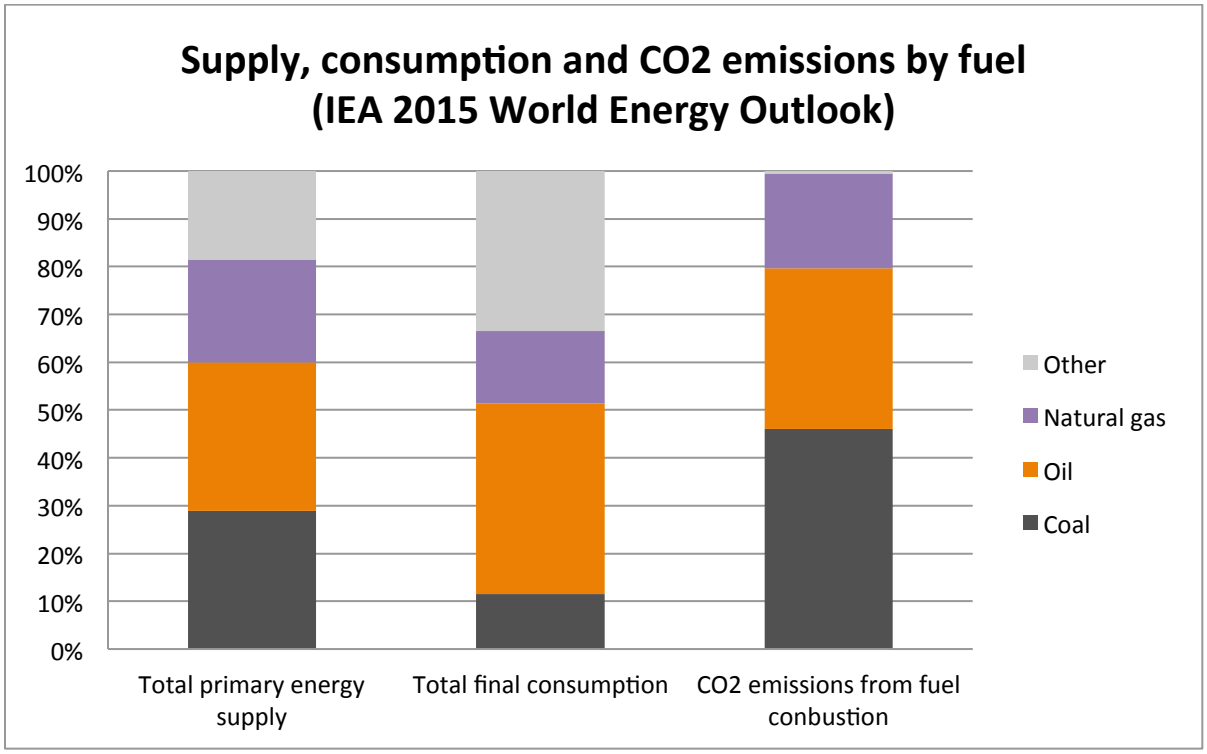
[18] International Energy Agency, "Special Report: World Energy Investment Outlook," 2014, p. 43, https://www.iea.org/publications/freepublications/publication/WEIO2014.pdf.

Demand Risk

At some point, demand for fossil fuels will peak and start to decline. The notion of "peak demand" is driven by the maturing of developing economies, particularly China's, and diversification beyond heavy industry into less energy-intense services. Demand risk is exacerbated by efforts to push economies toward non-carbon energy and higher efficiency.

Few believe that the world will reach peak *energy* demand anytime soon. But as climate policies come to the fore, governments will inevitably seek to meet some demand growth through cleaner energy. At the same time, non-carbon options are becoming viable replacements for retiring capital equipment, particularly in power generation. These forces are bound to affect demand for coal and, in the longer term, natural gas.

Figure 3: Supply, consumption, and CO_2 emissions by fuel



Coal demand looks to be most at risk from climate action. In fact, global coal consumption may have *already* peaked. In 2015, global coal consumption actually dropped by 100 million metric tons, or 1.8 percent, compared to 2014 levels, BP reported. China, which

[19] Fatih Birol, "Energy Investment for Global Growth," Slide presentation, G-7 energy ministerial meeting, May 2016, Japan, https://www.iea.org/newsroomandevents/speeches/160501_G7EnergyMinisterial_slides.pdf.

consumes half of global coal, has seen coal demand decline two years in a row, while US coal consumption plunged nearly 13 percent in 2015.[20] Under ExxonMobil's 2040 forecast, coal is the only fossil fuel that registers a drop in demand from current levels, falling 0.2 percent from its 2014 level. The IEA's base case for coal demand is a 0.8 percent increase in yearly demand through 2020. But an alternate "peak-coal scenario" presents the possibility that global coal demand has peaked and will drop by 0.1 percent per year through 2020.[21] The IEA sees 610 GW of coal power generation capacity being retired for environmental reasons by 2025.[22]

Over the medium term, gas will probably *benefit* from climate action. Since much of the phased out coal capacity will be replaced by natural gas, few observers believe that gas demand will reach a peak anytime soon. The US Energy Information Administration (EIA) forecasts that gas will surpass coal as the dominant US power generation feedstock *this year* (2016) as a result of environmental action and a glut of cheap shale gas.[23] Globally, gas is expected to surpass coal as a share of primary energy around 2030.[24]

[20] BP Statistical Review of World Energy 2016.

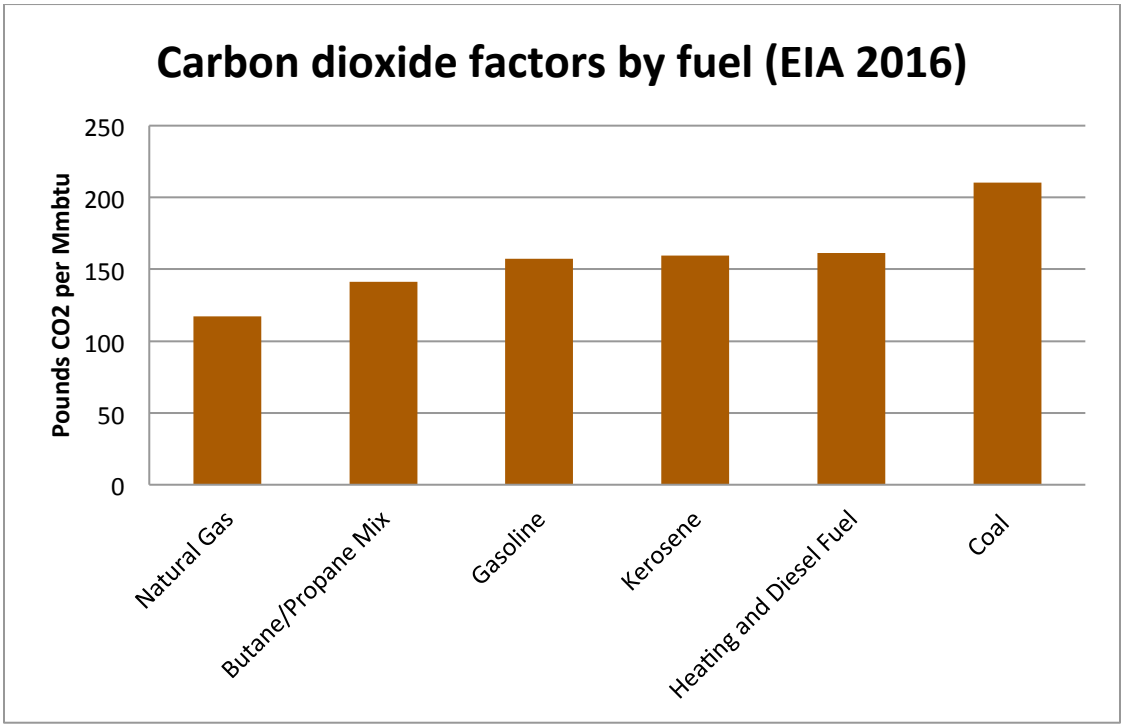
[21] "Coal: Medium-Term Market Report 2015," International Energy Agency, December 2015. http://www.iea.org/newsroomandevents/pressreleases/2015/december/global-coal-demand-stalls-after-more-than-a-decade-of-relentless-growth.html.

[22] "Re-Powering Markets: Market design and regulation during the transition to low-carbon power systems," International Energy Agency, 2016, p. 31.

[23] "Natural gas expected to surpass coal in mix of fuel used for U.S. power generation in 2016," US Energy Information Administration, March 16, 2016. http://www.eia.gov/todayinenergy/detail.cfm?id=25392.

[24] BP Energy Outlook 2016: Outlook to 2035, Slide presentation; see slide 14. https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf.

Figure 4: Carbon content of fossil fuels relative to energy output



Alternate scenarios are certainly possible. A 2016 report from *Bloomberg New Energy Finance* predicts that demand for *all* fossil fuels used in power generation will peak by 2025 and fall thereafter, chased out by cheaper wind and solar power with improved battery storage. By the late 2020s, the report argues, it will be cheaper to build *and* operate a new renewable generation plant than to simply operate an existing coal or gas-fired plant. The crucial element is battery storage, which allows constant output from intermittent generators.[25]

What about oil? Prominent oil executives have estimated that the world could see total oil demand reach its zenith by 2025[26] or 2030.[27] McKinsey predicts that oil demand for transportation will peak by 2025, while its use as a petrochemical feedstock will allow overall demand to increase slowly until 2050.[28] Other forecasts predict that global oil

[25] Tom Randall, "The World Nears Peak Fossil Fuels for Electricity," *Bloomberg*, June 12, 2016, http://www.bloomberg.com/news/articles/2016-06-13/we-ve-almost-reached-peak-fossil-fuels-for-electricity.

[26] Peter Waldman, "Saudi Arabia's Plan to Extend the Age of Oil," *Bloomberg*, April 12, 2015, http://www.bloomberg.com/news/articles/2015-04-12/saudi-arabia-s-plan-to-extend-the-age-of-oil.

[27] Ron Bousso, "'Peak demand' means world may never see oil at $100 a barrel again," *Reuters*, Nov. 5, 2015, http://www.reuters.com/article/oil-demand-idUSL8N12Z4ZJ20151105.

[28] Occo Roelofsen, Namit Sharma, Rembrandt Sutorius, and Christer Tryggestad, "Is peak oil demand in sight?" McKinsey, June 2016, http://www.mckinsey.com/industries/oil-and-gas/our-insights/Is-peak-oil-demand-in-sight.

demand will continue to grow beyond 2040, as developing countries grow wealthier and alternatives like biofuels and electric vehicles will have either proven disappointing or unable to grow at sufficient scale.[29] While oil will inevitably peak at some point, most forecasts find that demand will tail off gradually, requiring companies to continue producing for decades.

Divestment Risk

Shares in fossil fuel companies are falling out of favor. Private citizens, along with investor groups such as pension funds, religious organizations,[30] and universities,[31] have begun shifting investments away from oil and coal companies. Some divestment is based on ethical concerns related to companies profiting while damaging the climate. Some is based on financial grounds, including the risk of stranded reserves. Concerns over stranded assets are often expressed as exposure to a "carbon bubble," which assumes that climate risks have not been accounted for in asset prices.

Divestment participants are among the largest institutional investors in the world, including, ironically, funds responsible for investing fossil fuel profits. The Norwegian Government Pension Fund, the world's largest hydrocarbon-based sovereign wealth fund with some $900 billion in assets, decided in 2015 to divest from companies that received more than 30 percent of their revenues from coal.[32] The Rockefeller Brothers Fund, based on the Standard Oil fortune, pledged in 2014 to eliminate its exposure to coal and Canadian tar sands while examining the possibility of further fossil fuel divestment in coming years.[33] Among some institutional investors, investment selectivity on climate grounds now comes under the heading of corporate social responsibility. Increasing numbers of businesses and organizations have decided to act on climate despite a lack of government regulation.

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[29] For instance, Exxon Mobil's "Outlook for Energy: A View to 2040" finds no "peak" and projects average oil demand growth of 0.7 percent per year to 2040.

[30] See: GreenFaith, "A Listing of Known Religious Divest and Reinvest Efforts," http://www.greenfaith.org/programs/divest-and-reinvest/listing-of-known-religious-divestment-efforts. The Church of England has divested from coal and tar sands investment. See: Andrew Brown, "Church of England governing body approves divestment policy," *The Guardian*, July 14, 2015, https://www.theguardian.com/environment/2015/jul/14/church-of-england-governing-body-approves-divestment-policy.

[31] "Campuses & Organizations That Have Divested," University of Wisconsin, http://www.uwosh.edu/es/climate-change/divestment/the-divested.

[32] John Schwartz, "Norway Will Divest From Coal in Push Against Climate Change," *New York Times*, June 5, 2015. http://www.nytimes.com/2015/06/06/science/norway-in-push-against-climate-change-will-divest-from-coal.html.

[33] Rockefeller Brothers Fund, "Divestment Statement," September 2014, http://www.rbf.org/about/divestment.

Glomsrød and Wei find that divestment efforts will reduce future fossil fuel consumption by constraining the availability of financing and raising costs. The effect will be to reduce coal demand by 2.5 percent by 2030 versus a business-as-usual case.[34]

In the oil business, divestment risk only poses a problem for shareholder-owned IOCs, not state-owned national oil companies (NOCs), which control most oil production. Shareholder resolutions have sought to change reporting and investment criteria within IOCs. ExxonMobil, Shell, Total, Chevron, and Eni are among the majors targeted by such resolutions,[35] most of which have been voted down at the urging of corporate boards.

Three further risk types fit within the Divestment Risk category.

Insurance risk

The global insurance business finds itself on the opposite side of the climate equation from fossil fuel firms. Insurers face the potential of devastating losses from climate change itself, due to the increasing frequency of damaging weather events and subsequent payouts. The insurance sector is among those with the largest financial stake in climate progress, placing it at odds with the fossil fuel industry.

As a result, climate risk has begun to influence insurance investment portfolios. The French insurer AXA announced in 2015 that it would divest from its last remaining coal mining and utility assets, worth $560 million, while shifting into "green" investments that have lower or beneficial climate impacts. AXA CEO Henri de Castries said climate-driven events already represented 15 to 20 percent of the firm's business risk. He said it had become "absolutely clear" that warming beyond 2°C would make it "tougher and tougher and probably impossible" for insurers to cope with property damage.[36] Outside of France, insurance firms continue to invest in and sell their services to fossil fuel companies, but an evolution in that willingness is probably inevitable. In 2015, California's insurance commissioner called for insurance firms to disclose carbon-based investments that expose them to climate risks.[37]

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[34] The paper forecasts that divestment pressure could reduce global carbon emissions by the current combined total of the European Union and Japan. See: Solveig Glomsrød and Taoyuan Wei, "Business as Unusual: The Implications of Fossil Divestment and Green Bonds for Financial Flows, Economic Growth and Energy Market," CICERO Working Paper, Oslo, 2016.

[35] Tara Patel, "Fossil-Fuel Divestment Gains Momentum With Axa Selling Coal," *Bloomberg*, May 22, 2015, http://www.bloomberg.com/news/articles/2015-05-22/fossil-fuel-divestment-picks-up-momentum-with-axa-selling-coal.

[36] Ibid.

[37] CERES, "U.S. insurance sector heavily invested in fossil fuel sectors, despite growing awareness of climate change risks," Press release, May 24, 2015, https://www.ceres.org/press/press-releases/ceres-report-u.s.-insurance-sector-heavily-invested-in-fossil-fuel-sectors-despite-growing-awareness-of-climate-change-risks.

Lending risk

A related source of risk for fossil fuel companies is the drying up of financing. Bank of America, Citigroup, JP Morgan Chase, and Deutsche Bank have enacted climate-driven lending prohibitions linked to coal mining and coal-fired power plants. Lending prohibitions shrink the pool of willing financiers, possibly forcing coal businesses to turn to more expensive sources.[38] Citigroup has mandated a "risk review" prior to lending to businesses participating in Canadian oil sands.[39]

Asset risk

Taken together, the risks facing the fossil fuel industry suggest the possibility of a "carbon bubble." This is the contested notion that market capitalizations of publicly traded companies are exaggerated because the enforcement of carbon targets may prevent them from producing the reserves they have booked. For coal companies, at least, carbon risks are already being priced in.

The case for oil is more complicated. For IOCs with reserves-to-production ratios of 10 or 15 years, climate restrictions pose a much smaller risk in comparison to producer countries like Saudi Arabia or Kuwait (discussed below) where reserves can support current production for another 50 to 100 years. For IOCs, demographic and economic trends will probably maintain medium-term oil demand despite climate action. For these companies, climate risk looks more threatening over the long term, possibly affecting the value of future reserves. Still, given the huge valuations of IOCs, any sudden acknowledgement that a carbon bubble has not been priced in could destabilize markets and economies.[40]

Of course, a rapid shift in technology that renders fossil fuels obsolete could have the same effect on asset values.

Opposite cases are also possible: Energy shares could get a boost from a breakthrough that allows carbon-rich fuels to be exploited without harming the climate. Fossil fuels might also get a reprieve from large-scale adoption of geoengineering techniques that intervene in the Earth's climate system to reverse the greenhouse effect.[41]

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[38] Michael Corkery, "As Coal's Future Grows Murkier, Banks Pull Financing," *New York Times*, March 20, 2016, http://www.nytimes.com/2016/03/21/business/dealbook/as-coals-future-grows-murkier-banks-pull-financing.html.

[39] Citigroup, "Sector briefs: Oil sands," 2013. http://www.citigroup.com/citi/environment/data/1160844_Sector_Brief_Oil_Sands.pdf.

[40] Carole Mathieu, "Carbon Risk and the Fossil Fuel Industry," Research paper, Ifri Center for Energy, 2015, p. 7-8.

[41] See, for example: "What is Geoengineering?" Oxford Geoengineering Program. http://www.geoengineering.ox.ac.uk/what-is-geoengineering/what-is-geoengineering.

Competition Risk

Competition among technologies, companies, and producer countries has always been a source of risk in the oil and gas industry. Climate change introduces an intensified competitive challenge for fossil fuel companies. In general, the lower a resource's cost and carbon content, the more competitive it will be in a climate-constrained market.

Market risk and the Green Paradox

Climate change could exacerbate competition for market share by encouraging price war behavior. If oil producers believe climate-based restrictions might lead to stranded assets, they may decide to step up production in order to reduce exposure to stranded asset risk. This phenomenon has been dubbed "the green paradox" by German economist Hans-Werner Sinn, who argues that environmental policies that restrict carbon emissions have the perverse effect of accelerating fossil fuel production, thus exacerbating carbon emissions and their warming effects.

It is possible that the green paradox is already affecting energy markets. OPEC members Saudi Arabia, Kuwait, and the United Arab Emirates—holders of some of the largest and lowest-cost oil reserves—had until recently favored long-term depletion strategies that limited production and propped up market prices. This future-oriented strategy allowed greater participation by the so-called "fringe" producers outside OPEC—including US shale—despite higher costs.

But OPEC's future orientation appears to have diminished. Since November 2014, OPEC—led by Saudi Arabia—began to emphasize retaining a share of the oil market rather than sustaining high prices for its exports. The kingdom has since maintained production at historic highs and pushed higher-cost oil from the market. The Saudi change in strategy was probably driven by rising competition with US shale and other non-OPEC oil, which itself was incentivized by high prices.

However, if the Saudis worried that reserves might someday be stranded, they would probably behave the same way. The kingdom would increase current production in hopes of reducing the amount of resources it may eventually abandon.[42] Sinn argues that environmental policies that intensify over time threaten future demand more severely than current demand. The green paradox thus entices resource owners to prioritize current over future production.[43]

The curtailment of future oil demand would be disastrous for Saudi Arabia, Venezuela, and other large producer states, few of which have diversified economies ready to move

[42] This is a simplification of the Saudi strategy. Saudi officials take many aspects of oil markets into account. Climate factors may be outweighed by other interests, including price. The kingdom could still cut back on production in the future if policymakers believe it serves their interests. Further, even "unburnable" oil retains markets in petrochemicals, lubricants, etc.

[43] Hans-Werner Sinn, "Public Policies against Global Warming: A Supply Side Approach," *International Tax and Public Finance* 15, 4(2008): 360–94.

beyond oil. By increasing production and pushing down market prices, they might shift the risk of stranded assets to higher-cost players, including shareholder-owned IOCs. The same phenomenon could be affecting coal producers. For them, selling at a discount is preferable to seeing reserves stranded. By encouraging stepped-up production, the climate threat to fossil fuels can perversely lead to cheaper, more attractive fossil fuels.

Green competition risk

Fossil fuel companies also face competition from "green" investment portfolios and indexes that exclude carbon-exposed businesses. Investors, including big institutional funds, have begun to shift investments away from fossil energy toward companies with lower risk exposure to climate policy.

MSCI, a company that creates share indexes for investment managers, has developed new indexes and tools that exclude fossil fuel companies or highlight exposure to stranded carbon assets. The company assists in rebalancing portfolios by "deliberately tilting more aggressively toward companies with large and growing renewable capacity."[44] Likewise, *Bloomberg's* Carbon Risk Valuation Tool allows its clients to model the effects of scenarios such as "last ditch decarbonization" on their portfolios.[45]

Climate risk has thus led to the creation of products that allow for diversifying portfolios away from fossil exposure in favor of competing low-carbon companies. Coal remains the main focus, but oil and gas firms are excluded from some indexes, around which mutual funds tend to be based. Preferential investment also creates advantages for research and development and other avenues of competition with fossil-based firms.

Risks Relating to Individual Fossil Fuels

Stranded asset risk is not unique to fossil fuels. Any industry might be hurt by advances in technology or customer preferences that render capital equipment underutilized and otherwise "stranded" prior to the expected investment time horizon. Fossil fuel reserves are already routinely stranded, at least temporarily, by falling market prices. Climate risk is different. Governments, firms, individuals, and international organizations are actively pursuing actions that damage fossil fuel businesses irrespective of prices or the availability of more efficient substitutes.

Two recent financial reports outline the potential for enormous losses in revenues, the risk of which increases relative to concentrations of carbon and the costs of extraction. The first of these reports finds that adhering to the carbon threshold consistent with a 2°C temperature increase would, by 2035, leave the fossil fuel industry with $28 trillion in lost revenues from stranded reserves.[46] As mentioned above, Citicorp estimates that, with or

[44] MSCI, "2015 ESG Trends to Watch," January 2015, p. 3-5.

[45] Bloomberg Carbon Risk Valuation Tool, Nov. 26, 2013. http://about.bnef.com/white-papers/bloomberg-carbon-risk-valuation-tool-2.

[46] Kepler Cheuvreux, "Stranded assets, fossilized reserves," April 2014.

without carbon capture and storage (CCS), the value of stranded fossil fuels will surpass $100 trillion by 2050. The bank argues that these reductions to earnings should be considered when weighing the creditworthiness and future potential of producer companies and the economies of countries which own the reserves.[47]

Coal

Among fuels, coal stands to lose most. Recent estimates by McGlade and Ekins find that roughly 80 percent of known coal reserves must remain unburned if the 2°C target is to be met (Figure 5). The authors find that CCS technology is of little help, given its expense, the unwieldy parasitic load on power plants where it is deployed, and the lack of sufficient carbon pricing that might incentivize its construction. Citicorp estimates that the coal mining and power generation industries will lose investments worth $11.5 trillion over the next 25 years[48] (Table 1).

Figure 5: Unburnable reserves of oil, gas and coal

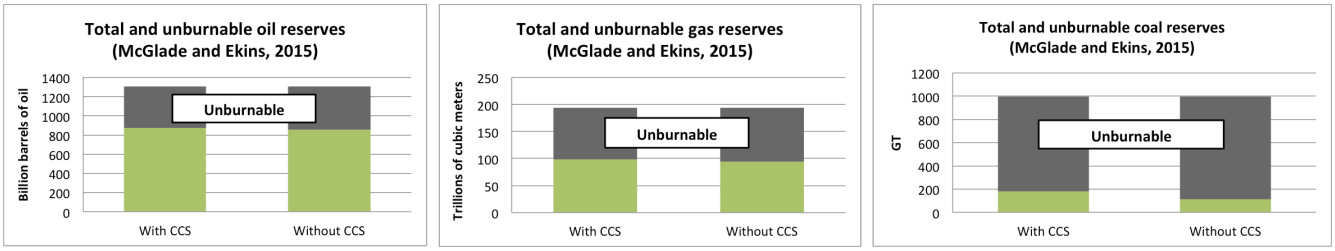

Table 1: Dollar values of unburnable fossil fuels in a 2°C scenario

Scenario	Value of unburnable oil (in trillion USD)	Value of unburnable gas (in trillion USD)	Value of unburnable coal (in trillion USD)
With CCS	30	22	57
Without CCS	25	24	62

Note: Assumes $70 per barrel of oil, $6.5 per MMBTU of gas and $70 per metric ton of coal.

Source: Citi Research.

In the United States, cheap natural gas is pushing coal out of the power market, helped by uncertainty over government emissions regulations that could render coal uneconomic for the foreseeable future. US coal producer Peabody Energy, the largest US coal mining firm,

[47] Citi GPS, "Energy Darwinism II: Why a Low Carbon Future Doesn't Have to Cost the Earth" Citicorp Global Perspectives & Solutions, August 2015, p. 84.

[48] Citi GPS, "Energy Darwinism II: Why a Low Carbon Future Doesn't Have to Cost the Earth," Citicorp Global Perspectives & Solutions, August 2015, p. 83.

declared bankruptcy in April. Peabody's filing was preceded by bankruptcies among several other coal producers, including Arch Coal, Alpha Natural Resources, Patriot Coal, and Walter Energy. US coal firms lost a combined $30 billion in share value since 2010, along with 31,000 jobs, as the industry has collapsed under competition with gas, which has been abetted by environmental regulations, declining US steel production, and a 60 percent decline in coal prices. In 2016, half of all US coal was being produced by bankrupt companies in the process of being broken up.[49]

Oil

Oil is a more difficult case, since it has few substitutes as a transportation fuel. McGlade and Ekins estimate that roughly a third of current conventional crude oil reserves would need to be abandoned by 2050, the smallest proportion of "stranded" reserves among the three major fuels.[50] Even so, divestment pressure on IOCs has gained ground.

A number of climate-based groups such as the Carbon Tracker Initiative and the Institutional Investors Group on Climate Change have warned that climate risks have not been priced into oil company stocks. CTI states that despite reserves already far exceeding burnable levels, the industry spent more than $600 billion on finding and developing new reserves.[51]

Academics have called for new valuation methods for IOCs that avoid booked reserves that may never be produced. Stevens argues that climate risk is one of a number of gathering threats to IOCs, which face the potential for declining global oil demand and a weakening business model based on replacing reserves of oil that are no longer scarce.[52]

A bigger quandary faces NOCs, which oversee about 97 percent of global oil reserves and 90 percent of global oil production and therefore face greater exposure to demand and competition risks. However, since most NOCs are owned by host governments, they are insulated from divestment and policy risk. However, even unregulated NOCs could be affected by the future creation of "climate clubs" empowered to levy carbon taxes on imports from "free riders."

Gas

Natural gas is a different case. Due to its lower carbon content, gas is classified as a "bridge fuel" for a decarbonizing world. Gas turbine power plants can start up quickly in a way that

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[49] John W. Miller and Matt Jarzemsky, "Peabody Energy Files for Chapter 11 Bankruptcy Protection," *Wall Street Journal*, April 14, 2016, http://www.wsj.com/articles/peabody-energy-files-for-chapter-11-protection-from-creditors-1460533760.

[50] Christophe McGlade and Paul Ekins, "The geographical distribution of fossil fuels unused when limiting global warming to 2 °C," *Nature*, January 2015.

[51] Carbon Tracker Initiative, "Unburnable carbon 2013: Wasted capital and stranded assets," April 2013. http://www.carbontracker.org/report/unburnable-carbon-wasted-capital-and-stranded-assets.

[52] Paul Stevens, "International Oil Companies: The Death of the Old Business Model," research paper (London: Chatham House, May 2016).

works well with intermittent renewables. The United States and Britain have both reduced their carbon footprints in recent years by switching from coal to gas.

However, gas (like coal) has substitutes, including some that emit no carbon: nuclear, hydro, wind, and solar energy. Furthermore, the decarbonization that must occur to meet the 2°C threshold does not allow gas to fully substitute for coal. McGlade and Ekins find that fully half of global gas reserves need to remain in the ground to meet the 2°C target.[53] Even so, gas has not attracted the same level of opposition as coal or oil. Divestment campaigns have mostly ignored gas, and grassroots opposition to hydraulic fracturing typically focuses on fears of water contamination and heavy road traffic, not carbon emissions. Gas reserves are huge, and North American shale gas has the benefit of lying in areas close to demand centers. Low prices and emissions have increased the attractiveness of gas as a coal substitute in China and India. However, since most gas is associated with oil production, any reduction in oil production would also affect gas.

There are specific cases in which gas might plausibly be stranded. Russia risks seeing some of its western gas reserves stranded, especially if the European Union, its main market, turns away from gas. EU member states have been shifting toward a generation mix that emphasizes renewables, but where coal and gas compete as baseload feedstocks. Given higher prices of gas relative to coal in the EU, and the energy security concerns of dependence on Russia, one could imagine Russian gas losing EU market share without a concerted Russian effort to reduce prices.[54]

Conclusion

As climate change effects grow more pronounced, there can be little doubt that an industry that produces 68 percent of human greenhouse gas emissions will find itself under increasing pressure.

The risks to the industry correlate with progress on climate goals. Unless a technological breakthrough can restrict carbon releases, the fortunes of the fossil fuel industry and the stability of Earth's climate will be locked in a zero-sum game. Climate's gain is the industry's loss and vice versa.

For coal, the threats posed by climate action are already being felt. Coal's fortunes now rest with developing countries, where decisions to seek China-style, coal-led development will increasingly be met by international pressure to choose an alternate path.

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[53] Christophe McGlade and Paul Ekins, "The geographical distribution of fossil fuels unused when limiting global warming to 2 °C," *Nature*, January 2015.

[54] James Henderson, "Gazprom – Is 2016 the Year for a Change of Pricing Strategy in Europe?" Oxford Institute for Energy Studies, January 2016. Gazprom has been reluctant to reduce prices to Europe because it uses EU sales revenues to cross-subsidize Russian customers and to finance its project portfolio, according to Tatiana Mitrova of the Russian Academy of Sciences in a presentation at the International Association for Energy Economics conference, Bergen, Norway, June 21, 2016.

Climate threats to gas businesses appear further afield, given the fuel's reduced carbon content. In fact, many anti-carbon policies that would damage coal would benefit gas, whether carbon taxes, cap-and-trade schemes, or other restrictions.

Oil, by contrast, is insulated by its unique and valuable role in transportation. That doesn't mean oil *firms* will be unaffected. Expectations of escalating restrictions encourage increases in current production. Environmental regulation could, through the "green paradox," lead to lower oil prices, increased demand, and a gain in market share by low-cost producers like Saudi Arabia at the expense of higher cost ones like those in North America. Since upstream oil investments are typically based on 20- or 30-year time horizons, one must accept the possibility that financial returns will be affected by climate action.

Competition among producers for market share will be complemented by competition between fossil fuels and renewables. Divestment and policy risks will magnify the challenges. Insurance companies and other sectors threatened by climate change can be expected to press for stronger action. Institutional investors and individuals will reward companies based on "future proofing" and penalize those deemed too exposed to carbon.

IOCs may weather the climate storm more deftly than fossil fuel-dependent producer countries. Nimble companies can modify their business lines. Just as IBM has shifted from computer hardware to business services, IOCs are shifting their businesses. Shell's acquisition of BG emphasizes a shift from upstream oil toward natural gas. Total has made a big bet on renewables and battery storage. Arguably, countries with ingrained political structures based on oil exports will have a harder time adapting.

It is clear that carbon-based businesses face increasing impediments to the consumption of their products. Whether through taxes, legal restrictions, moral arguments, favoritism for competitors, or hampered access to financial markets, the industry faces a future that is less accepting of its current practices. Some businesses will not survive. For others, the risks warrant changes in strategic direction.

Finally, it is important to keep in mind the greatest risk of all. Businesses may face existential threats from climate action, but these are dwarfed by a far greater risk—the possibility that climate actions may fail.

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