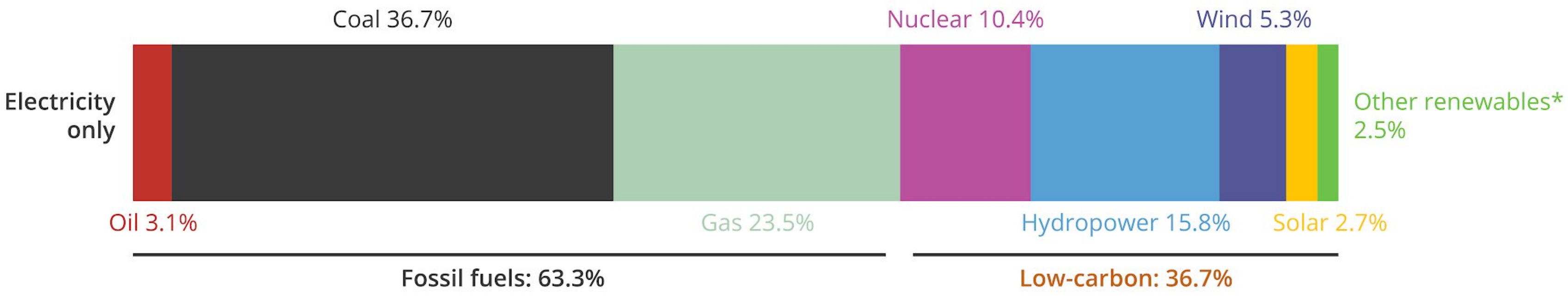
IESR Institute for Essential Services Reform

The Flexible Thermal Power Plant: An Analysis of Operating Flexible Coal-Fired Power Plants to Enable the High-Level Variable Renewables in Indonesia's Power System

Wednesday, 15 June 2022

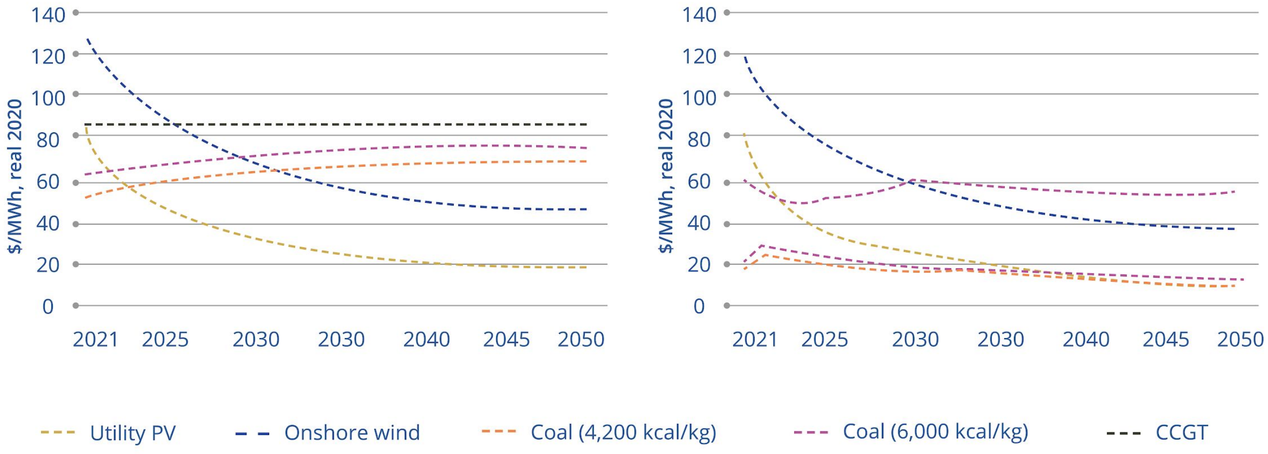
Global coal share in electricity generation



- Around 63.3% of the global generated electricity comes from the burning of fossil fuels
- Clearly, large chunk of global CO_2 emissions come from the fossil-based generation, with coal-fired power plants (CFPPs) are responsible for one third of it
- Around 60% of Indonesia electricity generation comes from CFPPs
- Will it still be cheaper than clear alternatives?

Source: Ritchie, H., & Roser, M. (2020a). CO_2 and Greenhouse Gas Emissions. Our World in Data. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

CFPPs vs Renewables in Indonesia: the future



- New CFPPs will have higher LCOE than solar PV in 2023, mainly due to the jump in CFPPs financing costs
- Solar PV will eventually overtake the marginal cost of running existing CFPPs in 2040
- Is there any temporary avenue for CFPPs then?

Source: BNEF, & IESR. (2021). Scaling Up Solar in Indonesia: Reform and Opportunity. BloombergNEF.

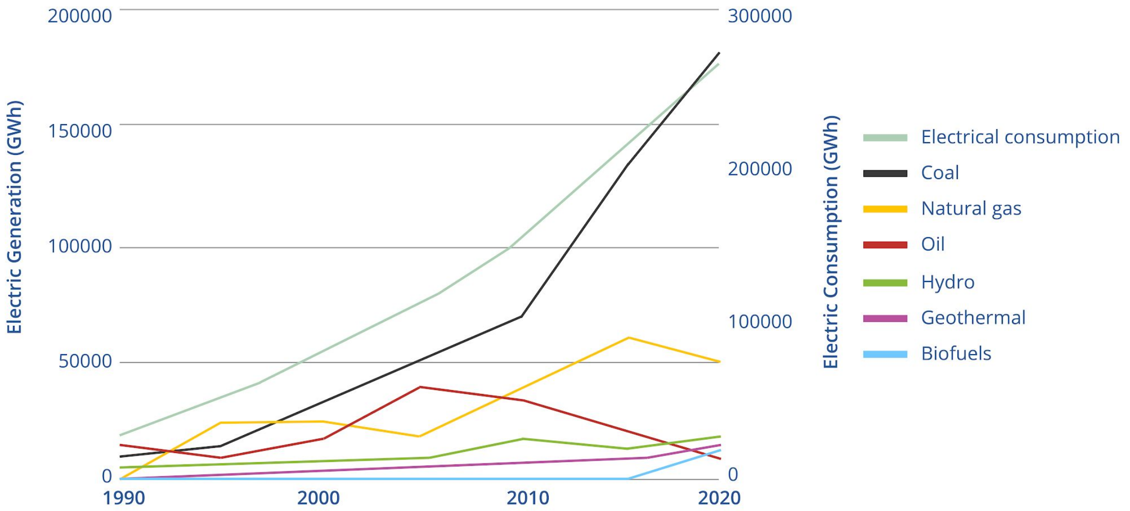
Flexible thermal power plants

- Due to its current share in the generation mix, thermal power plants could temporarily play a role in the energy transition
- How? By operating flexibly
- List of flexible operation yardsticks:
    - **Lower** minimum load
    - **Higher** ramping rates
    - **Quicker** start-up time
- The current operational practice in Indonesia's CFPPs:
    - Minimum load: 53% - 80%
    - Ramping rates: ~1%/min
    - Start-up time: 4 - 10 hours
- How to improve?

Lesson learned: Germany and India

Indicators	Germany	India
Installed capacity share: • **CFPPs** • **Renewables**	• CFPPs: 17.98% • Renewables: 61.96%	• CFPPs: 51.65% • Renewables: 38.3%
Flexible CFPPs age range considered in literatures	25-37 years	4-8 years
Status of CFPPs flexibilisation	Implemented on several units, e.g. Neurath Block E, Weisweiller Unit G & H, Bexbach	Pilot program on several units, e.g. Dadri Block 6, Mouda Unit 2, Ukai Unit 6
Flexibilisation approach	Plant modernisation, repowering using gas turbine, start-up optimisation, digital control system, single mill operation	Operational procedures adjustment without retrofit; units for the flexibilisation have been identified
Incentivizing market designs	Reserve market	Wholesale market with planned market addition for ancillary services
Supporting regulation	Not available	Compensation mechanism for degradation in heat rate due to part load operation and increase in energy and secondary fuel consumption due to multiple start/stop

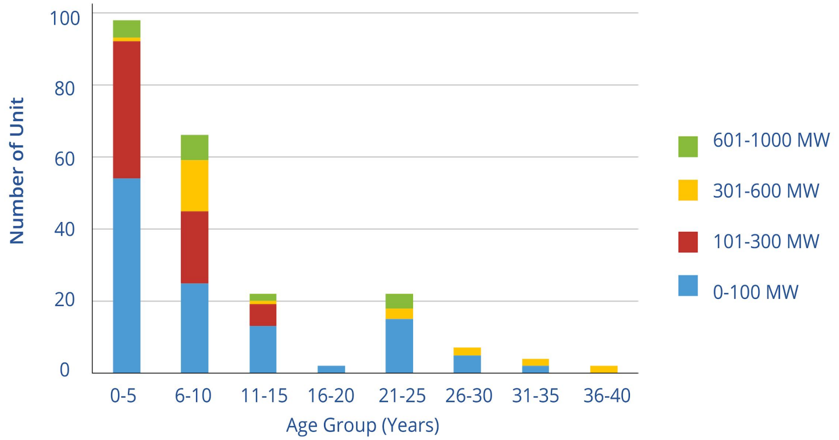
Indonesia CFPPs characteristic: historical electricity consumption

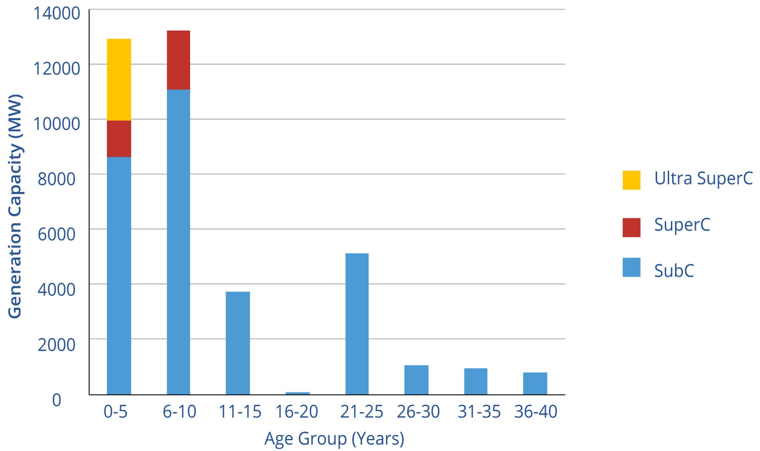


- The matching trend between the consumption and coal-based generation indicates an undoubtedly strong dependence of Indonesia's power sector on the unsustainable source of energy

Source: IEA. (n.d.). Indonesia—Countries & Regions. IEA. Retrieved 15 November 2021, from https://www.iea.org/countries/indonesia

Indonesia CFPPs characteristic: age, capacity and steam cycle technology distributions





- As an emerging economy, Indonesia's CFPP units are on average below 10 years old
- Most of these units have generation capacity below 300 MW
- Subcritical remains the most dominating steam cycle technology

Source: Compiled from different sources in the public domain

Study cases on flexible CFPP: plant specifications

Plant Specifications	Unit A	Unit B	Unit C
Nominal Capacity (MW)	100	600	100
Age group (Years)	21-25	21-25	0-5
Steam cycle technology	Subcritical	Subcritical	Subcritical
Minimum load (%)	55	79	38
Ramp rates (%/min)	1	0.58	1
Net generation efficiency at full load (%)	23	36.55	30.76
Estimated net generation efficiency at minimum load (%)	21.73	35.83	25.44
Fuel supply specific CO_2 emissions ($gramCO_2/kWh_{th}$)	316.88	332.21	326.51

Source: Compiled from different sources in the public domain, Unit A is specifically provided by PLN Div RSK

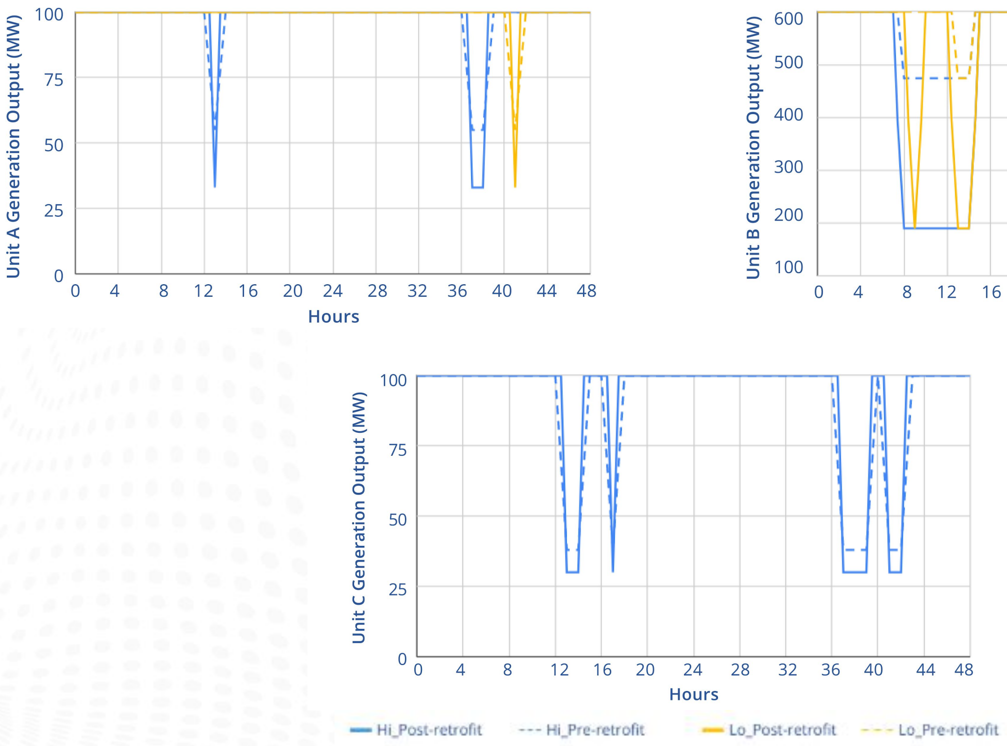
Study cases on flexible CFPP: flexible scenarios

Parameters	Unit A	Unit B	Unit C
Minimum load reduction (%)	22	48	8
Minimum load after retrofit (%)	33	31.6	29.82
Minimum load after retrofit (MW)	33	189.6	30.2
Ramp rates (%/min)	2	1.14	2
Estimated net generation efficiency at minimum load after retrofit (%)	11.73 - 17.73	20.83 - 29.83	20.44 - 23.44

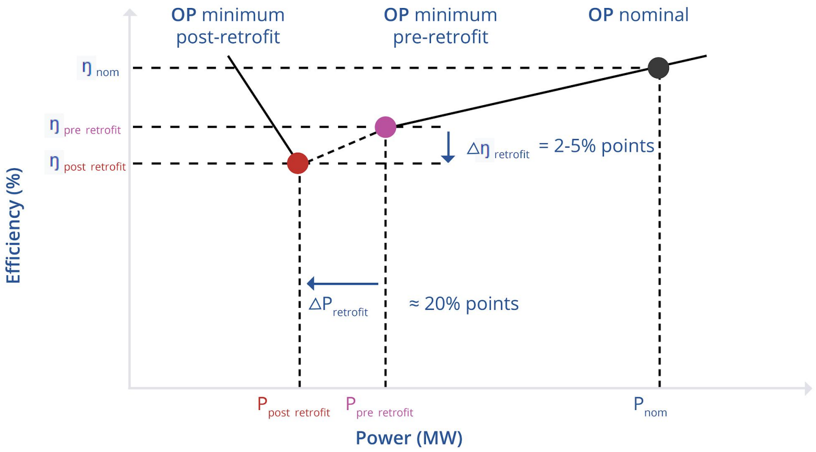
- Each unit is located at Sumatra, Jamali and Sulawesi systems
- All units has been retrofitted to achieve lower minimum load and higher ramping rates
- Load operational profiles of these retrofitted unit were extracted from IESR model on the expansion planning projection in 2030*

*the study has not been publicly launched

Study cases on flexible CFPP: flexible scenarios



Study cases on flexible CFPP: performance and emissions analyses



- A decrease in the efficiency means an increase in the Net Plant Heat Rate (NPHR) -> CO2 emissions will increase as the electric generation (kWh) requires more heat input (kcal) into the system, obtained from burning more coals

Source: Agora Energiewiende. (2017). Flexibility in thermal power plants – With a focus on existing coal-fired power plants.

Study cases on flexible CFPP: performance and emissions analyses

Parameters	Solar Irradiation	Unit A		Unit B		Unit C	
		Pre	Post	Pre	Post	Pre	Post
Efficiency (%)	-	0.2173	0.1773	0.3583	0.2983	0.2544	0.2344
Electric generation (MWh_{el})	High	4,665	4,666	27,074	23,054	4,304	4,380
	Low	4,755	4,767	28,271	25,722	-	-
CO_2 emissions (tonnes)	High	6,440	6,456	23,797	20,577	4,636	4,709
	Low	6,556	6,574	24,546	22,573	-	-
CO_2 emissions per generation (gramCO_2/kWhel)	High	1380.59	1383.54	878.98	892.55	1,077.14	1,075.09
	Low	1378.68	1379.16	868.24	877.59	-	-

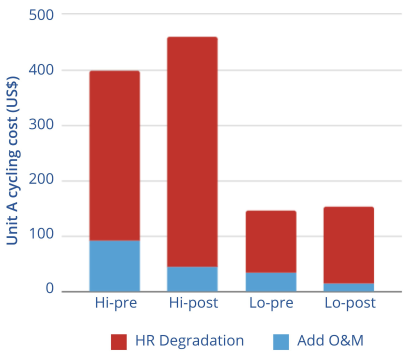
- Renewable share in each system:
  - Sumatra (Unit A):39.5% (Geothermal: 12.41%; Solar PV: 9.05%; Hydro: 6.78%)
  - Jamali (Unit B): 31.91% (Solar PV: 25.55%)
  - Sulawesi (Unit C): 51.2% (Solar PV: 28.36%; Hydro: 27.7%; Geothermal: 4.55%; Wind: 2.73%)

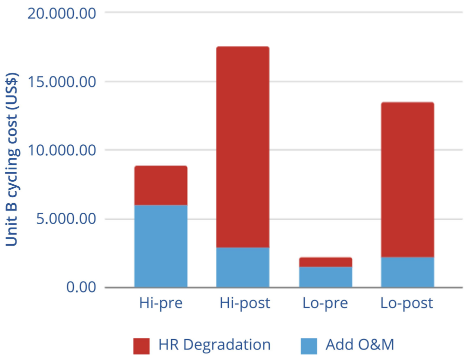
Study cases on flexible CFPP: cost analysis - investment

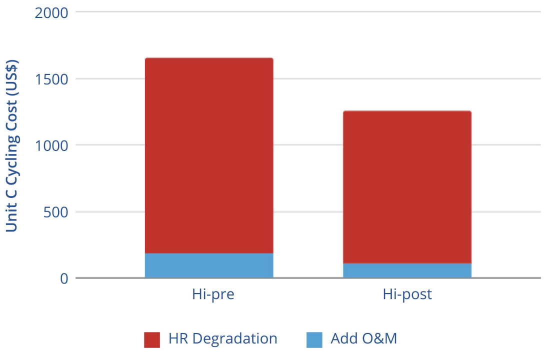
References for retrofit cost of investment	Unit A & C	Unit B	Note
Germany experience	$13.2 mil. - $40.5 mil.	$79.2 mil. - $243 mil.	The estimate comes for the country experiences in rejuvenating and modernising its old and ageing power plants; the cost covers the replacement of critical components, such as steam turbine blades and plant control system
India experience-1	$240,000 - $540,000	$1.44 mil. - $3.24 mil.	The estimation is based on a preliminary study that identifies the requirement to make a CFPP flexible; the study was carried out prior to the start of the pilot projects
India experience-2	n/a	n/a	During the trial run, the units were operated flexible simply by changing its operational procedure; Despite the null requirement for investment cost, there may, however, be fees for consultant and retraining operators, which could cost lower than the previous experience
VGB estimate	$500,000 - $1.5 mil.	$3 mil. - $9 mil.	The cost to achieve minimum load between 20% and 40%

- The cost analysis considered the investment required to retrofit, additional cost from cyclic operation and estimated Levelised Cost of Electricity (LCOE) considering the first two costs

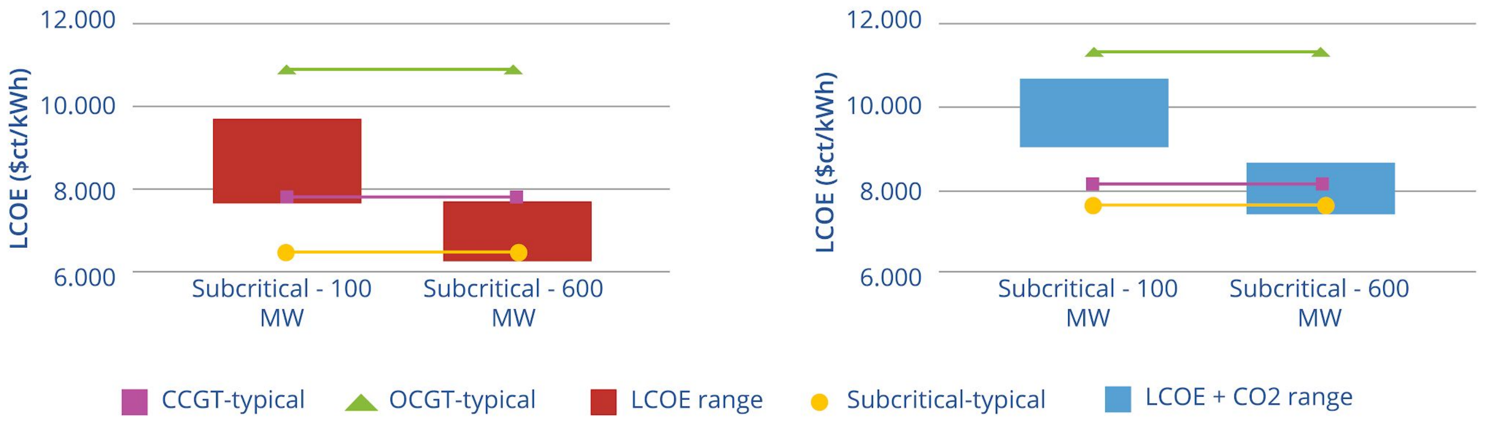
Study cases on flexible CFPP: cost analysis - cycling







Study cases on flexible CFPP: cost analysis - LCOE



- The report considers the Annuity Method, which is quite simple and allows for quick recalculation and comparison of the sensitivity of different indicators to the outcomes

Study cases on flexible CFPP: benefit qualitative analysis

- Reduced renewables curtailment rates
  - IESR model has shown already low curtailment rates from operating all existing CFPP units flexibly
    - Sumatra: 1.05%
    - Jamali: 0.24%
    - Sulawesi: 1.71%
- Avoided expensive start-up cost
- Reduced system cost
  - Due to less renewables curtailment (first point)
  - Due to the cost avoidance of utilising other expensive forms of technology to enable flexibility in the system, including energy storage, e.g. battery, and natural gas-fired power plants

Recommendations

- High level renewable integration in the power system planning is a requisite in the energy transition
- Market design and regulatory framework
  - Regulation to support flexible operation
  - Restructuring Power Purchasing Agreement (PPA) contractual terms to shift CFPP position from being a base load generation
  - Market-based mechanisms to embrace high share of variable renewables and flexible generation
- Technicality
  - Identify CFPP units in Indonesia for flexible CFPP pilot projects
  - Consider change in operational procedure in operating CFPP flexibly
- Capacity building for policy makers, electricity regulators and operators to run CFPP flexibly

IESR
Institute for Essential Services Reform

Thank You

Accelerating Low Carbon Energy Transition

www.iesr.or.id

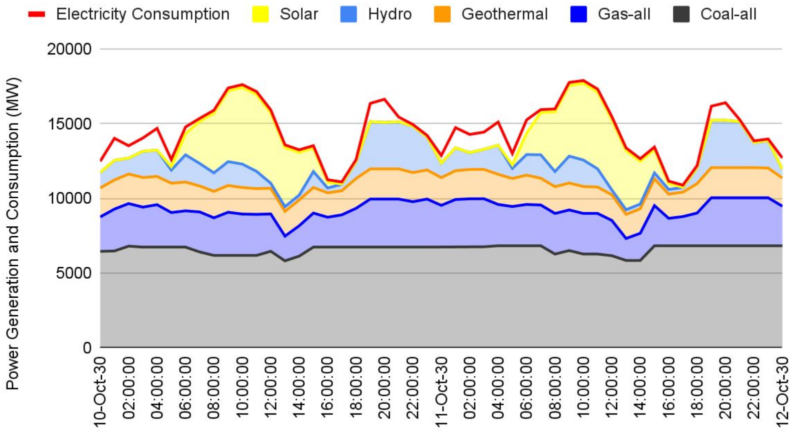
iesr.id

iesr.id

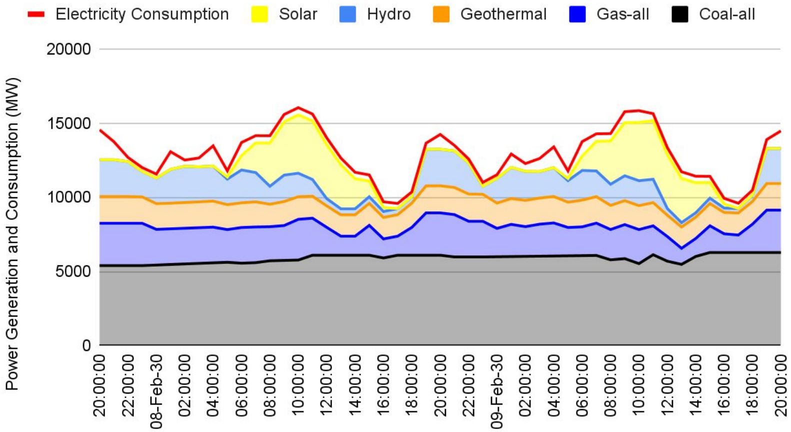
IESR

iesr

Study cases on flexible CFPP: flexible scenarios - Sumatra System



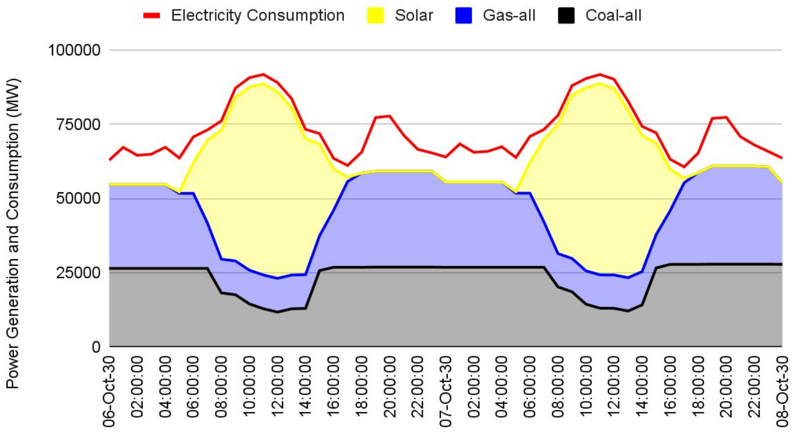
High solar irradiation scenario



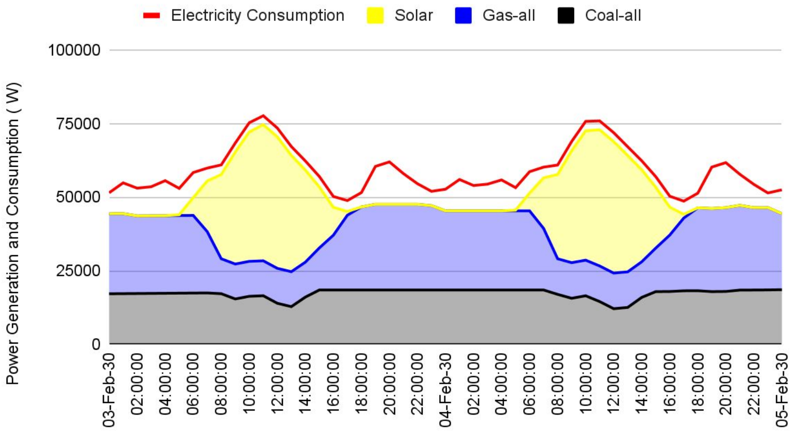
Low solar irradiation scenario

Hi_Post-retrofit --- Hi_Pre-retrofit Lo_Post-retrofit --- Lo_Pre-retrofit

Study cases on flexible CFPP: flexible scenarios - Jamali System



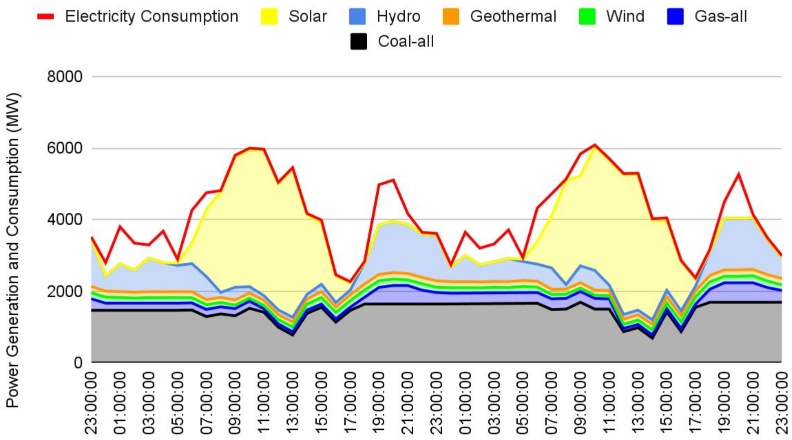
High solar irradiation scenario



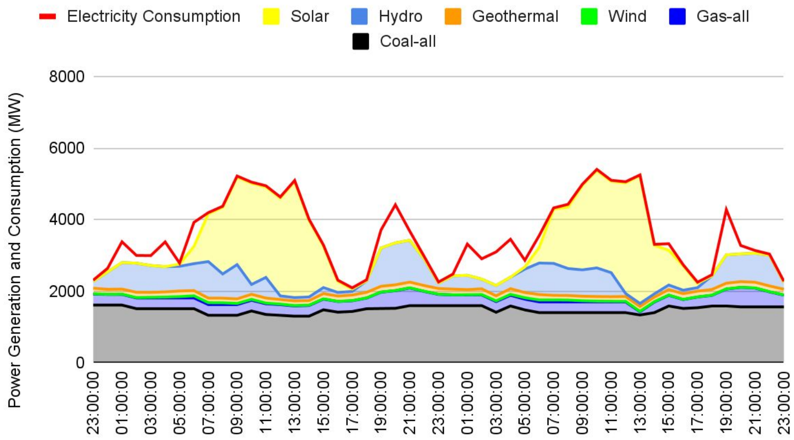
Low solar irradiation scenario

Hi_Post-retrofit --- Hi_Pre-retrofit Lo_Post-retrofit --- Lo_Pre-retrofit

Study cases on flexible CFPP: flexible scenarios - Sulawesi System



High solar irradiation scenario



Low solar irradiation scenario

Hi_Post-retrofit --- Hi_Pre-retrofit Lo_Post-retrofit --- Lo_Pre-retrofit