Indonesia's Energy Transition from Coal to Renewables, 2023-2050

Policy Options and Technical Considerations

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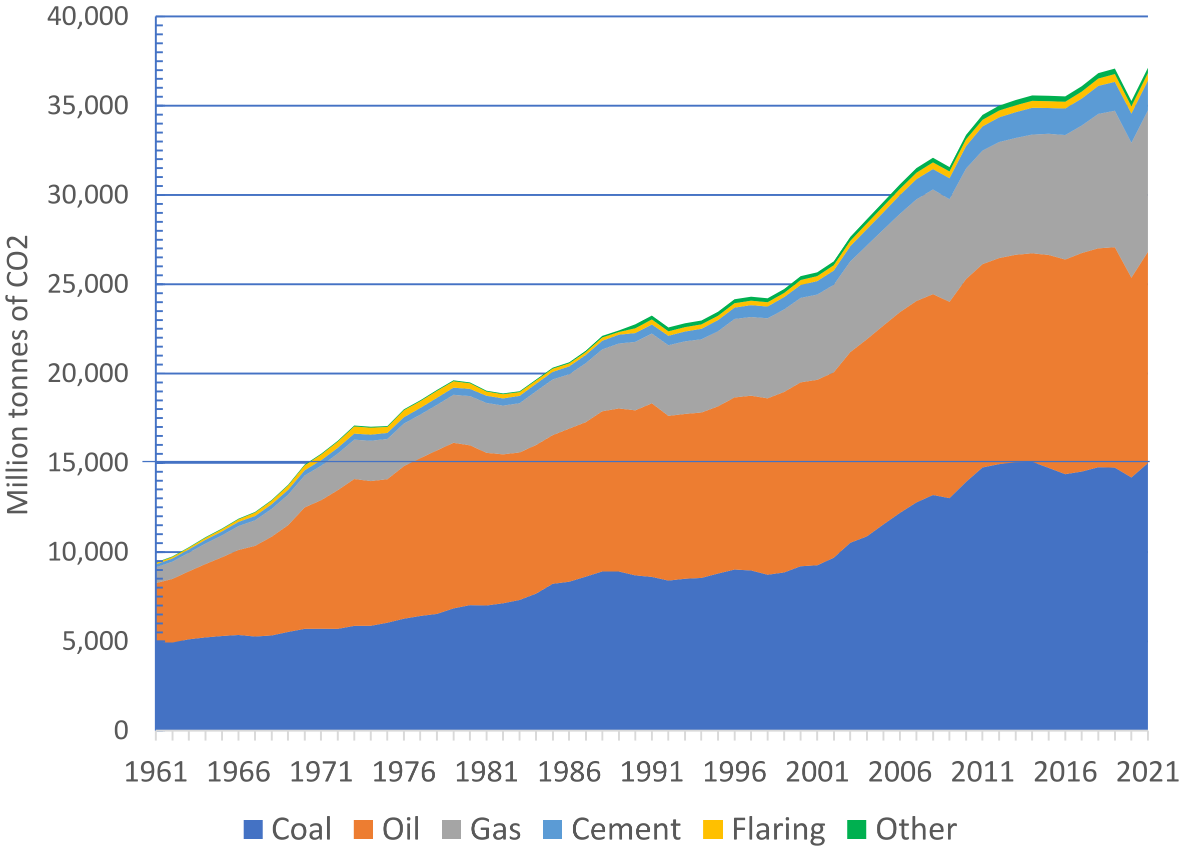
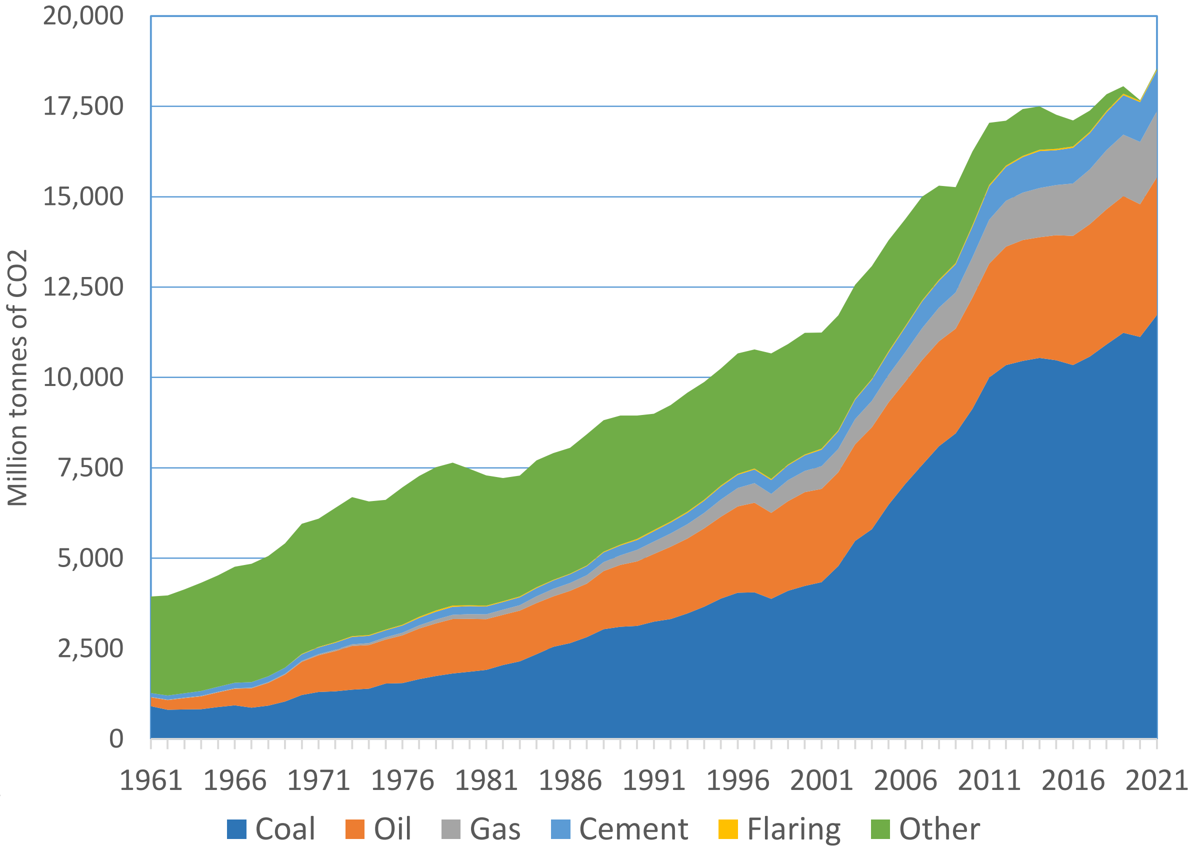
Putting Coal-fired Power Plant Retirement in Context

Global CO_2 Emissions from All Fossil Fuels, 1961-2021

Global CO_2 emissions from fossil fuels



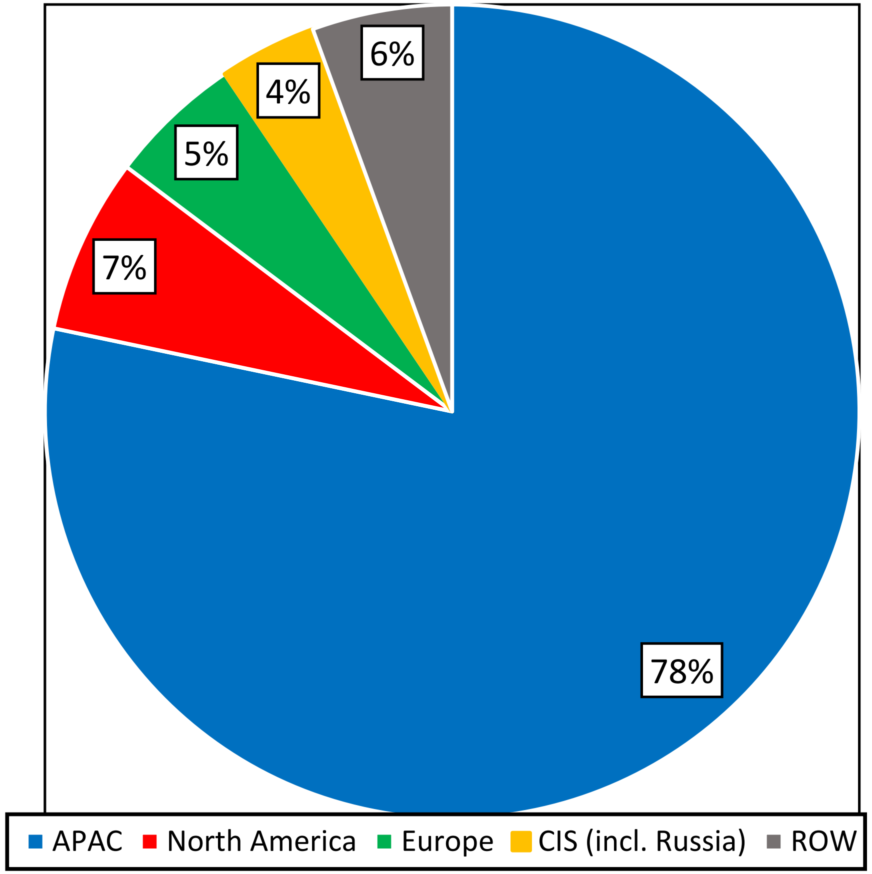
APAC CO_2 emissions from fossil fuels

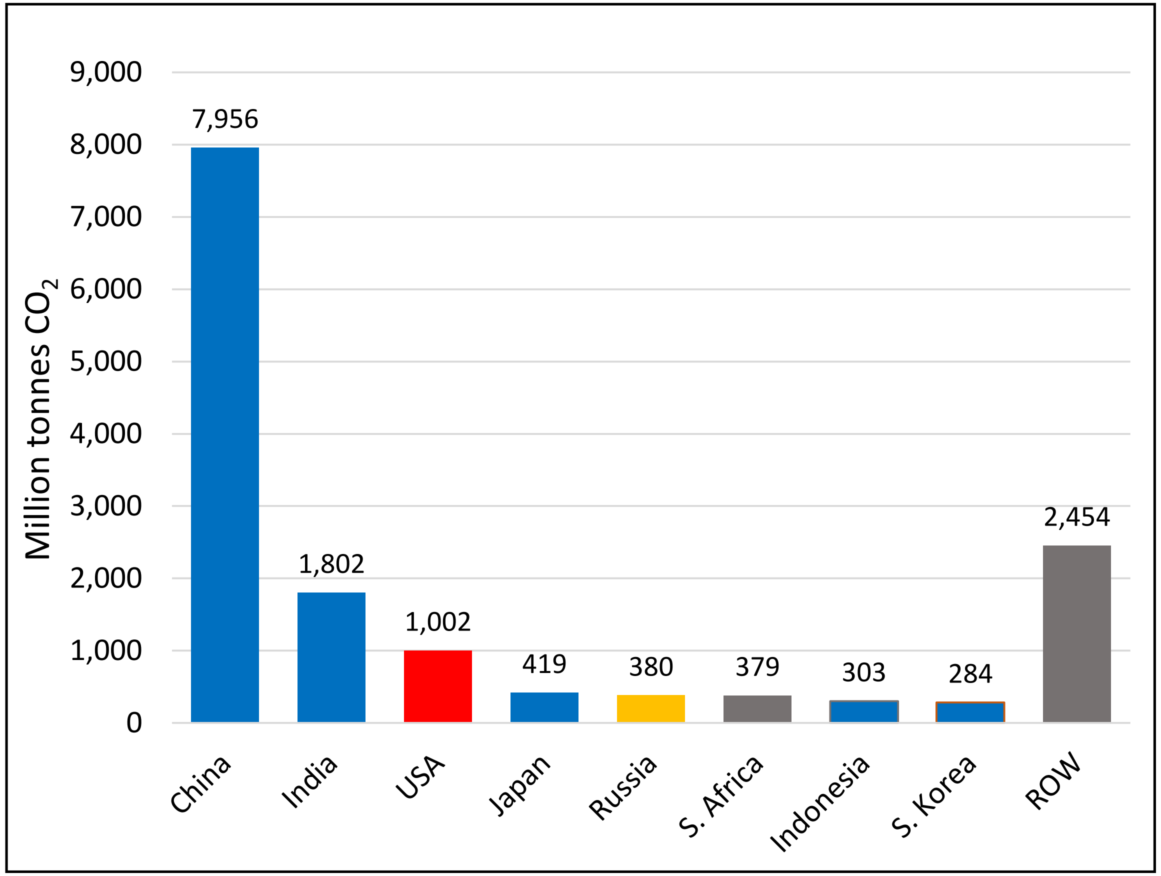


Source: Global Carbon Project (https://www.globalcarbonbudgetdata.org/latest-data.html)

Global and APAC CO_2 Emissions from Coal 2021

APAC accounted for about 78% of Global CO_2 emissions from coal (11,726 mt/14,980 mt) w/ China and India accounting for 65% of Global CO_2 emissions from coal (China 53%; India 12%).

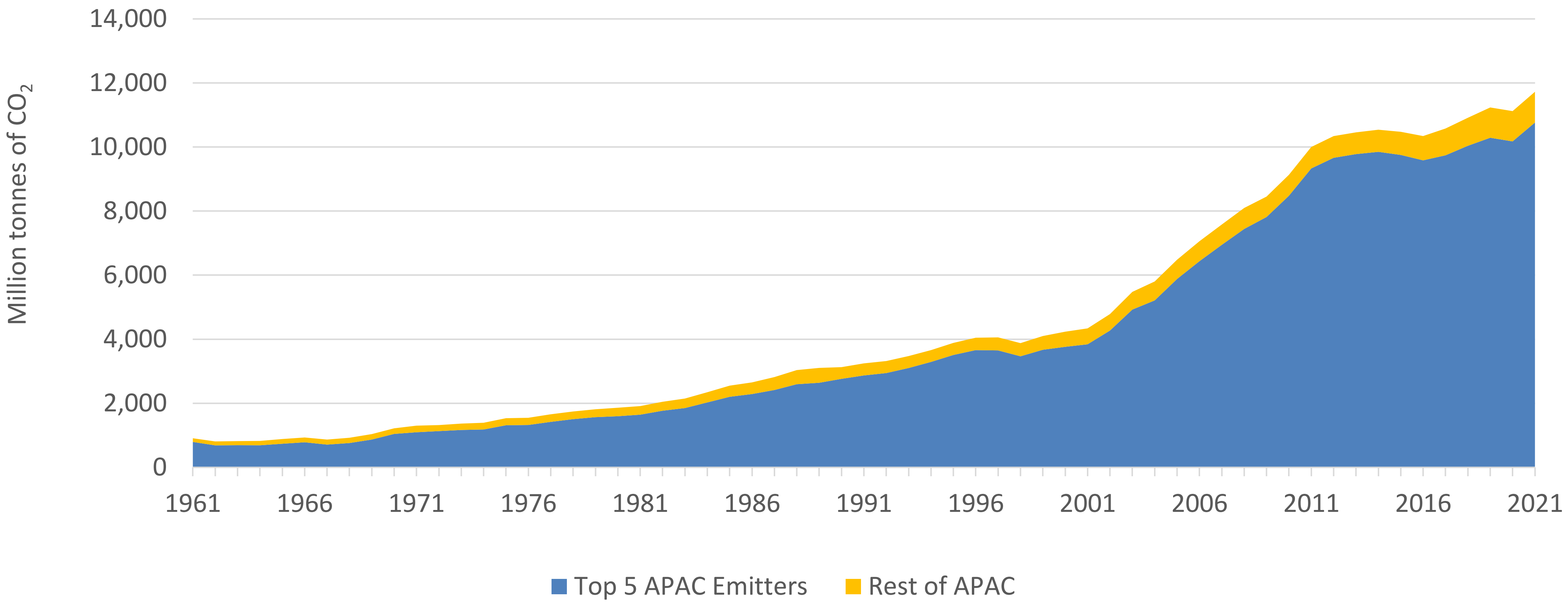




Source: Global Carbon Project (https://www.globalcarbonbudgetdata.org/latest-data.html)

APAC CO_2 Emissions from coal, 1961-2021

Between 1961 and 2021, the five biggest APAC emitters of CO_2 from coal were China, India, Japan, Indonesia and South Korea. On average over 60 years, they accounted for 88% of the region's CO_2 emissions from coal.

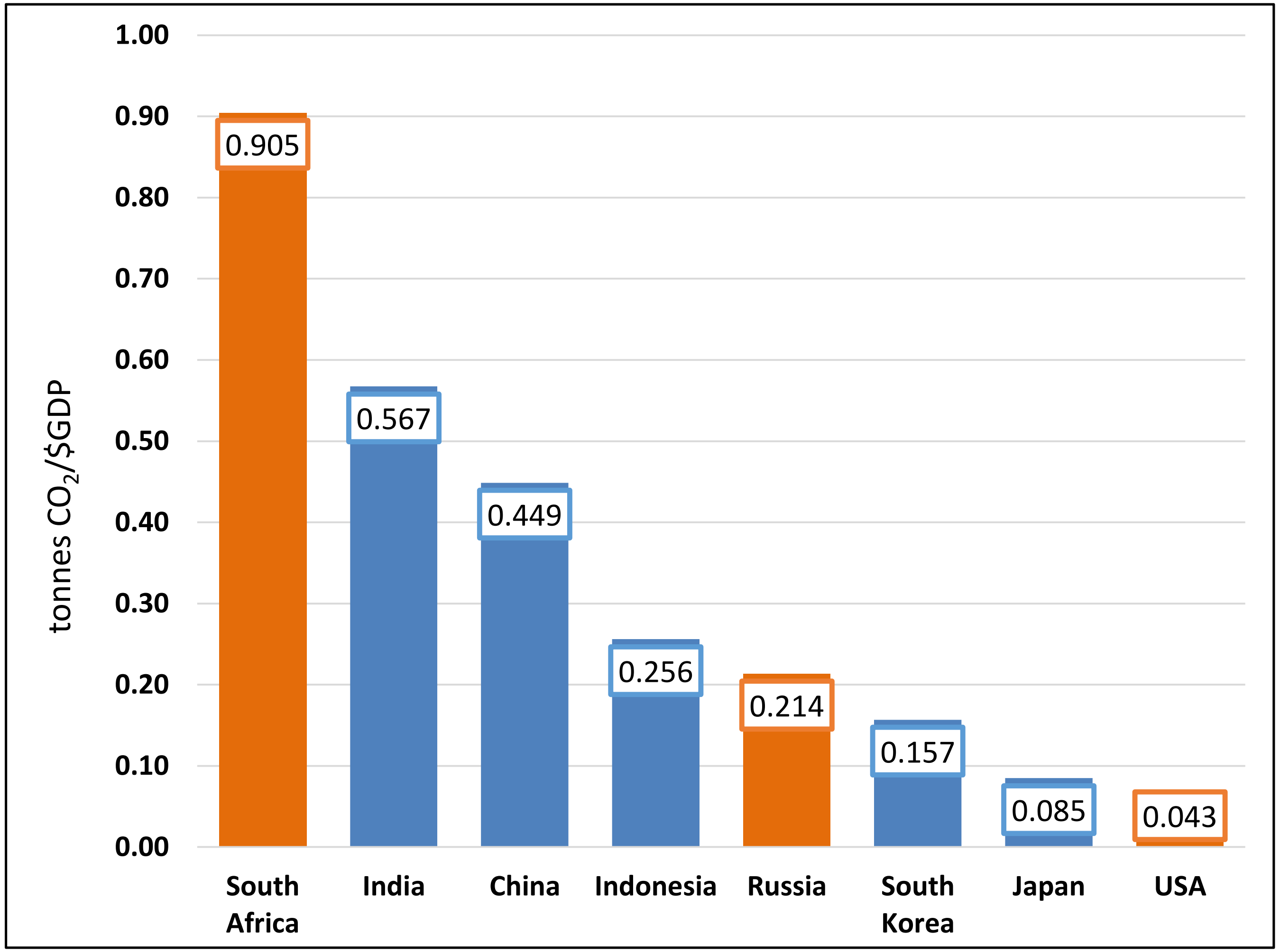


Source: Global Carbon Project (https://www.globalcarbonbudgetdata.org/latest-data.html)

Global CO_2 Emissions from coal in perspective, 2021

However, when considered on a $GDP basis, South Africa, India, and China are by far the biggest emitters of CO_2 from coal and 5 of the 8 largest CO_2 emitters from coal are APAC countries.

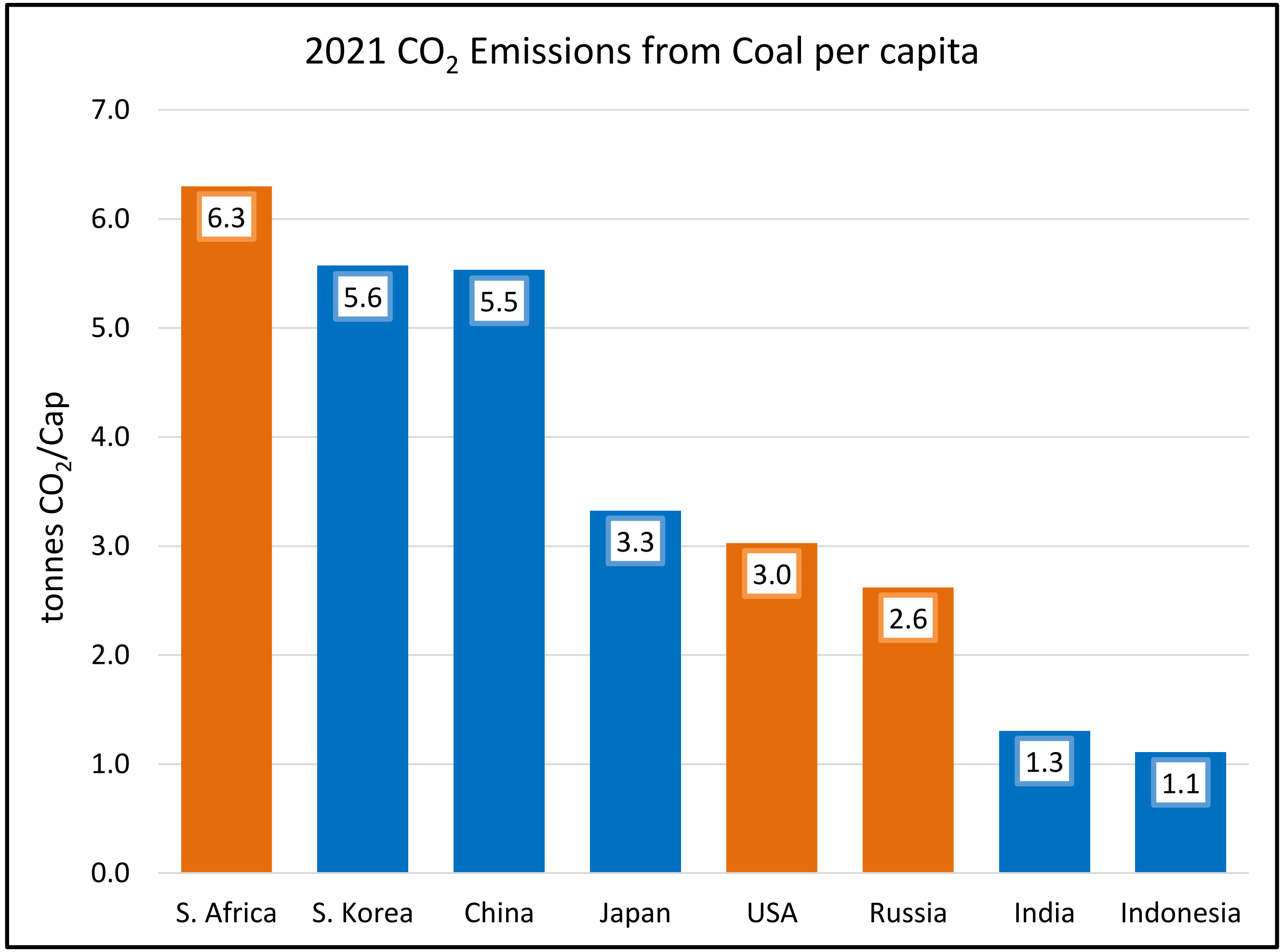
	2021 CO_2 Emissions (million tonnes)	2021 GDP (million $)	CO_2/GDP (tonnes/$GDP)
South Africa	379	419	0.905
India	1,802	3,176	0.567
China	7,956	17,730	0.449
Indonesia	303	1,186	0.256
Russia	380	1,779	0.214
South Korea	284	1,811	0.157
Japan	419	4,940	0.085
USA	1,002	23,320	0.043



Global CO_2 Emissions from coal in perspective, 2021

When considered on a per capita basis, South Africa, South Korea, and China were the top 3 CO_2 emitters per capita by a wide margin and 5 of the top 8 CO_2 emitters from coal were APAC countries.

	CO_2 (mt)	Population (millions)	CO_2/cap (tonnes/cap)
S. Africa	**379**	**60**	**6.3**
S. Korea	**284**	**51**	**5.6**
China	**7,956**	**1,439**	**5.5**
Japan	**419**	**126**	**3.3**
USA	**1,002**	**331**	**3.0**
Russia	**380**	**145**	**2.6**
India	**1,802**	**1,380**	**1.3**
Indonesia	**303**	**273**	**1.1**



General Policy Considerations for Transitioning from Coal to Cleaner Sources of Electricity, 2023-2050

Initial Thoughts on Policies for Transitioning from CFPPs to Renewables in Asia

Two generic policy types

- **Proscriptive public policies** - either prohibit or require certain actions, such as retiring CFPPs that are past a specific operating age
- **Prescriptive public policies -** identify a policy goal such as early retirement of CFPPs and then guide CFPP owners to that goal by means of financial incentives, disincentives, or both

Attributes of Good Public Policy

For a policy to be rated as "good", it must meet four "threshold" conditions:

- **Efficient** – must make efficient use of energy resources
- **Equitable** – must be fair to major stakeholders
- **Timely** – must not be enforced prematurely or too late to make a difference
- **Administratively feasible**-must be practical to implement, enforce, and monitor for compliance

Special Considerations Concerning CO_2 Emissions

- CO_2 - odorless, colorless gas that mixes easily in air and accumulates uniformly throughout the stratosphere
- It does not have direct environmental impacts on nearby communities, resulting in many non-OECD countries refusing to reduce their CO_2 emissions unless compensated for the cost of doing so.
- The common view among non-OECD countries is:
  - ➢ If I reduce my CO_2 emissions, I gain no benefit unless my neighbors do the same.
  - ➢ Unless paid or forced to do so, governments from most non-OECD Asian countries are reluctant to retire their CFPPs early.
- Major limiting factor: No enforcement mechanism
  - ➢ Compliance with CO_2 emission reduction goals under the Paris Accord or other international commitments are strictly forward looking and voluntary.

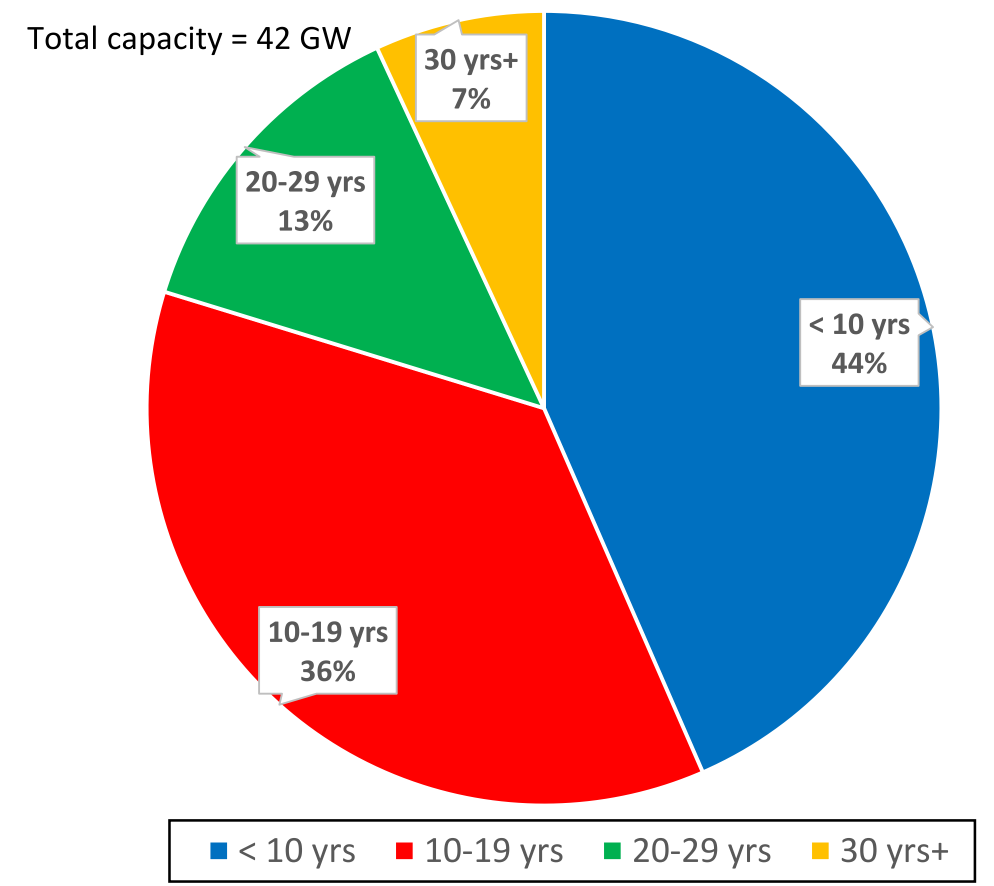
Technical and Socio-economic Considerations for the GOI related to CFPP Retirement

- If the GOI decides to retire "base load" CFPPs, it will need to find suitable base load replacements.
- Solar and wind are not acceptable replacements for CFPPs due to their intermittent nature plus their excessive land requirements.
- The GOI will also need to address the socio-economic impacts of any CFPP retirement program such as potential displaced workers and bankrupt businesses dependent on CFPPs and Indonesia's coal mining industry.
- Finally, the GOI earns significant revenues from the coal mining industry and is unlikely to walk away from those revenues without having alternatives in place.
- Good energy transition policy will therefore need to allow for a grace period for:
  (i) constructing new base load power plants
  (ii) creating new jobs for displaced workers and transition support for impacted businesses
  (iii) generating new GOI sources of revenues.

Scenarios for Transitioning from Coal to Cleaner Sources of Electricity, 2023-2050

So let's see what two retirement scenarios might look like concerning CO_2 emissions and domestic coal consumption for Indonesia if CFPPs are retired based on age.

By 31 Dec 2023, 80% of Indonesia's operating CFPPs will still be less than 20 years old with only 7% of CFPPs greater than 30 years old.



Two CFPP retirement scenarios considered

(i) Conservative scenario and (ii) Accelerated scenario

<u>Conservative Retirement Scenario</u>

- After 2030, CFPP owners must retire any CFPPs >=30 years old
- Prior to returning the site to the GOI, the CFPP owners must
  - remove all equipment, buildings, civil works, the ash pond, and coal stockpile
  - safely dispose of any toxic materials and chemicals stored on site
  - remediate the soil within the site

<u>Accelerated Retirement Scenario</u>

- After 2025, CFPP owners must retire any CFPPs >=25 years old
- Plant site returned to the GOI on same terms as stated above
- Incentives offered to CFPP owners who agree to retire their CFPPs less than 25 years old

Methodology
Step 1: SQL Database created
Step 2: Apply the following assumptions and equations to estimate NEO, Coal Usage and CO_2 emissions

Assumptions		
Unit Retirement Age	Units	Value
	Years	25 - 30
New & Clean Heat Rates (HHV)		
Subcritical	kJ/kWh	9800
Supercritical		9300
Ultra-Supercritical		9100
Heat Rate Adjustments		
1. HR Deterioration Equation that is a function of unit age	% per year	Varies annually based on age of unit
2. HR based on fixed Capacity Factor of 75%	Change in HR as % of HR @MCR	+2.5%
Heating Value of Coal	kcal/kg (gar)	4200
	GJ/t (gar)	17.573
Carbon Content of coal (as received)	%	45%

Equations for calculating Annual NEO, Coal Usage and CO_2 emissions for a new supercritical CFPP

NEO_y = NDC*8760 h*CF = 1.2* 8760*0.75 =7,884 GWh

Where:

- NEO_y = # of GWh in year y
- NDC = Net Dependable Capacity in GW = 1.2 GW
- 8760 = # of hours in non-leap year
- CF = Capacity Factor = percent of NDC =0.75

CU = (NEO_y*NHR)/HVC = (7,884 *9300) /17.573 = 4.172 million tonnes

Where:

- CU = Coal Usage in year y in million tonnes
- NEO_y = 7,884 GWh
- NHR = Net Heat Rate = 9300 KJ/kWh
- HVC = Heating Value of Coal = 17.573 GJ/t

$CO_{2,y}$ = CU *CCC*CO_2 Factor

Where:

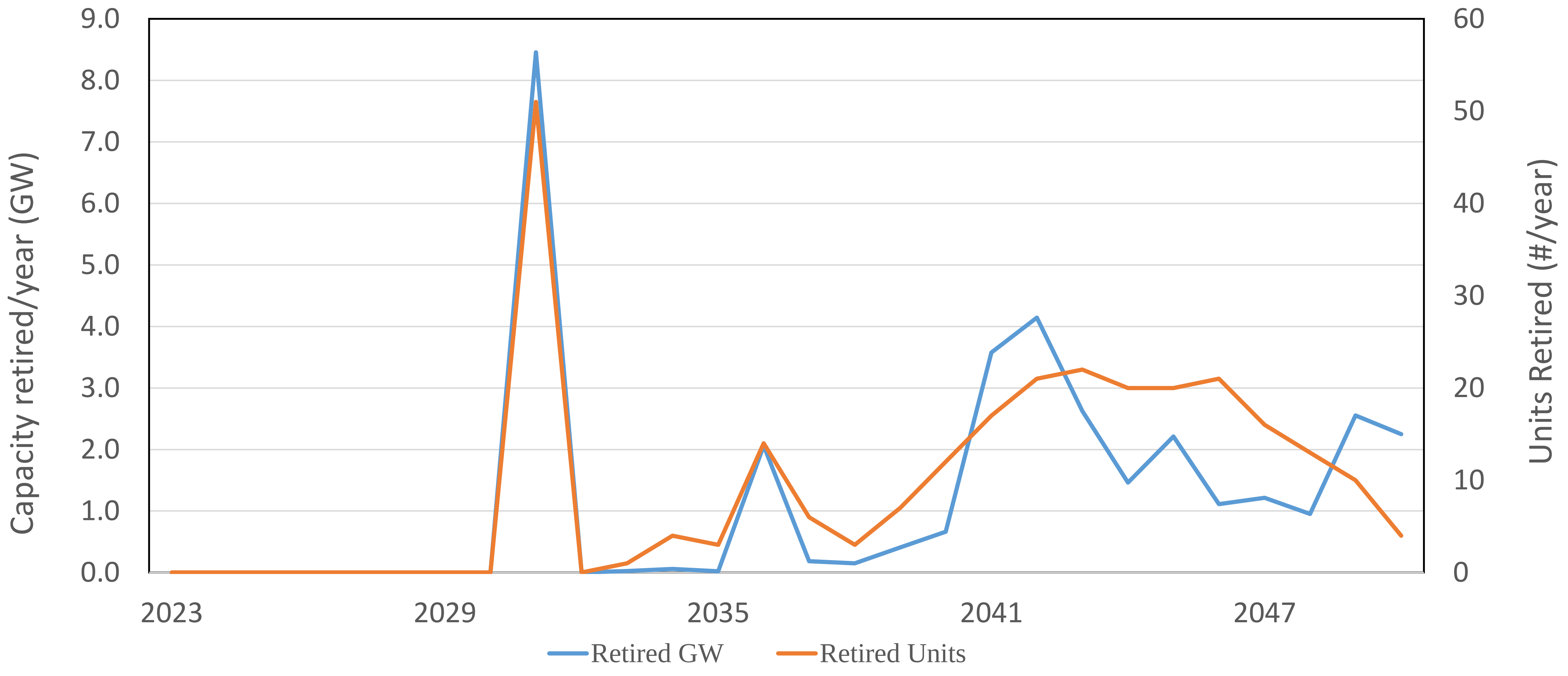
$CO_{2,y}$ = CO_2 emitted in year y = 4.172 mt*0.45*3.667 = 6.884 million tCO_2

CU = 4.172 million tonnes

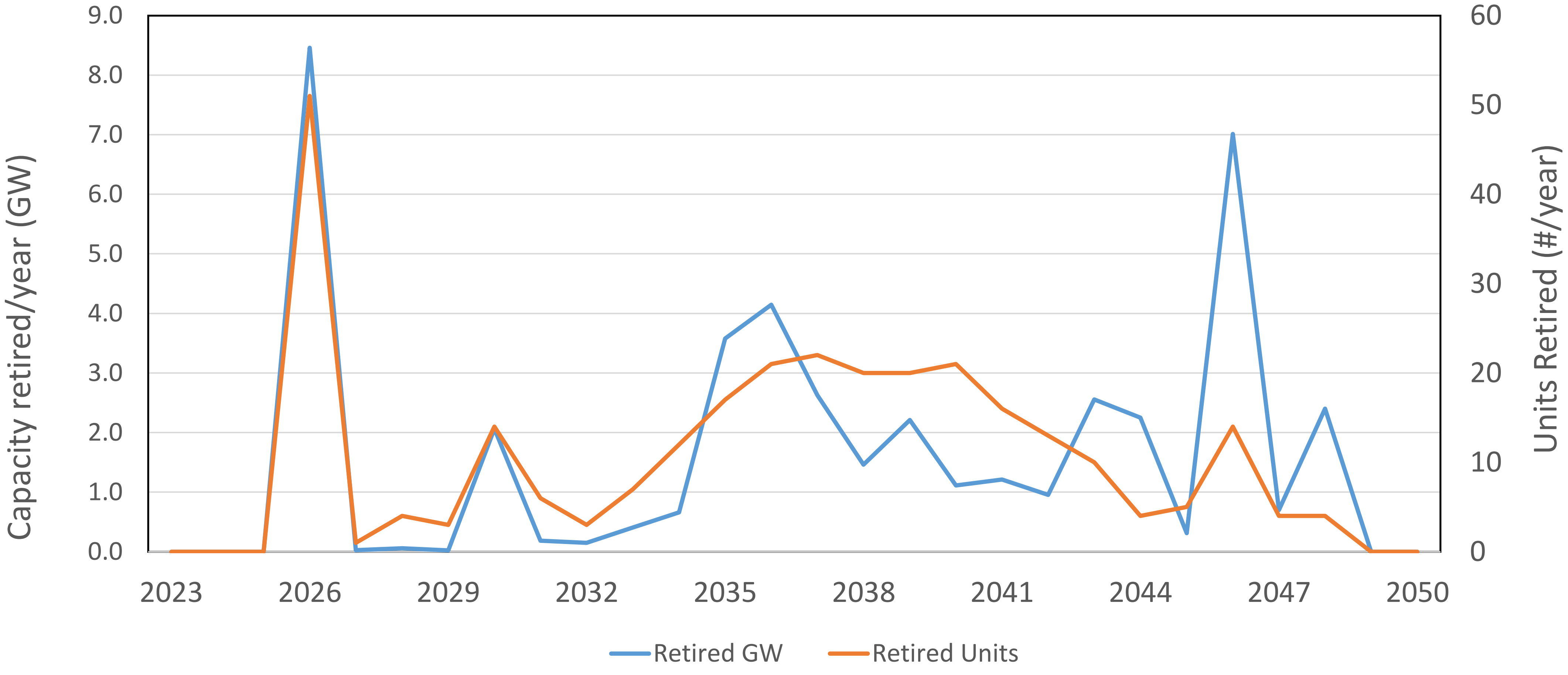
CCC = Carbon Content per tonne of coal = 45%

CO_2 Factor = Factor for converting 1 tonne of carbon to 1 tonne CO_2 = 3.667

Conservative Retirement Scenario - Retired Capacity (LHS) and Retired Units (RHS) per year

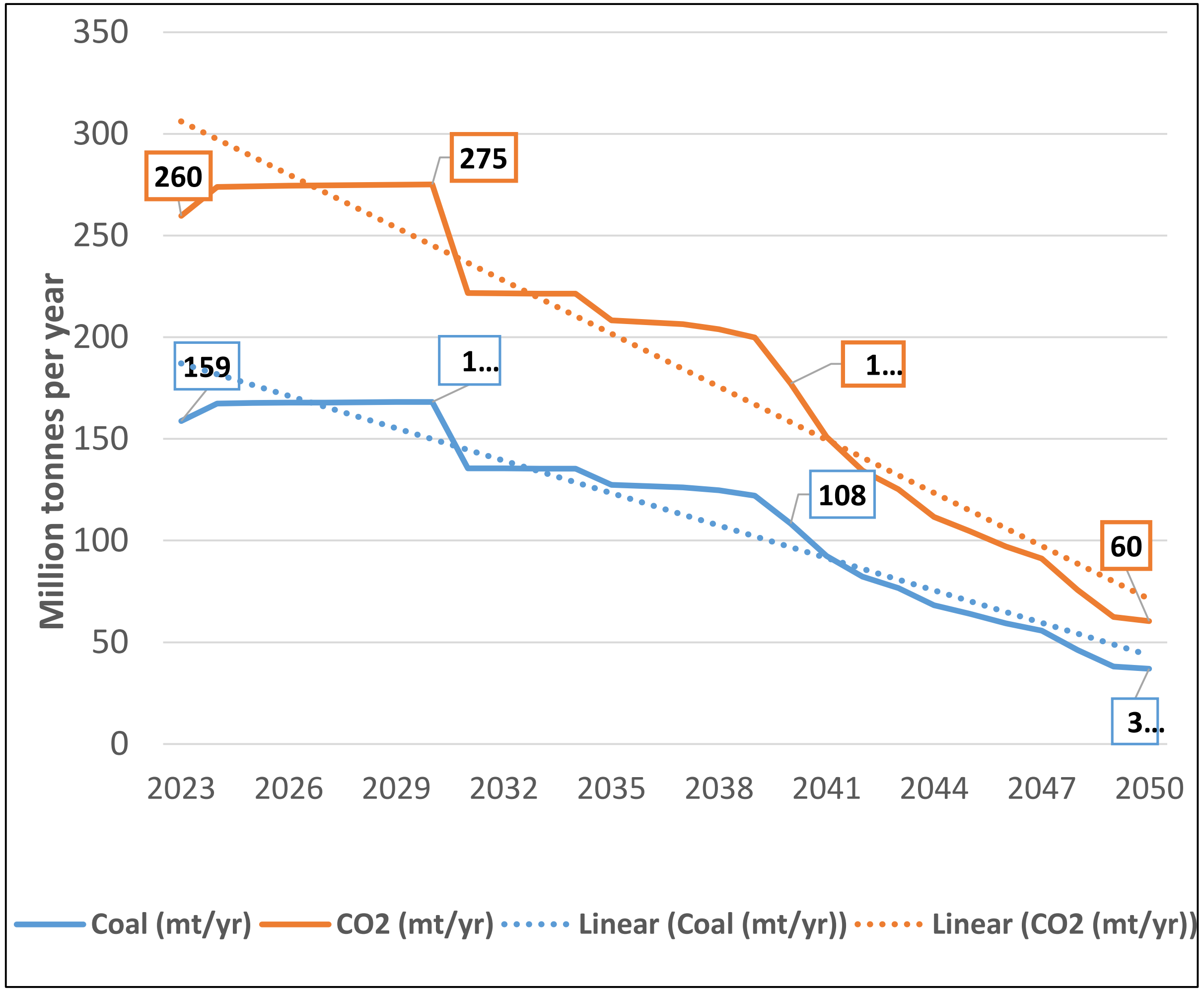


Accelerated Retirement Scenario - Retired Capacity (LHS) and Retired Units/RHS) per year



Results for the Conservative CFPP Retirement Scenario

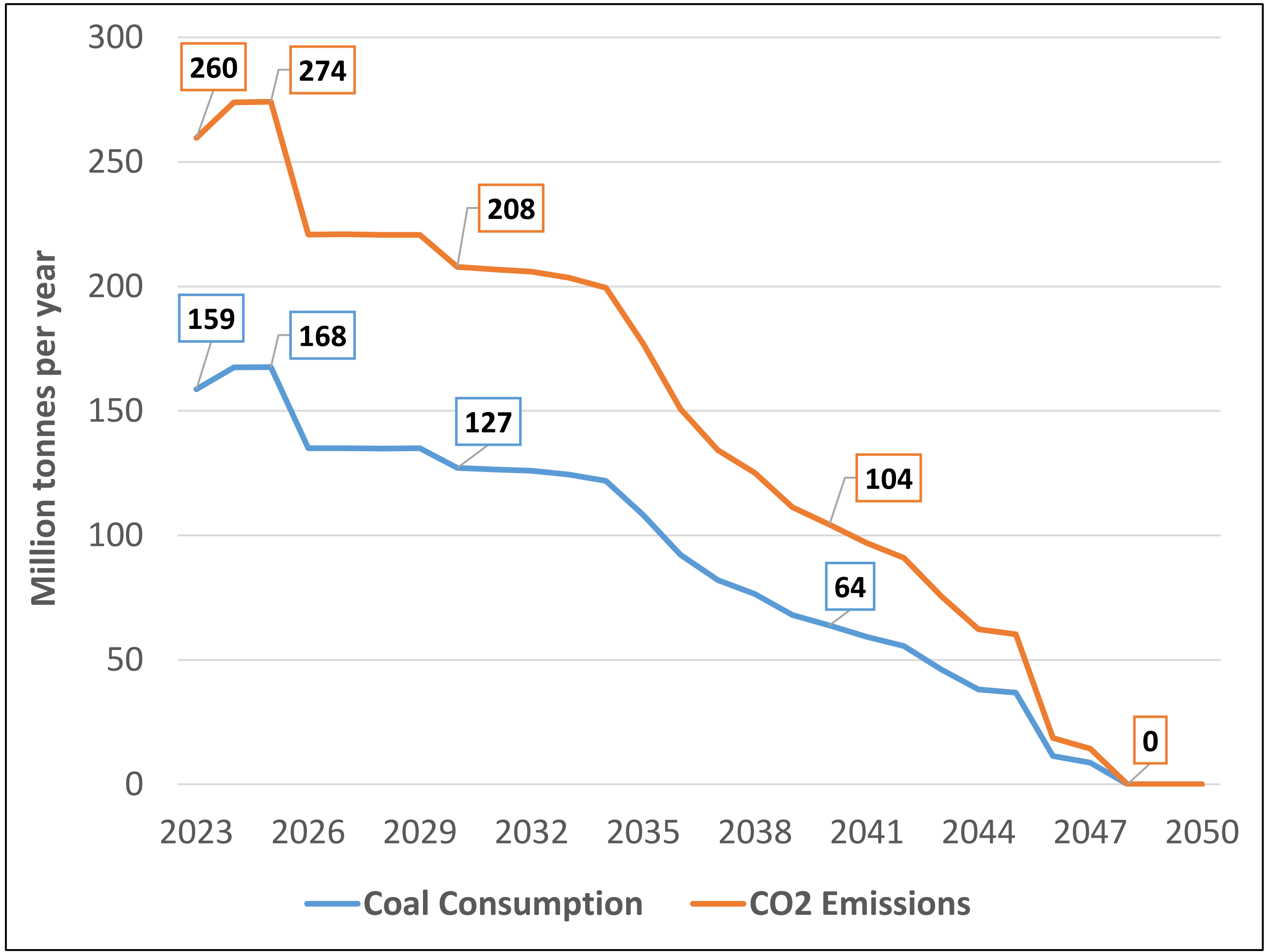
The reduction in CO_2 emissions occurs at twice the rate as the reduction in coal consumption due to the initial retirement of the old, low efficiency, subcritical plants followed later with the retirement of supercritical and ultra-supercritical plants



- In 2030, Indonesia's CFPPs are forecast to emit 275 million tonnes of CO_2.
- If CFPP owners are required to retire their plants after 30 years but not before 2031, Indonesia will reduce its CO_2 emissions to:
  - 177 mt in 2040, 36% reduction from 2030 emissions
  - 60 mt in 2050, 78% reduction from 2030 emissions
- Greater reductions in CO_2 emissions can be achieved by:
  - reducing CFPP operating period before retirement to 25 years
  - starting retirements in 2026
  - offering incentives to CFPP owners who agree to retire their CFPPs before 25th year of CFPP operating life.

Results for the Accelerated Retirement Scenario

The timeline for reducing CO_2 emissions can be shortened by reducing the mandatory early retirement date from 30 to 25 operating years and starting CFPP retirements in 2026.



- If CFPP owners retire their plants after 25 operating years starting in 2026, Indonesia will reduce its CO_2 emissions from CFPPs to:
  - 208 mt in 2030, a 24% reduction from the 2025 level
  - 104 mt in 2040, a 62% reduction from 2025
  - Zero emissions in 2048, the year when the last CFPP is retired.
- Greater reductions can be achieved between 2026 and 2048 if incentives are offered to CFPP owners who agree to retire their plants before their 25th year of operation.

Examples of potential incentives

- *GOI shares the cost of site remediation*
- *Sliding scale payments made to CFPP owners based on # of remaining operating years prior to the mandated 25 operating year shutdown date*

Comparison of Two Scenarios from a Good Policy perspective

Conservative Retirement Scenario

Equitable

- ✓ IPPs allowed to recover investments according to PPAs
- ✓ Policy phased in, allowing GOI time to (i) arrange cleaner base load capacity and (ii) implement training programs for those CFPP employees and coal miners who will be unemployed once CFPPs are retired

Efficient

- ✓ Provides CFPP owners with sufficient time to repurpose their sites for geothermal, compressed sCO2 energy storage, sCO2 power cycles, other base load alternatives
- ✓ Allows coal mine owners time to evaluate feasibility of converting remaining coal resources into blue petrochemicals and blue synthetic fuels

Administratively efficient

- ✓ The decision criterion is easily confirmed against COD
- ✓ Easy to design and implement incentives supporting earlier retirement based on plant age

Accelerated Retirement Scenario

Equitable

- ✓ IPPs allowed to recover investments according to their PPA terms
- X However, this scenario will unlikely allow the GOI sufficient time to (i) arrange clean base load capacity and (ii) implement training programs for miners and CFPP employees who will be unemployed once a CFPP is retired

Efficient

- X Unlikely that owners of CFPPs already >25 yrs as of 2026 will have sufficient time to repurpose their power plants as geothermal, sCO2 energy storage, sCO2 power cycles and other base load alternatives
- X Will also not allow coal mine owners sufficient time to evaluate the feasibility of converting remaining coal resources into blue petrochemicals and synthetic fuels

Administratively efficient

- ✓ The decision criterion is easily confirmed against COD
- ✓ Easy to design and implement Incentives supporting earlier retirement based on plant age
- ✓ Can implement variation clause to buy time if necessary

Advanced Nuclear and Geothermal Technologies- best base load replacement options

	Coal & Gas	Solar & Wind	Large Nuclear	Traditional Geothermal	Small Modular Reactors	Advanced Geothermal Systems
Carbon Free	x	✓	✓	0	✓	✓
Reliable Ramp up/ down	✓	x	0	0	✓	✓
Efficient Load Following	✓	x	x	✓	✓	✓
Industrial Heat Supply	✓	x	x	✓	✓	✓
Fuel safety	✓	✓	x	✓	0	✓
Efficient Land Use	✓ / 0	x	✓	x	✓	✓

X – not at all, 0 –some/partial,

Power plants must produce electricity efficiently when needed

Power Technology	Capacity Factor %	Remarks
Large Nuclear Plant	90%	Must run at full availability
Coal (Supercritical Plant)	65% - 75%	Availability 90%; 15%-25% held back as spinning reserve
Natural gas (CCGT Plant)	75% - 85%	Availability 92%, Efficiency drop-off below 75% MCR limits use of CCGT for deep and long duration load following
Hydroelectric	40%	Capacity factor depends on season of year, size of reservoir, multiple uses, and rainfall conditions
Wind	25% (onshore); 45% offshore	
Photovoltaic solar	15% - 19%	Depends on insolation conditions, cloud cover, time of day, and type of solar PV panel
Conventional Geothermal	35%	Varies between 40% and 80%

Technical Considerations
Clean Base Load Power Plant Options as Replacements for CFPPs

Advanced geothermal drilling and systems that allow the extraction of high temperature heat from hot rocks 5-10 kms below the surface are nearing commercial development

Click on links below for info on 3 companies trying to do that:

- Eavor – HQ Calgary, Canada established in 2017
  - https://www.youtube.com/watch?v=3cNO2cR5Azk
  - https://www.youtube.com/watch?v=nBj1GCb70A0&t=208s
  - https://www.youtube.com/watch?v=Oe8KlbTMiGs
  - https://www.youtube.com/watch?v=ypDQ4t_lIMo
- Quaise and GA Drilling
  - https://www.quaise.energy/
  - https://www.youtube.com/watch?v=RRum6FIHkNA
  - https://www.youtube.com/watch?v=LiMbv3r4yiM

Advanced Compressed CO_2 Energy Storage Systems

(i) charge by compressing CO_2 (sCO_2) during periods of high electricity production and low demand

(ii) store sCO_2 until needed in an above ground vessel

(iii) discharge sCO_2 through a turbine-generator set to generate electricity.

Technology Overview + Company that is developing sCO2 energy storage project

- https://www.youtube.com/watch?v=KslThwIurHs
- www.energydome.com/

sCO2 Power Cycles – Use O_2, CH4 & sCO2 to drive a CCGT plant instead of air and methane

- https://netpower.com/wp-content/uploads/2022/12/NPWR-PIPE-Presentation-12.14.22.pdf

Summary

1. ADB can collaborate with the GOI to develop and implement a viable Energy Transition Mechanism (ETM) that will lead to the retirement of all of Indonesia's CFPPs and replace them with clean base load capacity by 2050.
2. The ETM policy framework for doing so can meet "Good Policy" thresholds for efficiency, equity. timeliness and administrative feasibility as long as sufficient time is allowed for the creation of:

   (i) new jobs for displaced workers

   (ii) alternative supply chains and business opportunities for affected businesses

   (iii) new sources of revenue for the GOI.
3. Finally, when implementing this Good Policy, it is important not to make "perfect, the enemy of good enough".

For queries and feedback on this presentation, please send emails to **bart@rolevaenergy.com**