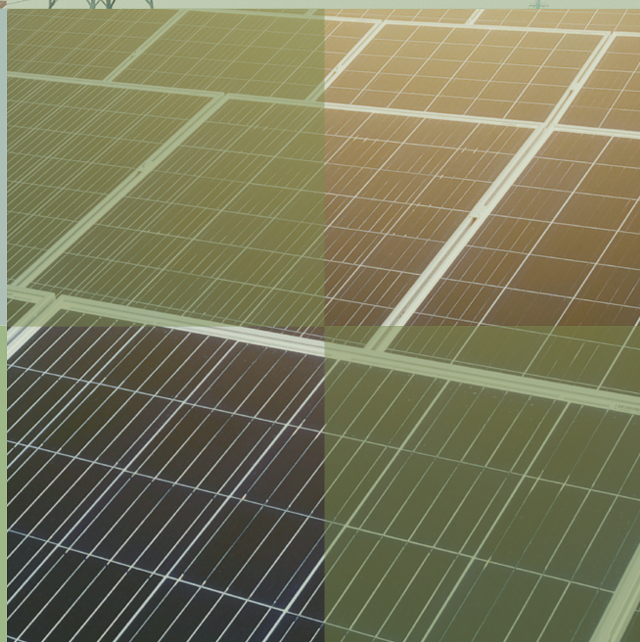
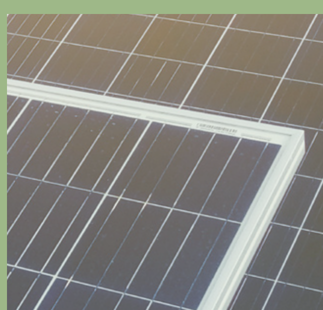
climate risk horizons



Greening Kerala’s Grid

Replacing coal power purchases with renewables can save consumers ₹9,000 CR over 5 years

Ashish Fernandes, Harshit Sharma



Greening Kerala's Grid: *Replacing coal power purchases with renewables can save consumers ₹ 9,000 CR over 5 years*

Authors

Ashish Fernandes, *CEO & Lead Analyst*
Email: *ashish.fernandes@climateriskhorizons.com*

Harshit Sharma, *Lead Researcher*
Email: *harshit.sharma@climateriskhorizons.com*

Suggested citation

Ashish Fernandes and Harshit Sharma. *Greening Kerala's Grid*. Climate Risk Horizons. April 2023.

This report is for information and educational purposes only and based upon a variety of public information sources which have been cited. CRH believes such information to be reliable but does not guarantee its accuracy, timeliness or completeness, or that it will continue to be accurate in the future.

—

Images: All images are from AdobeStock.com, unless otherwise mentioned

Design: Pallavi Baasri, *pallavibaasri@gmail.com*

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.

Learn more about us at *climateriskhorizons.com*

Registered address

Climate Risk Horizons
4th Floor, Umiya Emporium, Opp. Forum Mall,
Hosur Main Road, Koramangala, Bengaluru 560 029,
Karnataka, INDIA

Table of contents

01 *List of abbreviations*

02 *List of figures and tables*

03 *Executive summary*

04 *Background*

05 *Data and methods*

06 *Discussion*

07 *Recommendations*

08 *Endnotes*

1.0 List of abbreviations

ARR	Aggregate Revenue Requirement
BESS	Battery Energy Storage System
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CGS	Central Generating Stations
CRH	Climate Risk Horizons
CR	Crore
EPS	Electric Power Survey
ERC	Expected Revenue from Charges
FPV	Floating Solar Photovoltaic
FY	Financial Year
GW	Gigawatt
KSEB	Kerala State Electricity Board
KSEBL	Kerala State Electricity Board Limited
KSERC	Kerala State Electricity Regulatory Commission
KW	Kilowatt
kWh	Kilowatt Hour
MU	Million Units
MW	Megawatt
NTPC	National Thermal Power Corporation
PPA	Power Purchase Agreement
PSH	Pumped Storage Hydropower
PV	Photovoltaic (solar)
RE	Renewable Energy
RGCCPP	Rajiv Gandhi Combined Cycle Power Plant
SECI	Solar Energy Corporation of India

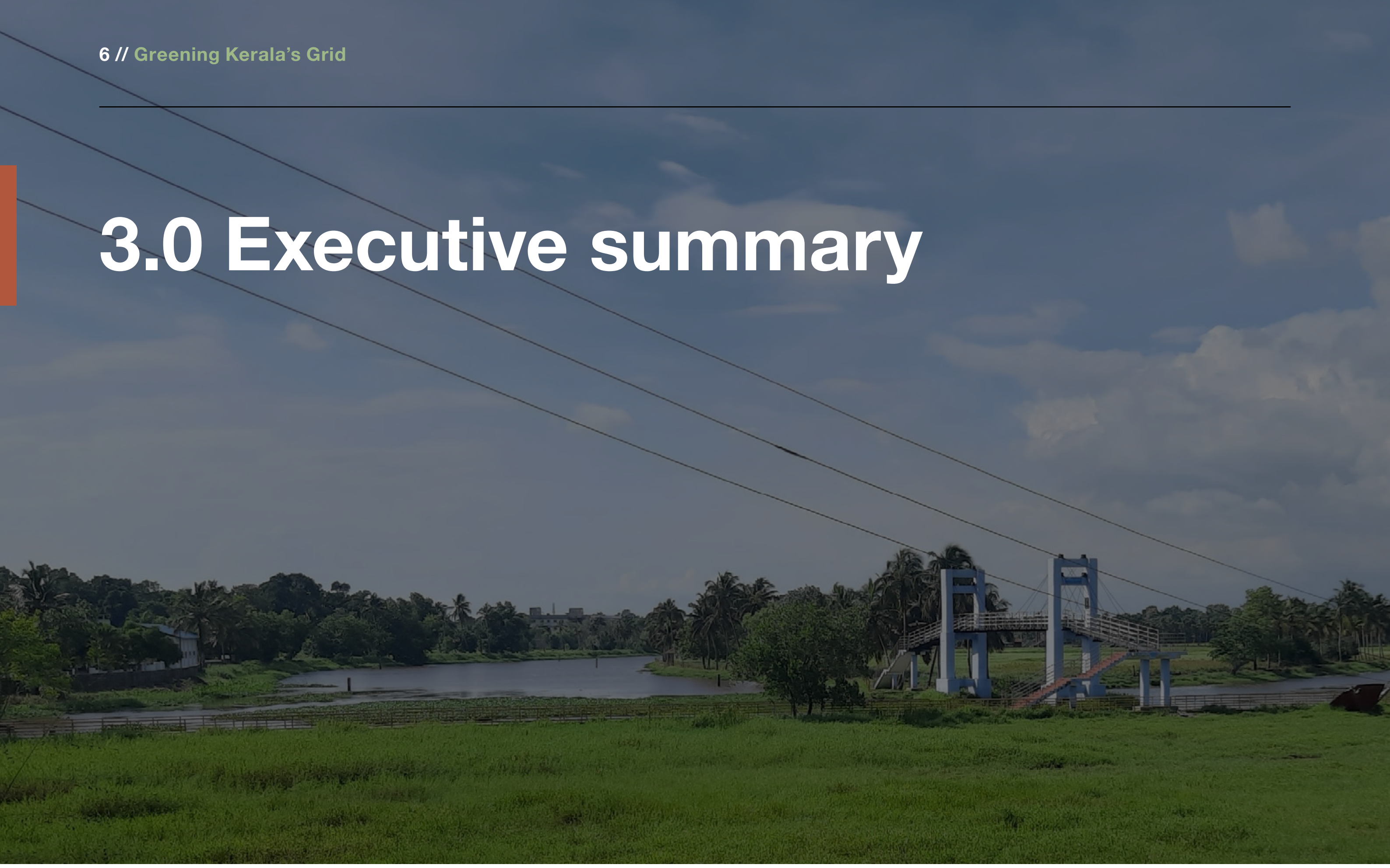
2.0 List of figures and tables

Figures

FIGURE 1	RE options to lower power costs in Kerala
FIGURE 2	Kerala electricity tariff trend (generation)

Tables

TABLE 1	Kerala's scheduled purchases from coal power stations, based on KSEB tariff petition for the 2022–2027 period
TABLE 2	Kerala's Floating Solar (FPV) Potential
TABLE 3	FPV transition pathway and savings



3.0 Executive summary

Kerala faces rising costs due to natural disasters that bear the imprint of climate change. In 2018 and again in 2021, unusually heavy rains led to flooding in many parts of the state, claiming dozens of lives and inflicting crores worth of damage. The state leadership has been vocal about the need to tackle climate change. Chief Minister Pinarayi Vijayan has said that Kerala is aiming to become a 100% renewable energy-based state by 2040 and net carbon neutral by 2050. Eliminating coal power purchases is essential to delivering on these goals.

Kerala can transition its electricity system to significantly reduce its dependence on increasingly unreliable and expensive coal power over the coming decade

Kerala itself has no coal power plants or energy-intensive industry, and is not considered a large emitter among Indian states. However, over 63% of Kerala's projected electricity consumption (as per FY 2023 tariff petition) has been scheduled from coal power plants outside Kerala, mainly in Tamil Nadu, Andhra Pradesh and Odisha. A coal crisis at these same plants in March and April 2022 led to power cuts in Kerala.[1] The state has ambitious renewable energy targets, but is struggling to achieve them.

Kerala also faces rising electricity tariffs due primarily to a reliance on expensive coal power purchase agreements. Based on KSEB's tariff petition submitted to KSERC,[2] the average cost of generation for power purchased from coal plants will jump significantly, implying either higher tariffs for consumers or a greater subsidy burden on the state's finances.

This analysis shows that despite its land constraints, Kerala can transition its electricity system to significantly reduce its dependence on increasingly unreliable and expensive coal power over the coming decade. This energy transition can save the state and power consumers thousands of crores over the coming years.

Key findings

#1

The per unit cost of generation for central sector plants has jumped by 12%, from ₹3.4/kWh in FY 22 to ₹3.8/kWh in FY 23, an indication of coal power's inflationary trajectory

#2

Most of the increase is from the old coal units of Ramagundam and Talcher, which account for a large portion of Kerala's supply from central stations

#3

There will be a 9.66% increase in per unit cost of energy from coal contracts during this financial year, increasing from ₹3.65/kWh in FY 21–22 to ₹4/kWh in FY 22–23. Total cost of power purchase based on energy scheduled from coal contracts for FY 22–23 is ₹7,370 CR, 10.5% higher than previous financial year

- If Kerala were to replace its scheduled purchases of coal power from central sector plants with new renewable energy at an average of ₹3/kWh, it would save approximately ₹969 crores per annum, based on the tariffs sought by KSEB for the ongoing control period of FY 2022–2027. Based on pre–2022 tariffs, the savings would still be a significant ₹372 CR per year.

- A phased energy transition plan with the goal of replacing all coal power contracts with renewable energy could ultimately save an estimated ₹1,843 CR annually, or over ₹9,000 CR over 5 years.

- Kerala can start this transition by scaling back purchases from central sector power stations, replacing that quantum of power with new renewable energy either generated within the state or purchased through contracts with SECI.

- Kerala has the potential to install over 8 GW of floating solar if it utilises 20% of surface area of its existing large and medium sized water bodies (reservoirs, irrigation tanks and village ponds).

#4

Pumped storage projects might have a role to play in balancing Kerala's future renewable energy, but have to be approached on a case-specific basis, given the likelihood of significant ecological and social impacts. PSH's higher costs and longer gestation period could impact state finances negatively in case of a large-scale, rapid expansion. The capital investment plan submitted by KSEB entails an expense of ₹150 CR for solar and battery storage, vs ₹4,100 CR for hydel over the next five years. Of this, ₹3,062 CR is for the Idukki Extension Scheme. This is a significant imbalance in light of the fact that solar and battery storage are able to deliver cheaper power with a shorter gestation period and will be less prone to physical disruption from climate impacts such as drought/floods

#5

KSEB can save significant resources by exiting its contract with NTPC's RGCCPP naphtha plant, on which it has spent hundreds of crores in the last few years, despite almost never needing it. These resources can be diverted to grid modernisation / RE capacity addition

4.0 Background

Rising cost of electricity in Kerala

In 2022, commercial, industrial and large domestic consumers all saw their electricity tariffs hiked significantly, in order to plug the Kerala State Electricity Board's (KSEB) revenue gap. Industrial units in particular have been hit hard, with their electricity charges going up by 10% or more on average.[3] Part of the reason for the hike is the escalation in coal power generation costs. Kerala is dependent on coal power generated outside the state for over 63% of its electricity supply. These plants have seen their costs jump 10–12%, raising the cost of procurement for KSEB.

Kerala is dependent on coal power generated outside the state for over 63% of its electricity supply

Kerala's green image is belied by its reliance on coal power generated outside the state. These coal power plants are linked to environmental problems arising from air and water pollution, flyash spills etc., apart from contributing to carbon emissions. These plants, almost without exception, have a combined tariff (fixed + running cost) higher than that of new renewable energy. Since coal price and freight charges will only increase, being dependent on coal power will only mean an escalation of electricity prices.

The advent of cheaper renewable energy offers Kerala a potential cost-reduction opportunity if it can phase out of more expensive coal contracts and replace them with cheaper renewable energy generation/purchases, while ensuring that there is sufficient supply for periods when RE generation is low. Augmenting supply through incentives for both generation and battery storage, selective pumped storage etc., will enable a progressive reduction in the cost of power purchase.

This analysis looks at potential savings from such efforts, estimated by analysing current generation tariffs based on the last approved tariff period (FY 2017–22) as well as the recent tariff revision petition submitted by KSEB to KSERC for approval.

An assessment of the average tariff for new renewable energy, both within Kerala and in other states provides an indicator of likely new RE tariffs. New solar PV tariffs across the country are in the ₹2.3–2.5/kWh range.[4] In Kerala, tariffs for new floating solar are ₹3.16/kWh, while the tariff range for wind, small hydro and ground mounted solar PV is between ₹2.82–5.23/kWh, ₹2.44–5.91/kWh and 2.44–3.83/kWh respectively.[5]

Based on this, we assume new renewable energy would be available at an average tariff of ₹3/kWh—conservatively discounting anticipated cost declines in the coming decade. We have also assumed battery costs in line with projections from the Central Electricity

Authority and Lawrence Berkeley National Laboratory. Recent bids for round the clock renewable energy (with storage) saw a combined tariff of ₹3.6.[6] The Lawrence Berkeley National Laboratory had estimated that solar PV with Li-ion battery storage in India can deliver electricity at a tariff of ₹3.32 by 2025 and ₹2.83 by 2030.[7]

Electricity demand trends

The state has seen an overall growth in annual electricity consumption of 2.85% CAGR from 21,259 MU in 2017–18 to an estimated 23,794 MU in 2021–22.[8] Kerala recorded its highest ever peak demand of 4,385 MW on April 27, 2022 and highest ever daily consumption at 92.88 MU on April 28, 2022. Since FY 2018, peak demand has grown at 18% from 3,890 MW to 4,600 MW in 2022.[9] This is further expected to grow to 5,230 MW by 2026–27.[10]

Projections for future annual electricity requirements by 2026–27 range from 29,588 to 29,968 MU.[11] However, meeting this demand does not mean that Kerala is restricted to extending old coal contracts or adding new coal power to its grid. Contrary to common perception, despite its small size and population density, Kerala has clean energy options that can meet a substantial percentage of demand, with the rest met through interstate purchases.

KSEB also has cost reduction options it can examine to lower costs for consumers. For example, KSEB is contracted to purchase power from NTPC's 350 MW Rajiv Gandhi Combined Cycle Power naphtha power plant (RGCCPP) in Kayamkulam, Alappuzha district. The plant is over 23 years of age, and in the last four years was utilised only once in March 2021 and has generated just 102 MU in total over this period.

In the current control period (2022–2027), KSEB is not expecting to schedule RGCCPP, except in case of emergency. However, the fixed charge commitment of ₹100 CR (annually) has to be paid to the generator for the period from FY 2022–23 to FY 2024–25. In the previous control period (2018–19 to 2021–22) the fixed charge was 200 crores annually, with no power planned to be purchased due to high fuel cost. The plant has in effect functioned as a very expensive backup generator in case of emergency.[12]

KSEB Limited has stated that because of the high variable costs of power from its two thermal stations viz., Kozhikode Diesel Power Plant and Brahmapuram Diesel Power Plant, no generation is proposed for the control period. However, scheduling of these plants may be resorted to only in the case of contingency.[13]

Against this background of rising electricity costs and cheaper new options, this analysis aims to quantify possible pathways for Kerala's electricity sector that meet the objectives of lowering costs, ensuring stability of supply and meeting environmental goals in terms of carbon emissions, biodiversity conservation and other sustainability benchmarks.

Role of energy efficiency/demand side management

Kerala is one of the leading states in India in terms of implementing energy efficiency programmes. This focus must continue, as the cheapest energy generation comes from efficiency. Similarly, reducing peak demand by load shifting/demand side management, will go a long way to curtailing costs. Due to a lack of publicly available data, this analysis was not able to explore these issues in detail.

5.0 Data and methods

This report relies on the lastest publicly available tariff, cost and scheduled dispatch data contained in the ARR & ERC Petition 2022–27 (dated January 2022) by the Kerala State Electricity Board.

Based on these figures, the likely net savings or loss per annum after replacing the lost generation from the plants being replaced by renewable energy are estimated. Since the latest petition will be followed by a KERC approved true up involving actual demand and generation figures, there will be variance with actual tariff and dispatch figures, therefore total power purchase cost will vary. Such variations are typically minor.

This analysis also errs on the conservative side by taking a floating solar energy tariff of ₹3.16/kWh based on the tariff from the NTPC Kayamkulam project. This does not take into account likely declines in prices as the technology matures. Moreover, new ground mounted solar PV and wind energy projects have reliably recorded tariffs below that level. Nevertheless, as this report suggests a large deployment of floating solar PV, we have assumed ₹3.16/kWh as the tariff for all renewable energy.

The 25.11% CUF used for calculation of annual energy generation from floating solar is based on the 22 MW Phase I Kayamkulam floating SPV project, which in turn has been calculated based on global solar radiation at the project site and approved by CERC. Phase II of the same project has a CUF of 27.4%, but this analysis assumes a 25.11% CUF for all floating solar. The actual annual generation will vary from site to site. The number of hours in a year (8766) used for calculation of annual energy generation with the given CUF has been taken based on CERC Renewable Energy Tariff Regulation.

The methodology used for the gradual expansion of FPV and prioritisation of expensive coal contracts for elimination is built keeping in mind the increasing cost of power generation from these coal plants over the years, as specified in the tariff petition. Cost of coal power used by KSEB will go up from an average tariff of ₹3.8/kWh in 2022–23 to ₹4.44/kWh by 2026–27.

Based on this, this analysis suggests a phase out schedule such that the most expensive coal contracts with the highest differential above that of the replacement renewable energy are replaced first, minimising costs to KSEB. This allows the the KSEB "blended tariff" of coal+FPV to remain in the 3.71 to 3.28 range, as opposed to the projected coal tariff range of 3.8 to 4.44 by 2026–27.

Thus, for example, power purchased from NTPC Talcher II, the least expensive coal CGS with a tariff of ₹2.86/kWh in 2022–23, would be removed in 2026–27 when its tariff would reach ₹3.56/kWh, as removing it earlier would incur a loss for KSEB.

6.0 Discussion

Enhancing energy security through accelerated RE deployment

Kerala's current energy mix is heavily reliant on supply from other states and, more concerningly, on generation sources subject to inflationary pressures and lengthy supply chains that can be disrupted by external factors. A more resilient system would necessitate a greater proportion of in-state generation from sources that are not as prone to disruption or inflation. Renewable energy fits the bill in many respects.

One of the common arguments against renewable energy in Kerala is that the state is small, densely populated and faces land constraints that prevent large-scale solar similar to that pursued in neighbouring states. However, Kerala still has significant untapped RE potential. We explore these in brief:

1 | Potential savings from replacing coal power with clean energy: KSEB is increasingly dependent on expensive coal power purchases from across state lines. These contracts will continue to escalate as coal prices increase and as plants retrofit with pollution control equipment, as is mandatory by 2024–25. Based on KSEB's current tariff petition before KSERC, there will be an approximately 10% increase in the cost of coal power purchases, without taking into account the running cost impacts of new pollution control equipment.

If KSEB is able to gradually replace its coal PPAs with renewable energy/RE+battery storage contracts, it can bring down the overall cost of power. As seen in the chart, the average RE (solar/wind) tariff, floating solar tariff and solar+Battery Energy Storage System tariff are below most coal PPA tariffs that Kerala has signed.

Figure 1 | RE options to lower power costs in Kerala

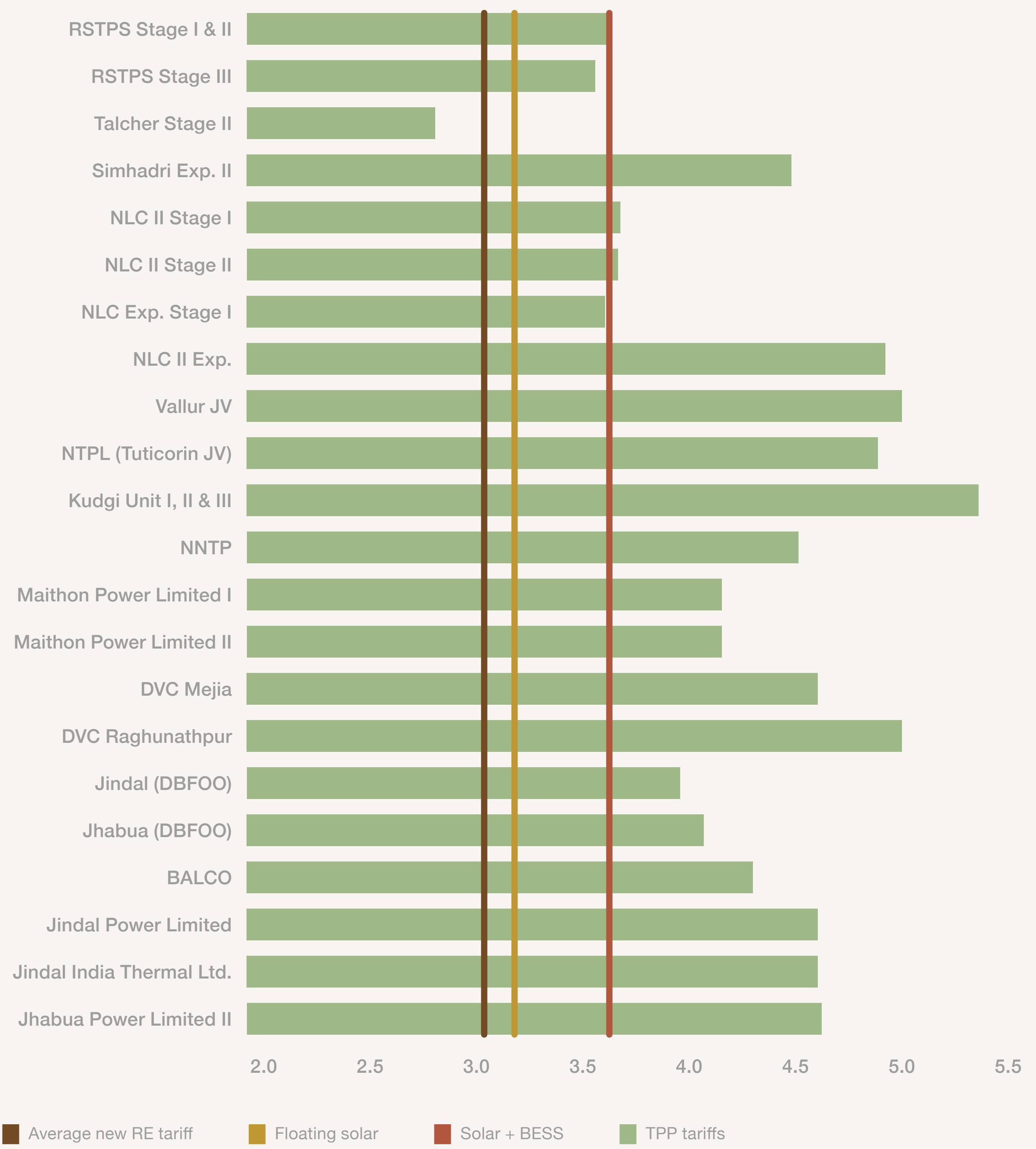


Table 1 below details KSEB's existing coal PPAs, and the hypothetical savings from replacing each with RE at an average tariff of ₹3/kWh. Scrapping PPAs with private power producers is legally contentious but a start can be made with Central sector projects, where several states have surrendered their share of generation on account of low demand/high cost. Replacing these contracts with RE would yield annual savings.

Table 1 | Kerala's scheduled purchases from coal power stations, based on KSEB tariff petition for the 2022–2027 period

Central Stations	
Ramagundam Stage I & II	
PPA signed 1993	**PPA duration (years)** Not specified
Contracted (MW) 245	**Fixed charge (CR)** 150.34
Variable charge (₹/kWh) 2.77	**Total cost (CR)** 621.6
Tariff (₹/kWh) 3.66	**Potential savings from RE at ₹3/kWh (CR)** 112.6
RSTPS Stage III	
PPA signed 2001	**PPA duration (years)** Not specified
Contracted (MW) 61	**Fixed charge (CR)** 41.88
Variable charge (₹/kWh) 2.61	**Total cost (CR)** 153.1
Tariff (₹/kWh) 3.59	**Potential savings from RE at ₹3/kWh (CR)** 25.32
Talcher Stage II	
PPA signed 1998	**PPA duration (years)** Not specified
Contracted (MW) 427	**Fixed charge (CR)** 297
Variable charge (₹/kWh) 1.86	**Total cost (CR)** 853.2
Tariff (₹/kWh) 2.86	**Potential savings from RE at ₹3/kWh (CR)** –41.1
Simhadri Exp. II	
PPA signed 2007	**PPA duration (years)** 30
Contracted (MW) 84	**Fixed charge (CR)** 95.2
Variable charge (₹/kWh) 2.92	**Total cost (CR)** 270.3
Tariff (₹/kWh) 4.51	**Potential savings from RE at ₹3/kWh (CR)** 90.3

NLC II Stage I	
PPA signed 2014 (renewed)	**PPA duration (years)** 15
Contracted (MW) 63	**Fixed charge (CR)** 42.9
Variable charge (₹/kWh) 2.7	**Total cost (CR)** 156.9
Tariff (₹/kWh) 3.71	**Potential savings from RE at ₹3/kWh (CR)** 30.18

NLC II Stage II	
PPA signed 2014 (renewed)	**PPA duration (years)** 15
Contracted (MW) 90	**Fixed charge (CR)** 60.55
Variable charge (₹/kWh) 2.7	**Total cost (CR)** 223.4
Tariff (₹/kWh) 3.7	**Potential savings from RE at ₹3/kWh (CR)** 42.5

NLC Exp. Stage I	
PPA signed 2002	**PPA duration (years)** 26
Contracted (MW) 67.7	**Fixed charge (CR)** 55.47
Variable charge (₹/kWh) 2.46	**Total cost (CR)** 169.4
Tariff (₹/kWh) 3.65	**Potential savings from RE at ₹3/kWh (CR)** 30.2

NLC II Exp.	
PPA signed 2008	**PPA duration (years)** 25 years from COD=2040
Contracted (MW) 80.6	**Fixed charge (CR)** 119.6
Variable charge (₹/kWh) 2.6	**Total cost (CR)** 252.7
Tariff (₹/kWh) 4.94	**Potential savings from RE at ₹3/kWh (CR)** 99.2

Vallur JV	
PPA signed 2009	**PPA duration (years)** 25
Contracted (MW) 47	**Fixed charge (CR)** 63.7
Variable charge (₹/kWh) 3.19	**Total cost (CR)** 175.7
Tariff (₹/kWh) 5	**Potential savings from RE at ₹3/kWh (CR)** 70.5

NTPL (Tuticorin JV)	
PPA signed 2008	**PPA duration (years)** 25
Contracted (MW) 72.5	**Fixed charge (CR)** 93.2
Variable charge (₹/kWh) 3.1	**Total cost (CR)** 248.4
Tariff (₹/kWh) 4.9	**Potential savings from RE at ₹3/kWh (CR)** 96.5

Kudgi Units I II & III	
PPA signed 2010	**PPA duration (years)** 25 years from COD=2040
Contracted (MW) 73.33	**Fixed charge (CR)** 140.5
Variable charge (₹/kWh) 3.56	**Total cost (CR)** 418.8
Tariff (₹/kWh) 5.36	**Potential savings from RE at ₹3/kWh (CR)** 184.6

NNTP	
PPA signed 2010	**PPA duration (years)** 25
Contracted (MW) 32	**Fixed charge (CR)** 51.9
Variable charge (₹/kWh) 2.24	**Total cost (CR)** 102.4
Tariff (₹/kWh) 4.53	**Potential savings from RE at ₹3/kWh (CR)** 34.6

Subtotal		
Contracted (MW) 1374		**Fixed charge (CR)** 1212
Total cost (CR) 3646	**Tariff (₹/kWh)** 3.8	**Savings from RE at ₹3/kWh (CR)** 775

Long Term Agreements (Private, CERC determined)	
Maithon I	
PPA signed 2013	**PPA duration (years)** 25
Contracted (MW) 150	**Fixed charge (CR)** 155.1
Variable charge (₹/kWh) 2.54	**Total cost (CR)** 418
Tariff (₹/kWh) 4.18	**Potential savings from RE at ₹3/kWh (CR)** 107.5

Maithon II	
PPA signed 2015	**PPA duration (years)** 25
Contracted (MW) 150	**Fixed charge (CR)** 155.1
Variable charge (₹/kWh) 2.54	**Total cost (CR)** 418
Tariff (₹/kWh) 4.18	**Potential savings from RE at ₹3/kWh (CR)** 107.5

DVC Mejia	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 100	**Fixed charge (CR)** 108.9
Variable charge (₹/kWh) 2.93	**Total cost (CR)** 315.7
Tariff (₹/kWh) 4.63	**Potential savings from RE at ₹3/kWh (CR)** 104

DVC Raghunathpur	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 50	**Fixed charge (CR)** 58.9
Variable charge (₹/kWh) 3.14	**Total cost (CR)** 168.2
Tariff (₹/kWh) 5	**Potential savings from RE at ₹3/kWh (CR)** 63.7

Subtotal		
Contracted (MW) 450		**Fixed charge (CR)** 478
Total cost (CR) 1320	**Tariff (₹/kWh)** 4.22	**Savings from RE at ₹3/kWh (CR)** 383

DBFOO LTA (Design, Build, Finance, Own & Operate)	
Jindal Power Limited	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 200	**Fixed charge (CR)** 397
Variable charge (₹/kWh) 1.33	**Total cost (CR)** 576.6
Tariff (₹/kWh) 3.99	**Potential savings from RE at ₹3/kWh (CR)** 127.2

Jhabua Power Limited*	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 115	**Fixed charge (CR)** 182.6
Variable charge (₹/kWh) 1.99	**Total cost (CR)** 340.6
Tariff (₹/kWh) 4.1	**Potential savings from RE at ₹3/kWh (CR)** 82.23

BALCO	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 100	**Fixed charge (CR)** 238.2
Variable charge (₹/kWh) 1.18	**Total cost (CR)** 313.25
Tariff (₹/kWh) 4.33	**Potential savings from RE at ₹3/kWh (CR)** 88.6

Subtotal		
Contracted (MW) 415		**Fixed charge (CR)** 817
Total cost (CR) 1230	**Tariff (₹/kWh)** 3.96	**Savings from RE at ₹3/kWh (CR)** 298

Allowed Scheduling as Per L1 of Bid 2	
Jindal Power Limited	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 150	**Fixed charge (CR)** 376.4
Variable charge (₹/kWh) 1.33	**Total cost (CR)** 502.8
Tariff (₹/kWh) 4.63	**Potential savings from RE at ₹3/kWh (CR)** 165.8

Jindal India Thermal Limited	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 100	**Fixed charge (CR)** 258.4
Variable charge (₹/kWh) 1.17	**Total cost (CR)** 334.6
Tariff (₹/kWh) 4.63	**Potential savings from RE at ₹3/kWh (CR)** 109.9

Jhabua Power Limited*	
PPA signed 2014	**PPA duration (years)** 25
Contracted (MW) 100	**Fixed charge (CR)** 198.5
Variable charge (₹/kWh) 2	**Total cost (CR)** 335.8
Tariff (₹/kWh) 4.64	**Potential savings from RE at ₹3/kWh (CR)** 111.11

Subtotal		
Contracted (MW) 350		**Fixed charge (CR)** 833
Total cost (CR) 1173	**Tariff (₹/kWh)** 4.47	**Savings from RE at ₹3/kWh (CR)** 387

Total		
Contracted (MW) 2589		**Fixed charge (CR)** 3341
Total cost (CR) 7369.65	**Tariff (₹/kWh)** 4	**Savings from RE at ₹3/kWh (CR)** 1843

* Figures and calculations based on ARR petition for FY2022-2027. Subsequently, NTPC has acquired the Jhabua Power Station, so this would now be considered a central sector plant.

2 | Floating solar PV: Given the land constraints Kerala faces, maximising floating solar while taking into consideration multiple resource use and ecological value of water bodies will help lower the state's dependence on coal, while also increasing in-state generation and energy security. For example, utilising just 20% of Kerala's total reservoir area,[14] (based on 4 acres/MW) would yield an installed capacity of 8.6 GW of floating solar PV. Current tariffs for floating solar in Kerala are ₹3.16/kWh. With increased deployment and economies of scale, this tariff could decline further. Co-locating battery storage with floating solar would add additional benefit in terms of being able to meet evening load.

As a small state with high population density, the availability of land for ground mounted solar arrays is a valid concern. Floating solar PV offers an option that addresses many of these concerns.

However, while the ecological/social impacts of floating solar might be lower than for ground mounted arrays, these will not be completely absent. Hence a process that takes into account valid concerns and ensures traditional use of water bodies is not negatively impacted would be important.

Compared to land-based solar panels, floating solar panels have the advantage of being free from the hassles of land acquisition and tree felling/land clearing associated with large solar projects. Floating solar also offers higher capacity factors due to the cooling effect of the water body. In the case of floating solar on the reservoirs of hydro power projects, there is ancillary grid connection infrastructure that can be shared to further reduce costs.[15] The Assam government had issued tenders to a Hyderabad-based developer to install solar panels on 10 water bodies, each with a capacity of 10 KW in 2021. One such project of capacity 10.5 KW has been successfully installed on a pond. It is surrounded by few households not connected to the grid.[16] The Assam Power Distribution Company (APDCL) has also signed a MoU agreement with Satluj Jal Vidyut Nigam (SJVN) to develop 1000 MW of floating solar projects in Assam by incorporating a Joint Venture Corporation.[17]

There are concerns about the impacts of floating solar PV on the pond/reservoir ecosystems. This is an emerging field with no hard data yet available, but to err on the side of caution, it would be advisable to keep the total water surface covered by floating solar PV down to 20% or less, to continue to allow for sufficient light and other uses of the water body.

NTPC's recent construction of a 95 MW floating solar system on a 450-acre lake adjacent to the Rajiv Gandhi Combined Cycle Power Project[18] is instructive as to the potential of floating solar in Kerala. The system was commissioned in 2022 and is generating power at a tariff of 3.16/kWh.

Utilising 20% of Kerala's reservoir area would yield 8.6 GW of floating solar PV

Based on state government data[19] on village and panchayat ponds and other water bodies in the state, CRH has estimated Kerala's floating solar potential in terms of installed capacity and annual generation.

Assuming a Capacity Utilisation Factor for floating solar of 25.11%[20] and assuming 4 acres of water surface per MW, and that only 20% of each water body was covered with solar panels, the total annual energy potential of various public and private freshwater bodies is about 19,000 million units (MU) which is over 70% of the state's annual electricity consumption estimate of 23,794 (MU)[21] for 2021–22. (26,626 MU Ex-Bus during 2021–22 as per CEA).[22]

The added benefit of the widespread adoption of floating solar would be its decentralised nature, reducing the need for large scale transmission infrastructure. In the case of village and panchayat water bodies, models that ensure distribution of benefits to local communities can hasten adoption.

Table 2 | Kerala's Floating Solar (FPV) potential						
Water body	**Number**	**Area (acres)**	**20% of area**	**Capacity (MW)**	**Generation (MU/year)**	**% of Kerala's energy**
Reservoirs	53	105983.5	21196.7	5299.17	11664.24	43.83
Private ponds	35763	54328.59	10865.72	2716.43	5979.25	22.47
Panchayat ponds	6848	3674.457	734.89	183.72	404.40	1.52
Quarry ponds	879	84	16.8	4.2	9.24	0.03
Village ponds	185	1225.64	245.128	61.28	134.89	0.51
Irrigation tanks	852	7005.438	1401.09	350.27	771.00	2.90
Public sector freshwater fish farms	13	210.04	42.008	10.50	23.12	0.09
Total				**8625.58**	**18986.14**	**71.34**

Pathway to replacing coal CGS with solar PV, including floating solar PV

Annually 11,179 million units, (nearly 45% of the state's electricity requirement during 2021–22), is scheduled from Central Generating Stations (CGS) running on coal, including NTPC's newly acquired Jhabua power plant.

Tapping into the state's vast floating solar photovoltaic (FPV) potential to gradually replace this 11,179 MU of electricity by the end of this control period i.e., from 2022–23 to 2026–27, could potentially save ₹4,505 CR by 2026–27, while also safeguarding the state from the impacts of future power cost inflation—a defining feature of coal PPAs.

This process can be carried out gradually, starting with the most expensive coal power contracts, replacing the scheduled electricity with power generated from clean sources within the state. This could be either ground mounted solar, wind or floating solar. We have hypothetically assumed floating solar as the bulk of new solar PV, given the land constraints faced in Kerala by ground mounted solar.

Table 3 lays out an indicative pathway for the replacement of coal power. Over five years, 5,078 MW of FPV could replace 1,590 MW of coal power currently purchased from Central Generation Stations, leading to an annual saving of ₹1,418 CR by FY 2027. **Table 4** suggests a year-wise removal of coal contracts along with their respective dispatch and tariffs over the years.

Table 3 | FPV transition pathway and savings

Year	Current scenario			Replacement scenario			Annual savings (CR)	FPV capacity (MW)
	Energy from CGS coal (MU)	Average tariff (₹/kWh)	Total cost (CR)	Energy from CGS coal (MU)	Energy from FPV @3.16/ kWh	Total cost (CR)		
2022–23	11179.11	3.85	4299.93	9536.17	1642.94	3971.90	328.03	746.40
2023–24	11179.11	4.30	4802.88	8203.64	2975.47	4154.49	648.39	1351.78
2024–25	11179.11	4.34	4850.71	6316.81	4862.3	3962.42	888.29	2208.99
2025–26	11179.11	4.38	4899.72	3406.89	7772.22	3676.57	1223.15	3530.99
2026–27	11179.11	4.43	4950.12	0	11179.11	3532.60	1417.52	5078.78

Table 4 | Year wise elimination of coal CGS based on their tariff rates

2022–23				
Plant name	**Kudgi I II & III**	**Vallur JV**	**NLC II Exp.**	**Total**
Energy	780.71	350.72	511.51	1642.94
Cost	418.8	175.75	252.65	847.2
Tariff (₹/kWh)	5.36	5.01	4.94	5.16
Contracted capacity	73.33	47	80.6	200.93

2023–24				
Plant name	**NTPL (Tuticorin JV)**	**NNTP**	**Simhadri Exp (II)**	**Total**
Energy	506.33	226.17	600.03	1332.53
Cost	267.56	116.45	288.09	672.1
Tariff (₹/kWh)	5.28	5.15	4.80	5.04
Contracted capacity	72.5	63	84	219.5

2024–25				
Plant name	**NLC II Stage I**	**NLC II Stage II**	**Jhabua Bid I**	**Total**
Energy	422.33	603.17	861.33	1886.83
Cost	184.41	264.82	373.6	822.83
Tariff (₹/kWh)	4.37	4.39	4.34	4.36
Contracted capacity	63	90	100	253

2025–26				
Plant name	**Jhabua Bid II**	**NLC Exp. Stage I**	**RSTPS Stage I & II**	**Total**
Energy	748.98	464.13	1696.81	2909.92
Cost	334.76	196.15	705.45	1236.36
Tariff (₹/kWh)	4.47	4.23	4.16	4.25
Contracted capacity	115	67.7	245	428

2026–27				
Plant name	**RSTPS Stage III**	**Talcher Stage II**		**Total**
Energy	425.93	2980.96		3406.89
Cost	179.39	1061.59		1240.98
Tariff (₹/kWh)	4.22	3.56		3.64
Contracted capacity	61	427		488

Meeting evening peak demand in a high RE scenario

This transition scenario requires the state to utilise about half of its total FPV potential by FY 2027 in order to replace expensive coal power. Given the intermittent nature of solar and the evening/night time peak demand pattern in the state, in the long run, large-scale adoption of storage systems, (battery and pumped most likely) will be needed.

However, in the short to medium term (until 2027) the 1.3 GW demand gap created due to replacement of targeted coal power contracts can be met through power from short-term market purchases and medium-term contracts. At present, despite an overall energy surplus and KSEBL's plan to sell this surplus energy, a peak demand deficit persists. KSEBL is bridging this with power bought from short and medium-term contracts, and plans to do the same in the future even when the peak demand deficit grows.

An additional 1.3 GW of evening/night-time energy deficit might seem like a very large figure to be replaced with short- and medium-term contracts. But when we look at the growing energy exchange market, the quantum of energy bought by other major states through exchanges and bilateral agreements and also the number of underutilised central as well as private thermal plants in the country, surrendering these long-term contracts in favour of in-state solar generation is logical both in terms of ensuring a reliable power source as well as overall cost optimisation.

There is precedent with numerous other states surrendering shares in power allocated from central generating stations in the past in order to reduce their fixed cost obligations. In the recent past, Ministry of Power has issued several letters[23] stating which states and beneficiaries have surrendered how much power from Central Generating Stations, and asking which states would be interested in availing of surplus power. Two such letters issued in February 2019 and November 2021 had more than 5 GW capacity being surrendered at each instance.

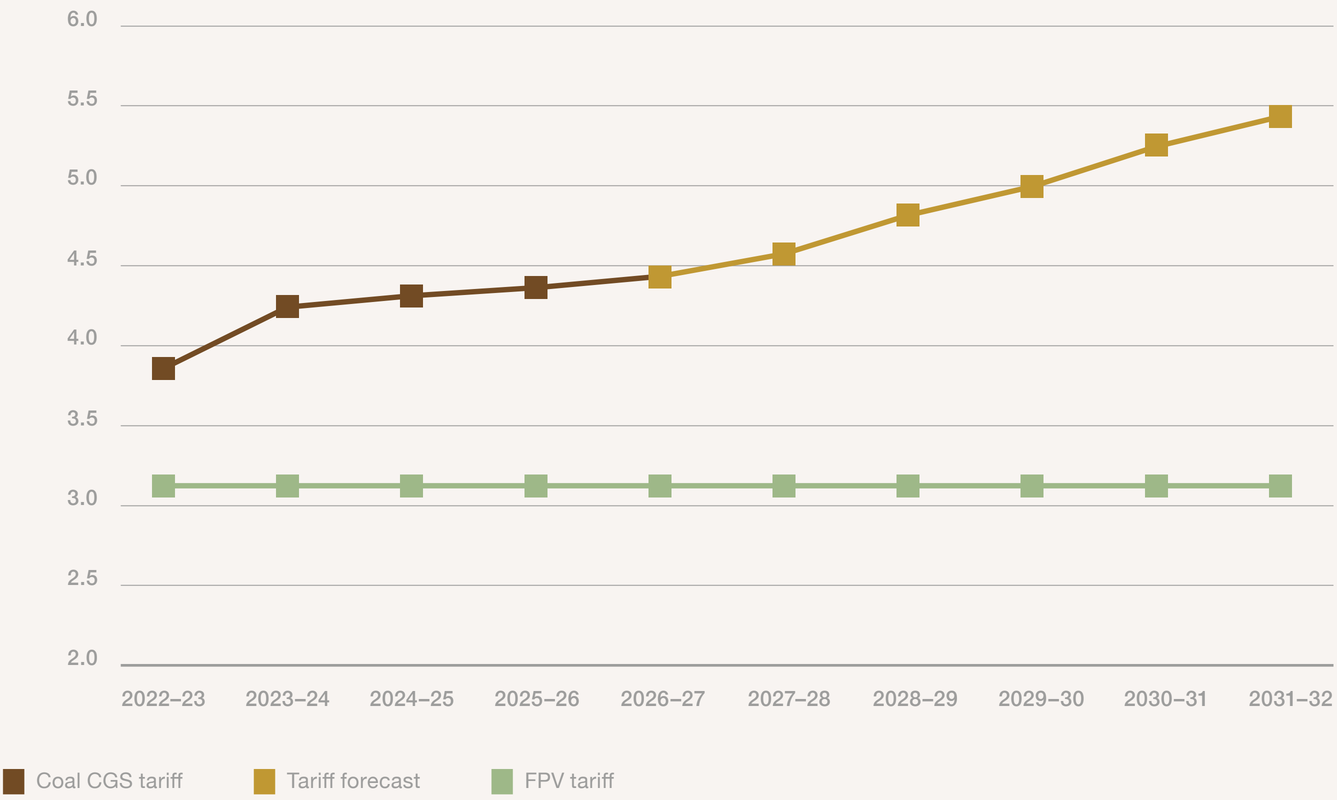
Another relevant example is KSEBL's 270 MW medium term agreement under the Ministry of Power's Pilot Scheme II under which Kerala will purchase power only during peak demand months from January to June for three years at a rate of ₹3.31/kWh. Unlike the existing long-term coal contracts, there is no year long fixed cost obligation on KSEBL. More such medium-term arrangements can be made with central as well as private generators.

As per KSEBL ARR&ERC petition, power from short and medium-term sources can be bought at a ceiling rate of ₹4/kWh. At the same time, it also anticipates selling surplus energy at a rate of ₹3.5/kWh and is even expecting a revenue of ₹668 CR in 2022–23 from such sales. Therefore, FPV or PV installed in excess of the transition scenario above could generate valuable revenue for the state, if the power generation is surplus to Kerala's requirements.

Thus, in the near future the gradual adoption of FPV/PV combined with an increase in power procurement from medium- and short-term sources to replace long-term coal agreements would reap marginal cost benefits as the blended tariff from these sources would be below ₹4/kWh but probably not as low as ₹3 or ₹3.16/kWh. The real benefits in the near future would be in terms of higher energy self-reliance, a growing ecosystem of entrepreneurs and installers, and a hedge against the ever-increasing cost of coal-based power. As visible in the graph below, this will eventually lead to significant cost savings in the post 2027 period, providing enough space to integrate larger scale batteries and pumped storage into the energy mix.

The tariff forecast given in the chart below is an extrapolation of cost growth rate expected between FY 23 to FY 27 as per KSEBL'S ARR&ERC petition.

Figure 2 | Kerala electricity tariff trend (generation)



3 | Distributed solar PV (rooftop and agro PV): Given land constraints, Kerala's solar focus should be on distributed applications and schemes to incentivise them. So far, Kerala has had limited success in facilitating rooftop solar adoption, despite the benefits this has for local communities. Rooftop solar in Perinjanam village has been positively received by the community. Increased financial assistance, a more attractive net metering policy and assistance with the installation of battery backup could be considered to facilitate faster growth. Similarly, agricultural PV has immense potential in the state, as evidenced by the agri-voltaic farm setup by Cochin International Airport Ltd (CIAL) in Kochi.

4 | Onshore and offshore wind: Onshore wind potential in Kerala has been estimated at between 600[26] to 1,699[27] MW. The state currently has about 60 MW of operating wind power. Some of these installations are also old and could be repowered with updated, higher capacity turbines.

The southern tips of both Kerala and Tamil Nadu have high offshore wind potential, as mapped by the National Institute of Wind Energy.[28] Offshore wind offers higher capacity factors than onshore installations. This is offset by higher costs as the industry is still developing. Kerala has an opportunity to be a leader through financial incentives to attract the industry to the state.

5 | Pumped hydro storage: As RE penetration grows, the role of energy storage systems becomes critical, to smooth over variations in generation and tide over periods of low RE generation. Pumped hydro has a role to play. The main concerns about pumped hydro pertain to its longer gestation period, high capital costs and possibility of environmental damage. Further, if the power used to lift water to the upper reservoir is sourced from expensive coal stations, there is no climate or financial benefit, and given efficiency losses, can even be worse on both fronts

KSEB has ambitious proposals for several PSH projects. KSEB's Capital Investment Plan [29] entails an expense of ₹150 CR for solar and battery storage, versus ₹4100 CR for hydel over the next five years. Of this, ₹3062 CR is for the Idukki Extension Scheme.

This is a notable imbalance, especially when solar and battery storage will deliver cheaper power sooner, compared to the new hydel projects. Based on KSEB's submission, the tariffs for most of these projects are higher than pure RE tariffs, and in many cases, higher than likely RE+battery storage tariffs as well. Further, many of the costs appear outdated and based on documents that are a decade old. Large infrastructure projects such as pumped hydro are notorious for cost overruns.

However, PSH does have advantages over battery storage—particularly the longevity of a project once built (40–60 years), and negligible running costs. A judicious re-examination of the number of PSH projects needed, and a site specific evaluation that considers total costs, gestation period, environmental issues and community input would be warranted.

7.0 Recommendations

Utilise Kerala's RE potential. Kerala has been slow to tap into its significant RE potential, having installed only about 10% of its 1,970 MW target by 2022. Given land constraints and largely domestic patterns of consumption, Kerala's RE model should focus on distributed generation, (wind power and rooftop, ground mounted, multi-use agricultural PV and floating solar PV).

Progressively phase out coal contracts, starting with the most expensive, replacing that power with new renewable energy.

Explore **financial incentives for battery systems** tied to larger renewable installations as this will help meet evening peak and provide grid stability.

Encourage repowering of old wind installations with newer, higher capacity turbine models.

Explore possible financial incentives for **development of the offshore wind industry**.

Re-evaluate **financial viability of proposed pumped storage projects**, using a cost comparison with other existing alternatives for meeting peak load.

Set a target date of 2030 to phase out all coal power purchases and ensure the state's grid is coal free.

8.0 Endnotes

1. https://www.onmanorama.com/news/kerala/2022/04/28/energy-crisis-in-kerala-kseb-powercuts.html

2. KSEBL ARR FY 2022-2027 Petition

3. https://english.mathrubhumi.com/news/kerala/industrial-units-hit-by-electricity-price-hike-suffer-loss-worth-lakhs-1.7828570

4. https://mercomindia.com/tata-power-amp-energy-ntpc-sjvn-winners-secis-1-2-gw-hybrid-auction/

5. Table 61, Renewable Energy Purchase for the control period (Existing and contracted), KSEBL ARR 22-27 Petition

6. https://mercomindia.com/renew-power-seci-round-clock-renewable-tender/

7. https://eta.lbl.gov/publications/estimating-cost-grid-scale-lithium

8. KSEBL ARR 22-27 (ARR&ERC Petition of KSEB Ltd for the control period from 2022-23 to 2026-27) https://kseb.in/index.php?option=com_jdownloads&view=download&id=23350:arr-erc-petition-of-kseb-ltd-for-the-control-period-from-2022-23-to-2026-27&catid=64&Itemid=654&lang=en

9. LGBR reports: https://cea.nic.in/l-g-b-r-report/?lang=en

10. KSEBL ARR 2022-27 pg195

11. KSEBL ARR 2022-27 Petition; CEA 20th Electricity Power Survey

12. KSEBL ARR 2022-27 pg221, KSEBL ARR 2018-22

13. KSEBL ARR 2022-27, KSEBL ARR 2018-22 pg40

14. http://www.kerenvis.nic.in/Database/Reservoirs_1635.aspx

15. https://india.mongabay.com/2021/11/floatingsolar/

16. https://aeda.assam.gov.in/portlets/floating-solar-power-plant

17. https://www.livemint.com/companies/news/sjvn-to-invest-rs-6-000-cr-for-1-000-mw-floating-solar-power-projects-in-assam-11666005670958.html

18. https://www.thehindu.com/news/national/kerala/prime-minister-narendra-modi-launches-floating-solar-power-plant-at-ntpc-kayamkulam/article65702800.ece

19. https://fisheries.kerala.gov.in/index.php/fresh-water-resources-kerala

20. Based on CERC order in Petition No. 341/GT/2019 https://cercind.gov.in/2022/orders/341-GT-2019.pdf

21. KSEBL ARR 22-27 (ARR&ERC Petition of KSEB Ltd for the control period from 2022-23 to 2026-27)

22. CEA 20th EPS report -pg 37

23. https://cea.nic.in/wp-content/uploads/notification/2022/11/20th_EPS____Report___Final___16.11.2022.pdf

24. https://powermin.gov.in/sites/default/files/uploads/Surrendered_share_of_power_English.pdf

25. https://www.indiatimes.com/news/india/perinjanam-model-how-a-kerala-village-became-energy-self-sufficient-with-rooftop-solar-584782.html

26. https://www.newindianexpress.com/states/kerala/2021/dec/13/cochin-airport-scales-up-agri-voltaic-farming-with-joint-production-of-food-and-energy-2395094.html

27. http://anert.gov.in/index.php/node/23

28. http://www.inwea.org/wind-energy-in-india/wind-power-potential/

29. https://niwe.res.in/assets/Docu/Offshore_Wind_Resource_Report_Dhanuskodi.pdf

30. Capital Investment Plan FY 2022-23 TO FY 2026-27, KSEB

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.

Learn more about us at *climateriskhorizons.com*

Registered address

Climate Risk Horizons
4th Floor, Umiya Emporium, Opp. Forum Mall,
Hosur Main Road, Koramangala, Bengaluru 560 029,
Karnataka, INDIA

climate
risk
horizons

Greening Kerala's grid

Replacing coal power purchases with renewables can save consumers ₹9,000 CR over 5 years

Ashish Fernandes, Harshit Sharma