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This policy brief identifies key criteria for targeting coal-fired plants for early retirement. It presents the results of a retirement index that ranks coal-fired plants on the basis of age, air pollution, and climate change. The key finding is that plants ideal for retirement are mostly located in populated areas of China and India rather than in industrialized countries.

Air pollution caused by operating coal-fired power plants. Source: World Health Organization (WHO)

IDENTIFYING COAL-FIRED PLANTS FOR EARLY RETIREMENT

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INTRODUCTION

Decarbonization of the global economy is necessary to ensure climate stability under the Paris agreement. Coal-fired electricity generation is the most carbon-intensive form of power generation and its emissions are associated with adverse health effects. Hence, it is essential to reduce global coal-fired electricity generation, and that includes the early retirement of existing operating plants. Using global data on operating coal-fired plants, an ISEP working paper presents a retirement index that identifies potential plants for retirement. The index identifies plants based on a set of criteria including age, annual CO_2 emissions and population exposed to their pollution. By doing so, the index accounts for the potential carbon emissions and health damage from air pollution. Results show that top polluting plants are located in China and India, followed by South Korea. This finding contrasts with the general trend in the current policy discourse, where older plants in developed and industrialized countries get the priority for retirement. The ISEP index emphasizes the importance of including additional criteria when identifying plants that are 'ripe' for retirement.

CURRENT STATUS OF GLOBAL COAL PIPELINE

Coal-fired electricity generation constitutes around 40% of global power generation, reaching close to 70% and 80% in India and China, respectively. In the absence of climate policies to limit the use of coal for power generation, and with more capacity being built over the coming years, these numbers may continue to grow. This poses as a risk for climate stability, as the average age of a coal-fired plant is 40 years (Johnson et al., 2015; Shearer et al., 2015). Moreover, air pollution from these coal plants is associated with several negative health effects including premature deaths. Emissions from coal-fired plants include a diverse range of pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM) and mercury. These gases have been associated with a range of diseases ranging from asthma and respiratory diseases to nervous, digestive, heart and immune system problems (Cohen et al., 2017; Hu et al., 2017). Additionally, the pollution leads to 800,000 premature deaths annually and the new capacity is expected to add another 130,000 deaths annually (Shearer et al., 2015, 2016).

> *"Strict policies addressing the reduction in new capacity built as well as motivating retirements in the region may go a long way, especially given that many Asian countries have lax emission standards."*

Globally, new coal-fired capacity addition has slowed down over the past few years. However, more than 365 GW was added in the past decade. China and India account for more than 85% of the new capacity built between 2006 and 2016. Strict policies addressing the reduction in new capacity built and motivating retirements in the region may go a long way, especially given that many Asian countries have lax emission standards (Shearer et al., 2016, 2017).

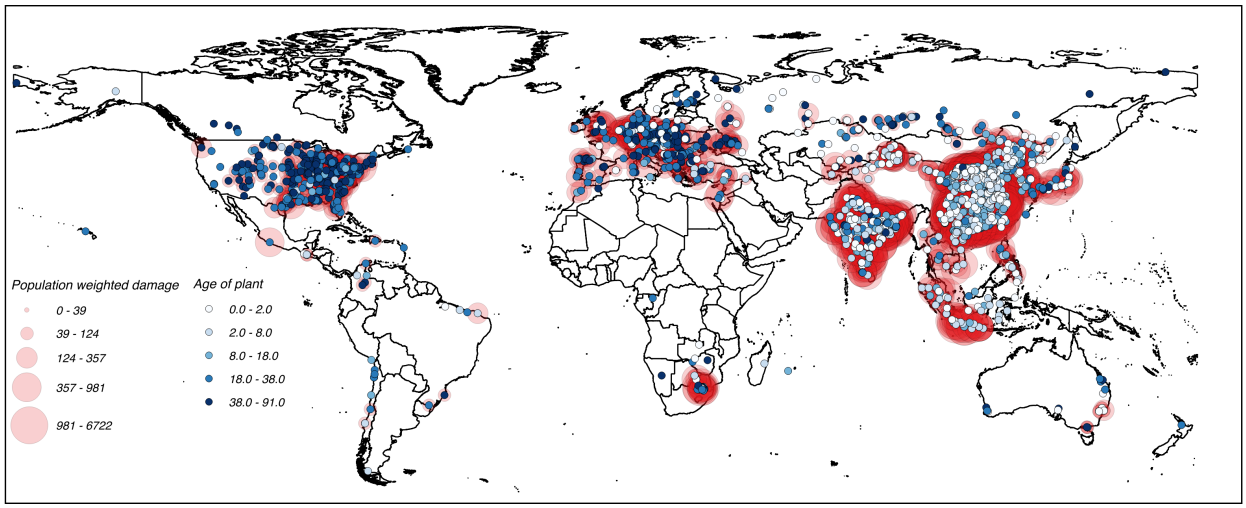
There has been a rise in cleaner alternatives such as natural gas and renewable energy. Nonetheless, the retirement of coal-fired plants is still imperative. According to a recent report by the Intergovernmental Panel on Climate Change (IPCC), pathways in line with the 1.5°C limit require rapid reductions in coal-fired electricity generation, and retirements of existing plants is critical for this goal (Nace, 2018).

This policy brief reports the results of an ISEP working paper that identifies key criteria for the early retirement of coal-fired plants. It presents a retirement index that ranks currently operating plants according to their suitability for retirement. Using global data on operating plants, the paper estimates where the pollutants emitted by these plants end up using a Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. This approach enables researchers to assess the potential for air pollution damage from coal-fired power plants. The results of the index provide a new outlook on retirement schedules, as the index sets priority of retirement to plants that are located in emerging economies such as China and India on the grounds of the public health damage they could cause, rather than plants located in the developed world based on retirement schedules that focus mostly on plant age, such as the one

presented in Nace (2018).

CRITERIA FOR RETIREMENT

The current trend in the global policy discourse on climate change mitigation is to focus on developed countries. The age of the plant is regarded as the main factor for ranking plants for retirements. That approach is not unreasonable, given that older plants are generally less efficient and more polluting than new plants. Additionally, this tactic follows a similar notion to that of the United Nations Framework Convention for Climate Change (UNFCCC) "common but differentiated responsibilities", where countries that benefited the most from industrialization have to pay more (Venkatesh et al., 2012; Fleischman et al., 2013; Miller, 2013; Jotzo and Mazouz, 2015; Huetteman, 2017; Nace, 2018). While age is an important factor for identifying plants to retire, it does not capture the fact that newer plants are often located in more populated areas, meaning that the potential magnitude of the harmful effects may actually end up being higher. The below figure illustrates the negative correlation between the age of the plant (blue) and the number of people affected by its polluting emissions (red).



Source: Data collected by authors.
Map of the age of global coal-fired plants and the global population-weighted damage based on the gridded population data (GPWv4) and the frequency of where the pollutants are estimated to end up by HYSPLIT model divided into quantiles. Population weighted damage represents the average population exposed to plant's pollutants. The lowest quantile represents young plants (light blue) and low population-weighted damage (red points with small radius) and the highest quantile represents the oldest plants (dark blue) and highest population-weighted damage (red points with large radius). The darker the red circles the higher the levels of population exposed to pollutants.

Another defining criterion when identifying plants that need to retire is their climate impact. Annual CO_2 emissions per plant depend on how efficient the plant is, its size (capacity), and the type of coal used.

While older plants are less efficient, they are also on average smaller in terms of capacity and hence may actually emit less CO_2. Since putting a limit on global warming is the main rationale for a shift to a less coal-intensive power sector, the annual CO_2 emissions of plants are important for retirement decisions.

Additionally, population exposure to the plants' emissions is considered one of the defining factors in the index, due to air pollution effects. When a plant is located in a populated area, its emissions affect a larger number of people. This increases the magnitude of damage this plant causes. Thus population exposure is included as one of the criteria used when ranking plants for retirement, so as to account for the health effects caused by polluting emissions of the plants.

The retirement index presented in the ISEP working paper thus considers age, population exposure to potential air pollution, and CO2 emissions. All three criteria are assigned equal weights, and the currently operating global coal-fired power generation fleet (a total of 2145 plants in 2017) are ranked according to the index. Plants scoring the highest on the retirement index are the plants most suitable for retirement.

According to the index, the top-20 plants are located in China, India and South Korea, with China accounting for 75% of these plants. The combined capacity of these plants is 87 GW and the average age is about 12-13 years. This result is very different from the commonly discussed retirement schedules, such as the Nace (2018) "oldest-first" strategy. The table below shows that the top ranking plants on the new ISEP retirement index are fairly young, and are mostly located in developing countries and South Korea.

Country	Capacity	CO2	Population-weighted damage	Age
China	65126	274.3	71015	13.97
India	11060	49	15609.41	13.64
South Korea	11120	45.8	6750.69	10.7

Source: Authors' results

Table 1: Countries where the top 20 polluting plants are located and their corresponding capacity (MW), CO2 (in million tons), weighted population exposure to pollutants, the average age (in years) of plants to be retired in each country and the average population living in areas exposed to air pollutants of these plants.

Extending the analysis to cover the top 10% (215 plants), plants from the developed world show up in the index. Nevertheless, China (264 GW) and India (92 GW) remain the top-ranking countries with plants needing retirement. They are followed by the U.S. (85 GW), South Africa (28 GW) and South Korea (27 GW). To ensure the robustness of the retirement index, we weighted the three index components differently and created 10 indices, each index with an alternative weighting scheme. The results of the sensitivity analyses show that the index rankings are consistent, with one exception. When age is assigned a heavy weight of the index (75% and higher), plants suitable for retirement tend to be in the OECD countries. Overall, these results show that the climate and health benefits of retiring plants in the developing world could be significant, and age-based retirement schedules may miss important

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opportunities.

POLICY RECOMMENDATIONS

- *Identifying retirement schedules based on age alone is not sufficient. A comprehensive approach would also account for air and carbon pollution.*

- *Good candidates for early retirement are older coal-fired plants (average age 20-30 years) located in China and India. Retired plants would ideally be older, bad for climate, and harmful to public health because of air pollution.*

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About ISEP

The Initiative for Sustainable Energy Policy (ISEP) is an interdisciplinary research program that uses cutting-edge social and behavioral science to design, test, and implement better energy policies in emerging economies.

Hosted at the Johns Hopkins School of Advanced International Studies (SAIS), ISEP identifies opportunities for policy reforms that allow emerging economies to achieve human development at minimal economic and environmental costs. The initiative pursues such opportunities both pro-actively, with continuous policy innovation and bold ideas, and by responding to policymakers’ demands and needs in sustained engagement and dialogue.

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