BU Global Development Policy Center

GEGI WORKING PAPER 066 • 10/2024

Sustainability Premium for the Early Retirement of Coal Plants with Evidence from Indonesia

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ABSTRACT

For fulfilling climate commitments and attaining net zero emission goals, there is a global effort to retire coal fired power plants (CFPPs) early. Development banks and finance institutions have a crucial role to play in facilitating early retirement of CFPPs given their unique business model and public welfare missions. This study develops a Cost-Benefit-Analysis (CBA) framework for early retirement of CFPPs applied to the Tenayan Riau CFPP in Indonesia based on three scenarios: business-as-usual (BAU) where the plant operates for its expected life, early retirement (RE) without any substitute and early retirement with the replacement by an alternative renewable plant (AR). We find that operating the CFPP or retiring it early without renewable substitute impose significant welfare costs on Indonesia. Welfare losses of keeping the power plant in operation are close to seven times larger than retiring the plant earlier and replacing it with alternative renewable sources. From the CBA we impute a 'sustainability premium' that would need to be added to carbon credit schemes and financing models to make the early retirement of the plant welfare enhancing.

Keywords: sustainability premium, coal power plant retirement, cost-benefit analysis, development finance institutions

Acknowledgments: This work was supported by the Boston University Global Development Policy Center [Rockefeller Brothers Fund 22-349 and 23-161].

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INTRODUCTION

Achieving the goals of the Paris Agreement on climate change requires drastic greenhouse gas (GHG) emission reductions in the power sector. As coal is one of the main sources of emissions, coal use must decrease significantly to limit warming to 1.5°C (IPCC 2022; Minx et al. 2024). To achieve these reductions, the Conference of the Parties (COP) in Glasgow in 2021 produced an agreement to phase-down unabated coal power (UNFCCC 2021). At the United Nations Climate Change Conference (COP28) in 2023, governments recommitted to this goal, and added a just, orderly and equitable transition away from fossil fuels in energy systems to the agenda (UNFCCC 2023). However, the global coal plant capacity has been steadily growing for decades, with net additions of 48.4 GW in 2023, of which around 5 GW were outside China (Global Energy Monitor 2024a). Given the large coal fleet and historical operation ages of 40-50 years in most countries, the early phase-down of coal units is inevitable to remain below 1.5°C and even 2°C warming (R. Y. Cui et al. 2019; Fofrich et al. 2020).

One key factor driving the persistent attractiveness of coal power is the methodology used to assess the costs and benefits. This paper examines the implications of more comprehensively accounting for the socio-economic benefits and costs of coal plant retirement. Retiring a coal plant has socio-economic and environmental costs and benefits across global, national, regional and local levels. Cost Benefit Analysis (CBA) is a useful tool for identifying pertinent costs and benefits and quantifying their economic value and provides a framework of analysis.

Phasing down coal-fired power plants (CFPPs) can have various additional benefits, but at the same time poses severe risks—if it is done in an unorderly fashion. Beyond climate mitigation, additional benefits include avoiding negative impacts of localized air and water pollution on human health and the environment. This in turn reduces the number of premature deaths due to kidney dysfunction (Munawer 2018) or respiratory diseases connected to particulate matter (Casey et al. 2020). Taking these aspects into account, a transition to meet the Paris targets would overall provide economic benefits (Rauner et al. 2020). An unmanaged coal phase-down, however, poses severe social and economic risks including energy insecurity, job losses and slowed economic growth (Manych et al. 2024). Thus, the decarbonization or early retirement of CFPPs must be facilitated and effectively managed.

Given the development-focused mandates of development finance institutions (DFIs), it is especially important for DFIs to consider all potential costs and benefits when evaluating the value proposition of a coal plant (and its retirement).

A large portion of the coal plants that will have to be phased down early are in countries that face high perceived investment risks, limited access to capital markets and high governmental influence in the energy sector. With their ability to offer low-cost, long-term loans, expertise working in the energy sector and experience in collaborating with governments, DFIs can play a vital role through various financial mechanisms (Kachi, Bendahou, and Outlaw 2024; Manych et al. 2024). However, to this date, only a few DFI-led initiatives have materialized, and most are in the early stages. Thus, there is a need to inform DFIs, enabling them to embrace their role as knowledge banks and fulfill their responsibility in advancing sustainable development while demonstrating climate leadership.

This paper provides a novel estimate of the costs and benefits associated with early CFPP phase-down and illustrates how a consideration of a broad range of costs and benefits can impact DFI financing. First, we present a novel holistic CBA framework to assess the socio-economic and environmental costs and benefits of coal plants. A business-as-usual (BAU) scenario is compared with an early retirement scenario and an early retirement scenario with solar power replacement. The costs and benefits in the analysis include social-economic costs and benefits for the labor market and public health, as well as environmental items such as carbon emissions and water quality.

Second, the paper provides an illustration of the framework using the Tenayan Riau (aka Tenayan Raya) coal power plant in Pekanbaru, Riau Province, Indonesia. We find the elements having the largest impact in the analysis are emissions, revenue from electricity and income losses to the plant. Replacing coal with solar promises the best outcome. Thirdly, we build on the results from the CBA and add data on refinancing mechanisms for the phase-down of the coal plant to calculate the "sustainability premium." Incorporating the CBA results into a model for refinancing for early retirement allows us to calculate a sustainability premium. This premium could be considered by DFIs while raising the required carbon credit price to compensate debt and equity holders.

The remainder of this paper is structured as follows. The relevant literature is summarized in the second section. The third section explains the applied methods before the fourth section details the data. The results and their conclusion are outlined in section five and six, respectively.

LITERATURE REVIEW

This paper aims to fill two major research gaps in literature. First, only a few studies consider CBA of CFPP phase-down (Akin et al. 2012; Cui et al. 2022; Rokhmawati et al. 2023). CBA can help to assess whether a project is 'worthwhile' from a societies perspective, to compare different scenarios and to inform decision-making (R. Cui et al. 2023; Mishan and Quah 2020; Erbas and Xie 2015; Akin et al. 2012) and has been recommended for coal plant phase-down (TransitionZero 2023). Some papers analyze specific aspects, highlighting for instance the significant water footprint of coal-fired power generation in China (Akin et al. 2012; Zhu et al. 2020) or the external public health costs of the Tenayan Raya coal plant (Rokhmawati et al. 2023). Two papers have advanced our understanding on financial instruments to retirement by calculating the related costs over time using cashflow analysis (Clark et al. 2023; Shrimali 2020). Other authors explicitly conduct a CBA for coal plant retirement: Cui et al. (2022) find that a country-level coal phase-out in Indonesia would produce overall benefits; Jindal & Shrimali (2022) show that repurposing a coal plant in India with synchronous condenser yields the largest benefits; Li et al. (2021) find a large cost-benefit heterogeneity for coal plant retrofitting with biomass co-firing in China.

Second, this paper identifies how the feasibility of coal plant retirement can be enhanced by advancing the notion of a sustainability premium in coal plant refinancing. Existing studies have explored barriers ranging from the individual plant level to the national policy level. Authors find that phasing out coal plants is technically feasible considering the power system (Yang et al. 2021), but difficult due to multiple barriers that need to be considered (Edianto et al. 2023; Chattopadhyay et al. 2021; Pinko and Pastor 2023; Tan et al. 2021). Other studies identify coal plants that should be prioritized for retirement, based on technical, economic and environmental factors, either globally (Maamoun et al. 2020) or for single countries, such as India (Maamoun et al. 2022), China (R. Y. Cui et al. 2021) and Indonesia (R. Cui et al. 2022; 2023). As a next step, several authors shed light on how coal plants can be phased down, highlighting a variety of financing mechanism (Bhat et al. 2023; Bodnar et al. 2020; Buchner et al. 2022; Calhoun et al. 2021; Holzman et al. 2023; Climate Investment Funds 2023; Nedopil et al. 2022; Glasgow Financial Alliance for Net Zero 2023). In particular, studies outline the use of carbon credits (Monetary Authority of Singapore and McKinsey & Company 2023), capacity payments (Yin et al. 2021) and asset management companies (Qian 2024) for CFPP phase-down.

A more recent set of studies have zoomed in on the role of DFIs in coal plant retirement. These studies have highlighted the benefits, potential barriers, financing mechanisms, the necessity of engaging

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with national policymakers and the need to avoid phase-down options that prolong dependence on coal (Manych et al. 2024; Kachi, Bendahou, and Outlaw 2024; Outlaw et al. 2024). These studies build on earlier analyses that investigated the source and drivers of foreign and domestic financing for coal plants. A paper by Manych, Steckel, and Jakob (2021) analyzing global financial flows finds that a substantial amount of CFPPs relies on foreign banks and investors, which provide loans and underwriting to coal plant developers and buy their bonds and shares. Most funding in the 2010s stems from public banks in China, Japan and South Korea (Manych et al. 2023). Several studies specifically show the significant coal capacity funded by Chinese banks abroad (Z. Li, Gallagher, and Mauzerall 2020; Chen, Gallagher, and Mauzerall 2020; Hervé-Mignucci and Wang 2015; Lin and Bega 2021) or by multilateral development banks (MDBs) (Steffen and Schmidt 2019; Sauer et al. 2022). Regardless of the incentives for banks to support the construction of CFPPs abroad, such as the export of services and technology (Kong and Gallagher 2019; Manych et al. 2023; Manych 2023) and meeting foreign governments' demand (Bhandary et al. 2022; Gallagher et al. 2021), most banks and countries have pledged to halt funding new coal projects abroad (Springer 2022; Davidson et al. 2023; Schiermeier 2021).

These studies have greatly advanced understanding of CFPP phase-down and the roles that DFIs can play in such. However, an important element is missing, namely a holistic implementable CBA for coal plant retirement and replacement with renewable energies to inform DFIs' decision-making, to operationalize sustainability aspects and further researchers' knowledge.

METHOD

To incorporate welfare and sustainability aspects of early retirement of CFPPs, this study develops a holistic CBA framework, customizes it to the Tenayan Riau coal plant in Indonesia for its early retirement and integrates the CBA results into a model for refinancing the early retirement of the plant. These three steps are explained hereafter.

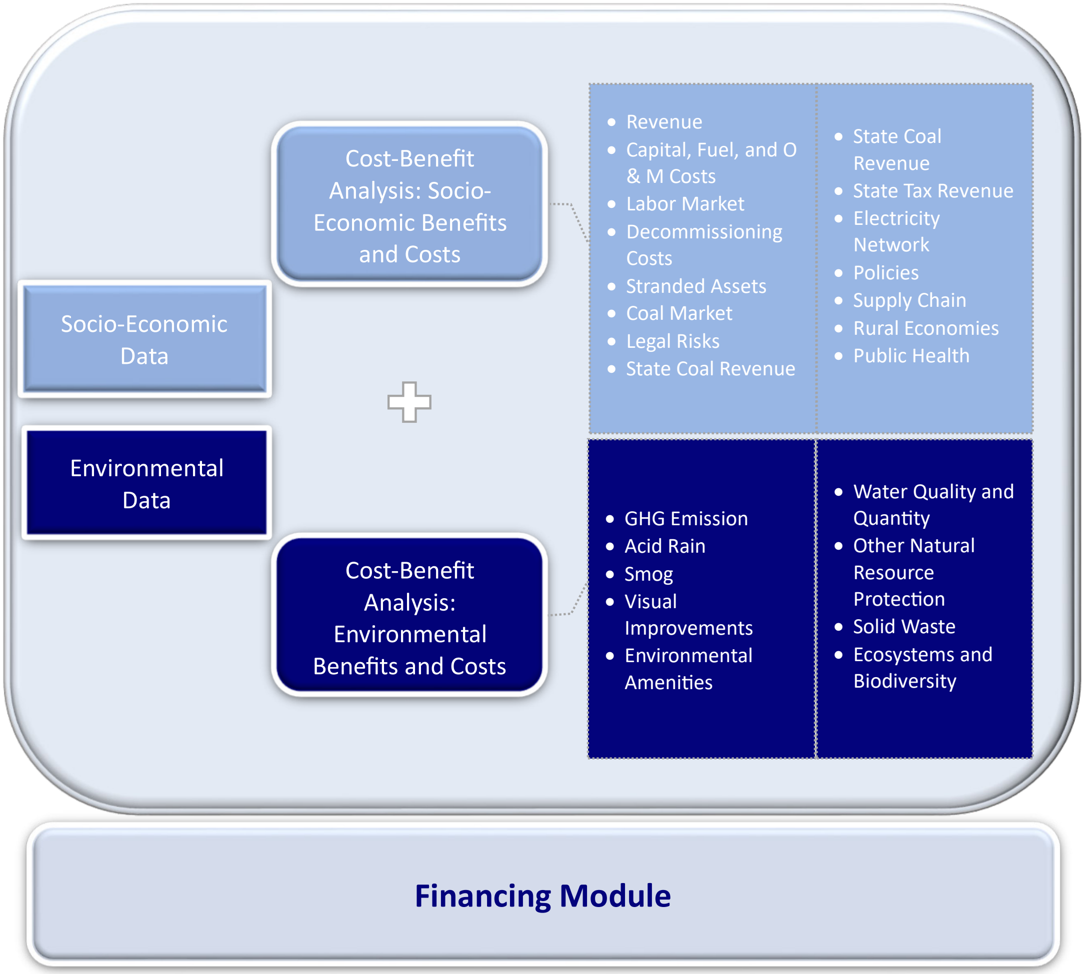
General CBA Framework

Developing a general framework of CBA is the initial important step in capturing local, regional and global welfare and sustainability implications of retiring CFPPs early.

The general CBA framework shown in Figure 1 has two main components: socio-economic and environmental. The socio-economic component constitutes direct social and economic benefits and costs associated with the early retirement of CFPPs with or without renewable substitutes. The environmental component captures direct benefits and costs of these decisions on the environment and natural resources, and thus in turn on human ecosystems.

Based on the relevant literature and assuming no limitation on the data availability, a general CBA framework includes socio-economic and environmental items. The socio-economic component includes revenue, capital, operating and management costs, fuel costs, labor market costs and benefits (related to job and income losses and creation, retirement benefits, and associate fiscal supports), decommissioning costs, stranded assets and costs, costs and benefits associated with legal risks, coal market, taxation, spillovers to rural economies, and public health. In the environmental component, benefits and costs are related to GHG emissions, acid rain, smog and visual impacts, water use and quality, other natural resources, solid waste and other ecosystem and biodiversity aspects.

Figure 1: A General CBA Framework



Source: Authors' illustration.

Note: An expanded version of the General CBA Framework in Figure 1 presenting three alternative scenarios of early retirement is provided in Table A1 in the Appendix.

Table 1: The Three Scenarios Studied

Scenario	Name	Assumptions
Scenario 1	Business As Usual	Plant operates to the end of its natural retirement age
Scenario 2	RE	Plant retired in seven years of operation in 2023
Scenario 3	AR	Plant retired in seven years of operation and replaced by renewable energy technology

Source: Authors' elaboration.

Note: The BAU assumes that the CFPP will continue to operate until the end of its natural retirement age, RE is retiring early in seven years of operation in 2023 without any renewable substitute replacing the CFPP, and AR is retiring early in seven years of operation in 2023 with replacing the CFPP with its renewable alternative .

Example: Tenayan Riau CFPP

In addition to developing the general CBA framework with three scenarios outlined in Figure 1, we customize it for Tenayan Riau CFPP (aka Tenayan Raya CFPP) in Pekanbaru, Riau Province, Indonesia (Tenayan Riau CFPP) by first building on and then expanding the model developed in Rokhmawati et al. (2023), which quantifies the levelized cost of electricity and health and integrates those generation cost of electricity to calculate net present value, internal rate of return and project payback period for the plant.

Indonesia is an emerging market with a major coal economy. The country is working on refinancing plans to support its transition from coal to clean energy to build a low-carbon economy. Indonesia announced plans to phase out coal by 2056, with a possibility of moving it to an earlier date to 2040 if there is an availability of financial assistance from international community. The Indonesian public utility, Perusahaan Listrik Negara (PLN), also committed to reach net-zero emissions by 2060. Therefore, Indonesia's $20 billion Just Energy Transition Partnership (JETP) deal reinforces these plans by offering blended finance packages to be used through various mechanisms. The Asian Development Bank's (ADB's) Energy Transition Mechanism (ETM) based coal retirement deals are being piloted in Indonesia: a roughly $250 million refinancing to retire the Cirebon-1 plant 15 years early and to retire the Pelabuhan Ratu plant nine years early (Climate Bonds Initiative, 2022). In this study, we use Tenayan Riau CFPP to conduct CBA for early retirement and its employment in refinancing as its data is available publicly.

Tenayan Riau CFPP has a total capacity of 220 MW with two units of 110 MW each, built in 2016 and 2017 (Global Energy Monitor 2024b). It was financed with a loan of $124 million from the Export-Import Bank of China (CHEXIM). The plant uses domestic coal to produce electricity which is sold to customers in Tenayan Industrial Zone and to residential customers in the city of Pekanbaru, in Riau region (Gunawan 2022). Table 2 displays relevant figures for Tenayan.

The extent that all publicly available data permits us to do so, we construct more comprehensive CBA model at plant level in the literature. We build and implement the CBA of three scenarios to investigate its implications for early retirement of CFPPs as well as to suggest implementable policy tools that can be used by DFIs.

Under the BAU scenario, we assume that the plant will retire in 2047 at the age of 30. In the early retirement scenario, RE, we model that the plant has retired in 2023 at the age of seven without any renewable substitutes. Given the importance of solar energy in energy planning in Indonesia in general and a planned solar generation unit under construction in Riau region specifically, we model solar energy as a substitute for Tenayan Riau CFPP (JETP Secretariat 2023) in the AR scenario, which replaces the CFPP in 2023 and to run until 2047.

Under each scenario, we calculate the benefit and cost streams in Table 3 by using various valuation methods with appropriate discount rates depending on whether the benefits and costs are born to private entities or to society. Data availability and limitations affect the categories of benefits and costs that are being calculated. Specific to Tenayan Riau CFPP, available data and its sources in Tables 4 and 5 allow us to calculate the following environmental costs and benefits: social cost of carbon, smog and visual improvements and mercury reduction for improved water quality when the plant is retired with or without solar energy substitution, and water use of the CFPPs in producing electricity. The socio-economic costs and benefits include revenue and total generation cost of Tenayan Riau CFPP, electric coal subsidies associated with the plant, state coal revenue generated, state tax revenue raised, total stranded assets, decommissioning costs, labor market income losses or job creation, integration and grid cost of renewable, fiscal support for job losses, foregone future income generated by industrial zone, cost of public health damage and benefits of the plant generated for

Table 2: Relevant Figures for the Tenayan CFPP in Pekanbaru, Riau, Indonesia

	Units	Input Data
Installed Capacity	MW	220
Overnight Cost	$/kW	1,218
Disbursement of Overnight Cost		
Year 1	%	24
Year 2	%	54
Year 3	%	14
Year 4	%	8
Electricity Production	MWh/yr	1,380,171.69
Fixed O&M	$/KW/yr	14.13
Variable O&M	$/MWh	9
Calorific Cost of Coal	$/106kcal	8.37
Coal Price	$/ton	47.72
Availability Factor	%	71.615
Discount Rate	%	10
Lifetime (n)	yr	30
Thermal Efficiency	%	37
Forced Outage	%	13
Scheduled Outage	weeks/yr	8

Source: Rokhmawati et al. 2023.

rural economies in the region. Sensitivity analysis is not currently illustrated in the CBA analysis, but the future work by implementing institutions should incorporate sensitivity analysis.

Social cost of carbon (SCC) is an estimate of the present value of costs of the damage done by each additional ton of carbon emissions over specified future years. Therefore, it is also an estimate of the benefit of any action taken to reduce a ton of carbon emissions. The SCC or benefit of the reduction of carbon emissions is born to global citizens and thus it is the economic value of global externality or public bad. The SCC values estimated by the US Environmental Protection Agency (EPA) (2022) can be directly used to calculate costs and benefits in other countries assuming that these countries adopt the same set of judgments and methodological assumptions used by the EPA. If policymakers in other countries have other policy judgments or methodological assumptions, then SCC estimated would need to be recalculated accordingly. Carbon emissions and SCC of Tenayan Riau CFPP are presented in Table A2 in the Appendix.

Coal-fired electricity is produced by using water in generation and coal mining process. In calculating cost of water use, we use unit value transfer method. Simple growth rate of wholesale price index is used to bring full cost of water from 1997-2017 (Rodgers and Hellegers 2005), which is then further increased by average inflation rate of 4.10 percent till 2046. Yearly total water use in both generation and mining is multiplied by the estimated full cost of water in Indonesia from 2023-2046 for the BAU scenario. Total cost of water use is discounted at 3 percent for the present value of water use and converted to its dollar equivalent by using Purchasing Power Parity (PPP) adjusted private

Table 3: CBA for the Tenayan CFPP: Benefits and Costs under Three Scenarios

Environmental and Socio-Economic Benefits and Costs	BAU	RE	AR
Social Cost of Carbon	–	–	–
Water Use	–		
Smog, Visual Improvements		+	+
Water Quality (Mercury Reduction)		+	+
Public Health Damage Cost	–		
Coal Electric Subsidies	–		
Revenue	+		+
State Coal Revenue	+		
Tax Revenue from CFPP/Solar	+		+
Rural Economies	+	+	+
Total Generation Cost	–		–
Total Stranded Assets		–	–
Total Decommissioning Costs		–	–
Labor Market Income Losses/Job Creation		–	+
Integration and Grid Cost of Renewable			–
Fiscal Support for Job Losses		–	
Foregone Future Income Generated by Industrial Zone		–	

Source: Authors' elaborations.
Note: Costs are denoted as '–' and benefits are denoted as '+' under each category

consumption rate. As retiring the Tenayan Riau CFPP would eliminate its water use and since solar energy does not have significant water use in generation process while harvesting solar power, RE and AR scenarios are assumed to have no water use cost. Water use reduction under RE and AR scenarios is considered as benefits to local and regional population.

The other two environmental benefits and costs are related to reduction in smog and thus improvement in visibility and decrease in mercury in water media near the plant. These benefits are realized under RE and AR scenarios. Both benefits are calculated by benefit transfer method (BTM). This method is commonly used in valuation literature (World Bank 2011; Rokhmawati et al. 2023; Burtraw et al. 1998). BTM is a widely used method in CBA, especially when there are data limitations in developing economies (Pearce, Atkinson, and Mourato 2006; Bai, Lam, and Li 2018). Appropriate studies on willingness to pay for improved residential and recreational visibility (Burtraw et al. 1998) and for reduction in mercury in water (Hagen, Vincent, and Welle 1999) are employed in transferring benefits in the form of willingness to pay (WTP) values in these studies to WTP values in our report. Initially, WTP per capita dollar values are converted to WTP per capita Rupiah in the study year by using PPP adjusted private consumption rate (OECD 2024) and then these values are increased by the Indonesian consumer price index (World Bank 2024) for the future years in the scenarios. Present value of total WTP in the region is calculated by multiplying the per capita WTP values by the population in Pekanbaru (World Population Review 2024) and discounting them at 10 percent for each year and summing them over the years in the scenarios.

In operating Tenayan Riau CFPP, electricity generation revenue and cost are recalculated to confirm the computations behind Rokhmawati et al. (2023) and used in the BAU and RE scenarios. Assuming that the tariff and electricity generation amount under coal is the same under the solar, the revenue of solar alternative is assumed to be same as the revenue of Tenayan Riau CFPP. However, the total generation costs are different under the two options. The present value of total generation cost of Tenayan Riau CFPP calculated as sum of the present values of total operating and management fixed and variable costs and total fuel cost streams, which are computed based on Rokhmawati et al. (2023). For the present value of the total generation cost for solar under RA scenario, we use the total operating and maintenance cost of $15,000 per MW of installed capacity (National Renewable Energy Laboratory 2021; Marketwatch 2024). In addition, we use the renewable investment costs from the Just Energy Transition Partnership Indonesia Comprehensive Investment and Policy Plan (JETP CIPP) 2023 (JETP Secretariat 2023) to calculate the total generation cost of solar alternative of Tenayan Riau CFPP.

Public Health Damage Cost calculations is also based on the BTM. Rokhmawati et al. (2023) uses Airpack Software to calculate air quality parameters (PM_{10}, SO_2 and NO_2) and benefit transfer method to calculate the unit cost of public health damage for Indonesia based on EU15 study. In our report, the unit cost of public health damage computed in Rokhmawati et al. (2023) is used to calculate yearly flow of cost of public health damage. The calculated value captures public health damage arising due to public exposures to PM_{10}, SO_2 and NO_2 emitted from Tenayan Riau CFPP and is consisting of mortality due to short-term and long-term exposure, restricted or limited activity days, new cases of long-term chronic bronchitis, respiratory hospital admissions and lower respiratory symptoms. By considering the yearly electricity production of Tenayan Riau CFPP, total health damage cost for each year over the time period associated with BAU scenario are computed.

Avoided coal electric subsidies, stranded assets, decommissioning costs, labor market income losses and job creations, and fiscal support for job losses are the socio-economics costs and benefits that are computed by unit value transfer method. Unit values used to calculate benefit and cost streams are specifically calculated for Tenayan Riau CFPP in Cui et al. (2022), which calculates these values for early retirement of CFPP fleets in Indonesia. The paper presumes retirement of Tenayan Riau CFPP 10 years earlier in 2037. Therefore, these values are adjusted for the differences in retirement age in Cui et al. (2022) and this study. Overnight cost of capital of Tenayan Riau CFPP is multiplied by a year specific weight. The weight captures appropriate portion of the capital costs that reflects the remaining life of the plant when it is not retired, and thus, these assets are employed. Under the scenario of replacing Tenayan Riau CFPP with a solar alternative, labor income losses need to be compensated by job creation generated by solar power. According to the JETP CIPP (JETP Secretariat 2023), solar alternative would create 2.5 times more jobs per GWh compared to coal energy in Indonesia according to scenarios from the 2019-2038 General National Electricity Plan, or RUKN. Between 2023-2030, Indonesia plans to invest additional 52.2 GW of renewable energy to produce electricity, of which 27.7 GW is solar. The investment cost of this additional capacity of renewable energy is $49 billion. Given the income losses that are calculated when Tenayan Riau CFPP is retired and the solar power plans of the country, the value of the benefit of job creation under solar power can also be calculated.

State coal revenue losses when retired and tax revenue collected from CFPP or solar when operated are calculated based on unit values presented in Rokhmawati et al. (2023). Levelized cost of coal of Tenayan Riau CFPP incurred is assumed to be equal to state coal revenue losses from Tenayan Riau CFPP when retired. Levelized cost of coal is calculated by adjusting the calorific cost of coal with thermal efficiency and a multiplier number to convert the unit kg of fuel to kilo-watt-hour (kWh). Calorific cost of coal is the ratio of coal price per kg and calorific value of coal. Tax revenue collected is the product of tax rate of 30 percent and net cash flow, which is revenues net off total generation costs.

Tenayan Riau CFPP is planned to feed its electricity to an Industrial Zone called "KIT" (Tenayan Industrial Zone). Early retirement of the CFPP, if not immediately replaced by alternative renewable, leads to reduction in energy supply for KIT and thus results in future revenue losses. The revenue loss is a cost to society and thus needed to be included in the CBA. Calculation of future revenue loss can be based on the portion of the initial financial investment made for the KIT associated with Tenayan Riau CFPP. This is based on the profitability requirement which assumes that present values of future revenues are expected to cover the initial investment costs. KIT received initial financial investment of Rp 10.99 trillion and Rp 20.7 trillion in the first quarter of 2021 and the second quarter of 2022, respectively (Gunawan 2022). The annual investment is estimated to be Rp 60.46 trillion in 2023 and 2024. We calculated the electricity supply share of the Teneyan Riau CFPP as 44.44 percent in energy consumption of KIT. In addition to Tenayan Riau CFPP, another power plant in the region is Riau Combined Cycled Power Plant CCPP of 275 MW (Asian Development Bank 2024). In addition, in 2032, in Pekanbaru Region a solar and storage power plant of 3500 MW is planned to go online, with plans to sell its electricity to Singapore (Matich 2022).

When CBA is combined with financial analysis of early retirement of CFPPs, it can operationalize sustainable development aspects of early retirement of these plants for empirical welfare analysis and also for development of policy tools for DFIs in implementing early retirement of these plants and meeting net zero goals. In this part of our study, we integrate the CBA analysis developed in the second part of our study into financial analyses of early retirements of Tenayan Riau CFPP to calculate the carbon credit prices with sustainability premium.

We use the financial model built by Clark et al. (2023) to integrate social and environmental benefits and costs of the CBA for Tenayan Riau CFPP. The study analyzes various types of refinancing mechanisms of early retirement of CFPPs. By employing various forms of discounted cash flow and present value methods, they develop concessional financing, carbon finance and concessional carbon finance mechanisms to calculate implied interest rate subsidy, determine cost of early retirement, compute avoided emissions and net present value of debt and equity cashflows, calculate carbon prices and determine carbon revenue net present value required to compensate debt and equity holders.

In this study, we customize the buyout mechanism of Clark et al. (2023) to study the impact of various cost and benefits in CBA in calculating carbon credit prices to justify early retirement at each year starting from initial construction of Tenayan Riau CFPPs to its retirement year at the age of 30. Buyout mechanism calculates carbon credit prices that are necessary to cover the net present value of outstanding debt, equity cashflows and shortfall in subsidies for equity/debt. We first customize the buyout mechanism of Clark et al. (2023) to Tenayan Riau CFPP and calculate carbon credit prices based on financial costs. Then we integrate the benefits and costs of CBA into financial costs to reconstruct carbon credit price (i.e. carbon credit price with CBA) that is associated with refinancing either debt or equity and debt and equity together of early retirement of Tenayan Riau CFPP for various retirement years. The reconstructed carbon credit price with CBA is higher than the carbon credit price without CBA, as it contains an additional economic value that we refer as a 'sustainability premium.'

DATA

Data is gathered from various publicly available sources. Some of this data is directly used in computations and some others are used to generate secondary data that are also inputs in our calculations. In order to be consistent with the existing computations in the literature and build on them, we regenerated the data in some of these studies (Rokhmawati et al. 2023; Bakatjan, Arikan, and Tiong 2003, Chen and Liou, 2017). Secondary data must be adjusted, given the assumption in our study including the plant's useful life and retirement age.

Tenayan Riau CFPP: Socio-economic Data

Base data on socio-economic benefit and cost items is provided in Table 4. For each category, the base data used and the sources are respectively reported in the second and third columns.

Table 4: CBA Base Data – Socio-Economic

Socio-Economic Benefits and Costs	Data	Main Data Sources
Public Health Damage Cost		
Health Damage Cost ($/kWh)	0.01599	(Rokhmawati et al. 2023)
PPP Conversion Factor (LCU to Int. $, 2022)	4,889.30	(World Bank 2024)
Average Yearly Inflation, GDP Deflator (%, 2017-2022)	4.15	(World Bank 2024)
Coal Electric Subsidies		
Avoided Coal Subsidies (Mil. $, 2036-2046)	207.71	(R. Cui et al. 2022)
Revenue		
Electricity Tariff ($/kWh)	0.062	(Rokhmawati et al. 2023)
State Coal Revenue		
Calorific Cost of Coal ($/10^6 kcal)	8.37	(Rokhmawati et al. 2023)
Calorific Value of Coal (kcal/kg)	5700	(Rokhmawati et al. 2023)
Coal Price ($/ton)	47.72	(Rokhmawati et al. 2023)
Tax Revenue from CFPP/Solar		
Income Tax Rate Corporations, Indonesia (%)	22	(PWC May 1, 2024)
Rural Economies		
Spillover (%/yr)	3	(Kalkuhl et al. 2019)
Total Generation Cost		
O&M Variable Cost ($/MW)	9	(Rokhmawati et al. 2023)
O&M Fixed Cost ($/kW/yr)	14.13	(Rokhmawati et al. 2023)
Total Stranded Assets		
Overnight Cost of Capital ($/kW)	1,218	(Rokhmawati et al. 2023)
Weight Factor (Exp. Life-Ret. Age/Exp. Life)	0.77	(R. Cui et al. 2022)
Total Decommissioning Costs		
Total Decommissioning Cost (Mil. $/1000 MW)	58.11	(R. Cui et al. 2022)
Labor Market Income Losses/Job Creation		
Labor Income Loss (Mil. $, 2036)	14.14	(R. Cui et al. 2022)
Solar Energy Job Creation, Indonesia (Factor/GWh)	2.5	(JETP Secretariat 2023)
Integration and Grid Cost of Renewable		
Aggregate Integration Cost (€/MWh, 2017)	30	(Heptonstall and Gross 2021)
Grid Cost (€/MWh)	14.27	(Heptonstall and Gross 2021)
Exchange Rates (€, 2017)	13,381 Rp	(Exc. Rt Org UK May 1, 2024)
Fiscal Support for Job Losses		
Fiscal Support for Job Losses (Mil. $, 2036)	2.7	(R. Cui et al. 2022)
Foregone Future Income of Industrial Zone		
Total Investment Cost (Trillion Rp, 2023)	259.7	(Gunawan Arif 2022)
Exchange Rates (Rp, $ 2023)	15,241	(Exc. Rt Org UK May 1, 2024)

Source: The last column lists the sources of each data given in the second column.

Tenayan Riau CFPP: Environmental Data

Base data on environmental benefits and costs is provided in Table 5. Like Table 4, for each category, the second and third column presents the base data and the sources, respectively.

Table 5: CBA Base Data – Environmental

Benefits and Costs	Data	Main Data Sources
Social Cost of Carbon		
Social Cost of Carbon ($/ton in 2020)	190	(US Environmental Protection Agency 2022)
Net Emission Factor for CO2 (g/kWh)	1,011	(World Bank 2011)
Total CO2 Emissions (ton/yr)	1,395,353	(Rokhmawati et al. 2023); (World Bank 2011)
Water Use Cost		
Industrial Water Full Cost, Indonesia (Rp/m3, 1997)	29.8	(Asian Development Bank 2012; Rodgers and Hellegers 2005)
Growth of Wholesale Price Index (1997, 2017)	291	(World Bank 2024)
Average Inflation Rate: Wholesale Price Index (%)	6	(World Bank 2024)
Water Use, Coal Electricity, Indonesia (m3/MWh)	2	(Asian Development Bank 2012; Rodgers and Hellegers 2005)
Water Use, Coal Mining, Indonesia (Mil. m3/yr)	291	(Asian Development Bank 2012; Rodgers and Hellegers 2005)
Tenayan Share, Coal Electricity Installed Capacity (%)	1.042	(Asian Development Bank 2012; Rodgers and Hellegers 2005)
Smog, Visual Improvements		
WTP for Recreational Visibility ($ per capita, 2010)	3.34	(Burtraw et al. 1998)
WTP for Residential Visibility ($ per capita, 2010)	5.81	(Burtraw et al. 1998)
PPP Conversion Factor (LCU to Int. $, 2010)	3,811.00	(World Bank 2024)
Average Yearly Growth Rate of CPI (%)	4.25	(World Bank 2024)
Average Annual Population Growth Rate, Riau Region Indonesia	5.44	(World Population Review 2024)
Water Quality Improvements (Mercury Reduction)		
WTP for Mercury Reduction ($ per capita/Day, 1999)	0.12	(Hagen, Vincent, and Welle 1999)
PPP Conversion Factor (LCU to Int. $, 1999)	1,117.00	(World Bank 2024)

Source: The last column lists the sources of each data given in the second column.

Integrating CBA with financing mechanisms

In customizing the buyout mechanism of Clark et al. (2023) for Tenayan Riau CFPP and integrating socio-economic and environmental benefits and costs under CBA, we first specified the financial inputs for Tenayan CFPP by using the data provided in Table 2, then we added a few more inputs under certain assumptions required by the financial analysis. We assume that Tenayan CFPP has 25 percent equity and 75 percent debt structure. Loan interest rate is 10 percent and the term is 15 years. The post-tax regulated return on equity is 16 percent for the term of 20 years.

RESULTS

CBA on Tenayan Riau CFPP

CBAs of the scenarios BAU, RE and AR, are conducted and all three have negative net present values of $7,683.773 million, $9,127.57 million and $1,125.88 million, respectively. These societal net losses are driven by different reasons under each scenario, as shown in Table 6.

Table 6: CBA Results – Three Scenarios

Present Value (Million $)	BAU	RE	AR
Social Cost of Carbon	($7,644.10)	($1,744.54)	($1,744.54)
Water Use Cost	($5.15)	$0.00	$0.00
Smog, Visual Improvements	$0.00	$124.03	$124.03
Water Quality (Mercury Reduction)	$0.00	$190.78	$190.78
Public Health Damage Cost	($324.81)	$0.00	$0.00
Coal Electric Subsidies	($498.50)	$0.00	$0.00
Revenue	$842.99	$0.00	$842.99
State Coal Revenue	$192.32	$0.00	0.00
Tax Revenue from CFPP/Solar	$106.49	$0.00	$106.49
Rural Economies	$5.94	$2.74	$5.94
Total Generation Cost	($358.93)	$0.00	($239.13)
Total Stranded Assets	$0.00	($205.44)	($205.44)
Total Decommissioning Costs	$0.00	($15.47)	($15.47)
Labor Market Income Losses/Job Creation	$0.00	($9.52)	$23.81
Integration and Grid Cost of Renewable	$0.00	$0.00	($215.34)
Fiscal Support for Job Losses	$0.00	($0.78)	$0.00
Industrial Zone Income Losses	$0.00	($7,484.56)	$0.00
NPV	**($7,683.77)**	**($9,142.76)**	**($1,125.88)**

Source: Authors' calculations.

When environmental and socio-economic costs are taken into account, society incurs welfare losses when the power plant is operated until its expected retirement age of 30. This loss, around $7.7 billion in present value, is almost seven times that of the AR scenario where the CFPP is replaced by a solar power plant. This result communicates the fact that financially profitable CFPPs might not be economically efficient and thus not beneficial for societies. Sustainable development goals require policy designs that can bridge and balance between economic efficiency and financial profitability in retiring CFPPs early.

Once in production, retiring CFPPs early without replacing them with a renewable substitute, RE might lead to an even larger welfare loss for societies, especially in developing economies, where economic development might traditionally rely on coal power. In the case of the Tenayan Riau CFPP, its electricity is planned to be used by industrial customers in the industrial zone. When it is retired early, with no substitution, a portion of income loss of the KIT industrial zone will generate a cost of $7,484.56 million in present value. When this fact is taken into account in the CBA, the size of the net welfare loss increases to be $9.1 billion in present value. This loss is larger than the loss when the plant is run until the full retirement age. However, if the plant is not crucial for the industrial zone, then the welfare loss of RE would be smaller and thus not exceed that of the BAU and making early retirement beneficial for the society. Similar to the Tenayan Riau CFPP case, it is possible that many early retirements of CFPPs in developing economies might require immediate installment of renewable energy plants to avoid electricity shortages. When this is done, crucial projects for economic planners as well as financial investors can carry on, which is also important from a sustainability point of view. Specific to the Tenayan Riau CFPP case, even with the environmental and socio-economic benefits of solar energy substitute when it is retired early and replaced by solar, the society would still experience a net welfare loss of $1.1 billion. When cost and benefits of AR scenario is analyzed, it is observed that the major driver of this net loss is the SCC, $1.8 billion in present value. Other environmental as well as socio-economic benefits are not enough to eliminate this net welfare loss. As the carbon emitted in the first seven years of operation of the Tenayan CFPP continues to contribute to climate change at a global scale, the SCC associated with the first seven years is computed and removed from the benefits generated by the solar energy. In other words, accumulated carbon emitted during the operation years of the CFPP has a public bad effect, even if it is replaced by solar in later years. This result indicates that, for the earlier the retirement of CFPPs, SCC would be lower and substituting it with renewable energy generates benefits that can result in net benefits for the society. The result also has an implication regarding the system perspective in retiring CFPPs. Each CFPP might have a breakeven point in balancing their global carbon costs with local net welfare benefits. Therefore, integration of global and local welfare impacts needs to be achieved in climate,

Table 7: CBA Results – Comparison of Scenarios

Change in Benefits and Costs (Million $)	RE vs BAU	AR vs BAU	RE vs AR
Social Cost of Carbon	$5,899.57	$5,899.57	$0.00
Water Use Cost	$5.15	$5.15	$0.00
Smog, Visual Improvements	$124.03	$124.03	$0.00
Water Quality (Mercury Reduction)	$190.78	$190.78	$0.00
Public Health Damage Cost	$324.81	$324.81	$0.00
Coal Electric Subsidies	$498.50	$498.50	$0.00
Revenue	($842.99)	$0.00	$842.99
State Coal Revenue	($192.32)	($192.32)	$0.00
Tax Revenue from CFPP/Solar	($106.49)	$0.00	$106.49
Rural Economies	($3.19)	$0.00	$3.19
Total Generation Cost	$358.93	$119.81	($239.13)
Total Stranded Assets	($205.44)	($205.44)	$0.00
Total Decommissioning Costs	($15.47)	($15.47)	$0.00
Labor Market Income Losses/Job Creation	($9.52)	$23.81	$33.33
Integration and Grid Cost of Renewable	$0.00	($215.34)	($215.34)
Fiscal Support for Job Losses	($0.78)	$0.00	$0.78
Industrial Zone Income Losses	($7,484.56)	$0.00	$7,484.56
Change in NPV	**($1,458.98)**	**$6,557.89**	**$8,016.88**

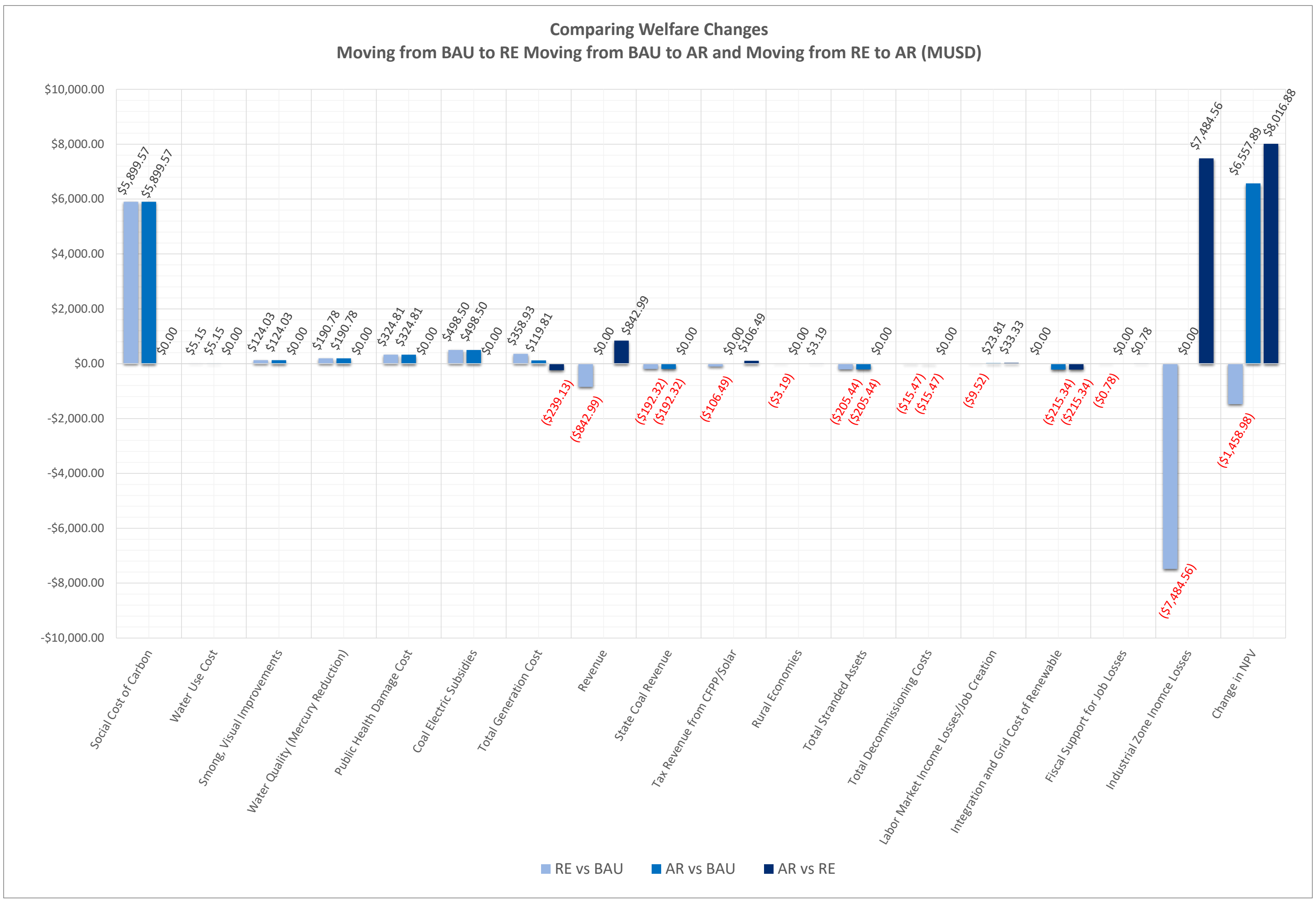
Source: Authors' Calculations.

energy and economic policy design in every country. MDBs and DFIs have important roles to play in integrating global costs and benefits with local ones in developing economies.

Pairwise comparisons of three scenarios are presented in Table 7 and the results are shown in Figure 2. The first column of Table 7 presents changes in the benefits and costs when moving from BAU to RE, that is retiring the Tenayan CFPP at age of seven in 2023, without renewable substitute. The second column captures the changes when moving from BAU to AR, which is retiring the plant early and substituting it with solar energy. The last column, reporting the changes from RE to AR, is to observe the welfare impact of solar energy once an early retirement decision is made. All three comparisons assist policymakers in making decisions to improve welfare of their societies in a sustainable way.

Once CFPPs are built and start to supply energy, retiring the plant without any renewable rather than running it until its expected retirement age leads to an additional welfare loss of $1,458.98 million. The main component of this additional loss is the foregone income of the industrial zone, $7,484.56 million, as seen in Figure 2. This loss is followed by costs arising due to foregone revenue, stranded assets, state coal revenue, tax revenue from the Tenayan CFPP, labor market income losses, fiscal support needed for job losses and foregone benefits for rural economies. These costs total around $8.9 million and around $7.4 million of it is balanced with an increase in total benefits. The largest component of the changes in total benefits comes from avoided carbon emissions which amounts

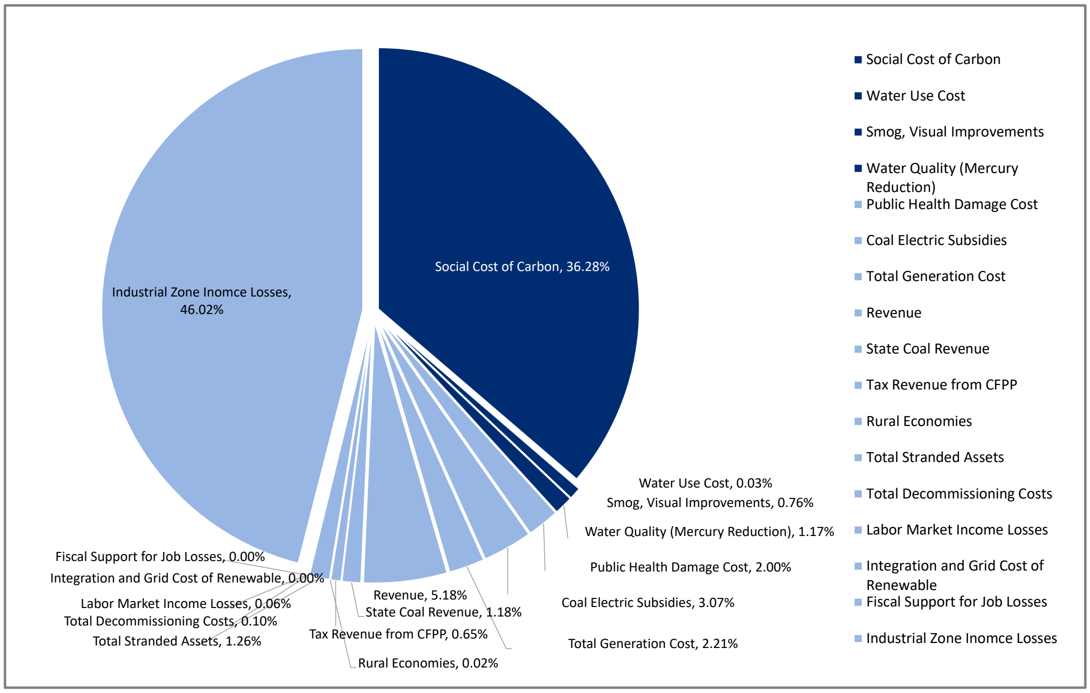
Figure 2: Comparing Welfare Changes



Source: Authors' illustration.

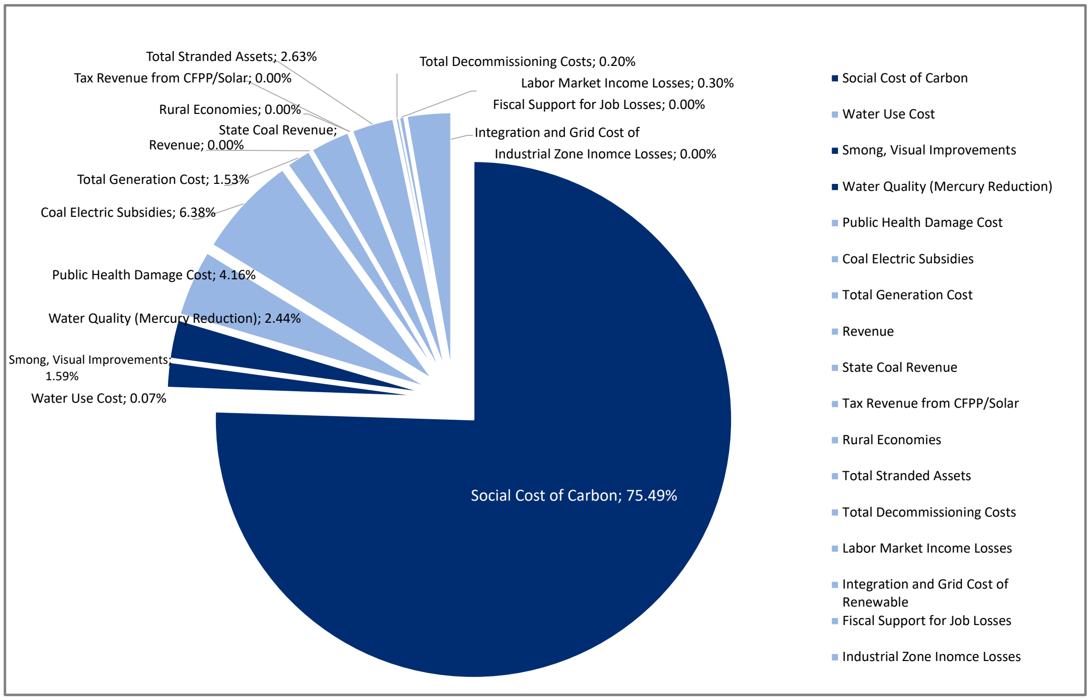
to $5.9 million, which compensates 80 percent of the cost increase, as seen in Figure 3. The second largest benefit is the foregone coal subsidies that Indonesian government pays, followed by the elimination of costs from electricity generation and public health issues.

Figure 3: Size of Welfare Impact in Moving from BAU to RE



Source: Authors' Illustration.

Figure 4: Size of Welfare Impact in Moving from BAU to AR



Source: Authors' Illustrations.

When solar energy is used in place of the Tenayan Riau CFPP, this substitution would produce net welfare increase of $6,557.89 million for the society. In moving from BAU to AR scenario total increase in the benefits is around $7.2 million, which is significantly larger than the increase in the costs, $0.6 million. The largest increase in the benefits is forgone SCC, followed by foregone costs of electric coal subsidies, public health damage, water use and water quality issues. The largest change in the cost categories is the integration and grid cost of solar which only exist for this scenario, shown in Figure 4. When solar substitutes the Tenayan Riau CFPP, and income from the industrial zone continues to flow together with additional environmental and renewable benefits, it becomes in turn a more preferable policy decision to support sustainable development. When the two alternative scenarios are compared with one and other, solar substitution brings higher welfare gain for the society.

Integrating CBA with refinancing mechanisms

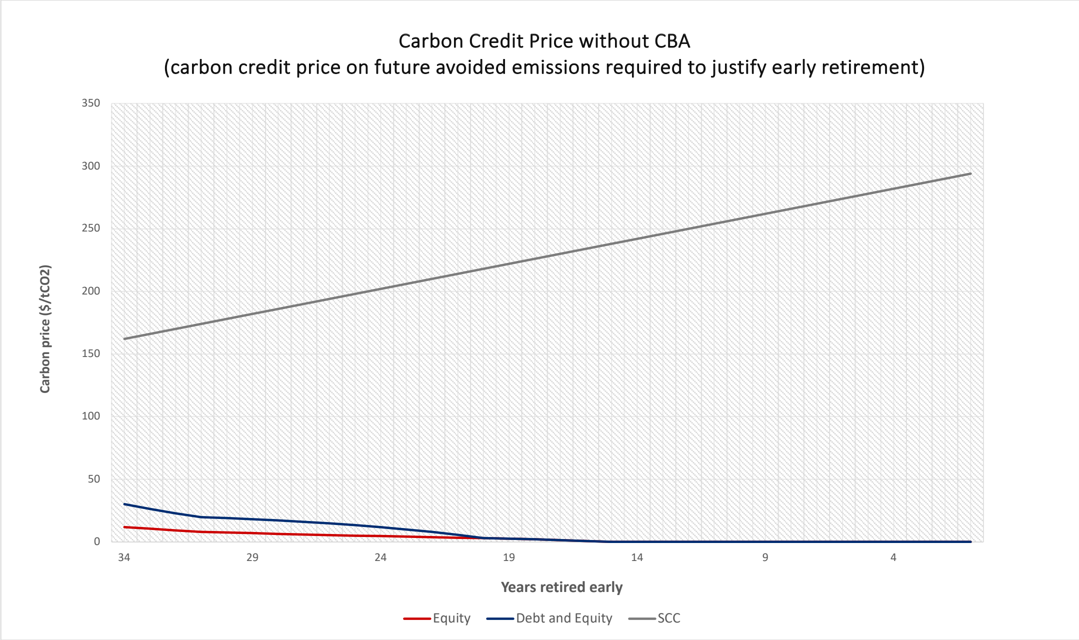
We conduct financial analyses based on the financial model developed in Clark et al. (2023). We first conduct a financial analysis for a buyout mechanism of early retirement of Tenayan Riau CFPP based only on financial costs (referred as financial analysis without CBA). Then, we perform another financial analysis for a buyout mechanism of early retirement of the plant to cover social and environmental costs and benefits in addition to the financial cost of early retirement (referred as financial analysis with CBA). Financial analysis for a buyout mechanism of early retirement calculates carbon credit prices that are necessary to cover NPV of outstanding debt, equity cashflows and shortfall in subsidies for equity/debt (Clark et al. 2023).

When we integrate the benefits and costs of CBA into financial costs to reconstruct a new carbon credit price. This new carbon credit price includes a specific component that captures socio-economic and environmental effect of early retirement, and thus we refer it as sustainability price or carbon credit price with CBA. The reconstructed new carbon credit price with CBA is higher than the carbon credit price without CBA, as it contains the specific component that we refer as a 'sustainability premium.'

The financial analysis of buyout mechanism is performed for Tenayan Riau CFPP, without integrating CBA, and carbon credit prices needed for equity and debt-equity refinancing for early retirement are computed (Table A3 in Appendix). Figure 5 provides visual plotting of carbon credit prices needed for equity and debt-equity refinancing in solid red and blue curves. Carbon credit prices required for equity refinancing come down from $11.95/ton to $0 over the early retirement years of 34 and 15, respectively. In a similar fashion, carbon credit prices needed for debt-equity refinancing decreases from 30.25/ton to $0 over the early retirement years of 34 to 15. The decline in carbon credit prices in both types of refinancing is due to the fact that the net present value of debt and equity of plants are higher when plants are retired in the early years of operation, which in turn requires higher carbon credit prices to pay for carbon reductions to buyout debt and equity.

To provide visual illustration of the differences in sizes of social cost of carbon and carbon credit price, we plot the SCC in green, as shown in Figure 5. SCC is the estimate of the cost of carbon emissions measured in 2020 dollars for metric ton of carbon dioxide (CO_2) for the years 2020-2080 at the discount rate of 2 percent. SCC is calculated to be a policy tool to evaluate economic values of benefits and costs of climate policies (US Environmental Protection Agency 2022). It is important to note that when only financial costs are considered, carbon credit price calculated is significantly lower than the SCC at any given year of retirement. If there were no other aspects of sustainability aside from carbon, society would be better off in retiring as early as possible, even after local and regional stakeholders are compensated.

Figure 5: Financial Analysis of Buyout Mechanism without CBA



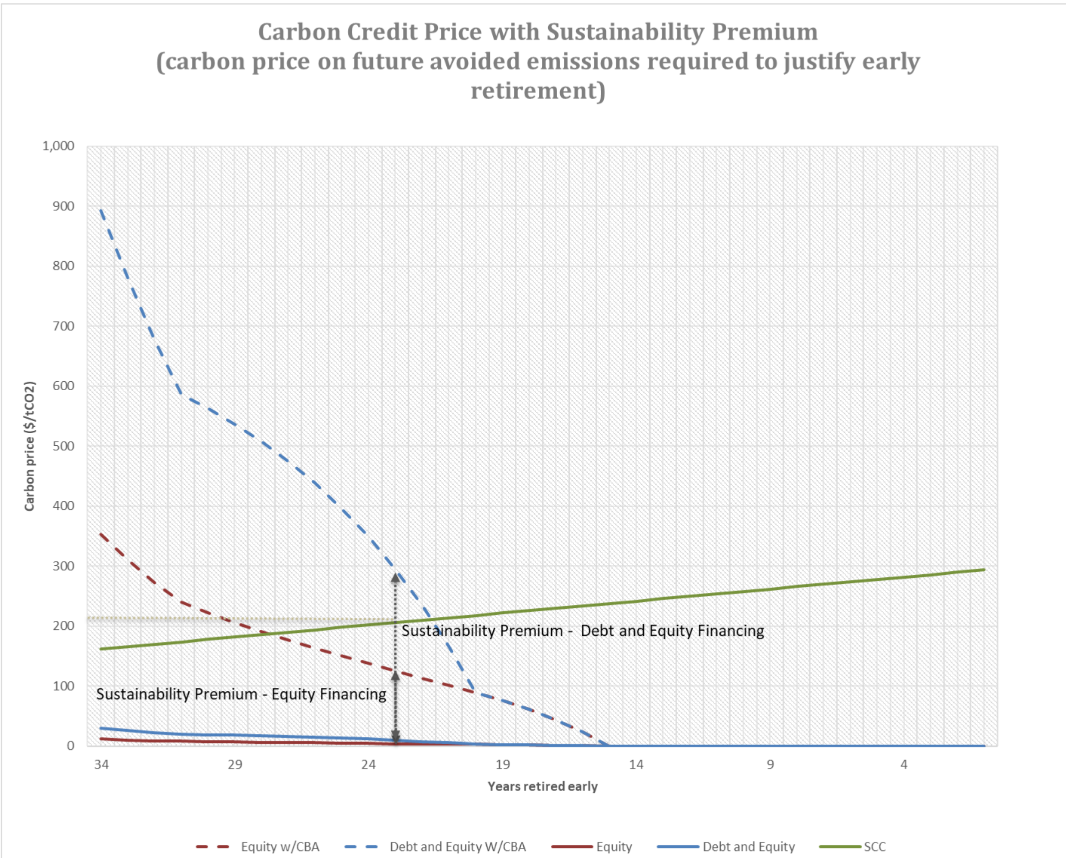
Source: Authors' Illustration.

When we integrate the socio-economic benefits and costs into the buyout mechanism to calculate carbon prices, higher carbon credit prices are needed for refinancing (Table A2 in Appendix). The dashed blue and red curves indicate carbon credit prices with CBA in Figure 6. When CFPPs retire early, the society does not incur only financial costs, but also socio-economic costs mentioned in the previous section. Depending on whether and how developing economies take the environmental benefits other than reduction in carbon emissions into account in their decision-making, net socio-economic and environmental costs of early retirement can be calculated. Implicitly assuming that these other benefits are not deducted from the social costs, we calculate the net social cost of $7,644 million and integrate it into the financial analysis. The carbon credit prices with CBA follow the similar declining pattern of carbon credit price without CBA as the retirement age becomes higher. The carbon credit prices are $352.72/ton for equity refinancing and $893.17/ton for debt-equity refinancing for 34 years of early retirement, while dropping to $0 for the early retirement year of 15.

These differences between the carbon credit prices with and without CBA are associated with social and other environmental costs or benefits of retiring Tenayan Riau CFPP early. In addition to financial costs (debt and equity balances) and carbon benefits, there are socio-economic and other environmental costs and benefits of early retirement. In line with the United Nations 2030 Sustainable Development Goals (SDGs), design of policies and policy tools for early retirement of CFPPs needs to consider all costs and benefits in addition to financial and carbon. Citizens of a developing economy with CFPPs in their energy fleet incur various types of local and regional costs and benefits in retiring their CFPPs early while generating global carbon benefits. Therefore, carbon credit prices calculated with CBA can also be referred to as a "sustainability prices (carbon credit prices with CBA)." In order words, when a 'sustainability premium' is added to carbon credit price without CBA, we obtain carbon credit price with CBA, which can also be referred to as a 'sustainability price.'

The sustainability price or carbon credit price with CBA can be operationalized and used by DFIs via carbon markets or in creating and transacting sustainable financial assets and bonds. To operationalize the sustainability prices or carbon credit prices with CBA, 'sustainability premiums' can be computed and added onto carbon credit prices, which are solely based on financial costs, for every specific early retirement year, as seen in Figure 6. For example, for the retirement year of 2023, carbon credit price is $4.67/ton under equity financing, whereas it is $137.85/ton under equity financing with CBA. The difference of $133.18/ton is the size of the sustainability premium. Social cost and benefits that make up sustainability premium increase the carbon credit price by 28.52 folds. If debt-equity refinancing is done to early retire the CFPP in 2023, the carbon credit price is $11.83/ton without considering other socio-economic costs and benefits, but it increases to $349.29 when sustainability premium is included.

Figure 6: Sustainability Premium in Carbon Credit Price under Debt and Equity Refinancing for Early Retirement



Source: Authors' illustration.

To evaluate and compare carbon credit prices with SCC, we present SCC in Table A2 in the Appendix and illustrate it in Figure 6. If SCC is used to price carbon reduction for early retirement, it might achieve early retirement of older power plants but might not be sufficient to retire younger ones. The earlier years of retirement enable higher levels of avoided carbon emissions at higher cost of retirement for owners, authorities and governments who construct and operate these plants. Therefore, at earlier retirement years, higher carbon credit prices are needed to buy carbon reductions from these local and regional actors. Carbon credit price that is equal to SCC might not be sufficiently large enough facilitate early retirement of these young plants. However, as plants get closer to their normal retirement years, the cost of retirement diminishes for the owners and authorities, which in turn require lower levels of carbon credit prices to buy avoided emissions. Therefore, remaining carbon reductions can be successfully bought at a relatively lower level of carbon credit prices than the level of SCC. Society can avoid larger levels of SCC by paying relatively less for the reductions. For these years, SCC can be used as maximum cap on carbon credit price that can be offered to buy carbon reductions. During the retirement of older plants, if these transactions turn out to be unsuccessful, then the damage to the global society is higher as well as the lost opportunities to eliminate carbon reductions. These results and observations communicate that there are case specific carbon credit prices that are governed by sustainability premiums of local, regional and country level stakeholders, and using prespecified SCC as carbon credit prices in especially early retirement might have a potential to lead to failed negotiations or transactions with local and regional stakeholders. Therefore, financial analysis integrated with CBA and the use of sustainability premiums have important potential to facilitate just energy transition carbon transactions.

CONCLUSION

In this study we develop a CBA framework to analyze the broad social welfare impacts of coal-fired power plants (CFPPs) and their potential early retirement. When taking local, national and global social and environmental costs and benefits into consideration, CFPPs generate major welfare losses to society. Those losses can be significantly reduced through the early retirement of coal plants, and the least amount of losses can be attained when plants are retired and replaced with new sources of renewable electricity. The paper emphasizes the importance of CBA in accounting for idiosyncratic aspects of each plant and prioritizing amongst coal fleet and thus adoption of a systematic approach in retiring CFPPs. It also shows how CBA can provide a broad framework for analyzing the tradeoffs of various power plant options. What is more, it shows how the results of CBA can be used to impute 'sustainability premiums' that would be needed to make early retirement financing schemes more attractive and effective.

CBA analyses like this may be best suited for collaborations of national governments with multilateral DFIs and development banks. Given their unique business models, missions to protect welfare at the national and the global level, and knowledge capacity, development banks can be equipped to conduct these types of analyses and play a role in financing such mechanisms. That said, in order to conduct comprehensive and cost-effective CBAs for early coal plant retirement, there are significant data needs that will have to be supplied by local and global authorities.

This paper illuminates a way forward for future research and policy, pointing to the broader sets of data that will be needed and made available in order to conduct such analyses and how decision-makers in governments and development banks should incorporate broad CBAs into their decision-making processes and climate change policies.

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APPENDIX

Table A1. A General CBA Framework Developed to Analyze Three Alternative Scenarios

Cost-Benefit-Categories Level 1	Cost-Benefit-Categories Level 2	Cost-Benefit-Categories Level 3	BAU		RE		AR	
			C	B	C	B	C	B
Socio-Economic	Revenue (Electricity Sale)							
	Capital Costs (Depreciation, Salvage Value Adjusted)							
	Fuel Costs							
	Operation and Maintenance Costs							
	Total Generation Cost							
	Labor Market							
		Job Losses and Generation						
		Employment in CFPPs						
		Employment in Complementary Markets						
		Income Losses and Generation						
		Early Retirement and Job Losses Compensation						
		Fiscal Support for Job Losses						
	Decomissioning Costs							
		Employee Costs						
		Station Overheads						
		O&M Expenses						
		Pre-demolition Costs: Env. Regulation (Asbestos)						
		Demolition Costs and Scrop Removal						
		Coal Combustion Residuals (Ash/residue Cleanup)						
		Coal Storage Area Cleanup						
		Total Decomissionig Cost						

Cost-Benefit-Categories Level 1	Cost-Benefit-Categories Level 2	Cost-Benefit-Categories Level 3	BAU		RE		AR	
			C	B	C	B	C	B
Socio-Economic	Stranded Assests/Costs							
		Conveyor Belt						
		Pulverizing Plant						
		Ash Disposal Pond						
		Boiler						
		Pumping Station						
		Reservoir						
		Cooling Tower						
		Condensor						
		Steam Turbines						
		Generators						
		Transformer						
		Regularoty Assets						
		Employment Transition Costs Due to Reregulation						
		Capitalized Investments in Social Programs						
		Long-Term Constracts for power or fuel						
		Total Stranded Asset value						
	Legal RisksInvester and State Disputes							
	Coal MarketNational Energy Dependency							
	State Coal Revenue or Revenue from AR							
	Tax Revenue from CFPPs or AR							
	Policies							
		Policy Incentives for Renewable Deployment						
		Coal Electricity Subsidies						

Cost-Benefit-Categories Level 1	Cost-Benefit-Categories Level 2	Cost-Benefit-Categories Level 3	BAU		RE		AR	
			C	B	C	B	C	B
	Electricity Network Balancing Costs							
	Supply ChainValue Added of Supply Chain							
	Rural Economies							
		Land Use (Including Reclamation Costs)						
		Tax Revenue Benefits from AR						
		Development of Complementary Markets						
		Positive Externalities Spilledover Rural Economies						
Socio-Economic	Public Health	Avoided Deaths						
		Avoided Low Birth Weights						
		Avoided Preterm Births						
		Avoided Years of Lives Lost						
		Avoided Years Lived with Disability						
		Avoided Technological Risks						
		Total Health Damage Cost						
	GHG Emissions							
	Other Environmental Effects							
		Acid Rain						
		Smog, Visual Improvements						
Environmental		Environmental Amenities						
		Water Quality						
		Water Quantity						
		Other Natural Resource Protection						
		Solid Waste						
		Ecosystem and Biodiversity						

BAU: Business as Usual, CFPP continues to Operate; RE: Retires Early with no Alternative Renewable Use; AR: Replacing CFPP by Alternative Renewable

Table A2. Carbon Emissions and Social Cost of Carbon of Tenayan Riau CFPP

Calendar Year	Social Cost of Carbon ($/Ton)	Total CO2 Emissions (Ton/yr)	PV of Social Cost of Carbon ($/yr)
2017	$178.0	1395353.581	$296,570,276.30
2018	$182.0	1395353.581	$294,402,696.01
2019	$186.0	1395353.581	$292,109,791.20
2020	$190.0	1395353.581	$289,700,701.16
2021	$194.0	1395353.581	$287,184,139.12
2022	$198.0	1395353.581	$284,568,409.29
2023	$202.0	1395353.581	$281,861,423.35
2024	$206.0	1395353.581	$279,070,716.18
2025	$210.0	1395353.581	$276,203,461.21
2026	$214.0	1395353.581	$273,266,484.97
2027	$218.0	1395353.581	$270,266,281.29
2028	$222.0	1395353.581	$267,209,024.88
2029	$226.0	1395353.581	$264,100,584.38
2030	$230.0	1395353.581	$260,946,534.95
2031	$234.0	1395353.581	$257,752,170.45
2032	$238.0	1395353.581	$254,522,515.01
2033	$242.0	1395353.581	$251,262,334.30
2034	$246.0	1395353.581	$247,976,146.35
2035	$250.0	1395353.581	$244,668,231.85
2036	$254.0	1395353.581	$241,342,644.24
2037	$258.0	1395353.581	$238,003,219.22
2038	$262.0	1395353.581	$234,653,584.09
2039	$266.0	1395353.581	$231,297,166.56
2040	$270.0	1395353.581	$227,937,203.34
2041	$274.0	1395353.581	$224,576,748.35
2042	$278.0	1395353.581	$221,218,680.61
2043	$282.0	1395353.581	$217,865,711.85
2044	$286.0	1395353.581	$214,520,393.82
2045	$290.0	1395353.581	$211,185,125.29
2046	$294.0	1395353.581	$207,862,158.81
PV of Total Social Cost of Carbon (BAU) at 3% Discount Rate			$7,644,104,558.42
PV of Total Social Cost of Carbon (RE and AR) at 3% Discount Rate			$1,744,536,013.09

Note: This section is based on the EPA new updated and proposed SCC of $190/ton in 2020 (Related updated excel worksheets are in orange, remaining sheets are left with the original values)

Table A3. Equity and Debt-Equity Refinancing with and without CBA

Years	Calendar Year	Years Retired Early	Equity with CBA	Debt and Equity with CBA	Equity	Debt a nd Equity	SCC	Sustainability Premium of Debt-Equity Refinance
YR-4	2013	34	$352.72	$893.17	$11.95	$30.25	$162.0	$862.92
YR-3	2014	33	$310.82	$779.59	$10.53	$26.40	$166.0	$753.19
YR-2	2015	32	$273.29	$677.45	$9.26	$22.94	$170.0	$654.50
YR-1	2016	31	$239.66	$585.61	$8.12	$19.83	$174.0	$565.78
YR1	2017	30	$222.55	$563.02	$7.54	$19.07	$178.0	$543.96
YR2	2018	29	$206.47	$537.41	$6.99	$18.20	$182.0	$519.21
YR3	2019	28	$191.33	$508.41	$6.48	$17.22	$186.0	$491.19
YR4	2020	27	$177.00	$475.60	$5.99	$16.11	$190.0	$459.49
YR5	2021	26	$163.39	$438.51	$5.53	$14.85	$194.0	$423.66
YR6	2022	25	$150.38	$396.62	$5.09	$13.43	$198.0	$383.18
YR7	2023	24	$137.85	$349.29	$4.67	$11.83	$202.0	$337.46
YR8	2024	23	$125.67	$295.83	$4.26	$10.02	$206.0	$285.81
YR9	2025	22	$113.66	$235.38	$3.85	$7.97	$210.0	$227.41
YR10	2026	21	$101.65	$166.97	$3.44	$5.65	$214.0	$161.31
YR11	2027	20	$89.36	$89.36	$3.03	$3.03	$218.0	$86.34
YR12	2028	19	$76.44	$76.44	$2.59	$2.59	$222.0	$73.86
YR13	2029	18	$61.51	$61.51	$2.08	$2.08	$226.0	$59.42
YR14	2030	17	$44.15	$44.15	$1.50	$1.50	$230.0	$42.65
YR15	2031	16	$23.86	$23.86	$0.81	$0.81	$234.0	$23.05
YR16	2032	15	$0.00	$0.00	$0.00	$0.00	$238.0	$0.00
YR17	2033	14	$0.00	$0.00	$0.00	$0.00	$242.0	$0.00
YR18	2034	13	$0.00	$0.00	$0.00	$0.00	$246.0	$0.00
YR19	2035	12	$0.00	$0.00	$0.00	$0.00	$250.0	$0.00
YR20	2036	11	$0.00	$0.00	$0.00	$0.00	$254.0	$0.00
YR21	2037	10	$0.00	$0.00	$0.00	$0.00	$258.0	$0.00
YR22	2038	9	$0.00	$0.00	$0.00	$0.00	$262.0	$0.00
YR23	2039	8	$0.00	$0.00	$0.00	$0.00	$266.0	$0.00
YR24	2040	7	$0.00	$0.00	$0.00	$0.00	$270.0	$0.00
YR25	2041	6	$0.00	$0.00	$0.00	$0.00	$274.0	$0.00
YR26	2042	5	$0.00	$0.00	$0.00	$0.00	$278.0	$0.00
YR27	2043	4	$0.00	$0.00	$0.00	$0.00	$282.0	$0.00
YR28	2044	3	$0.00	$0.00	$0.00	$0.00	$286.0	$0.00
YR29	2045	2	$0.00	$0.00	$0.00	$0.00	$290.0	$0.00
YR30	2046	1	$0.00	$0.00	$0.00	$0.00	$294.0	$0.00