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TECHNICAL REPORT

Financial benefits of repurposing Maharashtra's old coal plants

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Financial benefits of repurposing Maharashtra's old coal plants: *Commissioned and published by Climate Risk Horizons*

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About

Climate Risk Horizons' (CRH) work highlights the systemic risks that disruptive climate change poses to investors, lenders and infrastructure investments. Through a data-driven, research-oriented approach that incorporates a holistic understanding of climate policy, energy infrastructure and regulatory processes, CRH provides advice on risk management strategies to minimise stranded, non-performing assets and economic disruption in the face of climate change.

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1.0 List of abbreviations

BESS	Battery Energy Storage System
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CO2	Carbon Dioxide
SOx, NOx	Oxides of Sulphur and Nitrogen respectively
GW	Gigawatt
Hrs	Hours
INR	Indian Rupee (currency)
kWh	Kilowatt-hour
MOP	Ministry of Power
MW	Megawatt
MRPL	Mangalore Refinery and Petrochemicals Limited
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
PLF	Plant Load Factor
PV	Photovoltaic (solar)
RE	Renewable Energy
SynCON	Synchronous Condenser
MAHAGENCO	Maharashtra State Power Generating Company Ltd.

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4.0 Executive summary

In Maharashtra, old coal plants—totaling 4,020 MW in capacity—are operating beyond their economic lives. The central government has advocated that such power plants be shut down in the interests of improving air quality.[1] Based on a notification from Ministry of Environment Forest and Climate Change, these plants either need to be retrofitted with pollution control equipment, be shut down or incur financial penalties after 2025.[2] The former is going to be costly: Based on CEA estimates, pollution control retrofits for these plants would cost around ₹2,000 crores.

Given variable costs alone ranging from ₹3.15 to ₹6.3 per unit, these coal units are no longer cost-competitive compared to new renewable energy. So, rather than incurring significant capital expenditure on retrofitting old, inefficient and polluting coal plants, Climate Risk Horizons had calculated that retiring Maharashtra's old coal plants and replacing their planned generation with renewable energy would save Mahadiscom ₹75,000 crores over 10 years in terms of reduced power purchase costs, coal supply rationalisation and reduced retrofit expenditure.[3]

This analysis by Dr. Gireesh Shrimali of the Oxford Sustainable Finance Group at the University of Oxford suggests that the financial benefits could be even larger if these old coal plants are not only decommissioned but also repurposed by using the coal plant lands and facilities for solar PV, battery storage and grid stabilisation services.

This analysis of 15 selected older units at five coal plants—Bhusawal, Chandrapur, Khaparkheda, Koradi and Nashik—is a first attempt to enumerate the financial benefits that such coal plant repurposing would bring. It finds that the financial benefits of repurposing would far outweigh the costs of decommissioning the plants. Further, the benefits alone could cover a significant portion of CAPEX for repurposing options in each case. Three options for repurposing were assessed in this analysis:

a. Solar PV
b. Solar PV with battery storage (for providing flexibility)
c. Solar PV with battery storage and a synchronous condenser (to provide reactive power)

The synchronous condenser would essentially repurpose the turbogenerator from the old coal plant.

While the table below provides costs and benefits from individual plants, the key findings from this analysis are as follows:

1. The financial benefits of repurposing these coal units would be 2–4 times the costs of decommissioning.

2. Total decommissioning costs for the 5 plants assessed was approximately ₹1,756 crores, while the benefits from repurposing for solar PV with battery storage would be ₹4,346 crores.

3. While repurposing coal plant for solar PV and battery storage, if the old power plant turbogenerator is also repurposed to serve as a synchronous condenser, the benefits would climb to over ₹5,700 crores.

4. The financial benefits will cover 30–170% of new CAPEX required, depending on which repurposing option is chosen. That is, a significant percentage of the cost of repurposing will be recovered by the one-time benefits provided by repurposing. At some locations, the benefits will far outweigh CAPEX to repurpose.

5. Utilising the pre-existing land and grid connection facilities would result in a significantly reduced cost for the power generated—a 32% reduction approximately, for standalone solar PV and solar PV with battery storage. This would bring the Levelised Cost of Energy down to ₹1.87 and ₹2.69 per unit respectively, providing the state generating company Mahagenco with a cheap source of flexible power.

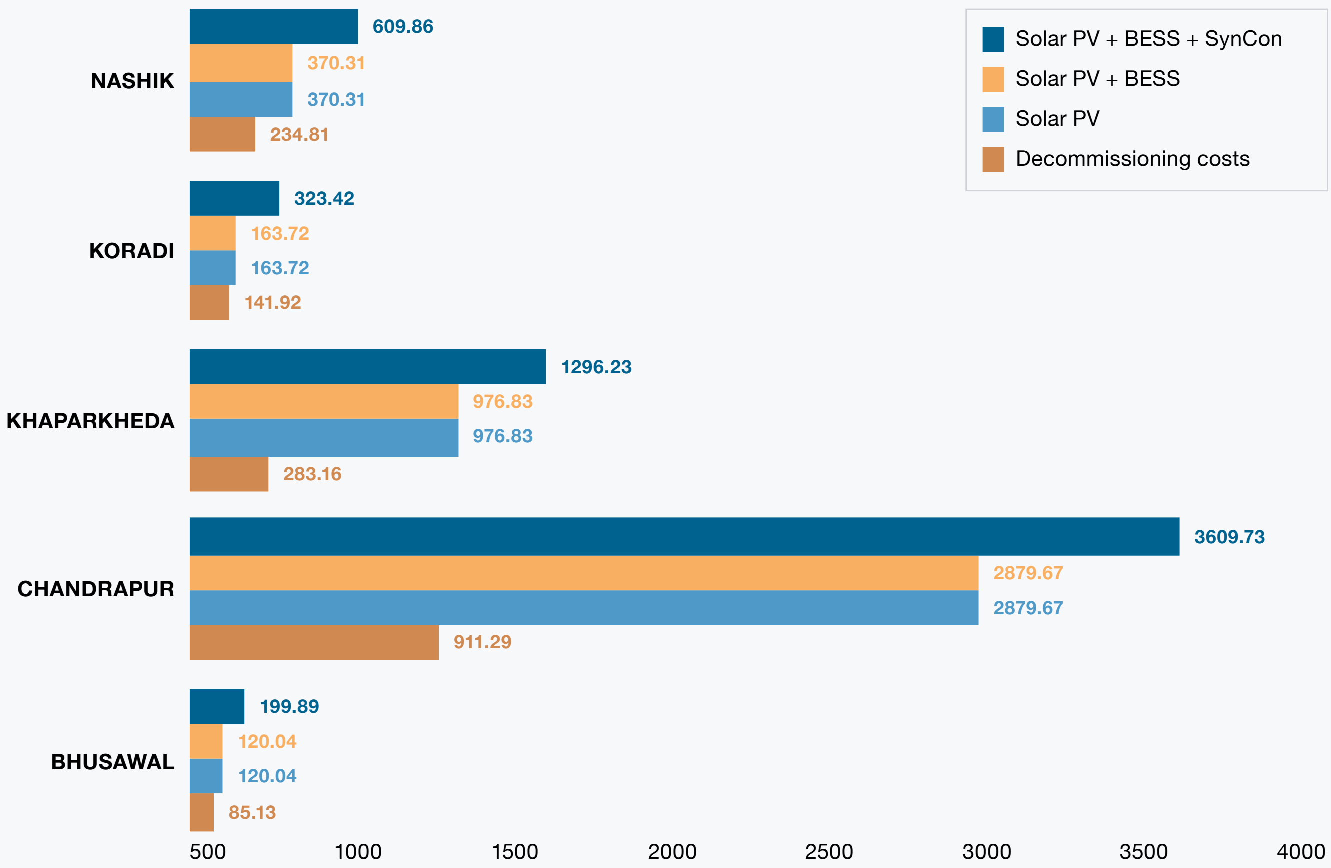
6. Repurposing the plants and their associated ash ponds for solar and battery storage would yield capacities of 1,224 MW of solar and 120 MW of 4-hour battery storage.

PLANT SPECIFIC SUMMARY TABLES, COSTS AND BENEFITS (₹ CR)

Plant	Decommissioning costs	SPV + BESS	SPV + BESS + SynCon	As % of CAPEX (SPV + BESS + SynCon)*
Bhusawal Unit 3	85.13	120.04	199.89	49.8%
Chandrapur Units 3–7	911.29	2879.67	3609.73	59.1%
Khaparkheda Units 1–4	283.16	976.83	1296.23	162.8%
Koradi Units 6–7	141.92	163.72	323.42	88.8%
Nashik Units 3–5	234.81	370.31	609.86	62.9%

*Including scrap value from decommissioned plant

Comparison of decommissioning costs and repurposing benefits (ash pond land only)



Source: Created by the author

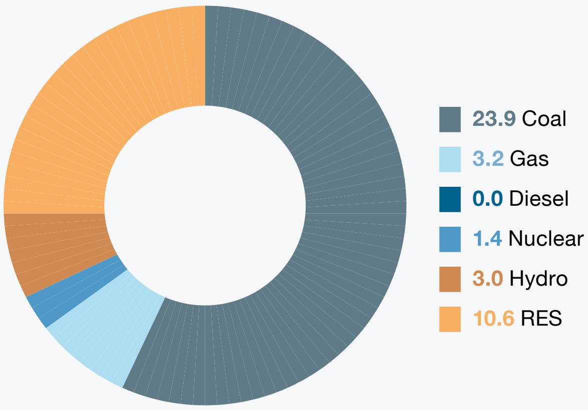
Clearly, there are significant financial benefits for the state of Maharashtra that would accrue from shutting down and repurposing its old coal plants, even as it continues to rely on newer coal plants for a significant proportion of its electricity. As the state grapples with the problems facing its electricity sector, shutting down and repurposing its old coal plants must be a key part of the discussion.

5.0 Overview of power scenario in Maharashtra

Located in the western part of India, Maharashtra is the third largest state geographically and second most populous state in the country. Maharashtra contributes nearly 15% to India's gross domestic product (GDP) and its power sector has been a key driver of the state's economy.

As of January 2022, the Maharashtra's installed capacity for renewable energy stands at 10,629 MW, i.e., at 25% of the total installed capacity of the state. Maharashtra's coal-fired thermal power accounts for nearly 60 per cent of its current installed capacity (Figure 1).

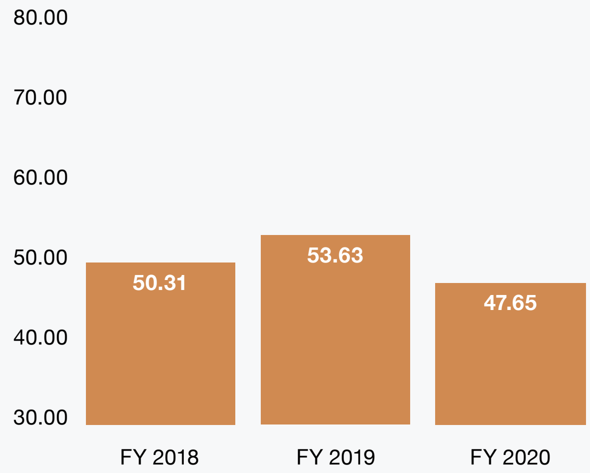
Figure 1: Maharashtra (installed capacities in GW as on 01.01.2022).



Source: Created by author from public data sources

The average Plant load factors (PLF) of the coal fleet in Maharashtra is much lower than the national average and those in other states. In fact, Maharashtra's coal fleet has been running at average PLFs (Figure 2) below the 55% mandated by the Central Electricity Authority (CEA).

Figure 2: Maharashtra (average PLFs)



Source: Created by author from public data sources

A report by Climate Risk Horizons in 2021 pointed out that Maharashtra can save up to ₹16,000 crore over five years by shutting down its old coal plants. These savings accrue in terms of avoided retrofit costs for Flue Gas Desulphurisers, Low Nox Burners and replacement of expensive scheduled dispatch of older plants with new renewable energy contracts or on the power exchange.

Maharashtra has significant old coal assets that have low capacity utilisation levels, reduced profitability and growing environmental concerns. It would thus be instructive to assess the financial feasibility and means to wean away from coal. One such approach includes repurposing coal plants for various productive end uses ranging from solar and wind energy generation to datacenters and ecological parks. Retirement of such coal plants can be better rationalised with clear empirical estimation of costs and benefits incurred in decommissioning plants versus repurposing them, which this analysis attempts.

In February 2022, the Maharashtra government had announced its intent to explore the phase-down of ageing and polluting coal-fired power plants in a systematic manner. Retrofitting older coal units at Koradi, Khaperkheda, Nasik and Chandrapur to control air and water pollution will cost thousands of crores and increase electricity costs, whereas replacement with cheaper renewable energy and battery storage will reduce the cost of power, address pollution and health issues residents are suffering from and create new employment opportunities (WE, 2022).

This study proposes an addition to the mere shutdown of five Maharashtra coal power plants, i.e., repurposing of the existing coal assets to a combination of (i) solar PV, (ii) battery storage energy systems (BESS), and (iii) synchronous condenser (SynCON). This move could also improve the financial health of the rest of the coal fleet in Maharashtra and of the state-owned MAHAGENCO.

A plant level analysis is provided illustrating the costs of decommissioning and the benefits of repurposing each plant for the options mentioned above. We then try to establish the utility of repurposing over plain decommissioning for these coal plants for a combination of repurposing options. In this study, the following five plants have been analysed:

- Bhusawal Thermal Power Station Unit 3 (210 MW)
- Chandrapur Thermal Power Station Unit 3–7 (1920 MW)
- Khaparkheda Thermal Power Station Unit 1–4 (840 MW)
- Koradi Thermal Power Station Unit 6 and 7 (420 MW)
- Nashik Thermal Power Station Unit 3–5 (630 MW)

All these plants have variable/running costs higher than ₹3/KWh (see Table 1) and average age >25 years.

TABLE 1: CHARACTERISTICS OF SELECTED OLD COAL PLANTS IN MAHARASHTRA

Plant	Installed coal capacity	Variable charge (ECR)
Bhusawal TPS Unit 3	210 MW	₹3.92/KWh
Chandrapur TPS Units 3–7	1920 MW	₹3.15–4.0/KWh
Khaparkheda TPS Units 1–4	840 MW	₹3.81/KWh
Koradi TPS Units 6–7	420 MW	₹4.73/KWh
Nashik TPS Units 3–5	630 MW	₹5.45–6.3/KWh

6.0 Coal plants analysed for repurposing: plant characteristics

A. Bhusawal Thermal Power Station Unit 3, Stage II (210 MW): Bhusawal Thermal Power Station is situated in Bhusawal city of Jalgaon district in Maharashtra. The current installed capacity of the power plant is 1210 MW with one unit of 210 MW and two units of 500 MW each. Older units of 62.5 MW and 310 MW were retired in 2010 and 2017 respectively. It is owned by Maharashtra State Power Generating Company Ltd. (MAHAGENCO), a state-owned utility.

TABLE 2: PLANT CHARACTERISTICS OF BHUSAWAL TPS UNIT 3

Stage	Capacity	Units	Age[1] (in years)	Project cost[2] (₹ CR.)	PLF (%)[3]	ECR (₹/KWh)
Stage II	210 MW	III	39 (Unit III)	75.25 CR.	45.30%	3.92

Note: [1] As on 01.07.2021. [2] The project cost estimates are dated as per the date of commissioning (commercial operation declaration COD) of the respective unit. [3] For FY 20–21.

B. Chandrapur Thermal Power Station Units 3–7 (1920 MW): Chandrapur Super Thermal Power Station (CSTPS) is located in Chandrapur District of Maharashtra and is owned by MAHAGENCO. The station has 3 stages. Stage I has 4 units of 210 MW capacity each out of which Units 1 and 2 have been retired. Stage II and III consist of 3 units and 2 units of 500 MW capacity each bringing the installed capacity of the plant to 2920 MW. Coal for the station is sourced from Durgapur & Padampur Coalfields of Western Coalfields Ltd. The plant relies on water from the Erai & Chargaon dams.

TABLE 3: PLANT CHARACTERISTICS OF CHANDRAPUR TPS UNITS 3–7

Stage	Capacity	Units	Age[1] (in years)	Project cost[2] (₹ CR.)	PLF (%)[3]	ECR (₹/KWh)
Stage I	2 X 210 MW	III, IV	36 (Unit–III) 36 (Unit–IV)	350.20 CR.	62.93%	4.00 (III–IV) 3.15 (V–VII)
Stage II	3 X 500 MW	V, VI, VII	30 (Unit–V) 30 (Unit–VI) 24 (Unit–VII)	1260.00 CR. (V & VI) 1205.00 CR. (VII)		

Note: [1] As on 01.07.2021. [2] The project cost estimates are dated as per the date of commissioning (commercial operation declaration COD) of the respective unit. [3] For FY 20–21.

C. Khaparkheda Thermal Power Station Units 1–4, StageI (840 MW): Khaparkheda Thermal Power Station is located in Khaparkheda Town Nagpur district of Maharashtra and is among the oldest power stations owned and operated by MAHAGENCO. The plant has 4 units of 210 MW capacity each, commissioned between 1990–2001. The total installed capacity of the station is 840 MW. Additionally, one unit of 500 MW capacity under Stage I was commissioned in 2011. Coal for the station is sourced from Mahanadi Coalfields Ltd. As with other Maharashtra plants discussed above, these units are also vintage with an average age of about 27 years.

TABLE 4: PLANT CHARACTERISTICS OF KHAPARKHEDA TPS UNITS 1–4

Stage	Capacity	Units	Age[1] (in years)	Project cost[2] (₹ CR.)	PLF (%)[3]	ECR (₹/KWh)
Stage I	4 x 210 MW	I, II, III & IV	32 (Unit I–II) 21 (Unit III–IV)	823.09 CR. (I–II) 1,485.37 CR. (III–IV)	67.56%	3.81

Note: [1] As on 01.07.2021. [2] The project cost estimates are dated as per the date of commissioning (commercial operation declaration COD) of the respective unit. [3] For FY 20–21.

D. Koradi Thermal Power Station Units 6 and 7, Stage III (420 MW): Owned and operated by MAHAGENCO, Koradi Thermal power station is located at Koradi near Nagpur. It is one of the four major power plants in Vidarbha—a power surplus region of India. All plants under Stage I and II have been retired. Under Stage III, Units 6–7 of 210 MW each were commissioned in 1982–1983. Koradi also has 3 newer units of 660 MW each at the same site, taking the total operational capacity to 2400 MW. Coal for the station is sourced from mines of Western Coalfields Limited (WCL) at Silewara, Pipla, Patansavangi, Kamptee, Inder, Walni, Gondegaon and Saoner; an average distance of 10 kilometres away. Water for the station comes from the nearby reservoir of Totaladoh hydroelectric power station. These units have an average age of about 38 years.

TABLE 5: PLANT CHARACTERISTICS OF KORADI TPS UNIT 6–7

Stage	Capacity	Units	Age[1] (in years)	Project cost[2] (₹ CR.)	PLF (%)[3]	ECR (₹/KWh)
Stage III	2 x 210 MW	VI, VII	38 (Unit VI–VII)	150.49 CR. (VI–VII)	40.10%	4.73

Note: [1] As on 01.07.2021. [2] The project cost estimates are dated as per the date of commissioning (commercial operation declaration COD) of the respective unit. [3] For FY 20–21.

E. Nashik Thermal Power Station Unit 3, 4 and 5, Stage II (630 MW): Nashik Thermal Power Station is located at Eklahare village near Nashik in Maharashtra and is owned and operated by MAHAGENCO. Stage I units 1 and 2 are retired. Stage II units 3, 4 and 5 were commissioned in 1979–1981 and are still operating. The total installed capacity of the station is 630 MW. Coal for the station is sourced from Mahanadi Coalfields by MahaGuj Collieries. These units are also vintage with an average age of about 41 years.

TABLE 6: PLANT CHARACTERISTICS OF NASHIK TPS UNITS 3–5

Stage	Capacity	Units	Age[1] (in years)	Project cost[2] (₹ CR.)	PLF (%)[3]	ECR (₹/KWh)
Stage II	3 x 210 MW	III, IV, V	42 (Unit III) 40 (Unit IV) 40 (Unit V)	94.73 CR. (Unit III) 143.95 CR. (Unit IV–V)	13.36%	5.45 (Unit III) 5.74 (Unit IV) 6.30 (Unit V)

Note: [1] As on 01.07.2021. [2] The project cost estimates are dated as per the date of commissioning (commercial operation declaration COD) of the respective unit. [3] For FY 20–21.

7.0 Results and discussion

This section first presents the results for estimated costs associated with decommissioning of the older units at five thermal power plants in Maharashtra. Next, the benefits arising out of repurposing these coal plants under two scenarios are presented (first considering ash pond land only and second considering entire coal plant area which includes ash pond). For this analysis, the repurposing options considered are a combination of (i) solar PV, (ii) battery energy storage systems (BESS) and (iii) synchronous condenser (SynCON). The repurposing benefits under scrap value, land and equipment reutilisation including remediation benefits are considered one-time benefits while the addition of system balancing through SynCON are considered as lifetime (10 year) benefits.

The SynCON benefits are net benefits as they have been computed after accounting for the cost of conversion of a turbo-generator to a synchronous condenser. Further, both the estimated costs of decommissioning and benefits of repurposing are in present value terms and could be compared with the Capital expenditure (CAPEX) of a new coal plant or solar PV/BESS/SynCON.

A. Bhusawal Thermal Power Station Unit 3, Stage II (210 MW): Table 7 shows the estimated cost of decommissioning of the 210 MW unit of Bhusawal TPS which, at 39 years, has already completed its useful economic life. Taking into consideration the different types of decommissioning costs discussed in the methodology section, the total cost implication of decommissioning Bhusawal TPS Unit 3, Stage II (210 MW) is estimated at ₹85.13 crore. These are direct costs and incurred over the entire decommissioning period (12–18 months). As can be seen from the table below, the major portion of the decommissioning cost of ₹51.67 crore is incurred under station overheads (₹35.49 crore) followed by ₹24.60 crore under coal combustion residuals cleanup. The former is incurred for decommissioning from the point of shutdown/closure till full demolition. The latter is part of environmental remediation needed for coal bearing areas within the plant.

TABLE 7: COSTS OF DECOMMISSIONING FOR BHUSAWAL TPS UNIT 3 (210 MW)

Sl. No.	Item	Million $	₹ CR.
1	Decommissioning costs (i+ii+iii)	7.38	51.67
	(i) Employee costs	1.49	10.45
	(ii) Station overheads	5.07	35.49
	(iii) O&M expenses	0.82	5.73
2	Pre-demolition costs: environmental remediation (asbestos cleanup)	0.02	0.13
3	Demolition costs including scrap removal	0.85	5.95
4	Coal combustion residuals	3.51	24.60
5	Coal storage area cleanup	0.40	2.77
Direct (total) decommissioning costs		**12.16**	**85.13**

Source: Compiled by the author. Note: O&M = operation and maintenance.

Analysing the benefits of repurposing, the corresponding indented benefit in monetary terms arising from utilising only the ash pond land area (284 acres) for repurposing with solar PV, as well as solar PV in combination with BESS, comes out to be ₹120.04 crore. With additional system balancing with SynCON (which delivers reactive power) in combination with solar and BESS, the estimated net benefit is ₹199.89 crore (refer Table 8). Note that for the first two repurposing options i.e. (i) solar PV and (ii) solar PV plus BESS, all benefits accrued are direct and one-time whereas for the third repurposing option i.e., (iii) solar PV plus BESS plus SynCON, the additional SynCON benefits are indirect and accrued over a lifetime (i.e., 10 years)[4].

TABLE 8: BENEFITS OF REPURPOSING (ASH POND LAND ONLY) FOR BHUSAWAL TPS UNIT 3

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	7.12	-	49.81	-
2	Land utilisation	2.03	-	14.20	-
3	Equipment (switchyard, substation)	0.92	-	6.42	-
4	Remediation benefits	3.51	-	24.60	-
5	Transmission and interconnection evacuation	3.57	-	25.00	-
Direct (plant specific) benefits: solar PV		**17.15**	**-**	**120.04**	**-**
Direct (plant specific) benefits: solar PV + BESS		**17.15**	**-**	**120.04**	**-**
6	System balancing (reactive power) benefits (net)	-	11.41	-	79.85
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**28.56**	**-**	**199.89**

Source: Compiled by the author.

Examining the repurposing option on the entire plant land area, the net benefit with solar PV alone, as well as solar PV in combination with BESS, would increase from ₹120.04 crore to ₹133.18 crore whereas with additional system balancing i.e., solar PV, BESS and SynCON the net benefit accrues to ₹213.03 crore.

Clearly, there are diminishing returns for each of the repurposing options for Bhusawal TPS Unit 3, in case the entire coal plant land is considered for repurposing, as there is an increase of only about ₹13 crore over and above that from utilising ash pond land only (refer Table 9).

1. For this analysis, one-time benefits represent benefits accrued in a year and life-time benefits represent benefits accrued in a span of 10 years.

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TABLE 9: BENEFITS OF REPURPOSING (ENTIRE COAL PLANT LAND) FOR BHUSAWAL TPS UNIT 3

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	7.09	-	49.66	-
2	Land utilisation	2.50	-	17.48	-
3	Equipment (switchyard, substation)	1.13	-	7.90	-
4	Remediation benefits	3.91	-	27.37	-
5	Transmission and interconnection evacuation	4.40	-	30.77	-
Direct (plant specific) benefits: solar PV		**19.03**	**-**	**133.18**	**-**
Direct (plant specific) benefits: solar PV + BESS		**19.03**	**-**	**133.18**	**-**
6	System balancing (reactive power) benefits (net)	-	11.41	-	79.85
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**30.43**	**-**	**213.03**

Source: Compiled by the author.

B. Chandrapur Thermal Power Station Unit 3–7 (1920 MW): Table 10 shows the estimated cost of decommissioning of units 3 and 4 (Stage I) and 5–7 (Stage II) of Chandrapur Thermal Power Station Stage I and II which, at 30–36 years, have already completed or are very close to completing their useful economic life. The analysis reveals that the total direct cost implication of decommissioning these units would be around ₹911.29 crore with coal combustion residuals clean up taking up the major chunk of ₹375.33 crore followed by station overheads (₹324.44 crore).

All the decommissioning cost components have increased significantly for the Chandrapur plant vis-à-vis the Bhusawal plant. This is largely attributed to much higher plant capacity for Chandrapur TPS (1920 MW) in comparison to Bhusawal (210 MW) TPS.

TABLE 10: COSTS OF DECOMMISSIONING FOR CHANDRAPUR TPS UNITS 3–7 (1,920 MW)

Sl. No.	Item	Million $	₹ CR.
1	Decommissioning costs (i+ii+iii)	67.49	472.42
	(i) Employee costs	13.65	95.56
	(ii) Station overheads	46.35	324.44
	(iii) O&M expenses	7.49	52.42
2	Pre-demolition costs: environmental remediation (asbestos cleanup)	0.17	1.21
3	Demolition costs including scrap removal	7.78	54.43
4	Coal combustion residuals	53.62	375.33
5	Coal storage area cleanup	1.13	7.90
Direct (total) decommissioning costs		**130.18**	**911.29**

Source: Compiled by the author. Note: O&M = operation and maintenance.

When the Chandrapur plant's ash pond land alone is considered for repurposing, the indented benefit comes out to ₹2879.67 crore with solar PV, as well as for a combination of solar PV with BESS. Scrap value makes up the bulk of benefits i.e., ₹1010.76 crore. With the combination of SynCON with solar PV and BESS, an additional benefit of ₹730.06 crores can be realised taking the net benefit to ₹3609.73 crore (refer Table 11). Note that the SynCON benefits estimated here are over a lifetime (i.e., for 10 years) whereas all other benefits are direct and one-time in nature.

TABLE 11: BENEFITS OF REPURPOSING OPTIONS (ASH POND LAND ONLY) FOR CHANDRAPUR TPS UNITS 3–7

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	144.39	-	1010.76	-
2	Land utilisation	30.95	-	216.66	-
3	Equipment (switchyard, substation)	127.94	-	895.60	-
4	Remediation benefits	53.62	-	375.33	-
5	Transmission and interconnection evacuation	54.47	-	381.31	-
Direct (plant specific) benefits: solar PV		**411.38**	**-**	**2,879.67**	**-**
Direct (plant specific) benefits: solar PV + BESS		**411.38**	**-**	**2,879.67**	**-**
6	System balancing (reactive power) benefits (net)	-	104.29	-	730.06
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**515.68**	**-**	**3,609.73**

Source: Compiled by the author.

With entire land area of Chandrapur TPS is considered for repurposing, the net benefit with solar PV alone as well as solar PV in combination with BESS is pegged at ₹2972.64 crore. When these are combined with SynCON, the net benefits increase to ₹3702.70 crore (refer Table 12). As with Bhuswal TPS, in case of Chandrapur TPS also there are diminishing returns for each of the repurposing options as there is an increase of about ₹93 crore over and above that from utilising ash pond land only.

TABLE 12: BENEFITS OF REPURPOSING OPTIONS (ENTIRE COAL PLANT LAND) FOR CHANDRAPUR TPS UNIT 3–7

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	143.62	-	1005.33	-
2	Land utilisation	32.83	-	229.79	-
3	Equipment (switchyard, substation)	135.70	-	949.88	-
4	Remediation benefits	54.75	-	383.23	-
5	Transmission and interconnection evacuation	57.77	-	404.42	-
Direct (plant specific) benefits: solar PV		**424.66**	**-**	**2,972.64**	**-**
Direct (plant specific) benefits: solar PV + BESS		**424.66**	**-**	**2,972.64**	**-**
6	System balancing (reactive power) benefits (net)	-	104.29	-	730.06
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**528.96**	**-**	**3,702.70**

Source: Compiled by the author.

C. Khaparkheda Thermal Power Station Units 1–4, Stage I (840 MW): Table 13 shows the estimated cost of decommissioning of all 4 units (840 MW) of Khaparkheda TPS. While units 1 and 2 have already completed their useful economic life (about 32 years), Units 3 and 4 are about 21 years old. The total direct cost implication of decommissioning the Khaparkheda TPS is estimated at ₹283.16 crore with station overheads contributing to ₹141.94 crore out of the total, followed by coal combustion residuals (₹48.35 crore) and employee expenses (₹41.81 crore). Among the five plants analysed, the per MW decommissioning cost estimates (₹cr./MW) are lowest for Khaparkheda TPS units 1–4.

TABLE 13: COSTS OF DECOMMISSIONING FOR KHAPARKHEDA TPS UNITS 1–4 (840 MW)

Sl. No.	Item	Million $	₹ CR.
1	Decommissioning costs (i+ii+iii)	29.53	206.68
	(i) Employee costs	5.97	41.81
	(ii) Station overheads	20.28	141.94
	(iii) O&M expenses	3.28	22.93
2	Pre-demolition costs: environmental remediation (asbestos cleanup)	0.08	0.53
3	Demolition costs including scrap removal	3.40	23.81
4	Coal combustion residuals	6.91	48.35
5	Coal storage area cleanup	0.54	3.78
Direct (total) decommissioning costs		**40.45**	**283.16**

Source: Compiled by the author. Note: O&M = operation and maintenance.

When considering repurposing options utilising only ash pond land of the TPS, the indented benefit (one time) is estimated to be ₹976.83 crore for solar PV alone as well as for a combination of solar PV with BESS. With the combination of SynCON with solar PV and BESS, the estimated net benefit (lifetime) comes to ₹1296.23 crore (refer Table 14), due to an additional benefit of ₹319.40 crore from the reactive power with the use of SynCON.

TABLE 14: BENEFITS OF REPURPOSING OPTIONS (ASH POND LAND ONLY) FOR KHAPARKHEDA TPS UNITS 1–4

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	114.4	-	800.97	-
2	Land utilisation	3.99	-	27.91	-
3	Equipment (switchyard, substation)	7.21	-	50.48	-
4	Remediation benefits	6.91	-	48.35	-
5	Transmission and interconnection evacuation	7.02	-	49.12	-
Direct (plant specific) benefits: solar PV		**139.55**	**-**	**976.83**	**-**
Direct (plant specific) benefits: solar PV + BESS		**139.55**	**-**	**976.83**	**-**
6	System balancing (reactive power) benefits (net)	-	45.63	-	319.40
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**185.18**	**-**	**1,296.23**

Source: Compiled by the author.

When the entire coal plant land area of Khaparkheda TPS units 1–4 is considered for repurposing, the net benefit with both solar PV as well as solar PV plus BESS are pegged at ₹1006.77 crore; whereas along with SynCON, the total net benefit surges to ₹1326.17 crore (refer Table 15) due to additional reactive power benefits of ₹319.40 crore over a lifetime of 10 years.

TABLE 15: BENEFITS OF REPURPOSING OPTIONS (ENTIRE COAL PLANT LAND) FOR KHAPARKHEDA TPS UNITS 1–4					
Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	114.27	-	799.89	-
2	Land utilisation	4.84	-	33.87	-
3	Equipment (Switchyard, substation)	8.75	-	61.26	-
4	Remediation benefits	7.45	-	52.13	-
5	Transmission and interconnection evacuation	8.52	-	59.62	-
Direct (plant specific) benefits: solar PV		**143.82**	**-**	**1,006.77**	**-**
Direct (plant specific) benefits: solar PV + BESS		**143.82**	**-**	**1,006.77**	**-**
6	System balancing (reactive power) benefits (net)	-	45.63	-	319.40
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**189.45**	**-**	**1326.17**

Source: Compiled by the author.

D. Koradi Thermal Power Station Unit 6 & 7, Stage-III (420 MW): Table 16 shows the estimated cost of decommissioning of the 2 units (420 MW) of Koradi TPS Stage III which at about 38 years, have already completed their useful economic life. The total direct cost implication of decommissioning all units of the TPP comes to ₹141.92 crore with station overheads taking up nearly half of the total decommissioning cost and coal combustion residuals (₹22.08 crore) and employee costs (₹20.90 crore) other major contributors.

TABLE 16: COSTS OF DECOMMISSIONING FOR KORADI TPS UNITS 6 AND 7 (420 MW)			
Sl. No.	Item	Million $	₹ CR.
1	Decommissioning costs (i+ii+iii)	14.76	103.34
	(i) Employee costs	2.99	20.90
	(ii) Station overheads	10.14	70.97
	(iii) O&M expenses	1.64	11.47
2	Pre-demolition costs: environmental remediation (asbestos cleanup)	0.04	0.26
3	Demolition costs including scrap removal	1.70	11.91
4	Coal combustion residuals	3.15	22.08
5	Coal storage area cleanup	0.62	4.33
Direct (total) decommissioning costs		**20.27**	**141.92**

Source: Compiled by the author. Note: O&M = operation and maintenance.

When considering repurposing options on ash pond land of the TPP only, the benefit is estimated to be ₹163.72 crore with solar PV alone, as well as with a combination of solar PV + BESS, with a major chunk of the benefits coming from scrap value. With the combination of SynCON with solar PV and BESS, an additional benefit equivalent to ₹159.70 crore can be realised taking the overall estimated benefit to ₹323.42 crore (refer Table 17).

TABLE 17: BENEFITS OF REPURPOSING OPTIONS (ASH POND LAND ONLY) FOR KORADI TPS UNITS 6 AND 7

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	13.56	-	94.94	-
2	Land utilisation	1.82	-	12.75	-
3	Equipment (switchyard, substation)	1.65	-	11.52	-
4	Remediation benefits	3.15	-	22.08	-
5	Transmission and interconnection evacuation	3.20	-	22.43	-
Direct (plant specific) benefits: solar PV		**23.39**	**-**	**163.72**	**-**
Direct (plant specific) benefits: solar PV + BESS		**23.39**	**-**	**163.72**	**-**
6	System balancing (reactive power) benefits (net)	-	22.81	-	159.70
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**46.20**	**-**	**323.42**

Source: Compiled by the author.

If the entire coal plant land area of Koradi TPS Unit 6 and 7 is considered for repurposing, the net benefit with solar PV as well as with solar PV plus BESS is pegged at ₹184.24 crore. As expected, majority of the repurposing benefits are realised from scrap value. With the addition of system balancing with SynCON, the overall benefit rises to ₹343.94 crore (refer Table 18).

Centre for Sustainable Development, Asar,Manthan Adhyayan Kendra

TABLE 18: BENEFITS OF REPURPOSING OPTIONS (ENTIRE COAL PLANT LAND) FOR KORADI TPS UNITS 6 & 7

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	13.50	-	94.53	-
2	Land utilisation	2.47	-	17.27	-
3	Equipment (switchyard, substation)	2.23	-	15.62	-
4	Remediation benefits	3.77	-	26.41	-
5	Transmission and interconnection evacuation	4.34	-	30.40	-
Direct (plant specific) benefits: solar PV		**26.32**	**-**	**184.24**	**-**
Direct (plant specific) benefits: solar PV + BESS		**26.32**	**-**	**184.24**	**-**
6	System balancing (reactive power) benefits (net)	-	22.81	-	159.70
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**49.13**	**-**	**343.94**

Source: Compiled by the author.

E. Nashik Thermal Power Station Unit 3, 4 and 5, Stage II (630 MW): Table 19 shows the estimated cost of decommissioning of all 3 units (630 MW) of Nashik TPS Stage II which, at 40–42 years, have already completed their useful economic life. The total direct cost implication of decommissioning all units comes to ₹234.81 crore with station overheads (₹106.46 crore) taking up nearly half of the total decommissioning cost, followed by coal combustion residuals (₹59.26 crore).

TABLE 19: COSTS OF DECOMMISSIONING FOR NASHIK TPS UNITS 3, 4 & 5

Sl. No.	Item	Million $	₹ CR.
1	Decommissioning costs (i+ii+iii)	22.14	155.01
	(i) Employee costs	4.48	31.36
	(ii) Station overheads	15.21	106.46
	(iii) O&M expenses	2.46	17.20
2	Pre-demolition costs: environmental remediation (asbestos cleanup)	0.06	0.40
3	Demolition costs including scrap removal	2.55	17.86
4	Coal combustion residuals	8.47	59.26
5	Coal storage area cleanup	0.32	2.27
Direct (total) decommissioning costs		**33.54**	**234.81**

Source: Compiled by the author. Note: O&M = operation and maintenance.

When considering repurposing options on ash pond land of the TPP only, the indented benefit is estimated to be ₹370.31 crore with solar PV alone as well as a combination of solar PV with BESS with nearly half of the benefits coming from scrap sale alone (₹170.23 crore). With the combination of SynCON with solar PV and BESS, an additional benefits equivalent to ₹239.55 crore can be realised taking the overall estimated benefit to ₹609.86 crore (refer Table 20).

TABLE 20: BENEFITS OF REPURPOSING OPTIONS (ASH POND LAND ONLY) FOR NASHIK TPS UNITS 3, 4 & 5

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	24.32	-	170.23	-
2	Land utilisation	4.89	-	34.21	-
3	Equipment (switchyard, substation)	6.63	-	46.40	-
4	Remediation benefits	8.47	-	59.26	-
5	Transmission and interconnection evacuation	8.60	-	60.21	-
Direct (plant specific) benefits: solar PV		**52.90**	**-**	**370.31**	**-**
Direct (plant specific) benefits: solar PV + BESS		**52.90**	**-**	**370.31**	**-**
6	System balancing (reactive power) benefits (net)	-	34.22	-	239.55
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**87.12**	**-**	**609.86**

Source: Compiled by the author.

When the entire coal plant area of Nashik TPS units 3–5 is considered for repurposing, the net benefit with solar PV as well as with solar PV plus BESS goes up to ₹388.35 crore. As expected, majority of the repurposing benefits are realised from scrap value (₹169.69 crore). With the addition of system balancing with SynCON, the overall benefits rises to ₹627.90 crores (refer Table 21).

TABLE 21: BENEFITS OF REPURPOSING OPTIONS (ENTIRE COAL PLANT LAND) FOR NASHIK TPS UNITS 3, 4 & 5

Sl. No.	Item	Million $		₹ CR.	
		One time	Lifetime	One time	Lifetime
1	Scrap value	24.24	-	169.69	-
2	Land utilisation	5.45	-	38.17	-
3	Equipment (switchyard, substation)	7.40	-	51.77	-
4	Remediation benefits	8.79	-	61.54	-
5	Transmission and interconnection evacuation	9.60	-	67.18	-
Direct (plant specific) benefits: solar PV		**55.48**	**-**	**388.35**	**-**
Direct (plant specific) benefits: solar PV + BESS		**55.48**	**-**	**388.35**	**-**
6	System balancing (reactive power) benefits (net)	-	34.22	-	239.55
Direct (plant specific) benefits: solar PV + BESS + SynCON		**-**	**89.70**	**-**	**627.90**

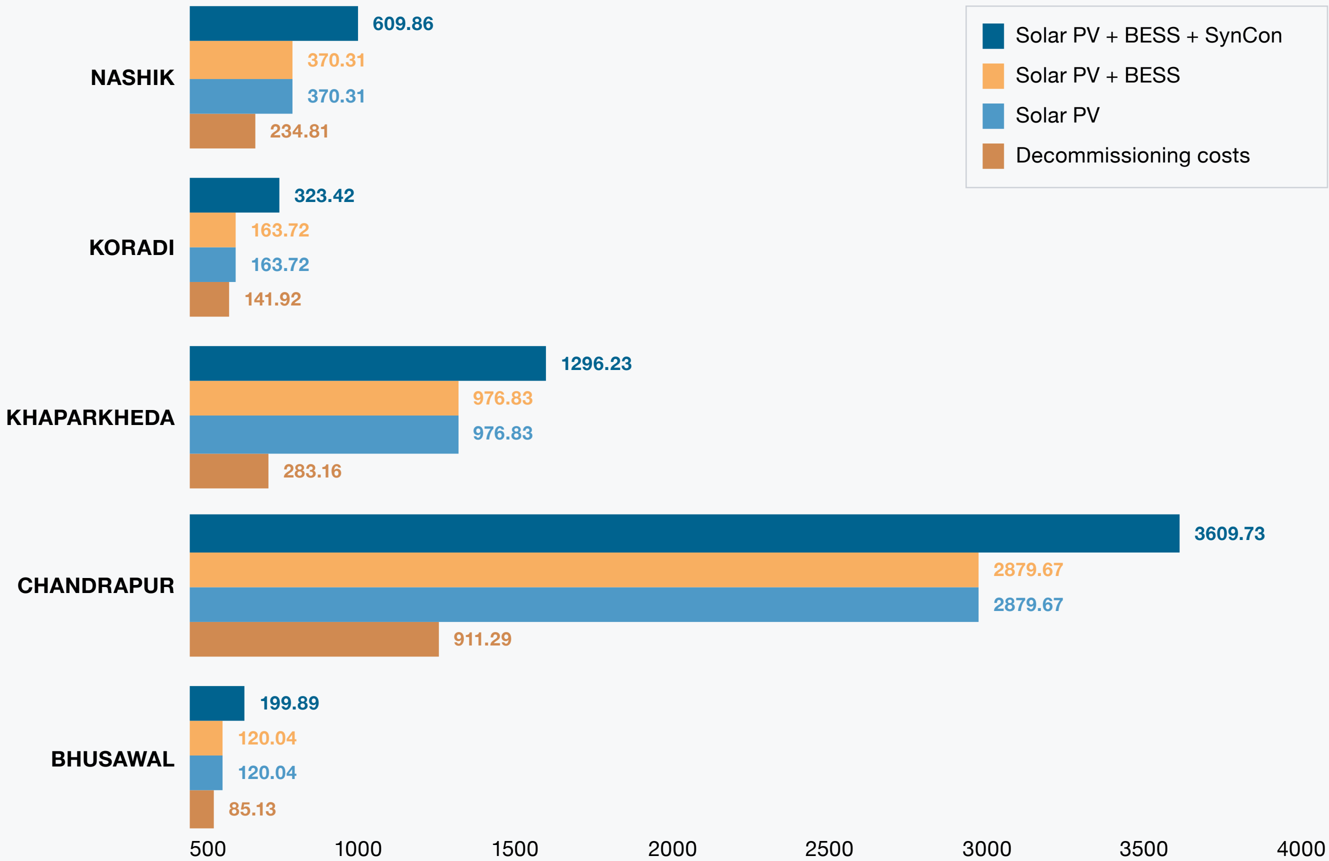
Source: Compiled by the author.

Among the five Maharashtra plants considered for repurposing, Chandrapur TPS offers highest repurposing benefits for each of the three repurposing options (i.e., solar PV, solar PV plus BESS and solar PV plus BESS plus SynCON). Figure 4 shows a comparison of decommissioning costs and repurposing benefits for the five plants for the repurposing options using ash pond land alone.

Figure 3: Decommissioning costs (₹ CR.) for Maharashtra coal plants

Source: Created by the author

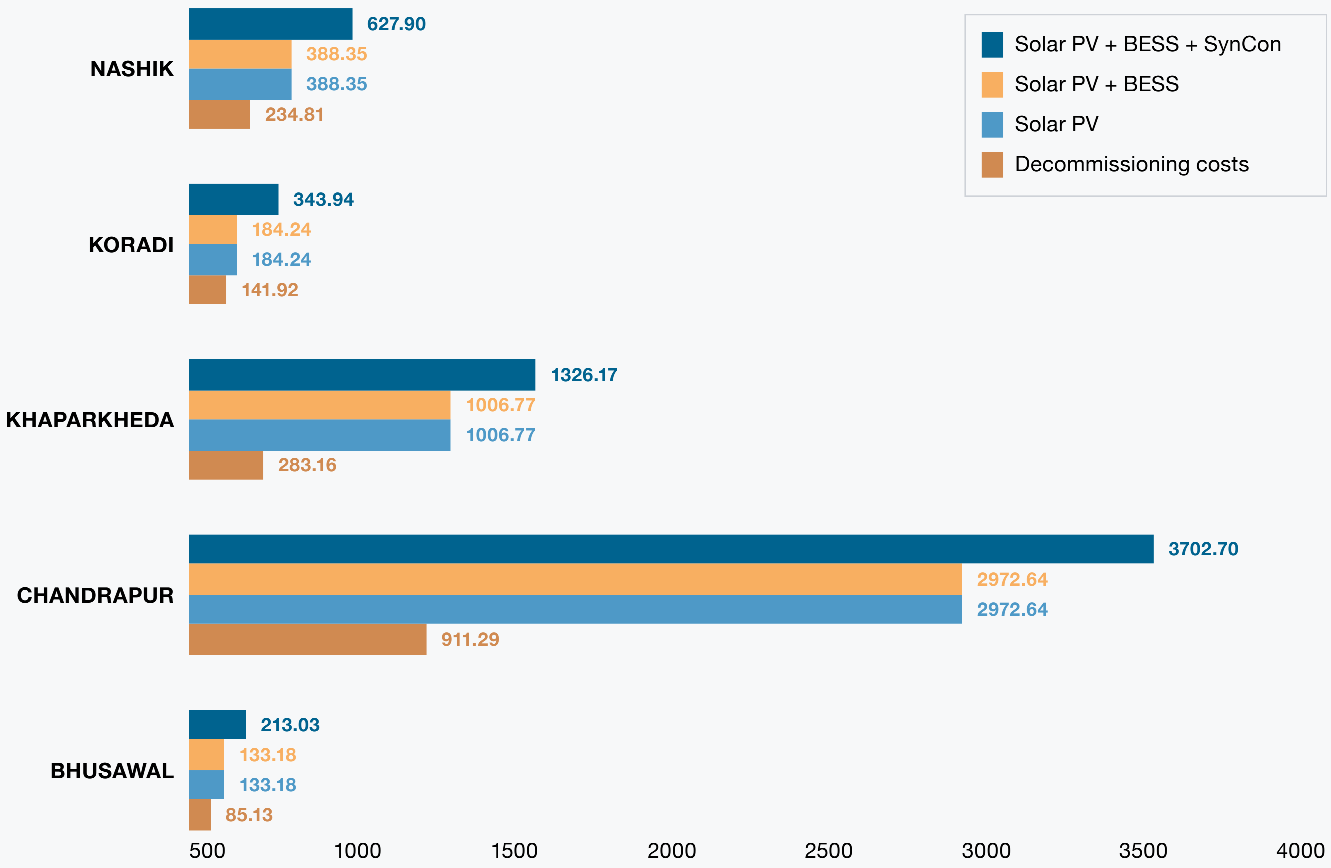
Figure 4: Comparison of decommissioning costs and repurposing benefits (ash pond land only)



Source: Created by the author

Similar to the result for repurposing with ash pond, repurposing with entire coal plant land also reveals the same order of benefits for the five plants with Chandrapur TPS showing highest benefits (refer Figure 5).

Figure 5: Repurposing benefits for Maharashtra coal plants (entire coal plant land)



Source: Created by the author

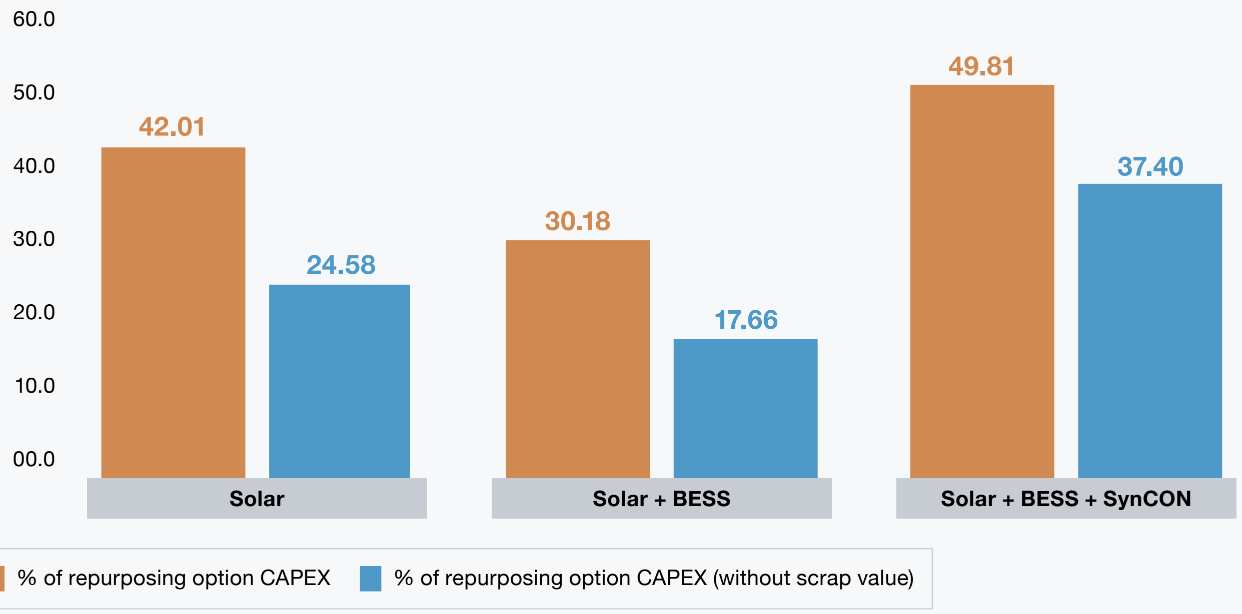
Repurposing benefits as a percentage of CAPEX repurposing option: In general there is an opinion that all coal plants beyond their useful life (i.e., 25 years) would be decommissioned, in which case the owners would accrue the scrap value benefits as discussed in the previous sections. However, there may be certain cases where decommissioning of coal plants may not be feasible or desirable either due to their younger age (less than 25 years) or due to political economy considerations. For this reason, we have now included the benefits inclusive of scrap value as a % of the capex needed for repurposing. This makes it clear that all or almost all of the repurposing capex needed can be met via the net repurposing benefits.

Accordingly, while computing the benefits as a % of repurposing capex, we have now considered two cases, including and excluding scrap value benefits. In the latter case, the scrap value has been excluded as that is anyway derived even with plain decommissioning of the coal plant.

In general, the repurposing benefits with solar PV + BESS + SynCON are the highest because SynCON benefits have been considered over a period of 10 years which in most cases would be the remaining lifetime period for which a turbogenerator could run[5]. It is noteworthy that, in case of Khaparkheda TPP, repurposing benefits have exceeded 100% capex repurposing option suggesting that the use of Solar+ BESS+SynCON at that location would easily cover entire CAPEX of Solar, BESS and SynCON put together. The benefits[6] as a percentage of capex repurposing option for each plant location are computed as follows:

1. Bhusawal thermal power station unit 3 (210 MW)

Figure 6: Net benefits as % of CAPEX repurposing costs, Bhusawal TPS unit 3



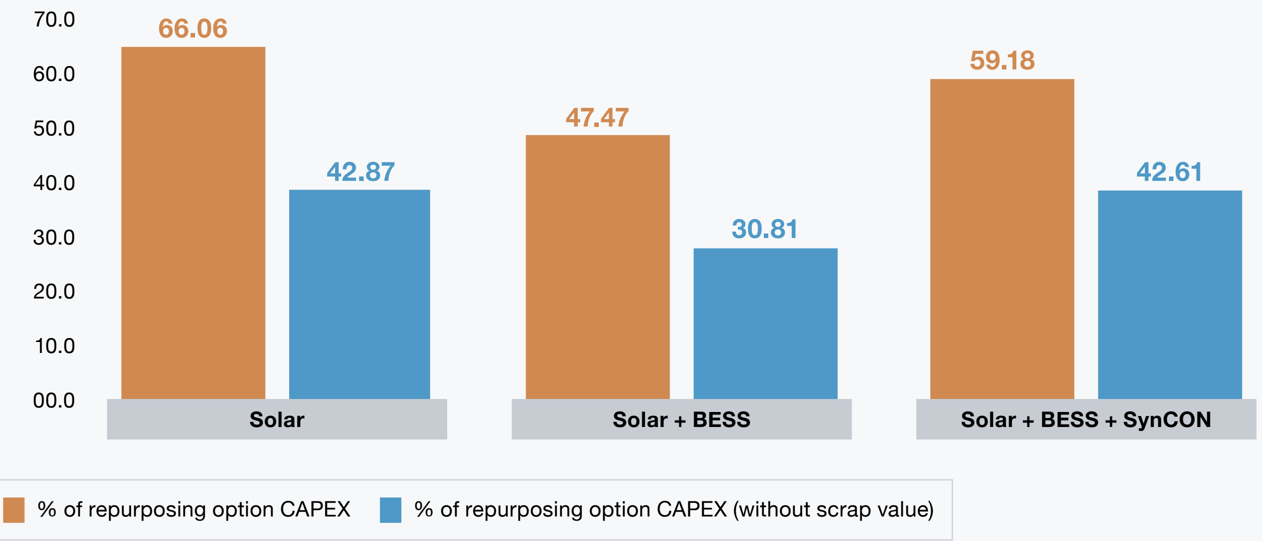
Source: Created by the author

2. This is an assumption based on the premise that most coal plants considered for repurposing are at the end of their economic lives and their turbogenerator would run for an additional 10 years after conversion to a synchronous condenser. However, actual useful life of a turbogenerator could vary from plant to plant depending on the wear and tear of the machinery, which is difficult to approximate as part of this analysis.

3. All the repurposing benefits are undiscounted.

2. Chandrapur thermal power station units 3–7 (1920 MW)

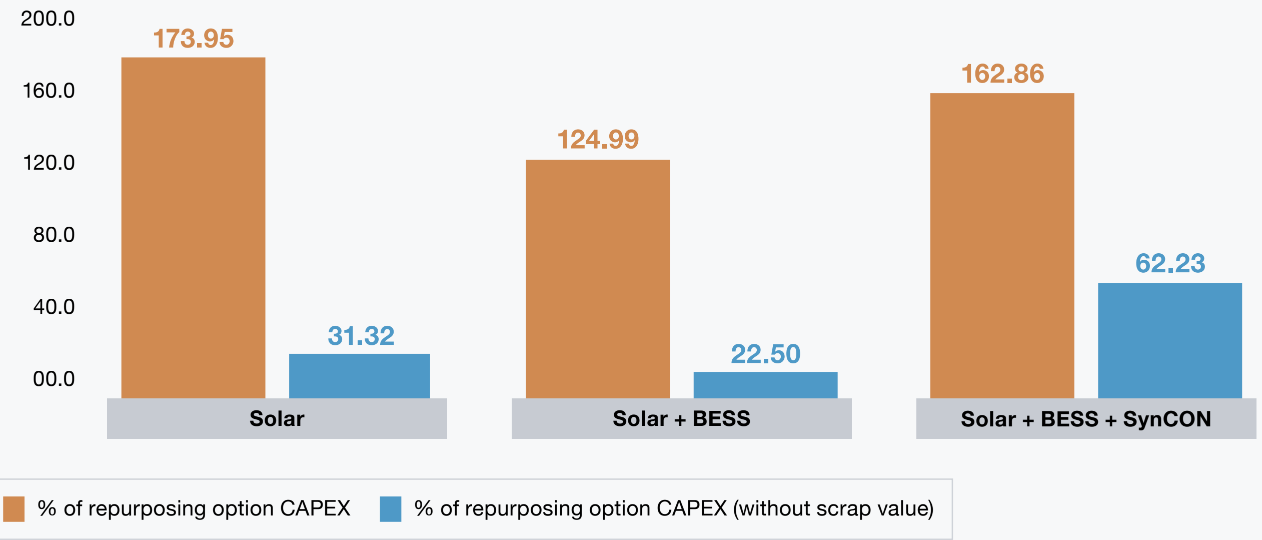
Figure 7: Net benefits as % of CAPEX repurposing costs, Chandrapur TPS units 3–7



Source: Created by the author

3. Khaparkheda thermal power station units 1–4 (840 MW)

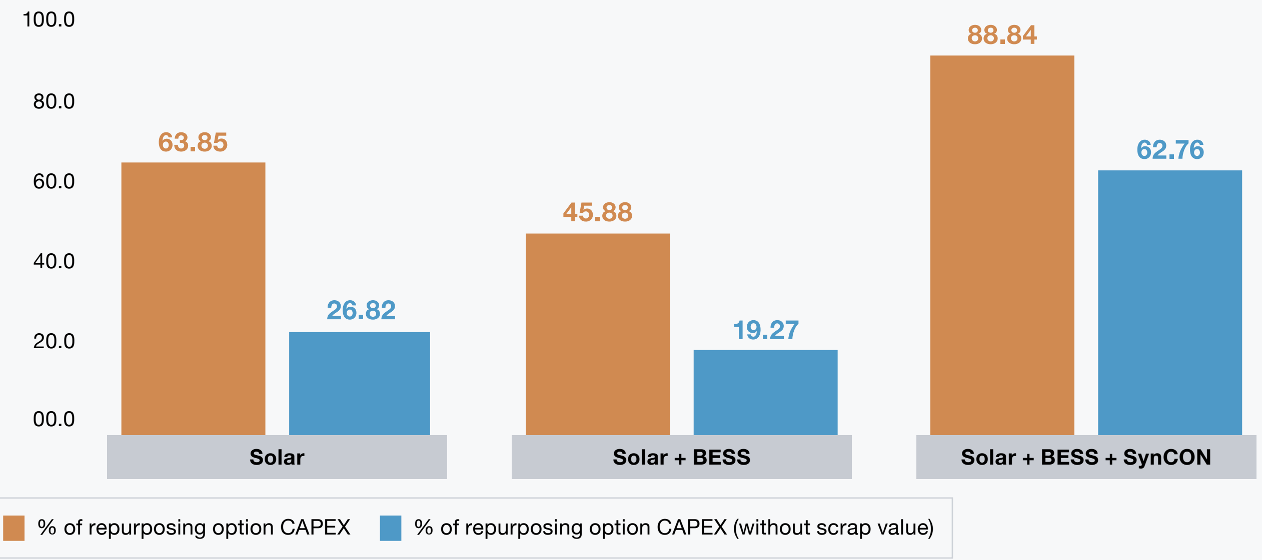
Figure 8: Net benefits as % of CAPEX repurposing costs, Khaparkheda TPS units 1–4



Source: Created by the author

4. Koradi thermal power station units 6 and 7 (420 MW)

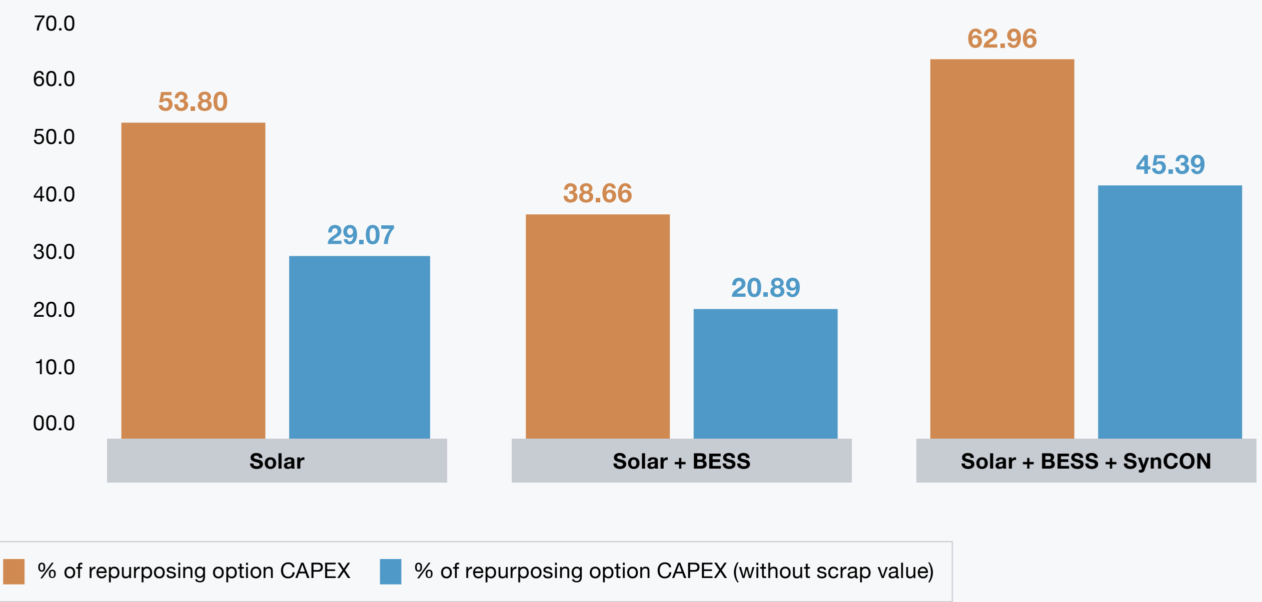
Figure 9: Net benefits as % of CAPEX repurposing costs, Koradi TPS units 6 and 7



Source: Created by the author

5. Nashik thermal power station units 3–5 (630 MW)

Figure 10: Net benefits as % of CAPEX repurposing costs, Nashik TPS units 3, 4 and 5



Source: Created by the author

Using repurposing benefits as a percentage of CAPEX, the generic savings in Levelised cost of energy (LCOE) for the repurposing options can be calculated. It is interesting to note that after accounting for these benefits, the LCOE for a new solar PV plant reduces by about 32.3% and the LCOE for a new Solar PV plus BESS plant reduces by about 31.1%, assuming both these are put up at the repurposed coal plant site. To illustrate, for instance, for a new solar PV and a new Solar PV plus BESS (i.e., co-located battery storage) set up at any location other than the repurposed site, the LCOE values would be ₹2.76/kWh and ₹3.90/kWh respectively. This would drop to ₹1.87/kWh and ₹2.69/kWh respectively in the case of solar PV/solar PV+BESS set up at a repurposed coal plant site.

8.0 Comparative analysis: costs and benefits

In the previous section, the decommissioning costs and intended benefits for a combination of three repurposing options for selected units at five thermal power plants of Maharashtra which had completed their useful economic life were estimated.

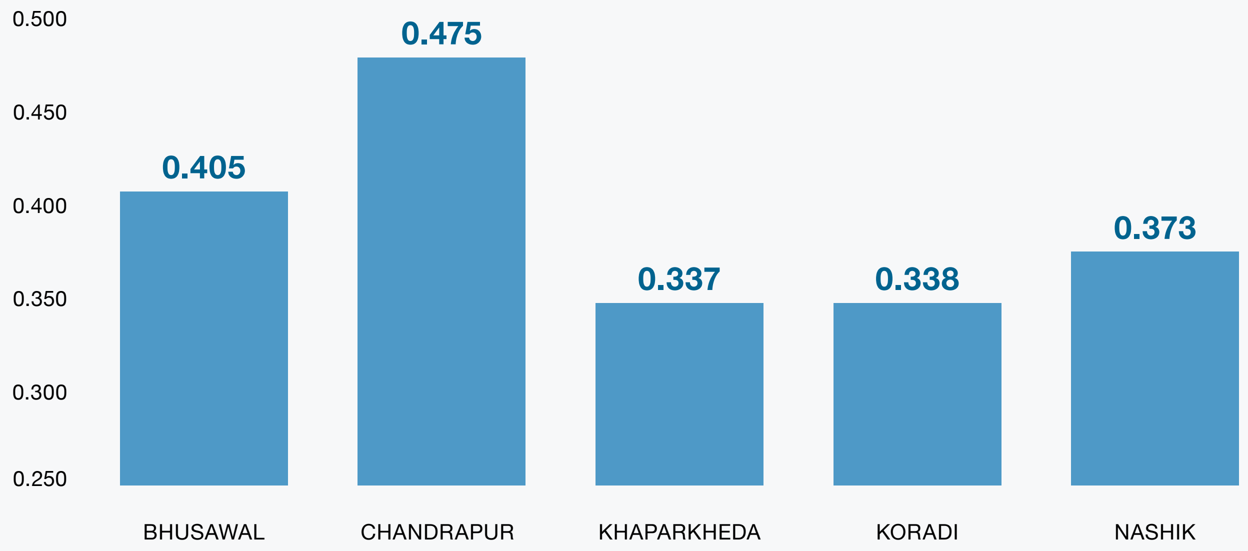
Further, to enable policy makers and utility managers to take an informed decision on the decommissioning related aspects of the stations discussed, and the benefits of repurposing over plain decommissioning, a comparative analysis of all five TPS under consideration is presented. The comparative analysis has been done per MW basis of each TPS under consideration for decommissioning to bring uniformity while making such an analysis.

Figure 11 plots the decommissioning cost estimates of plants in ₹cr./MW allowing for easy comparison.

Clearly, Chandrapur and Khaparkheda plants have the highest and lowest decommissioning costs respectively. However, in absolute terms, Chandrapur TPS exhibit the highest decommissioning costs and Bhusawal TPS shows the lowest (see Figure 3).

Our analysis reveals that two significant factors drive the differences in decommissioning costs: first, the installed capacity (i.e., size of the plant) and second, the area (i.e., layout of the plant) in terms of the ash pond land, coal bearing area land which has a direct bearing on the environmental remediation expenses incurred for areas exposed to ash, coal, asbestos etc. The former affects the decommissioning cost components mentioned at No. 1 (i), (ii) and (iii) and 3 and the latter impacts the decommissioning cost components mentioned at No. 2, 4 and 5 in Tables 7, 10, 13, 16 and 19 presented earlier.

Figure 11: Comparative analysis of decommissioning costs, ₹ CR./MW



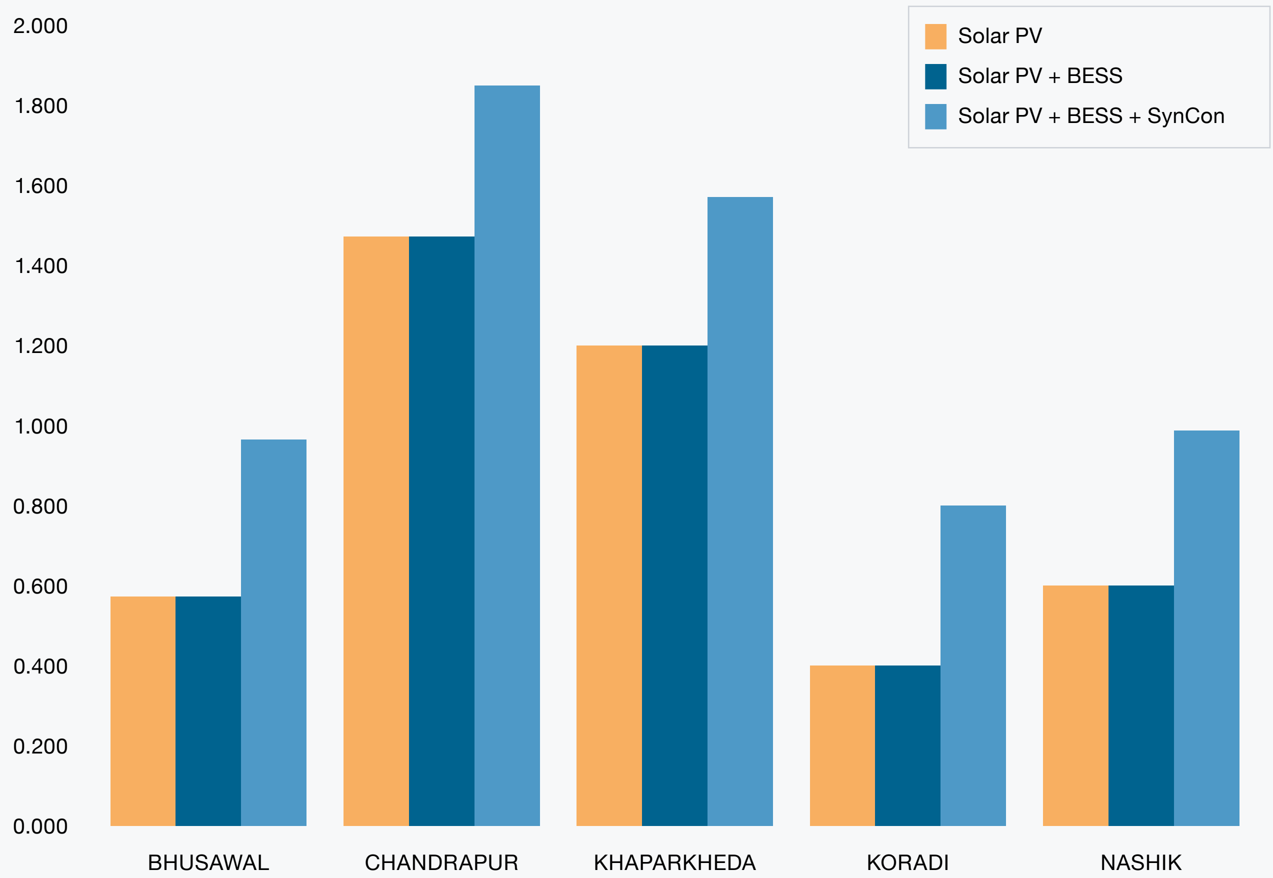
Source: Created by the author

We now compare the benefits of repurposing across the five TPPs. The Chandrapur plant gives the maximum benefits for each of the three repurposing options i.e., (i) solar PV, (ii) solar PV plus BESS, and (iii) solar PV plus BESS plus SynCON. This is the case both when repurposing is carried out on ash pond land alone as well as on entire coal plant land area.

Repurposing benefits follow the following order for all repurposing options and under both scenarios (see Figures 12 and 13): **Chandrapur TPS > Khaparkheda TPS > Bhusawal TPS > Nashik TPS > Koradi TPS**

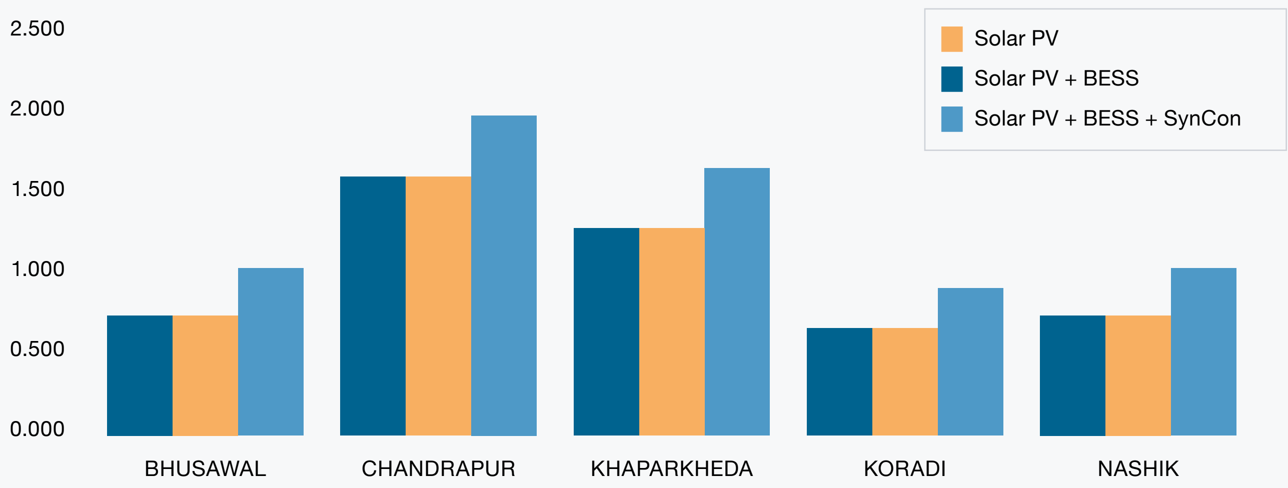
Based on our criteria[7], Chandrapur TPS yields maximum repurposing benefits suggesting positive impact of scale on benefits. This analysis suggests that three significant factors drive the differences in repurposing benefits among plants. First, the installed capacity (i.e., size of the plant) which relates to equipment (i.e, switch-yard, etc.) and transmission and interconnection benefits. Second factor is the area (i.e., layout of the plant) in terms of the ash dyke land, coal bearing area land, entire coal plant land which has a direct bearing on the land available for repurposing options and yields land reutilisation benefits as well as remediation benefits. The third and most significant factor is the CAPEX of the plant and its useful economic life in years which determines the salvage value (i.e., scrap value) of the plant. Clearly, plants with higher installed capacity and greater land available for repurposing would yield higher repurposing benefits.

Figure 12: Comparative analysis of repurposing benefits (ash pond land only), ₹ CR./MW



Source: Created by the author

Figure 13: Comparative analysis of repurposing benefits (entire coal plant land), ₹ CR./MW



Source: Created by the author

We now calculate the PV capacity/BESS capacity for each plant getting repurposed as under (Table 22). Repurposing the coal plants with their associated ash ponds for solar PV and battery storage would yield capacities of 1087 MW of solar and 106 MW of 4-hour battery storage.

TABLE 22: REPURPOSED CAPACITY OPTION, SOLAR PV/BESS

Plant	Installed coal capacity	Capacity	
		Solar PV	BESS
Bhusawal TPS unit 3	210 MW	57 MW	6 MW/24 MWh
Chandrapur TPS units 3–7	1920 MW	867 MW	85 MW/340 MWh
Khaparkheda TPS units 1–4	840 MW	112 MW	10 MW/40 MWh
Koradi TPS units 6 and 7	420 MW	51 MW	5 MW/20 MWh
Nashik TPS units 3, 4 and 5	630 MW	137 MW	14 MW/56 MWh

Source: Compiled by the author.

Table 23 provides the probable plant wise estimates of CAPEX for each repurposing option when only ash pond land is used. It's important to remember that the benefits accrued in the third repurposing option i.e., solar PV + BESS + SynCON are the net benefits i.e., gross benefits minus cost of repurposing turbogenerator.

TABLE 23: CAPEX | REPURPOSED OPTION–SOLAR PV/BESS/SYNCON (ASH POND REPURPOSING ONLY)

Plant	Installed coal capacity	Solar PV (₹ CR.)	Solar PV + BESS (₹ CR.)	Solar PV + BESS + SynCON (₹ CR.)
Bhusawal TPS unit 3	210 MW	286	398	401
Chandrapur TPS units 3–7	1,920 MW	4,359	6,066	6,099
Khaparkheda TPS units 1–4	840 MW	562	782	796
Koradi TPS units 6 and 7	420 MW	256	357	364
Nashik TPS units 3, 4 and 5	630 MW	688	958	969

Source: Compiled by the author

9.0 Conclusion

Maharashtra has announced a commitment towards achieving net zero carbon emissions in several cities, including the capital Mumbai which has set 2050 as the net zero target year. A crucial aspect of this transition would involve the shift in supply of power from coal plants to renewable energy sources. Maharashtra is also one of the first states in the country to consider phase down of its ageing and polluting coal-fired power plants in a systematic manner.

Maharashtra has significant coal capacities with low-capacity utilisation levels as many of these plants are old, unprofitable to the state and uneconomical to customers. Repurposing such plants for cheaper RE sources could provide a solution to overcome some of these challenges as well as provide much needed employment opportunities to local people. This study empirically demonstrate the benefits of repurposing for five old coal stations in Maharashtra in favour of a combination of repurposing options such as solar, BESS and SynCON.

This analysis yields three important findings. First, scrap value covers a significant portion of decommissioning costs and, in many cases, covers decommissioning costs entirely. Second, repurposing is more beneficial than plain decommissioning/retirement of coal plants as the repurposing benefits easily cover a reasonable part of the CAPEX of the repurposing option, even without scrap value benefits and indirect societal benefits such as avoided air pollution and CO_2 emissions. Third, this study presents repurposing using two land use scenarios (only ash pond land and entire coal plant land). The repurposing benefits realised from using the entire plant area vs. ash pond area alone are not significantly higher. While there is no constraint in using entire plant area for repurposing, there may be instances where power plants located in urban areas have higher land rates and other uses might yield higher land utilisation benefits.

In addition to the financial benefits already discussed, repurposing these ageing coal plants will not only help Maharashtra augment RE in its energy mix portfolio but will also lead to other environmental benefits in the form of avoided carbon emissions, elimination of ash residues along with other societal benefits which have not been considered in our empirical analysis.

10.0 Endnotes and references

Endnotes

1. *https://indianexpress.com/article/india/union-budget-old-polluting-coal-power-stations-to-be-closed-says-fm-6246629/*

2. G.S.R 243(E), Notification of Amendment to Environment (Protection) Rules dated March 31, 2021

3. Maharashtra's Energy Transition, Climate Risk Horizons, May 2021. *https://climateriskhorizons.com/research/Maharashtra-Enery-Transmission.pdf*

4. For this analysis, one-time benefits represent benefits accrued in a year and life-time benefits represent benefits accrued in a span of 10 years.

5. This is an assumption based on the premise that most coal plants considered for repurposing are at the end of their economic lives and their turbogenerator would run for an additional 10 years after conversion to a synchronous condenser. However, actual useful life of a turbogenerator could vary from plant to plant depending on the wear and tear of the machinery, which is difficult to approximate as part of this analysis.

6. All the repurposing benefits are undiscounted.

7. As per our criteria, the breakup of repurposing benefits considered is shown in Tables 11 and 12.

References

1. Ashish Fernandes & Harshit Sharma. (2020). TANGEDCO's Recipe for Recovery. Climate Risk Horizons. December 2020.

2. WE. (2022). *https://weather.com/en-IN/india/climate-change/news/2022-02-15-experts-welcome-coal-fired-power-plants-phase-down-in*

11.0 Methodology: Repurposing coal plants for the energy transition

Introduction

The Rationale

Globally, countries are phasing out coal plants due to their ageing fleet, reduced profitability and growing environmental concerns. In developed countries, coal power unit retirement is hardly new. A vast number of smaller, less efficient units have already been retired globally. Over the next 30 years, an accelerated phase out of approx. 1200GW of coal plants is expected (RMI, 2016). Developed countries with significant coal capacities such as Australia, Canada, Germany, UK and US; are taking different approaches to wean themselves off coal. One such approach includes retiring (i.e., decommissioning) and repurposing coal plants for various productive end uses, including solar plants (e.g., Nanticoke, Canada), wind plants (e.g., Brayton point, US), data centers (e.g., Widows creek, US), and energy storage (e.g., Liddell, Australia).

Straight out retiring of coal plants comes with its own sets of social, political, economic, and technical challenges. These range from issues like loss of employment opportunities to system flexibility considerations. Decommissioning power plants entails significant costs (Raimi, 2017); including dismantling, remediation, restoration, etc.; and making it suitable for reuse for development of an industrial facility.

Coal plant sites, their proximity to water, transportation, their connections to the power grid, associated human resources, their local community holds significant value. As old and polluting coal-fired power plants become uneconomical and ready for shutdown, their infrastructure could be reused for other productive purposes.

The strategy of conversion of shuttered coal-fired power plants, endowed with valuable assets, for providing economic, energy or grid services is referred to as coal plant repurposing

FIGURE 1: CONVERSION OF AN OLD AND UNPROFITABLE COAL PLANT INTO A RE + FLEX CENTER (CHATTOPADHYAY, ET AL., 2019)

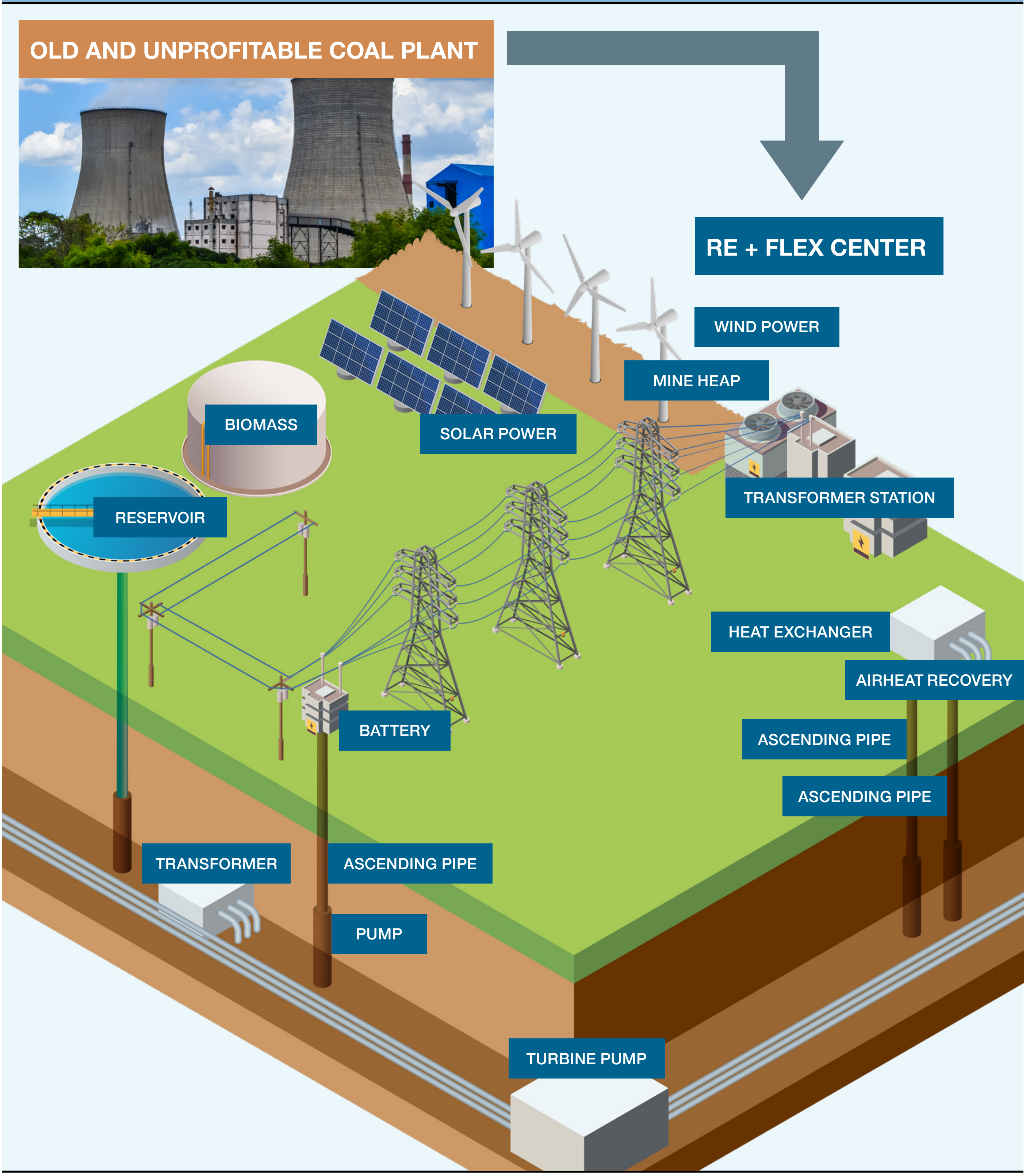


FIGURE 2: OVERVIEW OF THE DIRECT PLANT BENEFITS TO COAL PLANT REPURPOSING			
DECOMISSIONING COSTS	**IMPETUS TO RE**	**ECONOMIC DIVERSIFICATION**	**EXIT STRATEGY**
Reduces decommissioning costs: Partially avoid remediation requirements and allow re-use part of the existing assets such as generators and substations	Reduces the cost of commissioning greenfield RE capacity at the same site	For coal plants located in urban and semi-urban areas, repurposing manifests in a multiple end uses leading to economic diversification benefiting local economies	Provides a lucrative exit strategy for stranded and stressed coal plants

Repurposing an old coal plant for energy services allows for reusing a coal plant to continue some of the functions including power generation and ancillary services. For example, coal plant retirement provides an opportunity for enhancing renewable capacity addition as well as adding energy storage and repurposing coal plant components for grid stability services (Chattopadhyay et al, 2019). That is, coal plants can be repurposed in numerous ways, such as solar plant for energy; biomass plants for both energy and capacity; pumped hydro or battery storage for providing frequency control ancillary services, energy storage and capacity; and synchronous condensers for delivering reactive power and inertia.

Repurposing allows for early retirement of old, polluting and unprofitable coal plants, while capturing value by reusing part of the assets such as substation, generator, turbine, etc. More importantly, repurposing can prove to be an effective strategy for developing countries such as South Africa, Chile and India with significant RE investments in the offing. With land and reduced equipment costs, a repurposed coal plant site may potentially bring down high initial investment requirements for a greenfield RE or storage project and lowering the cost of RE power generated. Repurposing may also include continued use of the generator substation obviating the need for additional transmission and interconnection costs for RE and storage projects, thus reducing the overall cost of power. Beyond plant specific cost benefits, coal plant decommissioning and repurposing provides environmental, social, and grid stability benefits.

On the environmental front, the benefits include near elimination of power plant emissions namely CO_2, SOx, NOx, and particulate matter; as well as substantial savings on water usage. Additionally, repurposing a coal plant site reduces the costs needed for environmental remediation, associated with sustained use of coal and its combustion residuals i.e., fly ash generated.

On the grid stability front, repurposing coal plants may offer significant benefits over decommissioning (Chattopadhyay et al, 2019). For instance, repurposing coal plant equipment (e.g., the turbo-generator) into a synchronous condenser (SynCON) allows retaining a part of reactive power service for voltage control originally provided by the coal plant (Deecke and Kawecki, 2015). Similarly, utilizing a coal plant site for installation of battery energy storage system (BESS) helps in the delivery of essential frequency control ancillary services such as faster ramping and operating reserves.

On the social front, repurposing helps in mitigating the negative impact of decommissioning on employees and local communities (Raimi, 2017). In case of coal plant decommissioning, the local fiscal implications are significant as power plants makeup a significant portion of revenue for local government and surrounding areas (Raimi, 2017), and decommissioning can substantially reduce revenues for local governments and school districts. Repurposing allows for retaining part of the workforce for an upcoming RE or storage project at the same site (WB, 2018); this would partly ameliorate the socioeconomic impact of potential layoffs (Raimi, 2017). Like the original coal plant, the repurposed plant would also continue to support local economies and the surrounding communities by providing jobs, enabling economic activities and their wellbeing in the long run.

FIGURE 3: ENVIRONMENTAL, GRID STABILITY AND SOCIAL BENEFITS TO COAL PLANT REPURPOSING

ENVIRONMENTAL	GRID STABILITY	SOCIAL
• Near elimination of power plant emissions namely CO_2, SOx, NOx, and particulate matter • Substantial savings on water usage • Reduces the costs needed for environmental remediation	• Reactive power service for voltage control using SyCON • BESS for essential frequency control ancillary services	• Reduce local fiscal implications like reduced revenues for local governments • Reskilling and retaining part of the workforce for an upcoming RE or storage project at the same site

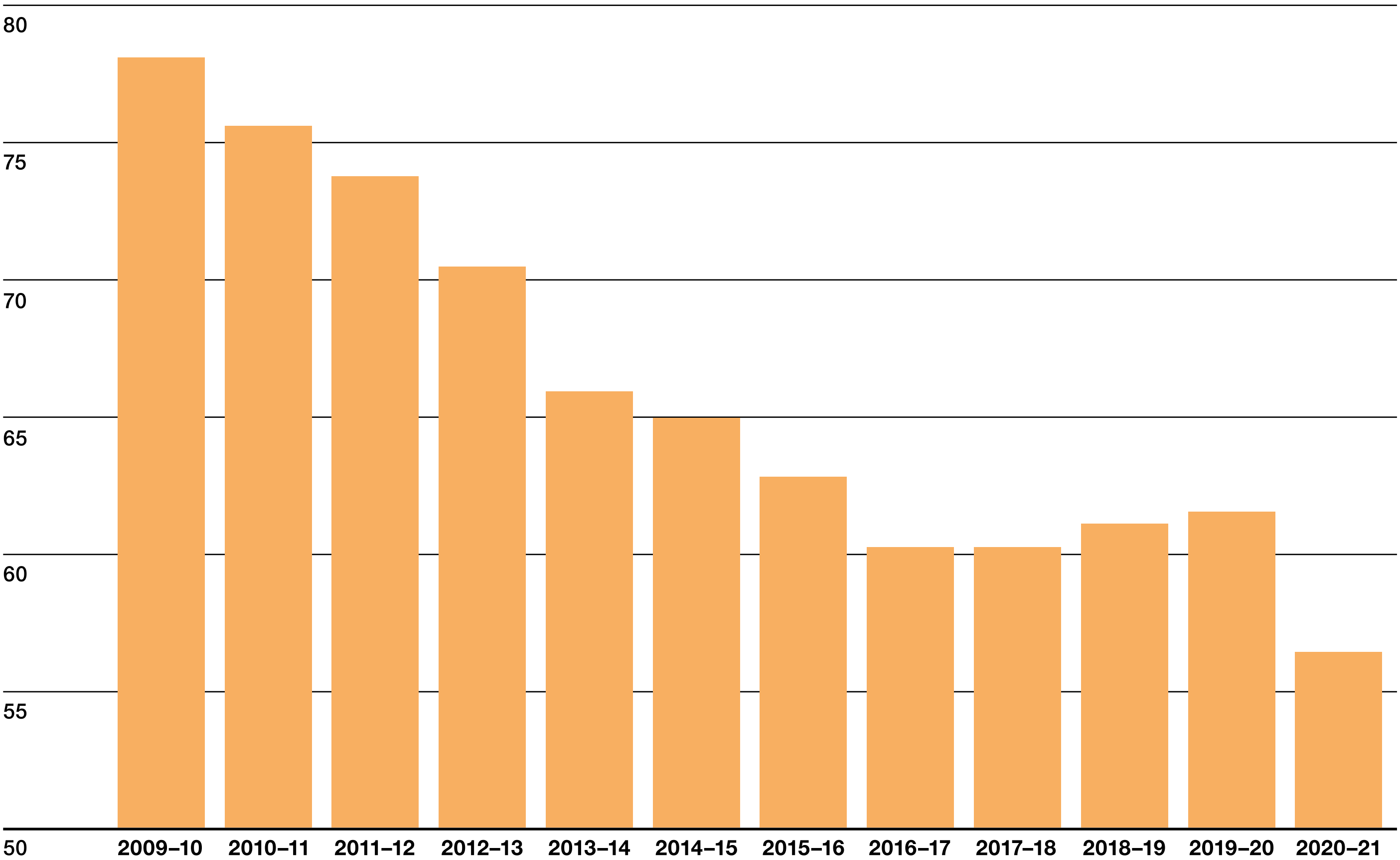
Indian context

India is at a crossroads in terms of increasingly unremunerative, old and polluting coal plants on one hand and ambitious renewable energy (RE) targets on the other with 175 GW RE capacity addition by 2022 and 50% generation capacity from non-fossil fuel sources by 2030. There is an overwhelming dominance of fossil fuels in power generation, with 50–55% of total installed generation capacity under coal plants producing more than 65% of total electricity generated.

In India, old plants are not only grappling with low capacity utilization and environmental issues but also have become uneconomical to customers and unprofitable to utilities (Forbes, 2018). In line with the needs of a growing economy, India's energy demand and peak demand have grown sharply during the period 2009–2019; however, the average plant load factor (PLF) of coal-fired plants, an indicator of capacity utilization, has seen a steady decline from 77.5% in 2009 to 53.37% in 2021 (MOP, 2020). Interestingly, India's energy and peak deficits have declined, which means that the dependence on coal has reduced as energy needs are being increasingly met from other cheaper energy sources including RE.

In addition to cheaper RE, increasing environmental concerns and the secular decline in capacity utilization of coal plants over the last decade have rendered the plants uneconomical as well as unprofitable (Shrimali, 2020). Therefore, a need for early retirement of coal plants is being felt and repurposing allows such stranded assets to derive potential value and provides an exit strategy to utilities.

FIGURE 4: AVERAGE PLANT LOAD FACTOR (PLF) OF COAL-FIRED PLANTS, AN INDICATOR OF CAPACITY UTILIZATION, HAS SEEN A STEADY DECLINE FROM 77.5% IN 2009 TO 53.37% IN 2021



The policy impetus in India appears to be in favor of replacing old and inefficient units by larger efficient units at a rapid pace (CEA, 2015). In 2016, the Central Electricity Authority (CEA) identified approximately 9000 MW coal based thermal power plants capacity for retirement/ replacement by new super-critical units on this basis of age (more than 25 years old) and un-economic operation (CEA, 2017). This not only decelerates the replacement of coal-based generation by cheaper and greener renewable energy options, but also gives rebirth to increased carbonization, albeit through new and less polluting plants.

As per the revised environmental norms notified by MoEFCC in 2015, Coal plants are required to install Pollution Control Equipment (PCE) like FGD, NeNox Systems. This additional capital expenditure is a concern, especially for older plants, since they may find it difficult to recoup the investments. The tariff impact due to the installation of PCE is estimated to be around ₹0.25–0.75/kWh (Srinivasan, et al., 2018). A more recent order has been issued by MoEFCC on April 1, 2021 according to which older plants close to retirement can continue to operate without installing PCE by paying a penalty, applicable on generation beyond their specified date of retirement.

Scope of study

Coal plant closures can be better rationalized with clear empirical estimation of costs and benefits incurred in decommissioning plants vis-à-vis repurposing them. While repurposing coal plants in favor of RE looks beneficial, it may encounter resistance stemming from several factors including cheaper power, impact on communities and livelihoods, and stranded assets (Kefford et al, 2018). To create a win-win situation for all stakeholders, our study undertakes a cost-benefit analysis to establish the utility of repurposing for coal plants in favor of a combination of solar, battery, and synchronous condenser. In this context, the study addresses the following key questions:

> *What are the costs of decommissioning old coal plants?*
> *What the benefits of repurposing decommissioned coal plants as a combination of solar, battery storage, and synchronous condenser?*
> *What proportion of capital expenditure (CAPEX) of repurposing option(s) are covered by the benefits of repurposing?*

Based on the above questions, the study aims to propose a business case for repurposing of coal power plant in favour of three potential alternatives namely, Solar PV, Solar PV plus BESS and SynCON. Although the proposition of coal plant phase out is gaining traction worldwide, there is pushback from some quarters due to social and economic concerns associated with the closure of coal plant. Our analysis makes a profitable case for coal plant utilities and addresses some of the barriers associated with the exit of coal plants.

In addition to the evident environmental benefits, we demonstrate that the repurposing benefits far outweigh the costs of both decommissioning as well as repurposing, which would prove to be a gainful proposition for the owners of these plants.

This work is novel on two counts. First, the report can be considered as an empirical application of the methodology discussed in Shrimali and Jindal (2021). Second, in the latter part, we suggest the corresponding solar PV and battery storage capacity that could be installed at coal plant site if the ash pond land is utilized for repurposing.

While in Shrimali and Jindal (2021), the authors used data on a model plant and estimated costs-benefits of repurposing, for this report, actual data on each plant is collected such as age, CAPEX, land, etc., and costs-benefits of repurposing are estimated for each plant. This would help us understand which plant makes an appropriate economic case for repurposing given its specific characteristics such as ash dyke land, total plant land, age etc. Among a set of existing coal plants, this would help the policy makers undertake decisions about prioritizing one plant over the other for repurposing.

Methodology

The Scenarios

Three scenarios have been developed to illustrate the repurposing options of coal plants.

Scenario 1 is the baseline scenario, which represents the business as usual case, and reflects the existing paradigm of the power sector in India, with coal plants staying operational. Scenario 2 considers the possibility of coal plants getting decommissioned even while solar and BESS capacity addition continues in a usual manner. Finally, scenario 3 offers repurposing of existing coal plants into appropriate combinations of solar, BESS, and SynCON at the coal plant site. To fully demonstrate how various costs and benefits unfold, scenario 2 is considered as an intermediate case; whereas scenario 3 is considered the goal.

FIGURE 5: SCENARIOS FOR ILLUSTRATION OF COST AND BENEFITS OF A COAL PLANT

SCENARIO 1
BUSINESS AS USUAL

Coal plant continues to stay operational

SCENARIO 2
INTERMEDIATE

Coal plant is decommissioned and new solar, battery energy storage system (BESS) comes up elsewhere

SCENARIO 3
GOAL

Coal plant is repurposed for combination of solar, BESS, and synchronous condenser (SynCON)

Selection of Plants

The identification of thermal plants is a complex function influenced by many technical, social and political factors. The shortlisted plants, indicated below, conform to various factors like age, variable costs, PLF% as identified and analyzed in Shrimali and Jindal (2021) and at the outset qualifies for consideration towards repurposing. This set was analyzed after individual plant level data collection.

INDIVIDUAL PLANT LEVEL DATA COLLECTION					
TAMIL NADU					
SL. NO.	**NAME OF PLANT**	**CAPACITY (MW)**	**ECR (₹/ KWH)**	**AGE (YEARS)**	**PLF (%)**
1	Tuticorin TPS	1050	4.44	29–42	55.9%
2	Mettur TPS	840	4.07	31–34	62.6%
3	North Chennai TPS	630	3.33	25–27	59.53%
4	NLC TS II Stage 1	630	3.36	33–34	79.86%

MAHARASHTRA					
SL. NO.	**NAME OF PLANT**	**CAPACITY (MW)**	**ECR (₹/ KWH)**	**AGE (YEARS)**	**PLF (%)**
5	Bhusawal TPS Unit 3	210	3.07	37	2.85%
6	Chandrapur Units 3–4	420	2.31	33–24	61.64%
7	Chandrapur Units 5–7	1500	2.31	22–28	51.62%
8	Khaparkheda TPP Units 1–4	840	2.73	18–30	52.18%
9	Koradi TPS Unit 6	210	2.26	36	13.93%
10	Koradi TPS Unit 7	210	2.26	37	13.93%
11	Nashik TPS Unit 3	210	3.27	40	34.88%
12	Nashik TPS Unit 4	210	3.27	39	48.41%
13	Nashik TPS Unit 5	210	3.27	38	

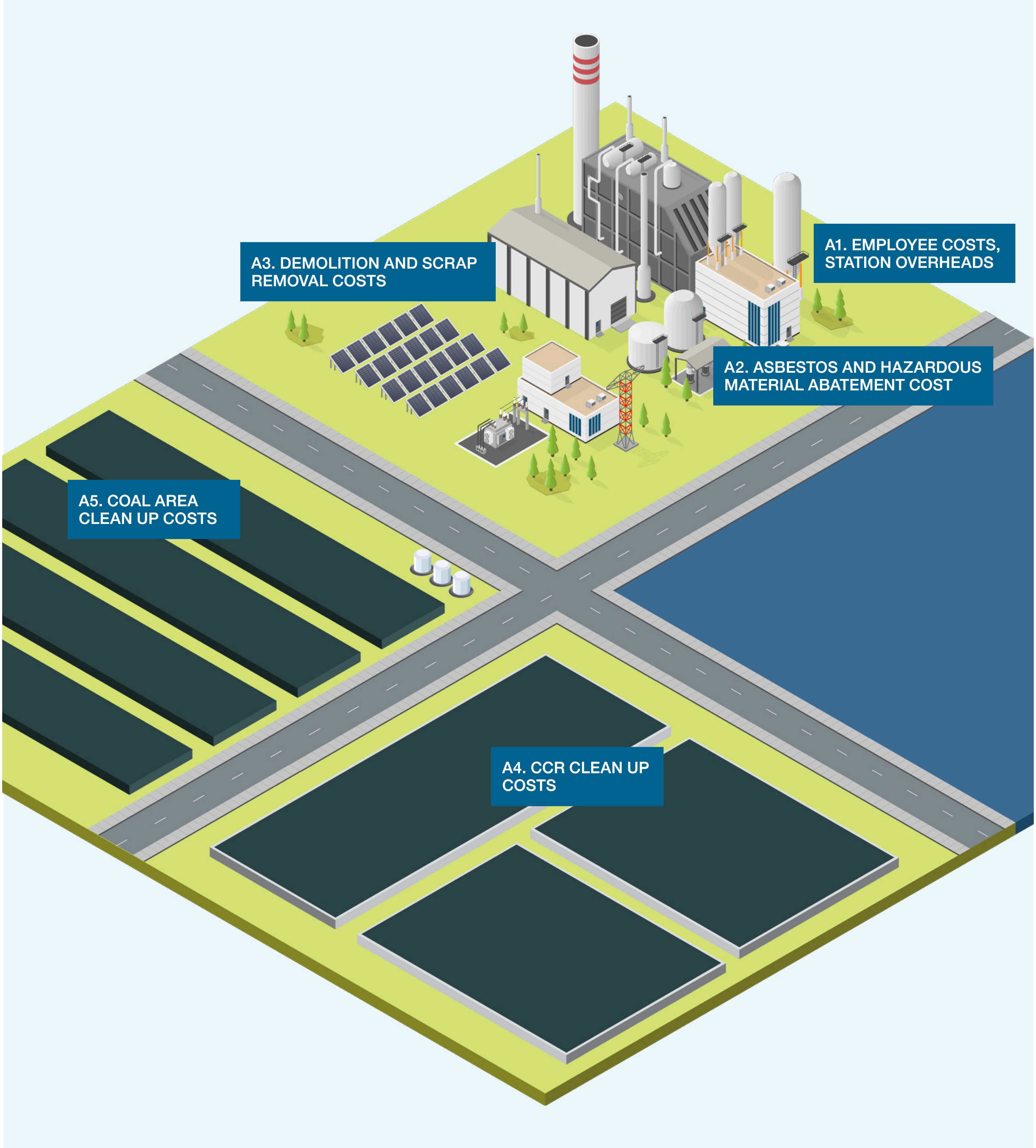
Costs

A comprehensive list of various costs and sub-costs is as below.

A. Plant-specific costs, including (as related to):	B. Environmental and social costs, including (as related to):	C. Additional repurposing costs, including (as related to):
1. Employee costs, station overheads as well as O&M expenses post retirement 2. Environmental regulation, such as asbestos and hazardous material abatement 3. Demolition of the plant and scrap removal from the coal plant equipment and machinery 4. Coal combustion residuals (i.e., ash/residue ponds) clean up 5. Coal storage areas clean up	1. Contingency costs, such as unanticipated environmental costs 2. Lost local (city, state) tax revenue 3. Social costs, such as temporary income support for employee rehabilitation	1. Remaining capital expenditure (CAPEX) on the coal plant 2. Remaining operational expenditure (OPEX) margins on the coal plant

A. Plant-specific costs

FIGURE 6: A TYPICAL COAL POWER PLANT LAYOUT AND ASSOCIATED COSTS (HASNAT, 2017)



A1. Employee costs, station overheads and O&M expenses post retirement

Decommissioning a coal plant can take substantial time (1.5–2 years), involving employee costs, station overheads, and O&M expenses (A1). Station overheads include expenses for security, horticulture and water. O&M expenses include mandatory services required during decommissioning. Finally, employee costs can be calculated as:

Employee Costs *= Remuneration Costs (a) + Liaising Costs (b) + Relocation Costs (c)*

Station Overheads *= Security Costs (a) + Power Costs (b) + Lease Costs (c) + Others (d)*

O&M Expenses *= Maintenance Costs (a) + Housekeeping Costs (b) + Firefighting Costs (c)*

FIGURE 7: COST FOR A REPRESENTATIVE 1000 MW PLANT; COMPONENTS AND SOURCES ARE INDICATED

$7.11M/GW
⁕ EMPLOYEE COST
⁜ NTPC, 2020

$24M/GW
⁕ STATION OVERHEADS
⁜ NTPC, 2020

$3.9M/GW
⁕ O&M EXPENSES
⁜ NTPC, 2020

A2. Environmental regulation, such as asbestos and hazardous material abatement costs

$0.09M/GW
⁕ ASBESTOS CLEAN UP COST
⁜ MRPL, 2020

Due to stringent environmental norms in developed countries, environmental remediation (A2) forms a crucial part of decommissioning. It includes removal and disposal of asbestos, polychlorinated biphenyls, lead paint, hydrocarbon storage tanks, mercury and contaminated soils (Raimi, 2017). Asbestos remediation should commence prior to performing other demolition activities (Burns and McDonnel, 2017).

A3. Demolition and scrap removal costs

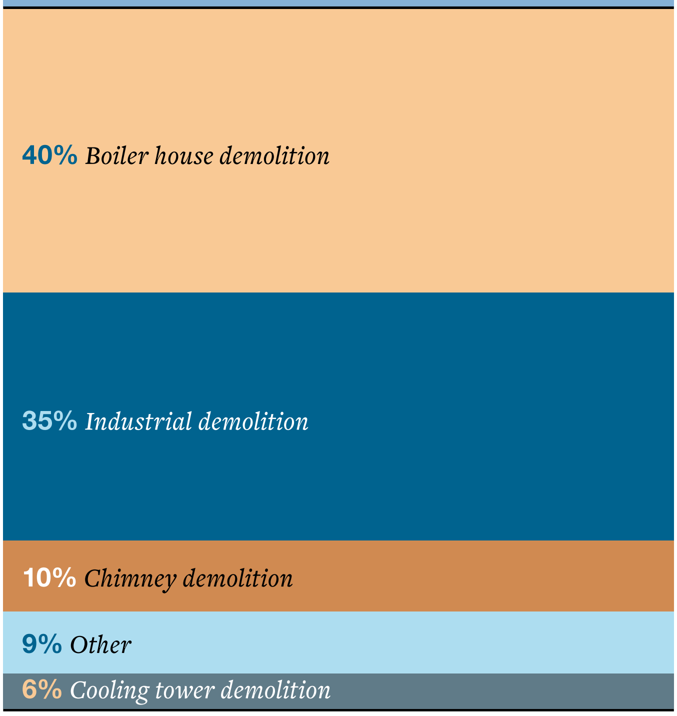
$4.05M/GW
⁕ DEMOLITION + SCRAP REMOVAL COST
⁜ NTPC, BADARPUR

Scrap removal costs are incurred in identification, removal and transportation of valuable or reused assets to a safe place before demolition actually begins. Demolition costs are a function of plant size as well as the safety norms followed for safe demolition of chimneys, boilers, buildings and other key structures. These costs are inherently dependent on the salvage value of an underlying asset and the end use of the site. For instance, in Scenario 3, since little transportation is needed due to assets being reused in view of repurposing the coal plant, these costs are expected to be relatively low.

Demolition costs form a substantive component of decommissioning cost; however, it tends to be higher for plants sited at more urban locations, due to the additional requirement of dust mitigation. For this analysis, the demolition cost includes costs incurred towards scrap removal as well.

Demolition and salvage activities begin with the identification of componenets that can be reused or sold for scrap like copper. Depending on the kind of demolition contracts, plant owners may retain scrap revenues or share the proceeds from the resale of such material with the contractor. Once valuable components have been identified and removed, buildings, chimneys, cooling towers are demolished. The cost breakup of decommisioning activities are identified in figure.

FIGURE 8: COST BREAKUP OF KEY COMPONENTS IN DECOMMISSIONING OF THERMAL POWER UNITS—SHARE IN PERCENTAGE FOR A MW SIZE (SHEKHAR, 2020)



A4, A5. Coal combustion residuals and coal area clean up

Management of coal combustion residuals (CCR), i.e. ash disposal/pond cleanup and coal storage area cleanup (A4 and A5), is regarded as one of the costliest tasks associated with decommissioning. Management of CCRs for ash cleanup is critical because of the prevalence of strict environmental regulations to avoid contamination of ground water. One way to manage these ash ponds is through dewatering (Raimi, 2017). These costs are significantly reduced from Scenario 2 to Scenario 3 as much of the ash pond land can be used for repurposing. The calculations for ash pond cleanup cost and coal area cleanup cost are as follows:

$$Ash\ Pond\_Cleanup\_Cost = Ash\_Area\ (a) * Earth\_filling\ (b) * Rate\ (c)$$

$$Coal\ Area\_Cleanup\_Cost = Coal\ Area\ (a) * Earth\_Filling\ (b) * Rate\ (c)$$

where,

a = ash disposal area/ash pond or coal bearing area to be remediated (m^2)
b = earth filling needed (in terms of thickness of soil) to be added to the remediated area (m)
c = rate (of execution of cleanup and filling) inclusive of cost of filling as well as labor ($/m^3)

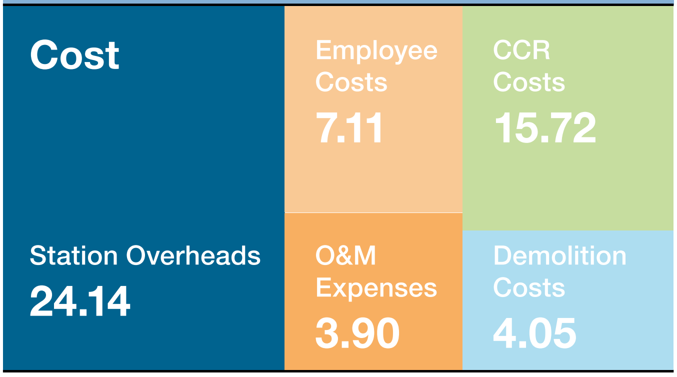
$15.72M/GW

- ASH POND CLEAN UP COST
- ASH DISPOSAL AREA—895 ACRES/GW, NTPC,BADARPUR (A)
- EARTH FILLING, 500MM, DSR 2016 (B)
- RATE FOR EARTH FILLING $6.11/M3, DSR 2016 (C)

$3.10M/GW

- COAL YARD CLEAN UP COST
- COAL YARD—1452 ACRES/GW NTPC, BADARPUR, 2020 (A)
- EARTH FILLING, 500MM, DSR 2016 (B)
- RATE FOR EARTH FILLING $6.11/M3, DSR 2016 (C)

FIGURE 9: AN OVERVIEW OF THE MAJOR PLANT SPECIFIC COSTS (IN MILLION $/MW)



B. Environmental and social costs

The various environmental and social costs related to decommissioning include:

- Post-decommissioning expenditure towards monitoring and mitigation of the negative effects of coal plant towards soil, habitat, etc.; and meeting contingencies related to unanticipated damages in the future
- Potential loss of revenue for local governments, especially in sparsely populated rural areas, which became reliant on coal plants for their revenue base (Raimi, 2017)
- Social costs towards post-layoff (temporary income) support and rehabilitation of people dependent on coal plants for their livelihoods

Continuing with our assumption that the plant may have been used for another 10 years, while decommissioning takes approximately 1.5–2 years, the social costs would be calculated for the remaining 8–8.5 years.

In Indian context, coal plants can be divided into three categories based on ownership: State, Centre, and Private plants. Most of the coal plants beyond their economic life are either State or Centre. The employees at these plants can be relocated to other plants, which could prove useful for both the plants as well as the employees, thus avoiding significant social costs. Quantification of environmental, social costs is not part of this analysis.

C. Other costs

Scenario 3 may entail additional costs, remaining CAPEX and OPEX costs. These arise mainly due to retirement of coal plants before the end of their economic lives and, therefore, are unlikely to exist for plants being retired after the end of their economic lives. These do not form part of our analysis, as the representative plant under consideration for repurposing has been assumed to have completed its economic life. In case utilities are interested in retiring plants before their economic life, consideration of these additional costs may be useful. In this context, we also note that we have ignored some additional benefits—both CAPEX and OPEX—covered in Shrimali (2020), given that the former is unlikely to be present for plants beyond their economic life and the latter may be debatable given the assumptions on levelized costs.

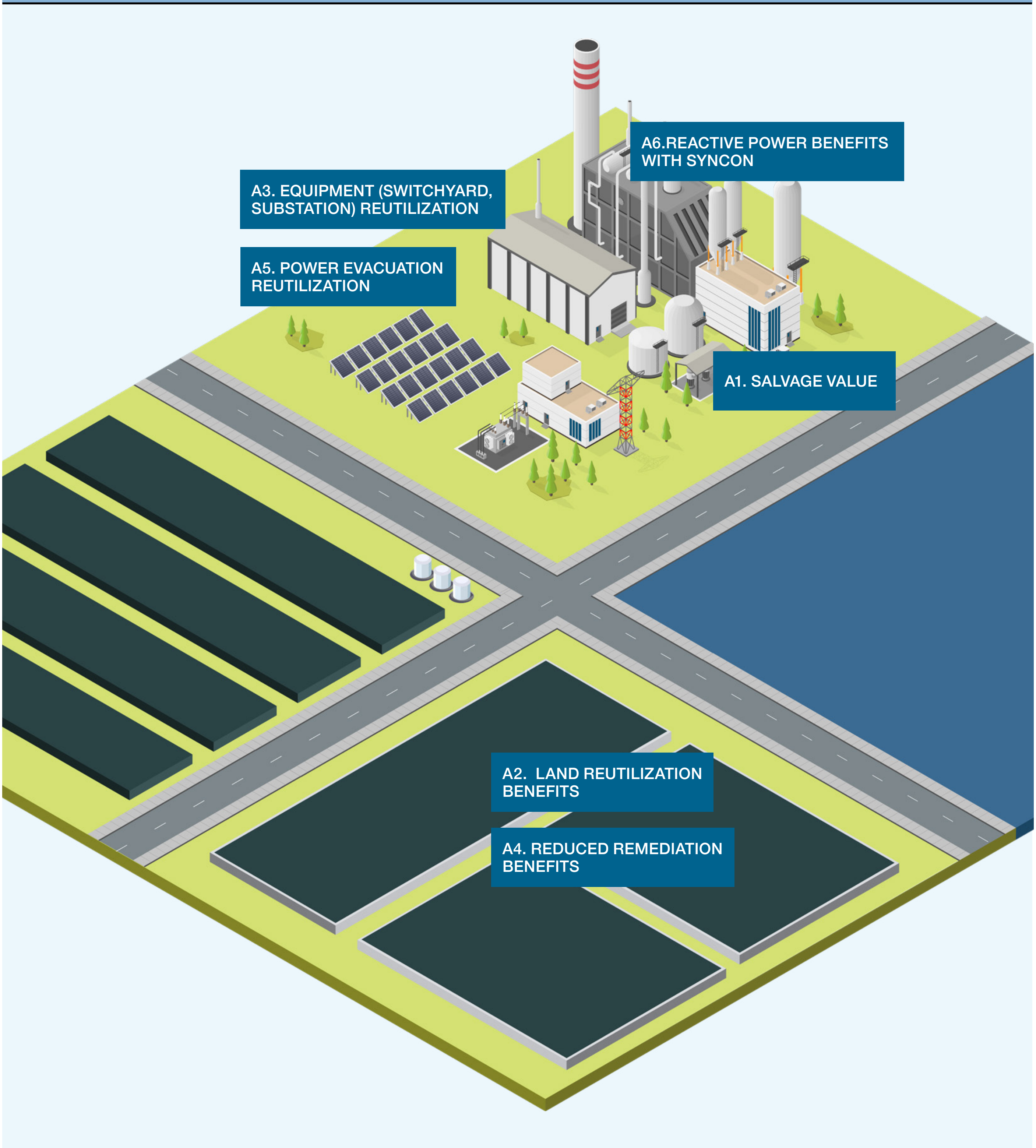
Benefits

Most of the benefits (including reductions in costs incurred while moving from Scenario 1 to Scenario 2) are from Scenario 2 to Scenario 3; however, some benefits are from Scenario 1 to Scenario 2 as well. Our ongoing assumption is that we are discussing the former (and therefore are implicit on the same), however we do explicitly mention the latter as appropriate. The plant specific benefits are in terms of monetary (and guaranteed) one-time benefits connected to coal plant decommissioning and repurposing, whereas the environmental and social benefits are additional, for a lifetime, and may either not be guaranteed or be subject to differing (and potentially subjective) opinions. A comprehensive list is as follows:

A. Plant-specific benefits, including (as related to):	B. Environmental and social benefits, including (as related to):
1. Salvage value/scrap value of coal plant machinery	1. Carbon benefits
2. Land reutilization	2. Health benefits
3. Equipment (i.e., switchyard, substation) reutilization	3. Water benefits
4. Remediation benefits i.e., reduced remediation costs	4. Reemployment benefits
5. Transmission and interconnection evacuation reutilization	
6. Reactive power benefits with SynCON by retaining system balancing services	

A. Plant-specific benefits

FIGURE 10: LAYOUT OF A TYPICAL POWER PLANT AND REPURPOSING BENEFITS



A1. Salvage value

Salvage_Value *= [CAPEX_Coal_Plant (a) - CAPEX_Repurpose_Equipment (b)] * Remaining_Depreciation (c)*

where,

- a = capital cost of the coal plant ($ million)
- b = capital cost of the repurposed equipment ($ million)
- c = remaining depreciation based on the remaining life of the plant (%)

$65.65M/GW
✱ SALVAGE VALUE
⁜ CAPEX (A)—INR 4.4M/MW, CERC 2012
⁜ REPURPOSED EQUIPMENT (B)—SEE A.3
⁜ DEPRECIATION(C)—10%, CERC 2019

It should be noted that repurposing may create significantly higher salvage value since the candidate plant may be in relatively better shape with remaining useful life and reusable assets, in contrast to a plant being decommissioned at the end of its useful life. The underlying assumption associated with 10% scrap value relates with the remaining useful life of plant i.e. candidate plants for decommissioning may be 25-30 years old. Further, the actual scrap value obtained (after auctions in the market) for plants after 25-30 years of useful life in Indian context is also close to 10% of CAPEX coal.

A2. Land reutilization

Utilization of land for repurposing is one of the most significant economic benefits since it reduces the CAPEX for the repurpose option. Land benefits (A.2) are calculated as follows:

Land_benefits *= Coal_Land_Area(a)*Available_for_Repurposing(b)*Repurposing_Land_Requirement_Norm (c) * Normative_Land_Rate (d)*

where,

- a = total land available with coal plant (acre),
- b = fraction of total coal plant land available for repurposing (%),
- c = normative land requirement for repurpose option (MW/Acre),
- d = normative land rate for repurpose option ($/MW)

$9.07M/GW
✱ LAND REUTILIZATION
⁜ AREA (A)- ASH DYKE, 1270ACRES/GW, NTPC
⁜ % AVAILABLE FOR REPURPOSING(B)—100%
⁜ NORMATIVE LAND REQUIREMENT (C)—5MW/ACRE, CERC 2016A
⁜ NORMATIVE LAND RATE (D)—$0.036M/MW SAHOO, 2019

A3. Equipment (i.e., switchyard, substation) reutilization)

The repurpose option can reuse some of coal plant equipment such as switchyard, substation, turbo-generator etc.; further reducing its CAPEX. Reutilized equipment benefits (A.3) are calculated as follows:

*Equipment_Benefits = Equipment_CAPEX (a) * Proportional_Usage (b)*

where,

- a = cost of the repurposed equipment ($ million),
- b = proportional usage of the repurposed equipment

$16.40M/GW
- EQUIPMENT REUTILIZATION
- COST OF REPURPOSED EQUIP (A)–64.59M/GW, NLC, 2019
- PROPORTIONAL USAGE (B)–SOLAR CAPACITY/ PLANT CAPACITY–0.254MW

In case the repurpose option is solar, this would be the ratio of solar capacity to coal capacity. For instance, for a 1000 MW coal plant repurposed as a 254 MW solar plant, this ratio would be 0.254.

A4. Remediation benefits i.e., reduced remediation costs

Ash impacted land, after minor remediation, can directly be used for repurposing, resulting in savings on the environmental remediation costs compared to a fully decommissioned plant. We assume that remediation benefits (A.4) are essentially ash/coal cleanup costs as calculated earlier.

$15.72M/GW
- REMEDIATION BENEFITS
- ASH DISPOSAL AREA–895 ACRES/GW, NTPC,BADARPUR (A)
- EARTH FILLING, 500MM, DSR 2016 (B)
- RATE FOR EARTH FILLING $6.11/M3, DSR 2016 (C)

A5. Transmission and interconnection evacuation reutilization

Power transmission and interconnection evacuation savings accrue due to reutilization of existing system capacity for evacuation of power from the repurpose option. Transmission and interconnection benefits (A.5) are computed as follows:

*Transmission_Interconnection_Benefits = Solar_Capacity (a) * Normative_Charges (b*

where,

- a = capacity of new solar plant (MW),
- b = normative transmission and interconnection charges allowed ($ million/ MW)

$15.96M/GW
- TRANSMISSION AND INTERCONNECTION BENEFITS
- CAPACITY OF SOLAR - 254MW (A)
- NORMATIVE TRANSMISSION AND INTERCONNECTION CHARGES - $0.063M/MW, CERC 2016A (B)

A6. Reactive power benefits with SynCON

The above benefits (A.1.-A.5) accrue when repurposing is done via solar alone as well as solar and BESS. In addition to these (A.1-A.5), repurposing with SynCON accrues additional benefits in terms of providing system balancing services such as reactive power for voltage control and system inertia (if flywheels are attached to the SynCON unit). For the purpose of this report, we focus on providing reactive power support via repurposing a coal plant's turbo-generator into a synchronous condenser.

SynCON lifetime benefits are calculated over a 10-year horizon based on the rationale that the coal plant being repurposed could have run for another 10 years, beyond which point it would have needed additional capex towards renovation and modernization. In the Indian context, at present there is no market compensation mechanism to provide ancillary system balancing services (i.e., reactive power) through coal plants, following Shrimali and Jindal (2021) study, we have used the compensation rate for SynCON as INR 0.14/kVArh i.e. ¢0.002/kVArh (POSOCO, 2019).

The conversion to a synchronous condenser, while incurring some additional CAPEX, eventually provides net benefits due to gross benefits exceeding costs over the lifetime. The gross reactive power benefits under this conversion are calculated as follows:

$$\textit{Reactive\_Power\_benefits} = \textit{Coal\_plant\_capacity}\ (a) * \textit{synchronous\_condenser\_rating}\ (b) * \textit{hrs}\ (c) * \textit{rate}\ (d)$$

where,

a = capacity of the coal plant (MW)

b = rating of the synchronous condenser (MVAr/MW)

c = operational time for synchronous condenser i.e., 8760 hrs

d = compensation rate ($/MVArh)

FIGURE 11: AN OVERVIEW OF THE MAJOR PLANT SPECIFIC BENEFITS (IN MILLION $/MW)

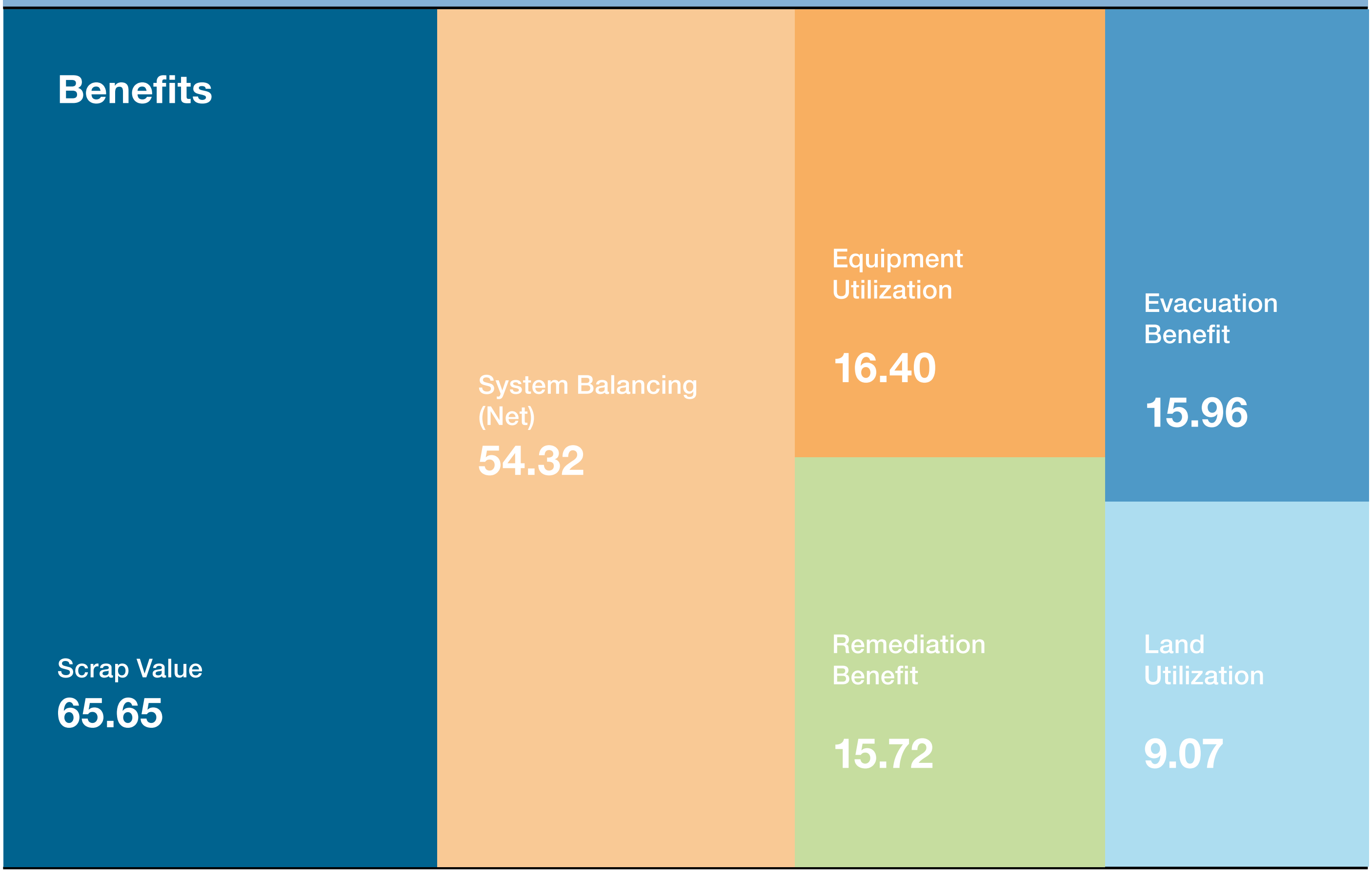
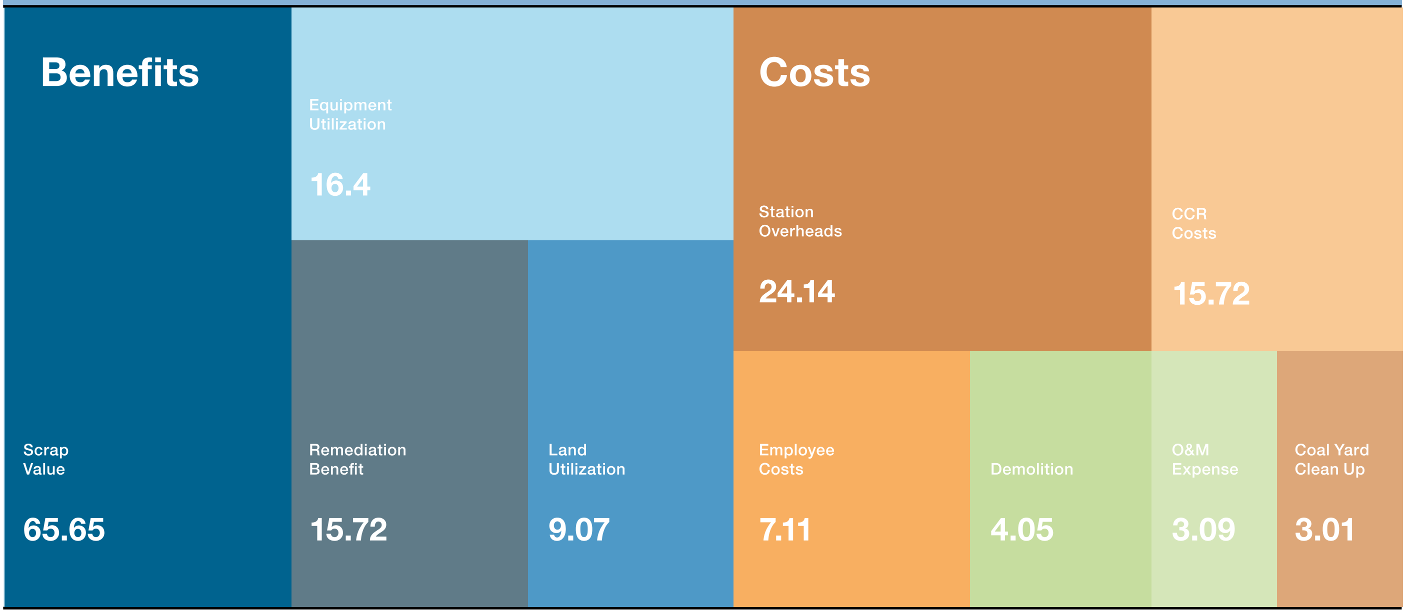


FIGURE 12: AN OVERVIEW OF THE MAJOR PLANT SPECIFIC COSTS AND BENEFITS (IN MILLION $/MW)



Data collection

For the identified plants, the following data is to be collected for calculation and the calculation of various cost and benefits.

Sl. No.	Data Point
1	**Location**
2	**Company**
3	**Ownership**
4	**Source of Coal**
5	**Source of Water**
6	**Type of Units**
7	**Expansion**
8	**Capacity**
8.1	Stage 1
8.2	Stage 2
8.3	Stage N
8.4	Total Capacity (MW)
8.5	No of Units
8.6	Maximum Rated Unit
9	**Commercial**
9.1	Year in Consideration
9.2	Fixed Cost (Rs/Unit)
9.3	Variable Cost (Rs/Unit)

9.4	Total Cost (Rs/Unit)
9.5	Merit Order for Disptach
9.6	Plant load factor (PLF)

10	**Area**
10.1	Main Plant
10.2	Ash Dyke Stage 1 (In hectares)
10.3	Ash Dyke Stage 2 (In hectares)
10.4	Coal Yard (StockPile+TPs)

11	**Project Cost (Crores Rs)**
11.1	Stage 1
11.2	Stage 2
11.3	Stage 3

12	**Commissioning Dates**
12.1	Unit 1
12.2	Unit 2
12.3	Unit 3
12.4	Unit 4
12.5	Unit 5
12.6	Max Age (In years)
12.7	Min Age (In years)
12.8	Average Age (In years)

Parameters

The various parameters considered for the calculation of costs and benefits along with the source are provided below (see Table 1).

Parameter	Value (Shrimali & Jindal, 2020)	Source (Shrimali & Jindal, 2020)	Value in INR	Units
Employee costs	$7.11 million	NTPC, 2020	49.77	Cr/GW
Station overheads costs	$24.14 million	NTPC, 2020	168.98	Cr/GW
O & M expenses	$3.90 million	NTPC, 2020	27.3	Cr/GW
Asbestos removal	$0.09 million	MRPL, 2020	0.63	Cr/GW
Demolition costs	$4.05 million	NTPC, 2020	28.35	Cr/GW

Parameter	**Value** (Shrimali & Jindal, 2020)	**Source** (Shrimali & Jindal, 2020)	**Value in INR**	**Units**
Earth filling for ash/coal area remediation	500 millimeters	DSR, 2016	500	mm
Rate of earth filling	$6.11/m^3	DSR, 2016	427.90	INR/m3
Remaining depreciation	10%	CERC, 2019	10%	%
Scrap value/Salvage value	10%	CERC, 2019	10%	%
Normative land rate for repurpose option	INR 2.5 million/MW	CERC, 2016a	0.25	Cr/MW
Standard land requirement for repurpose option	5 acre/MW	Sahoo, 2019	5	acre/MW
Normative transmission & Interconnection	INR 4.4 Million/MW	CERC, 2016a	0.44	Cr/GW
CAPEX solar	$182.45 million/ MW	CERC, 2016b	5.3	Cr/MW
Capacity utilization factor for solar	20%	SM, 2020	20%	
CAPEX solar and BESS	$253.90 million/MW	CEA, 2019a	7	Cr/MW
Storage duration (BESS)	4 hours	CEA, 2019a	4	hours
Efficiency (BESS)	85%	CEA, 2019a	85%	%
Compensation rate for SynCON	¢0.002 /kVArh	POSOCO, 2019	140	Rs/MVarh
SynCON rating	0.350 MVAr/MW of installed Capacity	Estimated	0.35	Mvar/MW

Assumptions

For this study, we have used actual data for each plant except decommissioning related expenses which have been drawn from Shrimali and Jindal (2021) and prorated for capacity for the respective plants. This is due to the fact that ex post estimation of decommissioning expenses for these plants individually would not be possible as these are operating and not yet decommissioned.

The table below provides key data assumptions utilized in this study.

Parameter	Impact	Assumption
Employee Costs, Station Overheads and O&M Expenses Post Retirement	**Decommissioning Costs**	Employee Costs, Station Overheads and O&M Expenses Post Retirement not calculated for each plant since this would depend on very specific inputs like security costs, Liaoning costs, Housekeeping costs incurred during the decommissioning period. These costs shall be drawn from Shrimali and Jindal (2021) and scaled as per installed capacity of plant under consideration.
Remaining Capex and Opex	**Decommissioning Costs**	Remaining capital expenditure (CAPEX) and operational expenditure (OPEX) margins on the coal plant. In general, the CAPEX gets fully recovered by the end of economic life of a plant and it is considered that the plants in consideration have completed their economic life of 25 years. OPEX margin here refers to the potential loss in notional efficiency gains when a profitable operating coal plant is repurposed. The same is debatable given the assumptions on levelized costs. Further, corresponding revenue from solar (at feed in tariff) has not been considered towards calculation of benefits.
Solar Capacity	**Benefits**	The potential solar capacity has been considered uniformly at 5MW/acres of repurposed land irrespective of the actual solar insolation available at the site.
Capex	**Benefits**	Towards calculation of scrap value, 10% of actual capex of plant wherever actual capex is available. Actual capex is considered in present value terms.

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