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The early retirement challenge for fossil fuel power plants in deep decarbonisation scenarios

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ABSTRACT

Rapid decarbonisation of the global energy sector will likely have a multitude of economic consequences, including the premature decommissioning of most fossil fuel power plants. In this analysis, we examine the impact of early retirements for oil, coal, and natural gas-fired generators required to follow a given 2 °C emissions trajectory (the IEA 2DS) and explore the policy implications surrounding this challenge. Modelling the period up to 2060, the drop in retirement age required to meet this scenario potentially creates $541 billion worth of stranded power plant assets across the US, EU, China, and India alone. In some cases, coal plants built within the past 5 years will need to be retired after only half the nominal operating lifetime. Regional analysis exposed disproportionate impacts in China and India, shouldering the vast majority of the costs and amplifying concerns over energy access and affordability. Policies such as burden-sharing for equitable mitigation, investment into CCS technology, and international financial compensation are discussed as potential avenues for mitigating this impact. However, limitations in all avenues highlight the need for further consideration of the inferred requirement to force early retirements, in order to avoid exacerbating regional imbalances and improve the feasibility of imposed targets.

1. Introduction

Concerns around climate change are growing in scientific, social and political circles alike. The increasingly dire narrative surrounding its potential effects has led governments to commit to country-specific goals that will put the world on a path towards significant emission reductions before mid-century. A majority of countries have also pledged a collective objective to achieve net-zero greenhouse gas emissions in the second half of the century. These commitments were made under the Paris Climate protocol (COP21) which has since been ratified by 174 of the 197 countries that participated at the convention (United Nations/Framework Convention on Climate Change, 2015). Key to this transition is breaking the paradigm that links carbon emissions to population and economic growth, a challenge neatly described by the Kaya identity (Kaya and Yokobori, 1997). With most scenarios projecting the global population to increase to between 9 and 12 billion (Melorose et al., 2015) and GDP projected to rise by more than 250% to USD 182 trillion in 2050 (OECD, 2017), energy intensity and/or carbon intensity must decrease significantly to counter growth.

The International Energy Agency (IEA), in their annual publication Energy Technology Perspectives (ETP) present long-term pathways for energy use that result in limiting global warming to various degrees (IEA, 2017). Of most comparable interest to the Paris Agreement is their 2 °C scenario (2DS), which could fulfil the pledge to limit warming to 2 °C within a probability of 50%. These scenarios are projected to reduce annual global energy sector emissions from 34 $GtCO_2$ in 2014 to 9 $GtCO_2$ in 2060, a reduction of just under 75% to meet the 2 °C target, with over 50% of this reduction coming from the power generation sector (IEA, 2017).

This scale of decarbonisation is formidable, with two significant challenges to be overcome if this goal is to be achieved. The first challenge is the rapid deployment of new, low-carbon energy infrastructure and the associated challenges that come with it, such as grid integration and intermittency. Despite growing energy demand, the emissions intensity of the electricity generation sector will need to fall from approximately 572 to 2.5 g CO_2/kWh by 2060 (IEA, 2017). The ability for such a transformation to take place within the allotted time scale has been challenged many times (Lane et al., 2016; Smil, 2016; Sovacool, 2016) although various projections claim this feat is achievable within a few decades both globally (Delucchi and Jacobson, 2011; Jacobson and Delucchi, 2011; Sorensen and Meibom, 2000; WWF, 2011), and regionally for Australia (Wright and Hearps, 2010), Germany (German Advisory Council on the Environment, 2011), and the UK (Centre for Alternative Technology, 2010).

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In addition to deploying low-carbon projects and infrastructure, the concomitant decommissioning of carbon intensive assets is necessary to reach the goals of 2DS and the Paris Agreement. We can categorise such asset retirements as:

a) End-of-life (EOL) retirement of assets which have reached the end of their technical lifetime; and/or
b) Early retirement of assets at a time prior to reaching their EOL.

Although other alternatives such as retrofitting CCS and repowering have the potential to alleviate the need for retirements, early retirement (or at least conversion) of fossil fuel power plants will be necessary to meet the commitments of the Paris Agreement and 2DS unless end-of-life retirements result in sufficient emissions reductions. This presents a significant barrier to decarbonisation, and while coal retirements may be increasing due to the growing profitability of natural gas assets in regions such as the US (Peters, 2017), achieving the ambitious emissions reduction targets in 2DS will require much more direct action. The early asset retirement issue has typically attracted less attention from academics and the general public than the opportunities for deploying low carbon technologies, despite it posing a significant economic and policy challenge to be overcome.

Indeed, the IEA have recognised this fact and speak briefly of the need for early retirements in their 2017 version of the ETP (IEA, 2017). However, despite recognition, the IEA do not attempt to quantify or analyse in-depth the impact of these early retirements either on asset valuations, or on political, social, and financial institutions and structures around the world. This sort of analysis is vital to understanding the feasibility and implications of reaching these emission targets as, based on historical experience, early retirement well before a power plant investment has been recouped is unlikely to proceed without strong economic incentives, regulatory measures, and/or compensation (Miller, 2013). At the same time, early retirements may lead to unintended consequences in the energy market such as reduced system reliability and energy security (Rahmani et al., 2016), as well as a less stable investment climate (Fabrizio, 2012). As an example, Páez et. al. (Páez et al., 2010) explore the effects of carbon policies in the US, showing the potential for economic disruption in states with high fossil penetration and budget deficits, and leading to typical socioeconomic consequences one might expect as a result of this transition.

Additionally, early retirements for high value assets inherently run the risk of creating stranded assets on the market – *i.e.* assets that must be written off before full depreciation due to premature closure. Previous studies place the magnitude of stranded assets for fossil fuel plants in the order of \$50 billion – \$120 billion[1] by 2035 depending on the assumption of compensation through capacity markets (Baron and Fischer, 2015). Other studies include an analysis of so-called “unburnable” coal and gas reserves (i.e. fuel that is unable to be burned without breaching a carbon budget), which have been valued between \$180 billion and \$1 trillion (Baron and Fischer, 2015). A clear understanding of these exposures is essential in determining an optimal pathway to deep decarbonisation, firstly to reveal the true impact of an energy transition of this size, and secondly to enhance the resilience of the transition.

This paper presents an analysis of fossil fuel asset early retirements necessary to achieve the IEA 2DS pathway and considers the economic and geopolitical implications. Rather than quantify the value of unburnable fuels and stranded reserves as most previous works have done (Ansar et al., 2013; Caldecott et al., 2016, 2014; Caldecott and Robins, 2014; Carbon Tracker Initiative, 2013; Jakob and Hilaire, 2015; Lazarus and Tempest, 2014; McGlade and Ekins, 2015, 2014; Robins et al., 2012; Rogelj et al., 2012), we focus on stranded fossil fuel power generation assets arising from a 2DS pathway. One notable study by Johnson et al. (2015) has previously investigated this challenge, modelling the magnitude of stranded power plant assets for various short-term carbon policies. We aim to build upon this branch of literature, introducing new methods for modelling end-of-life and early retirement rates, measuring the age at which assets must be brought offline, and integrating the analysis with the IEA projection. Taking a global focus, we can also compare impacts between different regions in the world and identify key issues that may affect the feasibility of early retirements in some countries. Ultimately, we aim with this work to expose the magnitude of the challenges surrounding early retirements in the fossil fuel industry and encourage consideration of these socioeconomic consequences in future integrated assessment models.

[1] All monetary figures within this analysis are provided in 2015 USD.

2. Methodology

2.1. The future of fossil fuels under a 2DS

The IEA 2 °C scenario (2DS) projects major changes in the market shares of various electricity generation technologies while simultaneously forecasting an increase in global installed capacity from 6 TW in 2014 to 19 TW in 2060, as shown in Fig. 1a and b. Notably in Fig. 1b, renewable technologies (including geothermal, onshore/offshore wind, solar PV, CSP, and ocean) make up 62% of installed capacity in 2060, up from 9% in 2014, driven primarily by an additional 6.2 TW of solar PV and 3 TW of onshore wind. To put this in perspective, the renewable capacity that must be installed in the next 40 years is almost double the current total capacity of the worldwide electricity generation sector.

In the same timeframe, gas-fired capacity also increases by around 16% as seen in Fig. 1c. This uptake of gas-fired generation supports the increasing penetration of VRE (variable renewable energy), which requires dispatchable, flexible, and load-following back-up generation and associated ancillary services. Additionally, natural gas offers a lower emissions intensity than coal or oil and at a significantly lower cost than battery storage, highlighting its role as a short to medium-term transitional technology. However, in stark contrast, traditional oil and coal power generation assets (without the addition of CCS) require a reduction in capacity of 74%[2] and 99% respectively over the same period (see Fig. 1c).

Although daunting, other projections in line with the Paris Agreement such as those from World Wildlife Fund (WWF) (Ayukawa et al., 2008), U.S. Climate Change Science Program (CCSP) (Clarke et al., 2007), and Worldwatch (Sawin and Moomaw, 2009) put a much stronger focus on renewable energy uptake and by that virtue, a much more rapid decline in fossil fuel capacity. Comparing several published decarbonisation pathways (Loftus et al., 2015) indicates that the IEA model presents a relatively measured transition in the electricity generation sector, making the 2DS a quasi-conservative transition scenario towards deep decarbonisation. Additionally, given the influential role that the IEA plays in international energy and climate policy formulation, 2DS seems to provide a meaningful lower bound for fossil fuel retirements in decarbonisation scenarios.

2.2. Examining plant lifetimes and retirement schedules

To model the pathway towards 2DS, we must first understand the age distribution of the existing fossil power plant fleet. We can measure the regional differences in fossil fuel plant ages worldwide using the Global Data power plant database (GlobalData, 2017) (see Fig. 2). For

[2] In the original 2DS from ETP2017, global oil-fired capacity increases from 143 GW to 391 GW from 2055 to 2060 with no associated increase in generated electricity (compared to 442 GW in 2014). This 5-year spike is most pronounced in the US (1–81 GW) and the EU (4–52 GW), and is not present in either the BAU or Beyond 2DS pathways provided by the same publication. Given the infeasibility of this deployment schedule, we assume this final data point is a modelling artefact, and we have adjusted it to reflect the same rate of capacity decline as the previous 5-year interval.