



Potential emissions of CO₂ and methane from proved reserves of fossil fuels: An alternative analysis[☆]



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ABSTRACT

Scientists have argued that no more than 275 GtC (IPCC, 2013) of the world's reserves of fossil fuels of 746 GtC can be produced in this century if the world is to restrict anthropogenic climate change to $\leq 2^\circ\text{C}$. This has raised concerns about the risk of these reserves becoming “stranded assets” and creating a dangerous “carbon bubble” with serious impacts on global financial markets, leading in turn to discussions of appropriate investor and consumer actions. However, previous studies have not always clearly distinguished between reserves and resources, nor differentiated reserves held by investor-owned and state-owned companies with the capital, infrastructure, and capacity to develop them in the short term from those held by nation-states that may or may not have such capacity. This paper analyzes the potential emissions of CO₂ and methane from the proved reserves as reported by the world's largest producers of oil, natural gas, and coal. We focus on the seventy companies and eight government-run industries that produced 63% of the world's fossil fuels from 1750 to 2010 (Heede, 2014), and have the technological and financial capacity to develop these reserves. While any reserve analysis is subject to uncertainty, we demonstrate that production of these reported reserves will result in emissions of 440 GtC of carbon dioxide, or 160% of the remaining 275 GtC carbon budget. Of the 440 GtC total, the 42 investor-owned oil, gas, and coal companies hold reserves with potential emissions of 44 GtC (16% of the remaining carbon budget, hereafter RCB), whereas the 28 state-owned entities possess reserves of 210 GtC (76% of the RCB). This analysis suggests that what may be needed to prevent dangerous anthropogenic interference (DAI) with the climate system differs when one considers the state-owned entities vs. the investor-owned entities. For the former, there is a profound risk involved simply in the prospect of their extracting their proved reserves. For the latter, the risk arises not so much from their relatively small proved reserves, but from their on-going exploration and development of new fossil fuel resources. For preventing DAI overall, effective action must include the state-owned companies, the investor-owned companies, and governments. However, given that the majority of the world's reserves are coal resources owned by governments with little capacity to extract them in the near term, we suggest that the more immediate urgency lies with the private sector, and that investor and consumer pressure should focus on phasing out these companies' on-going exploration programs.

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1. Introduction

Anthropogenic climate change presents a serious threat to the health, prosperity, and stability of human communities, to the stability and existence of non-human species and ecosystems, and to international political and military stability (IPCC, 2013, 2014; World Bank, 2012; Center for Naval Analysis, 2014; Holy Father

Francis, 2015). The United Nations Framework Convention on Climate Change commits its signatories to preventing “dangerous anthropogenic interference” (DAI) in the climate system, a level that has generally been thought to occur at about 2°C (UNFCCC, 1992; IPCC, 2013). This has raised the question of what proportion of existing reserves of fossil fuels may be used without exceeding that 2°C level. The International Energy Agency has concluded that “[n]o more than one-third of proved reserves of fossil fuels can be consumed prior to 2050 if the world is to achieve the 2°C goal, unless carbon capture and storage (CCS) technology is widely deployed” (IEA, 2012). Carbon Tracker concludes that a “precautionary approach” would leave 80% of reserves in the ground (CTI,

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2013). These conclusions are based on the carbon content of global reserves of fossil fuels, based on BP data (BP, 2014b), and World Energy Council surveys (World Energy Council, 2013), which are in turn based on data from resource and reserve assessments as reported by national governments, geological surveys, coal ministries, petroleum directorates, national oil companies, and the like. A geographic and economic dispatch model also based on global reserves data concludes that one-third of oil, half of gas, and 82 to 88% of coal reserves must remain unused to 2050 (McGlade and Ekins, 2015).

Many of these reserves, however, are located in nations that lack the productive capacity to exploit them. From the perspective of disruptive climate change, the most pressing concern is not the total quantity of fossil fuel in the Earth's crust, which in any event is an unknown quantity, but the proved recoverable reserves reported by the largest producers around the world—i.e., the companies poised to produce, refine, and deliver those fuels to global markets in the near term. This paper addresses the questions: What are the reported proved reserves held by companies with the capacity to deliver them to world markets? What are the potential emissions from their expected production? What percentage of the remaining 2°C carbon budget do they represent?

2. Potential emissions of CO₂ from proved reserves of oil, natural gas, and coal

The conclusion that a large portion of the world's reserves of fossil fuels must be left in the ground has led to concerns about the risk of these reserves becoming “stranded assets,” and creating a dangerous “carbon bubble” with large impacts on global financial markets (CTI, 2013, 2014a,b; CERES 2012; Generation Foundation, 2013; *The Economist*, 2014; Leggett, 2013). Analysis of many oil and gas producers' capital expenditures highlights the vulnerabilities of highly valued assets if restrictions on carbon emissions are put in place (CTI, 2014a,b). The total cumulative anthropogenic carbon budget consistent with >66% probability of not exceeding a 2°C target has been estimated at 1.0 trillion tons of carbon (TtC) (Allen et al., 2009; IPCC, 2013; Matthews et al., 2009; Matthews and Solomon, 2013; Meinshausen et al., 2009). If these figures are correct, they suggest that no more than 275 GtC remain to be emitted as carbon dioxide from fossil fuel use (see section on carbon budget below). How do these figures compare with the carbon that would be emitted if existing proved reserves of fossil fuels are produced and used? This paper attempts to answer that question by an analysis of reported proved reserves held by fossil fuel corporations with the technical and financial capacity to produce them in the near future. This includes investor-owned companies (IOC) such as BP and Peabody, state-owned Organization of Petroleum Exporting Countries (OPEC) producers such as Saudi Aramco and Sonatrach, and non-OPEC state-owned entities (SOE) such as Petrobras (Brazil), CNOOC (China), Statoil (Norway), and Gazprom (Russia). Our analysis does not forecast the rate of each entity's fossil fuel production, and therefore does not predict whether current reserves will be produced by 2050, 2100, or beyond. Clearly, the rate of production is relevant to emissions scenarios, and therefore to the rate at which climate change may occur (IPCC, 2014). However, investor-owned oil and gas companies have typical reserve-to-production ratios of 12 ± 5 years, coal producers 35 ± 15 years, and OPEC-member companies 150 ± 120 years. It is therefore reasonable to assume that absent policies to alter current trajectories, nearly all investor-owned reserves, and a lion's share of state-owned reserves, will be exploited before the end of the century. We also note that all fossil fuel reserve estimates are subject to considerable uncertainty arising from many diverse factors (Laherrère, 1999, 2011). Reserve

estimates vary by source, year, and by fuel. They may also be subject to deliberate inflation; OPEC oil and gas reserves, for example, are not audited, but are widely reported by international sources. Clearly, any attempt to quantify greenhouse gas emissions that will result from the use of these reserves is subject to any uncertainty already embedded in reserve estimates. Moreover, in some sense the term “proved” is misleading, insofar as nothing is proved until a resource has actually been extracted and sold. Nonetheless, the term is used conventionally to refer to that portion of a resource that is known to exist, has been well delineated, and which companies are poised to develop. “Proved reserves” is also a standard category that companies report to shareholders and therefore is available to the public and researchers and subject to peer review. Our analysis uses this term in this conventional sense, and relies on publicly available data that have been reported under this rubric.

We also note that for purposes of this analysis all carbon emissions are viewed as equivalent, although we recognize that with respect to the question of “dangerous anthropogenic interference” (DAI) in the climate system, this is not strictly the case.

3. Methods

This analysis is based primarily on company self-reported estimates of proved reserves of recoverable oil, natural gas, and coal, reduced for global average non-energy uses, and multiplied by emission factors for each fuel type. Uncertainties arise regarding estimated reserves and data sources (discussed below). In addition, company operations, crude oil sources, operational emissions, and the disposition and use of extracted, refined, and marketed carbon products vary from company to company. In the section that follows, we explain what data and assumptions are used in the analysis; the interested reader is referred as well to Heede for further details (Heede, 2013, 2014).

Oil, natural gas, and coal companies report annual production and recoverable reserves to investors and the U.S. Securities and Exchange Commission (SEC) on the basis of SEC guidelines if the company is based in the United States, is listed on U.S. securities exchanges, or operates producing assets within the U.S. or its offshore areas. The reserves attributed to the seventy investor-owned and state-owned fossil fuel companies (plus the coal sector in eight nation-states – China, Czech Republic, Kazakhstan, North Korea, Poland, Russian Federation, Slovakia, and Ukraine – with limited participation by investor-owned companies) in this analysis are estimates based on international reporting standards (in the case of non-OPEC companies) and on unknown standards and limited transparency in the case of entities operating in OPEC-member states, such as Saudi Aramco, Petroleos de Venezuela, Sonatrach, and others. National Oil Companies that are partially privatized are classified in this study as state-owned if >50% of shares are owned by the government. This includes Statoil, at 67% government-owned, Petrobras, 55.6% state-owned, and Gazprom, 50.01% state-owned.

3.1. Data sources

Our analysis is based on reported reserves data, gathered chiefly from the statements published by the U.S.-based companies for year-end 2013 in Form 10-K (20-F or 40-F, by foreign and Canadian companies with assets in the United States, respectively) filed with the U.S. Securities and Exchange Commission. Additional sources include statistics in the *Oil & Gas Journal*, the National Mining Association, company websites, annual reports, and government sources. State-owned companies do not submit statements to the SEC (unless they own producing assets in the United States, such as

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